Rapid weathering and terrestrial thermal history of meteorites from the Nullarbor Plain, Australia. P.H. Benoit, J.M.C. Akridge, and D.W.G. Sears. Cosmochemistry Group, University of Arkansas, Fayetteville, AR 72701 USA. E-mail: Cosmo@uafsysb.uark.edu.

Abstract. *We have measured the natural and induced thermoluminescence (TL) of a suite of meteorites from the Nullarbor Plain, Australia. Natural TL levels are similar to Saharan finds, but meteorites with terrestrial ages <5 ka have lower natural TL levels, reflecting either temperatures >40 °C or more extreme heating at the time of fall. The TL sensitivity of Nullarbor Plain meteorites is similar to that of meteorites from the Sahara, and lower than the modern falls, which we attribute to extensive weathering.*

Introduction. The ice sheet of Antarctica, bedrock surfaces in the Sahara desert and the high plains of North America are major sources of meteorite finds [1-3]. Another source is the arid to semiarid Nullarbor Plain of Australia, where over 400 meteorites have been found [4]. Here we report natural and induced thermoluminescence (TL) data for Nullarbor Plain meteorites, with emphasis on terrestrial age and thermal history, weathering, and possible pairings. Induced and natural TL data for desert finds from Antarctica, the Sahara, and North America have been previously reported [5].

Terrestrial age estimates for meteorites from the Nullarbor Plain are generally <20 ka, with many <5 ka [6]. Natural TL levels reflect terrestrial age, but are also influenced by temperature [7]. Weathering of equilibrated ordinary chondrites (EOC) can be quantified using modal analysis of thin-sections, Mössbauer spectroscopy, cosmogenic noble gas ratios [8-10] or induced TL. Qualitative weathering estimates from hand specimens indicate that meteorites from the Nullarbor Plain are highly weathered [4].

Methods. 100 - 200 mg samples of meteorites from the Nullarbor Plain were crushed to 100 mesh in an agate mortar and the magnetic fraction removed with a hand magnet. Three 4 mg aliquots were analyzed. Natural and induced TL measurements and data reduction have been described in ref. 11.

Results. Meteorites from the Nullarbor Plain typically have natural TL levels <0.2 krad at 250 °C in the glow curve. Forrest 009 has the lowest (<0.1 krad) and Reid 010 has the highest (0.5 krad) natural TL levels. For comparison, meteorite finds from the western United States have average natural TL levels of ~10 krad; finds from Roosevelt County (U.S.A.) average ~ 1 krad; about half of Saharan meteorites have natural TL levels similar to Nullarbor meteorites, but half have natural TL levels >0.4 krad [5]. There is no significant variation in natural TL as a function of terrestrial age (Fig.1), but meteorites with short terrestrial ages (<5 ka) may have lower natural TL levels than those with longer ages, although there are large uncertainties in both ^{14}C ages and natural TL data.

The TL sensitivity of meteorites from the Nullarbor Plain ranges from ~5 to <0.01 relative to Dhajala (H3.8) with most having values between 0.1 - 1 (Fig. 2). Modern falls tend to have TL sensitivitities between 1-10 [12] and Antarctic meteorites tend to have TL sensitivities between 0.1 to 10 [5].

Discussion. We used ^{14}C terrestrial ages, petrographic descriptions, and induced and natural TL to look for "pairings" [10]. Only Boorabie 001 and Carlisle Lakes 002 might be paired.

Superimposed on the data in Fig. 1 are TL buildup and decay curves for 30, 35 and 40 °C, using a constant absorbed radiation dose of 0.08 rad/yr. The decay curves assume natural TL levels were 100 krad immediately after fall (similar to modern falls), while the buildup curves assume no initial natural TL. We can interpret the present data in terms of TL decay on Earth at >40 °C. In this case, the TL level of meteorites with terrestrial ages >5 ka, might reflect uncertainties in the natural TL data and possibly in the parameters used to calculate the decay curves, notably terrestrial dose rate. Alternatively, it could be argued that all natural TL was drained at the beginning of terrestrial history, with the exception of Reid 010, and TL levels thus reflect TL buildup at temperatures of 30-35 °C.

The temperature range of 30-35 °C is closer to the current Nullarbor Plain than 40 °C. However, it is unclear how natural TL could have been completely drained in almost all these meteorites at the beginning of their Earth history. Samples taken just beneath fusion crust exhibit such histories [14] but the present samples were taken from the interior. Pre-terrestrial TL draining mechanisms, such as shock heating or extreme solar heating while in space, appear to be rare, based on TL studies of modern falls [5]. Possible terrestrial TL draining mechanisms might include brush fires, the arid portions of Australia being prone to large fires [15], or human firing. However, it seems unlikely that these events would occur only at time of fall and would be so efficient as to effect all the meteorites except Reid 010. The induced TL sensitivity of Nullarbor Plain meteorites probably reflects weathering [5]. Considering only petrologic type 5 and 6, Nullarbor meteorites with TL sensitivities similar to modern falls (<1 relative to Dhajala) tend to have terrestrial ages <5 ka (Fig 2), while meteorites with terrestrial ages >5 ka tend to have TL sensitivities <1. The extremely low TL sensitivity of Forrest 009 probably reflects intense shock processing, rather than weathering. These data suggest that high degrees of weathering develop in Nullarbor Plain meteorites in <5 thousand years of terrestrial history, despite the very arid conditions. Either conditions were wetter >5 ka, or, more likely, the short intense rainstorms of the region are efficient weathering agents.

