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Regional AEM Survey in NE Namibia

G. Peters
International Geoscience
8 May Ave Subiaco, WA 6008
Australia
gpeters@intergeo.com.au

G.J. Street
International Geoscience
8 May Ave Subiaco, WA 6008
Australia

I. Kahimise
Geological Survey of Namibia
Private Bag 13297
Windhoek Namibia

D. Hutchins
Geological Survey of Namibia
Private Bag 13297
Windhoek Namibia

SUMMARY

Regional surveys using the TEMPEST[208] airborne electromagnetic system were acquired for the Geological Survey of Namibia in 2011. The TEMPEST[208] is the lowest cost airborne electromagnetic system available currently worldwide and was selected to test a cost-effective means of covering the country with AEM and particularly to map thickness of the Kalahari Sequence to open new areas for mineral exploration.

This review of the data acquired showed that;

- The TEMPEST[208] system did have some noise problems but significant improvements could be achieved with minor system modifications.
- TEMPEST[208] can map areas of thin (0-60m), to medium (~100m) and thick cover (>150m) Kalahari Sequence. In areas of thin cover, conductors can be detected in the underlying basement. In areas of medium cover an estimate of thickness of the Kalahari (with LEI) is probably possible but in areas greater than 150m the system generally did not appear to detect the base of the Kalahari.
- Comparison with detailed surveys done with standard TEMPEST and VTEM shows that TEMPEST[208] detected most of the features seen in surveys by the more sophisticated system.
- The data will be useful for explorers selecting best areas for exploration particularly where the Kalahari Sequence is less than 60m.

Key words: Namibia, airborne electromagnetic system, mineral exploration, TEMPEST.

INTRODUCTION

As part of the Namibian Governments program to encourage mineral exploration a regional airborne electromagnetic survey (AEM) was carried out in far north-east corner of Namibia during 2011. The survey area includes a large portion covered by the Kalahari Sequence which has precluded most mineral exploration to date.

The survey was acquired with the Fugro Airborne Surveys TEMPEST[208] (Fugro, 2012) fixed wing electromagnetic system, as a regional-scale survey with widely spaced long lines and high total line kilometres (Figure 1). The TEMPEST[208] system is the lowest cost time domain airborne electromagnetic system available currently worldwide and was selected to test a lower cost means of covering the country with AEM and particularly to open new areas for mineral exploration by mapping the thickness of the Kalahari Sequence.

The key objectives of the project were:

1. Assess the effectiveness of the AEM system in terms of:

i. Determining the thickness of the Kalahari Sequence; and
ii. Detecting bedrock conductors beneath the Kalahari Sequence.

2. Assessing the survey specifications in terms of:

i. Instrumentation/AEM System – was the chosen system the appropriate one to use for the survey objectives?
ii. Line spacing – was the line spacing that was chosen appropriate for achieving the survey aims? What advantages will closer line spacing bring for future surveys?
iii. Compare the results with VTEM and TEMPEST data from smaller surveys within the regional survey block.

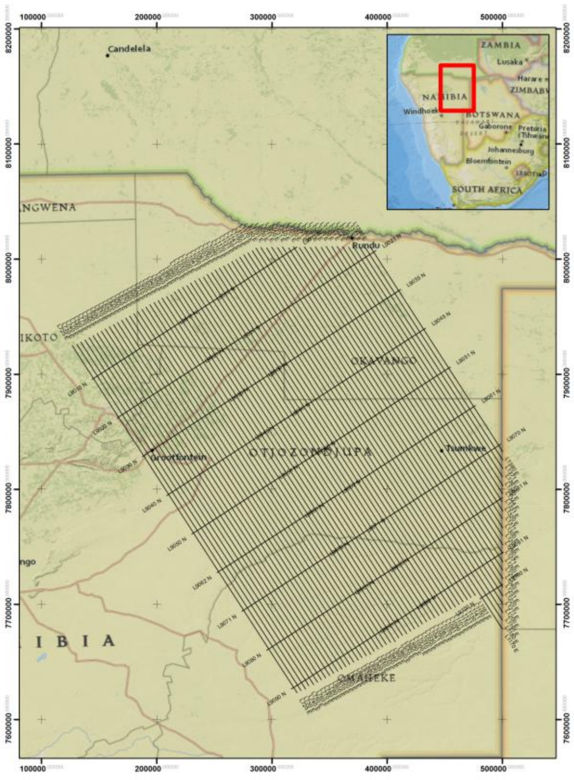

Figure 1. Location of survey area in NE Namibia showing 4km spaced flight lines and 40km tie lines. .

