Results of an Integrated Helicopter ZTEM-Gravity-Magnetic system test survey over the Vredefort Dome Structure, South Africa.

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SUMMARY

In 2016, Geotech completed a test of a helicopter-borne GT-2A gravimeter combined with ZTEM™ (Z-Axis Tipper Electromagnetics) and aeromagnetic towed bird system over the Vredefort Dome impact structure in South Africa. The survey consisted of nine (9) approx. 70 km long NW-SE oriented flight lines, totalling 640 km, acquired at a nominal spacing of 500 m over an area of approximately 650 km^2. The successful test demonstrates the feasibility of integrating density measurements using airborne gravimetry on a helicopter platform while combining the superior depth of investigation of ZTEM™ and aeromagnetics for regional geophysical survey applications.

Key words: Airborne, ZTEM, Magnetic, Gravity, Vredefort, case-study.

INTRODUCTION

Geotech has been flying the helicopter ZTEM™ (Z-axis Tipper Electromagnetic; Lo and Zang, 2008) natural field AFMAG (Labson et al., 1985) EM system commercially since 2007, and it has proven a most effective resistivity mapping technology with a large depth of investigation, exceeding 1km. Recently the integrated ZTEM and magnetic towed-bird receiver for fixed wing aircraft (Legault, 2012) has been adapted for use with a helicopter platform (Figure 1) and, by virtue of its lighter weight and aerodynamic properties, allows it to be flown at higher rate of speed thus improving its line-km efficiency. Additionally, the caesium magnetometer's location inside the EM bird (Figure 1), being lower to the ground, greatly improves its sensitivity to geology. Furthermore, since the ZTEM towed loop receiver does not transmit any EM signal, it also provides a low-noise platform for magnetic data acquisition, superior to both time- and frequency domain transmitter-receiver EM systems, as well as fixed-wing stinger magnetometer systems that also require removal of aircraft-induced effects. A combined ZTEM-Magnetic towed-bird system has been deployed in a recent fixed-wing ZTEM regional survey targeting bedrock below Kalahari sand cover in Namibia (Venter et al., 2015).

As part of an integrated geophysical system development, the helicopter ZTEM^{TM} -magnetometer towed-bird system has been successfully paired with the GT-2A airborne gravimeter on-board an Astar AS350-B3 helicopter platform, which is most commonly used for mineral exploration AEM surveys. The nature of the plane waves measured by the ZTEM™ system makes it relatively insensitive to flying height above the terrain relative to other active heli-EM systems (Sattel and Witherly, 2012), thus also making it an ideal pairing for airborne gravity measurements acquired at a fixed altitude to minimize turbulence. The resulting integrated helicopter ZTEM-gravity-magnetic system allows for concurrent measurements of resistivity, density and magnetic susceptibility properties, providing a relatively powerful, multi-parameter and deep investigation geophysical mapping capability for regional survey applications. To showcase the advantages of this integrated survey platform for regional mapping, we present a successful survey test over the well-known Vredefort Dome Structure (Lana et al., 2003) in South Africa, which has been extensively surveyed using geophysical methods; most notably airborne gravity-gradiometry (Cowan and Cooper, 2009; Martinez and Li, 2010).

Vredefort Geology

The Vredefort Dome Structure is a complex impact structure with a diameter of ~80 km located in the Kaapvaal Craton, the result of a large meteorite impact 2.02Ga ago (Cowan & Cooper, 2009), as evidenced by shock metamorphism and impact-melt breccias. The central Dome's 40-km wide core is comprised of high-grade mid-Archean migmatitic gneiss of 3.1-3.2Ga, from 25 to 36km thick, thus potentially exposing the paleo-Moho at its centre (Lana et al, 2003). Phanerozoic sediments and dolerite sills obscure the dome to the south and southeast.

METHOD AND RESULTS

ZTEM-Gravity-Magnetic System

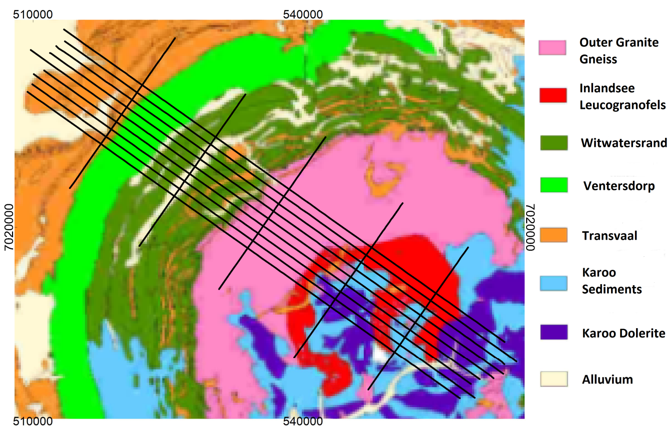

Figure 1: Vredefort Dome test survey lines overlain on surface geology (after Cowan and Cooper, 2009).

