# RELATING SURFICIAL REGOLITH-LANDFORM ATTRIBUTES TO 3D REGOLITH ARCHITECTURE: PRELIMINARY THOUGHTS AND CONCEPTS

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## INTRODUCTION

The depth of the regolith and how this measurement varies across the landscape is a fundamental attribute in the characterisation of the regolith, having many applications in both mineral exploration and natural resource management. The development of efficient, economical and accurate methods for determining the 3D architecture of regolith-dominated landscapes is a major challenge for regolith researchers and their stakeholders. Many of the present approaches used to understand and model the regolith architecture are limited in their widespread application, mostly because of their high costs and in some cases uncertainties with their accuracy.

One of the main challenges faced by companies involved in mineral exploration is to effectively explore through significant thicknesses of regolith. Generations of mineral exploration across those parts of minerals provinces with extensive bedrock exposure and shallow cover has meant that companies are now looking at areas of more extensive regolith thickness for 'green-fields' exploration targets. This has led to a reliance on drilling and geophysical methods to determine the thickness of the regolith and depth to basement, both of which can be costly. Recent research by CRC LEME scientists (particularly those based at CSIRO in Perth, e.g., Butt *et al.* 2001 Butt 2001) have indicated that many surface regolith exploration sampling media have variably reliable abilities to express mineralisation through greater thicknesses of transported regolith. From this research, many mineral explorers typically use transported regolith thicknesses of less than 5, 10 or in some cases 30 m as thresholds for the application of surface regolith geochemistry to express underlying mineralisation. For these explorers the ability to economically and accurately delineate areas of different transported regolith thicknesses would be of great value.

In many parts of Australia the close association between regolith and landforms has enabled accurate and efficient mapping and characterisation of surficial regolith materials, much of which has been represented on regolith-landform maps. The extension of this characterisation beyond surface expression, to greater depths, has previously had limited success and has been restricted in its application. There is potential however that some of the attributes of the surface regolith and landscape can allow for efficient and accurate characterisation of regolith at depth. If this potential can be realised then derivative 3D regolith maps may be produced from the understanding and mapping of surficial regolith attributes. A further implication of identifying surficial regolith attributes, that can be linked to subsurface regolith materials, is that this may also help identify chemical connections between the landsurface and buried materials, such as the possible driving processes and mechanisms behind surface geochemical and biogeochemical anomaly formation. This manuscript discusses some of the surficial attributes of the regolith and how they may be related to subsurface regolith materials and their depth. Particular emphasis will be given to ascertaining the depth of transported regolith, which specifically includes the material that overlies variably weathered bedrock and saprolite, however, some of this approach may also have some implications for determining the depth of weathered material (i.e., total regolith thickness).

## SURFICAL REGOLITH ATTRIBUTES AND THEIR ASSOCIATION WITH REGOLITH AT DEPTH

In regolith-landform mapping many attributes may be noted before assigning a regolith-landform unit label to a particular location. In a similar way, a multi-variate approach may be taken to the problem of relating surface and near-surface attributes to the thickness and the subsurface characteristics of the regolith. This manuscript considers three main surficial regolith attributes that shall be defined and developed as an exploration medium and may be closely associated with defining the 'z-parameter' (depth) of the regolith. These attributes include:

- surface regolith materials;
- landform expression; and,
- biota.

*In:* Roach I.C. ed. 2004. *Regolith 2004*. CRC LEME, pp. 260-263.

**Regolith Surface Materials**

Although the regolith may extend for depths of tens to even hundreds of metres, it is the surface materials that are most readily and extensively able to be examined across most landscapes. Depending on the regolith and landscape evolution history of an area, the surface regolith materials may contain evidence for the nature of the underlying regolith materials. Important controls on the effectiveness of this approach will largely depend on the sedimentary and erosion history of a given site, and to some extent the complexity of the underlying regolith materials.

Some general hypotheses for this can be gleaned from previous studies and field experiences. For example, in areas of shallowest regolith cover (or proximal to bedrock exposures) the surface regolith materials are most likely to contain the greatest amount of detritus directly derived from bedrock materials. This may take the form of variably weathered clasts of lithic fragments, in some cases with relatively fresh primary minerals, but in many highly weathered Australian landscapes this is most likely to include angular quartz vein and quartzite fragments or indurated saprolite (e.g., ferruginised or silicified saprolite). Surface lag clast size is also expected to be largest closest to source areas, which in some settings may be shallow bedrock exposures. By extension of this argument, areas of thicker transported regolith in many cases will feature surface lags that contain rounded and better-sorted surface lag clasts. For example, in many parts of semi-arid Australia rounded granules and small pebbles of maghemite have been used to identify underlying palaeovalley systems.

