GT-1A Airborne Gravity

A Case History over the Vredefort Dome, South Africa

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Presented By

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Table of Contents

Abstract

Recent development of vertically constrained INS DGPS airborne gravimeters has resulted in a significant improvement in the accuracy-resolution achieved with airborne gravity systems. As a consequence, a range of new markets has been opened, most notably detailed basin-mapping (oil and gas, placer gold, stratiform copper) and litho-structural mapping (greenstone gold, platinum group elements). Following an extensive period of testing Fugro Airborne Surveys has adopted the GT-1A INS DGPS airborne gravity system as the preferred technology for commercial gravity survey. A recent case study is presented comparing airborne and ground gravity data.

Introduction

The challenge presented by airborne gravity is being able to accurately discriminate between the aircraft accelerations (may be as large as 100 000 mgals) and accelerations due to variations in geology (10's of mgals). Although commercial surveys have been carried out from the late 1970s, the advent of differential GPS provided the cost-effective means of mapping the aircraft velocity: key for vertical aircraft accelerations; Eötvös and Coriolis effects. As GPS technology advanced the accuracy/resolution of airborne gravity systems improved. By 2001, sub-mgal accuracies for ~6 km resolution were reported using modified LaCoste and Romberg marine gravimeters (*Williams and MacQueen, 2001*). Despite this progress, commercial application of airborne gravity was limited primarily to basin-mapping for the petroleum market where it was focussed in transition zones and rugged topography where access made ground or marine gravity unfeasible. The limited application was partly due to relatively high survey cost and low production rates.

From 2001 – 2004 Fugro Airborne Surveys carried out a series of test surveys with the Russian GT-1A airborne gravity system. The GT-1A consistently performed to a high degree of accuracy, demonstrating a significant improvement in production capability and accuracy-resolution compared with previous systems. Fugro are currently employing the system commercially.

The GT-1A – An overview

The GT-1A system was developed by Gravimetric Technologies in Russia. A detailed description of the system is provided by *Berzhitzky et al (2002)* and *Gabell et al (2004).* The following summary is provided:

The GT-1A is an airborne, single vertical sensor, GPS-INS scalar gravimeter with a Schuler-tuned three-axis platform. The gravity sensor is a custom-designed accelerometer mounted inside a gyro-stabilised unit. Inputs from fibre optic gyro, inclinometers, angle sensors and dual frequency GPS are used to drive servo motors which maintain the sensor in a vertical position. This virtually eliminates the effects of horizontal accelerations in the measured signal. The entire assembly is mounted on a rotation table, maintaining the sensor orientation at the same heading.

Gravity data is sampled at ~18 Hz, sub-sampled to 2 Hz and integrated with dual frequency DGPS data to remove effects of vertical aircraft acceleration and Eötvös effect. Final gravity is reduced using a non-stationary adaptive Kalman filter using: raw gravity, aircraft vertical velocity (DGPS phase information), and platform misalignment errors. Filter length is user-defined according to resolution requirements.

Case Study: Vredefort Survey, South Africa

In March 2004, a series of airborne gravity test surveys were carried out in South Africa with the following objectives:

1. Evaluate the GT1-A's ability to resolve and map short wavelength gravity features necessary for geological mapping and longer wavelength features required for basin mapping.
2. Evaluate the repeatability and accuracy of the GT1-A gravity system.
3. Compare the GT-1A with the previously employed modified LaCoste and Romberg marine gravity system.

Background

A survey area covering the Vredefort Dome was selected due to the availability of ground gravity data (National gravity database, SA Council for Geoscience), wide range of frequency content and prominent structures present in the ground data.

Survey Specifications: The survey consisted of two parts:

1. Detailed Survey, 2 km x 22 km line spacing (3 600 line kms)
2. Regional Survey, 12 km x 42 km line spacing (1 700 line kms).

Geology: The Vredefort structure is generally accepted as being the remnant root of a large Archean aged impact structure. The dome comprises a 40 km wide core consisting of Archean granitoid gneisses. Surrounding the core is a 20 km wide collar of steeply dipping Archean aged sediments of the Witwatersrand Supergroup and volcanics of the Ventersdorp Supergroup. The detailed survey was designed to resolve the Vredefort structure. The regional survey covers the extension of the Witwatersrand and Transvaal sedimentary basins.

Figure 1 and 2 illustrate the survey boundaries on geology and ground Bouguer gravity images.

