

THE COMPLEX THERMAL HISTORY OF ENSTATITE CHONDRITES.

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The induced thermoluminescence properties of 32 enstatite chondrites have been measured in order to explore the metamorphic history of the EH and EL classes. The EH chondrites show a small increase in TL sensitivity with petrographic type consistent with the increase in blue luminescence as minor elements diffuse out of enstatite during metamorphism. However, the EL chondrites show a much greater range of TL sensitivity and the EL5,6 chondrites appear to be acting independently of the other EL chondrites. We speculate that this is because, unlike the other enstatite chondrites, enstatite is in the ordered structural state in the EL6 chondrites. The TL data provide further evidence, consistent with mineral composition data, that the EL6 chondrites do not constitute a simple monotonic metamorphic series.

Introduction. Induced thermoluminescence (TL) measurements have proved useful in exploring the metamorphic history of ordinary and carbonaceous chondrites and enabling their subdivision into petrographic types 3.0-3.9 [1,2]. The major TL phosphor in ordinary and carbonaceous chondrites is feldspar which is rare in enstatite chondrites [3]. However a number of cathodoluminescence (CL) studies [4,5] have shown that enstatite displays properties which are related to minor element chemistry which are of considerable significance in deciphering the formation and metamorphic history of the meteorites. The enstatite grains may display red or blue CL, of varying intensities, or no CL. Most importantly, the EH and EL chondrites, especially those of higher petrographic type, display very different CL; both EH and EL type 3 chondrites contain a mixture of blue and red CL enstatites but in EH6 chondrites the CL of the enstatite is almost entirely blue while for EL6 chondrites it is a distinctive magenta [6, Zhang *et al.*, this volume]. This is despite current data indicating that minor elements in enstatite decrease in concentration with increasing petrographic type in both classes. In view of the metamorphism-dependence of TL properties and the known CL properties of enstatite chondrites, we have examined the TL of EH and EL chondrites in order to explore their metamorphic histories.

Method and Results. Our apparatus and procedures were as described previously [2], the apparatus being especially sensitive to blue wavelengths. We have measured 12 EH and 20 EL of types 3-6 (and an EL7) [7]. Twelve were falls and 20 were finds displaying various degrees of weathering. The EH chondrites as a group have much lower TL sensitivity than the EL chondrites. The samples generally display two TL peaks, one at $\sim 140^\circ\text{C}$ and one at $\sim 300^\circ\text{C}$ in the glow curve, which both show a small increase in sensitivity from <0.01 to 0.2 (Dhajala = 1) among the EH chondrites. However, there is no systematic trend in TL sensitivity with petrographic type among the EL chondrites. Instead, both TL peaks range from <0.05 to 0.6 for the EL3 chondrites and from <0.01 to 0.9 for the EL6 chondrites (Fig.1).

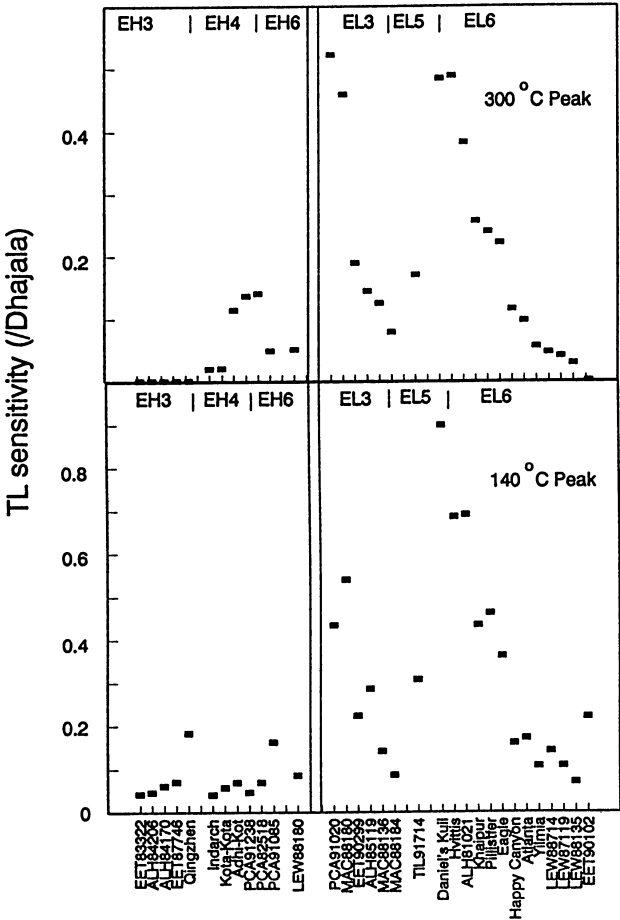
Acid-washing samples of both classes to remove weathering products increased the TL sensitivity of the falls and finds by factors of 3-4 and 4-10, respectively. However, this treatment did not change any of the trends observed.

The TL data are generally consistent with previous pairing suggestions [8]: PCA 91238 and 82518 (and probably PCA 91085); MAC 88184, 88136 and 88180 (MAC 88180 may be higher than the other two because of limited sample size); LEW 87119, 88135 and 88714.

Discussion. Since we routinely employ filters with a blue bandpass in our apparatus, the trends we see are governed by the abundance of blue luminescing enstatite. The magenta CL of EL6 chondrites apparently reflects the presence of a major red peak in addition to the blue peak, and this is confirmed by spectrometry of the CL photographic negatives [Zhang *et al.*, this volume]. The intensity of the blue CL depends on minor element content, being brighter for grains lower in Cr_2O_3 , MnO and TiO_2 [5]. We and others have shown that the concentration of these elements in enstatite decreases with increasing petrographic type in both EH and EL chondrites [3]. We thus have a ready explanation for the TL trends in EH chondrites,

both TL and CL reflecting metamorphism in this class, but not for the more complicated trends observed for the EL chondrites.

We doubt that the spread of TL sensitivities for EL chondrites reflects sample heterogeneity because (1) EH3 chondrites are just as heterogeneous but show very little spread, (2) EL6 chondrites are texturally and compositionally very homogeneous and (3) there is good agreement between paired EL samples. Neither have we found correlations between TL and mineral chemistry which might explain the trends in terms, for example, of considerable variation in metamorphism within a petrologic type, although new high precision EMPA data would help resolve this. We suspect that there is a major component producing TL in the EL5,6 chondrites which is absent from the EL3 and EH3-6 chondrites, in addition to the blue and red luminescing enstatites present in those classes. We suspect that the component is ordered enstatite, and experiments are in progress to test this idea. Whatever the case, the TL data show clearly that while the EH3-6 chondrites represent a metamorphic series analogous to the ordinary and carbonaceous chondrites, this is not true of the EL chondrites which show a major discontinuity between the EL3 and EL5,6 chondrites.



1. Sears *et al.* (1980) *Nature* **287**, 791-795. 2. Symes *et al.* (1993) *Meteoritics* **28**, 446. 3. Keil (1968) *JGR* **73**, 6945-6976. 4. Leitch and Smith (1982) *GCA* **46**, 2083-2097. 5. McKinley *et al.* (1984) *JGR Suppl.* **89**, B567-B572. 6. DeHart (1993) *pers. comm.* 7. Zhang *et al.* (1993) *Meteoritics* **28**, 468. 8. Mason (1992) *Antarct. Meteor. Newslett.* **12**(1), **13**(2), **15**(1), **16**(1). Supported by NASA grant NAGW-3519.

Fig. 1. Plot of the TL sensitivity of enstatite chondrites and the chemical-petrographic class.