THE HISTORY OF ARIDITY IN AUSTRALIA: CHRONOLOGICAL DEVELOPMENTS

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INTRODUCTION

Desert dune-fields are quintessential features of arid landscapes. During arid phases in the recent geological past, such as the global last glacial maximum (LGM) at around 20,000 years ago, many parts of Australia experienced significant sand movement, with sand migrating down-wind and forming linear dunes. Sand entrainment and deposition is controlled by vegetative surface stabilisation, wind speed and direction, which in turn are controlled by regional climate and local factors including ground-water levels. Climate also affects sand supply, through its effects on erosion in the source areas and transport to the dune-building areas.

Two important findings have emerged from the CRC LEME "History of Aridity" project so far. Firstly, Optically Stimulated Luminescence (OSL) age estimates from many different locations (Figure 1) indicate several periods of climate-controlled episodes of dune-building activity that were synchronous across Australia. Secondly, OSL age estimates from drillholes show that the cores of linear dunes in the Simpson Desert range to at least 600 ka and are much older than ages reported from dunes in the Tirari and Strzelecki deserts (Rhodes *et al.* 2004). The age difference coincides with a striking difference in the colour of the dunes themselves—the Simpson dunes are deep red, while most of the Strzelecki and Tirari dunes are pale. The colour of the Simpson dunes reflects the occurrence of haematitic coatings on the sand grains. Key OSL age estimates for the Simpson Dunes are shown in Figures 2a and b. Thirdly, all OSL ages so far obtained from dune fields are younger than the age of 2 to 4 Myr for neighbouring stony deserts, obtained from cosmogenic dating by Fujioka *et al.* (2005). This suggests that the dunefields became active after the stony deserts formed and may implying deepening aridity in the last 700 ka.

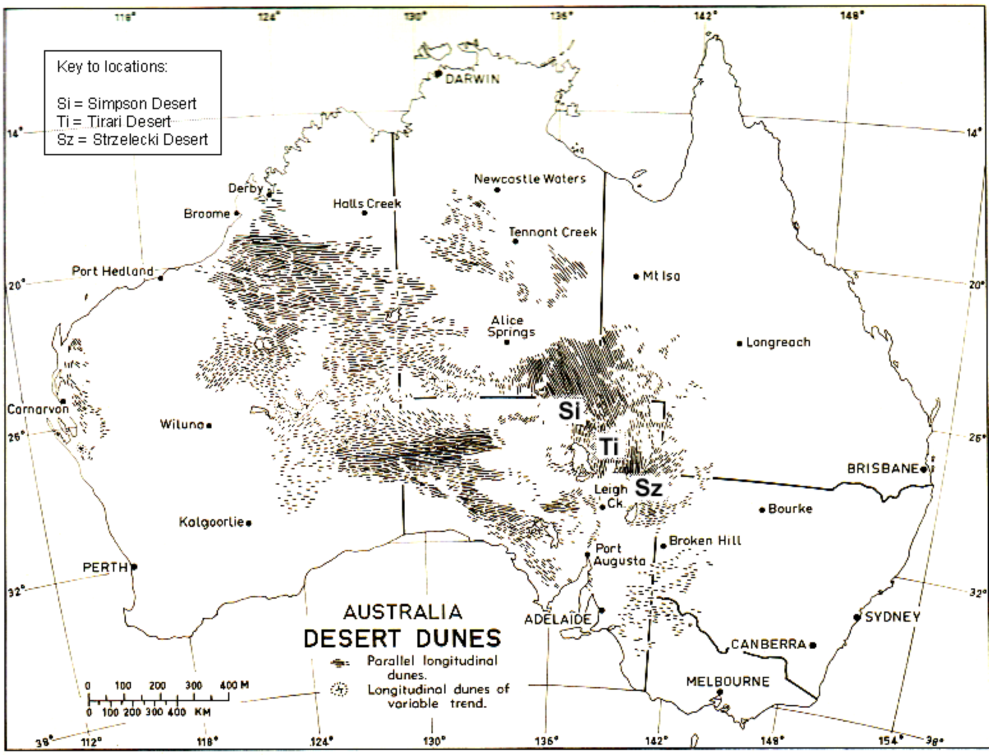

Figure 1: Map Australian Desert dunefields. Key shows sampled areas; Si = Simpson Desert, Ti = Tirari Desert, Sz = Strzelecki Desert.

