Gravity 3D modelling: a kimberlite case history and inversion methodology discussion.

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Abstract

The objective of the paper is to discuss the state of the art of the gravity modelling methodologies using a kimberlite in Rondonia state as an example.

The matter is particularly important today when both ground gravity and multiple airborne surveys are being carried out in Brazil and interpreters must choose the adequate inversion method to fulfill their geological needs.

In this paper we will apply two modelling methodologies, (A) the rigid and homogeneous bodies method and (B) the subsurface division on fixed small inversion parallelepipeds on the same dataset over a kimberlite in Rondonia and discuss the results and methods.

Introduction

At least four systems are commercially flying gravity or gravity gradiometry today in Brazil (2011), and ground data are still extensively being collected.

Several economic applications could benefit from a good quality gravity survey:

- Basin recognition and basin geometric parameters definition on oil/gas projects.
- Regional structures and trends on greenfields and brownfields mining projects.
- Direct detection of iron (BIFs and/or hematite), zinc, sulphide nickel, copper, kimberlites (diamonds) and carbonatites (phosphate).

To be useful for geologists, gravity surveys must be proper modelled and converted to a subsurface density model (or susceptibility subsurface model for magnetics). The process to convert gravity data to a subsurface density model is called inversion or modelling.

RO kimberlite data presentation

The kimberlite in RO was surveyed with 200x50m grid. Figure 1 shows the obtained Bouguer anomaly.

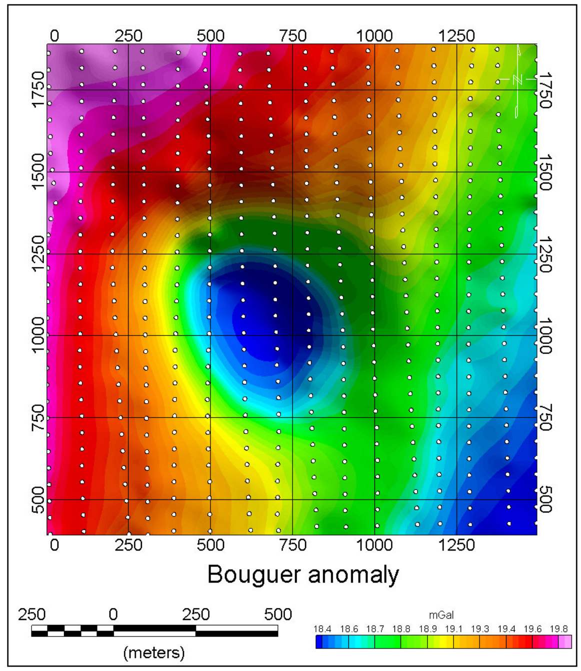

Figure1: Bouguer anomaly. White dots = stations.

Figure 2 shows the Bouguer trend removed and figure 3 shows magnetics over the same lines, although magnetics were sampled at 12.5m along the line.

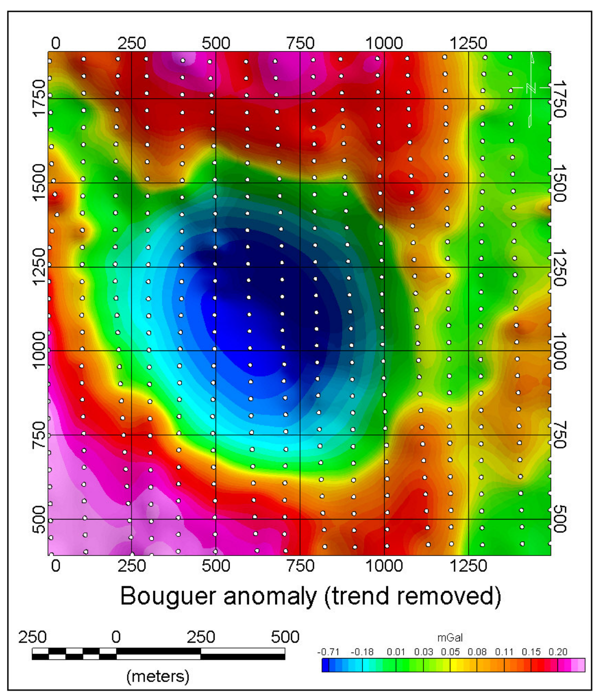

Figure 2: Bouguer anomaly trend removed.

