REGOLITH MAPPING – A DISCUSSION

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This paper is a slight advance on an unpublished discussion paper that has been doing the rounds since early June 2003. It takes into account some comments that have been received regarding the unpublished paper. However, it is still very much a "work-in-progress". In this paper I will look briefly at the current state of regolith mapping in Australia, and present some schemes currently used for mapping regolith and landscapes. I will look at geology maps as a guide to how we might map regolith, and make some recommendations for consideration by the regolith mapping community.

We make regolith maps for a number of reasons, including mineral exploration and natural resource management. In addition to general regolith maps that document the regolith of the mapped area, we produce thematic maps designed to address specific problems such as the distribution of different sampling media, and to help assess salinity risk. Our reasons for making a particular regolith map will to some extent dictate what the map looks like.

REGOLITH MAPS IN AUSTRALIA

There are now a number of regolith maps available for various parts of Australia. Figure 1 is also a "work-in-progress" showing where regolith maps of various scales have been produced in Australia. It does not include a number of maps produced by various state geological surveys – these will appear in an updated version of the map, to go on the CRCLEME web site.

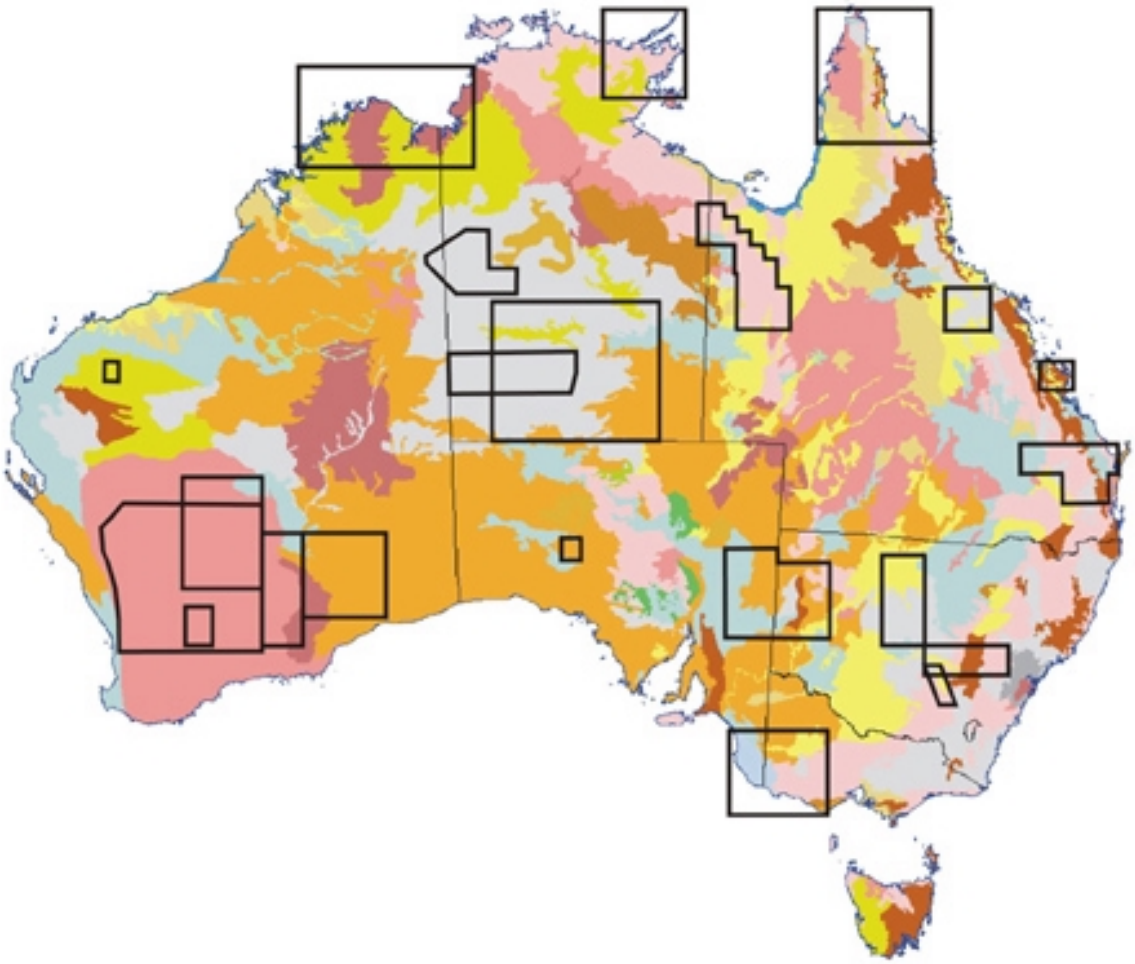

Figure 1: Distribution of some regolith maps in Australia, produced at various scales. Maps produced by geological surveys in WA, SA, and VIC. are not shown.

Although at first glance Figure 1 looks encouraging, in that a reasonable part of the continent is covered by regolith maps, there are major problems:

1. There is no standard mapping system, unlike that used to produce geology maps;
2. No correlation between maps is possible, in the sense that units on one map cannot be equated with units on another map:
3. Material classifications vary from map to map, even when compiled by the same organisation:
4. It is not possible to "tile" the maps together to compile regional or national regolith maps, because the legends are incompatible.

SOME GENERAL PRINCIPLES

One theme that came through in comments on the unpublished paper was that the state of geology mapping is not as rosy as I suggested, neither in the amount of agreement on how to map, nor the amount of 3D information portrayed on the average geology map. Never-the-less, let's assume that geology maps show the distribution of rocks at the surface, usually as lithostratigraphic units. 