MAGNETIC SUSCEPTIBILITIES OF SURFACE MATERIALS TAKEN AT FOWLERS GAP, NEW SOUTH WALES

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INTRODUCTION

Fowlers Gap is located approximately 100 km north of Broken Hill in New South Wales, Australia. It is the University of New South Wales' Arid Zone Research Station, for which many detailed regolith landform maps have been constructed during CRC LEME's teaching and research activities there (e.g., Hill & Roach 2003, Hill & Roach 2005). The regolith can be defined as everything from fresh rock to fresh air (Eggleton 2001). For the purposes of this study, I will only be looking at the uppermost part of the regolith, where the measurements were recorded; no downhole information was used. Primarily, we want to see how the regolith distorts the magnetic field of the Earth. For this, we need to look at the magnetic susceptibility of regolith materials.

All matter is affected by and distorts inducing magnetic fields. The protons and electrons within atoms respond to an external magnetic field. There are three main types of magnetisation: diamagnetic; paramagnetic; and, ferromagnetic (Blakely 1996). Diamagnetic materials contain a random arrangement of magnetic moments (electron spins) and do not affect the inducing magnetic field very much (examples include quartz, feldspars and micas). In ferromagnetic materials, the electron spins line up, re-enforcing the magnetic field (examples include bar magnets). Such materials retain magnetism even after the inducing field is removed. Paramagnetic materials also involve an ordered arrangement of magnetic dipoles but lose the magnetism once the inducing field is removed (many metals are paramagnetic; they will stick to a magnet but do not exhibit their own field).

The magnetic susceptibility of an object is effectively the ratio ofthe magnetisation to the inducing magnetic field. It is expressed as $K = M/u_oH$, where M = magnetisation (dipole moment per unit volume), u_o is the permeability of free space and H is inducing field. K is the magnetic susceptibility. As it is a simple ratio, it is a dimensionless quantity—it doesn't have units. Using the "micro-cgs" system for analysing magnetic susceptibility of material (Sheriff 2000), we can expect much diamagnetic material to have susceptibilities around 0 to 100 units (susceptibilities can also be negative). Ferromagnetic materials can have susceptibilities 5 orders of magnitude higher (Telford et al. 1996). Paramagnetic material will lie somewhere in the middle range.

Due to unsuitable weather conditions and time restrictions, only one day was available for data collection. In order to collect as much data as possible, readings were taken every few metres along traverses of regolith features (channel deposits, drainage systems and drainage depressions to name a few). Each data point consisted of a geographic location (an easting and a northing) and a magnetic susceptibility reading. The magnetic susceptibility reading was taken using an analogue hand-held magnetic susceptibility meter. The readings represent the dominant surface material (almost always a soil) in closest proximity to the instrument. An aerial photo mosaic of the area is shown in Figure 1.

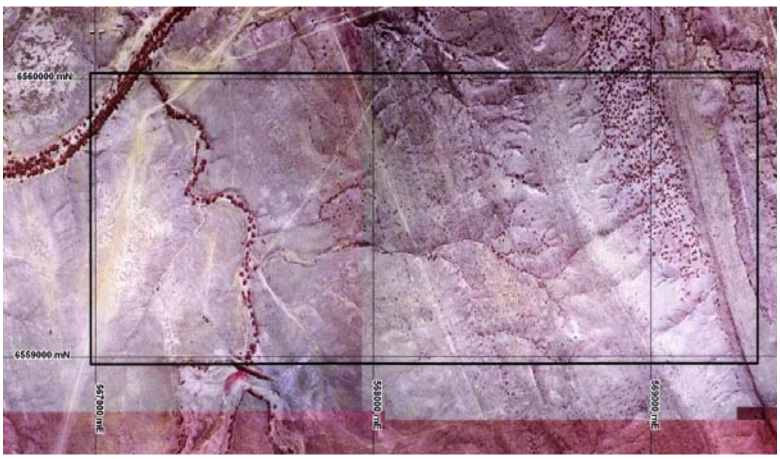

Figure 1: An aerial photo mosaic of the Fowlers Gap 2005 Joint Undergraduate Regolith Field Camp mapping area, with a 1 km grid for scale. Fowlers Gap Station is in the upper left-hand corner.

