NATURAL THERMOLUMINESCENCE EVIDENCE FOR MAJOR DIFFERENCES IN THE THERMAL HISTORY OF EH AND EL CHONDRITES Yanhong Zhang, Paul H. Benoit and Derek W. G. Sears, Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR72701, USA

The EH chondrites display a large range of natural thermoluminescence (TL) levels while most EL chondrites have little or no natural TL. The cosmic-ray exposure ages of EL chondrites are higher than those of EH chondrites, suggesting that duration of radiation exposure is not responsible for this difference. Similarly terrestrial ages are not consistent with the difference in natural TL being due to thermal decay on earth. Unlike other classes of enstatite chondrites, the natural TL of EL6 chondrites shows anomalous fading, which we interpret as being a property of ordered orthopyroxene. This difference in natural TL properties confirms earlier suggestions that the EL chondrites underwent a prolonged period of metamorphism at low-temperatures necessary to produce the ordered orthopyroxene.

Introduction The EH and EL chondrites have experienced very different thermal histories which some authors attribute to different parent bodies [1, 2]. The EH5,6 chondrites contain a mixture of clinopyroxene and disordered orthopyroxene, apparently because they experienced an episode of relatively fast cooling, while the EL5,6 chondrites contain homogeneous ordered orthopyroxene suggesting a very slow cooling history or a prolonged period of metamorphism at low temperature [3-5]. In attempting to explore the recent thermal and radiational history of the enstatite chondrites [6], we have measured their natural TL properties.

Experiment and Results. Our apparatus and procedures were described by Benoit *et al.* [7]. Thirteen EH and 20 EL chondrites (9 observed falls and 24 finds), were examined, and the data reduction methods described by Benoit *et al.* [7] were applied. The samples generally displayed one major TL peak at 300°C. The EH chondrites show a large range of natural TL levels. The EL chondrites have little or no natural TL, the only exceptions being three paired Antarctic EL3 chondrites and two EL6 finds (Fig. 1).

Discussion. There are four factors which could potentially explain the natural TL differences between EL and EH chondrites: (1) terrestrial history (age), (2) cosmic radiation, (3) orbital/thermal history and/or (4) crystallography-controlled factors affecting TL stability. The average natural TL of the EH finds is somewhat lower than that of the EH falls, which can be attributed to terrestrial thermal decay [7]. However, isotopically-determined terrestrial ages of Antarctic enstatite chondrites show a very large range (0 to 0.5 Ma) and there is no indication that EL chondrites have greater terrestrial ages than EH chondrites [8]. Thus differences in terrestrial age would not appear to be the source of the observed natural TL difference. Similarly, the relatively low natural TL of the EL falls can not be attributed to lower exposure to cosmic ray radiation, because cosmic-ray exposure ages (determined from ^{3}He and ^{21}Ne contents) are higher for EL chondrites (~30 Ma (^{3}He) or ~33 Ma (^{21}Ne)) than for EH chondrites (~9 Ma (^{3}He) or ~16 Ma (^{21}Ne)) [9, 10] (Fig. 2). It is possible that there are significant differences in the orbital parameters for EH and EL chondrites, but this explanation would require that all EL6 chondrites were in orbits with perihelion considerably lower than 1 AU prior to reaching earth. There is no support for this argument in the form of lower cosmogenic noble gases or time-of-fall differences between EH an EL chondrites [10, 11].

The remaining possibility is that the observed differences in natural TL levels are caused by factors affecting the stability of the TL signal, i.e., that EL chondrites are prone to "anomalous fading" similar to that observed in certain feldspar-bearing rocks [12]. This is a mechanism of TL decay, probably involving quantum-mechanical tunneling as the wavefunction of the trapped electron overlaps that of the ground state, in which TL loss is much more rapid than predicted by classical TL theory [13, 14]. The anomalous fading of feldspars is thought to involve structural state, since ordered feldspar exhibits this phenomenon while disordered felspar does not [13].

