REGOLITH-LANDFORM MAPPING AND SOIL SURVEY FOR MINING REHABILITATION AND ENVIRONMENTAL MANAGEMENT IN THE CADIA VALLEY, CENTRAL NSW

Kristy E. Bewert[1], Kenneth G. McQueen[1,2] & D.C. 'Bear' McPhail[1]

[1]CRCLEME, Department of Geology, Australian National University, ACT, 0200
[2]Division of Health, Design and Science, University of Canberra, ACT, 2601

INTRODUCTION

This project was carried out on the Cadia Mining Lease and adjacent agricultural land owned by Cadia Holdings Pty Ltd, in Central New South Wales (Figure 1). The Cadia region is located approximately 25 km southwest of Orange, N.S.W.

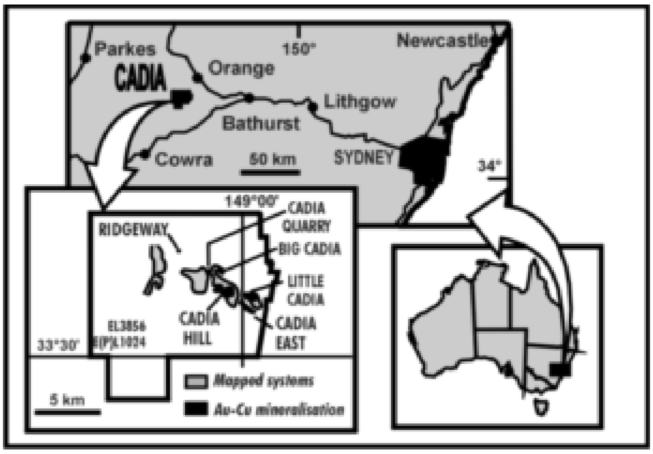


Figure 1: Location of the Cadia Region, Central NSW (after Newcrest Mining Staff, 1998). The majority of the area studied in this project lies south and west of the Ridgeway and Cadia Hill deposits.

Planned revegetation in the west of the mining lease area held by Cadia Holdings Pty Ltd, requires the re-establishment of native woodland in areas of existing remnant stands. The revegetation, to be carried out in stages over the next 5 to 8 years, will eventually form a wildlife corridor between the Belubula River in the south and Canobolas State Forest in the north. It will also form a natural barrier between the main mine workings at Cadia Hill in the east and farmland further to the west. The first stage of this rehabilitation plan is to be carried out at two locations on the properties of Ashleigh Park (Figure 2) and Oaky Creek. These sites are the focus of the soil survey component of the project. Ashleigh Park, one of the larger areas to be revegetated, will be scheduled each year for fencing, preparation and planting / seeding. Once established, revegetated areas will be maintained with annual weed control, feral animal control and replanting or seeding where required (Burton *pers. comm* 2003).

The regolith was chosen as the primary medium for study for this project as it forms the interface for all revegetation activity. Often, minesite rehabilitation/revegetation issues are studied with respect to one or two factors, e.g., soil, geology, hydrology or vegetation. By studying the regolith, the project addresses all factors in a multidisciplinary approach, i.e., the entire weathering profile, its setting and surficial interactions.

CLIMATE, PHYSIOGRAPHY AND REGIONAL DRAINAGE

The Cadia region experiences the warm temperate climate of central-west NSW, however, conditions vary locally due to the influence of elevation and proximity to Mt. Canobolas and the Canobolas State Forest (Kovac *et al.* 1990, Baldwin 1995). Annual rainfall averages 818 mm at Cadia to 1099 mm at Canobolas State Forest (Baldwin 1995), however, in recent years falls have been affected by prolonged periods of drought. The annual average temperature ranges from 6.2°C to17.2°C in Canobolas State Forest (BoM 2003) and 6.2°C to 19.7°C in the township of Orange (BoM 2003). Similarly, temperatures have been affected by periods of drought, impacting factors such as soil moisture and surface water availability, evaporation and pasture health. The project area features the Cadiangullong Creek catchment, which drains south to the Belubula River. The landscape around the Belubula, the southern boundary of the project area, is highly dissected and features steep sided hills and low hills. These hills also surround the broader region of the Cadia valley. To the north of the Belubula, the landscape is characterised by extensive rolling low hills and rises, with flatter plains around some other minor drainage lines, in particular Swallow and Rodds Creeks.

The northern end of the project area features strongly dissected hills and low hills. Most of the hilltops have resistant flows of Tertiary volcanics, a result of topographic inversion by the incision of numerous tributaries.