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METHOD

This project was undertaken during the 2005 CRC LEME Joint Undergraduate Regolith Field Camp. No completed regolith map was available for reference at the time; only the aerial photo mosaic was available.

Two traverses, or lines of data points were recorded, with a hand-held magnetic susceptibility meter placed at the ground surface every few metres. A GPS unit was used to record the location, and all data entered into a notebook. The data were then entered into a computer and the data points plotted in colour over the aerial photo mosaic. When the regolith map had been compiled, the susceptibility data values were superimposed on it. In addition, a histogram was created to show the occurrence of data points.

RESULTS

In total 338 data points were collected. Figure 2 shows the collected data overlain on the aerial photo mosaic. Dark colours correspond to low values, and light colours to high values. Figure 3 is the histogram that shows the range of the data. The mean magnetic susceptibility is 65, the median value is 50 and the standard deviation is about 44. Figure 4 displays the data overlain on the draft regolith-landform map of the area. Various sections of the data have been highlighted that will be discussed below. Figure 5 shows line 1 (the uppermost line) as a line graph. Vertical lines separate the regolith landform units, and the areas of interest are marked with thick, black lines. Figure 6 is similar to Figure 5, except the data is for line 2.

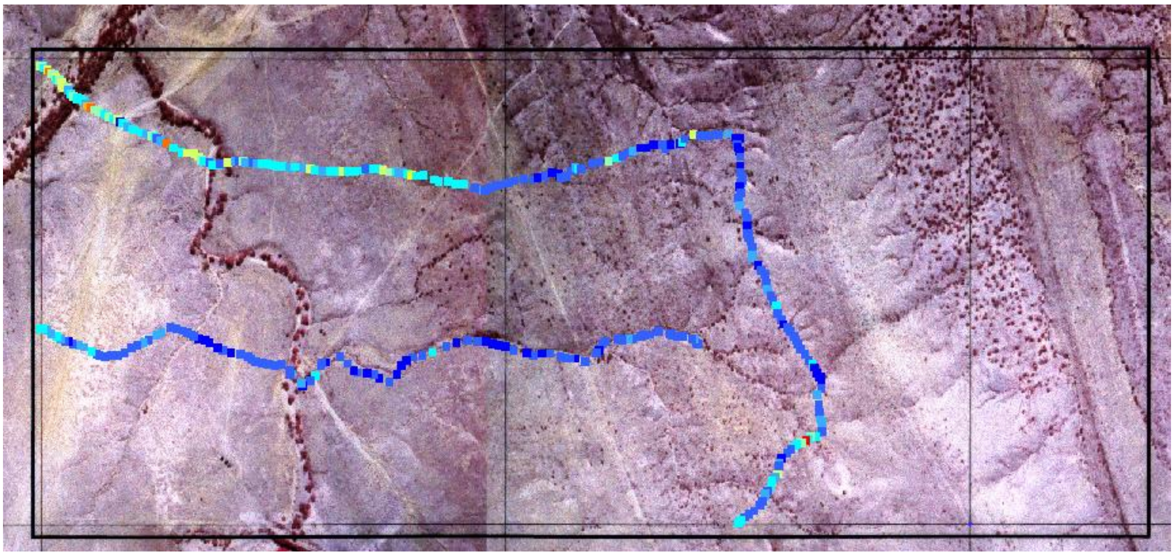

Figure 2: The data has been overlain on the aerial photo mosaic. Light colours reflect high values, and dark colours reflect low values.

DISCUSSION

Area 1 is within an alluvial channel (regolith code ACah). The values for magnetic susceptibilities here are quite high, and there is a large range—susceptibility readings vary from 95-160. Alluvial channels contain sediments from many sources, so this could explain the large range of readings.

