THE ORBITAL DISTRIBUTION OF METEORITES BASED ON HIGH TEMPERATURE THERMOLUMINESCENCE: 2. ORBITS OF METEOROIDS OVER THE LAST MILLION YEARS. P.H. Benoit, J.M.C. Akridge, and D.W.G. Sears. Center for Space and Planetary Sciences, Department of Chemistry, University of Arkansas, Fayetteville, AR 72701 USA. pbenoit@uark.edu

Detailed determination of TL parameters now allows us to apply high temperature TL data to the study of the orbital history of ordinary chondrites [1,2]. Application to modern falls shows that high temperature TL is determined by meteoroid orbit (notably, perihelion) within the last ~10^5 years. Here we apply our TL data to evaluate orbits of meteorite finds, especially for Antarctic ordinary chondrites.

We wish to estimate an orbital parameter for meteorites that fell >2000 years ago. Knowledge of orbital distributions of meteoroids over time is not available, although it is apparent that there have been changes in the meteoroid population on the 10^6 time scale, based on strong peaks in cosmic-ray exposure age distributions [3] and induced TL data [4]. There is also evidence for rapid orbital evolution (<10^5 years) of some meteorites to earth-crossing orbit [5] and evidence for extinct subgroups among H chondrite finds [4, 6]. Abundances and ratios of various cosmogenic radiogenic isotopes have been used to delineate orbital history of some meteorites [e.g., 7] but has not been widely applied due to the large amount of data required for each meteorite, data for individual samples from meteorites possibly reflecting changes in radiation flux and the effects of shielding in addition to orbital changes. Natural TL levels are largely independent of shielding in meteoroid bodies, and, have an "integration time" of ~10^5 years for meteorites with perihelia of ~1 AU. For meteorites with perihelia of ~0.85 AU, response time is significantly less, or ~10^4 years. Thus, with an integration time <10^6 years, TL is less likely to have been effected by long-term radiation flux changes than most cosmogenic radiogenic isotope abundances.

Theory. Fig. 1 shows calculated thermal decay curves for high temperature (400 °C in the glow curve) TL levels of ordinary chondrites at temperatures and radiation dose rates typical for Antarctic meteorites. The 0 °C curve approximates surface conditions, with water melting locally at meteorite collection sites during the summer, while the -5 °curve approximates burial of a few meters in the ice [8]. Although not shown, curves for temperatures <-5 °C, approximating deeper burial in the ice, are similar to the -5 °C curve. Even for meteorites on the surface, TL loss is no more than ~15% over 600,000 years. Most Antarctic meteorites have terrestrial ages between 40,000 and 100,000 years [9], and it is likely that they spent a portion of their history buried in the ice [10]. Thus, high temperature TL levels for Antarctic ordinary chondrites largely reflect radiation and thermal histories in space.

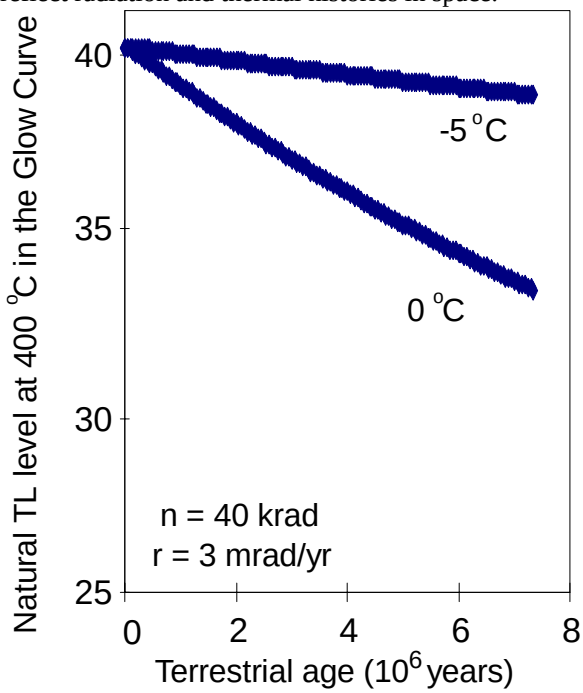

Fig. 1. Natural TL levels at 400 °C in the glow curve for environmental temperatures of 0 and -5 °C and terrestrial radiation dose rate. Calculated using the TL parameters of [2].

Database. We use the database of 778 equilibrated ordinary chondrites from the TL survey of Antarctic meteorites and we exclude possibly paired samples [11]. Most of the samples are from the Allan Hills(ALH), Elephant Moraine (EET), and Lewis Cliff region (LEW, MAC, QUE) sites (see ref. 12 for summaries).

Application. Antarctic ordinary chondrites have a similar high temperature TL distribution to modern falls (Fig. 2). Both data distributions exhibit a broad peak at ~35 krad, with tails to either side, with perhaps a less steep drop off towards higher natural TL levels. Apparently the orbital distribution (or, rather, distribution of perihelia) has not altered significantly over the last 10^5 years, based on the build-up response of TL under various thermal (orbital) conditions [1].