EXISTING VEGETATION AND LANDUSE

The project area consists of extensively cleared land that is used for sheep and cattle grazing on native and improved pastures. Improved pastures are dominated by *Phalaris*, annual and perennial rye grass and subterranean clover (also observed by Baldwin 1995). Native grasses dominate the native pastures in the project area, e.g., Wallaby Grass (*Danthonia* spp.), however many are also being over-run by introduced weed species, in particular Paterson's Curse *(Echium plantagineum)*, Cape Weed (*Arctotheca calendula)* and Silvergrass (*Vulpia* spp.). Remnants of the pre-existing (pre-European settlement) open woodland are mainly isolated stands on mid and upper slopes, and are dominated by *Eucalyptus albens* (White Box), *E. blakelyi* (Blakely's Red Gum), *E. bridgesiana* (Apple Box), *E. goniocalyx* (Bundy Box), *E. macorhyncha* (Red Stringybark) and *E. melliodora* (Yellow Box). The major drainage lines are dominated by *Salix babylonica* (Weeping Willow) and the pre-existing *Casuarina cunninghamiana* (River She-Oak), *E. viminalis* (Ribbon Gum) and *E. camalduensis* (River Red Gum).

Figure 2: Ashleigh Park - view overlooking the existing remnant vegetation on a colluvial erosional low hill (Cel). This site is one of the first marked for revegetation. It is surrounded by colluvial erosional rises (Cer) and colluvial erosional hills (Ceh). See text for further explanation of colluvial units.

REGOLITH-LANDFORM MAPPING

Regolith-landform mapping is a technique for describing the spatial distribution of different regolith materials and their relation to the landscape. It provides a framework for understanding the surficial environment. The regolith-landform map produced for this project can be effectively used for future environmental management in the Cadia Valley, including possible incorporation into a sustainability plan devised by the CSIRO for the project area and surrounds. In addition, environmental management issues, including erosion and slope stability and an assessment of dryland salinity hazards, have been identified as the two key areas to be considered when implementing the revegetation program. They have been identified via regolith-landform mapping, and unit classifications reflect these issues.

The initial process of regolith-landform mapping was based solely on defining different regolith landforms in the field. Interpretation of 1:10,000 (high-level) and 1: 65,000 aerial photography, airborne radiometric and total magnetic intensity data and reference to digital elevation models was carried out subsequent to field work in order to define polygon boundaries for regolith-landform units. The regolith-landform units were described according to the RTMAP database classification scheme (Pain *et al.* 2000). Modifiers have been extensively implemented to account for the vast impact agriculture has had on the land.

***In Situ* Regolith-Landforms**

Moderately and highly weathered bedrock subcrops or outcrops on the crests and mid-lower slopes of erosional rises, and the crests and upper slopes of erosional low hills (30-90 m relief) and hills (90-300 m relief) throughout the project area. Outcrops are commonly < 1 m in height and slopes range from 5° to 15°. The dissected hills and low hills in the southern, and some northern, parts of the project area have tors of up to 2 m in height, and, in places, have entire slopes of exposed moderately-weathered bedrock. Slopes in these areas range from 15° to 45°. Interspersed with the exposed bedrock is a thin (< 1 m) colluvial veneer, comprised of brown to red, very fine to coarse grained, sands and intermixed clays. A thin, gravel size, angular surficial lag composed of bedrock material may be present. White Box trees (*E. albens*) are commonly associated with the bedrock units.

Alluvial Regolith-Landforms

Alluvial sediments are associated with channels (ACar), erosional depressions (Aed), boggy areas (Aaw) and plains (Aap & Apd). Alluvial channels are discriminated on their width/depth and degree of gullying. Sediments associated with alluvial channels are brown and/or red, fine sands, silts and clays with lesser gravel-size lithic fragments. Channel beds have minor scattered angular to sub-rounded, gravels/boulders (up to 2 m across), as well as subcropping bedrock (lithified sands and silts). The more active, usually larger, channels also have suspended brown silts and clays, indicating the dispersive nature of the majority of clays found throughout the project area. Erosional depressions have been classified on the degree of channelising at the base of the depression: broad, shallow incised channels on gentler slopes (Aed_1); and narrow, deeper incised channels on steep slopes (Aed_2). Sediments associated with the depressions are red to dark brown, medium-fine grained, sandy/silty clay. Aed_2 units have a surficial quartzose and lithic gravel lag, as well as isolated Yellow Box *(E. melliodora)* and White Box *(E. albens)* trees. Plains areas are flat and restricted to within a few metres of the banks of drainage lines. Alluvial plain sediments are dark brown silts/clays and are dominated by Patersons Curse with isolated Apple Box *(E. bridgesiana)*, Yellow Box and River Red Gum (*E. camalduensis)* trees. Depositional plain sediments are similar to alluvial plains. However, they are lighter brown to red, have a higher clay content and lack River Red Gum trees. Sediments associated with alluvial swamps (Aaw) are brown/red, fine sandy silts. Proximity to a minor drainage line may indicate the waterlogged ground is an adjacent discharge area for groundwater.

