METALLOGRAPHIC COOLING RATE DIFFERENCES BETWEEN ANTARCTIC AND NON-ANTARCTIC H5 CHONDRITES AND SOME IMPLICATIONS. Paul H. Benoit and Derek W.G. Sears. Cosmochemistry Group, Dept. of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701.

Over the last few years, there has been considerable discussion on possible differences between Antarctic and non-Antarctic meteorites [1]. In the induced thermoluminescence (TL) database [1-3], the only major difference (aside from reduced TL sensitivities as a result of weathering in Antarctic meteorites, ref. 4) is the existence of an unusual group of H5 meteorites with high induced TL peak temperatures (hereafter referred to as the ">190 ^{O}C group") in the Antarctic collection (Fig. 1). This group has no analog in the modern falls. Significantly, the meteorites with high induced TL temperatures all have cosmic ray exposure (CRE) ages of ~8 Ma, whereas the lower, "normal" induced TL ("<190 ^{O}C group") meteorites have CRE ages >8 Ma and experienced lower levels of shielding during cosmic ray exposure [3]. Several independent sources of data (TL, cosmogenic nuclides, petrographic data) indicate that the >190 ^{O}C group is *not* the result of extensive pairing of a few unusual meteorites [2,5]. We suggest that this group represented a major portion of H5 chondrite flux during the time period covered by the oldest portion of the Antarctic collection, but that it has since "decayed" away to insignificance in modern falls [1]. In our previous work [3], we suggested that the TL groups experienced different thermal histories, but neither TL nor cosmic ray exposure data [5] permitted quantitative insights. We have now examined the metallographic cooling rates for meteorites from both TL groups and have found significant differences which are important to understanding the origin and temporal flux of the unusual >190 ^{O}C group.

We obtained polished sections of 13 Antarctic meteorites, six from the >190 ^{O}C group and seven from the <190 ^{O}C group, all of which had been part of the earlier TL study [2] and most of which had been previously examined for cosmogenic nuclides [5]. After petrographic examination, nickel profiles were obtained for taenite (Ni-rich metal) grains in each section using the electron microprobe at JSC. Beam conditions were 30 nA and 20 keV, pure metal standards were used, and all data were reduced using a ZAF correction procedure. Under these conditions, nickel concentrations are accurate to within 2 weight percent. The sections were analyzed in random order and at least ten profiles of well-defined, preferably equidimensional, taenite grains of various sizes were taken where possible. The step size of the profiles was variable, but generally less than 4 microns. A "cooling rate" for each grain was then determined by plotting the central nickel content verses the diameter of the grain (Fig. 2), following the procedure of Wood [6,7]. Only grains with well defined "M" profiles are plotted, except for the very smallest grains (<5 microns) where the beam interaction volume approaches the size of the grains.

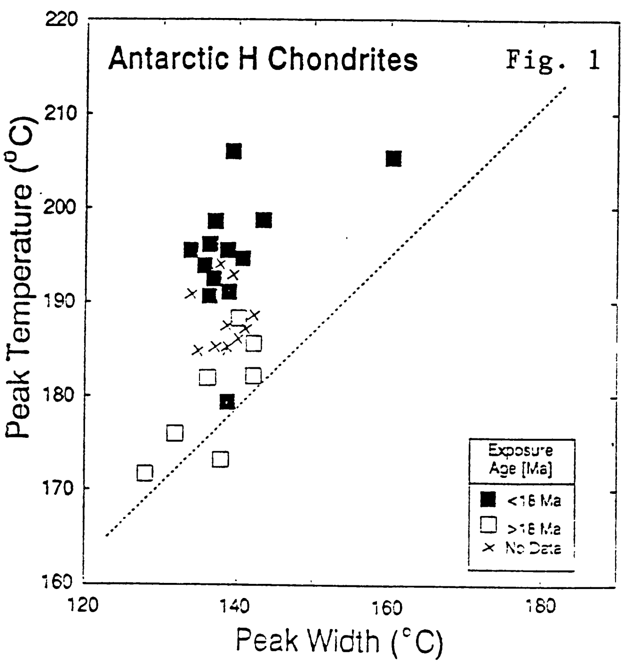
Figure 2 shows a very strong relationship between TL group and cooling rate. The meteorites of the >190 ^{O}C TL group have uniformly higher metallographic cooling rates than the <190 ^{O}C group. In fact, meteorites with metallographic cooling rates as high as 100 ^{O}C/My are extremely rare among non-Antarctic ordinary chondrites, virtually all of which are equivalent to the <190 ^{O}C TL group in Antarctic meteorites [8]. We stress that this difference is independent of the absolute calibration of the cooling rates [7]. Furthermore, Fig. 2 shows indirectly the paucity of taenite grains in the >190 ^{O}C TL group. Taenite in the >190 ^{O}C TL group tends to be concentrated as tetrataenite surrounding kamacite, rather than as discrete taenite grains. In fact, it proved impossible to find any taenite grains suitable for Ni profile measurements in one >190 ^{O}C group meteorite, ALHA77182, and taenite grains in several of the others were rare at best.

