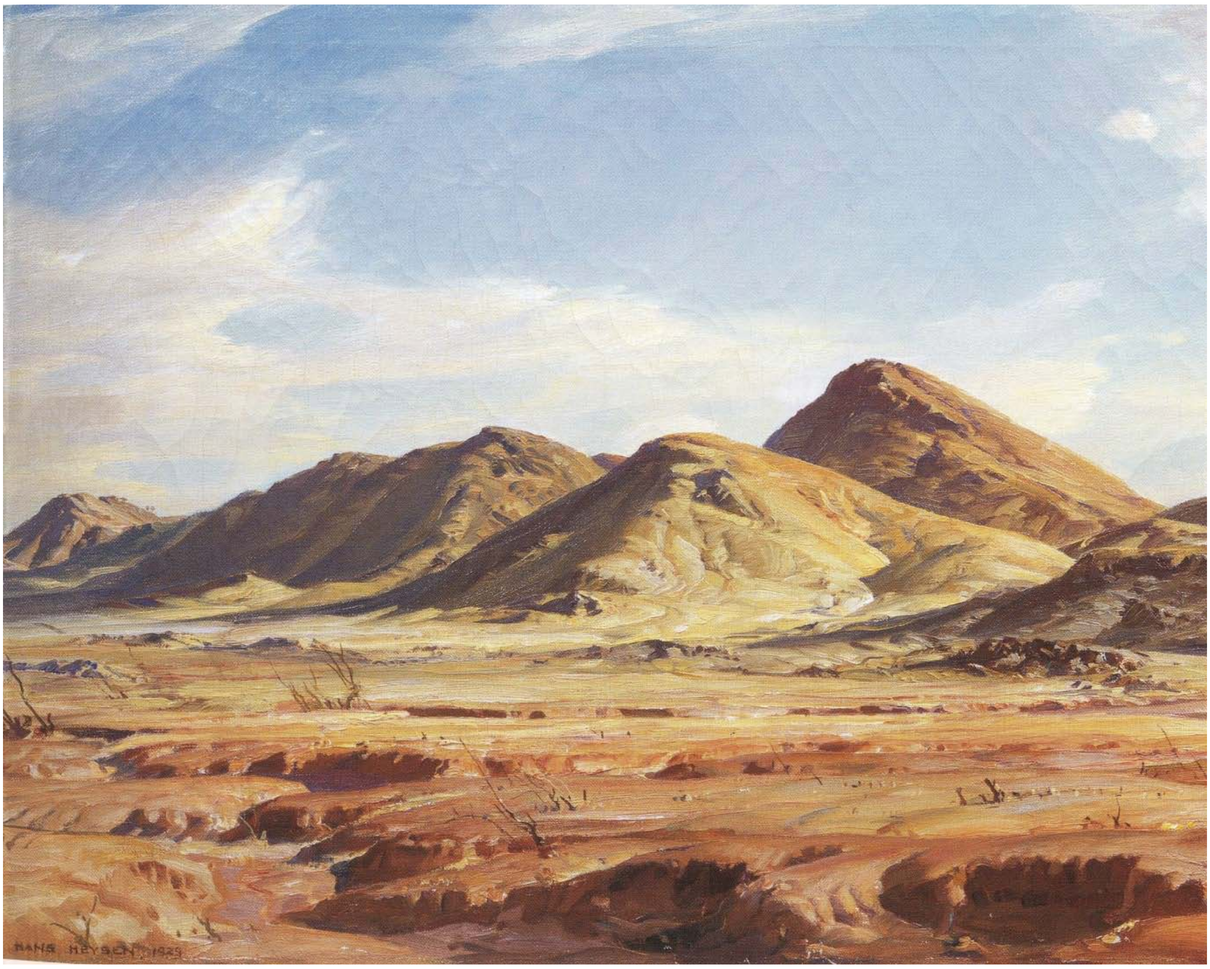
Loess and floods: late Pleistocene fine-grained valley-fill deposits in the Flinders Ranges, South Australia



