CRCLEME
Cooperative Research Centre for
Landscape Evolution & Mineral Exploration

AEOLIAN DUST: IMPLICATIONS FOR AUSTRALIAN MINERAL EXPLORATION AND ENVIRONMENTAL MANAGEMENT

Abstracts of the Symposium held at The Australian National University, Canberra, ACT

Editors: R. Gatehouse
R. Greene

CRC LEME REPORT 102

25 & 26 November 1998

CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining, established and supported under the Australian Government's Cooperative Research Centres Program.

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Editors: R. Gatehouse[1]
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TABLE OF CONTENTS

IMPLICATIONS OF AEOLIAN DUST FOR MINERAL EXPLORARTION

- Regolith Effects and Gold Exploration in the Blaney – Orange District, NSW

- Locating Aeolian Soils with Aerial Gamma-ray Surveys

- Mineral Exploration in Southern Africa – the Challenge of Windblown Sand

POSTER PAPERS

- Aeolian Contribution to Soils in the Boorowa Region

- Aeolian Component in Soil Profiles at the McKinnons Gold Deposit Area, Cobar, New South Wales

- Distribution of Sodic Soils in Central Western NSW

- Remote High-resolution Measurements of Wind Erosion with a Piezo-electric Crystal Sensor

- Aeolian Dust in the Broken Hill Landscape: Rates of Geochemical Dispersion and Implications for Mineral Exploration

- Pedogenically Modified Aeolian Carbonate Dust (calcrete mantle): An Excellent Exploration Sampling Medium – A case Study from the Birthday Gold Prospect, Gawler Craton, South Australia

INTRODUCTION

The impetus for this symposium on ***Aeolian Dust: Implications for Australian Mineral Exploration and Environmental Management*** arose out of the strong research interests of several members of the Cooperative Research Centre for landscape Evolution and Mineral Exploration (CRC LEME) in aeolian materials. In particular, many important problems in mineral exploration and environmental management require detailed understanding of aeolian materials and their interactions with other regolith materials. Accordingly the symposium has been structured into sessions under the following themes: ***Nature of Aeolian Dust, Environmental Implications of Aeolian Dust Accessions, Role of Aeolian Dust in Soil-Landscape Processes, and Implications of Aeolian Dust for Mineral Exploration.*** Each section starts with an overview of the key issues of that theme, followed by several papers that develop the theme. Poster presentations and a field trip to local aeolian deposits in the Canberra-Yass Region also illustrate important aspects of these themes. The aims of the final session are twofold (i) to link the nature, distribution and admixing of aeolian material in the regolith to their role in mineral exploration and environmental management, and (ii) to develop future areas of research and collaboration.

It is intended that the book of abstracts and the field guide will prove valuable, both as an official record of the symposium, and as a source of reference material for people involved in all areas of teaching and research related to aeolian dust. I wish to thank all of you for attending this important symposium, the authors of the papers for their contributions, and finally the members of the organising committee; Keith Scott, Robyn Gatehouse, Xiangyang Chen and Judy Papps for all of their hard work and patience with me. And finally I throw out to you all the challenge of working hard over these two days to achieve a positive outcome. Best wishes for an enjoyable and rewarding symposium.

Richard Greene
Convenor
November 1998

NATURE OF AEOLIAN DUST

The Identification, Composition and Origins of Aeolian Dust

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Aeolian dust is ubiquitous in many past and present environments. In its various forms it may occur as deep sheets of loess and parna, layers of volcanic ash, or be found mixed in soils or marine and lacustrine sediments. In this presentation, dust is defined as any material which can be wind transported as suspended load and therefore includes material ranging from approximately 100 µm diameter particles or aggregates to sub-micron-sized particles. This will include desert and glacially derived loess, parna, stratospheric dust and anthropogenic dust. In recent years the significance of respirable dusts generated by mining, industry and transport has become of increasing concern to medical authorities and is of growing interest in a range of countries.

Aeolian deposits can be identified using a wide range of techniques including their stratigraphic occurrence in the landscape, their distinctive morphology, their textural properties, their mineralogical properties, and their isotopic, chemical, radiometric and magnetic properties. In many cases, a combination of these techniques is required to identify aeolian contributions to soils and sediments and to assist with ascertaining the potential origin of the material.

This paper reviews previous Australian work regarding the identification, composition and origins of aeolian dust. It also presents data on the identification of aeolian derived soil materials on a range of substrates in NSW using oxygen isotope analysis.

Fingerprinting Windblown Dust by Uranium-lead Dating of Aeolian Zircon

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Far-travelled desert dust can impact regolith materials in areas remote from the dust source. In southeastern Australia, dust is carried from the arid and semi-arid interior and deposited in the more humid eastern margins of the continent including the riverine plains and highland areas.

The impact of the windblown dust on regolith materials in the region, is however, not well know. This is in part because of difficulties in recognizing the deposited dust. Typically, the dust does not form discrete mantles because relatively low accession rates, accompanied by erosion, weathering, and pedogenesis, lead to the reworking and mixing of the dust into existing soils and sediments. Where mantles do occur, they often cannot be confidently distinguished from alluvial or colluvial deposits. These problems highlight the need for a signature by which aeolian dust in regolith materials can be identified.

