Project scale exploration using GRACE satellite gravity data: two case studies

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Summary

The GRACE (Gravity Recovery and Climate Experiment) satellite data allow for project scale exploration for mineral deposits. The data provide good regional coverage in areas where no ground gravity data exist and can also be used to augment national databases. I used the data in two case studies. The first project was for potash exploration in the Bada Basin in eastern Eritrea. The GRACE gravity data were essential for establishing the regional gradient for modeling isolated ground gravity profiles across the basin. The second project was a gold exploration target in north central Nevada, USA. The GRACE satellite data showed a gravity high in the basin that was not indicated in the US National Geodetic Survey database. Detailed gravity surveying confirmed the GRACE gravity high was real and changed the geologic model for the project and is directing current exploration efforts.

Introduction

The GRACE program consists of two satellites orbiting in tandem 220 km apart and was launched in 2002. Tracking of the satellites is obtained using GPS and a radio link between the two satellites. The radio link allows a more accurate measurement of orbit perturbations caused by the earth's gravitational field. In 2008 the National Geospatial-Intelligence Agency (NGA) publicly released a 2.5 arc minute model (roughly 4.2 km) of the earth's geoid (Pavlis, et al., 2008). The International Gravimetric Bureau (BGI) calculated the complete Bouguer anomaly for these data using the ETOPO1 one arc minute grid to 167 km with a reduction density of 2.67 g/cm^3 (Fullea, et al., 2008). These data are free for download from the internet (BGI, 2010).

Bada Basin, Eritrea, Potash Exploration

Sanu Resources purchased mineral leases in the Bada Basin for potash exploration. Only regional geologic mapping had been completed by the Ministry of Mines so Sanu surveyed four gravity profiles and 24 magnetic profiles across the basin to better establish the limits and depth of the basin. The geophysical data were intended to optimize wide spaced drill locations to attempt to detect potash.

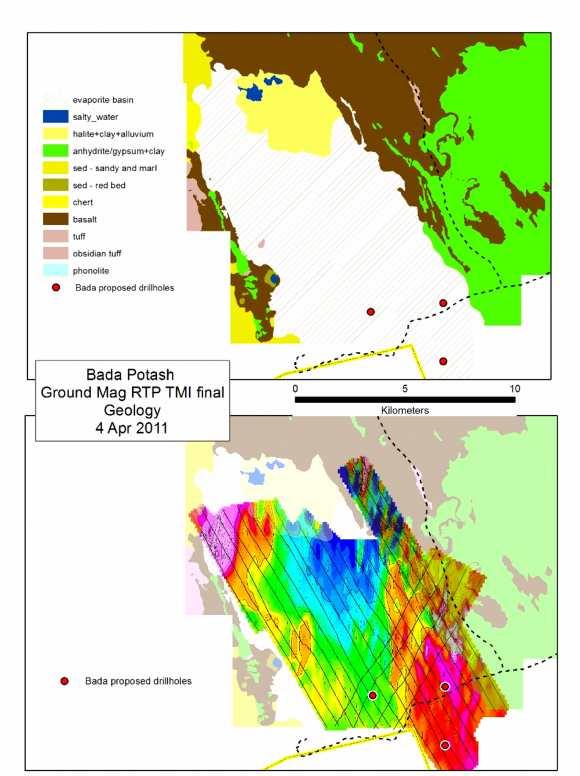

Figure 1: Geology of the Bada Basin and inverted reduced to pole magnetic data. The basin is shown in white, basalt in brown, anhydrite in green and proposed drill holes in red.

Interpretation of the magnetic data was difficult because the project site is at low latitude and the standard reduction to pole filter did not work. Therefore I used the UBC magnetic inversion software MAG3D (Li and Oldenburg, 1996) to solve for the magnetic susceptibility. I then used the forward modeling software to calculate the reduced to pole data from the susceptibility distribution (Figure 1). This greatly aided in the interpretation of which rocks were magnetic and where they were located.

