Quantitative 3D modelling of Geophysical Data in British Columbia.

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Mira Geoscience ...modelling the earth

Geoscience BC

Overview

The Mira Geoscience Advanced Geophysical Interpretation Centre has completed 3D inversion modelling, integration, and visualization of airborne gravity, magnetic, and electromagnetic data for Central BC, Canada including QUEST WEST and integrated it with the Nechako, QUEST, and QUEST South project areas. This was undertaken for Geoscience BC as follow-up analysis of geoscience data. The objective of this work is to provide useful 3D physical property products that can be directly employed in regional exploration to target prospective ground based on different exploration criteria.

This work considers all airborne gravity, magnetic and electromagnetic data available for the project area. The inversions were performed using the UBC-GIF GRAV3D, MAG3D, and EM1DTM, suite of algorithms for the gravity, magnetic, and AEM data respectively. The products are 3D inversion models of density contrast, magnetic susceptibility, and electrical conductivity, and integrated products combining the individual physical property models. In addition, detailed plate modelling of specific EM anomalies in several in-fill survey areas have been modelled using Maxwell discrete plates to provide a better interpretation where the target is less flat-lying in nature.

The available products can be directly employed in regional exploration using 3D-GIS methods to target prospective ground based on different exploration criteria relating to varying exploration strategies, and serve as an example of what can be achieved at a higher resolution in more detailed studies.

Background

Geoscience BC's series of QUEST projects, initiated in 2007, are a program of regional geochemical and geophysical surveys designed to attract the mineral exploration industry to under-explored regions of British Columbia (Figure 1).
(source: www.geosciencebc.com/s/Quest.asp).

3D inversion modelling of geophysical data provides located physical property distributions of the earth. This process enables direct spatial correlation between physical properties, geology, geochemistry, drill-hole databases, and known mineral resources or mineralized showings. At a regional scale, large geologic features can be defined, the thickness of overlying units better determined, and the relationship to mineralization can be investigated. The resulting physical property models are best viewed and analysed in a 3D environment where quantitative 3D GIS methods can be used to yield exploration targets.
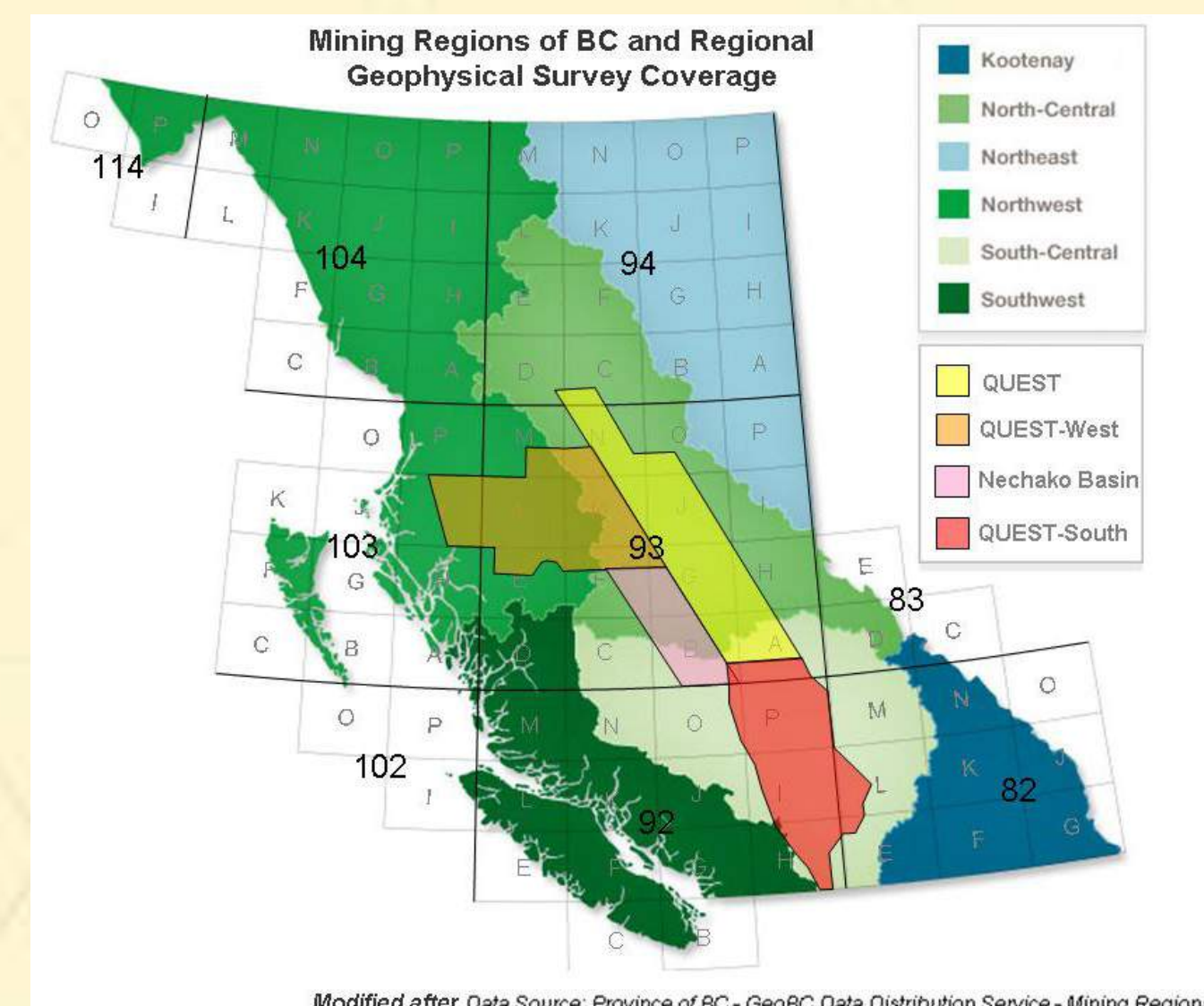

