VIEWING THE REGOLITH THROUGH DIFFERENT EYES: A NEW WAY OF INTERPRETING RESISTIVITY DATA

Tania Dhu, Graham Heinson & John Joseph

CRC LEME, School of Earth and Environmental Sciences, University of Adelaide, SA, 5005

INTRODUCTION

Electromagnetic (EM) and galvanic (DC) resistivity data is used to create resistivity images of the Earth, which can then used to infer subsurface properties such as porosity and salinity. However, interpretations are non-unique; resistive lows may be caused by saline water, conducting clays or even mineralisation.

Contemporary analysis of hydrological properties (porosity, permeability, etc.) has shown that their distributions are spatially non-stationary. Consequently, ideas of scale-length dependence and non-stationary stochastic processes have been introduced to explain and predict such phenomena (Molz *et al*. 2004). As the Earth's electrical response is highly dependent on hydraulic properties such as porosity and fluid content it is not surprising that it has also been shown to have scale-length dependence (Everett & Weiss 2002, Dhu *et al*. 2003). This means that not only are there variations in resistivity amplitude, but there are also varying textures (wavelengths contained within the signal). Analysis of how and where these wavelengths vary yields information on electrical connectivity.

In this study we conducted a textural analysis of EM data recorded at Tibooburra, NSW. This is an arid region with an average rainfall of 200-300 mm per year. Although the exact water table depth is not known, it is probable that most of the EM responses recorded in this region correspond to conduction within the vadose (unsaturated) zone. Several transects of data were recorded and compared with both their associated resistivity image and regional scale regolith landforms. Discrete data sets were also collected over different regolith landforms and their textures studied.

Results indicate that regions of low resistivity tend to be dominated by large-wavelength features. There are many deviations from this general trend and it is hoped that further analysis will lead to an understanding of how the principal wavelengths reflect electrical flow paths. This analysis has two purposes:

1. An understanding of the electrical flow paths in the vadose zone may be used to infer information on hydraulic flow paths in unsaturated media; and,
2. Relationships between lithology and textural variation may be used as an extra constraint for the inversion and interpretation of EM resistivity data

SURVEY DESIGN

Electromagnetic data were collected using a GEM300 multi-frequency EM meter. This meter allows for the simultaneous collection of apparent resistivity data at different frequencies. In this survey, data were recorded at 2,075 Hz, 4,425 Hz, 9,375 Hz, and 19,975 Hz. In a half-space with resistivity of 0.03 Ohm m (which is around the average resistivity recorded) these frequencies correspond to depths of approximately 65, 45, 30 and 20 m respectively. Ten lines, each approximately 2 km long, were recorded, together with seven discrete sections (Figure 1).

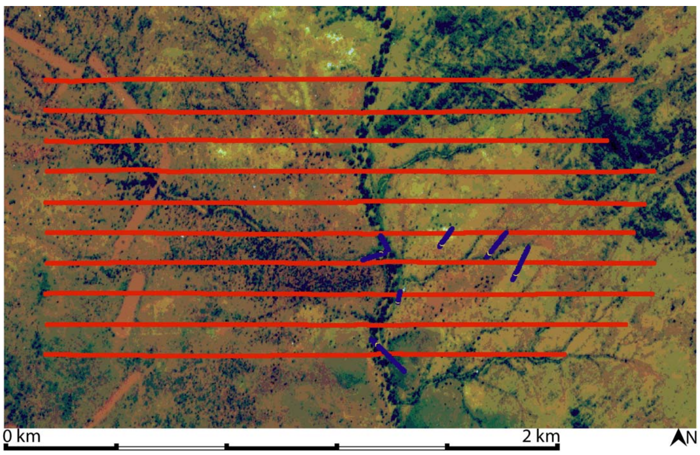

Figure 1: Ten long lines were collected to create a map of the region (red lines) along with several lines across discrete regolith-landforms.

To quantitatively evaluate the textures contained within the data a power spectral analysis is undertaken. This technique consists of plotting the wavenumber (1/wavelength) against the power contained within that wavelength. A line of best fit is then matched to the power spectrum and the slope of this line is used to gauge whether large-scale or small-scale wavelengths are dominant as described by Everett & Weiss (2002).

Figure 2 shows lines of best fit for different ideal earth responses. In terms of a real earth, gradients correspond to the scale on which the EM response varies. When the slope is less than one there is no spatial correlation between points. As the slope increases the spatial correlation and scale-length dependence also increases.

