DATA ON METEORITE ORBITS AND ORBITAL EVOLUTION FROM NATURAL THERMOLUMINESCENCE AND COSMIC RAY EXPOSURE AGES OF OBSERVED FALLS. Paul H. Benoit and Derek W.G. Sears, Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701

Introduction. Thermoluminescence (TL) has proven to be an extremely useful technique for studying the metamorphism and recent histories of meteorites [1]. Natural TL levels are governed by the competing forces of irradiation in space, which increases TL, and thermal decay which lowers TL. Measurements of natural TL are therefore useful in identifying meteorites that have undergone unusual shock and thermal histories. In particular, it has been suggested that natural TL is a sensitive indicator of unusual orbits, since close passage to the sun will result in increased thermal decay and hence lower natural TL [2,3]. Our calculations, based on McKeever's analysis of meteorite glow curves [4], suggest that natural TL should decrease markedly for orbits with perihelia between 0.9 and 1.0 AU, with considerable scatter as a result of albedo and, to a lesser degree, dose rate differences. We have recently measured the natural TL of 26 observed falls (including 22 ordinary chondrites) for which orbits have been estimated [5] and of 3 meteorites (Innisfree, Pribram, and Lost City) for which orbits have been determined by photographic networks. We measured triplicate aliquots of two samples from each meteorite. The laboratory procedures used in this study represent an improvement over the original work on these meteorites [6].

Results and Discussion. The relationship between calculated perihelia and our present data are consistant with the theoretical trend (Fig. 1). Differences in albedo, which determine the effective temperature of the meteorite in space, in addition to uncertainties in orbital parameters, can account for most of the scatter about the line. The two exceptions, Vengorovo and Pesayanoe, have very high uncertainties in their orbital parameters. Pesayanoe's extremely gas-rich character suggests its perihelion was greater than that calculated from visual observations. However, Innisfree and Lost City, known to have very similar orbits, differ by almost 20 krad in natural TL while Innisfree and Pribram, which differ greatly in perihelia, have almost the same natural TL. All three have fairly similar albedos. This suggests that there are other factors aside from albedo and calculated orbit to be considered.

We have found a relationship for observed falls, which is independent of chemical class, between natural TL and cosmic ray exposure (CRE) age, as determined by the method of Eugster [7,8] (Fig. 2). In general, young meteorites (<15 Ma) show a large spread of natural TL, ranging from 20 to 70 krad. Older meteorites (>15 Ma) have a much more restricted range between 20 and 40 krad. Measurements on other non-Antarctic meteorites seem to fit this distribution [2,3]. There are a small number of meteorites (from other studies [3]) with natural TL <5 krad. Many of these low-TL meteorites also have very low 3-He/22-Ne ratios (e.g. Malakal and Limerick, 3.2 and 3.3, respectively). It is likely that these meteorites have had an unusual history involving reheating, perhaps by close passage to the sun as suggested by our natural TL calculations.

Many basaltic meteorites also have very low natural TL, but this is at least in part the result of anomalous fading rather than an orbital and/or exposure age effect [9].

Conclusions.

1) Natural TL is extremely sensitive to perihelia <0.9 AU. In general, a meteorite with a TL > 30 krad cannot have a perihelion of less than 0.9 AU. However, natural TL, as a function of orbit, is also highly dependent on

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albedo. Thus, for a given orbit, a dark meteorite will have a lower natural TL TL than a meteorite with a high albedo.

2) However, in addition to orbit, one must also consider time in interpreting natural TL. Older meteorites (high CRE age) have a much lower and narrower range of natural TL than do young meteorites. This can be explained in terms of current ideas on asteroidal orbit evolution. Young meteorites are constrained to orbits with perihelia near 1 AU. Over time, their orbits evolve to smaller perihelia [10, 11]. Thus, older meteorites should have low levels of natural TL (c.g. Fig. 2). Younger meteorites should have a broad range of natural TL as a result of slight differences in perihelia (between 1 and 0.9 AU) and differences in albedo (c.g. Fig. 1).

3) Natural TL is a sensitive indicator of unusual histories involving close solar passage or recent shock reheating. Data from this and other TL studies [2,3] suggest that only a very small proportion of meteorites have recent orbits of <0.8 AU.

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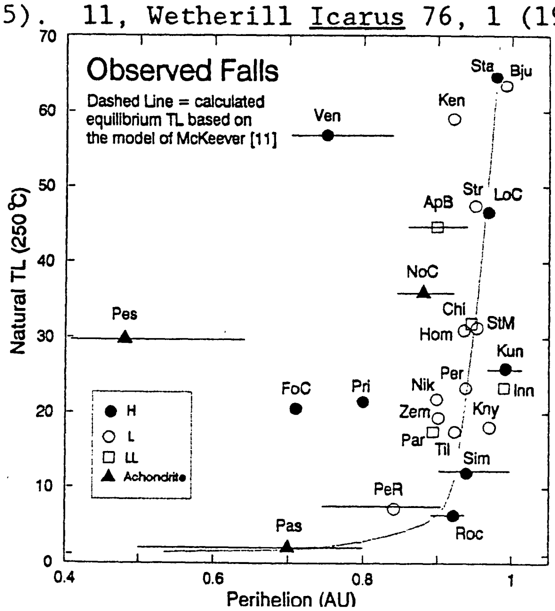

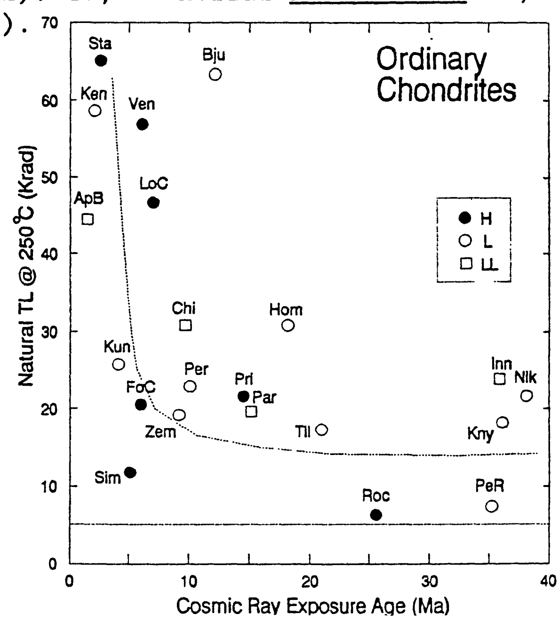

Fig. 1. (left) Natural TL vs. calculated perihelia from visual observations or photographic networks. Unless otherwise indicated, uncertainties in perihelia as a result of differing assumed velocities are within the size of the symbols. Theoretical TL curve based on TL parameters for Lost City [4]. The curve suggests that samples with natural TL <5 krad experienced small perihelia. Some meteorites with natural TL < 5 krad have low 3-He/22-Ne ratios, which is independent evidence for reheating.

Fig. 2. (right) Natural TL vs. CRE age for ordinary chondrites. Meteorites with CRE age <15 Ma show a large spread on natural TL, while those with CRE age > 15 Ma tend to have low levels of natural TL.