Figure 1. Map of BC showing the areas covered by Geoscience BC's regional geophysical surveys as well as the mining regions and NTS map sheets. The Central BC area is defined in this work as comprising the QUEST, QUEST West, QUEST South, and Nechako basin survey areas.

Data

Gravity Data:
The gravity data set consists of airborne gravity data collected by Sander Geophysics at a line spacing of 2000m (East-West lines) for the QUEST, QUEST West, QUEST South, and Nechako Basin surveys, and regional gravity data compiled by the Geologic Survey of Canada in the Canadian Gravity Database (Figure 2). Bouguer data corrected at a density of 2.67 g/cm³ is used.

The data are combined and prepared for regional inversion modelling as a processing step that enables effective removal of regional signal prior to detailed modelling.
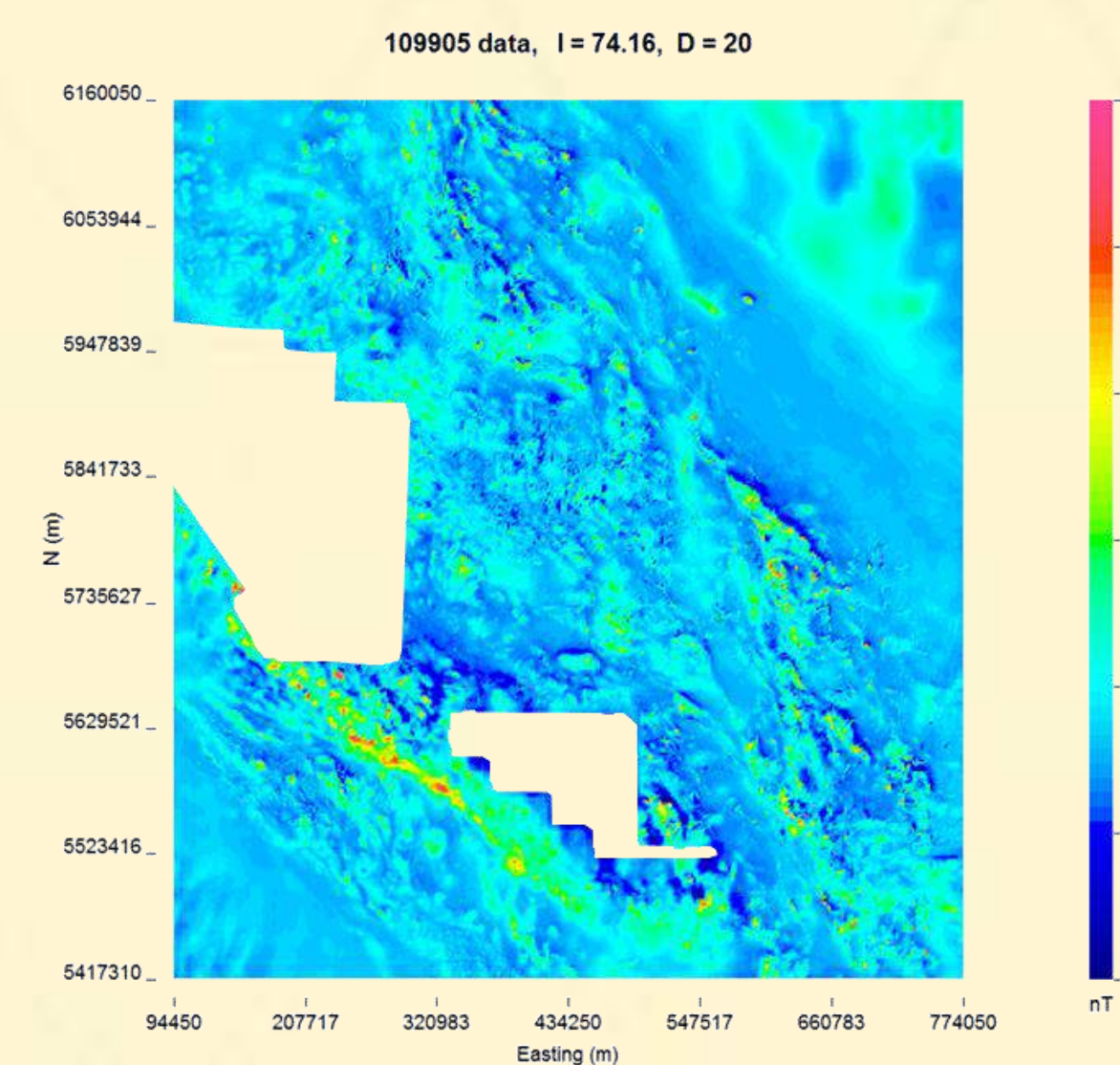

Figure 2: Terrain-corrected Bouguer gravity data prepared for regional inversion modelling.

Figure 3: Total Magnetic Intensity data prepared for regional inversion modelling. The CGRF has been removed.

Magnetic Data:
The magnetic data set consists of helicopter-borne data collected by Geotech Ltd (QUEST), and Aeroquest Ltd. (QUEST West), and data downloaded from the GSC Canadian repository databases and USGS magnetic data (USGS Open-File Report 2002–361) (Figure 3).

As with the gravity data, the data are combined and prepared for regional inversion modelling prior to regional signal removal and detailed modelling.

Electromagnetic Data:
Helicopter-borne AeroTEM data were collected by Aeroquest Ltd. concurrently with the airborne magnetic data acquisition and have the same data coverage. The AeroTEM III electromagnetic system was used along with a high-sensitivity caesium vapour magnetometer.

The total survey coverage is 13,219.1 line-km. Line spacing for the main survey was 4000 m with no tie-lines. Lines were flown East-West and the main survey split into 9 parts (A1, A2, B1, B2, C1, C2, C3, D, F) and 6 in-fill areas with 200 m line-spacing and tie lines present (Bell, Endako, Equity, Granisle, Huckleberry, and Morrison). The last 15 of the 33 data channels (the off-times) were used for the inversion.

