THE HISTORY OF ARIDITY IN AUSTRALIA: PRELIMINARY CHRONOLOGICAL DATA

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INTRODUCTION

Wind-blown sand represents a major constituent of Australia's regolith. During more arid phases of the recent geological past, such as the period associated with the last glacial maximum (LGM) around 20,000 years ago, many areas experienced extensive sand movement (e.g., Nanson *et al*. 1992). During dune building phases, sand grains (and clay pellets) migrate in a down-wind direction. Understanding the environmental controls on the magnitude and timing of these major sediment transport events is paramount to developing models of arid regolith entrainment, deposition and geochemical evolution. The interaction of dune forms with groundwater represents a significant regolith process, and the development of reliable chronological control for the rates and timing of events such as oxide precipitation, soil formation or calcrete development is an extremely important regolith tool.

In this abstract we present new optical dates for dune deposition at a number of locations around Australia. We collate luminescence age estimates presented by other workers, and we compare the timing and duration of periods of intense dune building activity with periods during which river discharges were significantly higher than at present. These new data allow us to begin to address questions including:

1. What is the age of Australia’s deserts?
2. Is dune formation a steady or episodic process?
3. Are periods of aridity contemporaneous in different locations?
4. Do temperate regions dry out in synch with arid regions?
5. When were large rivers sustaining high discharges?

At this stage in the LEME History of Aridity project, we are exploring the optimal OSL dating procedures to recover as much information as possible regarding past environmental changes and changes in depositional regime. The new OSL data we present here were collected incorporating recent technical developments which provide significant improvements in dating precision. The most important of these is the Single Aliquot Regenerative-dose (SAR) protocol of Murray & Wintle (2000). This method allows determination of the equivalent dose (D_e) value using a single aliquot or portion of each sample. For these samples 12 aliquots have been measured, the degree of homogeneity between different aliquots providing a measure of the magnitude of effects such as grain mixing which can lead to unreliable OSL age estimates.

In order to assess if regional climatic events were responsible for dune-building in different areas, age estimates from different locations are inter-compared. Basically, if the individual OSL age estimates fall into discrete time periods irrespective of location, then these may represent significant regional events. If the measured age estimates are rather evenly distributed in time, then this suggests that dune building was not concentrated into discrete time periods, different regions witnessed dune building at different times, or the chronological resolution of OSL dating is too coarse to differentiate different events. This is an important asymmetry; we cannot demonstrate continuous deposition even if age estimates are evenly distributed through time, as poor dating resolution of discrete events would lead to an indistinguishable outcome. However, if we observe significant grouping of age estimates, this implies both that dune-building occurred as a series of discrete events, and that our chronological resolution is sufficient to resolve them.

SAMPLE COLLECTION

The approach adopted here is based on the assumption that there is little or no bias in the selection of samples for dating. This is important if the Probability Distribution Function (PDF) plots are to be interpreted as representing a reasonable assessment of periods of deposition in the past. For example, if samples were only collected from the base or tops of dune profiles, then intervening periods of significant dune building might be very under-represented in the number of age estimates measured. Some of our samples were collected by vertical augering using a hand-operated system. The collection of samples at selected depths was achieved using a light-secure steel sampling cylinder. A similar sampling unit is shown in Figure 1, which has a sampling tube of around 24 cm length. This picture also shows the heavy-duty steel augers used with a truck-mounted drill rig, which has been utilized successfully for collecting OSL and cosmogenic samples in the Simpson Desert and elsewhere (Figure 2). Vertical augering is considered a good method of avoiding bias in the age estimates, as no prior stratigraphic information is available before selection of sample depths is required. For some samples, sections were available, for example in road cuts. In these instances, samples were collected from each stratigraphic unit which could be distinguished in the field. Again, this approach is expected to avoid significant sampling bias.

Figure 1 (left): 24cm OSL sampling tube for use with hand-operated or truck-mounted auger system.
Figure 2 (right): Truck-mounted drilling rig using augers and sampler during collection in the Simpson Desert.

PRELIMINARY OSL DATING RESULTS

Here, we have plotted results from several different datasets. Firstly, OSL age estimates from 34 locations in the Strzelecki and Tirari deserts are shown in Figure 3 (Fitzsimmons, unpublished PhD research). These plots (Figsures 3a and 3b) represent the sum of the 34 individual Gaussian probability distributions for each OSL age estimate. Figure 3a shows all the age estimates up to 150,000 years, while Figure 3b shows only those within the time range 0 to 50,000 years. As mentioned above, these plots provide a useful way to assess whether dune-building activity is concentrated into specific phases (or is a largely continuous process), and whether the chronological techniques applied are able to resolve regional climatic events at the appropriate timescales.

