# AUTOMATED REGOLITH LOGGING – A REALISTIC PROPOSITION?

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## INTRODUCTION:

With substantial parts of the Australian landscape covered by regolith, drillhole information remains critical to the discovery of buried mineral systems. As the exploration for blind or obscured mineral systems increases, so does our dependence on data from drilling and the need to offset the added costs to exploration. In part this can be achieved by increasing the value of geological information derived from boreholes, drill core, powders and chips. The advent of rapid, objective logging technologies based on the spectral measurement of geological materials (eg. Huntington et al., 2004) heralds an opportunity to use spectrally derived mineralogy in addition to other petrophysically based measurements (eg magnetic susceptibility) to generate new geological information by discriminating bedrock type from its weathered counterpart, distinguishing between transported and in situ regolith and separating hydrothermal alteration from weathering mineralogy.

From a regolith perspective, the automated and objective interpretation of drill hole cuttings and core is attractive for a number of reasons, not least for consistency when trying to interpret geochemical data in the context of a complex regolith setting, but also because potentially valuable geological information may not be evident through simple visual interpretation. Currently CRCLEME is collaborating with CSIRO Exploration and Mining, AusSpec and several mining companies to determine the potential of spectral methods for the automated logging of regolith, founded on a better understanding of their spectral properties. The prospect of automatically defining regolith units is predicated on different regolith materials having distinct physico-chemical properties that can be measured and interpreted quickly.

We are currently trialing computationally fast, readily adaptable software developed to assist in the automated interpretation of petrophysical logs. These procedures, which are in common use in the petroleum and coal industry, are increasingly being adapted for use in metalliferous and mineral exploration and mining sectors and have potential for application in exploration through the regolith. Several packages are available including LogTrans (www.minserve.com.au/software_logtrans.htm) and VIEWLOG (www.viewlog.com) which have been specifically developed for the rapid analysis of multi-parameter drillhole logs.

This paper reviews the application of the LogTrans software package in a simple case study concerned with discriminating between transported and in situ regolith materials in drill core collected from a mineralized system located in the Eastern Goldfields of Western Australia.

## METHODOLOGY:

Spectral measurements of drillchips for a number of holes drilled through a complex and varying regolith in the Eastern Goldfields of Western Australia, were measured using an ASD Spectroradiometer (www.asdi.com) measuring reflected light in the visible, near and shortwave infrared (350-2500nm). Spectral analysis and interpretation was completed using The Spectral Geologist (TSG) software. Mineralogical interpretations of those minerals that are spectrally active over the range of the spectrometer are calculated using “The Spectral Assistant” (TSA™) Algorithm (Berman et al., 1999), along with their relative proportions and an interpretation error.  User defined functions for the mapping of selected minerals species and defining crystallinity can be readily computed and saved for future use.

A range of spectral indices were determined, including the kaolinite crystallinity index which involves determining the depth of the so called “ordered kaolinite spectral feature” at 2160nm relative to the depth of the “disordered kaolinite feature” at 2180nm. Several workers (eg. Merry and Pontual, 1997, and Phang and Anand, 2000) have observed that this index can be used to identify regolith type, namely transported materials over in situ saprolitic clays. However, it has been recognized that this index alone cannot be used in reliably discriminating between regolith units and therefore other measures also have to be employed (Scott, 2003). In testing the use of spectral indices as a basis for the automated discrimination of regolith units, several other indices were determined, including a “Brightness index” based on the overall spectral albedo of the material being measured, A “Colour Index”, A hematite:goethite ratio, an AlOH intensity index and a $Fe^{2+}$ intensity index (C. Phang, *pers comm* 2004).

The automated interpretation of drill hole materials was undertaken using LogTrans, which performs automated interpretation of drillhole data, and was originally developed to interpret geophysical borehole logs (Fullagar et al., 1996). It has since been adapted to facilitate joint interpretation of logs and core-based data such as geochemical assays.

LogTrans exploits contrasts in the petrophysical, mineralogical and/or chemical properties of different rock types and presents the results in a form readily understood by geologists. The procedure involves the statistical characterisation of a representative set of geological units based upon the measured properties of those units. Then “unknown” materials collected from drilling elsewhere are assigned to a particular class of materials or units according to their proximity to known classes in “parameter space”. The parameter space is determined by the rock properties being measured and in the spectral sense consists of spectral indices, or spectrally determined mineralogy. A more complete summary of the LogTrans Algorithm is provided in Fullagar et al., (1999).

