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...modelling the earth

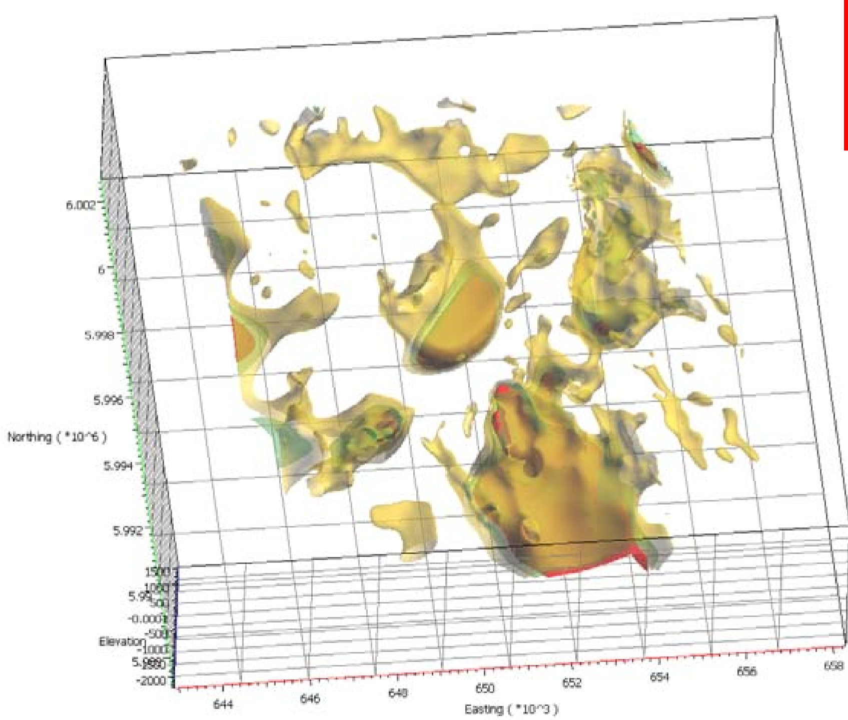
ADVANCED GEOPHYSICAL INTERPRETATION CENTRE

Mira Geoscience Limited
409 Granville Street, Suite 512 B
Vancouver, BC
Canada V6C 1T2

Tel: (778) 329-0430
Fax: (778) 329-0668
info@mirageoscience.com
www.mirageoscience.com

Unconstrained Airborne Magnetic Modelling of the Silver Queen Project, British Columbia.

BC Geological Survey
Assessment Report
33613f



Prepared for: New Nadina Explorations Ltd.

Project Number: 3619

By: Stanislawa Hickey

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Executive Summary

The Advanced Geophysical Inversion Centre (AGIC) of Mira Geoscience has completed unconstrained inversion modelling of airborne magnetic data from the Silver Queen Project, in Central British Columbia, for New Nadina Explorations Ltd. This work has been conducted to aid the geologic understanding of project areas and for prioritization of exploration targets.

The unconstrained inversions used the UBC-GIF MAG3D suite of algorithms. The results are presented as 3D magnetic susceptibility physical property models and provide guidance to the location and delineation of geology and mineralization.

Improvement of the magnetic susceptibility models may be achieved through geologically constrained modelling, over either a large area or on discrete anomalies.

Final magnetic susceptibility models are presented as UBC-GIF format ASCII 3D mesh and susceptibility model (SI units).

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1. Introduction

The Advanced Geophysical Interpretation Centre at Mira Geoscience has completed unconstrained magnetic modelling of airborne magnetic data from the Silver Queen property, Central British Columbia.

The process of magnetic "inversion" generates a 3D susceptibility model that has a computed response consistent with the observed survey data (to within user specified acceptance levels). The susceptibility model can in turn be interpreted in terms of mineralogy, and therefore lithology and/or geological processes and hence contribute to defining exploration targets.

The following sections provide information on the airborne magnetic data and methods employed for the modelling (sections 2 and 3), the data processing and geophysical modelling results (sections 4 and 5), and the conclusions and recommendations (sections 6 and 7). Project deliverables are tabulated in Appendix 1.

2. Data

The total magnetic intensity (TMI) data were provided to Mira Geoscience by New Nadina Explorations in the form of airborne magnetic dataset encompassing the Silver Queen property.