The data are modelled on a line-by-line basis for quality control of the inversion process and so inversion parameters (starting and reference conductivity, and data misfit) are tuned to the local geology using a laterally constrained procedure.
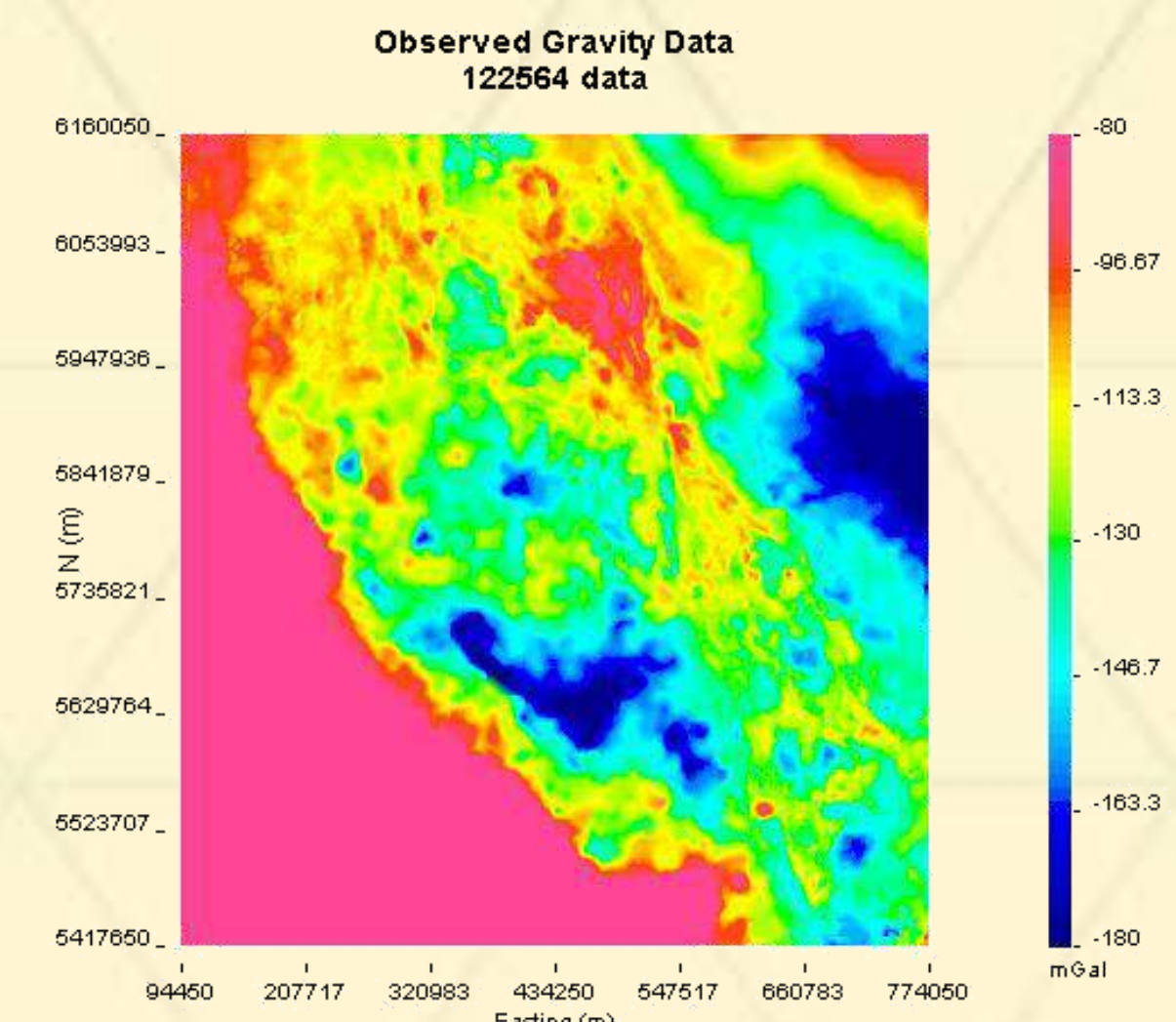
Modelling

Density contrast and magnetic susceptibility models have been produced for the survey areas. The models have been examined for consistency and merged with the existing model for the original QUEST area to construct detailed density contrast and magnetic susceptibility models for the entire Central BC area. Inversion modelling was performed using GRAV3D, MAG3D, a collection of modelling codes developed by the University of British Columbia Geophysical Inversion Facility.

