Understanding the local pedological and ecological impacts of dust emitted from Cowal Gold Mine

Adrienne Ryan[A] and Stephen Cattle[A]

[A]Faculty of Agriculture Food & Natural Resources, The University of Sydney, NSW 2006, Australia, Email a.ryan@usyd.edu.au

Abstract
The production of airborne particulates is a corollary of open-cut mining operations. Despite the best efforts of mine managers to minimise dispersal of these particulates, quantities of dust are inevitably carried beyond the mine margins and deposited in the surrounding landscape. Micromorphological and granulometric techniques were used to identify and subsequently isolate a likely aeolian component from the topsoils surrounding Cowal Gold Mine (CGM), in the Central West of New South Wales. Topsoil and subsoil samples were taken in four transects extending 12 km from the mine bund. An assessment of the geochemical properties of these samples will reveal the extent of contemporary aeolian deposition, and identify any trend consistent with CGM acting as a point source. In an effort to assess the likely ecological role of any mine dust accumulation, barley grass and rye grass were sampled along transects extending from the mine bund, and analysed for total metal concentration. Preliminary data infers that for a number of metals including lanthanum, molybdenum, lead and strontium, there is attenuation in plant uptake with increasing distance from CGM. A correlation of plant and soil data will extricate local soil factors and clarify the current role of mine-related dust, and the likely impacts of future accumulation of this dust.

Key Words
Aeolian dust, geochemistry, granulometry, pedogenesis, open-cut mining, micromorphology.

Introduction
The deposition of æolian dust is known to have been an active factor in the process of soil formation and landscape evolution on every continent. Given that the accession of dust to soils will impart properties not necessarily related to those developed by the weathering of underlying parent material, characterisation of the dust, its origin, nature and rate of deposition is essential to understanding soil development in receiving areas (Walker and Costin 1971). Dust particulates are categorised as being either naturally-occurring, agriculturally generated or formed by industrial activity Whilst the role of naturally-occurring dust particulates is relatively well understood in terms of pedogenesis and nutrient cycling in receiving areas, the function of anthropogenic dust is less well understood.

Dust produced by mining operations is likely to be enriched in metals not necessarily found in the overlying soil. Over time these dust-derived trace elements may accumulate in soils and sediments, and ultimately have a polluting effect. The greater environmental impact of any pollutant is realised once it becomes bio-available, and enters the food web (Agunbiade and Fawale 2009). Accordingly, this study will investigate potential metal accumulation by representative vegetative species in transects extending from the mine. This research will endeavour to give greater meaning to dust data in terms of the potential ecological effects on surrounding soil, water and biota, at the same time enhancing the understanding of any alteration to bulk soil attributes, pedological processes and properties.

Methods
Regional setting and sampling
Cowal Gold Mine (CGM) is located 50 km northwest of West Wyalong, in central western NSW. The mining bund protrudes into the high water mark of Lake Cowal, an ephemeral lake and wetland of national significance. Soil samples were taken on four perpendicular transects extending from the mining bund, as illustrated in Figure 1. These transects are 12.8 km in length, and are placed to encompass areas under the prevailing wind (south westerlies) across the mine as well as occasional wind receiving (and therefore potentially dust receiving) areas. It follows that this sampling system should allow for the characterisation of local soils in positions unlikely to be affected by mine dust and in positions likely to be affected by mine dust.

A parallel study by Hemi (2009) established a series of twelve Australian Standard dust traps in three transects extending from the CGM mine bund. Deposition data collected monthly over a two-year period indicates that despite considerable seasonal variation, the mine acts as a point source of dust; total deposition being greater to the east of CGM, and tapering with distance.

Figure 1. Soil sampling scheme for ecotoxicology study – 2009/2010. Sampling points are located where the concentric rings intersect the rays extending from the mining bund.

