ON THE ORIGIN OF ENSTATITE CHONDRITE CHONDRULES BASED ON THEIR PETROGRAPHY AND COMPARISON WITH EXPERIMENTALLY PRODUCED CHONDRULES; G.E. Lofgren, SN-4, NASA-JSC, Houston, TX 77058, J.M. DeHart, 1914 Amherst Ave., Casper, WY 82601, and P.J. Burkett, code 7431 NRL, Stennis Space Center, MS 39529.

The recent discovery of several types 3 and 4 enstatite chondrites (EC) in the Antarctic collection [1] increases greatly the ability to compare unaltered, naturally-formed EC chondrules with chondrules produced experimentally from melts of enstatite chondrule composition [2]. Because these discoveries are so recent we have undertaken the task of characterizing these chondrules for purposes of comparison. Two E3 chondrites have already been examined carefully, Yamato-691 and Qingzhen, and these will be compared as well. EC chondrules are similar in the range of textures to the ordinary chondrite (OC), pyroxene-rich chondrules. Porphyritic textures are most common followed by the fine grained radial textures. Two kinds of radially textured objects are found, the droplet or almost perfectly spherical chondrules and angular fragments. The experimental studies [2] that have duplicated these textures suggest a long and complex formation history for EC chondrules. The presence of sharply defined, radial chondrules in E5 and E5 chondrules suggests that they do not represent metamorphosed E3 and E4 chondrites.

The most extensive study of EH3 chondrite chondrule textures has been on EH3 Yamato-691. Ikeda [3] found that radial pyroxene (RP) textures dominate. Their textures ranged from excentro-, to centro-, to multiradial pyroxene; some with olivine, but most without. Prophyritic textures were also common with textures ranging form porphyritic pyroxene/olivine (POP) to porphyritic pyroxene (PP) to equigranular to microporphyritic (MP). Other less common types include barred pyroxene/olivine, cryptocrystalline (spherulitic or massive), and pure SiO_2. Grossman et al. [4] studied whole chondrules extracted from EH3 Qingzhen. Of the 15 chondrules they studied 4 were PP, 5 were POP, 5 were RP and one was a dendritic olivine and pyroxene mixture.

OBSERVATIONS: We have looked at several new Antarctic E3 chondrites (EH-3's: ALH-84170 and PCA-91020; EL3's: ALH-77156, ALH-7295, LEW-87223, and MAC-88136) and Qingzhen. They all have numerous chondrules with well defined outlines and readily identifiable textures. All have mostly porphyritic chondrules (PP and POP), but there are differences in the size and kinds of textures. RP (both the classic spherical radial and the more common angular fragments), barred/dendritic px, and cryptocrystalline chondrules are present in differing amounts with one exception noted below.

PCA-91020: Mostly PP & POP, olivine is a minor phase when present usually as an inclusion. Phenocrysts s range from euhedral to subhedral, elongate skeletal to equant euhedral to granular. Textures show a large variation and range from microporphrytic. to porphyritic to granular to seriate. Barred/dendritic pyroxene occurs as fragments, usually elongate and are rare. Classic spherical RP chondrules are rare, radial fragments are more common and range from coarsely radial to cryptocrystalline.

ALH-77156: Chondrules are more uniform in character and size and smaller on average than other E3's. Most are microporphyritic, phenocrysts are equant euhedral to subhedral. Classic RP chondrules are absent; a few cryptocrystalline and barred to dendrite fragments are present.

ALH-77295: This meteorite is paired with ALH-77156 and though the chondrule assemblage varies somewhat with a larger range in chondrule size and texture, it is far more similar to 77156 that any other E3.

LEW-87223: The most distinctive feature of this meteorite is the lack of dark, fine-grained matrix. Chondrules are mostly PP with some POP, olivine usually present as inclusions in pyroxene and as relicts. There is a large variation in chondrule size and porphyritic texture. Some PP have granular rims that appear to be a later feature, not observed in other E3's, and there is one quite large granular fragment. Classic and fragmental RP, barred/dendritic, and cryptocrystalline chondrules are present mostly as fragments. The Fe-metal is coarse grained more like what would be expected in an E6 not E3 chondrite texture.

MAC-88136: Mostly PP & POP with numerous MP chondrules. There is a large size range; most MP chondrules are smaller. There are a few granular PP. There is only one classic RP chondrule and some radial textured fragments. There are also very few barred/dendritic, and a couple large cryptocrystalline fragments; the largest fragment is cryptocrystalline.