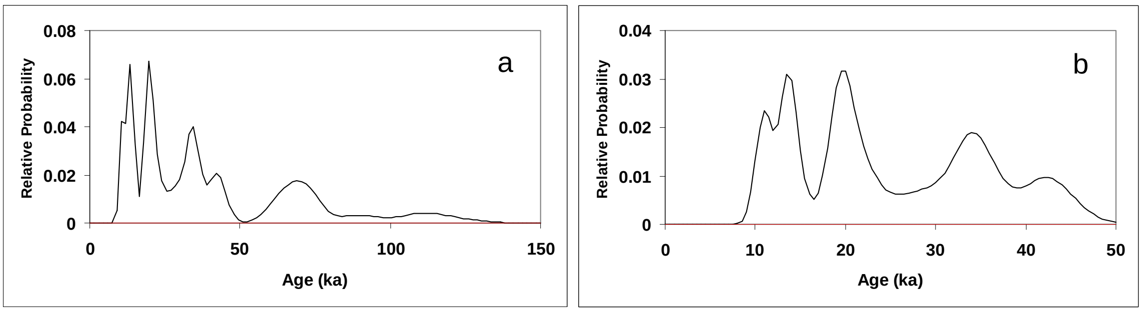

Figure 3: OSL age estimates from 34 locations in the Strzelecki and Tirari deserts. See text for details.

The plots shown in Figures 3a and 3b clearly demonstrate that there is some degree of grouping of the individual age estimates into specific phases of dune building. This is particularly clear for the age estimates shown to 50,000 years (Figure 3b), where well-separated peaks are observed at around 14,000, 20,000 (LGM) and 34,000 years, with minor peaks or shoulders at around 10,500 and 42,000 years. Equally noteworthy is the apparent trough between the 20,000 and 14,000 year peaks, suggesting that very little dune-building activity has been preserved from this period. This may be because little dune-building occurred, or because subsequent reworking has removed the evidence. In Figure 3a, a significant peak is also located at around 70,000 years, probably associated with marine oxygen isotope stage 4.

A collection of other recent aeolian OSL dates measured at the ANU from locations around Australia have been collated, and the PDF from these 20 age estimates is shown in Figure 4, extending to 100,000 years. These samples include linear dunes from Victoria (2 samples, unpublished data, Twidale, Spooner & Rhodes), source-bordering dunes from the Avon River, WA (3 samples, unpublished data, Rhodes & Wyrwoll), source-bordering dunes from the Lachlan River, NSW (2 samples, unpublished data, Kemp, Rhodes & Spooner), carbonate-cemented calcarenites from Rottnest Island, WA (10 samples, unpublished data, Rhodes, Hearty, Grün, McCulloch, Chappell & Dortch), and aeolian sand sheet deposits from around Miling, WA (3 samples, unpublished data, Rhodes & Chappell). Despite the very different geographical locations across Australia and the very different depositional contexts, which range from source-bordering dunes to sand sheets, linear dunes and reworked coastal calcarenites, aeolian activity was apparently concentrated into a number of discrete events. Significant peaks for this dataset are observed at around 21,000, 36,000 and 68,000 years, with a noticeable shoulder at around 43,000 years. The suggested periods of enhanced aeolian activity are consistent with those suggested by the dataset shown in Figures 3a and 3b. In fact, from these combined datasets (54 age estimates in total), there seem to have been periods of dune-building and aeolian activity across Australia centred at around 14,000, 20,000, 35,000, 42,000 and 70,000 years ago. The event which has the greatest number of samples is that at 20,000 years, the age of lowest global sea levels and greatest extent of land-based glaciers within the last 100,000 years, referred to as the last glacial maximum (LGM).