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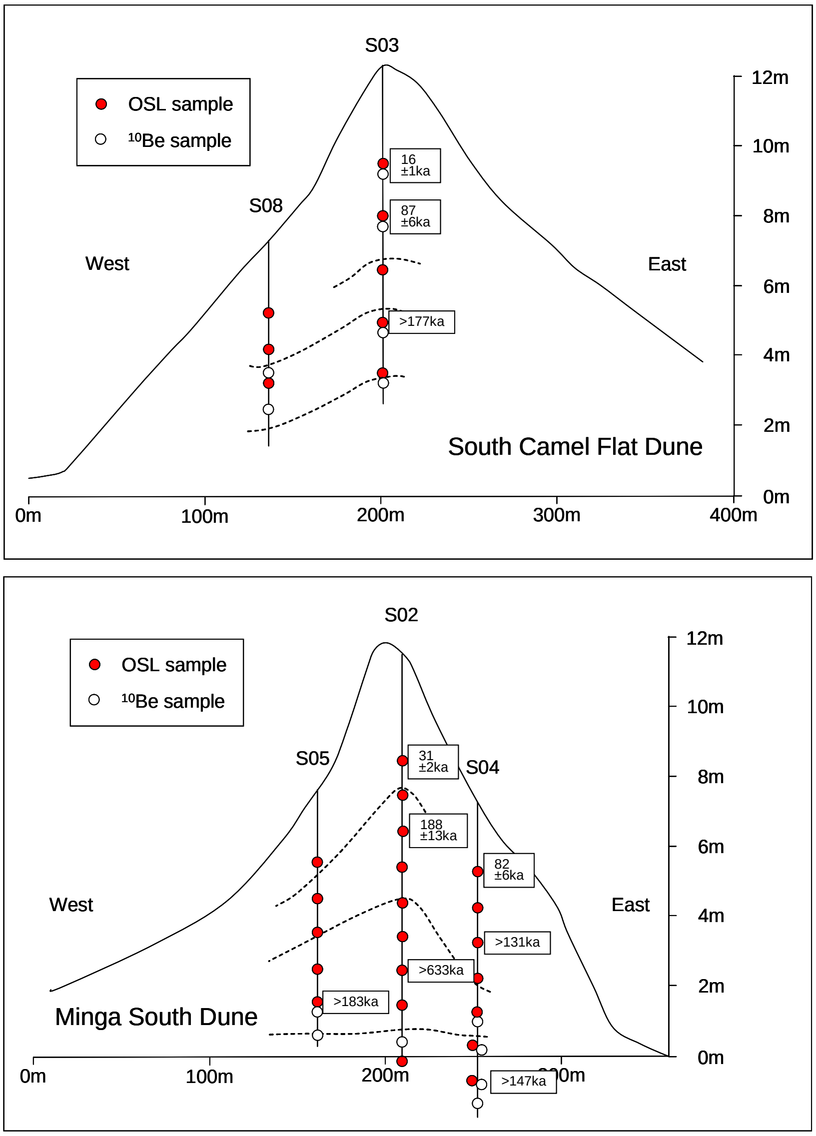

Figure 2a (top) and b (bottom): Surveyed sections across two Simpson Desert dunes at Minga South (25º 41.05' S 134º 54.88' E) and South Camel Flat (25º 35.27' S 134º 56.41' E). Note vertical exaggeration as indicated by horizontal and vertical scales. Dotted lines mark the positions of weak palaeolsols observed during coring. Sand auger core numbers are shown, and cores are represented by vertical lines, with the positions of OSL and cosmogenic ^{10}Be samples indicated. Key OSL age estimates are shown.