Figure 2: Helicopter ZTEM™-Mag-Gravity system installation.

A GT-2A airborne gravimeter, manufactured by Canadian Micro Gravity (Aurora CAN), is installed in the AS350-B3 helicopter cabin (Figure 2a), along with the Geotech Data Acquisition System. The integrated ZTEM™ and caesium-pumped magnetometer towed bird receiver (Figure 2b) is flown at a nominal 82 m distance below the helicopter as shown in Figure 3. A fixed survey height of 1825 m above the Geoid was set to minimize the effects of vertical movement on the gravimeter, safely above the highest terrain in the test area with the ZTEM™ sensor 110-420 m above the ground. Without the need to contour the terrain, flight speed is increased to 130km/h, 30 km/h faster than a standard ZTEM™ survey, with similar helicopter endurance and flight length.

ZTEM-Gravity-Magnetic Survey Results

The integrated helicopter system test was flown over the northwest side of the Vredefort Dome (Figure 1), near the towns of Vredefort, Potchefstroom and Parys (Figure 4), South Africa, approximately 12.0 km southwest of Johannesburg. Nine 70-km lines were flown at a spacing of 500 m oriented N 135° E, as well as five 20 km-long tie lines flown orthogonal at a spacing of 10,000m.

The airborne gravity and aeromagnetic data (Figures 4a and 4b) that were collected simultaneously with the heli-borne ZTEM™ data (Figure 4c and 4d) show excellent correlation with previously-acquired data over the Vredefort dome structure. This includes the gravity and magnetic highs in the central Dome region, and the ring-like anomaly signatures that extend outward, as shown. Figures 4cd present the ZTEM tipper data, displayed as the Total Phase Rotation (TPR; Legault et al., 2012), at both high and low frequencies, giving a sense of relative depth of investigation, according to EM skin depth rules. In spite of possible topographic artefacts (Sattel and Witherly, 2012), the differences in the two TPR signatures are noticeable; in particular the higher frequency (shallow depth) ZTEM results (Figure 4c) that are relatively low amplitude and likely reflect the lack of lateral resistivity variation in the near surface; whereas at lower frequency (Figure 4b) tipper data display relatively strong tipper response that indicate strong lateral resistivity variations at greater depth. Higher relative conductivities (warm colours) near the centre and also the northwestern edges correspond to mapped Karoo and Transvaal sediments, respectively (see Figure 1).

Gravity Repeat Lines

Four passes were made of L1040, in the centre of the survey area, to demonstrate the repeatability of the gravity measurements when installed with a ZTEM™ system. A 150-second Kalman filter was applied to counteract aircraft movement and turbulence. Overlapping profiles of each pass are shown in Figure 5. The RMS error between the repeat passes is 0.70 mGal.

CONCLUSIONS

Geotech conducted a successful test of a combined helicopter Gravity-Magnetics-ZTEM™ system over the Vredefort Dome in South Africa. The results demonstrate that high quality gravity measurements can be made concurrently with helicopter-borne ZTEM™ and magnetics, integrating density measurements as a valuable multi-parameter and deep penetrating geophysical mapping tool. The resulting integrated helicopter EM-Grav-Mag system is ideally suited for regional geophysical mapping applications .

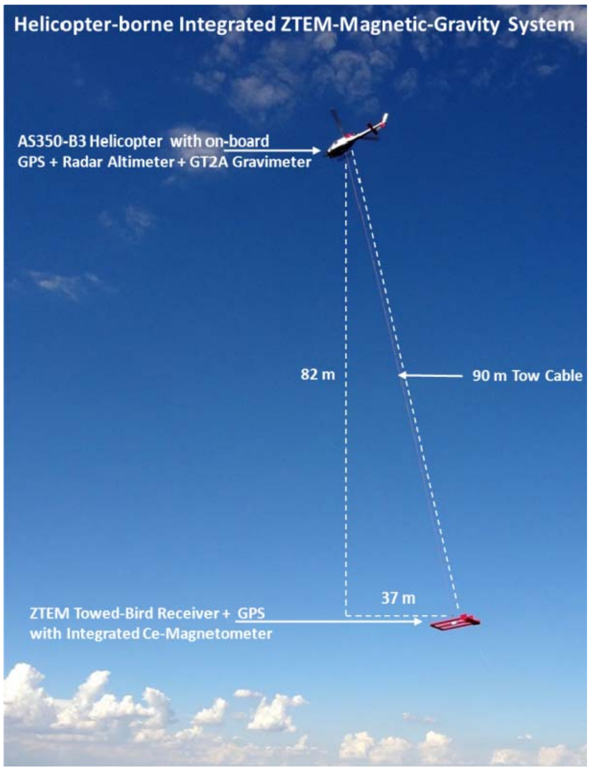

Figure 3: Helicopter ZTEM™-Grav-Mag system in flight.