Colluvial Regolith-Landforms

Colluvial sediments comprise the majority of transported regolith throughout the project area. Due to the extensive impact of clearing, establishment of improved pasture and grazing, each colluvial landform has been discriminated using a number of modifiers to account for this. Colluvial sediments associated with erosional hills and low hills (Ceh & Cel) are brown, fine-medium grained, sandy clays with varying percentages of lithic gravel component. Generally, if there is a subcrop or outcrop (as an *in situ* unit or minor feature of the colluvial unit) on the hilltop, there will be a lithic surficial lag on the upper and mid slopes, ranging from gravel to boulder size. Steeper slopes of hills, low hills and some rises, have well-developed terracettes. The terracettes are comprised of up to 40 cm of slumped clay-rich colluvium, underlain by a layer of lithic fragments, up to 10 cm across. Isolated trees grow on the mid-lower slopes of terraced hillslopes, and are commonly Apple Box, Red Gum and Red Stringybark. Erosional rises (Cer) have 9 m to 30 m relief and vary in the presence or absence of surficial lag and terracettes and type of vegetation. The colluvial sediments tend to be either a thick, brown, medium-fine grained, silty/clay; or a red/brown, fine-grained sandy/silt. Contour banking is prevalent on the gentle slopes (5-8°) of the rises. Surficial lag on rises is angular, gravel-size, lithic sands or sub-angular to sub-round, boulder-size, iron-stained basalt. Lag cover is usually 5-10%. Depositional plains (Cpd) have 1 m to 9 m relief, and are characterised by the absence of trees. This unit has been subdivided into two sub-units. Cpd_1 has a brown, fine, clayey colluvium and a 10-15% coverage of Spike Rush shrubs. Cpd_2 has a brown, silt/clay colluvium with abundant iron (orange & black) nodules. An angular, cobble – boulder size, surficial lag has 5-10% coverage (derived directly from outcrops of basalt at the base of surrounding erosional rises). Phalaris is the dominant vegetation type. Erosional depressions (Ced) are broad (5-10 m wide and < 1 m deep) and form saddles between rises. Colluvium is similar to that of erosional rises. Some depressions have a scattered surface lag as cobble-size, sub-angular to sub-round bedrock fragments.

SOIL SURVEY OF REVEGETATION SITES

Immediate plans (within the next 12 months) for revegetation on the properties of Ashleigh Park and Oaky Creek (Figure 3), led to these sites being targeted to obtain a more detailed level of information on the upper regolith (soil), including: nutrient levels at varying depths; clay mineralogy; soil moisture content; and organic matter. This has enabled the conditions for revegetation to be established and various comparisons made to determine optimal conditions.

In choosing sampling sites, catena sequences were chosen in order to gain a cross-section of the soil types. A hand-held soil auger was used to extract a soil profile. Field data was recorded on each horizon of the profile, including depth, boundary type, colour (using Munsell colour charts), mottling, texture, gravel content, structure, fabric, consistence, Fe/Mn nodule content, organic matter (using hydrogen peroxide), carbonate presence (using hydrochloric acid) and pH (using a field pH kit). Samples were usually taken from the B_2 or C horizon, however some were taken from the A_1 horizons, in order to gain an impression of variation in geochemistry with depth. The collected samples were analysed by the author, and a commercial laboratory, for nutrient content.

Irrespective of location, all sites displayed poorly-developed soils. Although horizon development had taken place (commonly as A_1, B_2 and C layers), the soils were thin and, except in depressions, were all less than 1 m deep. This trend is attributed to the clearing and extensive agricultural activity carried out on the land. An exception to this is the main revegetation site at Ashleigh Park, where the soils were still skeletal, contained a high percentage of gravels, and were poorly developed. However, this is attributed to the existence of remnant vegetation on the site. The pH range for the majority of soils was 5.5 to 6.5. Soils sampled on Ashleigh Park were more acid with depth, whereas soils on Oaky Creek were more alkaline with depth. These trends are attributed to differences in bedrock geology, topography and possible alluvial transport of materials, and, are matched by geochemical trends down the profile (Figure 4).