The project area is approximately 12.8 km by 13 km and the entire area was inverted. The modelling was carried out in the same coordinate system as that in which the data were provided; NAD83, UTM Zone 9N.

2.1. Topographic Data

The digital elevation model (DEM) data supplied with the aeromagnetic data was used to define the topography of the survey area for the inversion. An image of the topography defined from the DEM data is depicted in Figure 1.

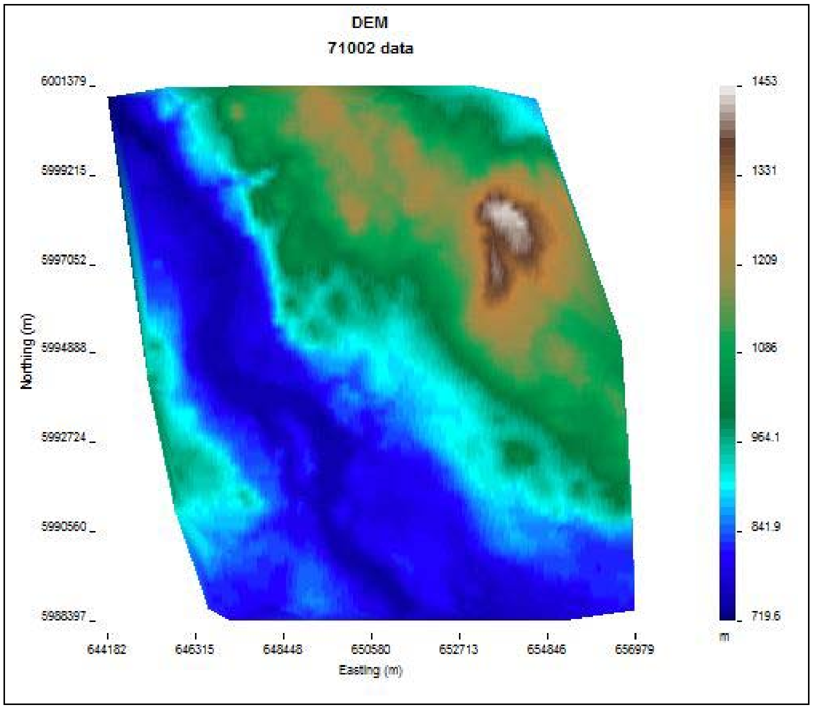

Figure 1: Survey area topography from the DEM data (meters).

2.2. **Magnetic Data**

The geophysical data consisted of a Geotech helicopter-borne magnetic survey acquired using a Geometrics split-beam optically pumped cesium vapor magnetic field sensor. The data were provided as a Geosoft database (GDB) file. The magnetometer elevation was set to 15 m above the EM receiver elevation. The levelled, diurnally corrected total magnetic data was used for the inversion. The inducing field parameters are shown in table 1. The data were collected along East-West lines with a nominal line-spacing of 200 meters. Tie lines were collected perpendicular to the survey lines, with a nominal line-spacing of 2 km. The distance along line between measurements is roughly 10 m.

3. Methodology

The objective of this project is to produce 3D susceptibility models for the survey area for exploration targeting that provides information about the local geology and mineralization.

The inversion modelling process creates a 3D representation of the earth using a discretization with many small cells each of constant magnetic susceptibility. The resulting model will predict the observed data to within a predetermined tolerance and will be optimized to produce robust, simple magnetic susceptibility features in the model that represent major geologic features when no additional geologic information is provided (unconstrained by geology). Topography is included in the modelling process. Total Field Magnetic data are inverted for a 3D susceptibility model of the earth using the UBC-GIF MAG3D inversion code. Appendix 2 summarizes the modeling software used.

Details of the data and model preparation and the inversion methodology are outlined below.

4. Processing

4.1. Magnetic Data Processing

The airborne magnetic data were prepared for inversion by reviewing the positioning and amplitude of the data. The data was considered to be of good quality and appropriate for inversion modelling.

The data were down sampled with a factor 3 to make the inversion modelling process tractable. The resulting data separation distance is approximately 30 m resulting in at least one data point per model cell. The International Geomagnetic Reference Field (IGRF) was removed prior the inversion. The inducing field parameters are shown in table 1.

