FUNDAMENTALS OF REGOLITH GEOLOGY

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INTRODUCTION

After reading a number of recent regolith papers and monographs it is clear to me that many authors are still not clear on some of the fundamental concepts and terminology as defined in the Regolith Glossary (Eggleton, 2001). It is thus appropriate to outline a few of the conceptual misunderstandings and misuses of models and terminology in regolith geology that I think are confusing or used with apparent lack of understanding of some fundamental knowledge.

I have quite purposely written this with few references as I only wish to put some ideas before this meeting, not criticize individuals, and hopefully what I have written below will provoke some more clear thinking and progress in regolith geology.

FERRUGINOUS MATERIALS

I find the terminology of ferruginous material confusing as there is an overabundance of terms that relate to ferruginous surface and near surface materials. The most confusing is *laterite*. Eggleton & Taylor (1999) have discussed the use of this term as has Bourman (1993 & 1995), yet confusion still remains common to readers about how the term is actually used by authors and exactly what it means. Laterite or lateritic regolith, lateritic residuum, ferricrete, and ferruginous duricrust are all terms used by different authors with apparently different meanings. Some of the terms are purely descriptive, while others have genetic connotations to them. The Regolith Glossary (Eggleton, 2001) defines these terms, but for me there are too many which refer to very similar materials. Surely after 14 years of CRC LEME we should have come up with more specific non-genetic definitions of ferruginous regolith materials.

Despite the input I and many others had to the Glossary I would suggest:

- we leave the term *laterite* alone except to describe profiles of ferruginous or aluminous materials which grade progressively down to mottled, pallid and saprolitic material;
- that *ferricrete* be used for materials at or near the surface that are wholly or partially cemented by iron or aluminium oxihydroxides; and,
- that loose surface ferruginous material be referred to as *ferruginous gravels* (or whatever size fraction is predominant).

Equally these terms could be used adjectively.

These three terms encompass the all terms currently used for ferruginous regolith materials. Each can be simply described in detail in papers and then authors can go on to discuss their interpreted origins for them.

THE MISSING DATA

One reads time and again the implication that where within a regolith sequence there is no ferricrete, mottled zone, or pallid zone these must have been stripped. This is basically poor science. It is equivalent to saying of Cretaceous rocks that because no dinosaur fossils they were found there none were around at the time. Nonsense – what their absence means is that either no dinosaur bones were around or none were preserved where we looked, an entirely different proposition. The thing about 'missing' weathering zones from a weathering profile assumes that the profile was lateritic in nature and unless there is good evidence to suggest there was one, it is fatuous to draw conclusions from the absence of weathering facies. So what sort of evidence would be needed to show this may have occurred? An erosion channel cut through an adjacent entire lateritic profile, or an immediately adjacent sedimentary pile that contains laterite profile materials in reverse order to those in the profile, or perhaps remaining lateritic mesas and buttes peppered across the region of missing parts of the profile, and unlikely scenario though.

To my mind good science can not be based on absent data. It is all very well to discuss the possibility of erosion but not to use its absence to draw conclusions about regolith and landscape evolution.

REGOLITH STRATIGRAPHY

Out there, there are still folks who write of regolith stratigraphy including zones within a weathering profile in their stratigraphy. I have no problem with applying the principles of lithostratigraphy to depositional sequences, but to apply them to weathering profiles is just muddled thinking. If one considers weathering to be a surface related phenomenon then it follows weathering characteristics are progressively overprinted from the pre-existing materials from the top down and the most weathered material (oldest) will be at or near the surface while those less weathered (younger) will occur deeper. This is the antithesis of lithostratigraphic thinking. Thinking of weathering stratigraphy leads to many misinterpretations of regolith evolution and is the basis on which many have, and still do, try to correlate weathering features over long or even moderate distances; more of this later.

For variations in the nature of weathered materials, I suggest we exclusively use the term facies, as it is used in metamorphic or sedimentary geology to denote materials in a sequence or complex that are different in appearance from one another for whatever reason. For example, a common regolith facies would be a white, clayey sand containing scattered, irregularly shaped, ferruginous mottles up to 10 cm across, or a surface red- and black-coloured granule sized layer up to 3 cm thick.