This discovery provides new insight into the differences between Antarctic and non-Antarctic H chondrites observed in the induced TL data (Fig. 1). We had earlier suggested [3], based on induced TL, that the meteorites of the >190 ^{O}C group had cooled more rapidly than those in the <190 ^{O}C group. In the case of equilibrated ordinary chondrites, the induced TL parameters are largely set at temperatures of ~800 ^{O}C [2]. Metallographic cooling rates, on the other hand, measure thermal history in the temperature range of 200-500 ^{O}C. The combined data (Fig. 2) indicate that the >190 ^{O}C group cooled at a significantly faster rate than the <190 ^{O}C group during the thermal event over a wide temperature range.

One interpretation of these data is that H5 chondrites in the >190 ^{O}C TL group formed a shallower depths than the <190 ^{O}C group. Using the thermal model of Wood [6], the cooling rates for the two groups indicate that the "normal" <190 ^{O}C group formed at depths >40 km on a body (or bodies) >100 km in diameter, while the >190 ^{O}C TL group formed at much shallower depths, perhaps as little as a few kilometers below the surface. These estimates are obviously dependent on assumed thermal diffusivities and are only suggestive. However, it is also clear, from the metallographic and TL data, that the groups reflect differences in parent body thermal history, not post-metamorphic shock since shock events intense enough to have affected peak temperatures would have left unequivable evidence in metal structures. The existence of a stratifed body does, however, provide an explanation for the apparent break-up history of the body [1]. If the >190 °C TL group represents a near-surface layer, it would be more affected by the 8 Ma impact than the deeper, more protected <190 °C group. The >190 °C group of meteoroid bodies probably would, in general, have been smaller than the <190 °C group and perhaps also released at higher velocities, which would be in accord with the CRE data and the "streaming" observed in the groups' history [1].

The existence of a stratified H parent body has been largely dismissed because of the lack of a correlation between petrologic type and metallographic cooling rates in observed falls [9]. Our present data show that there is a significantly large group of H5 chondrites, with very rapid cooling rates, which have not been considered in this context. One *possible* implication of our present data is that there at at least *two* H parent bodies, one of which was the source of the "background" of H meteoroid bodies and the other of which was stratified, predominately H5 in composition, and did not become an active source of meteroid bodies until the 8 Ma event. Figure 2 of our other paper [1] shows a schematic of this situation. We stress that there is no indication of stratification in L or LL chondrites in the TL data, in accord with other data which suggest that stratification, if any, in these bodies is very complex [10]. Our present data do suggest a multi-body and multi-stage history for H chondrites anda temporal variation in their delivery to Earth. (NASA Grant NAG 9-81).

1. Benoit and Sears (1991) This meeting. 2. Haq et al. (1988) *GCA* 52, 1679. 3. Sears *et al.* (1991) *GCA* 55, 1193. 4. Benoit et al. (1991) *Meteoritics* **26**, 157. 5. Schultz et al. (1991) *GCA* **55**, 59. 6. Wood (1967) *Icarus* 6, 1. 7. Willis and Goldstein (1981) *Proc. LPSC 12th*, 1135. 8. Sears and Batchelor (1990) *Abs. 53rd Met. Soc.*, 151. 9. Taylor et al. (1987) *Icarus* 69, 1. 10. McCoy et al. (1990) *LPSC XXI*, 749.



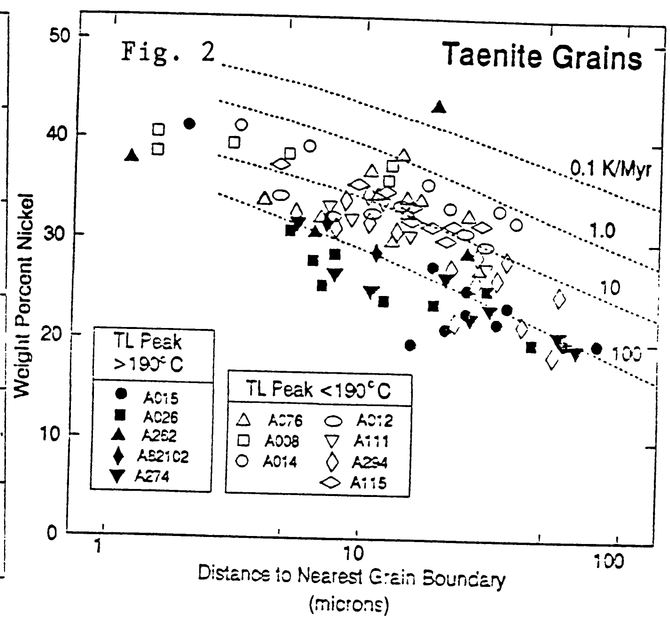


Fig. 1. Induced TL data for Antarctic H5 chondrites from ref. 2. CRE data from ref. 5.
Fig. 2. Electron microprobe data from taenite grains. Cooling rate curves from ref. 7.