THE UNIQUE THERMAL HISTORY OF EL CHONDRITES AND A NEW MEANS OF CLASSIFYING EQUILIBRATED ENSTATITE CHONDRITES.

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We have examined the cathodoluminescence (CL) properties of enstatite chondrites as function of petrographic type. The trends displayed by the EH and EL chondrites are very different. In the EH3 and EL3 chondrites the individual enstatite grains display red, blue or no CL, while in EH5,6 chondrites the CL of the enstatite is predominently blue. In contrast, essentially all of the enstatite in EL5,6 chondrites displays a magenta CL. Spectroscopy of the CL negatives indicates that there is a strong red peak in the CL of the enstatite of the EL5,6 chondrites in addition to the blue peak observed in EH5,6 chondrites. The CL of the equilibrated enstatite chondrites is therefore a sensitive method for classification and confirms the EL5 classification of RKPA 80259, which had previously been contentious, and TIL 91714, a newly recovered meteorite. The different CL properties of the equilibrated enstatite chondrites probably indicates different degrees of structural ordering for the enstatite in the EH and EL classes and that the EL5,6 chondrites contain structurally ordered pyroxene. This implies prolonged metamorphism at low temperatures for the EL5,6 chondrites.

Introduction. Enstatite chondrites formed in a very reducing environment and the low concentration of FeO in the enstatite results in intense CL which may be either red or blue [1], and of varying intensities [2], depending on minor element composition. Previous studies have concerned only EH3,4 chondrites, but with the recent discovery of EL3 [3,4], EH6 and EL7 chondrites [5] we thought it appropriate to examine the CL properties of a series of EH and EL chondrites of petrologic types 3 to 7. We are especially interested in thermal histories of the meteorities (*i.e.* cooling rates and equilibration temperatures) which are reflected in the minor element concentrations and crystal structures which, in turn, determine CL color and intensity.

Experimental details and results. We obtained CL mosaics of 0.5x1 cm^2 sections of 11 enstatite chondrites and examined photographs of the CL mosaics of eight enstatite chondrites supplied by John DeHart from work performed at the Johnson Space Center [6]. The samples included EH3-6 and EL3,5-7 chondrites. A Nuclide Luminescope operated at 13 ± 1 kv and 0.8 ± 0.1 mA and Kodak Gold 400 film, exposure times of 20 to 40 s and the C-41 development process were used.

Enstatite grains with red and blue CL, and a few areas of chondrule mesostasis with yellow CL, were observed in EH3,4 and EL3 chondrites. However, the enstatite in Saint-Sauveur (EH5) and LEW 88180 (EH6) displayed almost entirely a blue CL, with only a few magenta CL grains in LEW 88180. The blue CL of EL3 enstatite appeared less intense than that of EH3 enstatite, however essentially all the enstatite grains in the EL6 chondrites displayed a magenta CL, quite different from the EH5,6 chondrites. The EL6 chondrites also contain abundant areas of brown CL material (probably glass). The LEW 87119 (EL7) chondrite and Happy Canyon (EL6 impact melt) contain only red CL grains.

Spectra were obtained from the negatives of typical EH6 and EL6 chondrites (Fig. 1). These showed that the magenta CL in EL6 enstatite is due to a strong peak at red wavelengths which is absent in the spectrum for the EH6 chondrite. The blue peak has roughly the same intensity, and the same fine structure, in the EL6 and EH6 chondrites.

Discussion. The CL properties of enstatite chondrites provide a simple new means of classifying equilibrated EH and EL chondrites, EH5,6 and EL5,6 chondrites containing enstatite with blue and magenta CL, respectively. Thus, TIL 91714, which Mason described as an E5 chondrite [7] and which contains 0.6-0.8% Si in the metal which is characteristic of the EL group [5], contains only enstatite with magenta CL, confirming its EL classification. The RKPA 80259 chondrite, whose classification is contentious [8,9], also contains pyroxene with the distinctive magenta CL confirming its status as the first EL5 chondrite.

Our EH chondrite results resemble those of McKinley *et al.* [2] who found that as metamorphism increases, the pyroxene in enstatite chondrites assumes an intense blue CL, suggesting that the intense blue CL is a result of metamorphism. It is well-known that the red CL of enstatite in E3,4 chondrites is associated with high concentrations of transition metals (*e.g.* Mn and Cr) which diffuse out of the enstatite with increasing metamorphism [10]. It is possible that the blue luminescence is associated with structural defects, rather than impurities.