The TL of enstatite chondrites is produced almost entirely by enstatite and we are unaware of previous observation of anomalous fading in pyroxene. In order to determine whether the low natural TL of EL6 chondrites could be due to anomalous fading, we examined the kinetics of natural TL decay of two enstatite chondrites, ALH 81021 (EL6) and Indarch (EH4). Four-mg aliquots were irradiated in a 250mCi Sr-90 beta cell for 2.5 and 7.5 minutes for ALH 81021 and Indarch respectively, and their induced TL measured after 5 minute and 8 day decay intervals. We found that after the eight day decay period, the TL level (at 300°C in the glow curve) of the EL6 chondrite had fallen by 30±10% (2σ) whereas classical TL decay theory would not have predicated any measurable decay in so short an interval. Thus it appears the EL6 chondrite exhibits anomalous fading with kinetics comparable to that of feldspar. We suspect that the low natural TL level of most EL6 chondrites is due to anomalous fading. In contrast, the decay of the EH chondrite after 8-day decay was 15±18% (2σ) suggesting relatively little or no anomalous fading. We suggest that this difference in fading reflects differences in the structure state of enstatite in these meteorite. Most EL6 chondrites contain ordered orthopyroxene. The two EL6 chondrites with high level of natural TL, Yilmia and Happy Canyon, are the only EL6 chondrites (among those we studied) which contain disordered orthopyroxene, based on our X-ray diffraction analysis. The three paired EL3 chondrites, which also have relatively high natural TL levels, contain a mixture of clinopyroxene and disordered orthopyroxene [5].

CONCLUSION Significant differences in the natural TL levels of EL and EH chondrites have been observed. On the basis of laboratory studies of the kinetic of TL decay we suggest that this is because EL chondrites exhibit anomalous fading, while EH chondrites either do not, or do so to a much lesser degree. The main TL phosphor in these meteorites is enstatite and these differences in natural TL fading characteristics are attributed to differences in the average degree of ordering in orthopyroxene in these classes. Our results are preliminary and further studies of the kinetics of natural TL decay are planned, but it is possible that TL studies are uniquely suited to these studies because the enstatite is too fine grained for single crystal X-ray diffraction. The high abundance of ordered orthopyroxene in EL6 chondrites (with a few exceptions) indicates that the EL parent body underwent slow cooling, which is also apparent in a number of other mineral equilibria [16]. In contrast, the EH and EL3 chondrites underwent fast cooling resulting in a high abundance of disordered orthopyroxene.

References:

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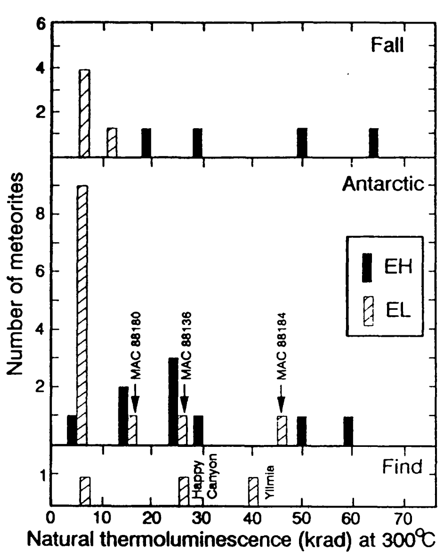

Fig.1 Natural thermoluminescence of enstatite chondrites including observed falls and finds from Antarctic and other fields.

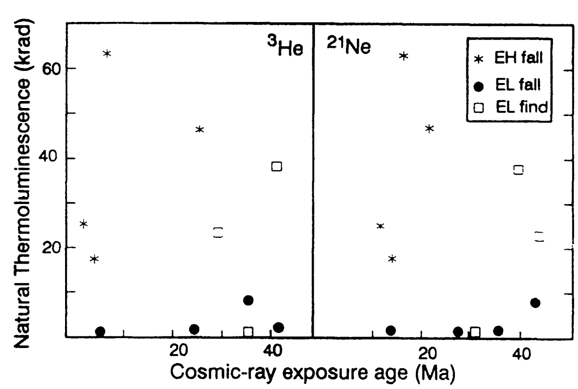

Fig.2 Cosmic-ray exposure age of enstatite chondrites. Left, CRE age determined from ^{3}He content; Right, CRE age determined from ^{21}Ne content.