Table 1: Inducing Magnetic Field Parameters

Latitude	54.08 N
Longitude	-126.6 E
Mean Elevation	954 m
Survey Date	2011.
Magnetic Field Inclination	73.22
Magnetic Field Declination	19.48
Magnetic Field Magnitude	56,289.7 nT

A standard deviation was assigned to the data for inversion modelling purposes. The standard deviation represents an estimate of all possible sources of data uncertainty including: sensor sensitivity and noise, GPS location uncertainty, modelling uncertainties (topographic representation in the model and small magnetic sources that cannot be accounted for in the discretization). The value is an estimate and the actual level of data misfit is determined during inversion. The uncertainties assigned to the data in the inversions were 2% of the magnitude with a 59.4 nT floor error. These uncertainties are used in the UBC inversion process to control the desired level of fit to the observed data.

The data were prepared in UBC ASCII data format.

Figure 2 shows the total magnetic field data, with IGRF removed and down sampled, over the Silver Queen property.

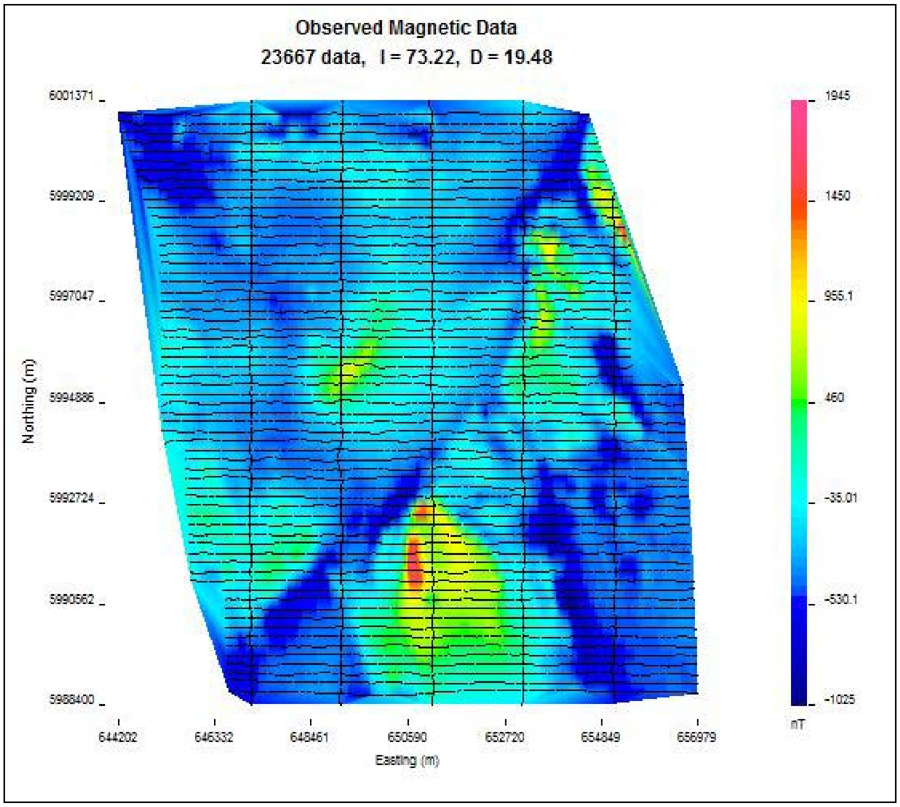

Figure 2: Total Magnetic Intensity, IGRF removed, down-sampled by a factor of 3 (in nT) plotted with the survey traverse lines.

It should be noted that the data will only be able to provide useful definition at depths equal to the distance from the edge of coverage. That is, the model will be well defined near the surface for all the data coverage, and in order for the model to be well defined at a depth of 1000 meters, the data coverage must extent in all directions at least 1000 meters.

5. Geophysical Modelling Results

5.1. Magnetic Inversion

The unconstrained magnetic inversion was performed using a 50 m x 50 m x 25 m cell size mesh. The inversion parameters are listed in Table 2.

The observed data, predicted data and the difference normalized by the standard deviation between the observed and predicted data are shown in the Figure 3.

The predicted TMI data generated by the model and the observed TMI data agree very well. Most of the features of the magnetic signal are reproduced, however there is some correlated signal seen in the difference plots suggesting that some of the localized magnetic anomalism of strong near surface anomalies has not been fully recovered. A smaller cell size is necessary to fully recover the detailed magnetic sources, although the most important magnetic sources have been reproduced with the inversion.