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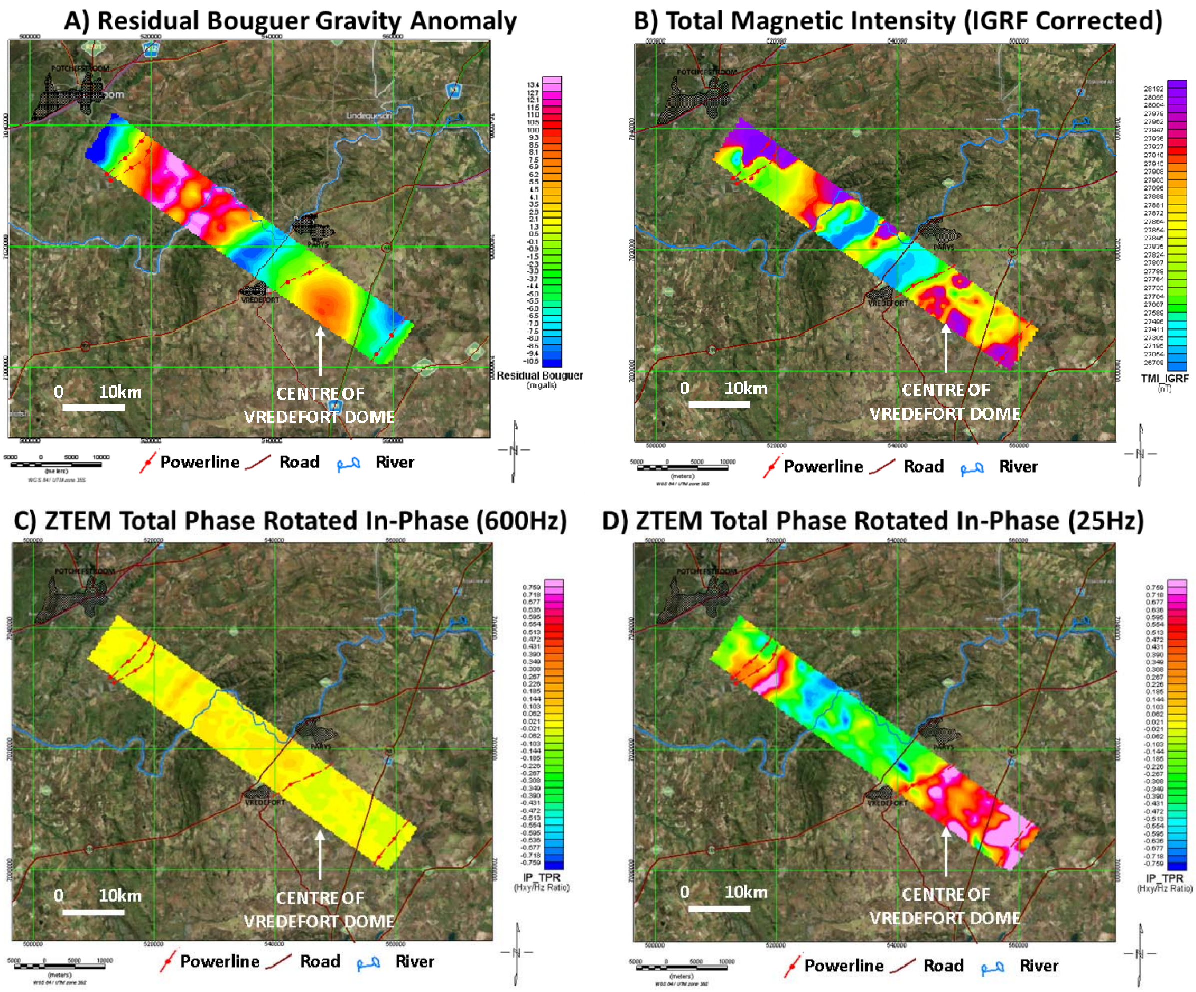

Figure 4: Helicopter ZTEM-Gravity-Magnetic survey results over Vredefort Impact Structure: a) Residual Bouguer Gravity Anomaly, and b) Total magnetic intensity (IGRF-corrected), c) ZTEM total phase rotated (TPR) In-phase tipper at 600Hz, and b) In-phase TPR at 25Hz, multi-parameter responses extending away from centre of Vredefort Dome.

