A COMPARISON OF THE COMPOSITIONS OF CHONDRULES IN EH AND EL CHONDRITES AND DISCUSSION OF SOME IMPLICATIONS. D. M. Schneider, A. Taunton, P. H. Benoit, and D. W. G. Sears. Cosmochemistry Group, University of Arkansas, Fayetteville, Arkansas, 72701, USA.

We report compositional data for chondrules from EL3 chondrites and compare them with data for EH3 chondrules. The chondrules in three EL3 chondrites display a range of compositional and textural properties similar to those of chondrules in EH3 chondrites. However, EL3 chondrules are significantly larger than chondrules from EH3 chondrites. This is consistent with the compositional differences between the EL and EH chondrite classes being due to metal-silicate fraction by aerodynamic and gravitational separation of components in a dynamic regolith and with mineralogical differences between the EH and EL classes reflecting different burial depths in the regolith.

Introduction. As the main constituent of chondrites, chondrules potentially provide unique information about chondrite history and processes occurring in the early solar system. The characterization and interclass comparison of chondrules is an essential step in deciphering this history. The chondrules in ordinary and carbonaceous chondrites have been well-studied [1-3], as have chondrules in EH3 chondrites [4-7]. Chondrules are essentially absent in EL6, the presence of relict chondrules indicating that the chondrules were largely destroyed by parent body metamorphism, but the recent discoveries of EL3 chondrites in Antarctica makes it now possible to examine chondrules from the EL class.

Experimental. We made cathodoluminescence (CL) mosaics of thin sections of three EL3 meteorites (ALH 85119, MAC 88180, and PCA 91020) using the techniques of ref. 8 because CL provides a useful means for survey and detailed studies of enstatite chondrites [8-11]. Textures observed under CL and transmitted light were noted using the terminology of ref. 2. The size distribution of all the chondrules in the sections were reported by ref. 12. Phases in selected chondrules in ALH 85119 (eight chondrules), MAC 88180 (nine chondrules) and PCA 91020 (ten chondrules) were analyzed using the Cameca SX100 electron microprobe at Johnson Space Center. (15 kV, 40 nA, 1 μm beam, hornblende (Mg, Na, Ca, K, Ti, Fe, Si and Al), chromite (Cr), and pure metal (Ni and Mn) standards and the PAP data reduction program were used).

Results. The chondrules contain enstatite with very intense red and occasionally blue CL, but most enstatite has a magenta color and was difficult to analyze because of ubiquitous sub-micron inclusions. Some chondrules contained refractory-rich mesostasis areas. In general, chondrules whose enstatite CL is red, magenta and/or blue are porphyritic pyroxene (PP) and radial pyroxene (RP) chondrules, while those whose CL is red with yellow-orange inclusions are porphyritic olivine-pyroxene (POP) chondrules. PP were most abundant, RP and POP are fairly rare (Table 1). Chondrules in these EL3 chondrites have a mean diameter and a range of 220-2200 μm and cumulative distributions very similar to those of LL chondrites [12]. The chondrules are composed primarily of low-Ca pyroxene with minor amounts of olivine, high-Ca pyroxene and, in a few chondrules, inclusions of nearly pure SiO_2. Occasional mesostatis regions are highly rich in Al. The minor element contents of the chondrules seem independent of CL properties or textural type.

Discussion. *Comparison of chondrules from EH and EL chondrites*. EH and EL chondrules are very similar in texture and distribution of textures (Table 1) and their enstatites are very similar in composition (Fig. 1). Chondrules from both EH and EL chondrites contain silicates with dusty metal, widely interpreted as the result of reduction during chondrule formation, but appears more widespread in EL than EH chondrites and gives their enstatite magenta CL rather than blue or red CL. Although they were not analyzed here, FeO-rich chondrules with non-luminescent enstatite similar to those observed in EH chondrites are present in EL chondrites [11]. The only major difference between chondrules from the two classes is their size distribution, chondrules from EH chondrites resembling chondrules from CM chondrites, while chondrules from EL chondrites resemble those of LL chondrites [12].

Comparison of chondrules from enstatite chondrites with other chondrites classes: In that their dominant silicate mineral has an FeO and minor element composition that gives them intense red CL, most chondrules in enstatite chondrites can be assigned to compositional class A1 or A2 (see ref. 13 for definitions), the majority being class A2. All textures observed in chondrules from EL and EH chondrites are also observed in ordinary and carbonaceous chondrites, although the proportions differ. Dusty metal has been reported in Semarkona, where it was attributed to *in situ* reduction [14].

Comparison of other phases in EH and EL chondrites. If chondrules in the EH and EL chondrites are very similar, this is not true of the metal, sulphides and phosphides, where compositional differences are interpreted as reflecting higher closure temperatures (and cooling rates) for EH than EL chondrites [see ref. 15 for a review]. (6 ^{o}C/h for EL6, 10^{3}-10^{4} ^{o}C/h for EH, *c. f.* 10-100 ^{o}C/Ma for ordinary chondrites [16]). Silicates, on the other hand, equilibrated at higher temperatures, most probably during chondrule formation [15].