GEOLOGY

Kalahari Sequence

Much of the survey area is covered by the Kalahari Sequence, ranging in thickness from two to greater than 200 metres.

Where the sequence is thick, mineral exploration is challenging due to uncertainty about the underlying bedrock type and prospectivity. As such, the main aims of the survey were to determine the thickness of the Kalahari Sequence, the underlying bedrock rock-type and to detect discreet bedrock conductors.

The Kalahari Sequence is mainly composed of sand and probably resistive, though no downhole conductivity logs are available. Water well logs indicate one or more layers of material logged as "loam" or "clay" which could provide enough conductivity contrast against the dry sands to show up as distinct layers in CDI's. Conductivity contrasts may also be caused by changes groundwater saturation and salinity. Qualitative water-well logs listed a range of water qualities ranging from "fresh" to 'salty".

Basement geology

The Damara Sequence outcrops in the northwest of the survey ridges as long strike ridges. For the rest of the area information on basement geology can only be provided from logs of water wells which are very limited in detail. In many cases the water wells terminate in the Kalahari Sequence. Where the wells penetrate into bedrock the logs show mostly rocks of the Damara Sequence dominated by quartzites and schists. Dolomites, schists, phyllites and granites are less common. Rocks of the Grootfontein Complex are encountered in a few wells in the east of the survey area. Rock types of the Grootfontein Complex include weathered basalts and granites.

SURVEY DESIGN AND SPECIFICATIONS REVIEW

A fixed wing system was chosen due to the size of the survey and the long length of the lines. Helicopter-borne systems have a much higher unit cost and are unable to acquire the long lines of 400 km in a single sortie. The TEMPEST^{208} system based on a single-engine aircraft has a low acquisition and mobilisation cost. It is limited for mineral exploration by the low moment and relatively high base frequency of 75Hz, which limits the decay measurement time to 5.7 milliseconds (centre of last channel).

SURVEY RESULTS

Data that was received from the Fugro Airborne Surveys included processed AEM data and conductivity depth images (CDI). Further data processing was not carried out.

Ternary EM Image

A ternary image (Figure 2) allows a qualitative overview of the regional electromagnetic (EM) responses and interpretation of various geological domains based on EM response.

Strong single colours in the ternary image indicate that the higher amplitude responses are concentrated within narrow bands in the EM decay. Blended pale colours indicate high amplitude responses in all (late, middle and early) channels while dark colours indicate low amplitude responses in all channels.

Late, middle and early times qualitatively translate to deep, intermediate and shallow parts of the geology. This relationship breaks down in extremely conductive areas where the EM signal is effectively absorbed by the conductive materials and the depth of investigation is significantly reduced. Therefore, a high amplitude late time response in a conductive area relates to material at a shallower depth than the equivalent late time response in a more resistive area. Any interpretation from EM channel responses is therefore qualitative.

The survey area was divided into sub-regions based on the EM response amplitudes at early, middle and late times (Figure 2). The areas in which the deeper conductors dominate the response, in otherwise resistive geology, show up as reddish zones. Notable are the area in the north-west and the east-west trending zone in the south of the survey area.

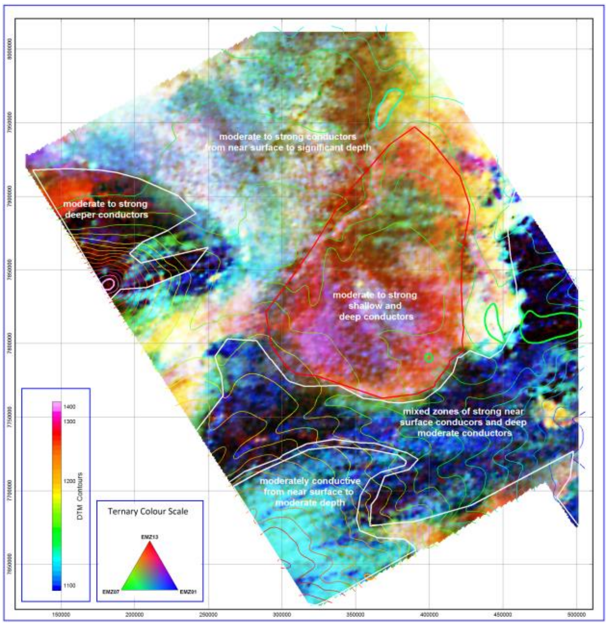

Figure 2, A ternary image of AEM results overlain by digital terrain model (DTM) contours. Sub-regions of different response are indicated.