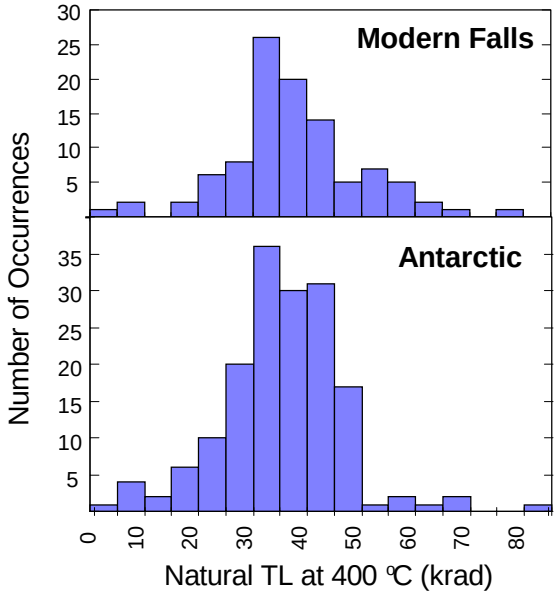

Fig. 2. Comparison of 400 °C TL levels for ordinary chondrites modern falls and Antarctic finds. Antarctic finds are corrected for possible pairings [11].

In Fig. 3 we compare petrographic classes. The classes and types exhibit similar TL distributions although H5 and H6 chondrites have a greater range than L chondrites, with a lower average TL level. The H5 and H6 chondrites have tended to have lower perihelia than L chondrities over the time represented by the Antarctic collection. Time-of-fall data lead to the same conclusion for modern falls [13].

Another application of these data would be examination of possible subgroups of Antarctic meteorites which are not present in the modern meteorite population. It is inferred that these groups ceased to contribute to the meteorite population over time either because their source was cut off or because their orbits evolved to become non-Earth crossing [e.g., 14]. Such groups have been identified on the basis of trace elemental composition [*e.g.*, 6], induced thermoluminescence properties [*e.g.*, 4] and possibly cosmogenic exposure ages [*e.g.*, 3]. However, it is not possible to use the present data for this purpose because at this time the meteorites in these subgroups are too few for comparison with the larger database.

Conclusion. The present data indicate that the distribution of at least one orbital parameter, namely perihelion, has been essentially constant for the ordinary chondrites, over the time represented by the Antarctic meteorite collection, or about the last 40,000 - 100,000 years [9].

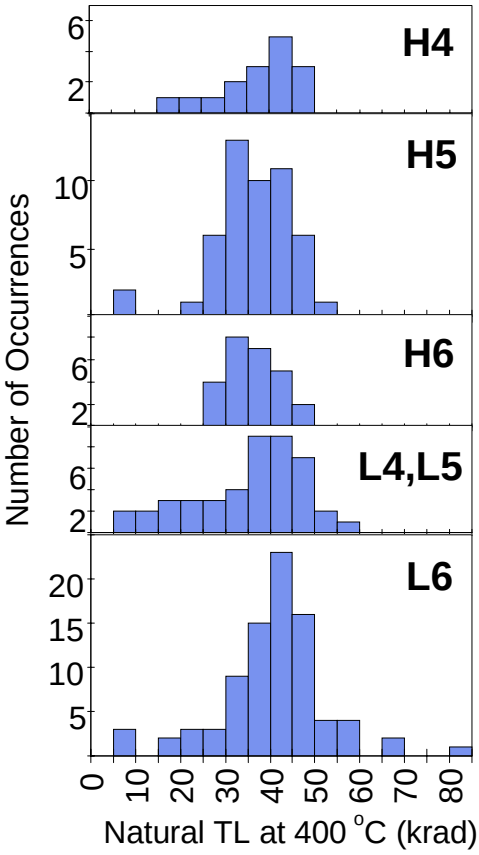

Fig. 3. Natural TL levels of Antarctic ordinary chondrites, subdivided by petrologic class and type. Possibly paired samples were removed from the database [11].

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References. [1] Benoit P.H. and Sears D.W.G. (2001) This meeting. [2] Akridge J.M.C. *et al.* (2001) *Radiat. Meas*. In press.[3] Crabb J. and Schultz L. (1981) *GCA* **45**, 2151; Graf Th. and Marti K. (1994) *Meteoritics* **29**, 643; Graf Th. and Marti K. (1995) *JGR* **100**, 21,247. [4] Benoit P.H. and Sears D.W.G. (1993) *Icarus* **101**, 188; (1996) *MAPS* **31**, 81. [5] Benoit P.H. and Sears D.W.G. (1993) *EPSL* **120**, 463. [6] Michlovich E.S. *et al.* (1995) *JGR* **100**, 3317; Wolf S.F. and Lipschutz M.E. (1995) *JGR* **100**, 3335. [7] Eugster O. *et al.* (1993) *GCA* **57**, 1115. [8] Mayewski P.A. *et al*. (1990) *J. Glac*. **36**, 11; Schultz L. (1990) In *LPI Tech. Rep.* **90-03**, 56; Benoit P.H. (1995) *Quat. Sci. Rev.* **14**, 531. [9] Nishiizumi K. *et al.* (1989) *EPSL* **93**, 299; Welten K.C. *et al.* (1999) *MAPS* **34**, 558. [10] Cassidy W. *et al.* (1992) *Meteoritics* **27**, 490. [11] Benoit P.H. *et al.* (2000) *MAPS* **35**, 393. [12] Benoit P.H. *et al*. (1992) *JGR* **97**, 4629; (1993) *JGR* **98**, 1875; (1994) *JGR* **99**, 2073. [13] Wetherill G.W. (1968) *Science* **159**, 72. [14] L. Schultz and H.W. Weber (1996) *JGR* **101**, 21,177; Wolf S.F. *et al*. (1997) *JGR* **102**, 9273.