Implications for the origin of the EH and EL chondrites. Metal (and sulfide) - silicate fractionation by aerodynamic and gravitational sorting in a thick dusty (possibly accretionary) regolith readily explains the bulk Fe/Si compositions and chondrule and grain sizes characteristic of the EH and EL chondrites [12]. The similarity of their chondrules suggests similar formation processes, but the different cooling rates and closure temperatures for sulfides, phosphides and metal indicates different post-accretionary histories, such as might be expected for different burial depths in a thick regolith. We agree with Wood [17] that chondrite formation need not have involved a succession of separate unrelated events spread over several Ma, but could have been the result of a single rapid event with multiple complex and unrelated subevents such as impact into a dynamic regolith, with chondrule formation and metal-silicate fractionation occurring concurrently and with cooling details dependent on burial depths in the resulting ejecta blanket/regolith.

Table 1. Percent by number of textures for EL3 chondrules†

Meteorite	Class	No.	%PP	%RP	%POP	Ref.
ALH 85119	EL3	54	59	19	22	Present
MAC 88180	EL3	57	72	18	11	Present
PCA 91020	EL3	66	55	18	27	Present
Qingzhen	EH3	12	33	33	33	5
Yamato 691	EH3	31	55	45	0	7‡
PCA 91085	EH3	41	83	12	5	Present

† No., number of chondrules; PP, porphyritic pyroxene; RP, radiating pyroxene; POP, porphyritic olivine-pyroxene.

‡ POP maybe included with PP.

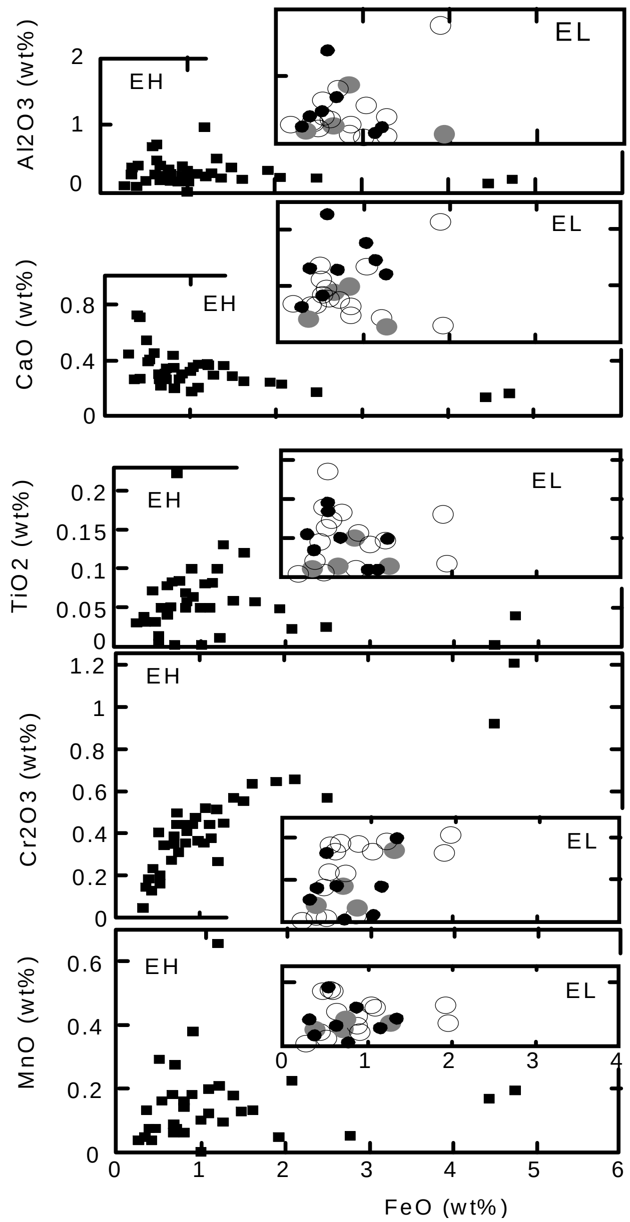

Fig. 1. Minor element composition of low-Ca enstatite in EH3 [5-7] and EL3 chondrites (open circles, PP; black circles, RP; grey circles, POP).

[1] McSween (1977) *G.C.A.* **41**, 477. [2] Gooding & Keil (1981) *Meteoritics* **16**, 17. [3] Sears *et al.* (1992) *Nature* **357**, 207. [4] Rambaldi *et al.* (1983) *E.P.S.L.* **66**, 11. [5] Grossman *et al.* (1985) *G.C.A.* **49**, 1781. [6] Ikeda (1988) *Proc. Symp. Ant. Met.* **1**, 3. [7] Ikeda (1989) *Proc. Symp. Ant. Met.* **2**, 75. [8] Zhang *et al.* (1996) *Meteor. Planet. Sci.* **31**, 87. [9] Steele and Smith (1987) *Meteoritics* **22**, 507. [10] Keil (1968) *J. G. R.* **73**, 6945. [11] Weisberg *et al.* (1994) *Meteoritics* **29**, 362. [12] Taunton *et al.* (1996) *MAPS* **31**, A139. [13] Sears *et al.* (1992) *Nature* **357**, 207. [14] Rambaldi and Wasson (1982) *G.C.A.* **46**, 929. [15] Zhang & Sears (1996) *MAPS* **31**, 647-655, [16] Zhang *et al.* (1996) *J.G.R. (Planets)* **100**, 9417. [17] Wood (1995) *Meteoritics* **30** 601.