The general suggestion here, therefore, is that the composition, fabrics and morphologies of regolith surface materials have the potential to provide some evidence relating to the depths of regolith materials. There are however many instances where these simple rules may not entirely hold true. For example, in areas of thin but rapidly deposited sand dunes, such as within parts of Australia's semi-arid and arid deserts, it can be difficult to ascertain regolith thickness from surface materials alone. On the margins of the Strezlecki Desert in western NSW, however, recent CRC LEME research has been able to use the surface expression of regolith materials within many of the dune swales to more closely relate to the underlying regolith substrates, and in some cases have identified previously unknown weathered subcrop of Willyama Supergroup bedrock that is highly prospective for Broken Hill-type and many other styles of mineralisation (Hill 2004, Ruperto 2004).

**Landforms**

A landform is defined as *"any physical, recognisable aspect or feature of the Earth's surface, having a characteristic shape, and produced by natural processes"* (Eggleton 2001). Landforms by nature have a 3D surface expression and therefore contain some 3D regolith information. As a result their morphological characterisation and relationships to certain regolith materials alone provides some 3D regolith information across an area. In areas with landforms superimposed over many older regolith materials, however, the information provided in the landform may not have such a robust application. Such areas include silcrete and ferricrete-capped rises formed from different regolith host materials. The same could be argued for the colluvial sediments covering 'pediments' composed of different regolith materials, such as typically encountered flanking rangefronts in Australia's interior, including the northern Flinders Ranges near Arkaroola in South Australia.

Regolith-landform mapping approaches exploit the surrogate relationships between near-surface materials and processes and how they are expressed as landforms, as well as how landforms can influence the distribution of near-surface materials and processes. This can have implications for using surface landforms in relation to determining the underlying regolith thickness. For example, extensive depositional landforms (such as those associated with alluvial systems) tend to be associated with greater transported regolith thicknesses. Similarly, erosional landforms such as hills and rises will tend to have thinner transported material covers, hence also less regolith thickness, largely because of the lower preservation potential and minimal sediment accommodation of these materials in these areas. Relationships like have already been exploited with some of the mineral exploration 'go-maps' produced as part of the Girralambone Regolith Project in central NSW (McQueen & McRae 2004).

**Biota**

Plants are well known to have close relationships with the underlying regolith substrate. For instance, plant roots have been shown to extend many tens and even hundreds of metres of depth through regolith materials. In this way plants develop both physical and chemical associations with subsurface regolith materials, and as such the above-ground organs of a plant may be connected with underlying regolith materials. This relationship is exploited in many biogeochemical geobotanical studies, but also has the potential to reveal significant information about subsurface regolith materials and thicknesses. This may be expressed at the landsurface by changes in plant communities, species distribution and abundance, biogeochemical characteristics and the morphology of plants and plant organs (e.g., stunted tree growth associated with shallow regolith thicknesses).

The links between fauna and regolith thickness is less well known but has enormous potential to be revealing. For example burrowing organisms, such as termites and ants, interact directly with subsurface regolith materials Therefore, their characteristics, such as distribution, abundance and surface structures such as termitaria could be closely related to regolith thickness if they are better understood.

## OUTLINE OF FUTURE RESEARCH

Future developments in this research will be part of a PhD research program that commenced in mid-2004. This research will combine different methods for relating landscape surface expression to underlying regolith thickness and other characteristics. For example, the characterisation of residual and sedimentary regolith materials, by petrographic, mineralogical and geochemical means, will be combined with district and local-scale regolith-landform mapping.

More specifically, future research in this PhD project will include:

- A detailed regolith study at two sites featuring prospects where there is significant sub-surface regolith information (e.g., drilling and/or geophysics);
- The production of a 3D regolith map based on existing data;
- Regolith-landform maps featuring the surface expression of various regolith and landscape attributes;
- Derivative maps of specific regolith-landform attributes. This will include surface dispersion vectors, vegetation characteristics (communities, species and plant morphology) and other biota (e.g., termitaria) maps, and surface lag maps in order to accurately portray these attributes and how they relate to the 3D model of the regolith as well as other the surface attributes.

Once prospect-scale models are developed these can be tested and applied on regional scales.

## CONCLUSION

The present distribution of regolith materials, landforms and other landscape attributes is the outcome of interactions between a wide range of landscape processes and attributes. The depth of the regolith, and more specifically the thickness of transported regolith, is potentially one regolith attribute that influences the nature and distribution of many of the other attributes of the regolith and landscape. There are a range of attributes that may be variably successful in being used to map the thickness of the regolith However, it must be emphasised that any one of these attributes will have strengths but also weaknesses in different settings. Many previous studies have tested and applied single techniques to the challenge of expressing regolith thickness from surficial expressions, but few have combined the expressions from different attributes. A multi-disciplinary approach is therefore proposed, where the characteristics of a range of attributes are used in combination to provide an efficient and accurate determination of the regolith thickness that may be used at both the prospect and regional scale.

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