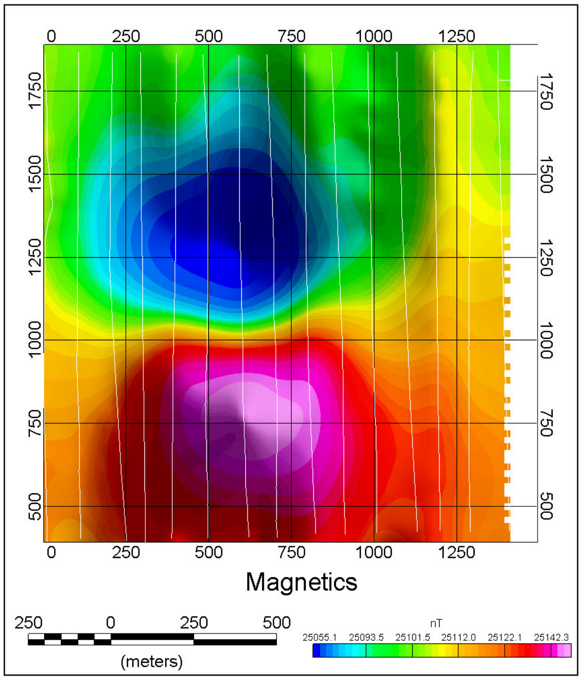

Figure 3: Magnetics. In white the line path, station spacing = 12.5m

(A) Rigid bodies modelling method – Modelvision

The method consists on building rigid and homogeneous models and then trying to match the anomalies due to the models with the actual measured data. We will name from now on the anomalies due to the build models as **gravmod** (gravity) and **magmod** (magnetics).

To build the initial models in this method it is necessary a good previous knowledge about the subsurface geology. Due to the presence of other kimberlites in the area, the chosen body type for the model was a pipe.

Figure 4 shows the performed modelling on a stacked profiles map and figure 5 shows three selected profiles (both magnetics and gravity at the same time). It is important to notice that the model honour all lines at the same time for both potential fields, magnetics and gravity.

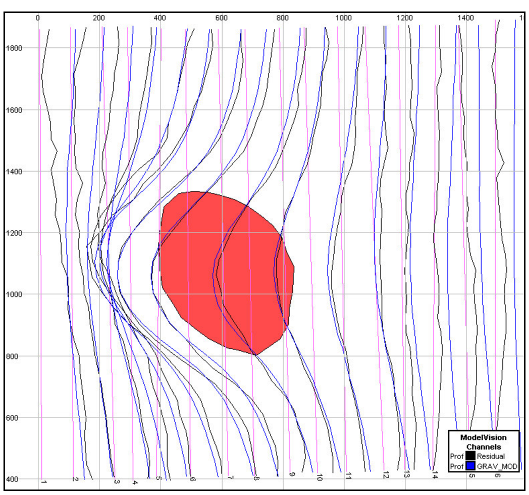

Figure 4: gravity actual measured profiles (black) and gravmod profiles (blue).

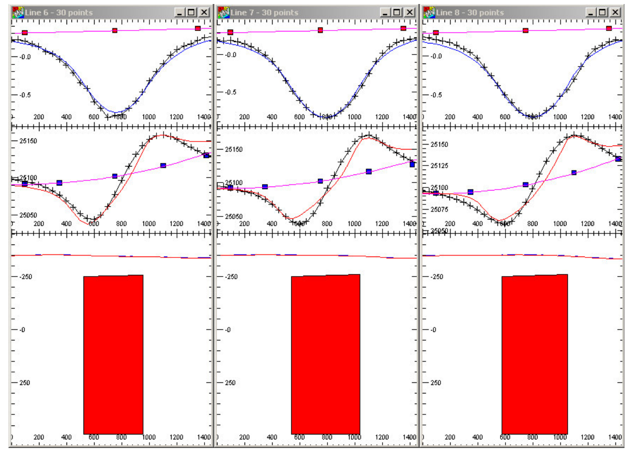

Figure 5: Profiles of lines 6, 7 and 8. Upper profile: black crosses Bouguer, blue line gravmod; Lower profile: black crosses: magnetics, red line: magmod.

Table 1 shows "red" model parameters:

Parameter	Value
Depth from surface to top	93m
Vertical body extension	750m
Density contrast	-0.22 g/cm^3
Susceptibility contrast	+0.003 SI
Q (Koenigsberger constant)	5
NRM inclination (remanent I)	41.96°
NRM declination (remanent D)	65.49°

Figure 6 shows the Bouguer trend removed of gravmod, at same colour scale of figure 2.

