Mapping and target generation in poorly exposed sub-tropical terrains: the application of heliborne VTEM and magnetic survey data in base metal exploration in the Central African Copperbelt

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SUMMARY

This study presents the result of an interpretation of heliborne electromagnetic (VTEM) and magnetic data over a base metal exploration tenement in the Central African Copperbelt in Zambia. The interpretation was based on several processed VTEM and magnetic grids, regional scale geological maps, geochemical data on soils and Landsat imagery. The electromagnetic responses in the VTEM or magnetic anomalies could not be ascribed directly to mineralisation. As a result, the identification and ranking of targets was based on the recognition of suitable geological conditions for base metal mineralisation rather than direct geophysical targeting.

Key words: Interpretation, VTEM, Magnetic, Base Metal, Zambian Copperbelt.

INTRODUCTION

The Central African Copperbelt is the largest and highest-grade sediment-hosted stratiform copper province in the world (Jackson et al. 2003). It includes the Zambian Copperbelt and the Congolese Copperbelt (in the Democratic Republic of Congo), which show different metallogenic characteristics and mineralisation styles. The study area is located in the “Domes Region” of the Zambian Copperbelt.

A heliborne electromagnetic (VTEM) and magnetic survey of 200 m line spacing was completed over the area by Geotech Airborne Ltd (Geotech), in 2008. Electromagnetic (VTEM) and magnetic data were interpreted in association with existing regional geophysical and geological data. The geological base maps used in this study include the 1:1,000,000 geological map of Zambia (after Thieme and Johnson, 1981) and a scan of the 1:100,000 map of the Mukubwe area (Keppie, 1994). A governmental regional aeromagnetic dataset was also provided. Landsat imagery and various alphanumerical data such as geochemistry, made available by Northcore Minerals Ltd., were also used.

METHOD AND RESULTS

Geological setting

The Cu-Co mineralisation of the Zambian Copperbelt is mainly hosted by the lower part of the Roan Group of the late Precambrian Katanga Supergroup. The geometry of the Katanga Supergroup has been controlled by the development of fold-and-thrust structures during the Lufilian orogeny, with a dominant transport direction toward the north-northeast.

Low-grade Cu-Co occur throughout the stratigraphy, but the principal interest within the lower part of the Roan Group in Zambia is the so-called Ore Shale Member contained in the Kitwe Subgroup (Figure 1), which together with some mineralisation in the footwall and hangingwall sandstone, hosts 70% of all known mineralisation in the Zambian Copperbelt. The Kitwe Subgroup becomes progressively more carbonaceous toward the top, and is overlain by the upper part of the Roan Group, comprising the Kirilabombwe and the Mwashia Subgroups, which record minor occurrences of copper mineralisation.

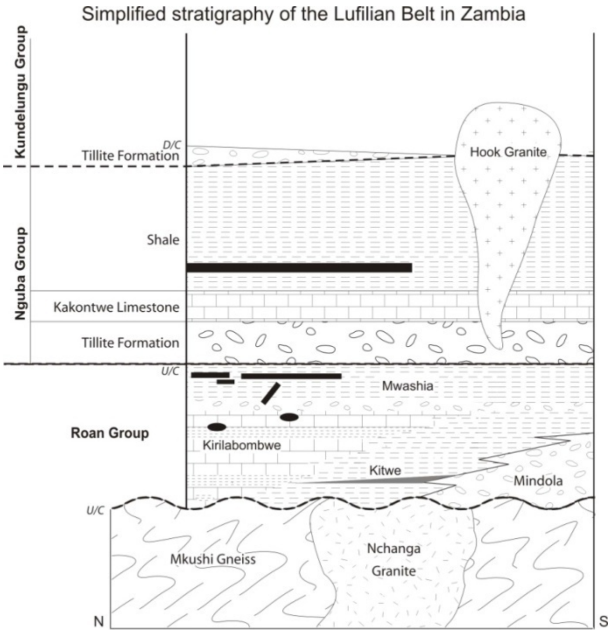

Figure 1 Simplified stratigraphy of Katanga Supergroup in Zambia (Johnson et al., 2007)

Finally, both the Frontier and Lonshi deposits in Zambia indicate that the Nguba Group, which unconformably overlies the Roan successions, can be considered an additional viable target for exploration.

Data and Methodologies

The geological interpretation is largely based on the interpretation of gridded aeromagnetic and VTEM data as well as Landsat satellite imagery. Based on the known stratigraphy and structures in the Zambian Copperbelt, a large part of the area is interpreted to be underlain by highly prospective the lower part of the Roan Group stratigraphy, mainly the Kitwe Subgroup.

