ACCUMULATION AND PRESERVATION OF LOESS DEPOSITS IN THE CENTRAL TABLELANDS OF NEW SOUTH WALES

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Loess-like deposits, sometimes called clayey loess but more commonly known as parna, have been identified in southern Australia since the 1940s. However, while Australian dust in Tasman Sea sediments provides a long and well dated record of dust deposition (Hesse 1994), there are very few dated examples of dust deposits from the Australian mainland or deposits with the potential for dating (Hesse & McTainsh 2003), and the age of the loessic mantles is still largely unknown.

Here we report the results of optically stimulated luminescence (OSL) dating (Hesse *et al.* in press) of two sites in the Central Tablelands of NSW where loess-like (Humphreys *et al.* 2002) deposits have been identified (Dickson & Scott 1998), mantling the crests of gentle hills on the plateau surface. Field mapping (Campbell 1999, Peterson 1999) has identified many sites in the area surrounding Blayney which include both primary depositional mantles on ridge crests and reworked, or colluvial, deposits in lower slope positions. The dust mantles of the Blayney area are ideal for dating because numerous analyses confirm that they are homogenous, allochthonous deposits (Dickson & Scott 1998, Gatehouse *et al.* 2001), with a consistent aeolian sedimentological character (Peterson *et al.* 2000, Humphreys *et al.* 2002), and because they are thick, primary airfall deposits from which the age of deposition can be determined.

For this study we sampled the south side of the Brown's Creek Road cutting (Figure 1) and from the northern side of the railway cutting at Mackenzie's Waterholes Creek. There are four main layers exposed in both cuttings (Figure 2). All the layers show great lateral continuity along both sides of the cutting such that the mantle appears to drape the landscape. The colour of the upper earthy unit at Mackenzie's Waterholes Creek ranges from red (2.5 YR) at the crest to yellow (10YR) on the eastern flank. This indicates that colour is not a reliable guide for the recognition of loess deposits. The Brown's Creek site occurs on quartz-free Ordovician Blayney Volcanics and the Mackenzie's Waterholes Creek site occurs on Silurian Carcoar Granodiorite.