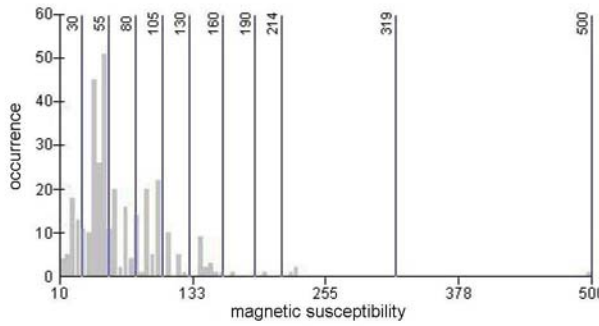

Figure 3: Histogram showing the variation of data in the sampled area. There are 338 data points, mean value is 106 and the median is 50.

The readings start to level out moving out of the channel up into area 2. Area 2 can be defined as slightly weathered bedrock on an erosional rise (code SMer). With bedrock present, it is reasonable to suggest that the readings obtained in this area are representative of the bedrock.A road (Fm) is present in this area, and similar readings are obtained on either side of it.

Area 3 is quite small, but contains a lot of variation in magnetic susceptibility, regolith type and landforms. The regolith types are alluvial sediments, channel deposits and highly weathered bedrock. The landforms are depositional plain, erosional plain and drainage depression. Magnetic susceptibility units range from 50 to 230.

Area 4 is part of a sheet flow deposit on a depositional plain (CHpd). The unit is large (approximately 100 metres across) and contains a fairly constant range of data. There is some variation towards the middle of this area which suggests (at least in this case) that magnetic susceptibility measurements will not stand by themselves as a method of defining regolith types and landforms.

From area 5 and onwards, the magnetic susceptibility values tend to remain at lower levels (generally less than 80 units). The reason for this change is not obvious. The regolith type and landform changes gradually from colluvial sediments on an erosional rise to colluvial sediments on an erosional plain. Technically, the only change here is in the slope of the surface, but the source for the sediments collecting here also needs to take into account. Note that left of area 5 there is a system that relates to the deposits from the channel at area 1 (this channel extends above the map and to the right). To the right of area 5 the erosional rise may act as a barrier against further sediments from the east. This may be the cause for the change in the readings here.

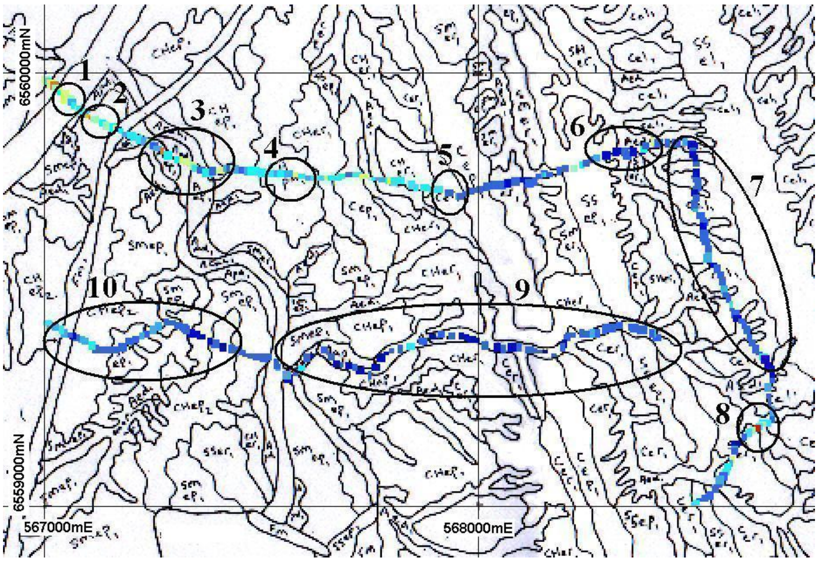

Figure 4: Magnetic susceptibility data superimposed on the draft regolith – landform map of the area. Areas within the numbered ovals are discussed in the text.

