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THERMOLUMINESCENCE AND CHARGED-PARTICLE TRACK STUDIES OF INDIVIDUAL CHONDRULES FROM THE ALTA'AMEEM (LL5), DHAJALA (H3) AND KIRIN (H5) METEORITES

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Thermoluminescence (TL) and cosmic-ray tracks have been studied in three recent falls. These are: Alta'ameem (Al-Bassam, 1978) (fell 20th August 1937; recovered mass ~ 6 kg; estimated fallen mass ~ 30 kg); Dhajala (Bagolia *et al.*, 1977) (fell 28th January 1976; recovered mass ~ 60 kkg; estimated fallen mass ~ 100 kg); and Kirin (Ouyang, 1979) (fell 8th March 1976; recovered mass 2.7 tonnes; estimated fallen mass > 3.7 tonnes). Chondrules as well as bulk powder samples were investigated.

TL STUDIES

Six individual chondrules each from Kirin and Dhajala and ten from Alta'ameem were used for the measurement of natural TL as well as that induced by 50 krad of ⁶⁰Co γ -rays in drained samples. Dhajala chondrules gave the most variable (by a factor of 7) TL of each type; individual chondrules from Kirin and Alta'ameem showed a range of ~ 3 in their natural and induced TL.

Two types of glow-curve shapes were observed for natural TL in the case of Alta'ameem and Dhajala chondrules, but only one from the Kirin chondrules. Figure 1 shows the two typical natural TL shapes for Dhajala: 'normal shape' (chondrule 4) and 'HHT deficient shape' (chondrule 6). In the latter case, while the low temperature (LT) peak occurs in its normal position, the high temperature (HT) peak occurs early and is prominent, whereas the very high temperature (HHT) region is greatly depleted in TL glow. The artificial curves for chondrules from all three meteorites are similar and are all "normal". The artificial LT peak usually occurs ~ 25° earlier than in the natural curves.

The natural TL glow from Kirin bulk powders was considerably brighter than that from the other two meteorites, the low-temperature peak-height ratios being Dhajala: Alta'ameem: Kirin = 1:6:16. Since the ratios for artificial TL were 1:7:6, the observations suggest a higher natural dose received by the Kirin sample, subject to comparable thermal stability of the LT peak in the three meteorites.

TRACK STUDIES

Olivine crystals from crushed and sieved bulk samples gave the following values of track densities. Alta'ameem: $(1.33 \pm 0.10) \times 10^6 \text{ cm}^{-2}$;

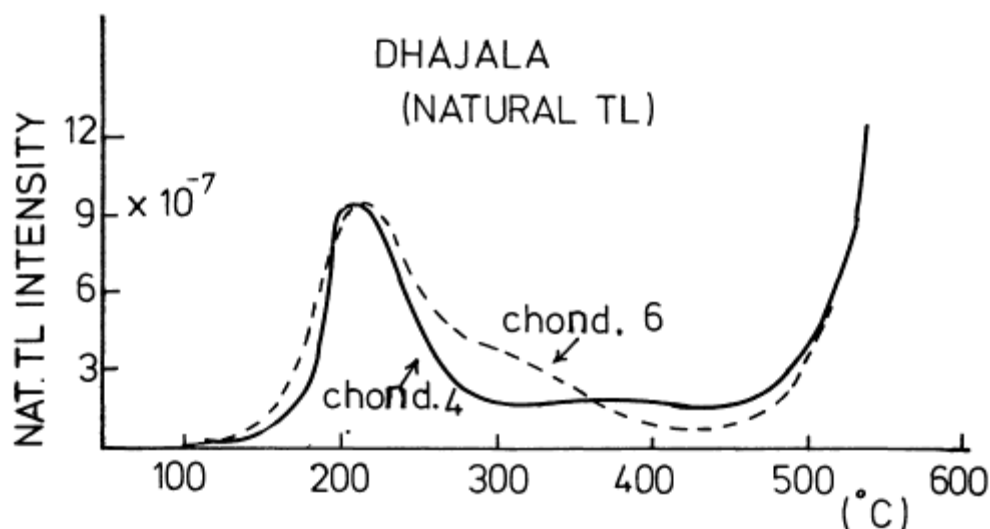


Fig. 1 Typical natural TL from Dhajala chondrules. Chondrule 4: 'normal shape'; chondrule 6: 'HHT deficient shape' (depressed TL glow at very high temperatures).

Dhajala: $\sim (1.2 \pm 0.2) \times 10^5 \text{ cm}^{-2}$; Kirin: $< 8 \times 10^2 \text{ cm}^{-2}$. These tracks are predominantly of VH cosmic-ray origin. Phosphate phase (chlorapatite) in the Alta'ameem bulk sample gave a track density of $(2.5) \times 10^6 \text{ cm}^{-2}$. No etchable phosphates have so far been found in Kirin (and not studied yet in Dhajala).

The preatmospheric shielding depths of our samples in the three meteorites have been determined, using the procedures of Fleischer *et al.* (1967) and based on the cosmic-ray exposure ages (known or assumed) as recorded in Table 1.

DISCUSSION

The greater shielding depth of our sample in the Kirin meteorite determined from track studies is consistent (Sears, 1975) with the trend in the values of LT/HT peak-height ratio for the natural TL from bulk powders: this ratio being ~ 13 for Kirin, but only ~ 4 and ~ 5 for Dhajala and hAlta'ameem, respectively. Our conclusion is supported by Chinese observations (Dr Ouyang, personal communication).

The chemical composition of individual chondrules has been determined by energy-dispersive X-ray analysis. The Ca/Si ratios for all three meteorites are fairly constant from chondrule to chondrule. The variation in the observed TL output (both natural and artificial) noted above is, however, in sharp contrast to this constancy. Dhajala natural TL is also the weakest

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Table 1
Calculated in-space shielding depths of
samples studied, and other related parameters

Meteorite	Track density ρ (cm ⁻²)	Exposure age T (m.y.)	Shielding depth (cm)	Recovered mass (kg)	Final radius r (cm)
Alta'ameem	1.3×10^6	15*†	3-5	6 (up to ~ 30)	13*
Dhajala	$\sim 1.2 \times 10^5$	7†	~ 8	60 (up to ~ 100)	38 ± 2 †
Kirin	$< 8.0 \times 10^2$	5††	> 25	2700 (> 3700)	> 63*

*Estimated from the stipulated total mass reaching the earth.

†Bagolia *et al.*, 1977.

*†Heusser *et al.*, 1978.

††Assumed; and confirmed by Ouyang *et al.* (personal communication), who found exposure ages of 3-8 m.y.

(D:A:K = 1:6:16; see above). These observations indicate that TL is most variable in the least equilibrated meteorite (Dhajala, H3), reflecting greater variation in the structure of its feldspathic content. The efficiency of TL production (both natural and artificial) also appears to be associated with petrological type: the lowest type (H3) giving the least TL, presumably because of its greater glass vs. crystal content.

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