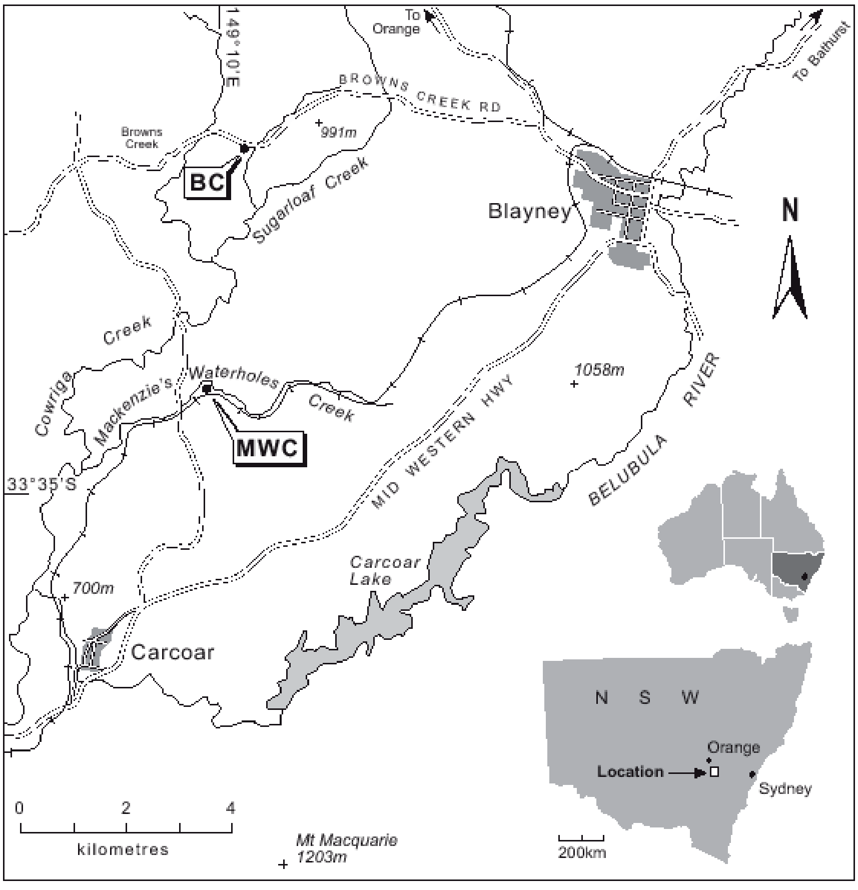

Figure 1: Location of the two study sites, Brown's Creek (BC) and Mackenzie's Waterholes Creek (MWC)

Detailed particle size analysis of samples from the A horizon (10-20 cm), B horizon (50-60 cm) and pan of the aeolian mantle show the typical signature of aeolian dust in the region. This is a very well sorted and prominent coarse silt population with average modal diameter of 30 µm (range 26-32 µm) (determined by SediGraph; Malvern Mastersizer measurements are around 40 µm diameter) and a very poorly sorted tail of fine silt and clay. The saprolite sample is very poorly sorted with more clay than the overlying unit. Clay (< 2 µm) content in the B horizon and A horizon is low (24% and 17% respectively at Brown's Creek). Detrital clay aggregates have not been found in thin-section examination. The clay fraction, determined by XRD, of the aeolian mantle and pan is a mixture of kaolinite and some illite, typical of Australian dust (Kiefert & McTainsh 1993). In the basaltic saprolite, vermiculite is present with some kaolinite.

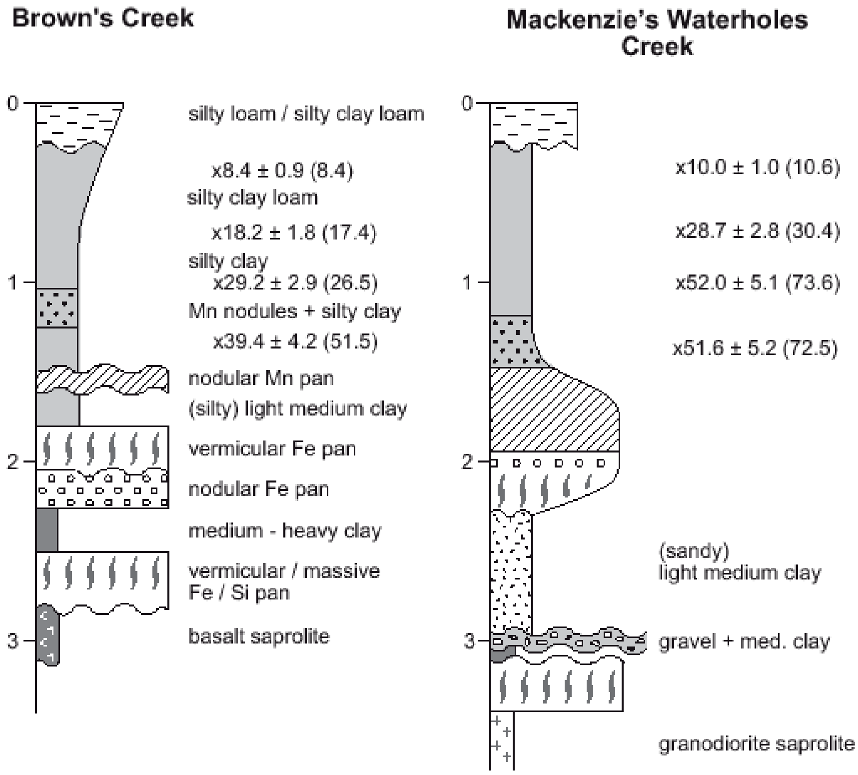

Figure 2: Graphic logs of the two study profiles. The width of the column represents the texture from fine (narrow) to coarse/cemented (wide). Laser OSL ages, with errors, are shown with their sampling locations and large aliquot method central ages in brackets.