Different Landsat image band-combinations were applied. Vegetation types grow on different soil types, thus the contrasts of colour in vegetated areas were used to help interpret some geological features. Slight differences in permeability and soil type, relating to underlying stratified rocks, often impart recognisable patterns in the imagery that were used to help constrain geological fabrics. Infrastructure such as farm industry and drainages were also identified.

The aeromagnetic data were reduced to pole, and further enhancements were applied to assist with the interpretation. The magnetic data indicate a low susceptibility zone in the centre, surrounded by variable high magnetic areas. The Kitwe Subgroup strata are characterised by a low magnetic anomaly, and are folded along a major regional fold with axis striking in NNE-SSW direction.

A 2D modelling technique was used to determine apparent dip and depth and improve the understanding of geological features. Tabular bodies were used to model contacts along interpreted thrusts. Even though such model solutions are non-unique and represent a single possible solution, they do help define the geometry of structural features.

Conductivity-Depth sections and conductivity contour maps at depth below the surface were generated by Geotech. The interpretation of VTEM was based on the contour grid showing the apparent conductivity at 50m, which showed the highest contrast levels and correlated well with the interpreted response at the greatest depth of 400m. Defined electromagnetic domains were identified, with the Kitwe Subgroup strata differentiated by very low conductivity.

Results

The lower part of the Roan Group, particularly the Kitwe Subgroup, does not show strong magnetic or electromagnetic signatures. In contrast, significant geophysical contrast exists with the Nguba Group and the upper part of the Roan Group owing to a wide range of geophysical response generated from alternating carbonaceous and clastic units.

Many contacts between the lower part of the Roan and both the upper part of the Roan and Nguba groups are structural in nature (thrusts) and therefore very sharp, and are clearly seen in the Landsat imagery, the magnetic and VTEM data, and in geochemical sample profiles (Figure 2). The Nguba Group in particular, displays a very different character on the Landsat imagery, in that it appears to support a vegetation with very different infrared absorption characteristics (Figure 2 C).

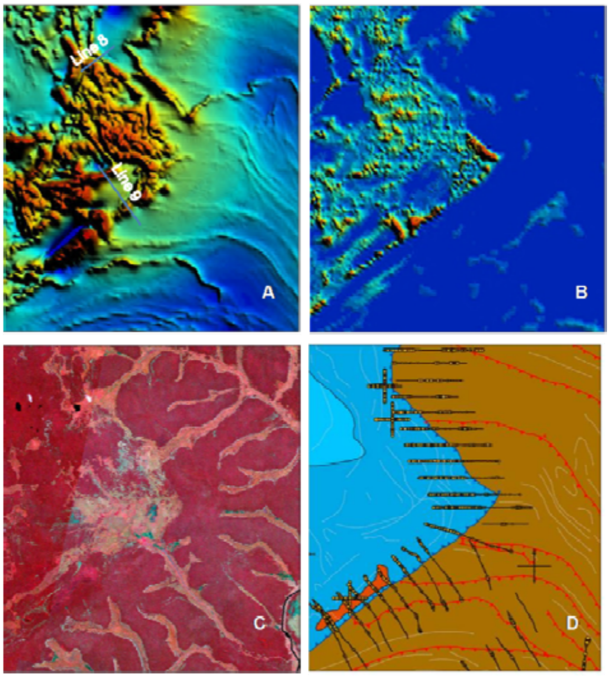

Figure 2: Illustration of the thrust contact between the lower part of the Roan Group and Nguba Group

Notes: (A) Aeromagnetic RTP; (B) 50m VTEM slice; (C) Landsat 432 RGB and (D) the geochemical data (Cu%) on top of the SRK interpretation. The brown colour represents the lower part of the Roan Group; the blue colours the Nguba Group. The red lines indicate imbricate thrusts within the lower part of the Roan Group and the grey lines are lineaments interpreted from the aeromagnetic data.

The magnetic data in the Nguba Group exhibit variable high magnetic, worm-like patterns (Figure 2 A). The inferred thrusts and layers in the lower part of the Roan Group are clearly truncated by these features and the contact is thus inferred to be a thrust. Two magnetic profiles were constructed across the inferred contact between the Nguba Group and the lower part of the Roan Group. These profiles are consistent with a west dipping thrust contact, although the dip angle steepened from the south to the north (line 9 to line 8) indicating that this structure is itself deformed and was steepened significantly.