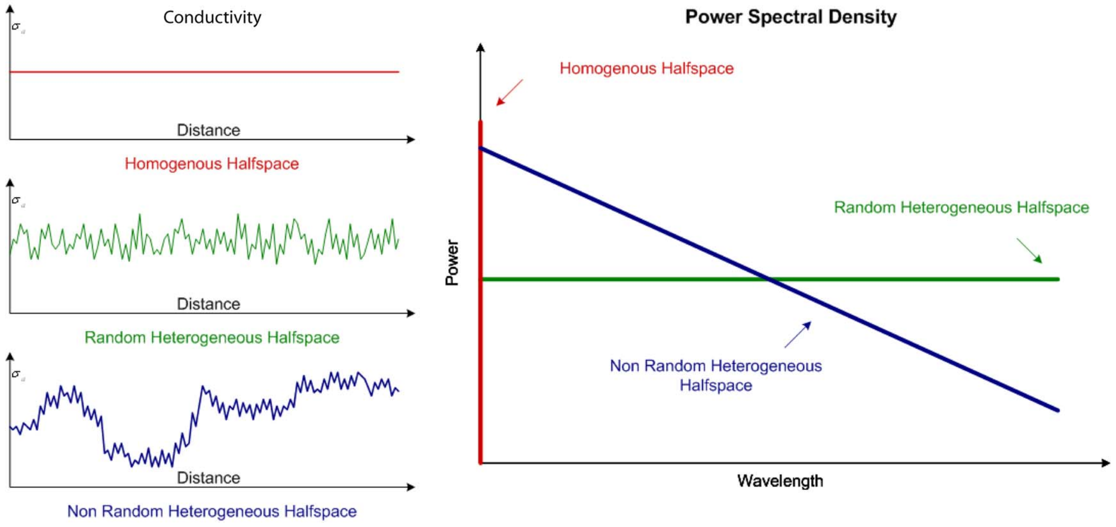

Figure 2: Left side of this Figure shows apparent resistivity for different Earth scenarios while the right shows how these scenarios would plot on a power spectral density plot.

This technique was applied to the data in two ways. For the long continuous lines a moving window of 256 points was used. This method involves selecting the first 256 points (points 1 to 257) in the line and calculating the gradient of the power spectrum. The window then moves up one (points 2 to 258) and the process is repeated until the entire line has been analysed. Gradient values are then gridded and plotted.

For the discrete data sets, repeat surveys were conducted (two lines in the same landform). The first 50 points from each line were taken and the gradient of their power spectrum calculated. These gradients were then averaged giving both a mean value and an estimation of error.

RESULTS

An apparent resistivity image of the region (for frequency 9,375 Hz and skin depth of 30 m) is shown in Figure 3. Exposed saprock is quite resistive with the most conductive regions (red/pink) following the river courses. Figure 4 shows a regolith-landform map adapted from the regional scale regolith-landform map by Chamberlain *et al.* (2002). Despite smaller scale variations, only four broad landforms are considered: one Aeolian; one colluvial; and, two saprock units. The aeolian unit is dominated by red, rounded, quartzose sand that contrasts with the less sorted, micaceous, quartzose silt and sand contained within the colluvial unit. The two saprock landforms have different geneses, the northern saprock is derived from granitic rocks, the southern from metamorphic rocks.

Figure 5 shows the gradients from the textural analysis of the 9,375 Hz EM data set. Regions that are dominated by large wavelengths and hence are related on a large scale are shown in blue. The eastern side of the image generally has small-scale spatial correlation with almost no variation in texture between the main alluvial channel and surrounding depositional plains. By comparison, the central north-south alluvial channel (Racecourse Creek) corresponds with a region of large scale-lengths, although the largest scales are slightly offset to the west of this channel. To the east of this channel the smaller alluvial channels also coincide with larger wavelength regions.

The gradients for the discrete sections are graphed in Figure 6 for two frequencies, 2,025 Hz (ca. 65 m) and 9,375 Hz (ca. 30 m). There were minimal differences between the gradient and resistivity maps for the four frequencies, just a smoothing of the general trends with depth. The discrete sections, on the other hand, did show changes with depth, depending on the landform. The two colluvial landforms CHpd1 and CHpd3 are almost exactly the same for both 9,375 Hz and 2,025 Hz whereas the two alluvial channel deposits change significantly, from 1.8 (9,375 Hz) to 1.2 (2,025 Hz).