In this research, the SHRIMP II ion microprobe, at the Research School of Earth Sciences, ANU, was used to determine uranium-lead (U-Pb) ages of individual zircon grains separated from soil and dust samples in order to establish a zircon-age distribution pattern to fingerprint aeolian dust. U-Pb ages of zircon give the time of zircon crystallisation during the cooling of its igneous or metamorphic host rock and hence provide a fingerprint characteristic of the region from which the zircon was derived. Potential source areas for exotic zircon grains are located by matching the zircon age pattern with the known ages of zircon in igneous, metamorphic, and sedimentary rocks in potential source areas.

Initial analysis was done on soils formed on rock types that typically do not contain zircon (e.g. basalt and mafic volcanics) so that any zircon present would signify an exotic component in the soil. In addition, sampling sites were chosen from hillcrest positions away from the influence of fluvial and colluvial sedimentation to ensure that the age signature of the exotic zircon could be related directly to windblown dust.

The resulting zircon-age distribution patterns are used to confirm the presence of windblown dust in soils, pinpoint the potential dust source areas, and distinguish regional (far-travelled) dust sources from local sources.

The U-Pb age data complement other evidence such as particle size distribution, mineralogy and geochemistry in establishing the nature and impact of windblown dust on regolith materials.

The Noora Boinka – A Source of Dust Pulses

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Groundwater discharge zones in the arid zone, or boinkas, accumulate salts which assist deflation. Boinkas have characteristic landform and sediment assemblages, including saline mudflats, accurate and lobate dunes, lunettes, shoreline features, and usually occur in linear dunefields. The Noora Boinka, in The Mallee Dunefield of Southeastern South Australia, has all these features. The dunes are derived from local deflation of the Parilla formation and Blanchetown clay, transport from upwind of these and other deposits, and by deflation of fluvial sediments washed into short-lived lacustrine environments in the boinka.

It is supposed that each episode of dune construction is accompanied by dust production, because the source materials for the dunes include fine sediments. Therefore, ages of dune construction should also be ages of dust production. The dating of dune building phases at Noora are coeval with phases of linear dune building in The Mallee and elsewhere.

Properties of Magnetic Mineralogy of Alaskan Loess: Evidence for Pedogenesis

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Variations in magnetic properties, such as the susceptibility, in loess/palaeosol sequences, are widely recognised as a proxy indicator of Quaternary climatic change. However the link between magnetic susceptibility and climate is not consistent. In mid-latitude deposits, such as those of China and central Europe, the magnetic susceptibility of palaeosols is enhanced relative to the intervening loess, due to the formation of ultrafine ferrimagnetic material during pedogenesis. Conversely, in high latitude deposits, such as Alaska and Siberia, magnetic susceptibility minima coincide with palaeosols.

This inverse relationship has been explained by the idea that susceptibility is reflecting the magnitude of an aeolian ferrimagnetic component of consistent mineralogy, the size of which is inversely related to average wind velocity. However, the magnetic study reported in this paper, which includes frequency-dependent and temperature-dependant (-196°C to 700°C) susceptibility, hysteresis loops and thermomagnetic (Curie) curves, suggests that there are differences in magnetic properties between Alaskan loess and palaeosols, not only in magnetic grain-size but also in magnetic mineralogy.

These findings complicate the simple hypothesis of a 'wind velocity' signal by introducing an additional factor in to the climatic signal. By analogy with magnetic variations between the central and southern parts of Chinese Loess Plateau, we argue that the low magnetic susceptibility values in the Alaskan palaeosol units are a reflection, at least in part, of post-depositional processes.

ENVIRONMENTAL IMPLICATIONS OF AEOLIAN DUST

Salt and Dust -A Quaternary Climate-driven Salt Cycle for the Eastern Highlands?

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Much is now being written regarding the possible origins of salt in the Eastern Highlands of Australia (for instance papers at this workshop). These origins and the way in which the salt is stored and transported in the landscape are key factors to properly managing the degradation problem of dryland salinity.

Over recent years it has been accepted that the preferred origin of salt in the Paleozoic terrains of the Lachlan Fold Belt is aeolian - as opposed to a connate or present day cyclic origin.

Evidence, both from a groundwater and chemical point of view, is presented from the Boorowa River Catchment to support the assertion that aeolian accession over Quaternary time is the dominant process. Catchment salt mass-balances, isotopic data and major ion chemistry will be presented.

A hypothesis regarding the nature of the salt cycle once in the catchment, its relationship to deeply weathered landforms, possible storage mechanisms and the timing and nature of storage processes are presented.

Aeolian Events Leading to Accession: Evidence from Soil Formation Studies on the Eastern Tablelands of NSW

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A series of pedogenesis and regolith formation studies from sites along the tablelands and slopes of N S W have all shown the accession of both quartz sand and parna derived clays within the time that "modern" soils have been forming. Both the mineralogy and grainsize evidence points to at least several different accessions of material and some multiple narrowly defined quartz grainsize distributions suggest multiple events with different sources or quite different events contributing material. The same may be true of the mineralogy of clay aggregates that have been added to soils.