(excerpt from Hans Heysen 1929: "Foothill of the Flinders", Morgan Thomas Bequest Fund 1939)

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4. Conclusions and Outlook

'ἓν οἶδα ὅτι οὐδὲν οἶδα' (Scio me nescire) – Socrates

Within the scope of this thesis, the fine-grained valley-fill deposits of the Flinders Ranges were first brought into a global context by comparing them with similar aeolian-fluvial sequences or so-called 'Silts' in Namibia, Sinai and the Sahara (Haberlah 2007a), and by relating them to the concept of loess-derived alluvium (Haberlah 2007b; 2008). Key questions concerning their provenance, depositional environment and age were identified and addressed by a regional-scale study involving radiocarbon and luminescence dating, parametric sediment-size analysis, and a number of conventional and emerging geophysical and geochemical techniques.

The main finding from the chronostratigraphic study based on 13 sections from three major catchments in the central Flinders Ranges is that the Flinders Silts aggraded throughout the last glacial cycle during intervals of rapid aggradation alternating with intervals of relative surface stability and erosion (Haberlah et al. 2009a). The final, most prominent and best preserved interval of aggradation spans the early lead-up and peak of the Last Glacial Maximum (LGM). Its near-synchronous onset and termination across most sections suggests that the regional palaeoclimate exercised more control than catchment/site-specific morphologic thresholds and possible neotectonic activity. Additional insights were obtained by comparing and juxtaposing different age proxies and dating methods. Accordingly, radiocarbon ages based on charcoal may not relate to the depositional event, due to its resilience towards erosion and re-deposition within the studied sedimentary environment. The presence of charcoal further reflects the abundance of woody vegetation within the catchment which varied throughout the last glacial cycle, and appears to be largely absent for the intervals of aggradation. Intact carbonate shells of aquatic gastropods appear to be more reliable depositional age proxies, as well as fine organic flotsam where preserved as undisturbed veneers. While optically stimulated luminescence dating is often less precise, with error ranges generally a magnitude larger than those reported for the radiocarbon ages, overall the luminescence age estimates seem to be more accurately reflecting the timing of the last depositional event. However, partial bleaching is common in the studied transport and depositional environment, necessitating careful interpretations of the D_e distributions by appropriate protocols and statistical age models.

The main finding from the sediment-sizing study is that laminated deposits situated in former protected embayments and tributary reaches of some confluences display cyclic sequences of upward-fining trends which are likely to reflect episodic backflooding (Haberlah and McTainsh 2009). Accordingly, these conspicuous sedimentary sequences comprise slackwater deposits, recording flood events charged with suspension load. It proved important to consider aggregation by an original approach involving comparative parametric statistics, because aggregates comprised the coarsest transported sediment fraction reflecting the former fluvial depositional environment best. In contrast, the fully-dispersed sediments were extraordinarily well-sorted and homogenous, with upper size ranges supporting the previously inferred aeolian provenance of the material (Williams and Nitschke 2005).

Additional geophysical and geochemical analyses performed on the layered to laminated stratigraphic section BRA-SD provided important detail on the local vegetation, hydrological and weathering history, and improved the reconstruction of the former depositional environment (Haberlah et al. 2009b). Accordingly, at ~24 ka recurring bedload deposition of reworked weathered loess mantles and/or former fine-grained terrace remnants was superseded by suspension fall-out during episodic flood fluxes charged with unweathered proximal dust. Peak aggradation rates coincide with peak continental aridity and aeolian activity, recorded by the isotopic plant composition in the catchment, and elsewhere by the deflation of adjacent terminal playa lakes (e.g. Bowler et al. 1986; Schmid 1990), the reactivation of source-bordering dune fields (e.g. Fitzsimmons et al. 2007), and in continental (e.g. Petherick et al. 2008), marine (Gingele and De Deckker 2005) and Antarctic (e.g. Revel-Rolland et al. 2006) distal dust records. Deposition was episodic, involving numerous smaller and a dozen or more large flood events preserved in form of stacked upward-fining sediment layers and veneers. The mineral spectroscopy results corroborate lithostratigraphic observations in that both indicate ponding surface water, however limited in penetration and duration not to cause the dissolution of underlying fine detrital carbonates and the alteration of hematite-masked sediment sheets.