3D information is implicit in the way the units are shown on the map face, with dips, strikes etc. shown as symbols. Map units are grouped by age in a legend. The criteria for geological units can be used anywhere, and geology maps are not linked to any specific model of Earth evolution. You may be a plate tectonicist, an Earth expander, or even a member of the Flat Earth Society – it doesn't matter, because, as a geologist, the map you produce will be based on the same principles, and will show more-or-less the same things. The map compiles evidence on which you base your particular model of Earth evolution. The correctness or otherwise of the model is irrelevant.

The same goes for regolith maps. They should show the distribution of regolith materials at the surface, with 3D information where available. Map units should be grouped according to a "factual" classification of regolith materials. Age is not suitable, because *in situ* regolith materials are not easily arranged in a stratigraphic order. Criteria for regolith units should be applicable anywhere and regolith maps should not be linked to any specific model of landscape evolution. You may be a follower of Davis, Woolnough and Jutson, and believe in the Great Australian Peneplain, or alternatively think that all landscapes are a result of dynamic equilibrium, with no relict features at all. Again, the map compiles evidence on which you base your preferred model of landscape evolution. The correctness or otherwise of the model is irrelevant.

REGOLITH MAPPING SCHEMES

The main contenders are:

- The RED scheme (CSIRO) and derivatives;
- Regolith-landform "fact maps" (RTMAP - AGSO/GA) and derivatives.

However, these are not really comparable because, as we will see, they are two very different things.

The RED Scheme

The RED scheme was developed by CSIRO Division of Exploration and Mining (Anand & Smith 1993), and went through various iterations during the 1990s, mainly in CRCLEME. It is based on the premise that the landscape can be divided into three regimes:

1. *Relict regimes* are areas characterised by widespread preservation of lateritic weathering profiles.
2. *Erosional regimes* consist of terrain within which varying degrees of erosion of the lateritic profile has occurred.
3. *Depositional regimes* are areas of terrestrial deposits, which commonly conceal extensive areas of complete or nearly complete lateritic profiles.

Surface materials are mapped only indirectly, and there is no factual classification of materials associated with mapping units. However, CSIRO has produced a classification of ferruginous materials. There is also a classification of mapping units, but as discussed below, mapping units and classification units are very different things.