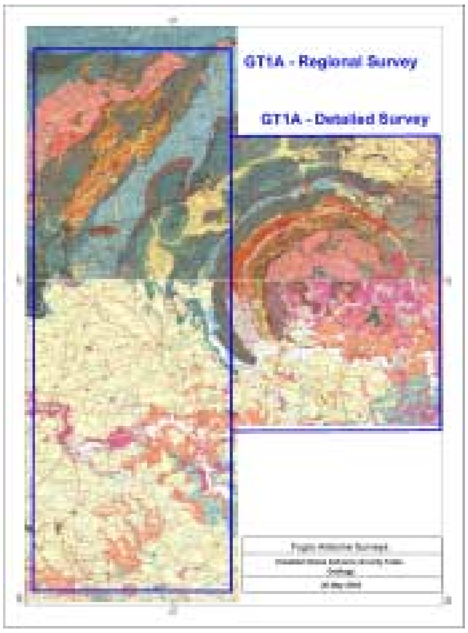


Figure 1. Survey boundary illustrated on geology

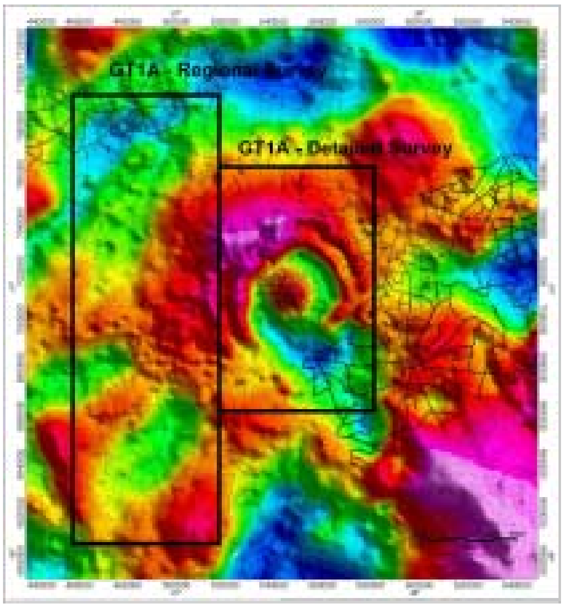
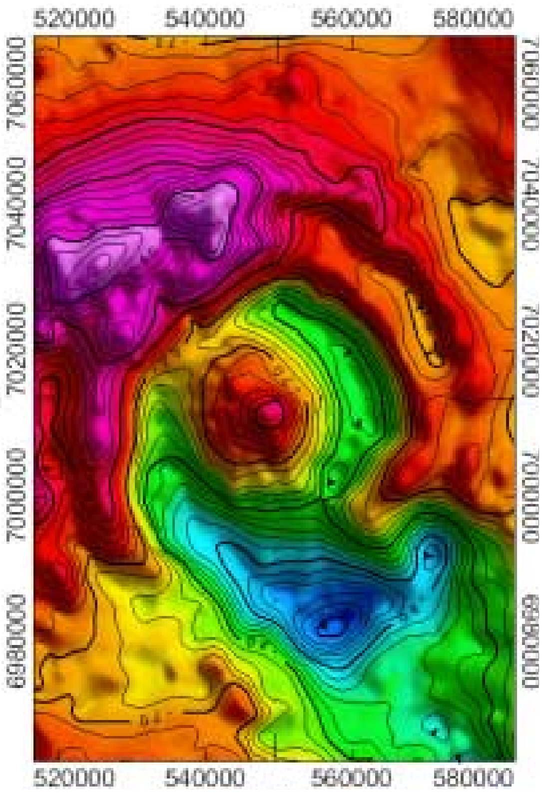


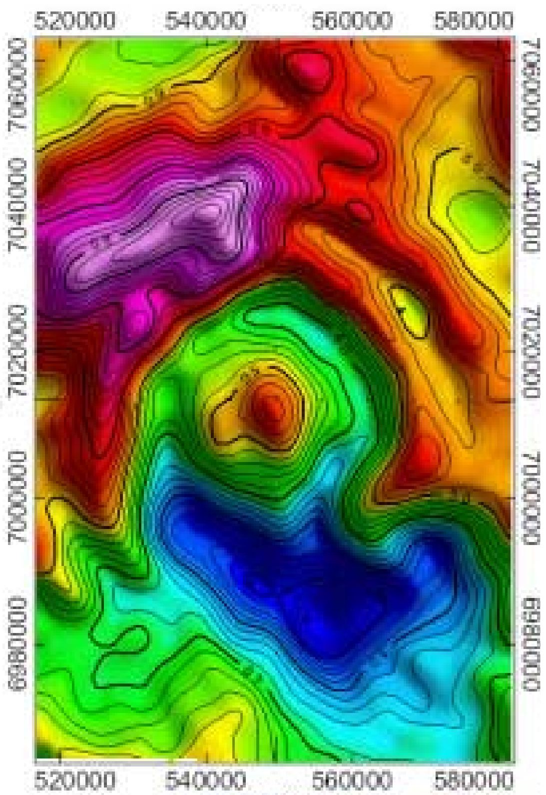
Figure 2. Survey boundary illustrated on sun-shaded Bouguer ground gravity

