THE WEATHERING OF ANTARCTIC METEORITES: CLIMATIC CONTROLS ON WEATHERING RATES AND IMPLICATIONS FOR METEORITE ACCUMULATION.

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Descriptions of weathering are typically qualitative. In the present paper, we use the induced thermoluminescence (TL) of equilibrated Antarctic ordinary chondrites to evaluate their degree of weathering. We find that induced TL sensitivity correlates with weathering estimates from hand specimen descriptions. We also find that the degree of weathering depends on terrestrial age, with meteorites that fell during the current interglacial period having higher degrees of weathering than meteorites that fell during the last glacial period (about 100 ka).

Introduction. Weathering of meteorites includes a variety of chemical and mineralogical changes, including conversion of metal to iron oxides, or rust. Other changes include the devitrification of glass, especially in fusion crust. On a longer time scale, major minerals such as olivine, pyroxene, and feldspar are partially or wholly converted to various phyllosilicates.

The degree of weathering of meteorite finds is often noted using a qualitative system based on visual inspection of hand specimens. Several quantitative weathering classification systems have been proposed or are currently under development. Wlotzka has proposed a classification system based on mineralogical changes observed in polished sections [2] and Mossbauer properties of meteorite powders have also been used [3]. In the current paper, we discuss induced thermoluminescence (TL) as an indicator of degree of weathering of individual meteorites. The quantitative measures of weathering, including induced TL, suffer from one major flaw, namely that their results only apply to small portions of the meteorite.

Methods. We obtained 200 - 400 mg samples of Antarctic equilibrated ordinary chondrites from Johnson Space Center. Each sample was taken >0.6 cm from any possible fusion crust. Three 4 mg aliquats of homogenized powder were used for induced TL measurements, the procedures given by [4]. The maximum TL intensity, or sensitivity, is reported relative to that of the Dhajala (H3.8) meteorite.

In order to evaluate heterogeneity, we analyzed multiple samples from LEW 85320, ALH A78084, MET A78028, LEW 85319, and Great Bend. These samples were taken at intervals along profiles.

Results. The induced TL sensitivity of equilibrated modern falls ranges from about 1 to 30, relative to Dhajala, with a few samples <1. Falls with TL sensitivities <1 generally exhibit petrographic evidence of high degrees of shock. The induced TL sensitivities of Antarctic equilibrated ordinary chondrites range from 0.1 to 10, with a few samples <0.1 (Fig. 1).

Highly weathered (class C) meteorites tend to have lower TL sensitivities than less weathered (class A/B) meteorites (Fig. 1). The least weathered Antarctic meteorites have a TL sensitivity distribution similar to that of modern falls.

Sample-to-sample variation in TL sensitivity within large meteorites is generally modest, generally no more than a factor of two. We note, however, that this degree of variation is only for interior samples.

We removed paired samples from our database, as determined on the basis of petrography, natural and induced TL, and cosmogenic nuclide abundances and activities [5].

Discussion. Shock processing also results in decreased TL sensitivities. However shock usually results in very low TL sensitivity levels (generally <0.1), much lower than typically observed for the most weathered Antarctic meteorites (Fig.1).

TL sensitivity generally decreases with increasing terrestrial age, reaching an "equilibrium" level of about 0.4 (relative to Dhajala) for terrestrial ages >0.4 Ma (Fig. 2). This suggests that the degree of weathering increases as a function of terrestrial age. However, there is a group of meteorites with low terrestrial ages with low TL sensitivity levels (Group 1), compared to a group with slightly larger terrestrial ages (Group 2, Table 1) which have TL sensitivity levels similar to modern falls.

