

Geological Applications for FTMG

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ABSTRACT

The geological applications of the Full Tensor Magnetic Gradiometer, or short "Mag SQUID", are manifold. At a similar resolution to the commercially available high-resolution aeromagnetic surveys, the Mag SQUID provides vector data and information on remanence. The vector data is of high importance as it may allow a better 3D modelling of magnetic bodies such as kimberlites, dykes and iron-rich ultramafic replacement pegmatitoids (IRUPs). In the data one may detect mineralisation directly, but the information can also be used to sense negative structural interferences with the mining process such as dykes and IRUPs (hazard zones). Further we expect to detect weaker magnetic features, e.g. the so-called non-magnetic dykes in the Mpumalanga coalfields. The anticipated information on remanence is required for enhanced anomaly discrimination and determination of age of intrusive or alteration events.

Finally there is a financial incentive as the flight lines do not have to be so tightly spaced in order not to miss an anomaly. The high oversampling rate (1000 Hz data) together with the vector mapping should avoid any targets or magnetic sources being missed at wider line spacing.

Anglo Technical, together with the support of the individual business units De Beers, Anglo Platinum and Kumba, has over the last 5 years tested, researched and developed an airborne system together with our partners IPHT in Jena, Germany.

Key words: Mag SQUID, vector data, 3D modelling, magnetics.

INTRODUCTION

Today the acquisition of airborne magnetic data is a standard procedure for every Brownfields and Near-Mine exploration exercise. If not yet, then at least it should be. It is a relatively inexpensive data set to acquire when compared to other airborne geophysical surveys, e.g. EM or gravity. At least for the PGE exploration of Anglo Platinum, aeromagnetic data has substantially contributed to the understanding of dykes and Iron-rich ultramafic replacement pegmatitoids (IRUPs) which are hazardous when mining in the vicinity. Furthermore, the magnetic data is a vital complement to the 3D Seismic surveys, as the latter does not show any magnetic features. After acquisition, the airborne data then needs to be modelled, inverted, and projected down to the imaged horizon shown by the 3D Seismics, e.g. the UG2 as the best reflector in the Critical Zone of the Rustenburg Layered Suite. Once combined, these two datasets form a powerful structural model of the orebody with a high confidence level as required by SAMREC.

In Anglo American we wanted to improve on the currently available magnetic data quality and its interpretation and have therefore embarked on an R&D project which aims to improve the sensitivity of the

magnetic sensors. The SQUID technology enables us to do exactly that by an order of magnitude. . Cryogenic magnetometers operate at the temperature of liquid nitrogen and detect magnetic field changes by means of a superconducting loop exhibiting zero resistivity and containing one or two Josephson junctions.

METHOD AND RESULTS

Once cooled down to -269°C inside the cryostat, the SQUIDS become superconductive. In laboratory conditions the magnetic SQUIDS show extremely high signal to noise ratios with intrinsic noise levels between 1 and 2 fT/ $\sqrt{\text{Hz}}$. The Institute for Photonic Technologies (IPHT) in Jena, Germany builds such systems, and Anglo American signed a partnership in January 2007.

As early as 2006, Anglo together with IPHT tested the system over several areas in southern Africa and over several commodities. De Beers and Anglo Platinum were early sponsors of the R&D program and Anglo Platinum's Styldrift project area was the preferred test site for many sorties throughout the years.

Styldrift, a PGE exploration concession adjacent to the neighbouring BRPM mine, has several advantages. Firstly, Spectrem Air Ltd manages the test flights owing

to their long-standing experience with airborne surveys. Spectrem is based at Lanseria, and hence the mobilisation to Styldrift is short.

Secondly, Styldrift contains a whole range of different lithologies related to diverse stratigraphies. Apart from lithologies of the Rustenburg Layered Suite, we find the Bushveld-bounding sediments of the Transvaal Supergroup, the in- and extrusive volcanic rocks of the Pilanesberg, many dykes of various generations and IRUPs, and kimberlites together with faulting in addition to these lithologies. Faulting cannot be directly detected by magnetics unless the fault is filled with magnetic material. However, displacements of magnetic continuities can be inferred as faulting.

The first SQUID magnetometer results from Styldrift (2004 + 2005) compared well with the Midas surveys flown in 2002 and 2003. Dykes and IRUPs showed well in the images of the various gradients (Figure 1), however the noise levels were unacceptably high. The resolution also needed some improvement, but that was mainly due to the flight height of 80m (fixed-wing) compared to 30m of the helicopter survey. Once the Midas data was upward continued to the height of the SQUID sensor, the SQUID data compared well with respect to resolution (Figure 2). This was highly encouraging