The final detailed models contain over 50 million cells each with a horizontal dimension of 500m and a 250m vertical dimension. The models extend to a depth of 10,000m throughout the survey area in order to capture large-scale geologic features. Models are best viewed in 3D using a variety of views with different slices, cut-off values, and colour-scales.
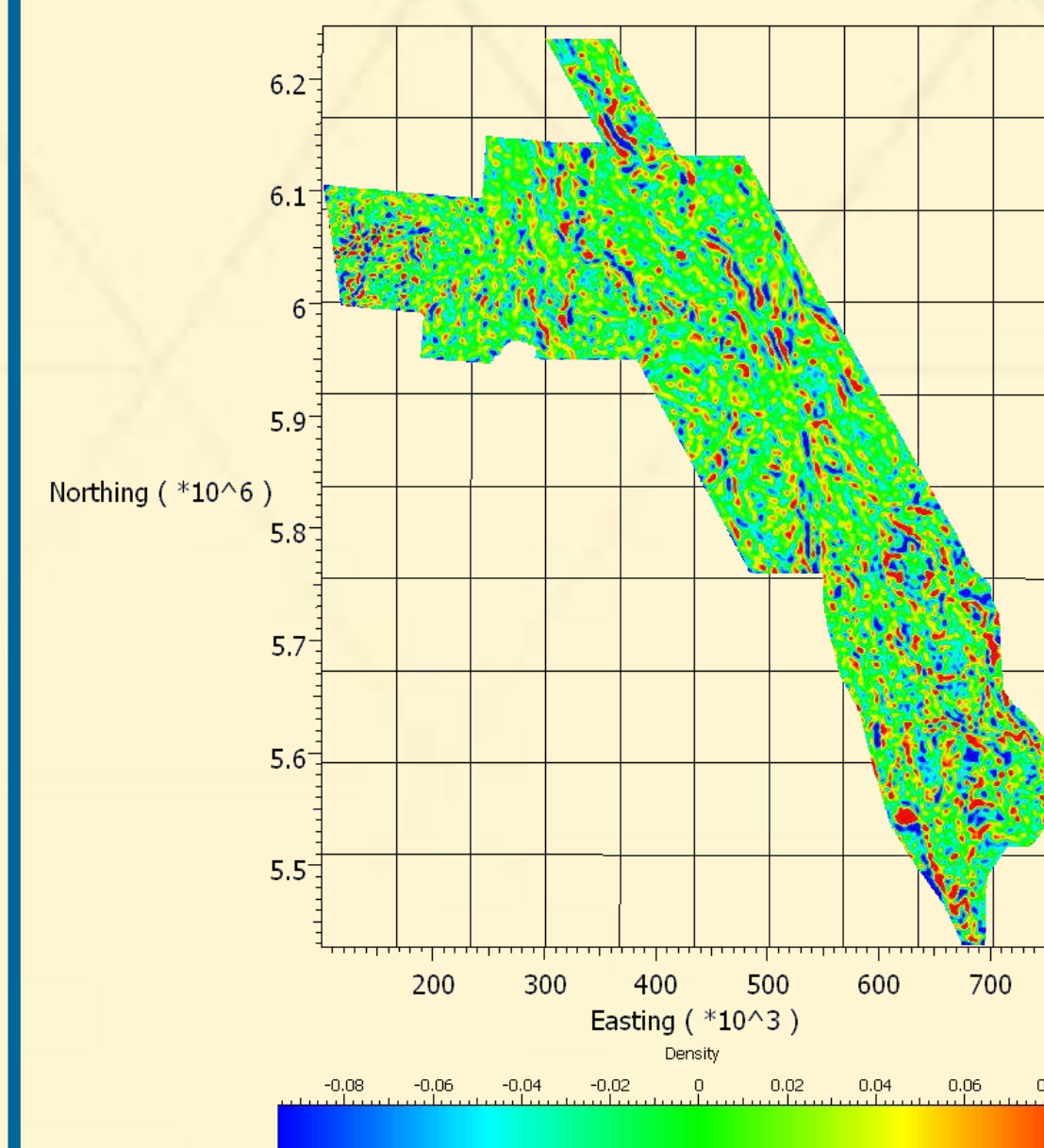