There are clay mineralogy signatures in some of the soil profiles that are not in keeping with the known mineral weathering pathways for the underlying parent material for these soils. Many of the clay minerals thought to make up parna are not stable in the environment of deposition, but a few seem to survive for very long periods and can act as a signature.

Micromorphological studies have proved to be very difficult, but there are some sets of evidence: ghosting after concentrically zoned particles of about the correct dimensions to have been wind blown; layering in some near surface soil horizons; and the shape of some quartz grains, again of about the right size to have been deposited by wind. The profiles studied are tabulated below with the forms of evidence collated for each and a brief comment about the nature of the site and the soils.

Table 1. Soil Pedogenesis and Regolith Formation Sites.

Site/location	Mineralogy	Grainsize	Micromorphology	Geomorphic position	Soil Type
Boorolong Ck. near Guyra	quartz on basalt	strongly bimodal	some ghosting	on Great Divide	black earth
Pipeclay Ck. near Armidale	quartz, smectites	trimodal quartz	layering of quartz	local divide	red-brown earth
Sandy Ck. near Armidale	quartz on granite	strongly bimodal	not seen	forms divide	podsolics
Baragans Mt. near Oberon	quartz on basalt	unimodal	good ghosting	local divide	chocolate soils
Lark's nest near Crookwell	quartz on basalt	unimodal	good ghosting	part of plateau	red earths
Bonhome near Taralga	quartz on basalt	bimodal	not seen	part of plateau	red earths
Wulwye Ck near Berridale	quartz on basalt	strongly bimodal	not seen	series of flows	shallow red earths
Frogmore Road cutting, near Boorowa	quartz and clays	several modes	ghosting and other structures	ridge top	non calcic brown and podsolics

In conclusion at least two stages of aeolian accession can be suggested and during each of these stages prevailing climate (and weather) determined grainsizes and mineralogy. The latter was determined by source areas accessed by the prevailing climate (and weather).

Provenance of Cainozoic Deposits and Related Dryland Salinity, Upper Dicks Creek Catchment, New South Wales

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Dryland salinity has manifested serious land degradation problems throughout many areas of New South Wales, including the Southern Tablelands. The occurrence of dryland salinity within the upper Dicks Creek catchment, located within the Southern Tablelands, is investigated in relation to the provenance of four Cainozoic deposits to elucidate the main controls on salinisation processes.

A minimum of four Cainozoic erosional/depositional cycles were identified overlying Ordovician bedrock within the upper Dicks Creek catchment. These units have been characterised and described as a basal gravity flow deposit (Mugga unit), an overlying debris flow deposit (Pialligo unit), a loess deposit (Kurrumbene unit) and overlying contemporary alluvial deposit.

Physical and chemical characteristics of the Pialligo and Kurrumbene deposits suggests a large aeolian component. The provenance of this aeolian material, including appreciable quantities of entrained salts, is postulated from the west including the Murray-Darling and Lake Eyre Basins.

Radiocarbon dating suggests deposition of the Pialligo unit was associated with increased aridity and winds some 26 000 ka - 30 000 ka during the late Pleistocene 'Glacial Ice Age'. Similarly, deposition of the Kurrumbene unit was associated with cooler, drier conditions of the late Holocene 'Little Ice Age', approximately 200 - 600 years ago.

Impedance of discharging groundwater through the Kurrumbene and Pialligo units facilitates the occurrence of dryland salinity. Cation exchange and dissolution reactions contribute to high ionic loadings in discharging groundwater. Concentration and efflorescence of salts at the surface occurs through evaporation and evapotranspiration processes. Bare, salt affected Pialligo deposits are focal points for erosion and land degradation whilst the Kurrumbene deposit is less prone to erosion when exposed. The Mugga deposit and contemporary alluvial deposit have few implications with regard to dryland salinity.

High Resolution Measurements of Wind-eroded Sediments to Determine Threshold Wind Velocities Using a Piezo-electric Crystal Sensor

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The erodibility of a surface changes with time and space. Estimates of erodibility have traditionally been extremely difficult to make with out a portable field wind tunnel. Recent development of a wind eroding mass field instrument based on a piezo-electric quartz crystal (SENSIT™) means it is now possible to continuously monitor erosion activity and wind velocity at high resolution (<1 minute). SENSIT™ output is expressed as particle count flux (counts per second) and wind velocity can be monitored simultaneously. From these data, threshold wind speeds for erosion activity can be specified.

A study was conducted for 8 weeks with 35 erosion events measured over a total of 9 monitoring periods on a highly erodible site in the Channel Country of south west Queensland, Australia. Results show how the threshold for erosion changes with time. Initial threshold wind velocity at the site was 6 m/s and gradually became higher with a maximum of 8.3 m/s over the monitoring period. The threshold velocity varied due to rainfall, surface weathering and erosion processes. For the first time the true dynamic nature of wind erosion has been observed in Australia. The technology has application to the mining industry and dust abatement programs because it can be used to indicate at what time and at what magnitude an area is eroding. Correlations can be developed to estimate the horizontal and vertical mass fluxes, thereby monitoring the success of dust abatement programs.