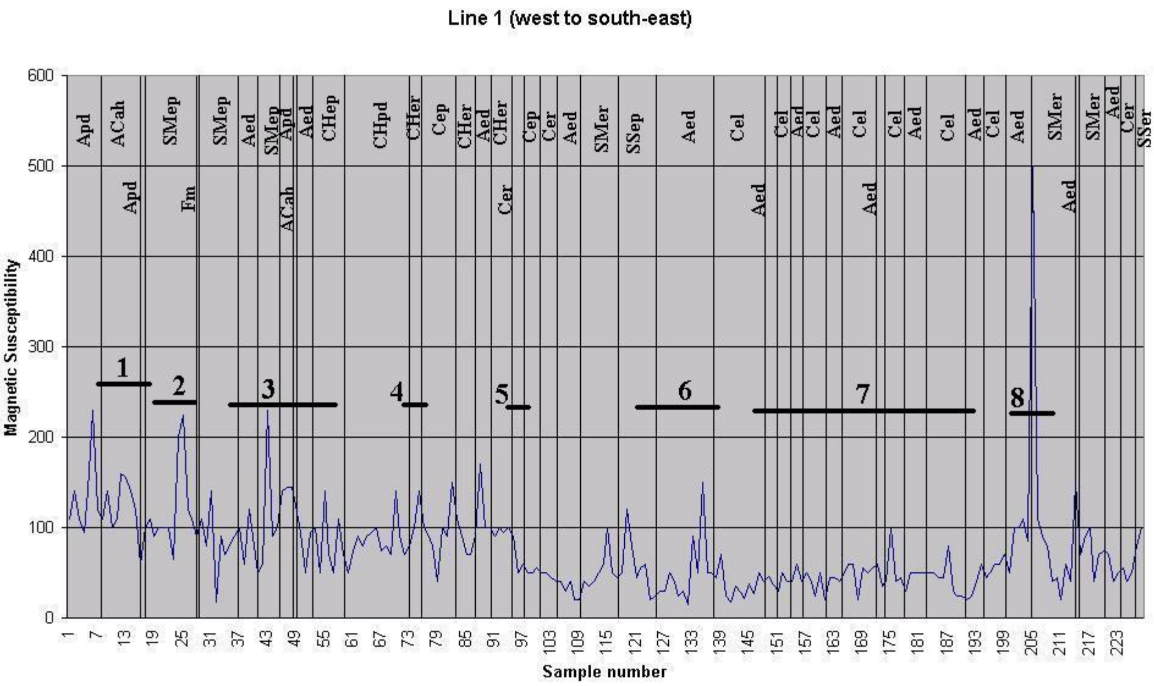

Figure 5: Line plot of magnetic susceptibility readings from Line 1 (west to south-east) with RLUs and areas referred to in the discussion highlighted.

Area 6 is on a slope, and contains combinations of alluvial sediments in drainage depressions and colluvial sediments on a low hill (Aed and Cel respectively). The magnetic susceptibility readings in this area are the lowest collected in the area (down to 10 units) and the values remain below 60 units. This does not mean that all Aed and Cel units everywhere will always have low magnetic susceptibility units; this is just a reflection of the source of the sediments in this area.

Area 7 represents a cross-section through the alluvial sediments in drainage depressions and the colluvial sediments on a low hill. This was undertaken to see if there was an easy way of picking the boundaries of such units. This does not seem to be the case. The changes in magnetic susceptibility here seem to not be dependent on the regolith type and landform, although the values do remain reasonably constant in the area (10 to 50 units).