Figure 4: Plan view of the Central BC detailed density contrast model at sea level [g/cc].
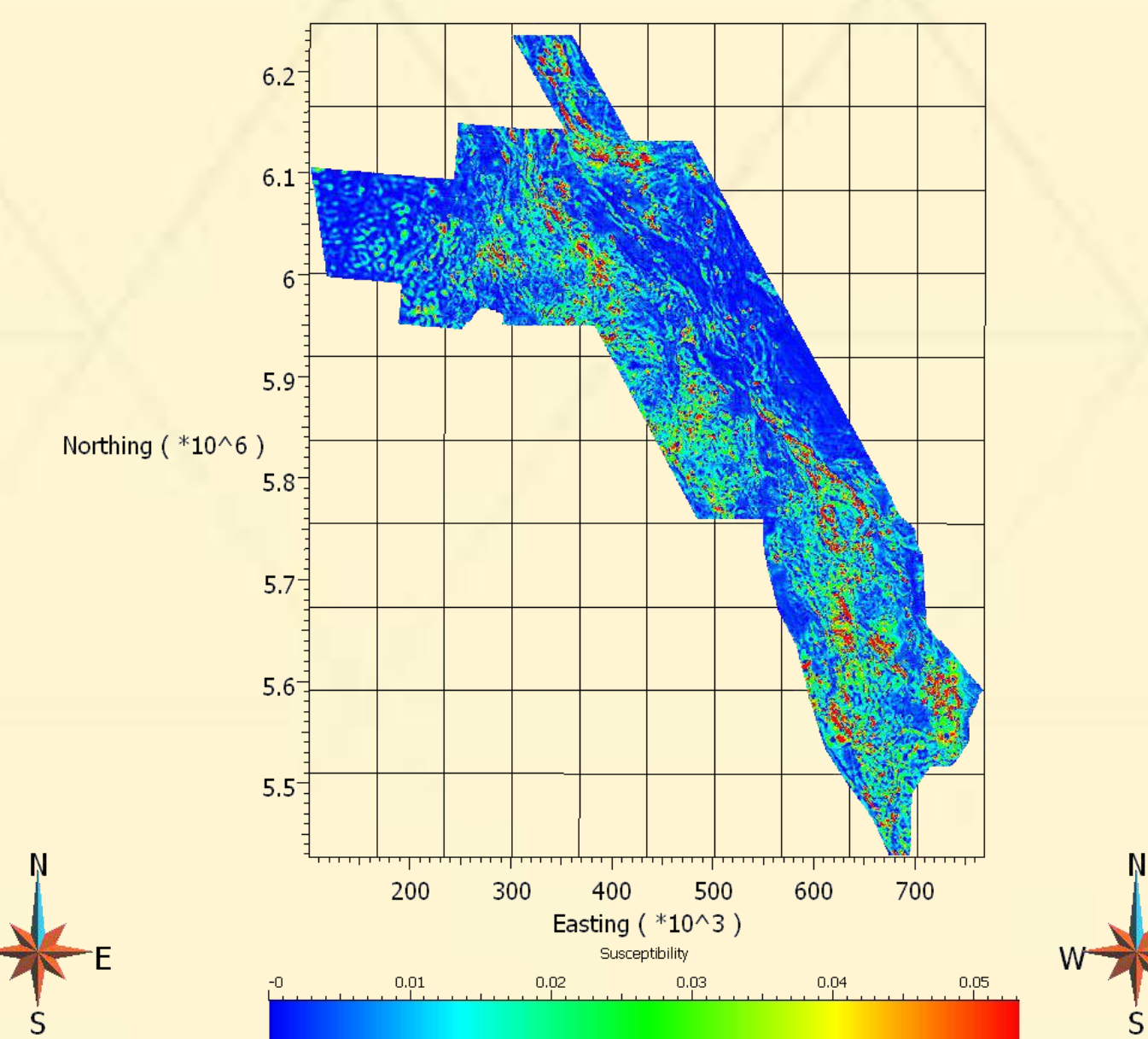

Figure 5: Plan view of the Central BC detailed magnetic susceptibility model at sea level [S.I.].