Depending on variations of textures, the reddish silty mantles are Gn1.42/Gn2.22 and Dr2.82 according to the Factual Key and equate to a type of Red Earth and Red Podzolic in the older Great Soil Group terminology. In the latest Australian system they are Petroferric Red Kandosols and Petroferric Red Chromosols at Brown's Creek and Mackenzie's Waterholes Creek, respectively.

Optical dating was performed on quartz grains in the 20-40 µm size fraction. The quartz was etched to remove the outer ~10 µm of quartz, so that the final particle size range of quartz used for analysis was approximately 10-20 µm. A combination of field gamma spectrometry and Neutron Activation Analysis (NAA) was used to determine concentrations of U, Th and K. Optical luminescence measurements were conducted using an automated Risø single-grain luminescence reader and measurements made on 100 aliquots of about 4000-5000 grains. A single aliquot regenerative (SAR) protocol similar to that described by Murray & Wintle (2000) was used to determine the equivalent-dose (De).

Contrary to expectation, the onset of dust accumulation occurred around 60,000 years ago at Brown's Creek and much earlier at Mackenzie's Waterholes Creek, well before the last glacial maximum (LGM ≈ 20 ka). The OSL ages are in correct stratigraphic order, although the two deepest samples from Mackenzie's Waterholes Creek are essentially the same. The exact time of onset of dust accumulation is uncertain as the pans and layers beneath were not dated. By linear extrapolation of the ages from the Brown's Creek profile, the pan at 2 m should be about 60,000 years old. However it is not possible to be certain of the age as not all the pan material is dust. At Mackenzie's Waterholes Creek, ages of around 52 ka above the pan are 1.6 m above the base of the aeolian layer. Because the lower two ages are so similar, the implied sedimentation rate is so high that we suspect an error in one, or both, of the deepest ages and the basal age cannot readily be estimated. However, assuming continuous deposition at rates based on the samples at 0.3 m, 0.7 m and 1.4 m (maximum sedimentation rate) a 'minimum' basal age of 160-170 ka at 3.0 m is estimated. Alternatively, there may be a hiatus within the Mackenzie's Waterholes Creek section and the lower unit may derive entirely from the previous glacial cycle. Other scenarios, with higher accumulation rates, are also possible but are beyond the scope of this paper.

To test the reliability of the deepest two dates at Mackenzie's Waterholes Creek site (MWC 1.0 and MWC 1.4) all samples were re-analysed using the large aliquot technique and a filtered (420-550 nm) light source. While the younger samples at both sites agree well in age with the laser method, the older samples yield significantly older ages than the laser method (Figure 2, bracketed ages). However, the oldest two samples from Mackenzie's Waterholes Creek site still yield identical ages, within the limits of uncertainty, i.e., we have identified differences between the two dating methods but not a source of error for either of the deep MWC samples. Nevertheless, the laser method results are thought to be more reliable because of the larger number of aliquots analysed, though they may prove to be minimum ages.

The shallowest samples dated at each site were at 30 cm depth, 5 cm below the base of the topsoil horizon. The early Holocene ages (8.4 ka and 10.0 ka) are consistent with a linear sedimentation rate continuing from before the LGM through to the post-glacial period. Linear regressions through the Brown's Creek sample ages and samples MWC 0.3, 0.7 and 1.4 intersect the surface near the present, implying unchanged linear sedimentation rates from LGM to present. The mass accumulation rates determined for both sites are nearly constant from the base of the deposits to the base of the topsoil. All variations in mass accumulation rate are driven by variations in bulk density (because we have assumed a constant accumulation rate) and the decline in mass accumulation rate near the surface of both profiles is attributable to the lower bulk density of the topsoil. Dust accumulation appears to have continued into the Holocene and we cannot rule out the continuation of quite high levels of dust accumulation.

During the LGM, when other climate proxy records show much greater aridity and greater aeolian activity than during the preceding period, the Brown's Creek and Mackenzie's Waterholes Creek loess profiles show unchanged sedimentation rates. What, therefore, is the climatic significance of these deposits? The simplest interpretation is that the flat age-depth relationship is a genuine record of dust deposition rates. However, it is difficult to reconcile these data with the deep-sea record of dust flux, the record of desert dune mobility or dust deposition at Lake Mungo. Furthermore, it does not seem possible that these sites are faithful recorders of dust deposition because the sites started accumulating at different times.