## RESULTS AND DISCUSSION

Fundamental to the adoption of a quantitative approach for automatically discriminating between regolith materials is the assumption that particular units can be defined by relatively invariant properties or parameters which in turn can be determined rapidly. In this study spectral indices which may differentiate between in situ and transported regolith materials have been used. Control data, based on “reliable” regolith logging are plotted in spectral “parameter space” defined by a kaolinite crystallinity index and a measure of brightness (Figure 1) with the different regolith units represented by various colours. Each of the units occupies a relatively distinct part of the scattergram, although an overlap between the saprolite and transported classes suggest that differentiation of unknown units based on these two spectral indices alone may be compromised in certain circumstances given the non-uniqueness of the two-parameter interpretation in this example. Where possible, control data should be consistent and representative and for the purposes of differentiation should be distinct. Results to-date suggest that more consistent differentiation of transported and in situ regolith requires a range of spectral indices including depth/width of the 1900nm water feature, the kaolinity crystallinity index, some measure of brightness and colour. Further studies are underway to determine what influence particular regolith settings and control materials have on the automatic differentiation of these material types.

Figure 2 illustrates the results from a LogTrans interpretation of regolith materials for one drillhole using control data from others in the area. The interpreted log is defined from the classification of regolith materials based upon a three spectrally derived parameters, a kaolinite crystallinity index, “brightness” and “colour”. The result indicates that LogTrans can be used to make a reasonably stratigraphic interpretation on the basis of spectral indices, although further work is required to understand how reliably this can be used in other settings.

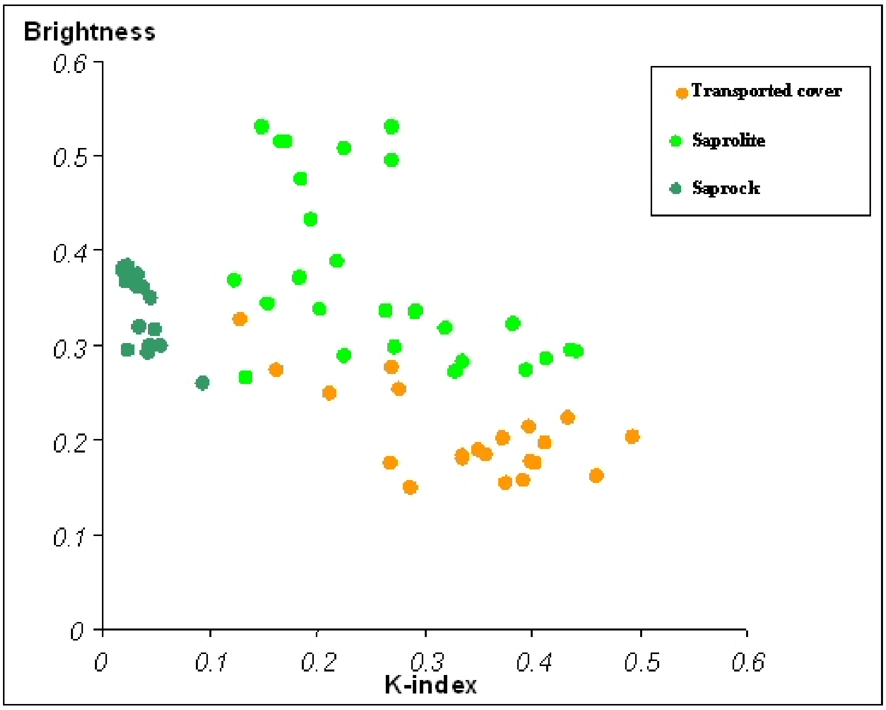


**Figure 1:** Spectral indices determined from the spectral measurement of drill chips, classified according to general regolith material type. Each material occupies a different "domain" in a "parameter space" as defined by these two spectral indices.