The RED scheme is based on Jutson's old and new plateau model, and assumes a former complete cover of a lateritic weathering profile. This means that it is applicable only to areas with lateritic weathering profiles and associated landscapes. In a practical sense, this means only the Yilgarn. It is not applicable to most of Australia, or to most of the rest of the world.

Organisations that have used variants of the RED scheme include the Geological Survey of Western Australia, Geological survey of Queensland, and PIRSA. A common theme of the RED scheme and its variants is that they are based on models of landscape evolution. One problem with this is that the RED

scheme enshrines the current model. But as any geologist knows, models change as additional work is done. Moreover, model-based mapping leads to interminable argument, and highlights the fallacy of the single cause. It's as if geologists set out on a mapping project with only geosynclinal concepts in their mind – if they did that they could map only fold belts.

There is also a tendency to incorporate geological (e.g. stratigraphy and bedrock lithology) information in the legend – but if you want geology, go to a geology map?

Regolith-landform maps (RTMAP)
RTMAP is a regolith database developed by Geoscience Australia. It was first used for maps of Cape York Peninsula and WA, and then for parts of NSW and SA. It has been adopted by Victoria and NSW, and by Executive decision is now the standard for most CRCLEME work, at least in principle. However, RTMAP is not a mapping scheme; it is a database containing authority tables (i.e., classifications) for a number of regolith and landform attributes. The mapping scheme that uses RTMAP has been described in detail in Pain *et al.* (1991, 2001, in press). It maps the dominant surface regolith materials in each map unit, and uses landforms as a surrogate for regolith. The units mapped are thus regolith-landform units.

IMPORTANCE OF CLASSIFICATION OF MATERIALS

The aim of regolith mapping is to map regolith materials, and therefore classification of regolith is critical. Such a classification must be consistent, and hierarchical. It is also important that we distinguish between what we map and how we map it.

Classification of rocks is largely genetic at higher levels, and based on rock characteristics at lower levels. Similarly, classification of regolith is largely genetic at higher levels, and based on regolith characteristics at lower levels. Two examples of regolith classification are Anand *et al.* (2002), which is mainly about ferruginous regolith, and Pain *et al.* (1991, in press), who give the RTMAP authority tables and definitions of each class in those tables.

GROUPING AND NAMING

Geology has formations, groups, and other levels of rock groupings. In pedology soils are classed by profile form. There are named soil series, with an implied common origin, but no implied age. There is no equivalent grouping in regolith.

Some regolith units are also stratigraphic units. For example, Tomba Tephra is a defined stratigraphic unit of volcanic ash at formation level. Transported regolith can be expected to follow normal stratigraphic rules. Some *in situ* regolith profiles have been named using stratigraphic concepts, but ages and correlations of zones developed in *in situ* weathering profiles are problematic (see Pain & Ollier 1995). Regolith is neither rock nor soil – it is betwixt and between.

Regolith-landform units based on landforms and regolith types can be grouped into broader units on the basis of, for example, regolith toposequences or bedrock type. In North Queensland this gave regolith-landform associations and regolith-landform provinces respectively (Pain *et al.* 1994).

This has been done in North Queensland, and in Victoria.

PURITY OF MAP UNITS

Many people seem to get confused about what a map actually portrays, hence this section.

Map units on a geology map are not pure rock types; rather, they define a stratigraphy. In many cases this means they are defined by position rather than by content – particularly at the young "messy" end. This also means that, having defined the stratigraphic boundaries of a geological unit, anything that falls within these boundaries is automatically part of that unit.

The same is not true for regolith, especially *in situ* weathered regolith, which behaves much more like soils in this regard. This means that regolith mapping units have impurities that relate to the way landscapes are organised. Moreover, map unit purity is scale-dependent. As with soil mapping, for regolith mapping it is critical that a distinction be made between classification and mapping units.