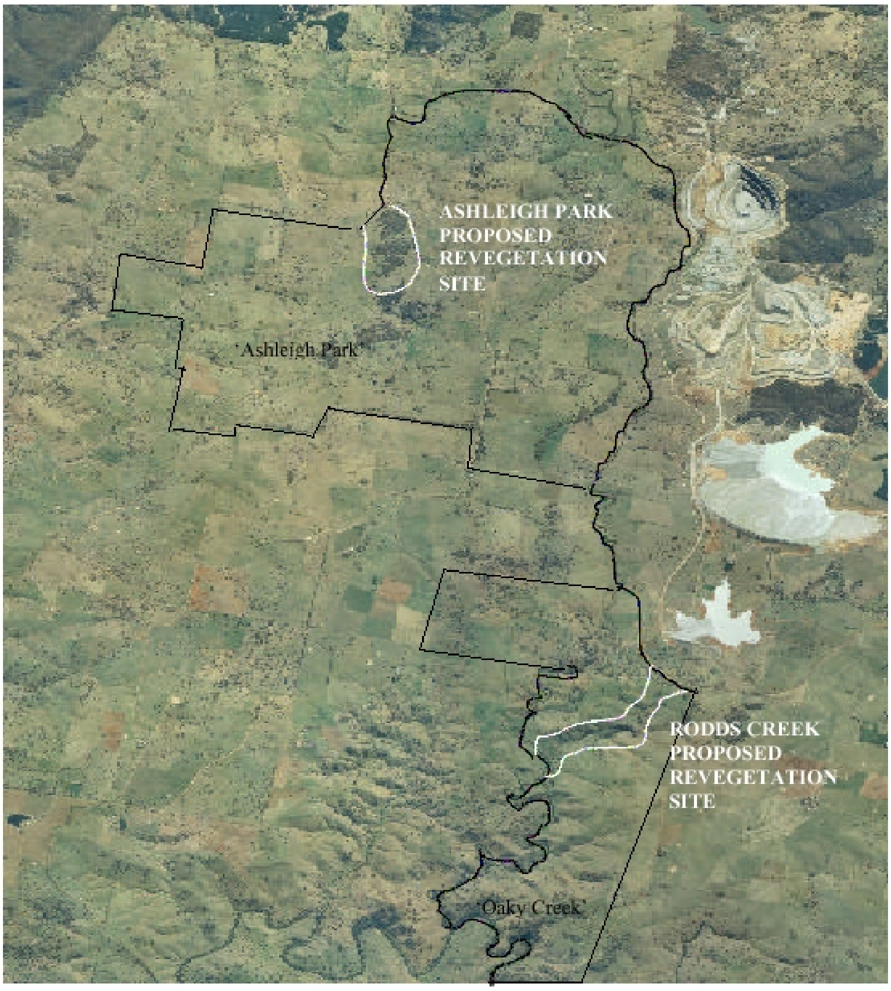
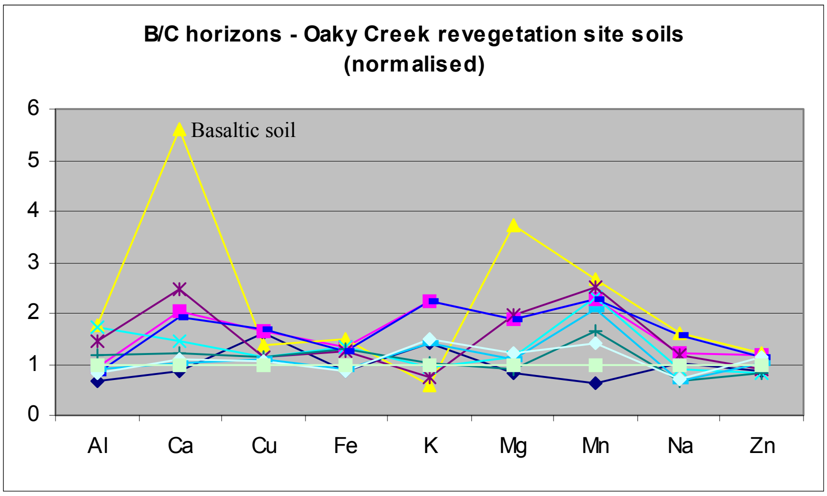


Figure 3: Aerial photograph of the Cadia region. The project area is outlined in black, and nominated revegetation sites in white. This Orthophoto was taken at 1: 10 000 scale.

By comparison, soils on Ashleigh Park remnant vegetation site are depleted in nutrient and mineral content, therefore nutrient deficiency on the remainder of sites set for revegetation is not a concern at this time. Soil moisture content is not foreseen as an immediate problem, with most containing an average of 10% moisture. Organic matter is generally low (2%) in all soils.