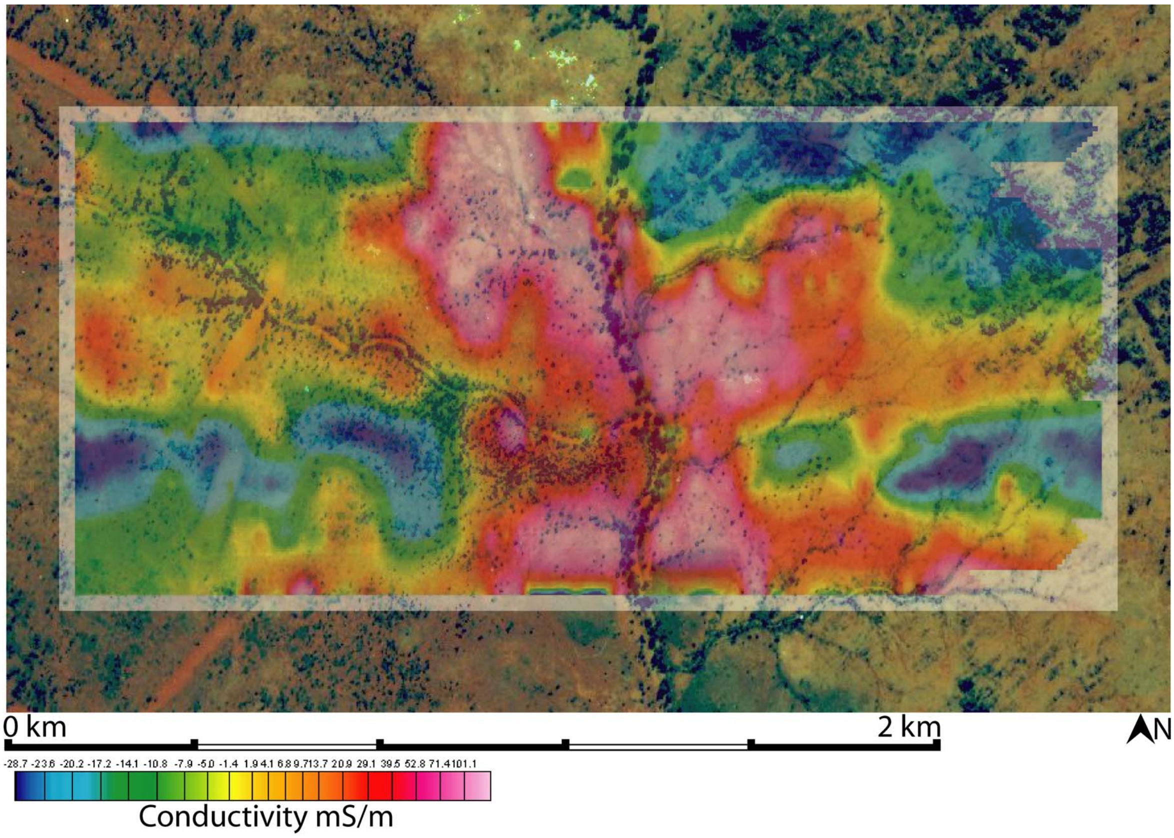

Figure 3: Map of conductivity created from the 10 long lines. Blue regions are highly resistive.

