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THE ORBITAL DISTRIBUTION OF EARTH-CROSSING ASTEROIDS AND METEOROIDS. P. H. Benoit and D. W. G. Sears, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville AR 72701, USA.

The relationship between meteorites and Earth-crossing asteroids and between individual meteorites and meteor showers has been the subject of debate for some time. Recently, links have been claimed between certain meteorites and meteoroid complexes [e.g., 1] and it has been suggested that some meteorites are members of orbital "streams" [2]. It is difficult to evaluate these ideas because of the lack of appropriate measureable properties in the meteorites themselves. Cosmic ray exposure ages provide one approach, but most cosmogenic nuclides have large half-lives and hence generally reflect the long-term radiation exposure of the body rather than the short-term orbital evolution leading up to Earth impact. Here we use natural thermoluminescence (TL) data to determine the "average" perihelion of ordinary chondrites among the modern falls over periods of time of less than 10^3–10^5 yr prior to Earth impact.

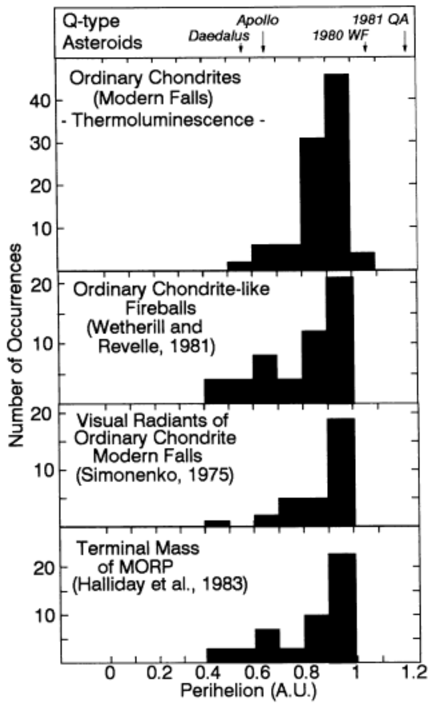

Fig. 1.

The level of natural TL of a meteorite (at a given glow-curve temperature) is a function of buildup through radiation dose (which, in turn, is a function of depth or "shielding" and external cosmic ray flux) and decay through thermal draining [3]. The shallow TL vs. depth profile observed in lunar cores [4] can, after correction for irradiation geometry, be used to to calculate TL profiles in meteoroid-sized bodies. Our new calculations indicate a range of natural TL of only about 15% in large meteoroid-sized bodies and an even smaller range in smaller bodies. The "half-life" of TL is far greater than the solar/cosmic ray flux cycle and hence variations in the external flux over time are expected to have only very minor effects. It is thus possible to calculate an "irradiation temperature" for a meteorite using its natural TL level, which can be shown through decay calculations to largely reflect the perihelion of the meteoroid body. The time period over which this irradiation temperature is averaged is a function of the temperature (perihelion); the period is $<10^3$ yr at 0.7 AU, $<10^4$ yr at 0.9 AU, $<10^5$ yr at 1.0 AU, and $<5 \times 10^6$ yr at >1.2 AU. Conversion of irradiation temperatures to perihelion requires that a value for meteoroid albedo be assumed; in the present analysis we assume such bodies have an albedo of ≈0.2.

For a collection of H, L, and LL modern falls (Fig. 1) we find a perihelion distribution that is fairly similar to those suggested by other observations. Perihelia for modern falls tend to be concentrated between 0.9 and 1.0 AU. However, our distribution is most similar to that found for ordinary chondritelike fireballs by [5] in that we find a large number of meteorites with perihelia between 0.8 and 0.9 AU. About 10% of modern falls have perihelia <0.7 AU and about 5% of modern falls apparently struck the Earth prior to reaching thermal equilibrium after evolving from orbits with perihelia >1.0 AU, and thus have calculated perihelia >1.0 AU. We observe no apparent direct link between any group of meteorites and individual Q asteroids (Fig. 1).

Our data support the conclusions of orbital calculations for Lost City [6] and Innisfree [7] that suggest Lost City had a perihelion of ~1.0 AU for at least the last 10^5 yr and that Innisfree had a perihelion as low as 0.8 AU within the last 10^5 yr. Our data do not support a direct link between Farmington (with a TL-derived perihelion of 0.82) and the Taurid meteoroid complex (perihelion of ≈0.4) [1]. We also observe a tendency for meteorites with large cosmic ray exposure ages (>35 m.y.) to have shallower perihelia, typically close to 0.8 AU, than those with relatively short cosmic ray exposure ages, which tend to have perihelia between 0.85 and 1.0 AU.

In summary, we find that natural TL data can be used to quantitatively derive the perihelia of meteorite falls. These data are free of potential observational biases (such as those present in, for example, time-of-fall data) and assumptions of orbital parameters (which are a problem for orbits calculated from the radiants of observed falls). Potential applications of these data include investigation of possible meteorite "streams" [2] and exploring questions such as whether different types and classes of meteorites have different orbital distributions [8].

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