Results over Kalahari Sequence

Four water-well logs were compared with the TEMPEST^{208} CDI data. The chosen logs were within 200 metres of a survey flight-line, and therefore should have better depth correlation with the CDI's in comparison to holes further away from the flight-lines.

Apart from the deeper clay and "loam" layers present in many holes there is little logged variation in the Kalahari Sequence other than some sand dominated intervals reported as being more or less "calcareous" than neighbouring intervals. This minimal variation appears to be reflected in the CDIs over thicker Kalahari Sequence (Figure 3).

There is no definitive correlation between cover/basement lithologies and conductivity contrasts seen in the CDI's. As such, groundwater saturation and salinity were considered to be likely cause of conductivity contrasts. Based on these observations, the groundwater appears to control the vertical conductivity contrasts seen in the CDI data more than the geology. The well logs are lacking in detail and a more logical interpretation is a zone of increased moisture lies at the bedrock interface probably in a zone of weathered rock. The CDI depths cannot be used quantitatively and compared from area to area.

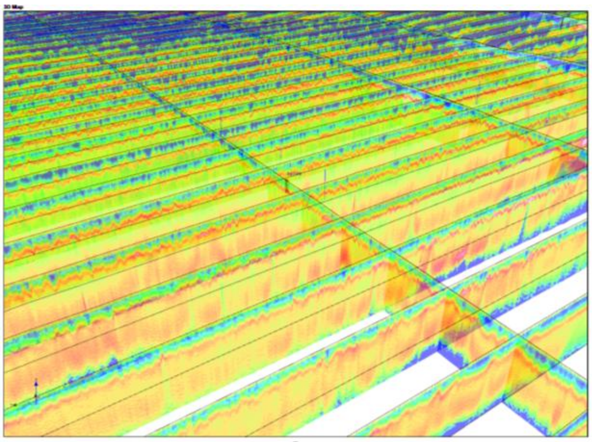

Figure3: 3D perspective viewed from the west of the area comprised of thick Kalahari sediments – note that the CDI's show moderate to strong conductivities at all depths

The offset between the groundwater heights and the resistive / conductive contrast in the CDI appears to be in the order of 20 – 50 metres and is apparent in all of the examples shown. A 1D layered earth inversion algorithm provides a more accurate control on conductivity variation with respect to depth than CDI's and some 1D layered earth inversions (LEI) are recommended.

Conductivity logging of some of the deeper wells would greatly assist in calibration of the depth transformation used in the LEIs, and would help to establish relationships between the vertical conductivity variation and down-hole changes in geology, groundwater levels and salinity.

COMPARISON WITH OTHER AEM SYSTEMS

A qualitative comparison was carried out with other AEM systems flown in detailed surveys within the regional TEMPEST^{208} survey.

VTEM

A VTEM heli-borne EM survey was carried out at Maroelaboom within the TEMPEST survey area. The line spacing was 400 metres, so at much greater level of detail than the 4 kilometre spaced TEMPEST data.

A large amplitude anomaly which is crossed by both TEMPEST^{208} and VTEM flight lines is annotated "A" in Figure 4. Because the anomaly is traversed in both datasets, it allows for a comparison of decays from soundings directly over the anomaly (Figure 5). The decays shown feature only the late time gates. The VTEM decay shows 8 gates spanning a 5.5 millisecond interval from 2.3 – 7.8 milliseconds, while the TEMPEST208 decay shows 5 gates spanning a 4.6 millisecond interval from 1.1 – 5.7 milliseconds.