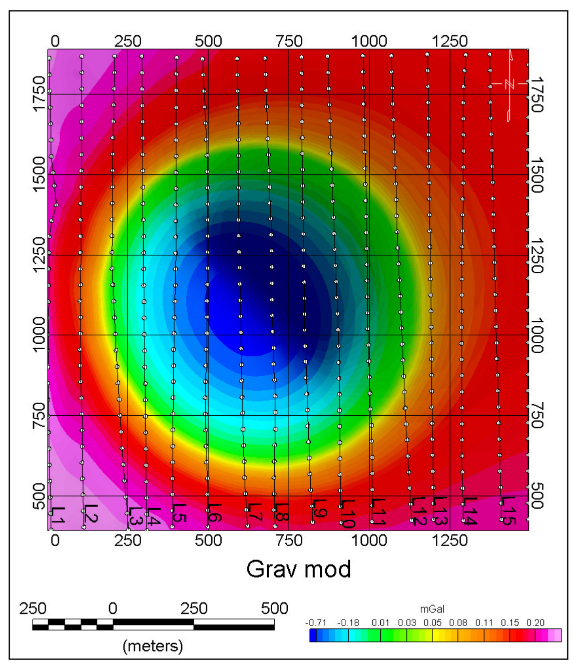

Figure 6: Gravmod Grid, same colour scale of figure 2.

Due to similarity of the actual measurements and gravmod / magmod and also due to geology consistency, the geophysicist claims that the actual pipe is probably similar to the model, and it is ready for drilling.

(B) Subsurface division modelling method – UBC-GIF
The method consists on discretize the subsurface 3-D model region into a set of rectangular cells, each having a constant density. Solutions are obtained by minimizing a global objective function composed of the model objective function and data misfit (Oldenburg and Li, 1994 and Li and Oldenburg, 1996).

We run the UGC-GIF 3D inversion on the same gravity dataset (Figures 2 and 3). Figure 7 shows the 3D density subsurface model, cut in X direction to display the low-density central distribution, and figure 8 shows the density distribution with –0.06 g/cm^3 cutoff.

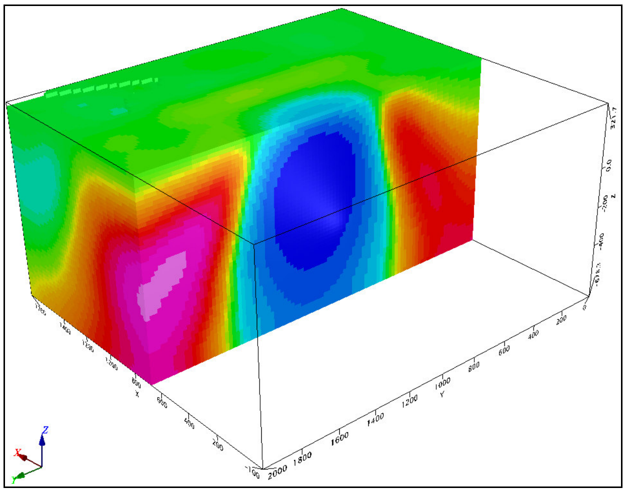

Figure 7: UBC subsurface density model cut ix X direction to display the low-density distribution.

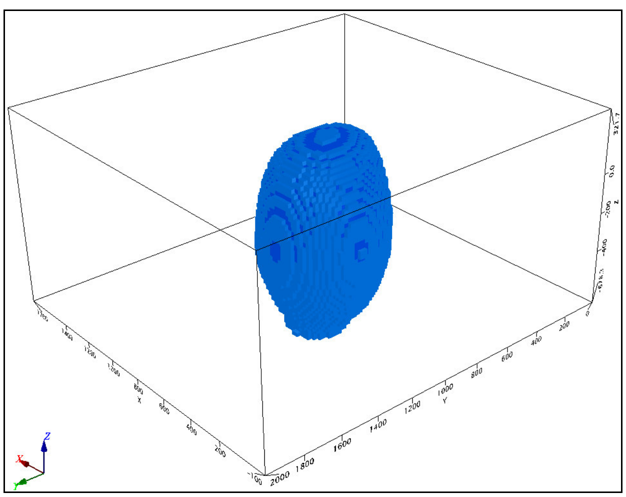

Figure 8: UBC subsurface density model displayed with density cutoff of –0.06 g/cm^3.

Again we need a comparison with actual data to validate the quality of the modelling. Figure 9 shows actual data compared to gravmod.