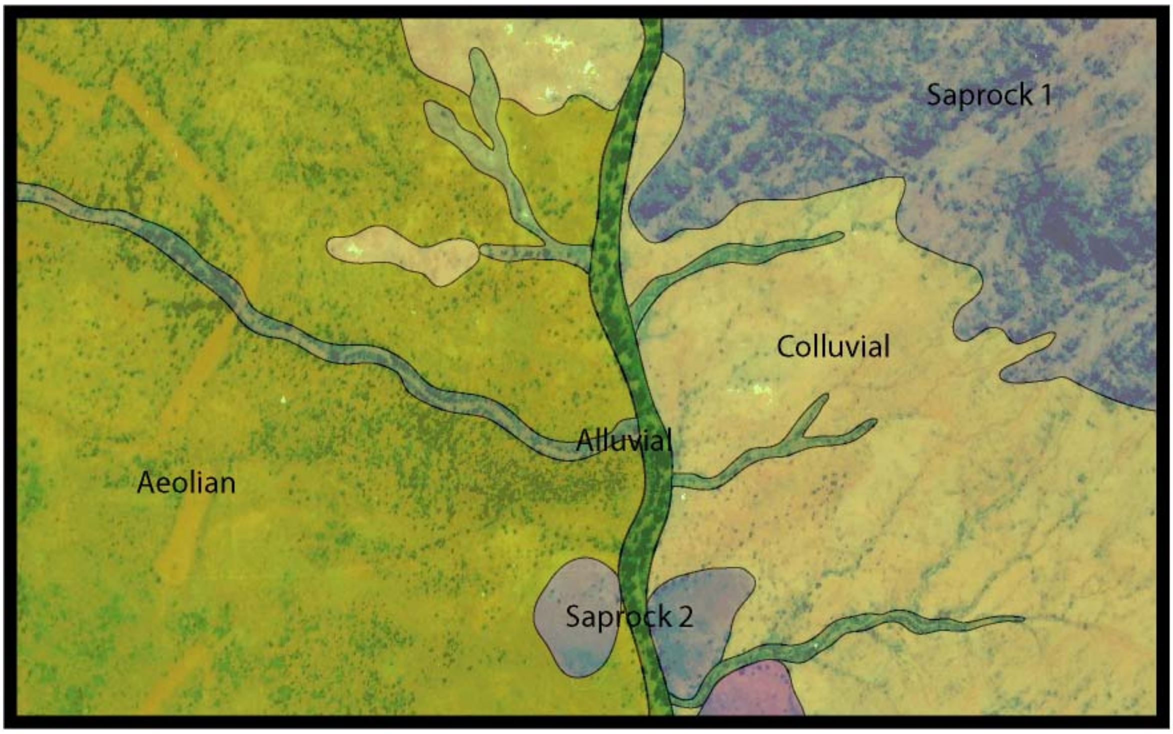

Figure 4: Regional regolith-landform map from Chamberlain & Hill (2002).

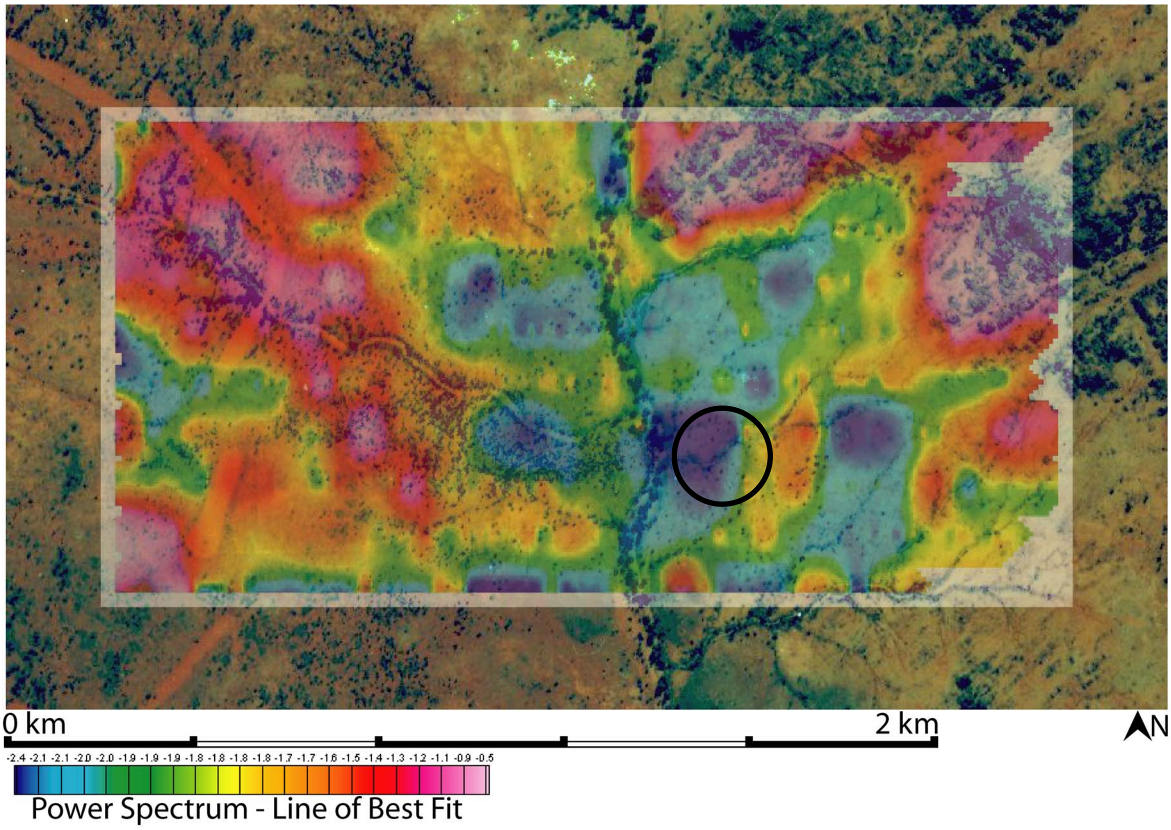

Figure 5: Map of dominant wavelengths. Blue areas have are dominated by large wavelengths (large-scale features).