ROLE OF AEOLIAN DUST IN SOIL-LANDSCAPE PROCESSES

Aeolian Dust Deposits and Soil Landscapes: Examples From Wagga Wagga, NSW

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The wide distribution of Quaternary aeolian dust deposits (parna) in southeastern Australia has long been recognised. The total thickness of such deposits, reaches at most, several metres in the studied areas. These aeolian dust deposits have a significant influence on soils. The most remarkable influence is probably the wide occurrence of red clayey soil materials throughout large areas with diverse landforms and substrates, forming an apparent dust mantle. However, because of the relatively low deposition rates, the aeolian dust materials may have been mostly reworked after initial deposition and mixed up with locally derived materials. The apparent dust mantle can be recognised as residual, colluvial and alluvial sediments by detailed studies. Whether or not the dust materials are present and dominant in soils at a particular site depends on the landscape processes and landform history.

In the Wagga Wagga area, the aeolian dusts are least apparent in two types of landform: relatively active floodplains and steep hills. In the floodplain of Murrumbidgee River, however, the present soils are characterised by grey and brown silty clays which contain fine silts instead of coarse silt – an indicator of aeolian dust. Along Burke's Creek, a local stream, red clayey soils occur in mid-reaches where river channel has incised >10m and floods are very rare. However, in both upper and lower reaches such red clayey soils are much less common and soils are more variable. On steep hills (>20-30% slopes) red clays are rare and soils show various features closely related to the underlying bedrock. In more gently sloped (5-20%) hills and rises, soils tend to show common features with red clayey B horizons. In undulating plains and long foot slopes (<5-3%), soils are highly uniform in morphology and have red clayey B horizons underlain by yellow and brown clays which were described by early studies as the type parna sequence.

This pattern may be found in other dustfall areas, ie. aeolian dusts are present most likely in the undulating areas without any significant alluvial influence since the Holocene. In steep hilly areas, dust deposits tend to be insignificant in soils. However, in less steep hilly areas, the existence of dust materials is much less predictable, because accidental events in the past, eg. bushfires, may have caused very different stability of land surfaces from one place to another.

Aeolian Additions to the Soils of the Central Highlands and NW Plains of New South Wales: Characterization and Impacts

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The amount and nature of aeolian dust additions to soils was investigated at several sites in the Central Highlands of NSW, the Macquarie Valley and Murray Basin. Although some literature has identified aeolian dust mantles based on grain size, chemistry, mineralogy and subplasticity of clays, a strategy was selected which would allow for detection of aeolian dust additions to soils and sediments without assuming physical or chemical properties. Specifically, sites were selected according to quartz free substrate character (basalt and pure limestone) and silt and clay-free substrate character (sand dunes). Signatures of exotic aeolian material were identified using detailed particle size analysis and mineralogical identification of soil and substrate through X-Ray diffraction (XRD) and thin section analysis.

A single aeolian signature was found to be ubiquitous across diverse substrates covering a wide area (31° - 35°S). The signature identified consisted of discrete mineral grains, of which quartz is the major component. Accessory minerals include feldspar, haematite, clay minerals and mica. The modal size of the aeolian material is 30-40μ m which has been identified across diverse substrates over hundreds of kilometres. Clay content of the aeolian dust was found to be consistently low. The aeolian content of the soils from the western and central areas of the highlands was estimated to be as much as 25%.

The clay pellet parna model (Butler 1956) which has been so widely applied to the Murray Riverine Plain, other areas of Australia and even Mars (Greeley and Williams, 1994, Icarus) was found to be inappropriate for the identification of the aeolian component in these soils. With the automation and sophistication of contemporary measuring equipment, dust addition to soil can be more accurately defined and quantified than has so far been the case. Generalizations and general classifications of dust deposits in Southeastern Australia require detailed reconsideration using detailed analysis of suitable diagnostic sites.

Dust Accession Rates Over the Late Pleistocene in Northern NSW; the Potential for the Formation of Aeolian Mantles and Reworking Within the Landscape

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The dating and quantification of dust deposition in Australia remains largely unresolved despite the recognition of dust mantles in the landscape at least 40 years ago. We have used fine aeolian dust additions to two dated well-sorted source-bordering sand dunes in interior northern NSW to calculate aeolian dust accumulation rates.

These rates of accumulation can be compared with both modern measured rates and similar long-term rates from the deep-sea sediment record for confirmation and correlation.

The source bordering dunes are exceptionally good repositories of dust, with almost no surface wash (reworking) because of their very high infiltration rates. They therefore allow estimation of the maximum possible thickness of aeolian dust deposited over the wider landscape for the same period (63 ka and 40 ka). Comparison with the amount of identifiable dust in topsoils of the region also allows determination of the amount which is reworked by wash to lower slopes or into the river system.

It seems unlikely that in any of the region studied (35°S to 31°S) there was sufficient deposition of aeolian dust to leave primary aeolian dust mantles in the Late Pleistocene given the twin effects of reworking and incorporation into the substrate.

