3D Inversion of Tensor Gravity Data

Introduction

Airborne gravity gradiometry surveys are becoming commonplace in mineral and hydrocarbon exploration. Each survey can consist of up to six gravity tensor components at millions of measurement locations. Three-dimensional inversion is desirable to recover a three-dimensional subsurface model that simultaneously fits all components of the collected data. High-resolution models can be used as an exploration tool by examining the recovered physical parameters rather than transforms of the observed tensors. Up until now, the number of data and model parameters associated with these data sets made an inversion difficult to carry out, even with substantial computational resources. In this work, we present a finite-volume, differential-equation method for gravity gradiometry data inversion. A principal benefit of the differential equation formulation arises from not explicitly forming the dense matrix that is required through the integral equation approach. Forward modeling involves solving a linear system of sparse, discrete operators by preconditioned conjugate gradients. This can save a significant amount of time over the entire inversion process. The number of data does not directly affect the size of the inversion as the fields are solved on the model and then interpolated to the observation locations. To demonstrate the effectiveness of our method, we present an inversion of the Bathurst Mining Camp region that consists of 1.4 million data measurements and a mesh of 24 million cells.

Bathurst Mining Camp

We demonstrate the inversion capabilities of Computational Geosciences Inc. (CGI) by inverting six-component data flown by Bell Geospace and obtained from the New Brunswick Department of Natural Resources at the Bathurst Mining Camp in New Brunswick, Canada. The area has been extensively studied with geo-chemistry, geology and geophysics. Figure 1 shows the complex regional geology in an area rich with volcanogenic massive sulfide (VMS) ore deposits. The density contrast (∼1.2 g/cm³) of these deposits to the host sediments creates an ideal target for gravity gradiometry surveys.

![Figure 1: Geology of the Bathurst Mining Camp overlain with known VMS deposits](image-url)
Inversion Results

The area covers 65 km by 70 km and has more than 15,000 line kilometers of data. Each line was flown at a 200-m spacing and draped 80 m over topography. The observed data (Figure 2) have been terrain corrected at 2.7 g/cm³. Our mesh consists of 100-m cubic cells in its core and padding cells for boundary conditions. The total size of the mesh was 30,277,632 cells (704 × 672 × 64) with 24,695,973 cells below topography. There were 243,251 locations with six tensor components for a total of 1,459,506 data that were inverted. A depth slice of the inverted model can be seen in figure 3. The 3D model provides great detail into the geologic structures and allow geoscientists to effectively explore targets of interest.