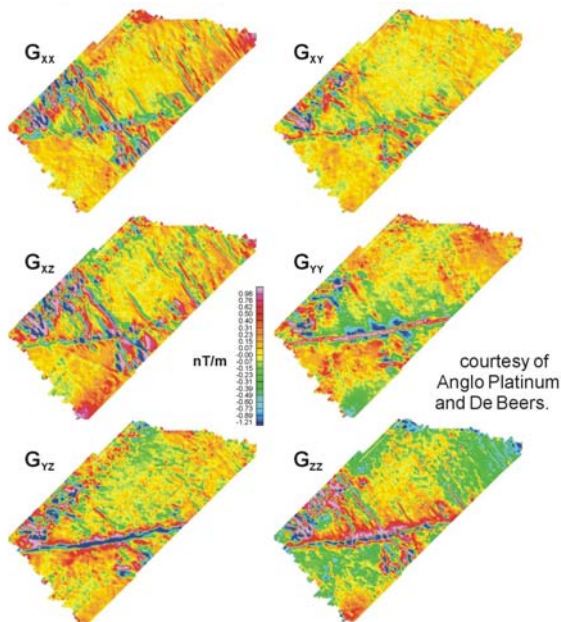


Figure 1. First test flight results over Styldrift, Anglo Platinum showing six different gradients with different results.

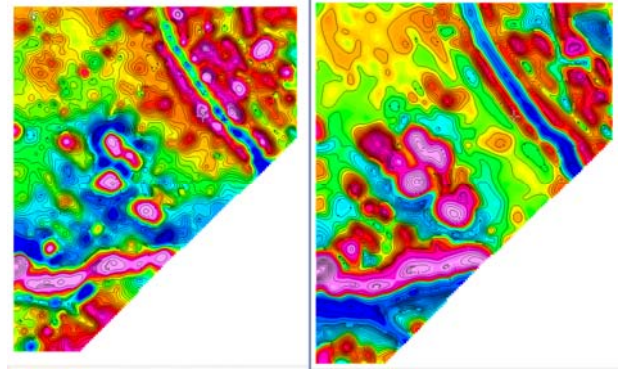


Figure 2. SQUID Tzz (left) and upward continued Midas survey (right) compares well in resolution.

The following years were defined by fine-tuning the system, improving the actual SQUID mounting and an attempt to fly a more stable platform and above all, to fly lower. Flying low is probably the most important aspect of a successful system as the signal increases dramatically (inverse cube law). The current configuration exhibits a tow bird suspended under a helicopter with a 40m tow rope (Figure 3). Signal transfer is wireless.

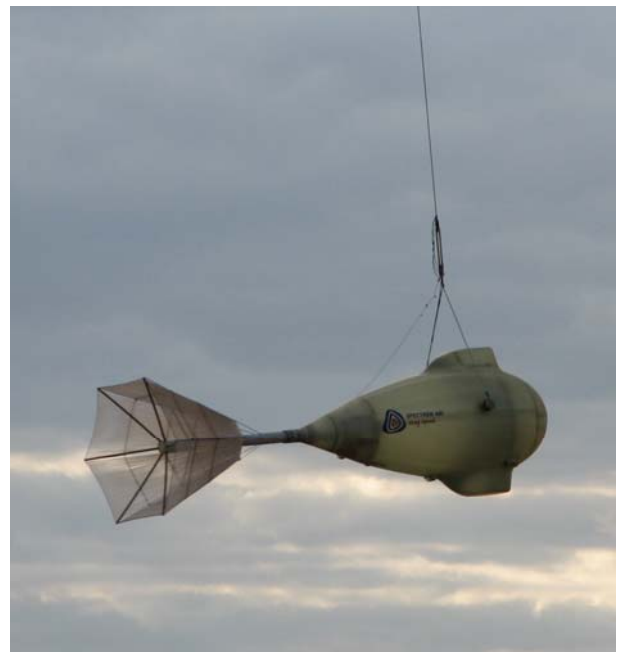


Figure 3. Current towbird arrangement, suspended on a 40m rope. Data transmission is wireless.

Successes and setbacks have been omnipresent over the years, and new solutions had to be developed all the time. Particularly noise problems dampened the spirit, initially being an order of magnitude too high. Under laboratory conditions little noise was experienced, however, once airborne several noise sources come into play.

The mounting of the SQUIDS is the first source. In the mean time IPHT has improved the arrangement from

the initial configuration to a more rigid mounting which results in less movement of the SQUIDs relative to each other. It has to be born in mind that the substrate is exposed to -269°C and as a result becomes highly fragile.

The second noise source the tow body itself and its movement relative to the Earth's magnetic field and vibrations. In 2007 we developed the towbird displayed in Figure 3 from its predecessor (Figure 4). Even though the predecessor was tested in the wind tunnel at CSIR in Pretoria, the upright cylindrical design of the system proved to have poor aerodynamic qualities. The current tow bird has better characteristics and recent tests showed that the anticipated $10\text{pT}/\text{m}/\text{Hz}$ have been approximately achieved.



Figure 4. Predecessor towbird which proved not to be very aerodynamic in the wind tunnel. L. Polomé for scale.