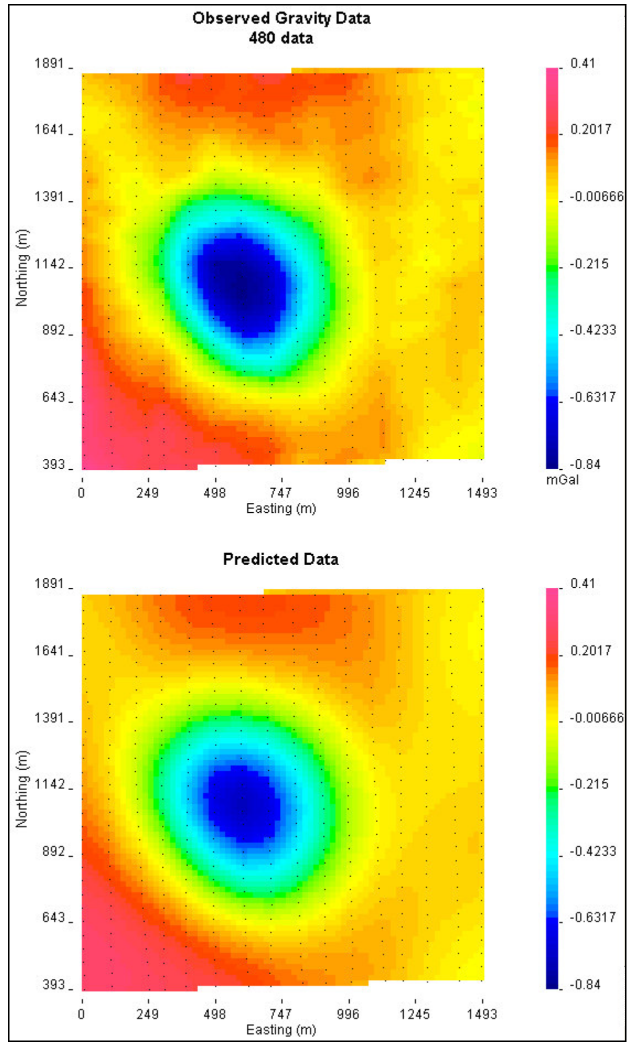

Figure 9: Actual data (upper) x gravmod (lower), same colour scale.

Since this method is not “rigid”, it does not deliver “a” model but a density distribution instead, and therefore there is no such a “parameters table”.

However, it is possible to compare in the same diagram the body obtained by (A) the rigid body method (red model figures 4 and 5) with the (B) method (figure 8 cutoff –0.06 g/cm^3). Figure 10 shows the comparison between method (A) and (B).

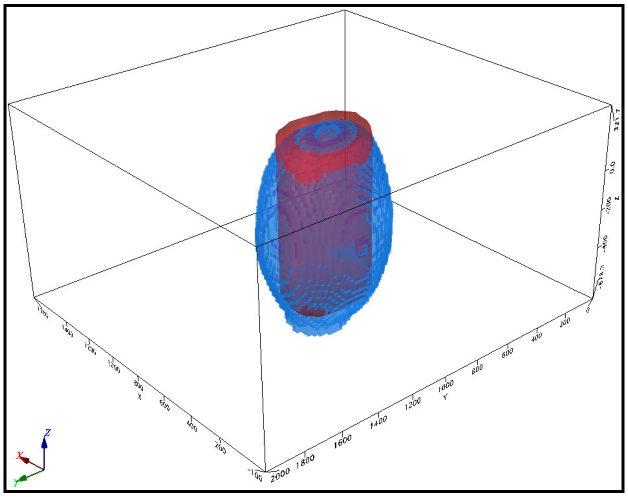

Figure 10: rigid red model from method (A) displayed with blue UBC surface density model (method B) using density cutoff of –0.06 g/cm^3.

Discussion

It is possible to notice on the figure 10 that in this case history the obtained models are quite similar, particularly considering the main drilling parameter, the depth from surface to top.

The volume of the "blue" model is significantly larger than "red" model volume, but changing the density cutoff for the blue model the volumes could adequately match. Also, the shapes of the top faces are quite different, and particularly for this parameter the magnetics helped on building the red model top face shape.

The presented example shows some of the advantages of method (A).

- A body parameters table.
- It is easier to export and present the obtained model for geologists.
- It is easier to find a drill location.
- It is possible to joint modelling of gravity and magnetics.

And some of the advantages of Method (B):

- Geology is seldom "rigid" and the bodies are often heterogeneous. Therefore method (2) is often more reliable.
- The interpreter does not need much previous information.
- It is more suitable for large datasets, for example a sedimentary basin.

It is also important to be said – and it is not clear in the present ground gravity example – that method (A) could directly model the measured gradients in eötvös (Falcon or FTG), while method (B) needs a residual anomaly in mGal.

Since the construction of the residual is often not trivial, the use of methodology (A) is frequently the best choice on gravity gradiometry surveys (Falcon or FTG).

Conclusions

We modelled a gravity survey over a kimberlite in Rondonia applying two different methodologies and obtained similar model results.

We discussed the differences between modelling methods and the reasons to choose one or other methodology.

Basically, if the density of the rock target is very different from the host, the source of gravity data is gravity gradients and the geophysicist has previous knowledge about densities and/or geometry, method (A) is probably the best choice.

However, if the contrast between target and host is uncertain, and/or there is little information about the subsurface, method (B) would be the best choice.

Ideally, the geophysicist should run the two methodologies and collect benefits from the better of each one.

Acknowledgments

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References

Li, Y. and Oldenburg, D. W., 1994. 3-D inversion of gravity data. SEG Annual Meeting Expanded Technical Program Abstracts with Biographies, 65, 264-267.

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