With regard to regolith:

- *Classification units* consist of regolith or landform units that are defined in terms of various regolith or

landform characteristics. They are ideal or conceptual units that can be precisely defined.
- *Mapping units* are real regolith landform units that can be conveniently mapped, and their definition will therefore depend to some extent on the scale of the map. The more detailed the map scale, the more pure the regolith landform mapping units will be.

Thus regolith map units group regolith types that are associated in a landscape, and they contain various classification units that can be precisely defined. A very common impurity in regolith mapping units is the presence of small areas of alluvium in mapping units that are dominated by saprolite. This distinction means that mapping units cannot be classified.

To go into more detail:

The arrangement of regolith types in a classification is based on logical and hierarchical relationships between the different kinds of regolith [whatever criteria are used]. However, such an arrangement has little in common with the spatial arrangement of these regolith types in a landscape. The arrangement of regolith types in a landscape depends on the geomorphic development and character of the area. There is thus a fundamental difference between regolith classification units and regolith mapping units. Classification units consist of regolith materials that are defined in terms of various regolith characteristics. They are ideal or conceptual units that can be precisely defined. They are used as a medium for the transfer of knowledge, and can be grouped in various ways for particular purposes.

Regolith mapping units are real landscape units that can be conveniently mapped, and their definition will therefore depend on the scale of the map. The more detailed the map scale, the more pure the mapping units will be. A mapping unit will almost always include regolith types that do not belong to the appropriate classification unit. These different units occur in areas that are too small to appear on the map, for example, narrow sedimentary areas in floodplains in dominantly deeply weathered terrain.

I repeat – the logical arrangement of regolith types in a classification has little in common with the spatial arrangement of these types in a landscape. To use an analogy: Butterflies can be classified into blue ones, brown ones, red ones, dotted ones, etc. Criteria other than colour could also be used in a logical fashion to divide the butterflies of the world into many different types. Each type would be mutually exclusive. This is the nature of classification; it gives us mutually exclusive classification units. We could also divide butterflies into types on the basis of where they are found: hill tops; valley floors; rain forests; and grasslands. However, we would be hard pressed to use location as a basis for a classification, because we would find a mix of butterflies at each location. Some butterflies would be confined to a few hill tops, and others would be found both on hill tops and valley floors. In other words, a classification based on location would lead to mixed categories that are not mutually exclusive. What we end up with are convenient groups rather than logical classes. And that is exactly what regolith mapping units are, convenient groupings of regolith materials that happen to be spatially associated in a particular area. The more detailed the map, the closer the mapped units will be to classification units. The only way to solve this problem of impure mapping units is to follow Lewis Carroll's cartographers and prepare the map at a scale of 1:1. As I'm sure you know, their problem was that the land owners wouldn't let them unroll it – they said it blocked out the light. Their solution was to use the land as its own map!

TAKE-HOME MESSAGES

There is an urgent need for a national regolith mapping standard. In developing this standard, the basic principle must be that it is better to map what is there, and then do the interpretation, rather than decide how the landscape and regolith evolved, and then construct the map according to the model.

If a map of regolith-landform units is produced using the principles embodied in the GA approach, it is possible to produce a RED map from a GIS very easily. Moreover, the correctness or otherwise of the evolutionary model implied by the RED scheme is irrelevant. A regolith-landform map provides evidence on which a model of landscape evolution can be based, and as more information becomes available, changes to such models can be made. A RED map does not allow this because it is based on one particular model.

It is equally easy to use a regolith-landform map to produce a map showing geochemical sampling media, or areas of regolith likely to host salt stores. But if you have a RED map, you cannot go the other way – it is not possible to produce a map of regolith materials from a RED map.

The basic recommendation from this discussion paper is thus: regolith maps should show the distribution of

regolith materials, subdivided according to an agreed classification. Having decided this, all (?) that remains is to agree on a regolith classification. RTMAP provides a basis for further discussion on the classification of regolith.

Let Cliff Ollier have the last word – at least thus far: "We do the best we can to map the partially-understood into potentially helpful maps".

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