FROM LITTLE THINGS BIG THINGS GROW: RECONSTRUCTING PAST ENVIRONMENTS FROM QUATERNARY DESERT DUNE SEDIMENTS AND STRATIGRAPHY

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INTRODUCTION

Arid landscapes are susceptible to even slight changes in hydrology and climate, making them dynamic regions that provide sensitive records of environmental change over time. Understanding the geomorphology of deserts has significant implications for environmental management, particularly in addressing the increasing global challenge of desertification.

This research contributes to an understanding of the history of aridity in Australia by investigating the geomorphology of the desert dunefields within the southern Lake Eyre Basin in South Australia. The interaction of dunes with other landforms such as floodplains, creeks and playas influences their sedimentary composition, stratigraphic evolution and morphology. This abstract contains some of the sedimentological and stratigraphic work undertaken as part of the larger project, in order to demonstrate the inferences that can be uncovered about past environmental conditions from a few handfuls of sand and an auger.

Much information can be gleaned from a simple handful of sand. The types of minerals, their size, shape and homogeneity are all important clues for reconstructing the environmental conditions under which they were deposited, to form the dunes that sit in the desert today. Sedimentological data were collected using thin-section microscopy, X-Ray Diffraction (XRD) and particle size analysis, and were placed within the context of the formation of each dune using stratigraphy.

RECONSTRUCTING PAST ENVIRONMENTS

The Strzelecki Desert lies within the southern part of the Lake Eyre Basin (Figure 1), and is dominated by longitudinal dunes. The northern dunefield margin is bordered by the Cooper Creek and the silcreted, low hills of the Innamincka Dome. Longitudinal dunes are established on the Cooper floodplain. The major playa Lake Frome forms the southeastern dunefield margin. Landforms such as small playas, ephemeral creeks, alluvial plains and floodplains are also present, some of which are relict features. The interaction of the dunes with other landforms has influenced the sedimentary character of the dunes over time. Hydrology and climatic conditions have changed over time, resulting in variable levels of activity in different landforms and flux in sedimentation. This paper discusses preliminary conclusions about the evolution of the environment as inferred from the sediments and stratigraphy of two dunes: the Cowboy site in the south, close to Lake Frome; and, the Pablo dune on the floodplains in the north (Figure 1).

Cowboy site - Southern Strzelecki Desert

The Cowboy dune site is located northeast of Lake Frome in the southern Strzelecki Desert, and east of the northern Flinders Ranges. Changing hydrologic and climatic regimes have facilitated the formation of four parallel transverse lunette dunes relating to the general regression of the playa, from which longitudinal dunes extend perpendicularly in a northeast orientation. The Cowboy longitudinal dune lies in between two lunettes and is therefore closely geomorphically related to the lunettes and playa hydrology.

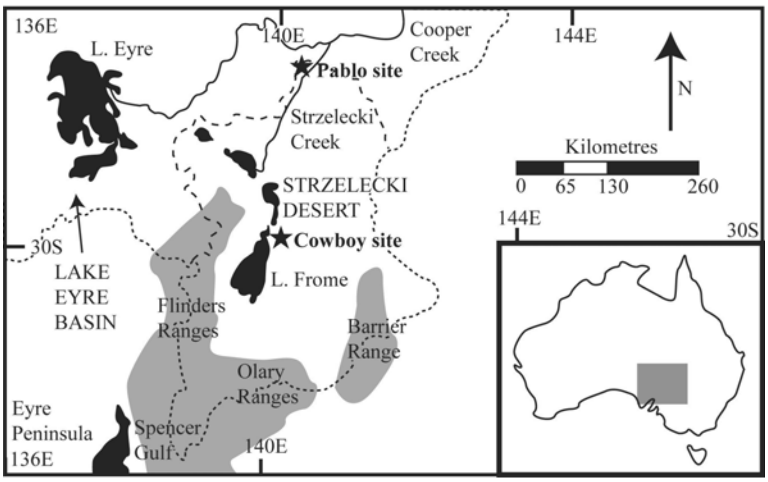

Figure 1: Location of the Strzelecki Desert in the southern Lake Eyre basin, and the field sites of Cowboy and Pablo.