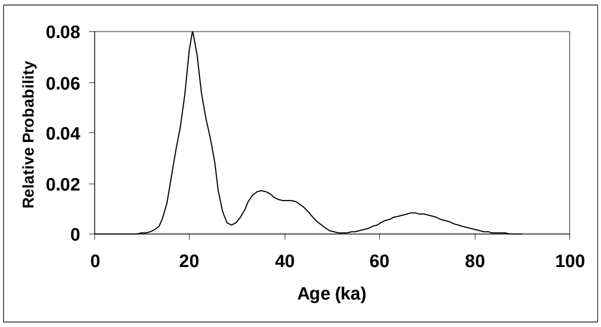

Figure 4: OSL age estimates from 20 aeolian samples from across Australia. See text for details.

In Figure 3, the full aeolian data (those samples shown in Figures 3 and 4) of 54 samples are shown (solid line), in direct comparison to data from Australian fluvial contexts. The fluvial data are much sparser, comprising only 12 dates from 2 locations. Nine samples come from the Lachlan River, NSW (Kemp & Rhodes unpublished data) and three samples are from a terrace of the Swan River, WA (Rhodes & Chappell, unpublished data). The younger fluvial dates form two peaks at around 23,000 and 32,000 years. These dates are all from NSW, and the low numbers of analyses mean that it is difficult to conclude whether the appearance of two peaks is meaningful. The older fluvial dates from WA are more even more equivocal, as some signs of grain mixing, probably by bioturbation processes, were observed in the OSL data, and these age estimates should be treated with some caution.

At present, all of these age estimates must be considered preliminary for several different reasons. Firstly, there are on-going measurements and model calculations to improve the estimates of cosmic dose rate and mean water content for these samples. There are also on-going source calibration issues, and for the most recently collected data, further quantification of environmental dose rate is required. In some cases, individual aliquots have been observed with outlying high or low D_e (equivalent dose) values. At this stage these are interpreted as resulting from the effects of bioturbation (by animal burrows or plant roots) or incomplete zeroing on deposition, considered much less likely, though not impossible, for aeolian samples. This latter effect is expected to be minimal in large-scale sandy dune systems, but samples demonstrating high-value outliers require further investigation using single grain OSL methods. Although these data are preliminary, the magnitude of any subsequent refinements based on more detailed measurements or environmental modelling are expected to be relatively small, and probably within 10% of the preliminary value.

DISCUSSION

Nanson *et al*. (1992) provide histograms of past aeolian (and fluvial) activity in different parts of Australia, based on 37 TL dates. Figure 6 shows their aeolian data redrawn as a smoothed frequency distribution. A comparison of this figure with the solid line shown in Figure 5, representing our 54 new aeolian age estimates from around Australia, shows many similarities. These include apparent clustering of dates around the LGM, at 30,000-40,000 years and a peak around 70,000 years. Very striking, though, is the significantly enhanced resolution of the new OSL data.

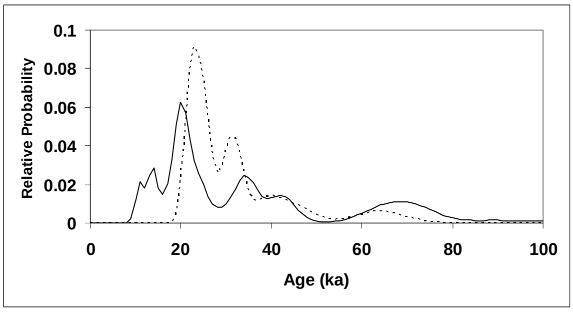

Figure 5 (left): Solid line: OSL age estimates from the 54 aeolian samples shown in Figures 3 and 4. Dotted line: OSL age estimates from 12 fluvial samples from NSW and WA. See text for details.
Figure 6 (right): TL age estimates from 37 samples, redrawn from Nanson et al. (1992). See text for details.

Further technical improvements in the OSL dating are envisaged, and in some cases still required. The selection of optimal OSL measurement conditions can be improved; a surprisingly varied response to uniform preheating conditions has been observed even within the same profile, possibly relating to changes in quartz provenance or past heating events. Some samples display D_e (equivalent dose) outliers, and single grain OSL methods will be applied to explore the origins of these effects. Thirdly, accurate estimation of the past environmental dose rate is critical in luminescence dating, and preliminary geochemical exploration of the location and mobility of ^{238}U and ^{235}U and their daughter isotopes, ^{232}Th and daughters and ^{40}K poses some interesting questions.

Acknowledgements: The authors would like to thank Mr Norman Hill for sample preparation, and all those who assisted in sample collection and field support. Research funding was provided from a number of sources including LEME, ARC and NSF.

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