Survey Results

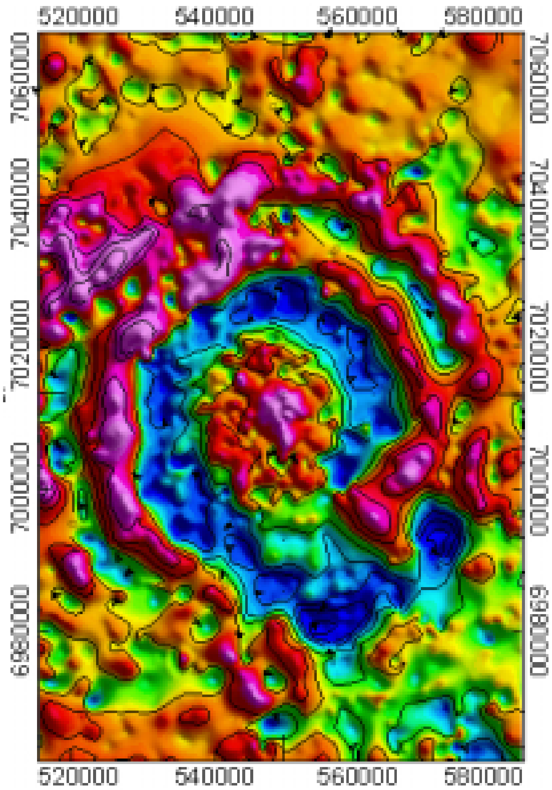
The following figures compare the high resolution and regional GT-1A airborne gravity survey with ground gravity. The correlation between datasets is excellent for high and low frequency features (small variations occur where sample coverage is poor in the ground gravity dataset). Statistical comparison between the datasets was not possible due to the irregular sample coverage in the ground data.



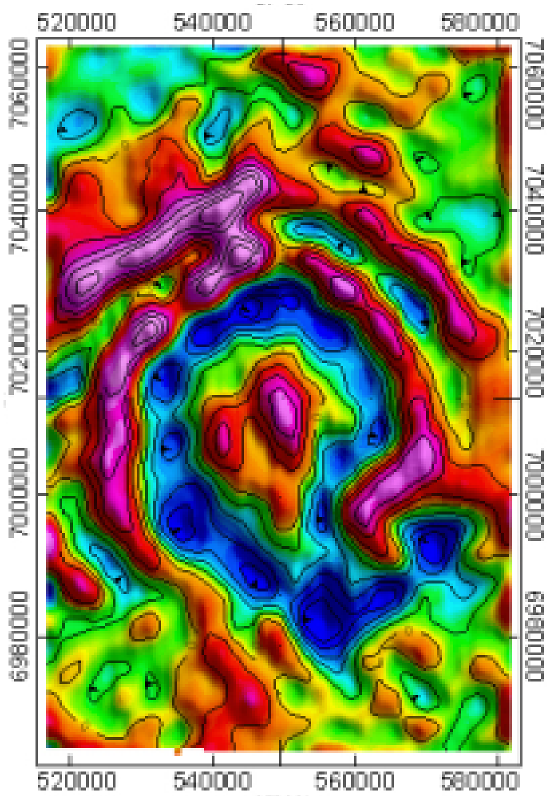
Sun-shaded upward continued Free Air ground gravity