The Cowboy dune contains four horizons, including a mobile surface layer (Figure 2). The underlying horizons are separated from one another by increased concentrations of nodular and mottled carbonates, which form the remaining parts of palaeosols. The stratigraphic column also shows the chronology defined as part of this project. The dune was surveyed to a height of approximately 11 m, thus dictating the depth of the auger hole.

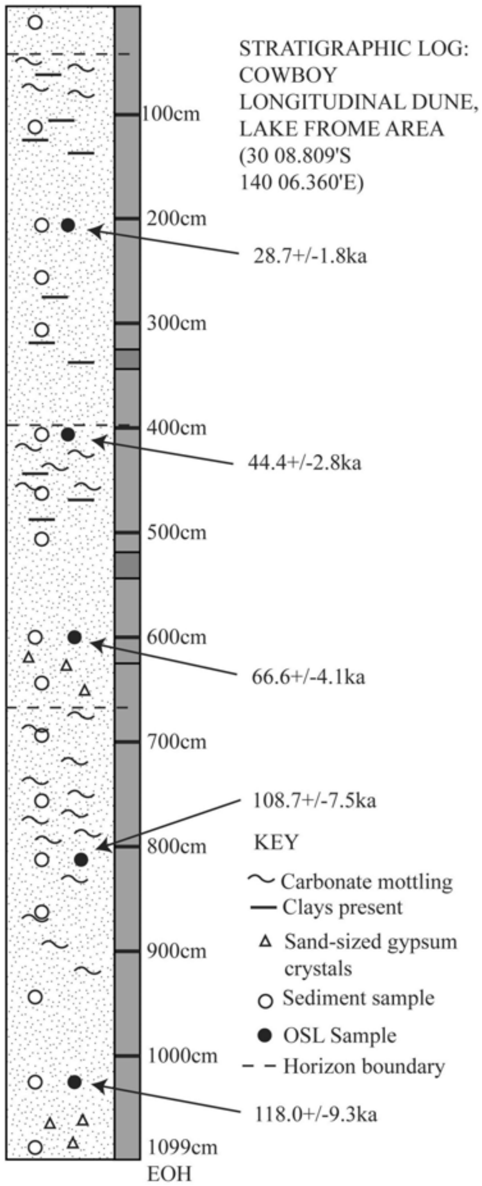

Figure 2: Stratigraphic log of Cowboy dune, southern Strzelecki Desert.

Thin-sections of each horizon were prepared and examined under the microscope for sedimentological characteristics. Subtle differences were identified between the different horizons. However, essential similarities suggested that environmental conditions during the episodes of enhanced aeolian activity, when the horizons accumulated, were broadly similar. The presence of palaeosols infers that dune formation was not continuous (Miller & Leopold 1953); the process was episodic and interspersed with periods of relative humidity conducive to soil formation.

The lowest palaeohorizon contains clay concentrated at the top and bottom of the horizon, with very little clay in the middle. The presence of clay within dune sediments requires fluctuating groundwater tables to bring salts to the surface, which as conditions dry out effloresces with clays to form sand sized aggregates that become mobile within the aeolian system (Bowler 1973). Once deposited, precipitation disperses the clays to form matrix, so stabilising the dune. It is possible that hydrologic conditions relating to Lake Frome varied somewhat during the deposition of this horizon, beginning with fluctuating groundwater tables, becoming more arid and then resuming groundwater instability. This would account for the enrichment of clays at the base of the horizon. XRD analysis of the middle part of the horizon yielded 81.8% quartz, 9.2% microcline and 9.0% albite. The proportion of fresh feldspars present is unexpectedly high, and was observed in thin-section along with crystalline rock fragments. This suggests that the original sediment source is close by, most likely the crystalline basement of the northern Flinders Ranges (Pell *et al.* 2000). Rock fragments are relatively more common towards the base of the horizon. Particle size analysis of two samples within this horizon indicates that both the modal and volume weighted mean grain sizes decrease downwards (Figure 3).