The magenta CL of enstatite in the EL5,6 chondrites is associated with very low minor element concentrations and might also be due to structural defects rather than impurities. The X-ray-stimulated luminescence of enstatite achondrites is more stronger at blue wavelengths for disordered pyroxenes but stronger at red wavelength for ordered pyroxenes, especially for grains within a given meteorite [11]. We suggest that while disordered orthopyroxenes are abundant in EH5,6 chondrites, the pyroxenes in the EL5,6 chondrites are in the ordered state (see also ref. 10). The composition of the cubic monosulfides in these meteorites also suggests that the EL5,6 chondrites cooled more slowly than the EH5,6 chondrites [12]. The presence of ordered orthopyroxene in EL5,6 chondrites, and not in the other enstatite chondrites, implies there was a period of prolonged metamorphism at low temperatures for the EL5,6 chondrites but not the others.

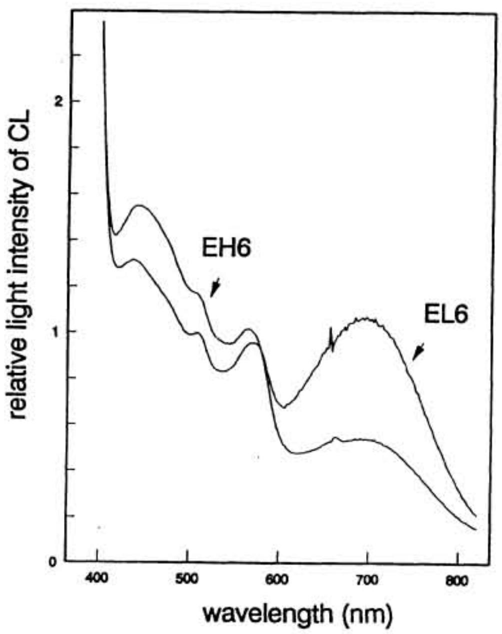

Fig. 1. Visible spectra for the CL of representative regions of EL6 and EH6 chondrites. The spectra were obtained from negatives of the CL photographs, correcting for color reversal in the negatives.

Table 1. The CL of enstatite chondrites.

Meteorite†	Class	CL color‡	Data source
Qingzhen	EH3	Red+Blue	DeHart
ALH 84170	EH3	Red+Blue	DeHart
ALH 84206	EH3	Red+Blue	This work
EET 83254	E3	Red+Blue	DeHart
PCA 82518	EH4	Red+Blue	DeHart
PCA 91085	E4	Red+Blue	This work
Indarch	EH4	Red+Blue	DeHart
St.-Sauveur	EH5	Blue	This work
LEW 88180	EH6	Blue	This work
MAC 88136	EL3	Red+Blue	DeHart
ALH 85119	EL3	Red+Blue	This work
TIL 91714	EL5	Magenta	This work
RKPA 80259	EL5	Magenta	DeHart
ALH 81021	EL6	Magenta	This work
Atlanta	EL6	Magenta	This work
Khairpur	EL6	Magenta	This work
Happy Canyon	EL6§	Red	This work
LEW 87119	EL7	Red	This work
LEW 87223	E3	Red+Blue	DeHart

† PCA 82518 and PCA 91085 are paired
‡ "Red+Blue" indicates isolated individual grains, some with red and some with blue CL.
§ Impact melt.

1. Leitch and Smith (1982) *GCA* **46**, 2083-2097. 2. McKinley *et al.* (1984) *JGR* **89**, B567-B572. 3. Lin *et al.* (1991) *LPS* **22**, 811-812. 4. Chang *et al.* (1992) *LPS* **23**, 217-218. 5. Zhang *et al.* (1993) *Meteoritics* **28**, 468. 6. DeHart (1993) *pers. comm.* 7. *Antarct. Meteor. Newslet.* **16** (1). 8. Kallemeyn and Wasson (1986) *GCA* **50**, 2153-2164. 9. Sears *et al.* (1984) *Nature* **308**, 257-259. 10. Keil (1968) *JGR* **73**, 6945-6977. 11. Reid *et al.* (1964) *Nature* **204**, 1292-1293. 12. Skinner and Luce (1971) *Amer. Mineral.* **56**, 1269-1295. Supported by NASA grant NAGW-3519.