Sun shaded Free Air airborne GT-1A gravity

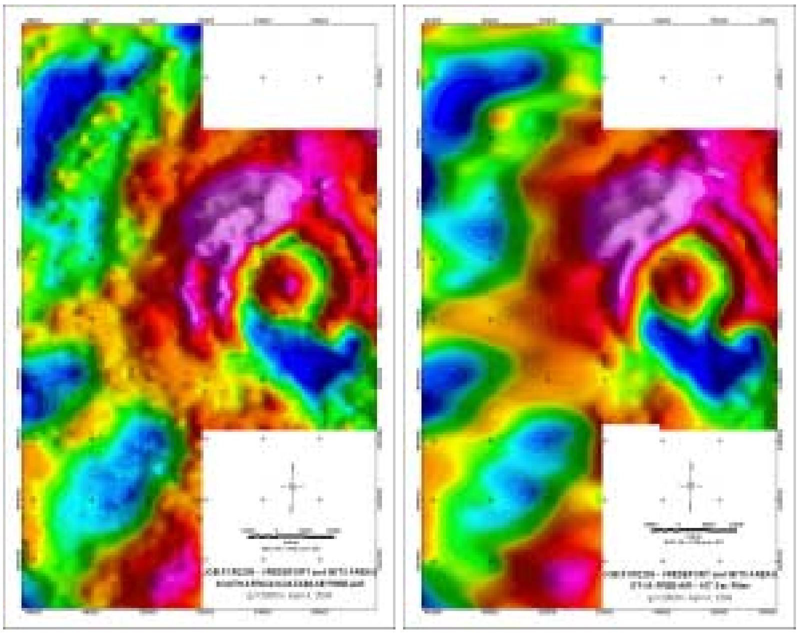


Sun-shaded upward continued First VD ground gravity



Sun-shaded First VD airborne GT-1A gravity

Figure 3. Comparing the detailed airborne survey with ground gravity data



Sun-shaded upward continued Free Air ground gravity

Sun-shaded Free Air airborne GT-1A gravity

Figure 4. Comparing regional and detailed ground and airborne datasets

Repeat Line Statistics

In order to evaluate the accuracy-resolution of the system, a 100 km repeat-line was flown five times. The gravity data was then reduced using a range of Kalman filter lengths (50, 80, 107, 130 and 180s) corresponding to resolutions of 1.7 – 6 km for an aircraft velocity of 69 m/s. Note that no levelling or spatial filtering has been applied to the data. Noise levels were estimated using Green and Lanes method (*Green and Lane, 2003*). The resultant accuracy-resolution curve is illustrated in Figure 5.

Due to the fact that noise in airborne gravity is predominantly uncorrelated, it is possible to stack or oversample the data to further increase accuracy where necessary. This can be done by tightening the line spacing or repeating lines and applying spatial filters to the data. As a result, surveys can be designed to resolve detailed geological structure. For data with uncorrelated noise, such as airborne gravity, each stack (or halving of line spacing) results in an improvement in accuracy of $\sqrt{2}$ (Figure 5).