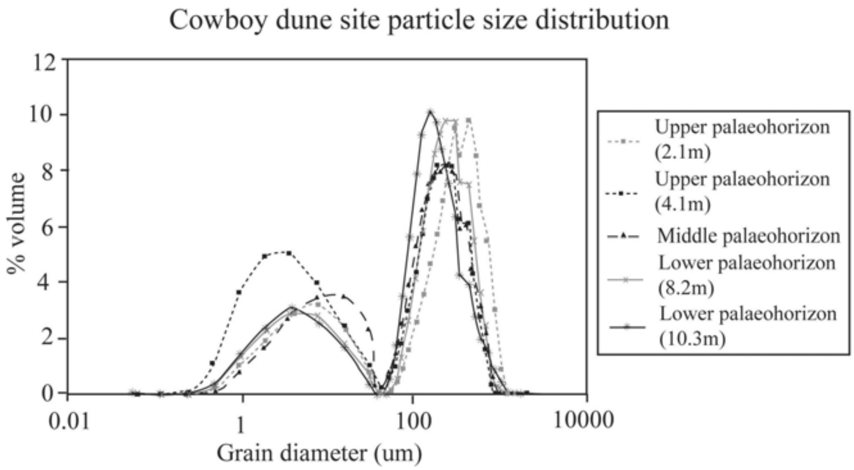

Figure 3: Particle size distribution of all horizons sampled within Cowboy dune.

Clays are more widespread throughout the middle palaeohorizon, occurring as localised matrix and secondary cutans coating sand sized grains. Some intact clay aggregates were observed, indicating that not all clays have dispersed due to precipitation or compaction. Clay sized particles represent 6.3% of the total sediment, and comprise montmorillonite, illite, kaolinite and quartz. The remaining sediment is 86.7% quartz, 3.9% albite and 3.1% orthoclase. The feldspar content, while high, is not as significant as in the lower horizon, and rock fragments are not as common. This may have implications for the hydrology and supply of sediment from the ranges, via Lake Frome, to the dunes. Iron rich cutans coat many of the sand sized grains, and in some instances iron oxide cementation has occurred.

The upper palaeohorizon contains relatively less clay than the middle horizon. Rock fragments and feldspars are more common. Quartz represents 76.9% of the sediment, with 7.7% albite, 7.6% microcline, 2.0% muscovite and 3.1% fine grained amorphous material. Two samples were analysed for particle size distribution, and revealed the same pattern observed in the lower horizon—an downward decrease in modal and mean grain size. Fine silt sized grains, between 20 and 60 µm, bearing dark red cutans, are likely to be aeolian rather than fluvial in origin, deposited from suspension by a distant source. Suspended grains of this size from desert sources have been described as parna (Butler 1956). Iron rich cutans were also observed coating sand sized grains, particularly toward the base of the horizon, close to the iron oxide cementation zone observed below. This may be related to pedogenic processes or groundwater infiltration.

The uppermost, modern, horizon is subtly different, lacking in clay and parna, although containing feldspars. Clearly the absence of clay suggests that groundwater conditions do not currently fluctuate close to the surface, indicating a different sort of aridity to that responsible for dune formation in the past.

Pablo site – Northern Strzelecki Desert

The Pablo dune site is located near the northern margin of the Strzelecki Desert near Innamincka, lying on the floodplain south of the Cooper Creek. Longitudinal dunes in this area occur in clusters on the floodplain. ASTER satellite imagery suggests that these clusters develop downwind from old transverse dunes which are no longer discernible on the ground. The transverse dunes are interpreted to represent source bordering features relict from Cooper Creek palaeochannels. The source sediment for the Pablo site is most likely to derive from both the floodplain and the denuded source bordering dunes, the latter of which contain sediment derived from the palaeochannel when it was active.

The Pablo site contains three horizons (Figure 4). The dune rises 8m above the floodplain on its western slope and only 2m on the eastern flank. This indicates that the substrate slopes upward to the east below the dune. The auger site was on the western slope close to the crest. Substrate was encountered at 4 m, and was also sampled for analysis.