PRELIMINARY OBSERVATIONS FOR ENVIRONMENTAL MANAGEMENT

The facts that the soils are not well developed due to heavy grazing, and all have a fair percentage of gravels, may pose problems for establishment of seedlings/young trees. Terracette formation on the steep slopes of hills and low hills of both Ashleigh Park and Oaky Creek cannot be effectively fenced and therefore revegetated. Remedial measures will need to be taken around these areas to prevent soil loss. The groundwater table was not reached at the bottom of any profile, and was observed at about 3 m depth in gullies. This fact suggests that dryland salinity is not an immediate concern for the majority of revegetation sites, however, there is an area at Swallow Creek (Ashleigh Park) which has elevated sodium (Na) and pH, and it is recommended that this site be monitored, particularly if revegetation is to take place in the next 5 years. No evidence has been found to suggest that the proximity of the mine has affected the soils of the areas studied. Any problems (such as the soils at Swallow Creek) are pre-existing and may be the result of alteration halo associated with orebody, or presence of shales in the Weemalla Formation sequence, which have subsequently been alluvially transported through the Cadiangullong catchment.



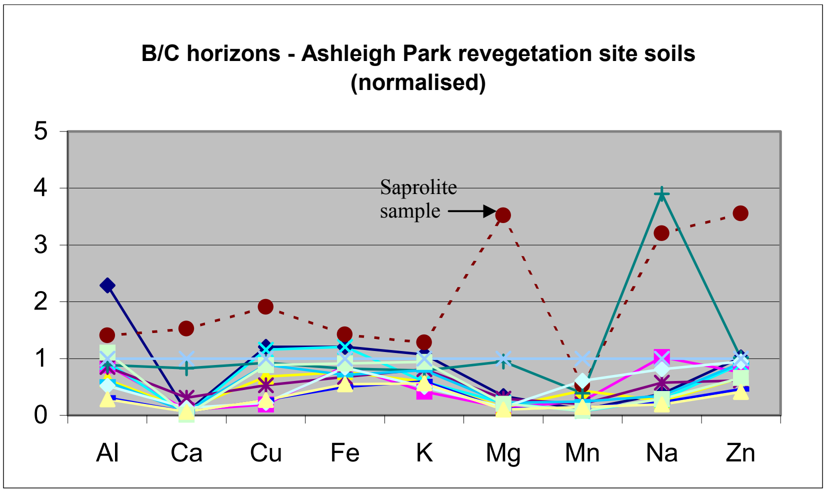


Figure 4: Geochemical data for the B and C horizons of revegetation site soils. Each line represents one sample, and are normalised to the average B/C soil horizon (equal to 1). Trends show that Oaky Creek B/C horizons are twice the average composition. Ashleigh Park soils are a fraction of the average composition. Exceptions are saprolitic samples, and those containing transported materials (indicated).

REFERENCES

BALDWIN B.J. 1995. *Cadia Gold Mine – Environmental Impact Statement. Volume 3*. Unpublished report by AGC Woodward-Clyde for Newcrest Mining Limited, Orange.

BUREAU OF METEOROLOGY 2003. Climate averages for Australian sites #063018 and #063065. [Online] *http://www.bom.gov.au/climate/averages/tables*. 04/08/03

KOVAC M., MURPHY B.W. & LAWRIE J.W. 1990. *Soil Landscapes of the Bathurst 1:250 000 sheet*. Soil Conservation Service of NSW, Sydney.

NEWCREST MINING STAFF 1998. Cadia gold-copper deposit. *In:* BERKMAN D.A. & MACKENZIE D.H. eds. *Geology of Australian and Papua New Guinean Mineral Deposits*. Australasian Institute of Mining and Metallurgy: Melbourne. pp 641-646.

PAIN C., CHAN R., CRAIG M., GIBSON D., URSEM P. & WILFORD J. in prep. *RTMAP Regolith Database Field Book and Users Guide (Second Edition).* **CRCLEME Report 138**.

Acknowledgements: Thanks to the Environmental Team at Cadia Valley Operations (Bob Drury, John Watson, Jeff Burton, Belinda Perry, Jim Seaman and John Ford) for access, logistical and financial support given to this project. Thanks to the agisted landholders of CHPL land for access and hospitality. Thanks to the staff of technical services and the geochemistry and XRD laboratories at ANU for field work logistics and ongoing help with soil sample analysis. Thanks to CRCLEME for financial and logistical support.

Permission to publish this work was given by senior staff of Newcrest Mining Ltd (Cadia Valley Operations).