The Influence of Aeolian Dust Deposition on Alpine Soils in South-East Australia

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The presence of aeolian dust in montane and alpine soils has been debated for several years around the world. In Australia it is thought that the accession of aeolian dust across mountainous areas in the South-East has played a significant factor in the development of alpine soils, in particular, snowpatch meadow soils (Walker and Costin, 1971). The clay content (<2 μm) of these soils is comprised of clays of several origins. These include, current chemical weathering, weathering prior to periglaciation, decomposition of the deep-rooted alpine/subalpine vegetation to produce colloid sized sesquioxides at the soil surface, and dusts (resembling parna) blown in from the semi-arid and arid zones of Australia (Costin, 1986; Costin, Hallsworth and Woof, 1952). The latter two processes are a major factor in why these soils resist podsolisation.

Dust accessions of the order of 20-1000 tonnes per hectare, depending upon site and aspect, are estimated to have occurred on alpine soils in the Kosciuszko region during postglacial times. Walker and Costin (1971) found that the dust collected from snowpatch soils in leeward sites in which there was maximum snow accumulation, had a median diameter of 4 μm, relatively high organic content, and minerology in the less than 2 μm fraction dominated by illite and kaolin. Snowpatch meadow soils exhibited 47% clay and 22% silt and alpine humus soils 21% clay and 8% silt, with the clay contents being dominated by Kaolin. These findings are supported by Johnston (1995, 1998) where alpine meadow soils exhibited 45-46% clay and 21-23% silt and alpine humus soils 18-22 % clay and 9-17% silt.

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Mid Pleistocene Arid Shift in Southern Australia, Dated by Magnetostratgraphy

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In coastal sections at Hallett Cove and Sellicks Beach, south of Adelaide, and at Red Cliffs section on Kangaroo Island, the Brunhes/Matuyama polarity transition (0.78 Ma) is identified in the strongly oxide-mottled Ochre Cove Formation (Pillans & Bourman 1996, *AGSO Jnl. Aust. Geol. Geophys. 16*, 289-294). At all three sections, the Ochre Cove Formation is overlain by a calcareous grey-green aeolian clay, called Ngaltinga Clay, which in turn is overlain by calcareous sediments of the Christies Beach and Taringa Formations. The marked change from an oxide-dominated weathering regime to a carbonate weathering regime is estimated to have occurred at about 500 to 600 ka, and is interpreted as a major arid shift in regional climates.

Similar arid shifts are reported from Lake Bungunnia in the Murray Basin (An *et al.* 1986, *Palaeo.*^{3} *54*, 219-239) and Lake Lefroy in southern Western Australia (Zheng *et al.* 1998, *Global & Planet. Change 18*, 175-187), where changes from lacustrine clays to evaporites and dune sediments are estimated to have occurred between 400 and 700 ka, and about 500 ka, respectively. An increase in aeolian dust input to Tasman Sea sediments also occurs in the last 400 ka (Hesse 1994, *Quat. Sci. Rev. 13*, 257-272).

Between 600 and 900 ka, oxygen isotope fluctuations in deep sea cores show a pronounced change in frequency, from a 40 ka (obliquity dominated) to a 100 ka (eccentricity dominated) pattern. At the same time, glacial-interglacial amplitudes increased, with a marked enrichment of glacial $\delta^{18}O$ values consistent with larger continental based ice-sheets. Colder global temperatures, and lower sea levels during glacials may have played a part in the mid Pleistocene arid shift recorded in southern Australia. Associated variations in the strength of the warm Leeuwin Current (McGowran *et al.* 1997, *Palaeo.*^{3} *136*, 19-40) may also have affected regional rainfall patterns in southern Australia.

Aeolian Dust in the Western Victorian Landscape

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One of the first workers to record deposits of fine sand and silt across the Western Victorian Volcanic Plains was Gill who in the 1960s noted calcareous silt deposits on the basalt plains near Melbourne, also reworked into alluvial terraces along rivers such as the Maribyrnong at Keilor, and important to archaeological studies. Gill and others also described layers of silt and fine sand as part of buried soils lying within lava flows and ash deposits in the Camperdown area of central Western Victoria.

Soils workers such as Gibbons, and later Jackson and others, mapping the volcanic plains in the far west around Hamilton, noted quartz grains in the clay soils, and found that soil-landscape relationships suggested the amounts increased with the age of the soils and of the parent lava flows.

More recently, Kershaw has noted possible wind-blown layers within lake deposits in the maar craters of Lake Terang and Pejark Marsh in central Western Victoria.

In far western Victoria and into SE South Australia, extensive thin grey sand sheets have been mapped by Kenley, and sand and clay lunette ridges downwind of lakes and depressions are common across the Western Victorian Volcanic Plains. These are likely sources for the wind-blown deposits now found widely across the plains.

The movement of this wind-blown material may be related to climatic fluctuations of the past several million years, with strong westerly winds periodically acting on sparsely-vegetated glacial age landscapes. Recent airborne radiometric imagery may assist in mapping the surface distribution of the silt and sand and assessing its relationship to soil development. Some relevant radiocarbon dates are available, suggesting aeolian activity about 20,000 B.P. Thermoluminescence dating would help determine the times of past aeolian activity and also add to the volcanic landscape history of the region.