An alternative viewpoint is that the sites provide records of dust accumulation; that is, the net result of deposition minus erosion (Goossens 2001), and therefore record local site factors as well as regional dust deposition. Apart from variations in the rate of supply of deposited dust, there are other factors which determine whether all or some of the dust accumulates or is reworked. A wet or heavily vegetated surface will prevent re-entrainment of dust by the wind, whereas a bare surface will allow complete or partial re-entrainment, depending on the occurrence of suitably strong winds. Bare surfaces will also promote erosion of deposited dust by water whereas well-vegetated surfaces will be subject to less water erosion. It is possible that the sites accumulated dust initially under dense vegetation but over time, going into the LGM, climate changed making vegetation more sparse so that more remobilisation occurred and the accumulation rate decreased. The lost dust could be that preserved as the lower slope colluvial silt deposits at sites like Stirling Downs and Millthorpe, near Blayney. In this scenario, the measured mass accumulation rate is a function of the balance of deposition and erosion rates.

Site differences are the only obvious explanation for dust beginning to accumulate at Brown's Creek perhaps tens of thousands of years after beginning at Mackenzie's Waterholes Creek, although it remains unclear just what these differences may be. Dust must have been deposited at Brown's Creek, and all over the area, during this period but has only been preserved in rare circumstances, the rest having been reworked by wind or water to other locations. The prevalence of loess-free slopes in the area amply demonstrates that conditions suitable for loess accumulation are rare and site-specific.

Two contrasting sets of pedologic features characterise the loessic mantles. Presumably the characteristics of the silty mantle represent post-depositional modification or pedogensis to develop redness, an earthy fabric, and a texture trend. If much of the mantle material was deposited as silt to sand size pellets, or single quartz silt grains with clay coatings (Wustenquarz), then it is necessary to reorganise the constituents, i.e., to convert a pelletal structure to a massive structure with an earthy fabric. Two lines of evidence indicate that the pans post-date dust deposition. The pans lie within silty material which has yielded finite ages consistent with the sedimentation rates established from the ages from the overlying reddish silty mantle. Therefore, there can be no significant time break between deposition of the silts now partly cemented by manganese in this horizon and the overlying uncemented silts. Furthermore, this layer of manganese nodule development lies between samples dated to 29 ka and 39 ka at Brown's Creek and at around 52 ka at Mackenzie's Waterholes Creek and is therefore diachronous and marks neither a regional hiatus or stratigraphic event but is consistent with formation at depth in the soil profile at depths determined in each case by the local redox gradient. Presumably the pan formed when suitable redox conditions developed, after deposition of the mantle. The pan does not mark the pre-loess surface and is not a palaeosol but a subsoil feature possibly still forming. A feature at both sites is the absence of recognisable buried A and B horizons such that the silty material appears to sit atop moderately weathered saprolite.

The presence of saprolitic material in the pans and lower parts of the Mackenzie's Waterholes Creek profile indicates a more complex history involving mixing of constituents from two sources. In general terms the silty mantle represents a discrete depositional event but in detail a more complex history is evident since it is necessary to account for the mixing to varying degrees of material from different provenances. A mechanism involving upward mixing by bioturbation seems likely since both sites are on crestal positions without any upslope source of saprolitic material or bedrock at or near the surface. Biomixing may also develop an earthy fabric (Humphreys *et al.* 2002) and, in conjunction with rainwash, may also lead to the coarsening in textures at the near surface (Paton *et al.* 1995).

These loess deposits provide evidence of significant deposition of dust over a wide area during the Late Quaternary, including the Holocene. However, significant post-depositional alteration, including pedogenesis and erosion, makes it difficult to use them to quantify the dust depositional load in the area (or its salt component) and may have removed a large part of their value as palaeoclimatic indicators.

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