Conclusions. The natural and induced TL of meteorites from the Nullarbor Plain share similarities with TL data for meteorites from the Sahara, reflecting the similar terrestrial histories these meteorites have experienced. However, it appears that Nullarbor meteorites have either experienced temperatures >40 °C, or somehow had their natural TL drained at or near time of fall. It appears that weathering occurs on the time scale of a few thousand years, despite the arid conditions.

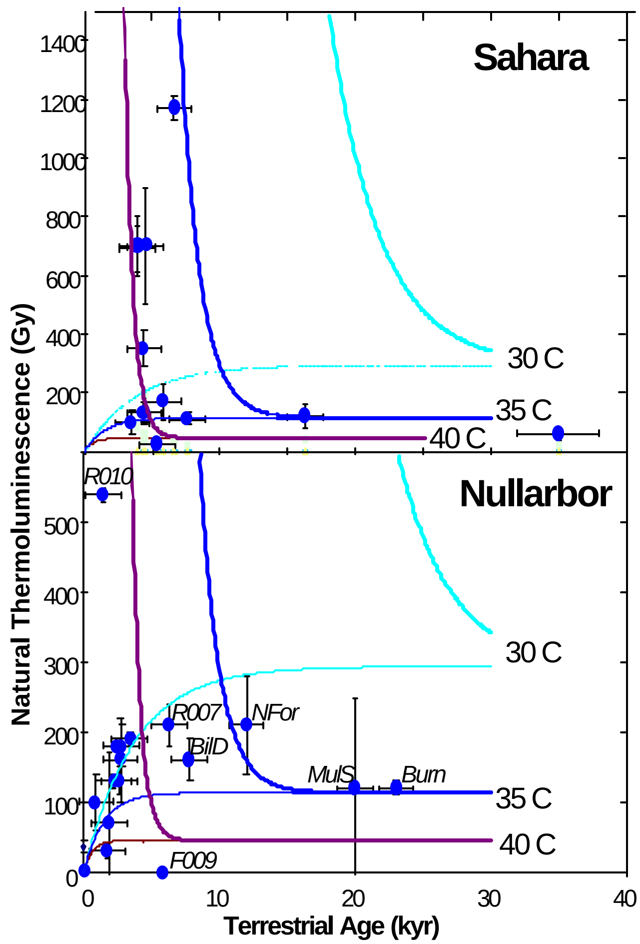

Fig. 1. Natural TL vs. terrestrial age for meteorite finds from the Sahara desert and the Nullarbor Plain (Australia). Terrestrial age estimates from Jull *et al.* [3,6]. Lines are calculated TL decay (thick) and buildup (thin) curves for 30, 35, and 40 °C, using the assumptions described in the text.

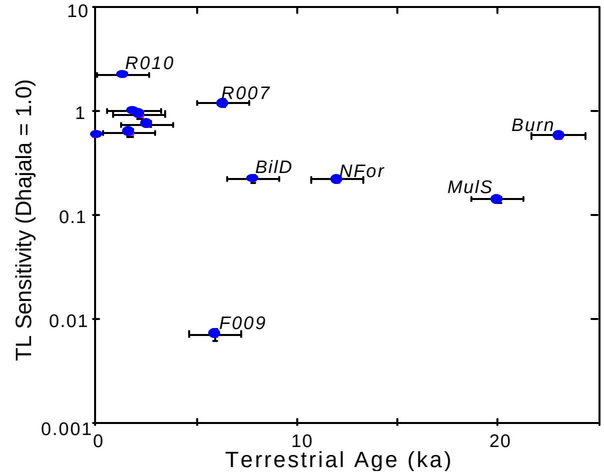

Fig. 2. Induced TL of meteorites from the Nullarbor Plain vs. terrestrial age. T_{age} estimates from Jull *et al.* [6].

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Abbrev. *BilD*: Billygoat Donga; *Boo1*: Boorabie 001; *Burn*: Burnabbie; *CL02*: Carlisle Lakes 002; *Coc*: Cocklebiddy; *F0xx*: Forrest 007, 009 or 010; *Kybo1*: Kybo 001; *MulN*: Mulga (North); *MulS*: Mulga (South); *Mun5*: Mundrabilla 005; *Nfor*: North Forrest; *N0xx*: Nullarbor 012 or 013; *Nurxx*: Nurina 002 or 004; *NL07*: Nyanga Lake 007; *OH02*: Old Homestead 002; *R0xx*: Reid 001, 006, 007, or 010.