THE ORBITAL DISTRIBUTION OF METEORITES BASED ON HIGH TEMPERATURE THERMOLUMINESCENCE: 1. THEORY AND MODERN FALLS. P.H. Benoit and D.W.G. Sears. Center for Space and Planetary Sciences, Chemistry Building, University of Arkansas, Fayetteville, AR 72701 USA. pbenoit@uark.edu.

Introduction. The parent bodies of meteorites are not known, although some major classes have been associated with specific asteroids using reflectance spectroscopy [1]. Information on the location of potential meteorite parent bodies and the evolution of meteoroid bodies to Earth-crossing orbits can be derived to some extent from their orbits immediately prior to Earth impact. Orbits can be delineated by several methods: from camera observations of their fall (four meteorites) [2], from visual observations of falls (~50 meteorites to date) [3], and from time-of-fall for populations of meteorites [4]. We have previously shown that natural thermoluminescence (TL) levels of ordinary chondrites reflect their closest approach to the Sun (perihelion) [5].

The natural TL level of a meteorite, at a given glow curve temperature, can be described by:

$$\frac{n_o}{N} = \left[\frac{s \cdot R \cdot \exp(-E/kT)}{\ln(2) \cdot r} + 1\right]^{-1}$$

where n_o = the number of filled traps, N = the total number of traps, R = the radiation dose required to fill half of the total traps, k = Boltzmann's constant, T = temperature, and r = dose rate [6]. E and s are physical descriptors of the TL behavior of specific TL traps in the phosphors and they exhibit little variation within major meteorite groups [7]. Thus, TL levels reflect temperature and dose rate, where temperatures are determined by perihelion and albedo. Dose rate reflects attenuation of the primary galactic cosmic rays and build-up of secondary cascade particles, solar cosmic rays being attenuated near the surface which is largely lost during atmospheric passage. Thus TL profiles through typical ordinary chondrites are fairly flat, except for the samples taken immediately under the fusion crust where atmospheric heating drained the TL [8]. The time required for TL levels to reach equilibration in the 400 °C region of the glow curve of newly exposed samples varies as a function of temperature, ~10^5 years at for solar heating at 1.5 AU but ~10^4 years at for solar heating 0.8 AU [5, and by calculation from values in ref. 9].

Our previous work on modern falls [5] used the 250 °C region of the glow curve (TL_{250}). TL_{250} is notable for its high intensity (and thus low analytical uncertainties), well-determined TL parameters [7], and high sensitivity to thermal events in the temperature range of 20-50 °C. However, TL_{250} can also be affected by post-fall history, such that TL_{250} levels for finds in temperate climates largely reflect terrestrial age for meteorites with terrestrial ages >1000 years, [10].

Why use high temperature TL? We have not previously reported TL data for high temperature TL (>250 °C) because TL parameters for ordinary chondrites (E and s) were poorly known, We have now determined these parameters for ordinary chondrites [9]. TL levels at 400 °C in the glow curve (TL_{400}) are less responsive to thermal events than TL_{250} (Fig. 1), but they are also less sensitive to loss due to heating on Earth. Higher temperature portions of the glow curve can be used to evaluate perihelia for samples whose TL in the low temperature portion of the glow curve has been affected by heating or large terrestrial ages.

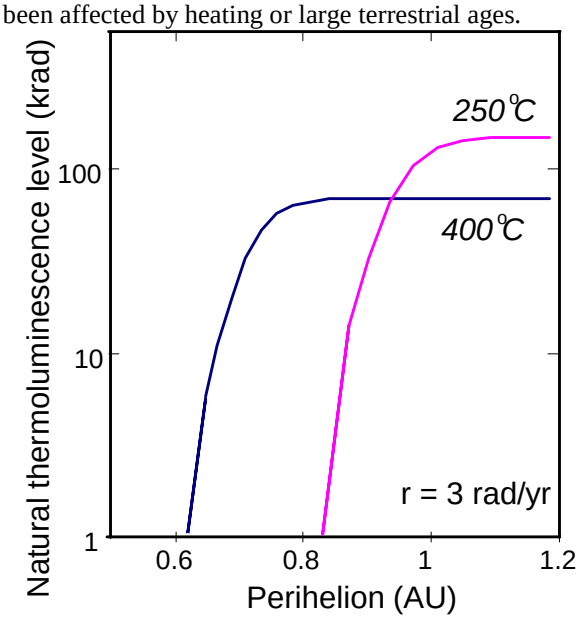

Fig. 1. Calculated TL levels at 250 and 400 °C in the glow curve for ordinary chondrites against perihelion. Calculated using the TL parameters of [7, 9] and an albedo of 0.15.