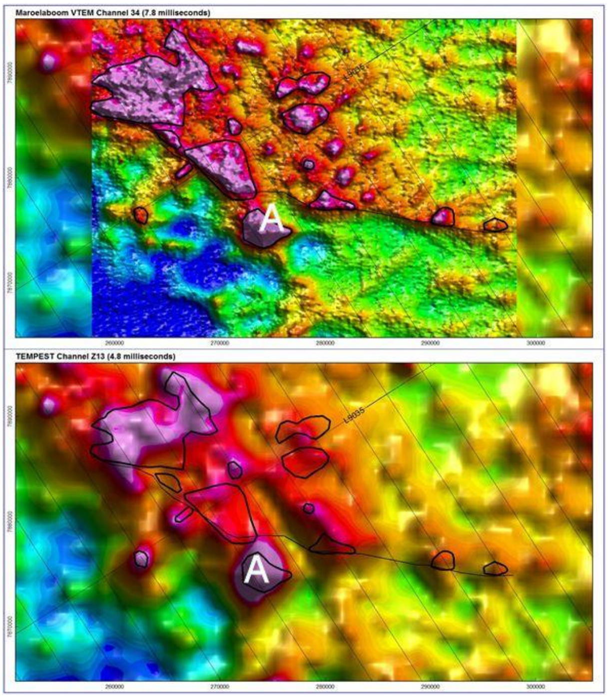

Figure 4: (Top) Late-time Z-component channel 34 grid from the VTEM survey with polygons around conductors. (Bottom) Late-time TEMPEST^{208} Z-component (Ch13) grid with the VTEM conductors overlaid. TEMPEST^{208} flight lines and Anomaly "A" are annotated on both images.

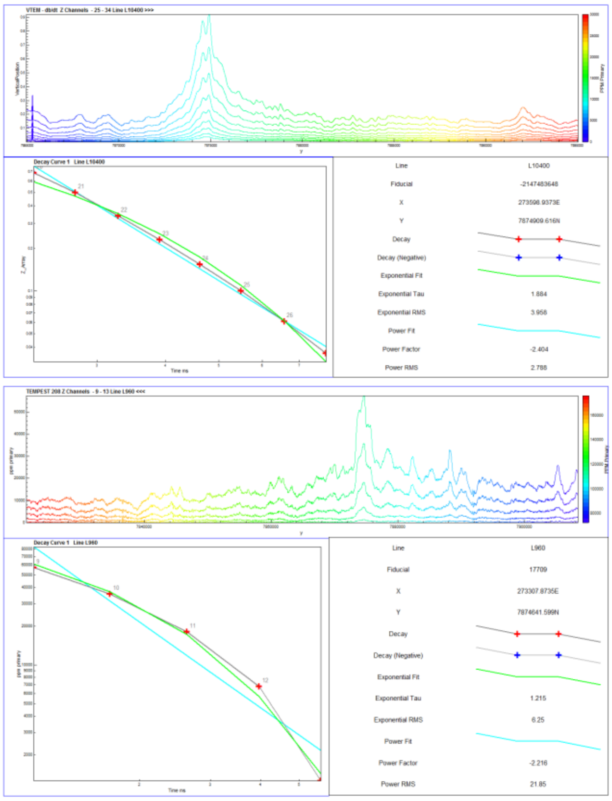

Figure4: (Top) - Profile and Decay curve from a VTEM traverse over anomaly (A); (Bottom) - Profile and Decay curve from a TEMPEST^{208} traverse over anomaly (A)

CONCLUSIONS

From correlation of EM with the limited available well-log information, it is apparent that certain basement lithologies can be recognised on the basis of their conductivity. However, there are large areas with little to no available log information. In addition, many holes are only drilled to shallow depth. As such it is not possible to comprehensively classify each basement type in the survey area.

The TEMPEST^{208} survey was successful in achieving many of the aims of the North West Namibia survey including:

- mapping the extent of relatively shallow bedrock where drilling of targets will be relatively cheap;
- giving an indication of the thickness of cover overlying bedrock up to a depth of 100 metres;
- mapping out the areas where Kalahari cover is very thick and exploration will be difficult; and
- detecting some bedrock conductors in the basement;
- Areas where the TEMPEST208 has shortcomings include:
- data was noisy due probably to changes in system geometry;
- bedrock conductors were not detected where there was thick Kalahari Sequence cover, however it appears that even more powerful airborne EM systems did not penetrate the thicker cover;
- the short measurement time of the secondary field and low number of sample gates made analysis of decays difficult. Therefore it was difficult to distinguish between bedrock and regolith responses; and
- the widely spaced traverse lines will not detect many short strike length anomalies that may be potential mineral targets.

REFERENCES

Fugro, 2012. Geological Survey of Namibia Large Scale Airborne TDEM mapping over NE Namibia – TEMPEST208 Case Study. Fugro Airborne Surveys South Africa.