The gravity profiles were also difficult to interpret. All of the profiles showed a strong gradient from west to east which I did not expect since the profiles were collected over a basin. Therefore I downloaded the GRACE gravity data for the area and compared them to the profile data (Figure 2). The GRACE data supported the regional

gradient shown in the ground profiles and gave me confidence those data were valid.

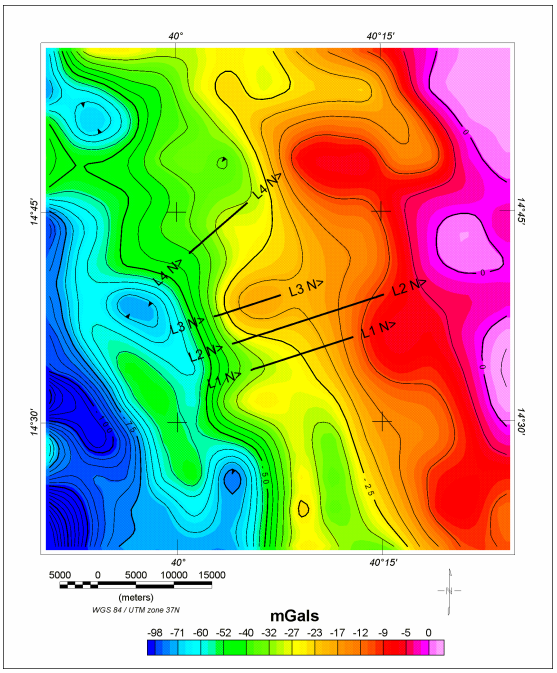

Figure 2: Compete Bouguer anomaly GRACE data with four gravity profile locations. Contour interval is 5 mGals.

Aided by the inverted magnetic data and knowledge of the regional gravity gradient, I was able to model the approximate shape and depth of the basin for the three profile lines (Figure 3). The fourth gravity profile tested an area that had no significant sediment thickness and was not modeled. Based upon the basin modeling the project geologist was better able to optimize drill locations to test for potash. No salt units were intersected and the project was dropped.

