Anomaly Detection and Gravity Noise Estimates from Modeling and Field Data

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Summary

Gravitational attraction can be measured on the ground, or in a ship or aircraft using gravimeters or gravity gradiometers. No matter how the measurement is made, the same gravitational attraction of the material below the surface is measured. The type of measurement can, however, affect the resolution and accuracy with which a specific geological situation can be measured. This presentation examines the effect of survey parameters and noise on the detectability of various modeled anomalies by measuring gravity on the ground, or in the air using a gravimeter or gravity gradiometer. In addition, it evaluates the effects of line spacing, survey altitude, terrain correction errors and near surface density changes on the accuracy of gravity data sets.

Introduction

A sample area with typical geological features has been constructed using a 3D gravity forward modeling program, based on data from airborne gravity surveys over petroleum and mining prospects. Gravitational attraction of the model area and its geological features was calculated assuming a variety of acquisition scenarios, varying the type of survey (ground gravity, airborne gravity, airborne gravity gradiometer), and station or survey line spacing. Anomaly maps produced by the modeling program were compared before and after adding expected measurement noise of the survey systems used.

Measurement noise level was determined from comparative tests performed by Sander Geophysics (SGL) and from published data. The effect of errors in the input Digital Elevation Model (DEM) on the accuracy of gravity terrain corrections, and the effect of near surface density changes on the measured gravity field were also calculated for each gravity measurement type. The modeled gravity field and associated noise levels were compared to examples of airborne and ground gravity data sets over prospective petroleum and mining exploration areas.

Several papers cover the topics of measuring noise in real data sets (Elieff *et al,* 2008), comparing noise levels between systems (Studinger, *et al,* 2008) and using observed and theoretical noise calculations to compare noise levels and detectability for ground gravity, and airborne gravity and gradient measurements (Barnes, *et al,* 2011).

These authors do a good job of investigating specific aspects of gravity measurement noise. Other sources of noise, which are more difficult to measure or to calculate, are included in this paper by 3D modeling of an idealized geological model.

Description

Field data and geological interpretations from a variety of airborne gravity surveys were used to construct a model to test the detectability of a wide variety of geological features with gravity data. The model consists of two linked basins, one deeper and the other shallower, which incorporate intrabasinal faults and basement highs at various depths, and a basement high between the basins. Located alongside the basins is an area of exposed basement containing a variety of ore bodies at various depths (Figure 1). The detectability of the features in the model were evaluated using a 3D modeling program which calculates the gravitational field, and gravity gradient. Images were prepared for the data assuming it was collected as a ground gravity survey, and as airborne surveys using a gravimeter (SGL's AIRGrav system) and using a gravity gradiometer (Lockheed Martin's airborne gravity gradiometer). Survey altitude (the survey aircraft's height above the ground) and line spacing (the distance between adjacent survey lines) were varied for each system to evaluate the effect of data acquisition parameters on the detectability of the modeled features. Irregular ground gravity station spacing was also evaluated by calculating the effect on gravity grid data of irregular station locations from real ground gravity surveys.

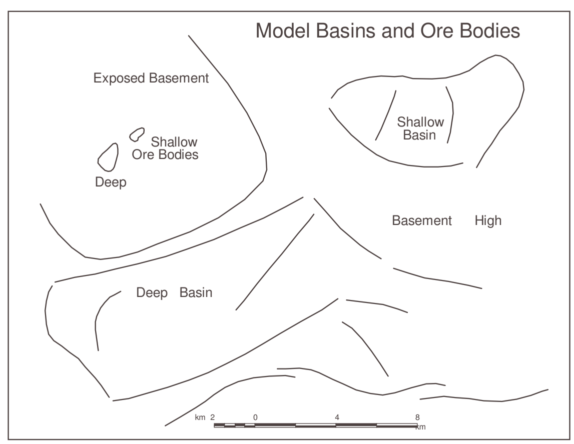
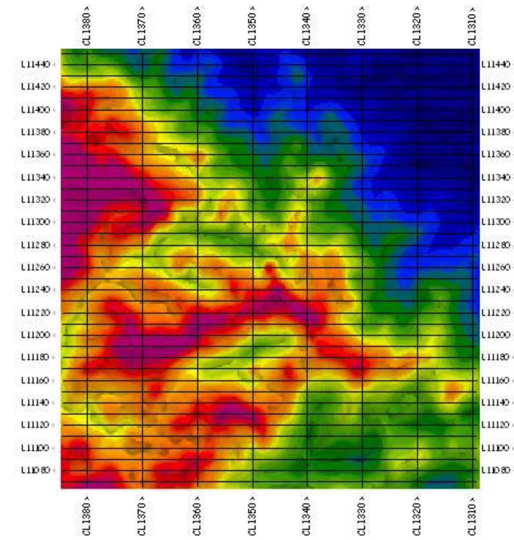


