11th SAGA Biennial Technical Meeting and Exhibition
Swaziland, 16 - 18 September 2009, pages 105 - 107

The Good, the Bad, and the Ugly: Airborne EM and the regolith

C. Wijns

First Quantum Minerals Ltd, Australia, chris.wijns@fqml.com

ABSTRACT

EM signals may be highly influenced by the regolith in weathered terrain, to the point of obscuring geologic targets at deeper levels. In time-domain data, this influence can extend from the earliest measurement times into the mid-range time gates. The degree of interference by the regolith varies according to the terrain, and is mostly influenced by the longevity and variability of weathering. Examples from different parts of Africa illustrate the extent to which long-lived regolith dominates the signal of airborne EM surveys.

Key words: Airborne EM, regolith.

INTRODUCTION

The drive to explore under cover necessitates methods of geological mapping that can “see through” the masking cover rocks in areas of little exposure. Airborne EM systems, originally developed for conductive anomaly or “bump” detection, are increasingly being used as structural and lithological mapping tools. In this context it is vital to separate geological noise from the underlying geology. The regolith in weathered terrains is the most important source of such geological noise, and it can vary from little or no influence, to entirely masking the EM signal. The series of examples that follows is drawn from regolith terrains of varying longevity, and correlates the degree of regolith masking to the weathering history of the terrain.

EM SYSTEMS

The airborne EM data for the case studies below are all in the time domain. While the conclusions hold for EM systems in general, the masking effect of the regolith is most easily illustrated using successive time gates as the signal travels deeper.

Surveys in Tanzania and Mali used Geotech Airborne Ltd’s VTEM (Versatile Time-Domain EM) system. The set-up was a horizontal, concentric loop transmitter and receiver system using a 25 Hz base frequency. The Z component of the secondary EM signal was read from 90 to 8900 µs. The slow-moving helicopter platform means that station spacing after stacking is approximately 3 m, and the nominal loop altitude is 30 m above the surface. A more complete system description is given by Witherly *et al.* (2004), although system improvements have been made in the intervening years with respect to power and noise levels.

The Fugro Airborne Surveys Ltd GENESIS system is similar to TEMPEST in terms of waveform. It is a fixed-wing platform with Z and X component receivers in a towed bird flying at about 60 m above the ground. The transmitter was set to a 75 Hz base frequency, and responses were measured from 12.7 to 6514 µs.

CENTRAL AFRICAN COPPERBELT

The Zambian environment is very wet and conducive to rapid weathering of rock. Although weathering can sometimes be deep (70 m), the regolith in this example from the Lufillian Arc of the Central African Copperbelt does not seem to interfere with EM images of the geology (Figure 1). An early time channel at 172 µs is clearly imaging the underlying geology, and does not reflect the drainage patterns seen in the bottom panel of Figure 1. The geological pattern seen in the EM is very consistent with that seen in magnetic data, which also points to the fact that the regolith response is consistent with the bedrock. In this case, following the spaghetti western classification of this paper’s title, the regolith is “good”, as it does not impede subsurface imaging,

LAKE VICTORIA, TANZANIA

The next example in Figure 2 is from Archaean terrain in the Lake Victoria Goldfields of northwest Tanzania. The depth to fresh rock can be over 100 m, especially in the vicinity of the major regional shear zone in the SW of the image. Here the earlier time channels still reflect features of the underlying geology, including a number of NW-trending conductive shear zones in the western half of Figure 2 (top panel). There are also a lot of near-