In conclusion, this study extends the record of fine-grained valley-fill deposits in the Flinders Ranges to the last glacial cycle and across multiple catchments. It presents a depositional model that explains the aggradation of a layered to laminated facies embedded in tabular fine-grained floodplain remnants which extend into the gorges throughout intervals of increased aridity, as opposed to their subsequent erosion under the present climate. The depositional model resolves inconsistencies in the previously suggested wetland scenario (Williams et al. 2001); mainly that bioturbation appears to have been limited in most reaches and in particular in the well-preserved laminated facies. However, gleyic colours, precipitation of groundwater calcrete and considerable mottling in reaches directly upstream of narrow gorge entrances not studied here do not preclude a scenario in which low-frequency high-magnitude floods coupled with low evapo-transpiration could result in spatially restricted prolonged ponding. The thesis further draws attention to the complex interaction of aeolian-fluvial processes resulting in widespread deposition of loess-derived alluvium which have not been studied to this extent in the Australian context before. The inferred processes played an important role in shaping the landscape over the last glacial cycle. The Flinders Silts present continuous terrestrial archives throughout intervals of peak aridity, elsewhere marked by deflation and erosion.

The regional study on the Flinders Silts can help resolving some ongoing debates on the age, source and nature of similar fine-grained valley-fill remnants in other arid mountainous regions (see Haberlah 2007a). The present results are consistent with recent inferences of the allochthonous aeolian origin of the silt terraces in the drainage lines of the Great Escarpment of Namibia, and in some of the creeks and tributaries cutting through the largely Precambrian basement of the southern Sinai Peninsula of Egypt. Dust is proposed to contribute significantly to the Namib Silts based on geochemical similarities between the allochthonous micritic calcites in the fine-grained valley-fills and the playa lakes and karstic calcrete surfaces of the western Kalahari (Eitel et al. 2001). For the Sinai Silts, Rögner et al. (2004) confirmed Nir's earlier hypothesis (1970) of an aeolian origin by Miocene foraminifera finds, and suggest the Gulf of Suez to the west as a dust source throughout glacial intervals of low sea levels exposing unconsolidated Miocene globigerina marls. While the latest papers from Namibia and Sinai (e.g. Srivastava et al. 2006; Heine and Völkel 2009; Rögner et al. 2004) agree with the pioneering studies that described the silt terraces as fluvial sedimentary sequences deposited by flood events (Klaer 1962; Ollier 1977), uncertainty remains on how exactly the sediments were deposited, and how to reconcile rapid aggradation rates with peak aridity. This resulted in the contested re-evaluation of existing depositional models and chronostratigraphies (Bourke et al. 2003; Srivastava et al. 2006). The present regional chronology from semi-arid South Australia and its discussion of age proxies and age models can contribute to this debate. The forwarded palaeo-environmental model could help to resolve some of the *prima facie* incompatible observations, by discussing the complex impact of climate and vegetation changes on both sediment supply and the stability of valley slope mantles in a comparable environment.

This study sets the stage for future research linking the erosion of the Flinders Silts with terminal LGM/early Deglacial rapid lacustrine deposition recorded for the adjacent terminal playas Lake Frome and Lake Torrens involving comparative chronostratigraphic, granulometric and mineralogical work (appendix 5.4.2 and 5.4.3). The latest preliminary sediment-size study is consistent with the inferred aeolian transect from west to east (appendix 5.4.4) but requires further work. The tempo-spatial variability of flood deposition and fluvial gradients needs to be established in more detail and for the catchments extending to the increasingly arid north and humid south to infer the nature and extent of the palaeo-circulation patterns. Finally, aggradation and erosion of the Flinders Silts throughout the first half of the last glacial cycle remain sketchy, and need to be tied in with the stacked palaeosol record in the piedmont plains (Williams 1973; Callen et al. 1983) by additional single grain luminescence dating and geochemical analyses.

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