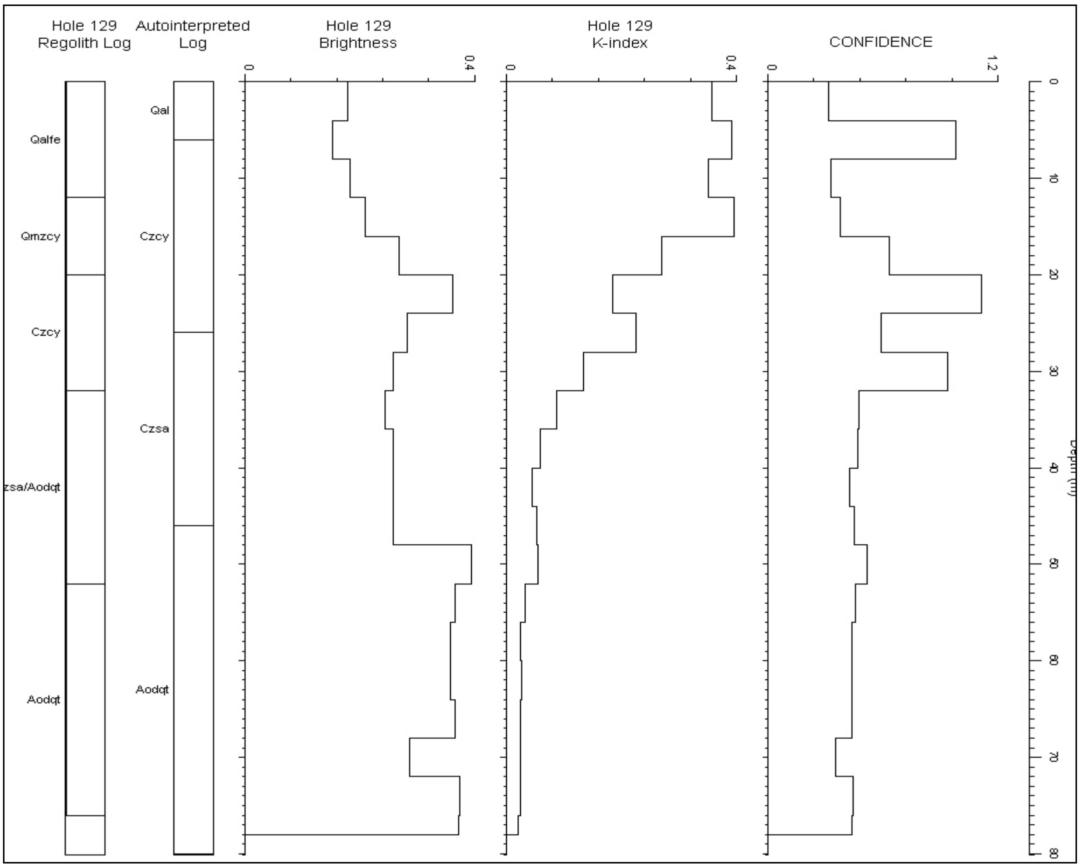


**Figure 2**: Actual and LogTrans interpreted geological log for drillhole #129, with corresponding spectral indices for "Brightness" and Kaolinite Crystallinity on which the automatic interpretation was based  A measure of confidence for the derived interpretation  is also plotted. Qal = alluvium; CzCv = colluvium, Cza= saprolite, Aodqt=saprock

LogTrans calculates a measure of confidence in the derived interpretation using a measure of standardized distances to assess the membership of particular groups (or in this case stratigraphic units). This feature is similar to that employed in cluster analysis and provides a measure of how effective the classification has been. In this example the most reliable classification is observed at the top of the profile where the most marked differences in the spectral indices are observed.

## SUMMARY

Potentially drillhole returns as core, chips or powders are amenable to automated spectral analysis and interpretation, with results that could be returned in timeframes that would suit exploration. Rapid and detailed, spectrally determined mineralogical logging has already been demonstrated with the CSIRO HyLogging technologies and spectral data derived from these and other systems lend themselves to automated interpretation. However, as regolith materials are characterized by varying spectral responses, careful choice of spectral indices along with the measurement of other petrophysical properties is required for robust and reliable discrimination between particular regolith units. That said however, the principles involved in using relatively simple, computationally fast, statistically-based classification procedures such as employed in the LogTrans package, hold considerable promise for the development of automated regolith logging methods, which in turn would add value to information currently returned from exploration drilling through the regolith.

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