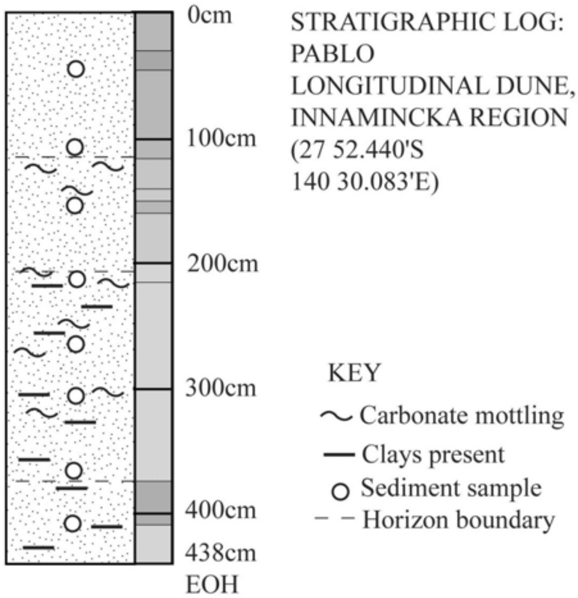

Figure 4: Stratigraphic log for Pablo dune, northern Strzelecki Desert.

The substrate, as floodplain, is relatively clay rich, containing clay plugs and localised matrix developed as clays washed into the sediments during flood events. Some iron oxide was observed as red-brown coloured induration in small areas. Most of the sediment is clay and sand sized, although significant quantities of silt sized grains are also present. Mean grain size is significantly smaller than the aeolian horizons above (Figure 5); this is consistent with the high population of clay and silt sized grains observed. Quartz and clay minerals dominate, and appreciable quantities of sand sized crystalline rock fragments were observed. It is possible that these crystalline fragments have travelled a significant distance down the channel—this has been noted further downstream (Teale *et al.* 1995)—although it is equally possible that they were derived from the local Tertiary Eyre Formation conglomerates, which contain pebbles of quartz rich material (Wopfner *et al.* 1974).

The lower aeolian horizon is noticeably more sand rich and clay poor. Clays are dispersed as localised matrix. This horizon contains 5.9% amorphous matter (< 5 µm), comprising kaolinite, illite, quartz and an osmotically swollen montmorillonite. This fine fraction, as with the clays in the Cowboy dune sediments, is not capable of simple aeolian transport and must have formed sand sized aggregates facilitated by salt efflorescence during conditions of occasional flooding and water recession. This suggests that the floodplain was regularly flooded and desiccated during the time of formation of this horizon. Quartz dominates the sedimentary petrology (88.9%), with minor microcline feldspar (3.1%), illite (2.0%), and the remaining fraction amorphous material. The clays and feldspars are likely to be derived from nearby exposures upstream of the kaolinitic and feldspathic sandstones of the Winton Formation (Wopfner *et al.* 1974). Particle size analysis (Figure 5) shows this horizon to be trimodal, comprising two modal peaks in the sand size range, and continuous, including silt size grains. Silts were observed clustered both in small pockets and within the matrix.