Sampling was carried out at intervals increasing exponentially with distance from the mining bund, such that a total of nine samples were taken along each of the four transects. At each point three samples were taken; a topsoil sample encompassing the top 10-20 mm of soil, a sample of the top 50 mm of the soil profile (representing the total expected depth incursion of recent dust accessions) and finally a subsoil sample at 400 mm depth. The deepest sample is assumed to be unaffected by contemporary (mine) dust and therefore provides data for comparison with overlying soil. The likely aeolian component, taken as those soil particles with diameters between 2 and 200 µm, was fractionated from the bulk soil material and used for subsequent analyses. A number of standard soil measurements were made on all bulk samples collected in the field including pH, EC and CEC.

Granulometry
The particle size distribution of bulk soil material from each sampling point was determined using the pipette method. The material 2 – 200 µm was analysed using a Coulter Multisizer 2, producing a high-resolution particle size distribution encompassing 256 size classes per sample (McTainsh *et al.* 1997). The high resolution analysis allows the identification of characteristic aeolian particle populations within the bulk soil, informing supposition about the distance travelled by the dust particles, and hence their likely source.

Mineralogy and elemental composition
Clay mineral suites of the segregated dust-sized fraction will be determined using X-ray diffraction (XRD) and then checked for dissimilarities observed between bulk soil and the dust sized fraction.
All soil samples have been digested using hydrofluoric acid, and await elemental analysis by ICP-MS. A comparison of the geochemistry of topsoil and subsoil samples will indicate whether a contemporary aeolian accession is implicit, and this data will then be rationalised with geochemical signatures of captured dust samples.

Morphology and micromorphology
Vertically-oriented thin sections (25 µm thick) were prepared using Kübiena tins of undisturbed topsoils collected at several points along each transect. Micromorphological features of these thin sections were examined under both plane-polarised and cross-polarised light using a petrographic microscope, with particular attention paid to the distribution, composition and morphology of any deposited dust.
Scanning Electron Microscopy (SEM) was also used to examine the morphology and composition of ‘dust-sized’ particulates occurring within the topsoil.

Collection and analysis of plant samples
Two annual grass species, Barley Grass (*Hordeum leporinum)* and Wimmera Rye (*Lolium rigidum*) were selected as ‘indicator species’ for the purpose of this study. In October 2008 and October 2009 ten individual plants of each species were harvested adjacent to existing dust traps that are established in transects extending from the mine bund. The plants were dried for 24 hours, ground and homogenised then digested using nitric/perchloric acid. The plant digests were analysed using inductively coupled plasma atomic emission spectroscopy (ICP-AES).

Results and Discussion
Preliminary analyses confirm the presence of a fine, seemingly allochthonous, and likely aeolian component in the topsoils surrounding CGM. The photomicrograph shown in Figure 2 was taken from a topsoil extracted approximately 1.6 km east of CGM, an area downwind of the mine. Figure 2 shows an explicit depositional layer (labelled as ‘A’). The boundary between the existing solum (labelled as ‘B’) and the deposited material (‘A’) is clearly defined in terms of elementary fabric, skeleton grains and the colour of the fine matrix material. Given that this sample is effectively taken in a lake-bed, the depositional layer could theoretically be lacustrine clay, although reason would suggest otherwise. Lake Cowal has not held water in a number of years, and in that time the soil surface has experienced extreme desiccation, a resultant depletion of vegetation and consequently some significant disturbance. Furthermore the heavy, self-mulching vertosol soils which cover the lake-bed would have since incorporated any thin lacustrine deposit laid down during the last flood. Therefore the depositional layer is assumed to be aeolian. The source of this aeolian material is a matter to be determined, although the sizes of detrital grains in the depositional layer (20-150 µm) are consistent with that which may plausibly have travelled from the mine.