IMPLICATIONS OF AEOLIAN DUST FOR MINERAL EXPLORATION

Regolith Effects and Gold Exploration in the Blaney - Orange District, NSW

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Au mineralisation in the Blayney - Orange district, 180 km west of Sydney in the Lachlan Fold Belt, may contain significant As, Cu, Pb, Sb and Zn contents. Such potential pathfinders are retained in gossanous outcrop, where present, and may also be retained in residual soils. Study of residual soil at Osborneville (10 km south of Blayney) suggests that the fine (<63μm) fraction of the soil contains higher concentrations of Au and base metals than the coarser soil fractions. However aeolian material is also known to be deposited in the Lachlan Fold Belt during the last 260,000 years. Aeolian material successions produce loamy soils with > 80% of their weight having a grain size < 63μm and having consistent Ti / Zr = 10-13. Furthermore, many soils of the region contain an aeolian component which is not immediately apparent except after sieving and chemical characterisation.

If a significant amount of an aeolian component is present in a soil, the magnitude of any Au or base metal anomaly (associated with residual material) could be substantially reduced. Thus sampling based on the use of the fine fraction of soils may not have fully tested the economic potential of the region. Instead, use of the coarse (>2mm) fraction of the soils is recommended, preferably after inspection of such material for the degree of rounding of grains or other signs of transport. The use of pisoliths in the district is also briefly discussed.

Locating Aeolian Soils with Aerial Gamma-ray Surveys

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Aerial gamma-ray surveys (AGRS) measure the distribution of potassium (K), uranium (U) and thorium (Th) in the earth's surface using detectors mounted in low flying aircraft and are widely used for mapping of geology and in mineral exploration. Scatter plots comparing K, U and Th contents of samples of outcrop with those of soils collected adjacent to the outcrop may be used to identify and map transported soils, and if other evidence is available, aeolian soils.

The interpretation of an aerial survey is made using relative abundances of K, U and Th. These abundances give a signature for each area in the survey. Note that individual soil and parental rock signatures can not be obtained from the survey data as each area seen by the detectors covers both rock and soil. Instead we must use scatter plots of the mixed signatures to identify signatures of transported soils. Such plots must be interpreted with care as changes in elemental concentrations occur during pedogenesis, which can mimic or obscure the signatures of transported soils. The changes are dependent on the lithology of the parent rock.

The analysis of two aerial gamma-ray surveys, conducted in the Blayney and Cobar areas, NSW, will be demonstrated. These two areas have been shown by separate studies to have a significant contribution to local soils by aeolian material. Examination of the aerial survey data shows that where transported soils have quite a different composition to residual soils then analysis of K vs Th scatter plots may be used to map the distribution of those soils.

Mineral Exploration in Southern Africa - the Challenge of Windblown Sand

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The centre and west of the southern African subcontinent is dominated by arid and semi-arid regions, and windblown sand is a common feature of the landscape. This sand reaches its greatest thickness in the Kalahari Basin which occupies most of Botswana, as well as parts of eastern Namibia, north-western South Africa and western Zimbabwe. While the thicker sequences in the centre of the Basin pose a major challenge to exploration geochemists it is still possible to explore successfully around the margins where a thinner, discontinuous cover may not completely mask geochemical signatures of underlying rocks. However, exploration in such regions is not easy and it is essential that the underlying processes that have shaped the landscape are clearly understood.

The Putsberg (Cu) and Kantienpan (Zn) deposits in the north-west of South Africa both occur on, or close to, the African erosion surface which is a mature peneplain dating back to the Cretaceous. They are masked by both calcrete and windblown sand, and while a geochemical signature from both can still be detected at the surface, the nature and intensity of that signature is strongly influenced by the type of sample collected and analysed.

Extremely subdued, localised anomalies in -80 mesh material at Putsberg were not even recognised at the time of initial exploration and it was only after the deposit had been located (by pattern drilling of regional geophysical anomalies) that the initial soil geochemistry was shown to have been successful. Anomalous values were typically 40 ppm Cu over a background of 20 ppm Cu with a surface dispersion halo of no more than 30 - 50 metres downslope. Such subdued geochemistry can be explained by the presence of significant amounts of windblown sand in the sample collected for analysis. Subsequent work showed that a strong signature in the 1 - 2 mm heavy mineral fraction (over 1000 ppm Cu) could be detected at a distance of over one kilometre from the deposit. This fraction effectively eliminated the windblown sand component, although it still posed challenges to the geochemist in that the total weight of sample isolated for analysis was invariably less than one gram even though the initial field sample weighed two to three kilograms. Similar results were also obtained from Kantienpan although dilution from other heavy minerals resulted in a more restricted anomaly.

POSTER PAPERS

Aeolian Contribution to Soils in the Boorowa Region

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Previous work by several researchers has postulated the presence of windblown material in soil profiles in South - Eastern Australia. It has been found that the mantle of aeolian dust as identified by Butler in 1956, occurs significantly in temperate areas of South Eastern N.S.W. The aim of this study was to identify conclusively, the presence of aeolian materials in soil profiles of the Boorowa Region, N.S.W.