Application to Modern falls. We have TL_{400} data for 104 equilibrated ordinary chondrite meteorite falls. Sampling and measurement details are described elsewhere [5].

The samples exhibit a range ofTL_{400} of 0.6 - 80 krad. In comparison, TL_{250} exhibits a range of 0.05 - 150 krad. TL_{400}, however, exhibits a strong preference for ~30 krad (Fig. 2).

Comparing TL_{250} and TL_{400}, we find three groups of meteorites: (a) samples with low TL at both temperatures (Laochenzen, Saratov, and Shaw), (b) samples with TL_{250} <1 krad but TL_{400} >15 krad (13 mete-

orites), and (c) samples with TL_{250} >1 krad and TL_{400} >15 krad.

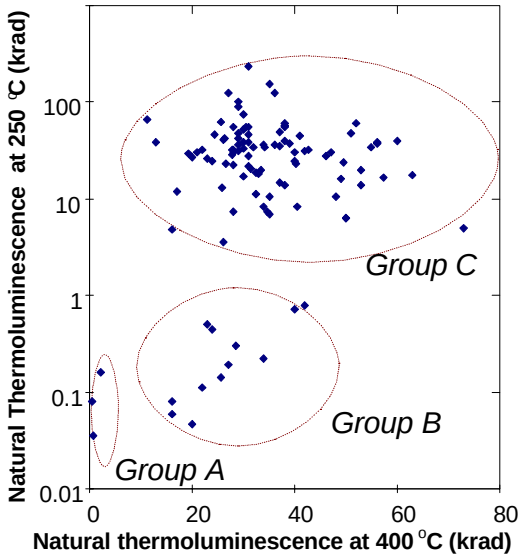

Fig. 2. Natural TL levels for 250 and 400 °C in the glow curve for ordinary chondrite modern falls.

We interpret these groupings as reflecting different classes of orbital histories. Low TL levels through the entire glow curve (Group A) are indicative of extensive heating, probably by orbits with perihelia <0.6 AU (Fig. 1), $<10^5$ years prior to reaching earth. Samples in Group B experienced orbits with perihelia 0.7<x<0.9. Samples in Group C are candidates for orbits with perihelia >0.9 AU over the last 10^5 years.

The high proportion of meteorites with perihelia >0.9 AU is in good agreement with databases of meteoroid orbits based on meteorite falls and "chondrite-like" fireball observations [11]. Within the populous Group C, however, there are also more subtle indications of orbital history. Time-of-fall has been used as a perihelion indicator for groups of meteorites, the greater abundance of ordinary chondrites falling in the PM vs. the AM being interpreted as indicative of perihelia of ~1 AU. We find that AM falls tend to have slightly lower TL_{400} (Fig. 3) than PM falls, and PM falls exhibit a wide peak with a gradual tail to higher TL levels. This can be interpreted as indicating that PM meteorites had perihelia of ~1 AU, or had still not adjusted to inner solar system conditions and thus had only recently evolved to earth-crossing orbit, while AM meteorites have, with some exceptions, experienced orbits with perihelia <1 AU within the last $\sim 10^5$ years.

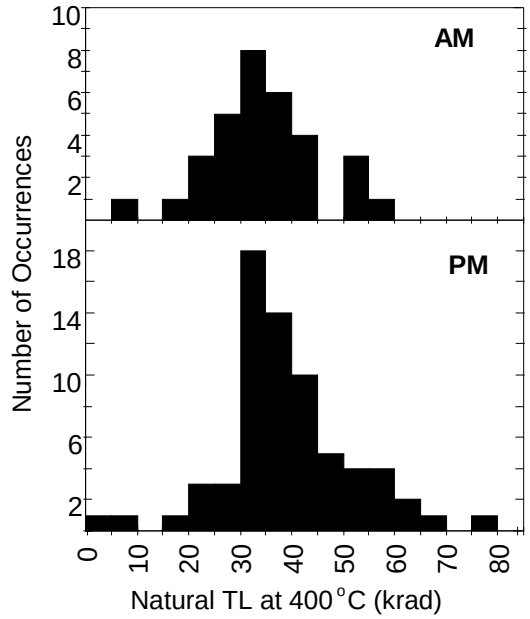

Fig. 3. Comparison of 400 °C TL levels for ordinary chondrite modern falls, subdivided by time-of-fall.

Conclusion. We suggest that, like the 250 °C TL data, 400 °C TL levels of modern falls largely reflect solar heating, and thus perihelia. The 400 °C data offers additional constraints on orbital information from 250 °C data, notably in placing additional limits on perihelia for meteorites with perihelia <0.9 AU.

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