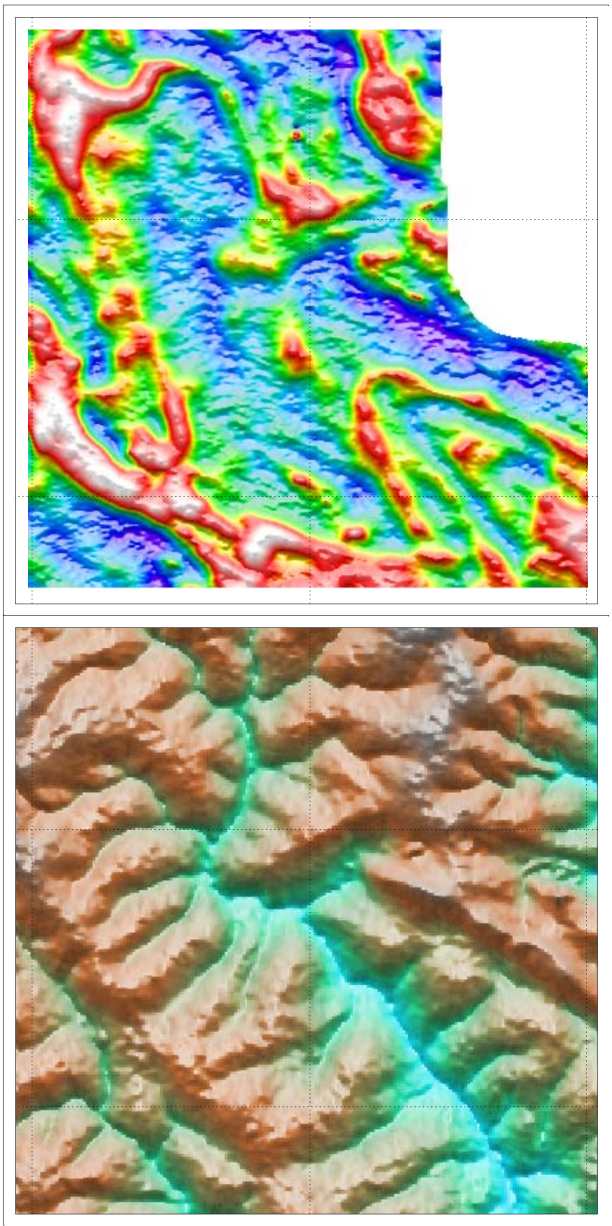

Figure 1. EM response of the regolith in the Zambian Copperbelt. The top panel shows an early-time response at 172 µs, and the bottom panel is the topography. Grid lines are 5 km apart.

surface conductivity effects dominating the central part of the image, which disappear to reveal the major NW-SE structural and lithological trends at later times (Figure 2, bottom panel). The regolith could be classified as “bad”, since it sometimes masks the underlying geology, but most surveys would see through this.

SOUTHERN MALI

The final example is from the Birrimian (Proterozoic) West African Craton in southern Mali. Figure 3 illustrates the dramatic difference between early and late time channels. While the depth of weathering rarely exceeds about 60 m except along the major regional shear zone, the EM signal is dominated by regolith patterns (top panel), from earliest times until about 680 µs. These regolith patterns mostly reflect modern and paleo-drainage channels that strike perpendicular to the underlying geological features (bottom panel). Only from about 1000 µs does a clean picture emerge of the basement geology.

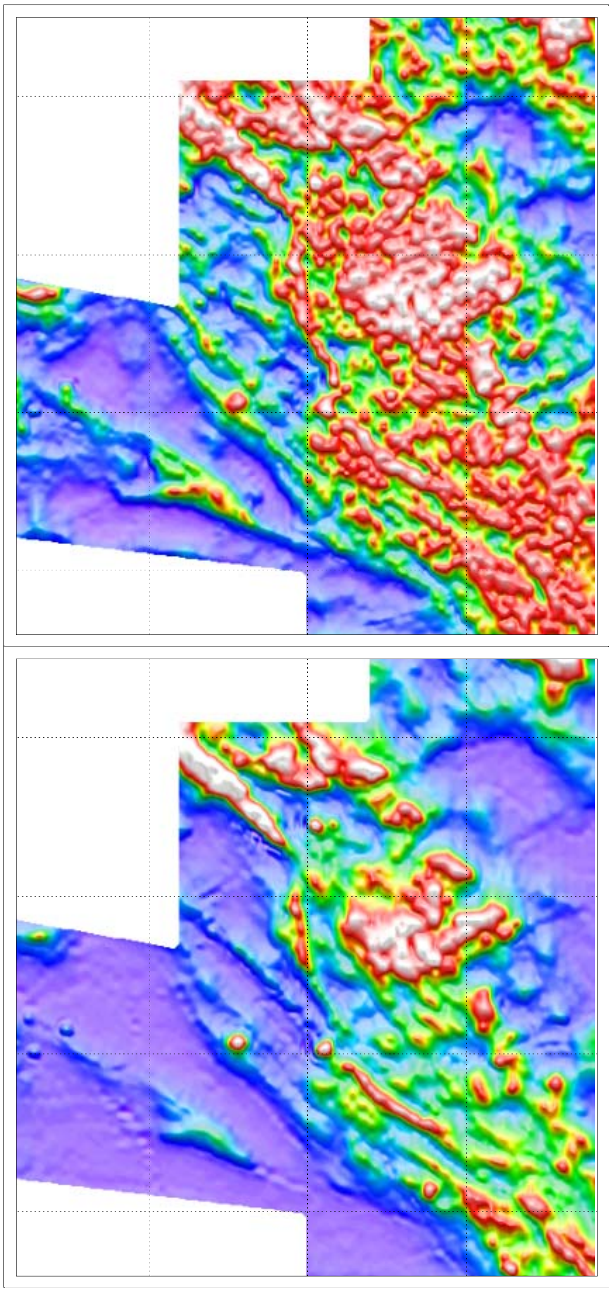

Figure 2. EM response over deeply weathered Archaean terrain in Tanzania. The top panel shows an early-time response at 220 µs, and the bottom panel is a later response at 1640 µs. Grid lines are 5 km apart.

The bottom panel of Figure 3 shows the main shear of this greenstone belt as the continuous high-amplitude feature running along the eastern edge of the data; to the west the data highlight low-amplitude intrusive bodies and numerous subtle stratigraphic contacts in the basin sedimentary rocks. Shallow EM mapping systems would not see through this regolith mask, so in this in this case the regolith can be classified as “ugly”.