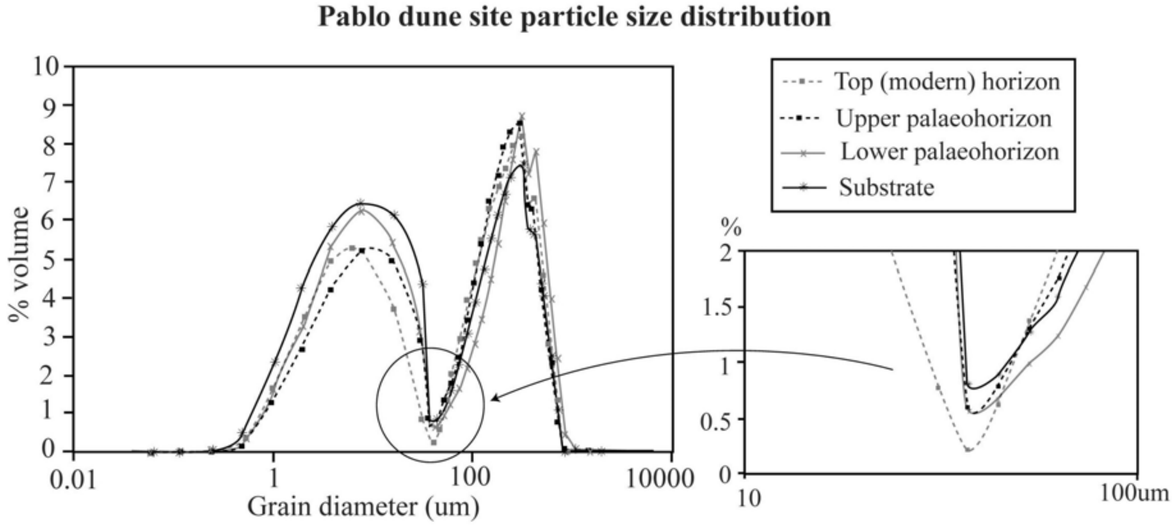

Figure 5: Particle size distribution of all horizons sampled within Pablo dune, including an enlargement illustrating proportions of silt-sized grains.

The upper palaeohorizon contains less clay than the lower stratum. It is nevertheless present, indicating that regular high water tables or flooding assisted clay deflation, though to a lesser degree than before. Minor quantities of crystalline rock fragments are present, as are potassium feldspars, again probably derived from the nearby exposures of the Winton Formation (Wopfner *et al.* 1974). The mineralogy comprises quartz, microcline, orthoclase and illite. Sand sized clasts are typically coated with very thin, irregular cutans rich in iron oxide, suggesting that the sands are reworked aeolian grains which have been separate from the fluvial system long enough to have attracted such coatings, since fluvial grains are generally cleaner and more rounded. Possibly the environmental conditions prevalent during the time of deposition were drier and followed a relative hiatus in the introduction of new fluvial sediment to this part of the floodplain. The mean and modal grain size is finer than the horizon below, despite having a greater proportion of coarser sand sized grains.

The uppermost horizon comprises entirely unconsolidated sand of a darker colour than the lower horizons. The sediment from this horizon is noticeably different from its underlying counterparts, lacking in clay just as the mobile sediments of Cowboy dune do. Clearly conditions conducive to clay mobilisation do not occur here at present either. Minor rock fragments were found, although feldspars were not. Cutans coat most sand grains; these are irregular and relatively thicker than those observed in the horizon below. Some parna grains were observed within the sediment. Most likely this horizon represents recently reworked aeolian material.

CONCLUSION

The particle size analysis data shows no continuous pattern with regard to stratigraphy. This can only suggest that each episode of dune building evolved separately to the previous one, involving some reworking of the underlying sediment as well as introduction of new material from the substrate, which itself may have received fresh sediment in between periods of aeolian deposition.

These environmental histories represent a small part of the work undertaken for this thesis. It is clear that sedimentological and stratigraphic data yield a great deal of information about the environmental conditions of dune formation and the complexity involved in landscape evolution. This work will be placed in the spatial context of regional landscape patterns and given chronological context through optical dating of the stratigraphic units.

REFERENCES

BOWLER J.M. 1973. Clay dunes: their occurrence, formation and environmental significance. *Earth Science Reviews* **9**, 315-338.

BUTLER B.E. 1956. Parna – an aeolian clay. *Australian Journal of Science* **18**, 145-151.

MILLER J. & LEOPOLD L.B. 1953. The use of soils and palaeosols for interpreting geomorphic and climatic history of arid regions. *In: Desert Research: Proceedings of the International Symposium held in Jerusalem, 1952.* Research Council of Israel **Special Publication no.2**, Jerusalem Post Press, Israel, 453-462.

PELL S.D., CHIVAS A.R. & WILLIAMS I.S. 2000. The Simpson, Strzelecki and Tirari Deserts: development and sand provenance. *Sedimentary Geology* **130**, 107-130.

TEALE G.S., FLOOD R.H. & SHAW S.E. 1995. Devonian cordierite-bearing volcanic pebble from the Cretaceous Bulldog Shale, South Australia. *Quarterly Geological Notes - Geological Survey of South Australia* **128**, 17-23.

WOPFNER H., CALLEN R. & HARRIS W.K. 1974. The lower Tertiary Eyre formation of the southwestern Great Artesian Basin. *Journal of the Geological Society of Australia* **21**, 17-51.

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