The principal rock type in the area consists of mid to late Silurian, felsic Douro volcanics. The region is known for the depth of weathering with many surficial deposits of Quaternary age. The contribution of colluvial material (possibly from nearby Ordovician meta sediments) to soil properties is part of an ongoing investigation.

The presence of aeolian material in the Boorowa area was identified by Hird in 1991 and was found to be valid through analysis of the soil characteristics. The traditional method of identification of aeolian material in soil profiles is through the analysis of quartz and clay content. This method showed significant variations in soil properties from the result of weathering of the parent rock. Mineralogical and particle size analysis showed modal quartz trends with depth in the profile. The clay type and distribution showed that the source of the weathering particles could not be locally derived.

The size and composition of the clays present indicate they are most likely to be of aeolian origin with a possible source area being winnowed lacustrine deposits in central Australia.

Aeolian Component in Soil Profiles at the McKinnons Gold Deposit Area, Cobar, New South Wales

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The Quaternary history of the Cobar region was characterised by the alternation of erosion-deposition periods and pluvial periods when the landscape was stable and soils were formed. The soils in the Cobar region belong to the Parakylia soil layer which consists of a mixture of wind-borne materials and locally derived colluvium and alluvium (Jessup 1961).

A number of profiles across an 8 x 12 km^2 area around the McKinnons Gold deposit were examined. The soil profiles are found to be associated with four types of landscapes: 1) gentle rises (gradient $\approx 2^{\circ}$) with shallow soils (10 - 50 cm); 2) sloping plains ($< 1^{\circ}$) with moderately deep soils ($\approx$ 1 m); 3) alluvial flats ($< 1^{\circ}$) with deep soils (> 1 m); and 4) narrow drainage depressions (gradient $< 1^{\circ}$) with moderately deep soils ($\approx$ 1 m). There were four soil materials identified in the mapping area: gravels; red silty loam; alluvial sand; and well structured red clay. The red silty loam covers almost all the landscapes. This red silty loam may occur as a uniform deep soil and may overlay: a stone line; a uniform red silty loam; a well structured red clay layer (often with carbonate at depth); or weathered bedrock (for shallow soils).

As shown by particle size analysis of the fine fraction (< 2 mm): the red silty loam consists of significant proportion of fine sand (2 - 4 Φ) and coarse silt (4 - 6 Φ), and less fine silt (7 - 9 Φ) and clay (> 9 Φ). The alluvial sand consists of significant proportion of coarse to medium sand (-1 - 2 Φ) with less medium silt (5 - 6 Φ), fine silt and clay. The well structured red clay comprises significant proportions of coarse silt, fine silt and clay with lesser abundance of fine sand. The fine size fraction of stone lines has a bi-modal distribution, with one modal in fine sand (2 - 4 Φ) and another in clay (> 9 Φ) fractions, with minor coarse and fine silt.

The fine sand fraction (2 - 3 Φ) represents material derived from parent bedrock (i.e. Devonian sandstone and siltstone) while the coarse to medium silt (3 - 6 Φ) is transported aeolian dust that has been subsequently reworked by colluvial and alluvial processes (Beattie, 1969 and Chartres, 1982). The clay (> 9 Φ) may originate from both aeolian dusts and weathering products. Skewness versus standard deviation (sorting) for each soil material was plotted and the results show that the alluvial sand has very different sorting and skewness from the fine fraction of stone lines. This suggests that both materials have been formed under different processes. Stone lines may have originated from surficial lags formed by deflation whereas the red silty loam is mostly derived from aeolian dusts that were subsequently reworked by colluvial and alluvial processes. Most of the data from the structured clay formed a different distribution to the rest of the soil materials, and the presence a of minor silt size component provides evidence that such clays have probably been formed/deposited under a previous wetter climate.

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Distribution of Sodic Soils in Central Western NSW

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Sodic soils are defined as those soils with high levels of exchangeable sodium relative to calcium and magnesium. This causes these soils to have severe soil structure problems including surface sealing, surface ponding, high runoff, poor drainage, very poor soil tilth and high soil strength, and often makes them very susceptible to erosion. Soil test results and soil properties show that a large proportion of soils in Central Western NSW are sodic. The soil landscape maps were used as the basis for mapping the distribution of sodic soils, and the occurrence of sodic soils within each soil landscape is briefly described. These descriptions are based on information collected in the course of mapping the soil landscapes of the region, soil testing programs in the area, and in the course of investigations for land management. The occurrence of sodic soils within each soil landscape is described as one of the following:

❑ Sodic topsoils	❑ Sodic subsurfaces	❑ Sodic upper subsoils	❑ Sodic lower subsoils	❑ No sodic soils in soil landscape
▣ widespread ▣ common ▣ localised	▣ widespread ▣ common ▣ localised (often in the lower parts of the landscape)	▣ widespread ▣ common ▣ localised (often in the lower parts of the landscape)	▣ widespread ▣ common ▣ localised (often in the lower parts of the landscape)	

The implications for land use and the causes of the distributions of the sodic soils are discussed briefly, particularly in relation to erosion and land management.