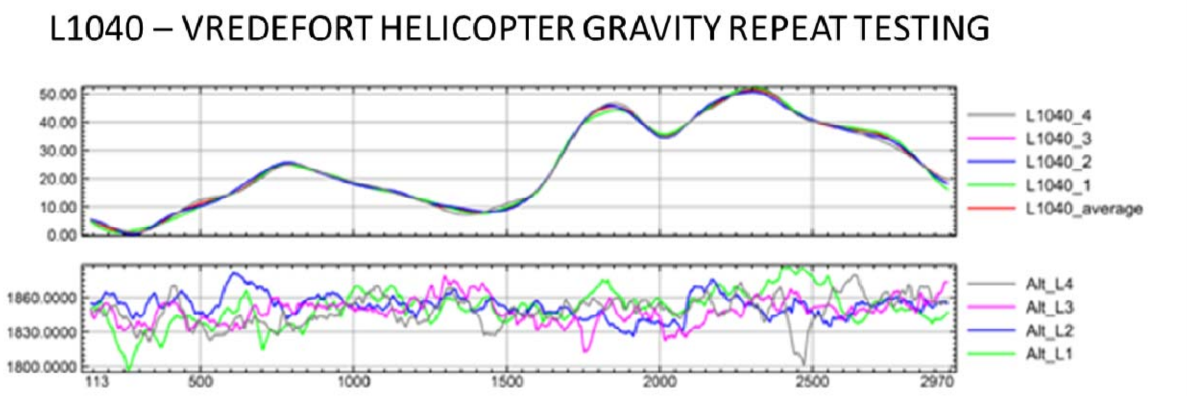

Figure 5: Vredefort airborne gravity repeats over line L1040, showing Residual Bouguer Gravity Anomaly profiles (above) and aircraft altitude for repeat flights (bottom).

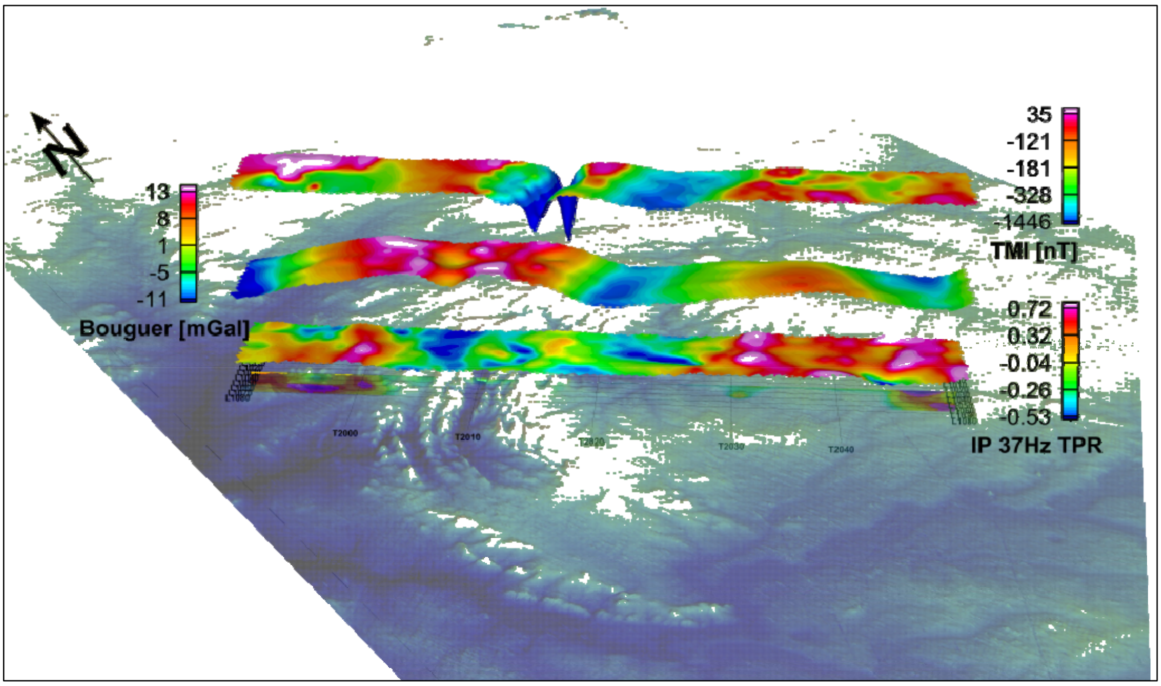

Figure 6: 3D View of Helicopter ZTEM-Gravity-Magnetic survey results over Vredefort Impact Structure: a) Residual Bouguer Gravity Anomaly, and b) Total magnetic intensity (IGRF-corrected), c) ZTEM total phase rotated (TPR) In-phase tipper at 37Hz, over satellite AGDEM model (ASTER, 2009).