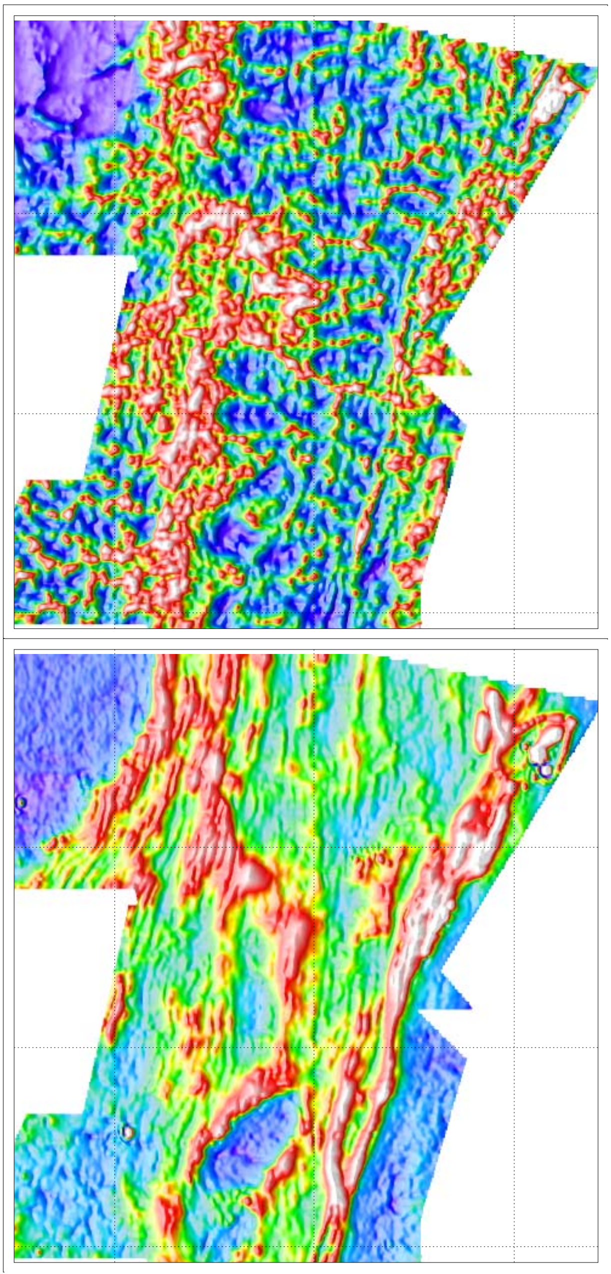

Figure 3. EM response over Proterozoic terrain in southern Mali. The early time channel at 280 µs (top panel) is dominated by drainage patterns, including paleo-drainage, striking mostly perpendicular to geological boundaries. Only late time channels, for example 1640 µs (bottom panel) and later, show clean basement geology. Grid lines are 10 km apart.

DISCUSSION AND CONCLUSIONS

The degree and complexity of weathering of the regolith is related principally to tectonic stability (Butt *et al.*, 2000) and Neogene erosional history. Deeply weathered terrains evolve over a period of 10 Ma (Butt *et al.*, 2000), and thus land surfaces must be stable over this timeframe to avoid excessive regolith erosion. The most stable land surfaces will be found in intra-cratonic settings, as for the examples in Tanzania and Mali, whereas the Lufillian Arc example in Zambia is less insulated from current tectonic activity. In this elevated and actively eroding terrain, the regolith is younger and has a simple weathering history, which can explain why it represents the bedrock geology.

While both the Lake Victoria Goldfields and the Birrimian greenstone terrains of West Africa are within stable cratonic crust, the major difference in regolith expression in the EM is probably attributable to two factors: (1) northwest Tanzania is much more elevated and actively eroding, and (2) the phenomenon of landscape inversion in Mali. As is typical of erosion processes in the arid part of the West African Craton, resistive laterite formations in topographic lows become plateaus during topographic inversion. While the regolith itself is not more conductive than in other terrains, its longevity and particular history record successive and discordant drainage patterns with highly variable conductivity distributions that are unrelated to the bedrock, complicating the EM signal much more than in the Tanzanian case.

The case studies shown above illustrate the critical issue of understanding the regolith environment when choosing the type of EM system to use. With respect to geological mapping, younger regolith should be conducive to using shallow mapping systems. Older regolith will demand deeper penetration to escape the masking regolith signature. The extreme case of the arid Birrimian of West Africa requires an EM system that can return clean signals from very late times in order to map the bedrock geology.

ACKNOWLEDGMENTS

Resolute Mining Ltd kindly gave permission to use the VTEM data in Tanzania and Mali. Ken Witherly provided valuable input and reference material, and also suggested the spaghetti western theme.

REFERENCES

Butt, C.R.M., Lintern, M.J., and Anand, R.R., 2000, Evolution of regoliths and landscapes in deeply weathered terrain - implications for geochemical exploration, Ore Geology Reviews, 16, 167-183, DOI:10.1016/S0169-1368(99)00029-3.

Witherly, K., Irvine, R., and Morrison, E., 2004, The Geotech VTEM time domain helicopter EM system: ASEG Extended Abstracts 2004, DOI:10.1071/ASEG2004ab162.