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Existence of two groups in thermoluminescence of meteorites

THE thermoluminescence (TL) properties of meteorites[1-4] may be applicable to the determination of exposure age, terrestrial age, thermal gradients, radiation history and preatmospheric shape. In an attempt to apply TL to the determination of terrestrial age we have discovered that meteorites can be divided into two groups, the existence of which is relevant to several of the applications.

Our apparatus consists of a molybdenum strip heated electrically at 5 ± 0.05° C s^{-1} by an electronic control unit. The light emitted by 10 mg of 50 μm sieved powder placed on a defined area of the strip is measured by a cooled and shielded 9635B EMI photomultiplier tube. The amplified signal is plotted automatically against temperature. The resulting 'glow curve' has two peaks, one at about 200° C (LT) and one at about 350° C (HT).

Table 1 Details of meteorites of known terrestrial age

Meteorite	Terrestrial age (yr)	BM no. (if applicable)	Class	Thermoluminescence group
Barwell	8		L6	Low
Bruderheim	13		L6	Low
Khanpur	21		LL5	Low
Mangwendi	39		LL6	Low
Olivenza	49		LL5	Low
Saratov	55	BM1956, 169	L4	High
Crumlin	71	BM86115	L5	Low
Gambat	76	BM83864	L6	Low
Jelica	83		LL6	Low
Soko Banja	96		LL4	High
Tennasilm	101	BM1913, 218	L4	High
Butsura	112	BM34795	H6	High
Dhurmsala	113		LL6	Low
Aldsworth	138	BM61308	LL5	Low
Durala	158	BM32097	L6	High
Limerick	160		H5	Low
Wold Cottage	178	BM1073	L6	High
Mauerkirchen	205	BM19967	L6	High
Ogi	232	BM55256	H6	High

We recorded the glow curves of nineteen meteorites that were seen to fall and are therefore of accurately known terrestrial age (Table 1). Two groups were immediately apparent; one in which LT falls below HT in about 100 yr after fall, and one in which it takes several hundred years for this to occur. Although the two groups are evident by visual inspection of the glow curves they are more obvious in Fig. 1, a plot of $\log_e$ (peak height ratio, LT/HT) against the terrestrial age of the meteorite. The low retentivity group, in which LT is fading fastest, shows much scatter from the line but the high group shows surprisingly little. The cause of the scatter is probably small initial differences in the TL of the meteorites, different thermal histories since the decay is temperature sensitive and, in the case of the low group, varying degrees of shock.

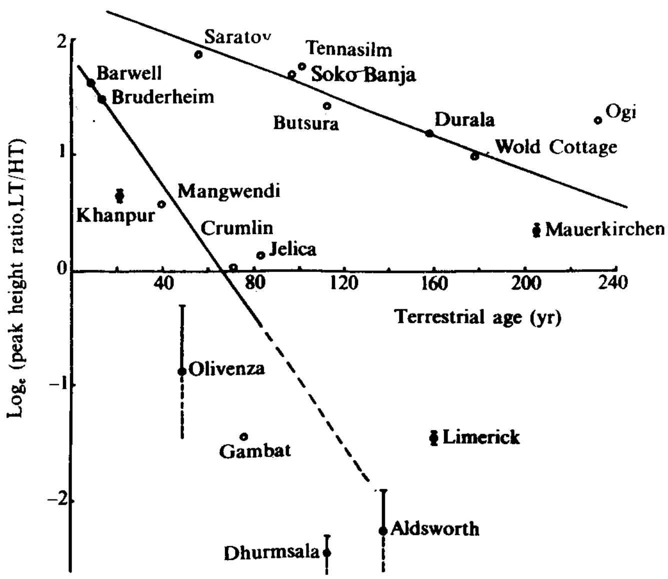

Fig. 1 Natural logarithm of the peak height ratio (LT/HT) as a function of terrestrial age, for meteorites of known terrestrial age.

To confirm that meteorites in the low retentivity group are fading faster than meteorites in the high retentivity group, the mean life (time to fall to 1/e) of LT in six meteorites was determined. We heated powder from three high and three low group meteorites in the dark at 120° C for various periods up to 70 h. Heating was done in an Abderhalden drying pistol surrounded by refluxing tetrachloroethylene. The results are shown in Fig. 2. Although the curves are not exponential, and the results must be treated as approximate, it is clear that the two groups are due to different mean lives of LT in the luminescent material. The mean life, τ, at room temperature can be calculated from

$$\tau\,(300\mathrm{K}) = \tau(393\mathrm{K}) \exp\,[(E/k300) - (E/k393)]$$

where E, the energy of the peak, can be found by the initial rise method and k is the Boltzman constant[5]. For the low retentivity group the mean life at room temperature is 6–8 yr and for the high group 45–55 yr.

We have not been able to determine with certainty the reason for the two groups but suspect that it is related to shock. Both metamorphism and shock change the nature of the luminescent feldspar, shock producing maskelynite and metamorphism causing recrystallisation. Chemical–petrological groups assigned on the extent of metamorphism[6] show no correlation

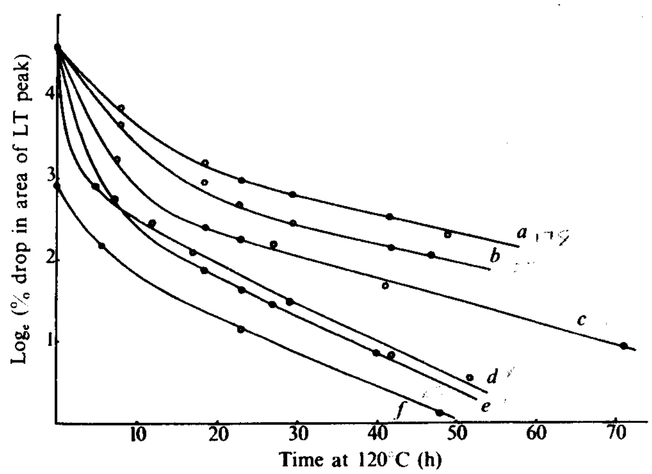

Fig. 2 Isothermal annealing curves for three high and three low retentivity meteorites. The ordinate is the natural logarithm of the percentage drop in the area under LT. Overlap has been allowed for where necessary and the curve for Jelica has been displaced vertically downwards for clarity. *a*, Wold Cottage (50–54 h); *b*, Saratov (50–55 h); *c*, Tennasilm (50–55 h); *d* Barwell (28–34 h); *e*, Bruderheim (26–34 h); *f*, Jelica (28–34 h). The numerical values are estimated for the mean lives at 120°C.

with the TL groups of the meteorites, inferring that metamorphism does not govern TL group membership. Shock is known to reduce TL intensity, however, and we have reason to believe that it also reduces the mean life of LT. Most of the members of the low group have been shocked or are breccias (R. Hutchison, personal communication). Olivenza and Barwell are anomalous in this respect, as is Soko Banja which is in the high group but is a breccia. Shock may also explain the scatter in the low group line in Fig. 1 since it can occur with various degrees of severity.

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D. W. SEARS
A. A. MILLS

Departments of Astronomy and Geology,
University of Leicester, UK.

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