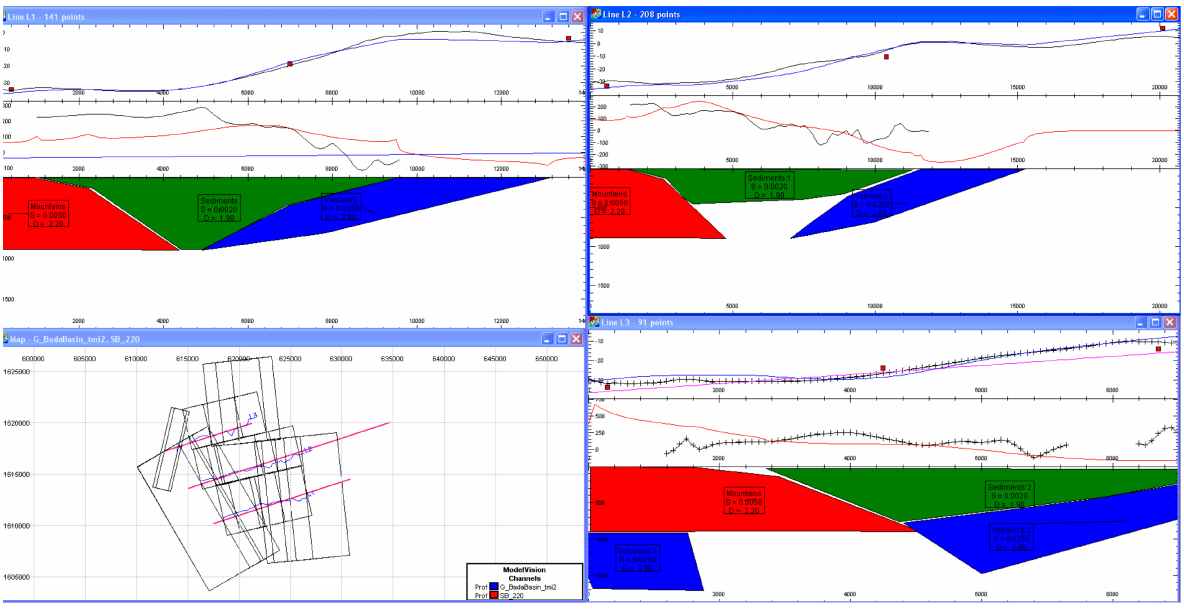

Figure 3: 2 ¾D modeling results for profiles lines 1 (left top), 2 (right top), and 3 (right bottom). Each model consists of three panels with gravity model (in blue), magnetic model (in red), and modeled bodies. Regional gradient was removed based upon the GRACE data and is indicated by the three red squares.

Project scale exploration using GRACE gravity data

Great Basin, USA, Gold Exploration

The Snowstorm Mine is located in north central Nevada on the western flank of the Sheepcreek Range. Historic mining activity and good geochemical anomalies make this a prospective area for gold exploration. A comparison of the National Geodetic Survey (NGS) and GRACE gravity data (Figures 4 and 5) show general similarities but also significant differences. The amplitudes of the anomalies are similar but the GRACE anomalies appear narrower than those based upon the ground data. The Great Basin has significant topographic variations which might cause artifacts in the GRACE data created by the terrain corrections.

For the Area of Interest around the Snowstorm Mine the GRACE data show a gravity high not indicated in the national database. There are only three gravity stations on the edge of the Area of Interest in the NGS database to constrain the contouring of the anomaly.

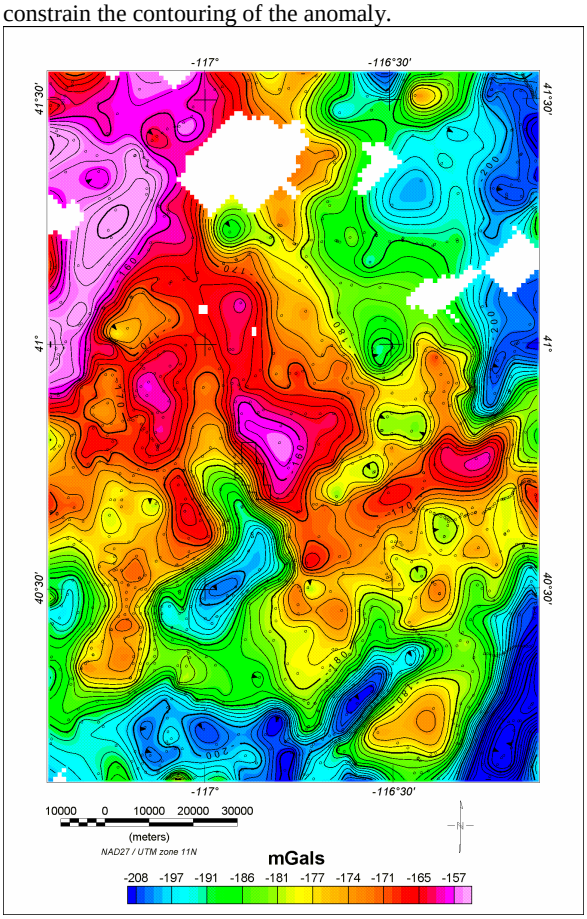

Figure 4: NGS complete Bouguer anomaly data for north central Nevada gridded at 1 km interval with a 2 mGal contour interval. The Area of Interest is outlined in black.

A detailed gravity survey over the Area of Interested was undertaken using a nominal station spacing of 300 to 400 meters (Figure 6). The ground data confirmed the gravity high in the GRACE data is real. Modeling of the gravity high suggests it is part of the North Central Nevada Rift. This has changed the exploration focus of the project. It is now assumed the rift was responsible for providing the fluids which emplaced the gold at the Snowstorm Mine.