As an OSL age measures the time elapsed since sand was last exposed to daylight; these observations suggest that the Strzelecki Desert dunes were more frequently and/or more deeply reworked than the Simpson Desert dunes during arid phases. This is consistent with the colour difference; microscopic examination shows that the haematitic grain coatings tend to be removed by abrasion during sand mobilisation and transport. Moreover, we consider that the red coatings formed when dunes were stable and vegetated, according to our observations from palaeosols found in drillholes from Simpson Desert dunes. Hence, we hypothesise that the arid phases were more intense (and may have been more frequent) in the pale dune field region, than in the Simpson and similarly red deserts.

To explore these findings in greater detail, we are measuring a further 48 OSL samples from central Australia and have begun several subsidiary projects, including:

1. A detailed study of the OSL characteristics and age determination procedures for red-coated desert sand, to improve dating precision, accuracy and time range;
2. A study of the haematitic coatings of Simpson sand grains, to determine their geochemistry and possible origins;
3. Measurements of cosmogenic isotopes to determine, in conjunction with OSL dating, the composite history of grain exposure and burial; and,
4. Field sampling of deep red dunes from the eastern Strzelecki Desert and northwestern NSW to test the hypothesis that pale dunefields are younger, more deeply reworked and indicate deeper or more persistent aridity than red dunefields.

DISCUSSION

Cosmogenic Isotope dating allows us to elucidate the longer history of Australian aridity. Forest covered central Australia until 25-30 My ago but northward continental drift after separation from Antarctica at about 55 Ma led to drying, as Australia entered sub-tropical desert latitudes. Other factors also affected the climate including Miocene growth of the Antarctic ice sheet, intensified zonality and development of the sub-Antarctic oceanic convergence (Hill 1994, White 1994). Alkaline lakes developed as conditions became drier in the Miocene, but wetter conditions apparently returned in the Pliocene, before the onset of Pleistocene aridity, but chronology and landscape conditions are sketchy.

Some arid landforms such as desert sand-dunes are prone to reworking and early deposits tend to be obliterated. Thus, only Late Pleistocene phases of sand-dune activity in Australia are common. In contrast, stony desert surfaces endure as landscape features. Typically comprised of a single layer of varnished stones known in Australia as gibber, stony desert covers ca. 10% of the continent. Much of the gibber is derived from silcrete—a resistant rock formed by pedogenic or groundwater silicification of sediment and rock. Gibber occurs locally as lag deposit on exposed silcrete pavement, but more widely overlies alluvium or floats on stone-free clayey aeolian silt (Mabbutt 1977). Landscape hydrology is transformed when gibber develops at the expense of soil; runoff from gibber is high and vegetation becomes sparse. Once formed, the stony monolayer persists at the ground surface. The age of representative stony desert was recently estimated as 2-4 My, based on cosmogenic exposure ages of gibbers at sites between Oodnadatta and Coober Pedy (Fujioka *et al.* 2005).

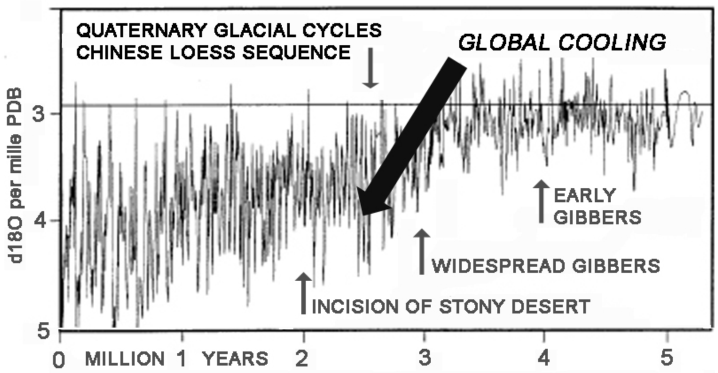

Figure 3: Gibber ages (arrowed) indicate that Australia's stony deserts formed during Late Cenozoic global cooling as seen in marine sediments (benthic oxygen isotopes: east Atlantic site 659 *(28)*), that led to Quaternary glacial cycles and heightened aridity (loess formation *(6)*) in northwest China. From Jujioka *et al.* in press.

