AEOLIAN DUST DEPOSITION IN SOUTH EASTERN AUSTRALIA: IMPACTS ON SALINITY AND EROSION

Stephen R. Cattle[1], Richard S.B. Greene[2] & Andrew A. McPherson[3]

[1]Faculty of Agriculture, Food and Natural Resources, University of Sydney, NSW, 2006
[2]CRCLEME, School of Resources, Environment and Society, Australian National University, Canberra, ACT, 0200
[3]Geospatial & Earth Monitoring Division, Geoscience Australia, GPO Box 378, Canberra, ACT, 2601

INTRODUCTION

Salinity and water erosion are two of the major land degradation issues in the Murray Darling Basin (MDB) of SE Australia. The extent of salinity in the MDB has been well documented and is expected to increase from the current figure of 0.2×10^6 ha to 1.3×10^6 ha by 2050. It is more difficult to document the extent of degradation due to water erosion.

Large parts of those areas of the MDB landscape affected by salinity and erosion have also had a significant input of aeolian dust. These dust accessions were particularly active during the Quaternary and still occur today on a smaller scale (Bowler 1978, Walker *et al.* 1988, Hesse 1993, 1994). For example, in 1987 and 2002, large parts of eastern Australia affected by drought were hit by large dust storms, which removed millions of tonnes of topsoil (Knight *et al.* 1995, McTainsh *et al.* 2005). By virtue of its composition, this dust is considered to have had a major influence of salinisation and erosion processes. Even though the extent of the dust distribution has been well documented by a range of previous studies, little is understood of the relationships between the types of dust deposits and soil processes such as salinisation and erosion. This paper outlines a project that proposes to describe the physico-chemical attributes of a range of known dust deposits in SE Australia, focusing particularly on salt load and mineral composition. Expected outcomes are a better understanding of the role of dust both in soil profile development and in the development of landscape salt stores and soil erodibility.

EVIDENCE FOR AEOLIAN DEPOSITS IN AUSTRALIAN LANDSCAPES

One of the first sets of compelling evidence for the role of aeolian dust on soil formation in eastern Australia came from Butler (1956), working in the Riverine Plain of NSW. Butler developed the concept of *parna* to describe the calcareous red clay materials, of aeolian origin, that blanket large parts of the Murrumbidgee and Murray River valleys. A central tenet of this model is that the aeolian material is transported as silt-sized pellets from locations remote to the site of deposition. Assumed sources of this pelletal material include floodplains, dune fields and playa lakes of western NSW, northwestern Victoria and South Australia (Hesse 1993, Acworth *et al.* 1997). The aridity of these source regions, and the prevalence of soluble salts in topsoils of these regions, accounts for the calcareous nature of the parna deposits. Following the seminal work of Butler (1956), many studies have described parna, or parna-like deposits, in various locations across southern NSW and northern Victoria (e.g., Mays *et al.* 2003, Summerell *et al.* 2000). Figure 1 indicates the assumed trajectory of this parna material and the various locations where parna deposits have been described.

However, when Hesse & McTainsh (2003) reviewed the evidence for aeolian deposits in Australian soil, they concluded that it was considerably wider in distribution than that initially proposed by Butler and that its composition also varied markedly, depending on the nature of the source areas. For example, a number of more recent studies (e.g., Cattle *et al.* 2002) have demonstrated that aeolian dust deposits of northern NSW have been considerably silica-enriched compared with the clay-rich deposits described by Butler (1956). Furthermore, Hesse *et al.* (2003) showed that post-depositional pedogenesis, mediated by the weathering regime, can result in quite profound alteration of the original dust material. Consequently, differences in dust deposit attributes are presumed to reflect both the source area soil characteristics and the weathering regime operating at the site of deposition. Dust deposits can be expected to have varying effects on landscape processes such as salinisation and soil erodibility, depending on the interplay of these source and environmental factors.

In: Roach I.C. ed. 2005. *Regolith 2005 – Ten Years of CRC LEME.* CRC LEME, pp. 38-42.