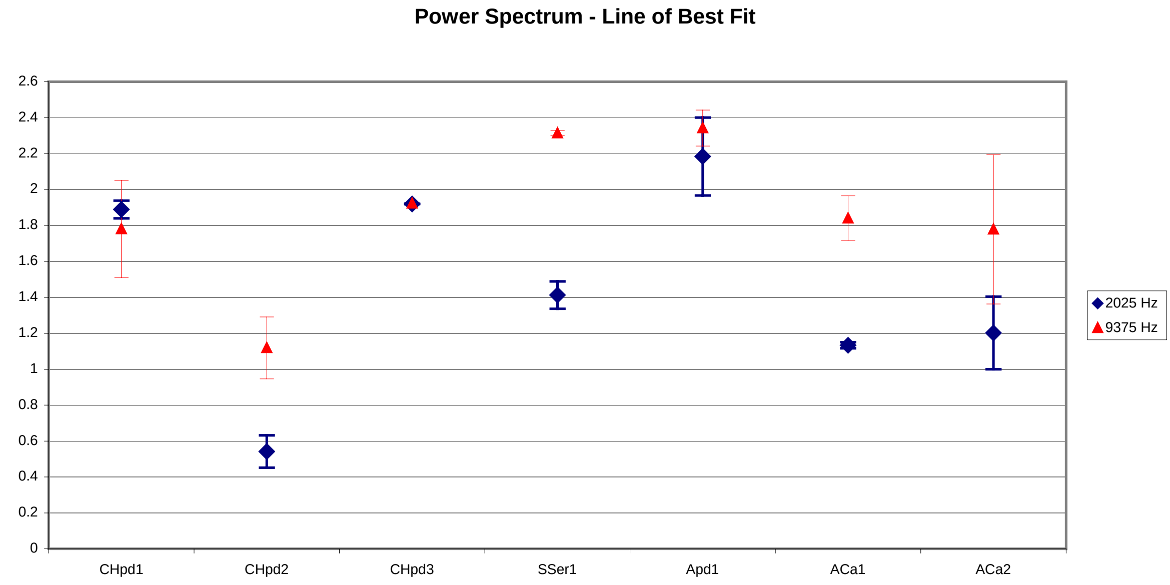

Figure 6: Plot of power spectrum gradients of different regolith landforms.

DISCUSSION

On first analysis, there exists a general trend of low resistivity occurring in areas where there is large scale-length dependence. Intuitively this makes sense as areas of low resistivity will tend to have good electrical connection and therefore may connect up over a larger scale. There are also many smaller scale variations from this trend. The circled region in Figure 5 has large scale-length dependence but is located on the outside bend in the creek bed, slightly offset from the main resistivity low (which is centred on the creek bed). Ground investigation showed that this anomaly is sited on a region of overbank deposits; fine sediments with high clay content.

The 9,375 Hz discrete sections show minimal variation in scale-length dependence between the assorted landforms, however, the 2,025 Hz sections show significant differences between the two colluvial landforms (CHpd1 and CHpd3) plotting around 1.8 and the alluvial channel deposits (ACa1 and ACa2) plotting around 1.2. One colluvial landform (CHpd2) did not follow this trend and it is not as yet understood why, although the physical properties of landforms do vary locally.

Comparison of the regolith landform map with the dominant wavelengths showed several trends:

1. Regions of saprock had very low scale-lengths;
2. The aeolian depositional plain had a lower scale-length than the colluvial plain deposits;
3. The alluvial channel deposits were variable and may be influenced by the adjacent regolith landforms (channels cutting through the aeolian deposits were not picked out whereas channels cutting through the colluvial deposits were associated with large scale-lengths).

SUMMARY

At this stage the results are not conclusive, however, general trends are emerging. As further empirical analysis is undertaken (matching of sediments to their scale-lengths) it is believed that these trends will become clearer. Despite the current uncertainties in linking observed anomalies to causative geology, it is becoming apparent that this technique does hold useful information about the subsurface.

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