The Nguba Group is also characterised by the presence of highly conductive materials which remain to be drill tested (Figure 2 B). In VTEM section, the structural break between the lower part of the Roan Group and the Nguba Group is also evident (Figure 3). In these sections, a thin, shallow conductor represents the water table, while a thick, deeper layer (up to 300m below the surface) records folded conductive rock in the Nguba Group. This deeper layer displays antiform-synform pairs which can be traced from one profile to the next.

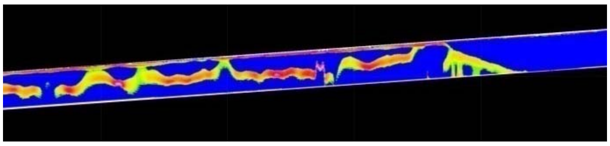

Figure 3: VTEM profile crossing the Nguba Group and the inferred contact with the lower part of the Roan Group

Notes: Northeast view of a VTEM section generated in Leapfrog© – Antiform-synform pattern are visible on the western side (Nguba Group) as well as a break in the signal within the Nguba Group, interpreted to represent a fault, and the loss of signature across the thrust contact.

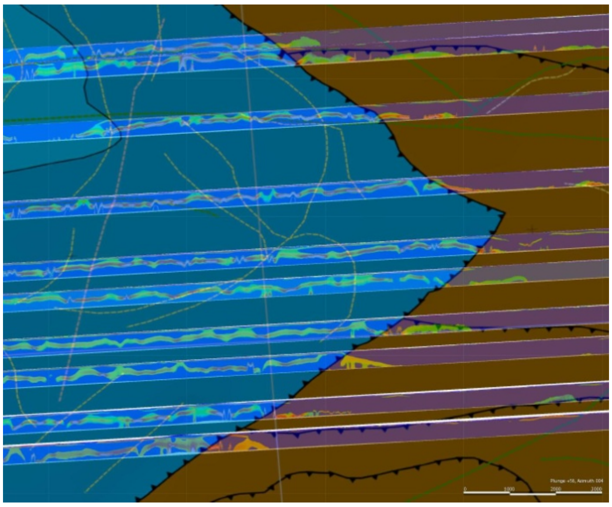

Figure 4: Correlation between the depth sections and the interpretation of the contact between the Nguba Group (blue) and the lower part of the Roan Group (brown)

Historical geochemical sampling transects (see Figure 2D) were originally designed to intersect the proposed contact between interpreted basement and lower part of the Roan Group. The geochemical data clearly support the various (newly) mapped units. Most of the samples were collected on what SRK reinterprets to be the lower part of the Roan Group. The geochemical data indicate that the upper part of the Roan Group and the Nguba Group have similar background Cu values, which are higher than the background in the lower part of the Roan Group. The geochemical profiles therefore clearly map out the contact between either lower part of the Roan and upper part of the Roan, or lower part of the Roan and Nguba Group.

Our final geological map, based on an integrated interpretation of new geophysical data with remote sensing and historic work, redefines the structural models for the region and contacts between the geological units (Figure 5).

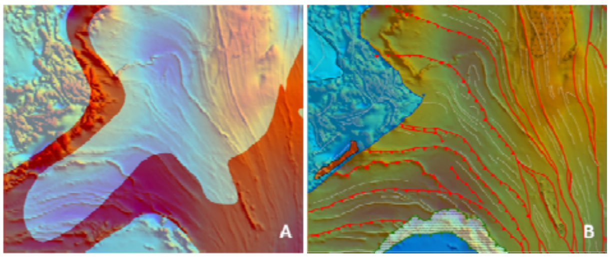

Figure 5: Improvement of the geological understanding of the area using an integrated approach

Notes: (A) Geological interpretation from earlier explorers; and (B) SRK interpretation

CONCLUSIONS

An integrated geological interpretation of heliborne VTEM and magnetic data has provided a dramatically improved geological and structural understanding of the study area. Our new geological map suggests that the area is largely covered by sedimentary units of the lower part of the Roan Group. Numerous major structures, mainly thrusts in the lower part of the Roan Group, could have provided suitable pathways for the migration of base metal-bearing brines during the Lufilian Orogeny.

However, no significant electromagnetic signatures were found within the lower part of the Roan Group. This may be due to (1) the Ore Shale Member not being present in the area; (2) the Ore Shale Member, although present, being too thin, or insufficiently mineralised to yield a detectable electromagnetic response or (3) mineralisation in the Ore Shale Member or at other levels of the stratigraphy are too deep to be detected by VTEM. Nevertheless, conductive targets have been detected outside of the lower part of the Roan Group providing suitable geophysical targets for further testing.

ACKNOWLEDGMENTS

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