Electromagnetic modelling was performed using 1D inversion modelling with EM1DTM in order to define the thickness of overlying sediments and basalts, and to detect and define underlying conductive features (Figure 6), and using plate modelling with Maxwell for the 6 in-fill areas to provide complimentary information to the 1D conductivity inversions (Figure 7). While a plate model is an approximation to the true geometry, dips of specific geologic features are more easily interpreted and in some places may provide a more appropriate earth model.
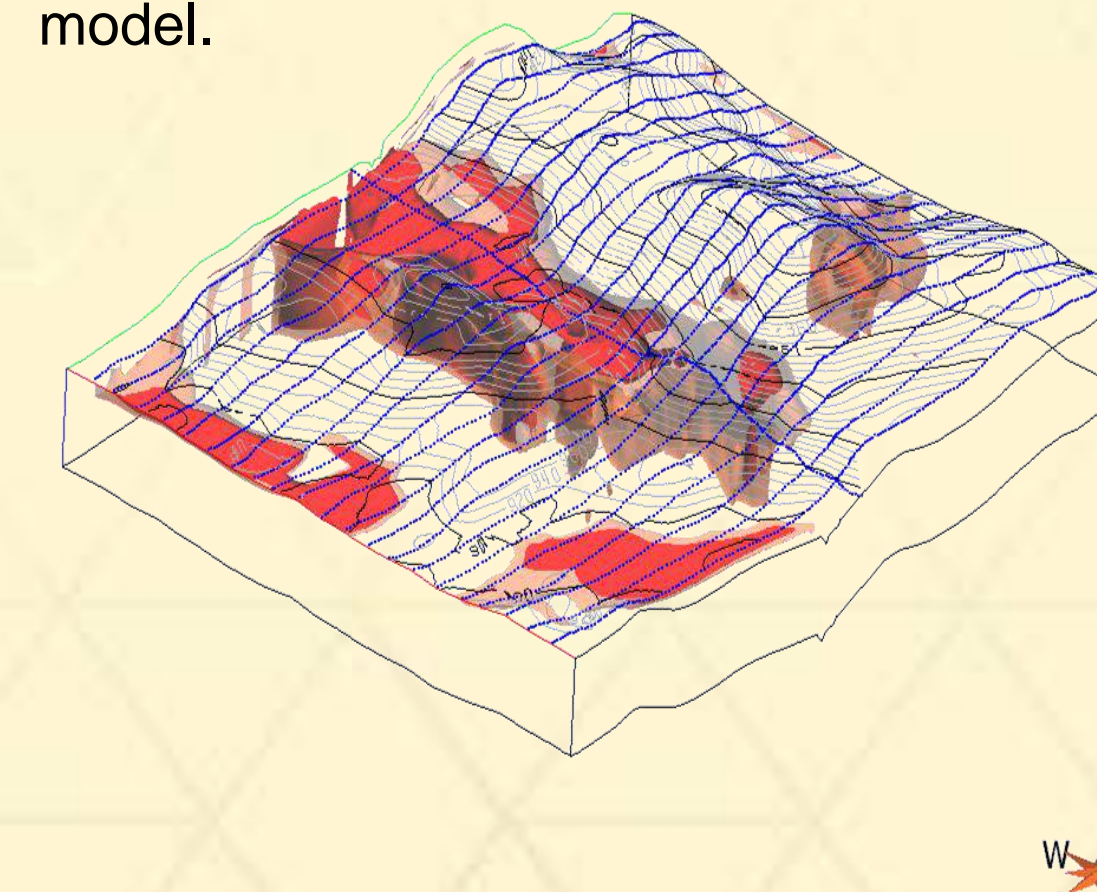