In the Tablelands the association of the high occurrence of sodic soils with particular geological units is noted. These geological units include granites and granodiorites like the Bathurst Granite and parts of the Yeoval Granite. Another broad geological unit which seem to have a higher proportion of sodic soils is the Hill End Trough. On the slopes and plains in the western part of the region, there is not the same apparent association of sodic soils with geological units. This implies that the sodium may have different, less localised sources, such as aeolian dust or salt, or groundwater and throughflow. The possibility of aeolian dust contributing to sodicity in Central Western NSW is a conclusion from this study.

Remote High-resolution Measurements of Wind Erosion with a Piezo-electric Crystal Sensor

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Investigations had been undertaken into the performance of a wind eroding mass field instrument based on a piezo-electric quartz crystal (SENSIT™). Data output signals are expressed as particle count flux (counts per second) and kinetic energy flux (ergs per second). These outputs were correlated with data from a wind vane sampler array with known performance and efficiency. Previous attempts to calibrate the SENSIT™ against measurements of soil erosion (g^1 m^{-2} s^{-1}) has proven frustrating. This study aimed to calibrate the SENSIT™ against sediment mass flux (g^1 m^{-1} s^{-1}) because this is a more realistic measurement of what the SENSIT™ actually measures. The study was conducted for 4 months and a total of 9 erosion events were monitored on a highly erodible site in the Channel Country of south west Queensland, Australia. Three predictors of mass flux at the height of the SENSIT™ were investigated: 1) particle counts (r^2= 0.94); 2) kinetic energy (r^2= 0.96); and 3) kinetic energy/friction velocity (r^2= 0.96). The instrument appears to be reliable for the measurement of horizontal mass flux estimation with the kinetic energy output providing the best predictor. Investigations are outlined that improve the understanding of the instrument and the underlying physical processes.

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Aeolian Dust in the Broken Hill Landscape: Rates of Geochemical Dispersion and Implications for Mineral Exploration

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A study of regolith in the Broken Hill area has provided detailed maps of two areas, Maybell to the north and Stirling Vale to the southwest of Broken Hill (Joyce 1994). In both areas a thin slope cover of dark red silty clay, identified as wind-blown by its distribution, grain-size and relict clay pellets, lies directly on the bedrock of Proterozoic metasediments and metavolcanics, and also extends as a water-reworked deposit along adjacent drainage lines. Chemical analyses show that the mineral signature of the underlying rocks has been transferred to the aeolian cover, both physically as incorporated rock fragments and chemically by leaching and precipitation.

There is no evidence of more than one period of wind addition to the landscape, and the age of the cover may be inferred as that of the last period of major wind deposition i.e. during and particularly at the end of the last glacial. From this we conclude that the chemical (water-borne) dispersion of a Cu and Zn mineral signature from bedrock to an added cover may take place relatively quickly, even under a dry climate. This has implications for sampling transported regolith in geochemical exploration.

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Pedogenically Modified Aeolian Carbonate Dust (calcrete mantle): An Excellent Exploration Sampling Medium - A Case Study from the Birthday Gold Prospect, Gawler Craton, South Australia

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A large area of southern Australia was mantled by calcareous aeolian dusts during the Pleistocene glacial periods, when low sea levels exposed large areas of carbonate-clad continental shelf. Strong prevailing southerly winds transported this dust up to ~1000 km inland to cover, in South Australia, most of the arid Gawler and Curnamona Cratons and adjacent inland basins. Subsequent evapotranspiration and pedogenic processes, including dissolution and reprecipitation by meteoric water, have modified this dust mantle into near-surface segregations and cements - commonly termed calcrete.

Successful application of the Western Australian-developed CSIRO "calcrete geochemistry" technique to South Australian landscapes has led to the discovery of numerous occurrences of gold and base metal mineralisation. One of these is at the Birthday Au Prospect (750 km NW of Adelaide), which is located on an area of low topographic relief having an open woodland and shrubland vegetation cover. Within an upper regolith of clay-rich saprolite and some thin (<2 m) locally transported materials, the calcrete is ubiquitous, occurring in the soil B horizon as pisoliths, nodules and plates. Over mineralisation (at 30-40 m deep, Au grades 0.5 to 1.5 ppm), the calcrete is anomalous in Au (>5 ppb, peaking at 68 ppb), whereas in the adjacent area, Au is generally at background concentrations (<3 ppb).

Calcrete, soil, lag, vegetation and drill cuttings were sampled and assayed. The results suggest that, although elevated Au contents (>5 ppb) in calcrete can locate underlying mineralisation, caution is required because similar concentrations may occur where there is no apparent source. For example, an apparent false anomaly is located on relatively steeper-sloping terrain and at the base of a slope, (400 m) to the west of known mineralisation. The Au enrichment in calcrete here may suggest (i) the presence of mineralisation further to the west, implying that the Au has been either chemically or physically transported to this site or (ii) that mineralisation may occur at a greater depth then presently drill tested.

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AEOLIAN DUST: IMPLICATIONS FOR AUSTRALIAN MINERAL EXPLORATION AND ENVIRONMENTAL MANAGEMENT

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