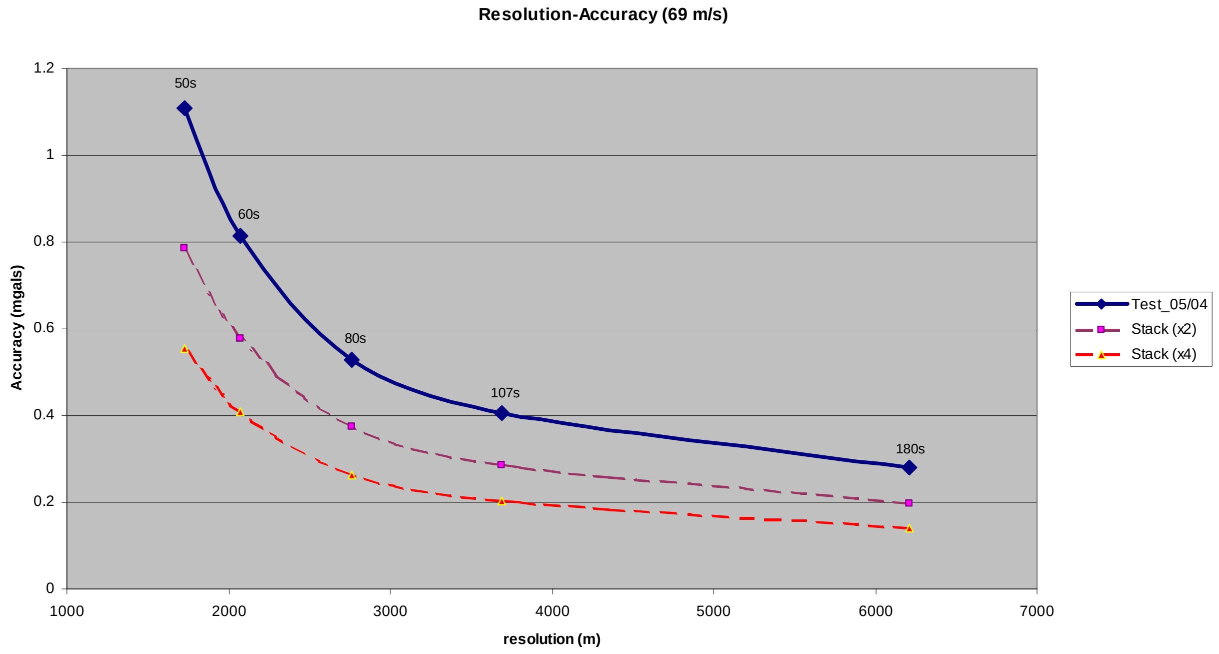
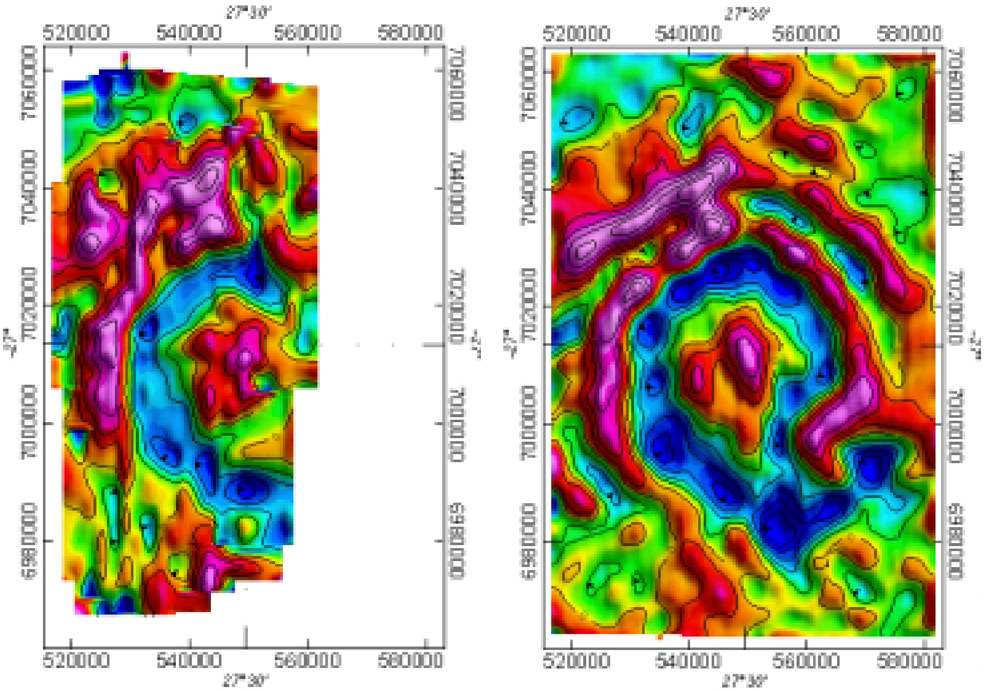


Figure 5. Accuracy-resolution graph based on five ~100 km repeat lines. The benefit of oversampling is demonstrated in curves Stack (x2) and (x4).

Comparing the GT-1A and Custom Modified LaCoste and Romberg

To complete the survey tests, data was compared with a recently flown survey carried out over a portion of the high-resolution block with a custom modified LaCoste and Romberg gravimeter (industry standard before INS DGPS systems). Both surveys were flown at the same specifications. The GT-1A demonstrated an improvement in accuracy (over 3x), production (> 3x) and processing time (data is available daily for QC).

Figure 6 below compares 1st vertical derivative images for both systems. The improvement in resolution with the GT-1A system is clearly demonstrated.



Sun-shaded First VD Free Air Modified L&R gravity

Sun-shaded First VD Free Air GT-1A gravity

Figure 6. Comparing airborne gravity systems

Conclusions and Applications

The GT-1A has demonstrated its ability to collect accurate repeatable data with excellent productivity rates during both test surveys and recent commercial surveys. The significant improvement in accuracy and resolution offered by the new generation INS DGPS airborne gravity systems has introduced a range of new market applications. Although traditionally the airborne gravity market has focussed on basin-mapping for oil and gas exploration, achieving resolutions of 2 – 4 km with accuracies of ~0.5 mgals compares favourably with most regional ground gravity datasets. New markets include:

- Regional geological mapping in conjunction with magnetics (ideal for regional structural mapping, mapping non-magnetic lithologies, providing estimates on unit thickness and continuity at depth).
- Basin mapping for stratiform copper and placer gold.
- Detailed basin mapping for oil and gas (salt diapir identification, assisting seismic survey planning, processing and model constraint).
- Regional mapping of layered complexes (PGE exploration).

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