Once noise levels had been reduced as much as practically possible, the next solution was to increase the signal. Initial tests starting in 2004 used a 95m long rope. Subsequently this has been reduced to 40m. This is possible through the usage of “de-magnetised” helicopters. Of course the noise of the helicopter will interfere with the signal. A 40m tow rope allows us to fly the tow body very close to the ground, depending on terrain, yet far enough away from the helicopter with respect to noise levels.

In 2006 we achieved an early success during a reliability test at Der Brochen, an Anglo Platinum exploration area in the Eastern Bushveld. Figure 5 exhibits the improved resolution when compared to the

commercially available magnetic survey, which was flown in 2002.

A further success was the direct detection of the individual dipoles in the Chaneng dyke and surrounding IRUPs at Styldrift utilising the recorded vector data of two adjacent flight lines. Once this detection is visualised in 3D, we will in future be able to model magnetic bodies from the intersection of the vectors (Figure 6).

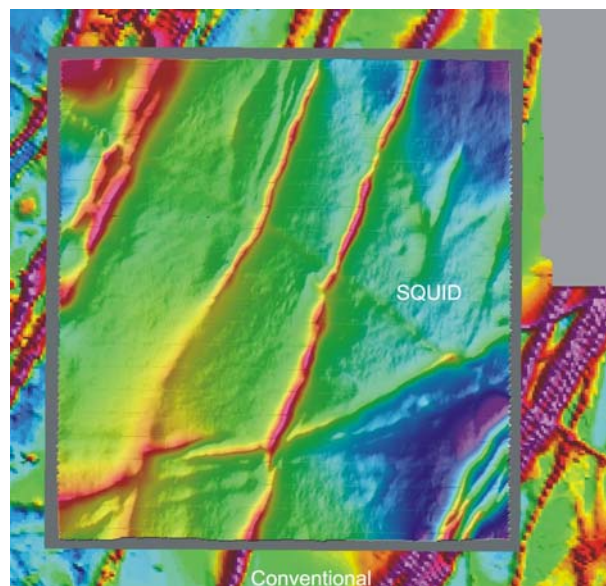


Figure 5. Excerpt of the Der Brochen magnetic survey and the SQUID survey overlain in the centre. Dyke swarms display a much higher definition and can be resolved individually on the SQUID data.

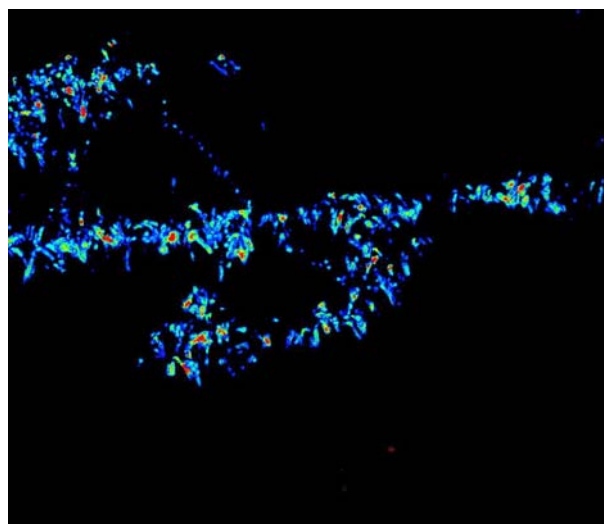


Figure 6. Intersection of vectors aiming at dipoles in the Chaneng dyke and at IRUPs at Styldrift. The warmer the colours, the more intersections of vectors.

Iron-bearing minerals such as magnetite may record past orientations of the Earth's magnetic field.

Preservation of this Palaeo-magnetisation (remanent magnetisation) contains key information on historical polar wandering. This allows reconstructions of Palaeo-continental figuration and plate-tectonic movements. The high-sensitivity FTMG will yield information on remanent magnetism. Hopefully this will permit the more accurate modelling of the 3-dimensional geometries potential ore bodies.

Mapping of remanence is an important aspect of the full tensor magnetic interpretation. It will produce maps that relate to a physical property that cannot be measured with any degree of precision using existing total field magnetic methods. Remanence provides a physical property that has significant importance in diamond, gold, platinum and base metals exploration (D. Pratt, pers. comm.).

FUTURE WORK

The test results achieved so far have encouraged us to continue and bring our R&D program to a successful conclusion. Subsequently we will roll out the technology into the business units of Anglo American and De Beers. The results should assist exploration to find ore bodies. In other cases the results should predict mining hazards such as dykes and IRUPs before mining takes place.

Additionally we anticipate better geological mapping results such as possible grade mapping of iron -bearing lithologies as a result of varying susceptibility.

Furthermore, we would like to reduce the flight height and consequently increase the signal and subsequently the signal to noise ratio drastically (inverse cube ($/R^3$)).

Therefore we have to establish the increased noise level due to the helicopter and find ways to filter it.

A possible cost saving is indicated by a widened flight line spacing. The high oversampling rate of the SQUID should ensure that any magnetic bodies will be successfully detected even with an increase in line spacing.

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ADDITIONAL REFERENCES AND RECOMMENDED READING

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