ALH-84170: There is very little dark, matrix material, almost like 87223. Chondrules are mostly PP & POP; the MP chondrules are smaller; The larger PP's are porphyritic with large En phenocrysts, some with olivine inclusions; some have a granular texture. There is one classic RP, one coarse RP fragment, and cryptocrystalline fragments

Qingzhen: Mostly PP & POP chondrules with a large size range. The smaller ones are mostly MP with skeletal to equant euhedral phenocrysts. The larger En phenocrysts often have olivine inclusions (probably not relict); there are some olivine phenocrysts (skeletal, primary and rounded, relict??) set in a pyroxene matrix. A few granular pyroxene, a single classic RP, barred/dendritic, and cryptocrystalline chondrules are present.

The chondrules in the E4 chondrites from the Antarctic collection that have been examined and they resemble the E3 chondrites closely except for the slightly increased degree of alteration. The E5 and E6 chondrites examined have distinctly different textures. Chondrules are barely distinguishable, but each of them has a few sharply defined ones. In TIL-91714 (E5), there are 2 sharply defined, coarsely radial fragments and 1 coarse, barred fragment. In RKP-80259 there is 1 very sharply defined, coarsely excentroradial chondrule and 2 radial fragments. In ALH-81021 (E6) there is 1 coarsely radial fragment and in LEW-88180 (E6) there are 2 sharply defined, excentroradial chondrules and several radial fragments (in fact there are enough sharply defined chondrules that we question its classification as an E6)

COMPARISON WITH EXPERIMENTS: Comparison of the textures observed in the chondrules with dynamic crystallization experiments [2] presents some insight into the EC chondrule forming process. The complex array of PP and POP textures suggests multiple melting of heterogeneously agglomerated precursor material at varying temperatures. The MP chondrules, however, mostly likely formed from even grained, relatively homogeneous precursor material. Melting occurred near the liquidus and cooling was relatively rapid. The more complexly porphyritic, larger chondrules with seriate or bimodal phenocryst textures most likely had more heterogeneous precursor material, especially grain size. The presence of olivine in these chondrules can be explained partly by the complex nucleation kinetics in this system. The peritectic relationship that has olivine on the liquidus of the EC chondrule composition requires that pyroxene nuclei be present at the initiation of cooling in any chondrule melts that are ultimately to crystallize pyroxene. The presence of olivine with shapes from equant to skeletal to barred is the result of a paucity of pyroxene nuclei, and the relative ease of olivine nucleation. Early formed olivines are also found as inclusions in pyroxene phenocrysts in the experiments and thus are not relict, but part of the melting, nucleation and growth process. Similar olivine inclusions observed in natural EC chondrules must be interpreted with care.

The radially textured, often angular fragments are clearly crystallized melt. It is not so clear that they were chondrules, but because radially textures are common in chondrules, it is a logical conclusion. If that is true, they are very large chondrules. Some fragments of radial material have round edges that represent part of the original chondrule outline. Projection of this outline in such fragments suggests the unbroken chondrules have diameters of 2 to 4 mm. Significant superheating of the precursor melts would be required to produce such textures. The range of complex EC chondrule textures suggests a long and complicated event or events.

The presence of clearly defined radial chondrules and radial and barred fragments in E5 and E6 chondrites and the virtual absence of others kinds of sharply defined chondrules suggests to us that it would be difficult to produce the E5 and E6 chondrite by simple metamorphism of E3 and E4 chondrites. Porphyritic chondrules are more difficult to distinguish in the metamorphically altered chondrites partly because the blend with the pyroxene fragments in the matrix readily. The radial textures stand out more readily, but they are also more disequilibrim features that should be more susceptible to alteration than the prophyritic chondrules. The presence of sharply defined, radial chondrules and fragments suggests that the E5 and E6 chondrites are assembled from slightly different material perhaps some of which is already altered before the chondrites are aggregated (see discussion of this topic in Dodd, 1981 chapter 5 [5]).

CONCLUSIONS: The EC chondrule forming event is complex and the precursor material is quite variable. There is a suggestion based only on the analysis of the textures of the chondrites and their chondrules that the E5 and E6 chondrites are not metamorphosed E3 and E4 chondrites.

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