Figure 4a represents our aeolian age estimates (34 dates from the Strezelecki and Tirari Deserts, and Figure 4b at total of 54 dates (including the above 34) from around Australia. Both show clusters of dates around 20,000 years (equivalent to the LGM), 30–40,000 years and around 70,000 years. Similar peaks were suggested in earlier data reported by Nanson *et al.* (1992) (Figure 4c), but in terms of definition and resolution the peaks are strikingly enhanced in our new results. However, OSL ages from the Simpson desert range to > 670 ka and, significantly, our new cosmogenic data indicate that the cores of the Simpson dunes are at least 1 My old, and may range back to the time of formation of the stony deserts.

Further technical improvements in the OSL dating are envisaged, and in some cases still required. The selection of optimal OSL measurement conditions (Maurray and Wintle 2000) 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.

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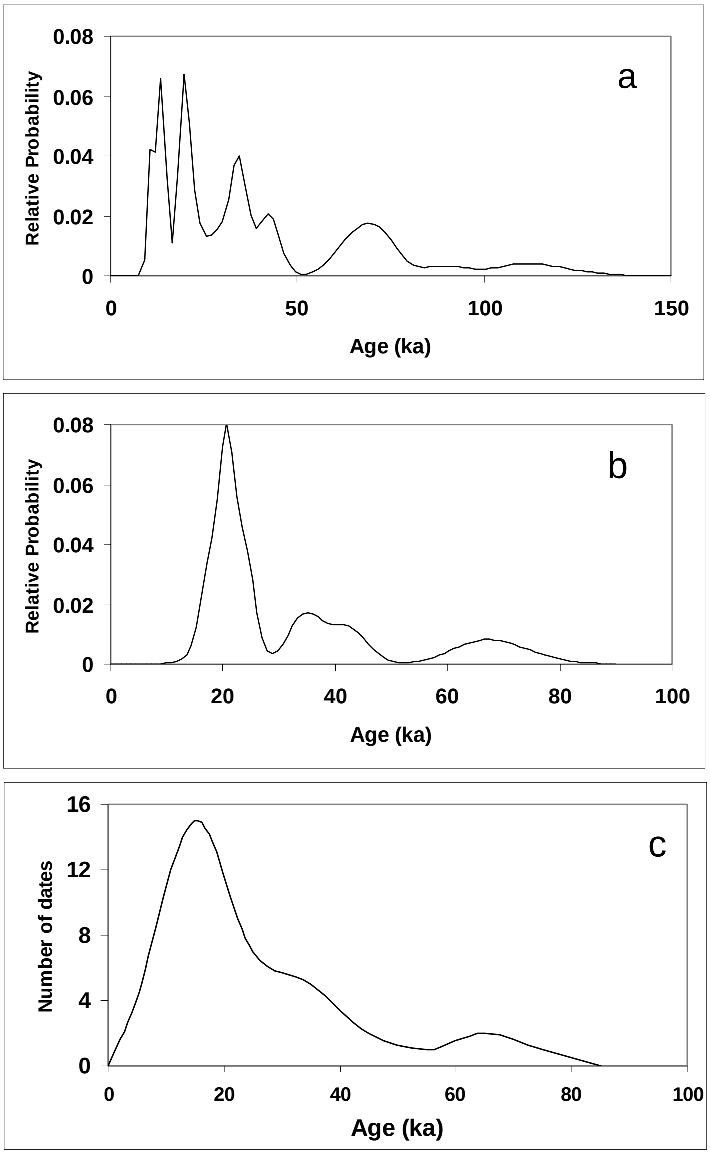

Figure 4a (top), b (middle) and c (bottom): Probability density functions (a and b) for a) 34 dates from the Strzelecki and Tirari Deserts (Rhodes *et al.* 2004), b) a total of 54 dates including the above 34, and c) TL age estimates from Nanson *et al.* (1992).