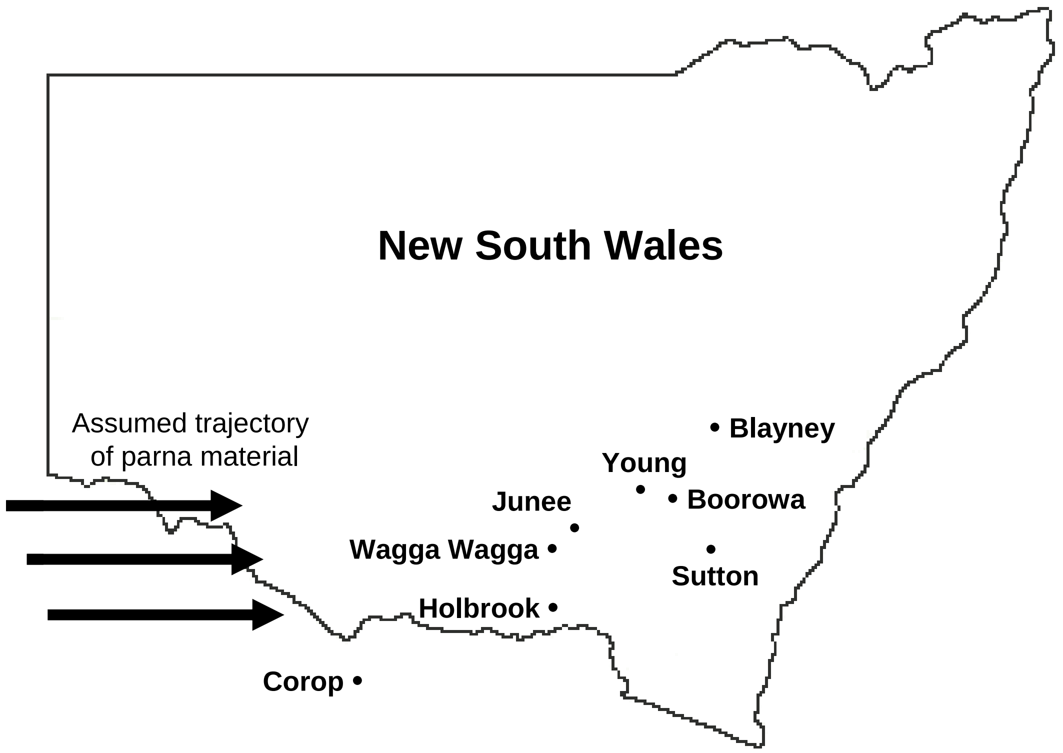

Figure 1: Location of proposed study sites in southeast Australia, showing their proximity to an aeolian dust transport path.

ROLE OF AEOLIAN MATERIALS ON SALINITY AND SOIL EROSION/STABILITY

Previous and current dust events are known to transport and add comparatively salt-rich clay aggregates into soil profiles of SE Australia. The salt input from these events will be one potential factor in determining likely areas of salinity (Evans 1998). In addition to the salt content, the stability of the clay materials in the dust accessions will be important in controlling soil-landscape processes of erosion and properties of the soil surface such as crusting (Greene & Nettleton 1995, Greene *et al.* 1998). The following sections briefly review the role of aeolian dust in transporting salts and the role of the clay aggregates in landscape processes.

Salt transport by aeolian mechanisms

Taking a minimum dust deposition rate of 5 mm Ka^{-1} for the Wagga Wagga region (Chen *et al.* 2002) and assuming a bulk density of 1 Mg m^{-3} after deposition (Almond & Tonkin 1999), dust accession for this area is conservatively estimated at approximately 50 kg ha^{-1} yr^{-1}. Applying the maximum deposition rate of 50 mm Ka^{-1} from the Last Glacial Maximum (Chen *et al.* 2002), estimated dust deposition rates are of the order of 500 kg ha^{-1} yr^{-1}. Assuming 1% of this dust is in the form of salt (e.g., calcite), equivalent salt deposition rates of 0.5-5 kg ha^{-1} yr^{-1} are achieved, while application of Kiefert's (1997) maximum figure of 50% by weight gives deposition rates in the range of 25-250 kg ha^{-1} yr^{-1}. From these calculations, the combined maximum rates of dust deposition and salt input via aeolian mechanisms can reasonably explain the accumulation of significant quantities of aeolian clay and salts respectively in landscapes of the eastern Murray-Darling Basin. This highlights the critical role that aeolian activity may have in certain areas in soil forming and other landscape processes. However, it should be noted that this is generally restricted to areas where post-depositional leaching is insufficient to counteract re-supply via further aeolian activity and precipitation. It is also important to point out that, while the dominant salt in parna is thought to be calcite, the contribution of sodium salts to the landscape via dusts of different source areas is less well characterised.

Stability of clay microaggregates in aeolian sediments

As described by Butler (1956), parna is an aeolian sediment, consisting largely of silt-and fine sand-sized clay microaggregates, as well as silt-sized quartz grains, which form significant components of the regolith in SE Australia. These sediments occur in the contemporary landscape as either: (i) discrete deposits e.g., dunes; or, (ii) widespread sheets of material of varying thickness. The properties of these sediments, and in particular the stability of their clay microaggregates, can have significant effects on a range of landscape processes and hence have major implications for land management. For example, if the clay microaggregates present in these sediments are highly unstable and disperse into < 2 μm particles, the soil profiles containing these materials will be highly prone to land degradation processes such as soil erosion (gullying, piping and rilling), poor air quality through ready dust entrainment and surface sealing, crusting and hardsetting problems (Greene *et al.* 1998).