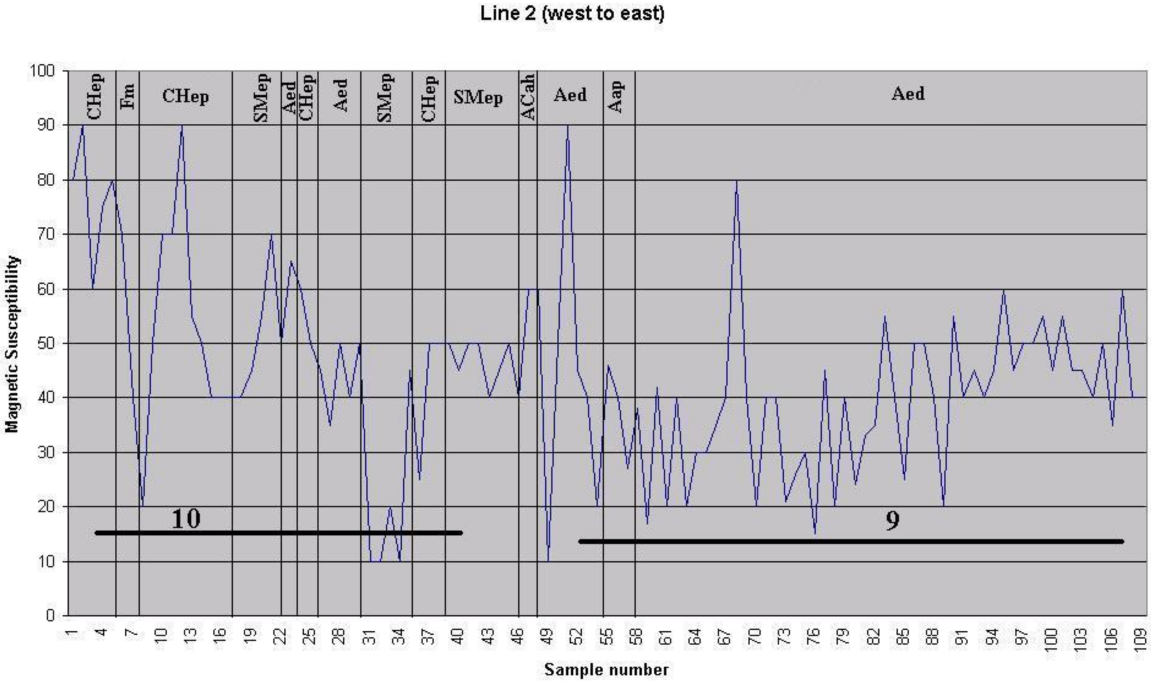

Figure 6: Line plot of magnetic susceptibility readings from Line 2 (west to east) with RLUs and areas referred to in the discussion highlighted.

Area 8 contains the highest value obtained in the mapping area—500 units. The regolith type and landform is SSer, slightly weathered bedrock on an erosional rise. This may be related to some ferruginous saprolite reported in the area, hence resulting in high susceptibility. Note that the peak occurs very close to the boundary between different regolith landform units suggesting some geochemical interaction between units.

Area 9 is a section through an alluvial drainage depression. Data are reasonably constant, with some high values up to 110 units. The drainage system contains run-off from the low hills (i.e., from the same source), so the fairly constant set of values is understandable.

Finally, area 10 contains numerous regolith-landform features. There is some bedrock to the right of the area that has low magnetic susceptibility associated with it. This suggests that the bedrock changes over the total mapping area.

DISCUSSION

Changes in magnetic susceptibility do not appear to be related to the change in regolith type and landform. The changes in magnetic susceptibility sometimes occur in places where there is no change in regolith type or landform and sometimes they do; a straightforward relationship is not immediatelyobvious. Changes in magnetic susceptibility may also be related to the presence of maghemite produced by surface processes such as bushfires.

The precision and accuracy of the magnetic susceptibility meter are not known, so placing error bars on the data is not possible. However, the meter was designed for hand samples, so placing it against the ground should pose no difficulty and it ought to have performed at maximum efficiency.

Finally, to extend this work, it would be worth setting up a grid and taking a more extensive range of data. A full-scale statistical analysis should be undertaken to assign mean susceptibility and standard deviations to each regolith unit, and the boundaries between units examined in more detail. With only one day to collect data, and no regolith map of the area, this was not a feasible option at the time.

CONCLUSIONS

Magnetic susceptibility may be a useful way to characterise the regolith materials of the area, although a direct relationship between regolith type, landforms and susceptibility was not apparent at Fowler's Gap given the insufficient data.

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