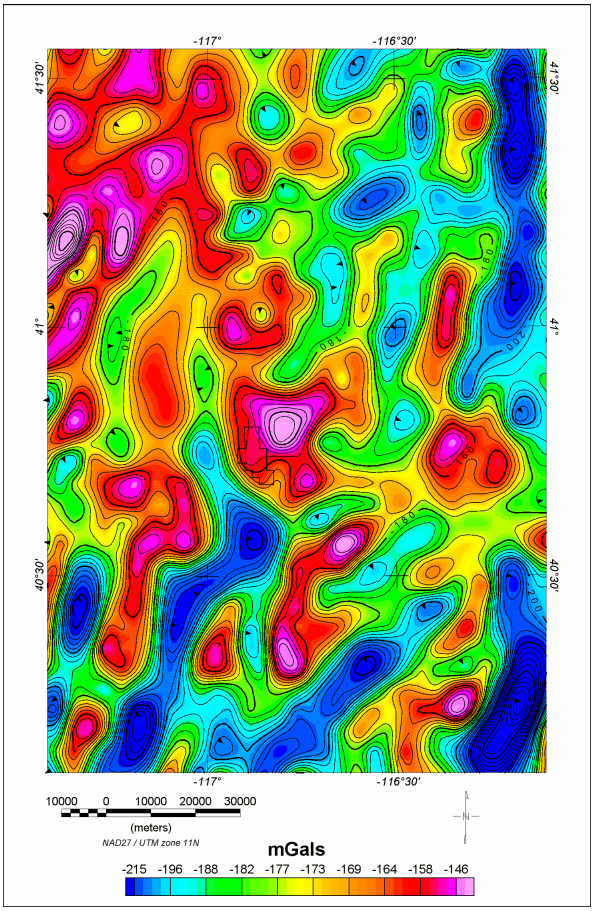

Figure 5: GRACE complete Bouguer anomaly for north central Nevada gridded at 1 km with a 4 mGal contour interval. The Area of Interest is outlined in black.

Project scale exploration using GRACE gravity data

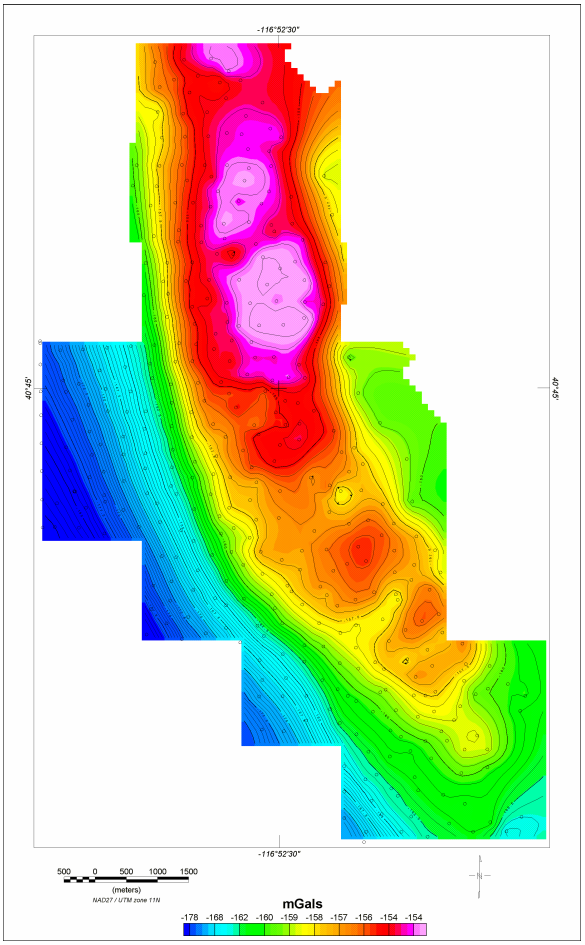

Figure 6: Detailed (nominal station spacing is 300-400 meters) ground gravity survey for the Area of Interest. The ground survey confirms the existence of a gravity high seen in the GRACE data but not observed in the NGS data.

Conclusions

GRACE gravity data have been processed as complete Bouguer anomaly data by the BGI and are available for download for free. I have shown in two case studies where these data have been used to constrain geologic models and aid in exploration. The data have been shown to be useful in an area with no national gravity database as well as in a country which is considered to have a good national database.