Figure 1: Map View of Model Basins and Ore Bodies

Measurement noise was added to each image to determine the cumulative effect of random noise on the modeled features. Measurement noise is the random or pseudo random noise associated with the acquisition system. It includes noise from the gravimeter or gravity gradiometer, and from position measurements. For an airborne system it would also include any noise from the aircraft itself, and from uncorrected accelerations of the aircraft. Airborne gravity noise was determined from evaluations performed on a test line outside of Ottawa, which has been flown over a hundred times using SGL's AIRGrav system (Elieff). AIRGrav was directly compared to the GT1A gravimeter by Studinger, where he found that under all survey conditions the AIRGrav system had significantly less noise. Noise levels for ground gravity and airborne gravity gradiometers were determined from published data (Barnes). Measurement noise levels affected the detectability of the modeled features, as subtle features were successively obscured by increasing measurement noise levels. Modeled data were filtered to evaluate the effect of filtering on the measurement noise, and the detectability of the modeled features.

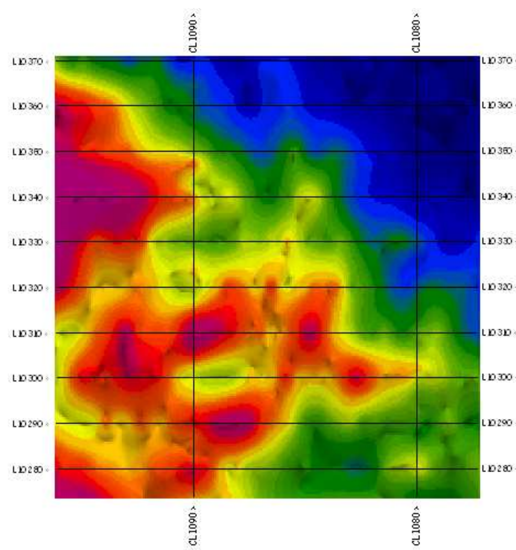
A terrain surface was added to the model to evaluate the effect of terrain correction errors on the gravity and gravity gradient data. Errors in the DEM used for terrain corrections were evaluated by comparing a highly detailed DEM derived from laser scanner data to an SRTM derived DEM, a DEM derived from a laser profile along a flight path, and a DEM derived from the heights measured at ground gravity data points. Each DEM error was modeled using ground and airborne gravity and gravity gradiometer survey parameters. Near surface density differences were evaluated by adding three buried river channels of various sizes modeled on a large, medium and small sized river in the Ottawa area.

Real publicly available gravity data sets, from the Kauring Airborne Gravity Test Site (Lane *et al,* 2009) and from SGL's Timmins test survey (Elieff *et al,* 2004) were also used to evaluate the effect of line spacing and DEM errors on gravity and gravity gradiometer data. Figures 2 and 3 show gravity grids as would be measured at 500 m and 2000 m line spacing on an airborne gravity survey over the Kauring Airborne Gravity Test Site, calculated using all of the data in the 20 by 20 km middle zone, re sampled at 500 m and 2000 m line spacing. The same data sets were used to calculate the effect of DEM errors on measured gravity and gradient data using ground gravity, and airborne gravity and gravity gradiometer systems.



500 m Traverse / 2500 m Control Line Spacing

Figure 2: Gravity grids measured at 500 m



2,000 m Traverse / 10,000 m Control Line Spacing

Figure 3: Gravity grids measured at 2000 m

Discussion and Conclusions

Detectability of anomalies is reduced by decreasing the size of the geological feature, or by increasing the depth of burial, the line or station spacing of the survey, the survey height above ground, and the amount of measurement noise of the survey system. Incorrect terrain corrections due to errors in the DEM, and unmodeled near surface density changes can also cause significant "noise" which can obscure the geological features of interest. Ground and airborne gravity and gradiometer data are affected differently by different sources of error. Ground gravity surveys are affected by irregular station locations, near surface density differences and by DEM errors between stations. The attenuation effect of increased line spacing, and survey height was greater for gradiometer surveys than for gravimeter surveys due to the higher degree of attenuation of gravity gradients. Gravity gradient data were also more affected by DEM errors and near surface density differences for the same reason.