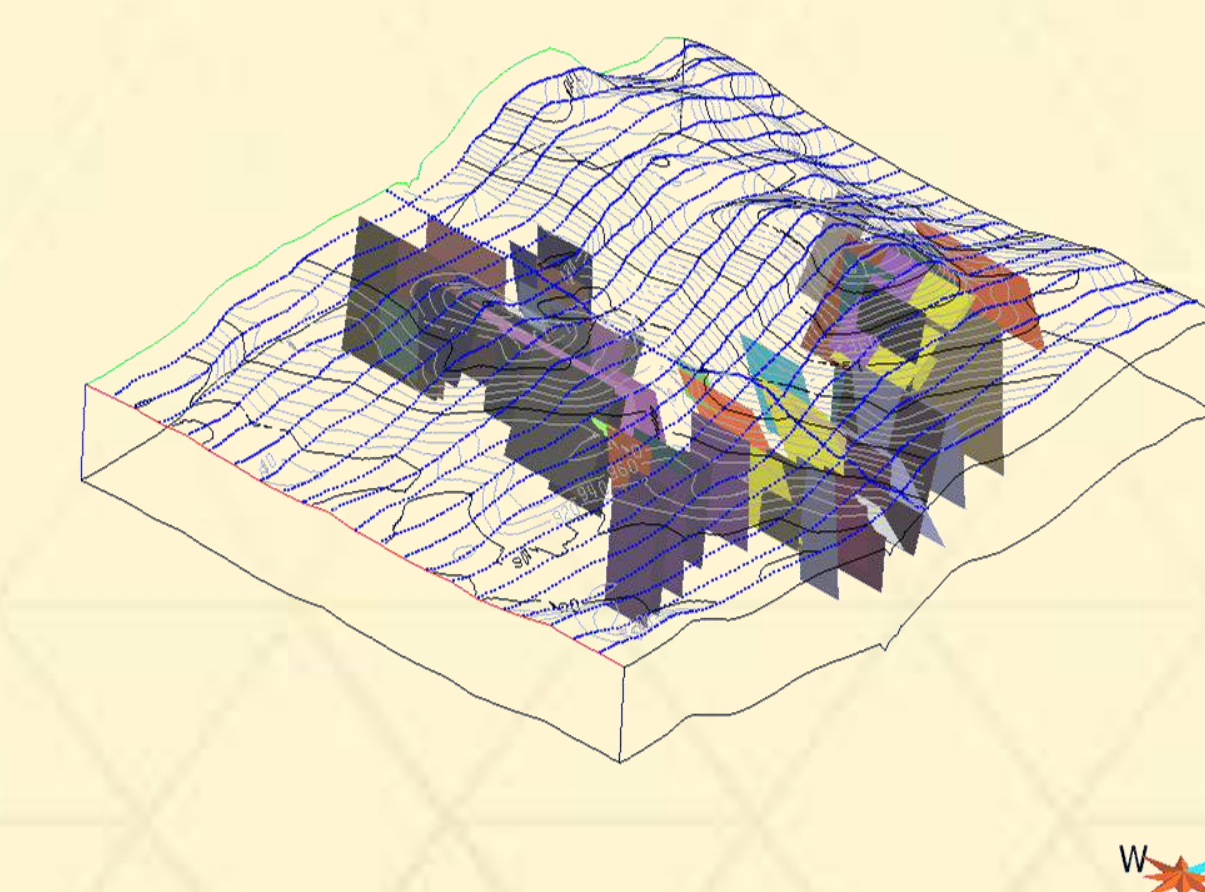*Figure 6: Huckleberry conductivity iso-surfaces for main conductive areas*

Figure 7: Huckleberry conductivity plate models

Integration and Analysis

Detailed density contrast, magnetic susceptibility, and conductivity inversion models have been produced for the Central BC survey area. These models, and the extensive suite of associated digital deliverables, will aid visualisation, interpretation, and quantitative analysis of the data for regional exploration in the area. As well as the modelling products, the work undertaken in modelling preparation is valuable quality control of the data. This will be of benefit as exploration personnel use these geophysical data sets.

Plan-, depth-, and cross-sections, and iso-surfaces are generated for integration with other exploration data. The physical property models can easily be brought into a 3D GIS environment where they can be analyzed and quantitatively interrogated.

Rocks are not uniquely characterized by a single physical property. The importance of the work presented here is that there are now volumetric regions in the Central BC area that are characterized by two, and in some cases three, physical properties. These distributions can be used with 3D GIS query technology to help identify potential exploration areas.

Regions of anomalously high or low physical properties can be identified, and intersections of these regions from the different modeling results can be computed in 3D using basic 3D GIS functionality. Through the understanding of physical properties, these regions can be related to geology and be assigned an exploration significance; and subsequently used in regional targeting using appropriate exploration criteria.

In follow-up work in these local regions, inclusion of additional a priori information in the form of geologic knowledge (conceptual model, overburden thickness, drilling, outcrop lithology, etc.), petrophysical information, and further geophysics, will help guide the selection of inversion parameters and constraints so that models with enhanced resolution can be obtained. This should make exploration more successful and cost effective.

Deliverables

An extensive suite of digital products have been delivered. These include several format types: Gocad, UBC, Maxwell, Geosoft, DXF, column ASCII, and PDF.
The following products are available at http://www.geosciencebc.com/s/Report2011-15:

- Observed and predicted data (gravity, magnetic, electromagnetic)
- 3D density contrast and magnetic susceptibility models
- Conductivity models:
  - Background Conductivity Model
  - 1D models
  - 1D models presented along line and draped under topography ˆ
  - 3D interpolated conductivity model as a function of depth below topography
  - 3D interpolated conductivity model conformable with topography.
  - Maxwell plates
- Several derivative products such as iso-surfaces and interpolated 3D models
- Gocad projects containing data and models for each survey block
- PDF3D scenes for easy visualization and communication of the results. The 3D PDF display products are produced as an output from Gocad. These can be viewed in the freely available Adobe Reader (versions 8 and higher).
- Report in PDF format.

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