EPISODIC WEATHERING

Weathering is a process that does not stop while materials are at or near the Earth's surface. Primary agents of weathering are water and perhaps micro-organisms, with temperature and water chemistry being secondary. Much weathering of fresh rock occurs well below the surface where temperature is less controlled by the local weather but, is more influenced by the local geothermal gradient. Water and micro-organisms are ubiquitous and therefore deeper weathering occurs somewhat independently of surface conditions. Many examples of contemporary weathering under climates as varied as arctic to arid deserts are available to testify to this proposition.

This model of episodic weathering can and often does, build into elaborate paleoclimatic interpretations based on the concept that humid hot and maybe seasonal (tropical) climates pertained at the time of weathering and that where weathering profiles are not observed the climates must have been significantly more arid. Such arguments show a lack of appreciation of both weathering processes and of reliable ways to reconstruct past climates.

The regolith literature is crammed with examples of episodic weathering. This implies that weathering starts and stops. I argue this can not happen, but rather when one observes a weathering profile in the geological record we are looking at what has managed to be preserved rather than regional episodic weathering. The likelihood of preservation is however affected by the relative rates of weathering and the preservation potential (i.e. burial by sediments or basalts, or erosion occurring more rapidly than the weathered regolith can build).

WEATHERING, BURRIAL, EXHUMATION, AND PRESERVATION

Some authors, with some support from apatite thermochronology, suggest that old (Mesozoic or Paleozoic) weathering profiles at the surface now have been buried by significant thicknesses of sediments and since exhumed so that the older weathering profile is again at the surface. This seems to me a considerable coincidence.

The age of most of these weathering profiles have been determined using paleomagnetic methods. In quoting the age it is rare for authors to describe in detail the nature of the hematite, but it seems unlikely to me that fine-grained hematite could survive long-term deep burial. At such depths the environment is probably reducing and this would mean the hematite would be destroyed in groundwater. Even at comparatively shallow depths in contemporary weathering profile hematite and goethite drop off rapidly below the water table. So how then can these exhumed profile preserve their magnetic character over 100's of millions of years and kilometers of burial and then exhumation? It is up to those who employ this model to explain in detail the nature of the materials, their geochemical and burial history before such a model can be widely invoked.

AGES OF REGOLITH

Many regolith profiles are given ages by authors using various dating techniques but they generally do not relate the mineral phase being dated to the other minerals in the profile, much less give limits to the reliability of the ages. This is a major failing and need addressing. This is particularly so when one considers that the profile may have been undergoing weathering and mineralogical alteration over long periods of time (perhaps

100's of millions of years). So the fabric and geochemical relationships between the individual mineral crystals is paramount in considering the relevance of the date to the age of the overall weathering profile. In my experience Mn minerals are formed late in the overall weathering sequence, hence dates from Mn mineral would indicate minimal ages for weathering. The story with iron minerals is more complex but none the less requires that any age quoted on the basis of paleomagnetic dating should be accompanied with some indication of the relative time of iron mineralization/s within the profile. This lack of attention to detail by many authors is leading all regolith scientists to potentially incorrect conclusions about the age of weathering and the reliability of dates.

CORRELATION USING WEATHERING FEATURES

The concept of widespread ferricrete or other duricrust capped peneplains seems to continue in many authors' minds. We still read of landsurfaces separated by wide valleys flanked by hills capped by ferricrete where the author correlates these ferricretes on either side of the valley to 'reconstruct' a former landsucface. While this may be correct, very few data are ever presented to show the duricrusts are on either side of the valley are the same age. Unless independently determined ages for these duricrusts (ferricretes) can be shown to be the same age then correlation over moderate to large areas is dangerous and leads to simplistic landscape evolution interpretations.

If we look at contemporary environments we can find areas which demonstrate that ferricrete, for example, forms contemporaneously at various places on a landscape, for example on hill tops, valley slopes or valley bottoms. In many cases it is the position of the water table that controls the position of ferricrete in a landscape and not so much the landscape position. Equally we can find regions where they are forming over wide areas simultaneously, but to infer that this was always the case is fallacious. There is no reason to suggest that duricrusts formed any differently in the past from the way the form now, and presently we can observe changes in duricrust formation over distances on meters to 10's of kilometers, so the past was likely to be similar.

Fundamental to understanding landscape evolution is to ask why are the hills and valleys where they are? Many authors demonstrate this concept of landscape evolution by employing the concept of landscape inversion implying that areas with weathering/erosion resistant rocks/regolith remain as high points in the landscape longer than those underlain or covered by less resistant rock/regolith, thus demonstrating that there is no necessary temporal correlation between duricrusts in that landscape.

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