One possible explanation of the two groups observed in Fig. 2 is that the degree of weathering depends on the climatic conditions at the time of fall. The terrestrial ages suggest that the meteorites in

Group 1 fell during the current interglacial period and those in Group 2 fell during the last glacial period, although the large uncertainties on most of the terrestrial age estimates (from ^{36}Cl) are very large. Precipitation in the interior of Antarctica in the area of most of the meteorite collection sites is determined by the extent of sea ice [8]. During glacial periods, temperatures are lower, and the amount of precipitation is low; during interglacial periods temperatures are warmer, and conditions are much wetter. Our data suggest that most weathering occurs during interglacial periods, and extensive weathering can occur within a single period.

The relative lack of weathering in meteorites from the last glacial suggests that these meteorites have been shielded from weathering, probably by entrainment in the ice. This suggests that meteorites are buried and entrained in ice during glacial periods, while those that fall in interglacial periods tend to remain exposed on or near the ice surface.

Conclusions. Induced TL sensitivity of equilibrated ordinary chondrites from Antarctica largely reflects their degree of weathering. We find that induced TL sensitivity generally decreases in these meteorites as a function of terrestrial age, with an "equilbrium" TL level being reached in about 0.4 Ma, but it appears that weathering depends more on climatic conditions at the time of fall than on terrestrial age. During interglacial periods, exposed meteorites are apparently weathered quite rapidly.

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Table 1. Antarctic meteorites of possible time-of-fall groups (Fig. 2). The last glacial period in Antarctica was approximately between 18 - 70 ka.

	Class	Terrestrial Age (ka)
Group 1		
ALHA78194	H5	50±50
ALH 82102	H5	11±1
ALH 85037	H6	70±70
ALH 85123	L5	45±45
LEW 85725	L6	30±30
Group 2		
ALHA76008	H6	100±70
ALHA79003	L6	110±70
ALHA79007	L6	45±45
ALH 85033	L4	40±40
ALH 85319	H5	70±70

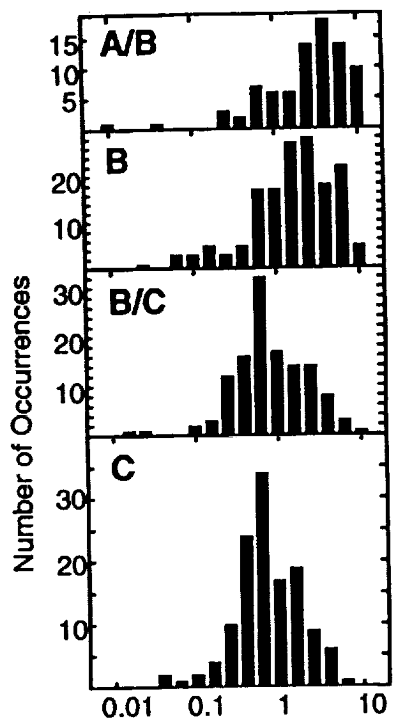

Fig. 1. Induced TL sensitivity of Antarctic equilibrated chondrites.

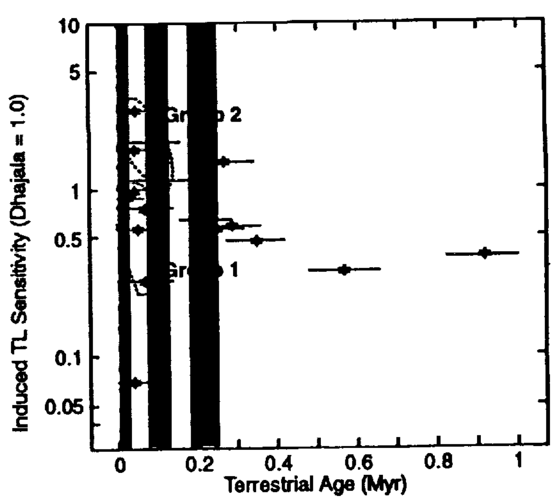

Fig. 2. Induced TL sensitivity as a function of estimated terrestrial age for equilibrated ordinary chondrites. Climatic periods are shown for the last 300 ka, with interglacial periods shown in stippling. Most of the terrestrial age estimates have large uncertainties [6] but possibly there are two groups (Table 1).