Results of studies by McIntyre (1976) indicate that clay microaggregates occurring in some parna sediments are very stable, i.e., they resist breakdown in water. Mays *et al.* (2003) postulated that because these microaggregates originated in deserts, and formed slowly under hot conditions, the clay particles in them are strongly bound in a face-to-face orientation. This is in marked contrast to those microaggregates found in loess deposits in mid-western USA. The cold glacial environments that were the source areas for the loess provided conditions far less conducive to the development of stable microaggregates. In these materials the clay particles only exist in an unstable face-to-edge orientation, making them highly susceptible to dispersion in water.

RATIONALE AND METHODOLOGY FOR PROPOSED STUDIES

Previous studies on aeolian materials have all tended to focus on the recognition of the materials in the landscape. While this is important in terms of explaining their origin, more work is needed to actually characterise these aeolian materials from a salinity/structural stability point of view. In the proposed study, it is planned to investigate various sites in SE Australia that host recognised, well documented aeolian dust deposits. The sites to be studied are shown in Figure 1, and include:

- Corop, VIC (Tate 2003, Mays *et al.* 2003);
- Boorowa, NSW (McIntosh 1999);
- Blayney, NSW (Dickson & Scott 1998, Hesse *et al.* 2003);
- Sutton (Walker *et al.* 1988);
- Junee, NSW (Munday *et al.* 2000);
- Wagga Wagga, NSW (Chen 1997, Chen *et al.* 2002); and,
- Holbrook, NSW (McPherson 2004).

Table 1 outlines some of the primary diagnostic features of these deposits, while Table 2 outlines some of the physico-chemical attributes of these deposits. It is evident that there are only limited physico-chemical data available for these dust deposits, in particular those critical properties relating to salinity and stability.

It is planned to collect samples from these sites and analyse them for a range of physical and chemical attributes that relate to salinity potential and soil structural stability. In addition to the limited number of properties shown in Table 2, other properties will be measured using the following techniques: (i) micromorphological (using both plain and crossed polarised light) and scanning electron microscope studies; (ii) X-ray diffraction analysis; (iii) the effects of different dispersion treatments, such as ultrasonics, and/or chemical dispersants, on the particle size distribution (as measured using laser detection techniques); (iv) measurement of the ratio of the 15 bar water content to clay content; and, (v) exchangeable cations and the role of the exchangeable cation/soluble cation balance of clay particles on their physico-chemical behaviour (Rengasamy *et al*. 1984).

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Table 1: Primary diagnostic features of aeolian dust deposits at recognised sites in SE Australia.

Site	Primary diagnostic features of parna/dust deposits				
	Thickness (m)	**Particle size (μm)**	**Colour**	**Subplasticity**	**Other features**
Corop	3.5-3.8	> 75% clay	Yellow red reddish red	strong	Source bordering dune
Holbrook	0.46–1.46	63% clay 7% silt 30% sand	Yellow brown; dark yellowish brown to yellowish red mottles	n.r.	Moderately structured light clay; upper layers sandier due to colluvial reworking. Mn nodules at base but lacks minerals from weathered bedrock
Wagga Wagga	0.4–1	42% clay 33% silt (16–63 μm)	red	n.r.	Clayey texture, regardless of underlying lithology
Junee	6	40% clay 45% silt	mottled (red?)	n.r.	Mixed with weathered granite as re-worked sediment
Young	0.1–0.5	16 % clay 12% silt 36% fine sand	red	n.r.	Red topsoil on eastern side of hills; uniform topsoil from crests to lower slopes
Boorowa	0.15-0.25	n.r.	yellow red	n.r.	Surface soil; just below crest
Sutton	0.17-1.03	50% (31-50μm)	yellow red	n.r.	Profile near crest of hill
Blayney	>1	30	reddish	n.r.	Characteristic Ti/Zr ratios, large Th content

n.r. = not reported

Table 2: Physico-chemical features of aeolian dust deposits at recognised sites in SE Australia.

Site	Physico-chemical attributes of parna/dust deposits				
	Mineral suite	pH	EC[1] (dS/m)	ESP[2]	Physical attributes
Corop	quartz, muscovite, kaolinite	10.4	0.5	36	Subsoil/rough faced peds
Holbrook	kaolinite, mica, quartz, goethite	4.7	0.12	12.5	Large Th content; dominant exchangeable cation is Mg^{2+}.
Wagga Wagga	quartz, kaolinite, illite, smectite	n.r.	n.r.	n.r.	Weakly structured topsoil; clay bands in sand dunes
Junee	Quartz, kaolinite	n.r.	0.03	n.r.	Thought to constrain water movement
Young	clayey; some quartz, feldspar grains	n.r.	n.r.	n.r.	–
Boorowa	quartz, illie/mica, kaolinite	6.5	n.r.	n.r.	Weakly structured surface soil
Sutton	Quartz, kaolinite	n.r.	n.r.	n.r.	Coarse silt throughout profile
Blayney	quartz, kaolinite, illite	6.0-6.5	n.r.	n.r.	Massive; earthy fabric

[1]Electrical conductivity (1:5); [2]Exchangeable Sodium Percentage