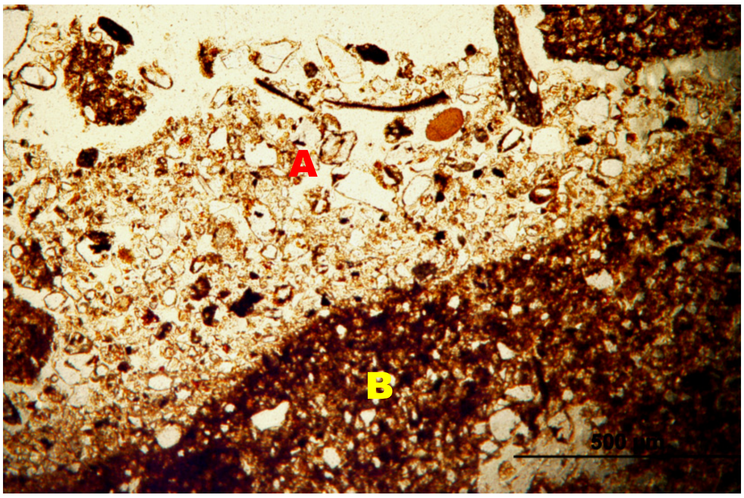

Figure 2. Photomicrograph of topsoil 1.6 km east of the mine bund, viewed under plane polarised light.

Preliminary results from the ICP-AES analysis of barley grass samples collected in October 2008 are shown in Table 1. The most consistent feature appears to be that background samples generally report much smaller values than those plants sampled downwind of CGM. Whilst this anomaly may be a related to an absence of dust accretion, it might also be accounted for by differing soil types. An examination of total metal concentrations in the topsoil and subsoil at plant sampling sites will be necessary before this data can be decisively interpreted.

This preliminary data does infer that for some metals at least, there is attenuation in plant uptake with distance from the mine. This trend certainly holds for lanthanum, molybdenum, lead and strontium concentrations in both rye and barley grass and the trend is consistent with an aeolian point source for these metals. Geochemical data from dust samples collected along equivalent transects, as reported by Hemi (2009), sustains the notion that these metals are supplied by CGM. Hemi (2009) describes a pattern of decreasing concentrations of a number of metals, including the lanthanides cerium and lanthanum as well as molybdenum, strontium and vanadium, with increasing distance from CGM, emulating the observed pattern of metal uptake by barley and rye grass.

Table 1. ICP-AES determined concentrations of selected metals in Barley Grass (*Hordeum leporinum*), relative to distance from the mine pit centre. Background samples taken 10.4 km south west of CGM.

Distance from centre of pit (km)	Metal Concentrations (mg/kg)										
	Ce	**Cr**	**Cu**	**La**	**Mo**	**Ni**	**Pb**	**Sr**	**Ti**	**V**	**Zn**
0.7	1.44	30.32	4.43	1.19	1.57	12.91	1.09	20.64	5.68	1.57	18.88
1.6	1.51	19.77	5.98	1.21	0.89	8.95	0.94	15.64	4.00	1.32	18.69
3.9	0.81	20.34	5.73	0.91	0.79	9.63	1.01	13.82	1.43	1.06	28.90
7.8	1.31	12.28	5.96	1.05	0.87	6.12	0.69	10.47	4.59	1.24	15.33
Background	0.86	7.75	3.41	0.69	0.14	4.92	0.46	16.17	5.79	0.40	27.74

Conclusions

Preliminary analyses have confirmed the accumulation of an aeolian component in the topsoil surrounding Cowal Gold Mine. Subsequent analyses of geochemistry and granulometry will allow apportionment of this aeolian material to a mine or non-mine source.

Plant uptake of a number of heavy metals appears to decline with increasing distance from the mining bund, suggesting that CGM may be acting as a point source for dust-derived trace elements. Pending investigation of local soil characteristics will allow the role of point source dust to be better clarified.

References

Agunbiade FO, Fawale AT (2009) Use of Siam weed biomarker in assessing heavy metal contaminations in traffic and solid waste polluted areas. *International Journal of Environmental Science and Technology* **6**, 267-276.

Hemi KD (2009) Characterisation and provenance of dust in the vicinity of Cowal Gold Mine (CGM). Unpublished PhD Thesis. Faculty of Agriculture, Food and Natural Resources, The University of Sydney.

McTainsh GH, Lynch AW, Hales R (1997) Particle-size analysis of aeolian dusts, soils and sediments in very small quantities using a Coulter Multisizer. *Earth Surface Processes and Landforms* **22**, 1207-1216.

Walker PH, Costin AB (1971) Atmospheric dust accession in south-eastern Australia. *Australian Journal of Soil Research* **9**, 1-5.