Table 2: Inversion Parameters

Inversion Modelling Parameters	Inversion Modelling Parameter Value
Convergence Criteria	Fixed Target Misfit (Chi factor = 0.9)
3D Mesh	Core 50 x 50 x 25 m cells with increasing horizontal length and vertical depth thicknesses on a scale of 1.4
Number of cells in mesh	6,589,200
Length Scales	150, 150, 75 (Le, Ln, Lz)
Number of data inverted	23,667
Achieved Data Misfit	2.216265E+04
Data errors	2% of the magnitude with a 59.4 nT floor was applied to all the data

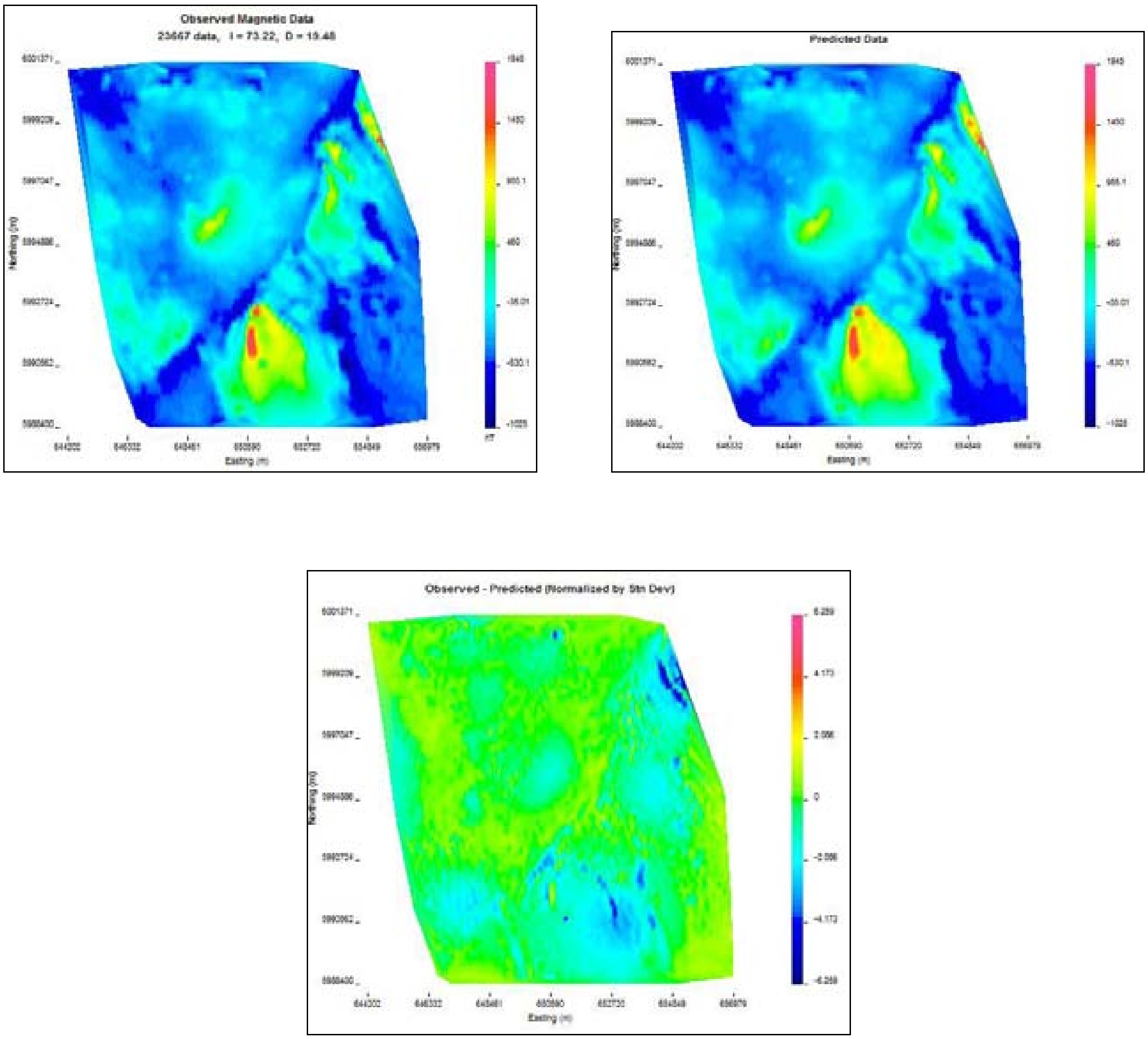

Figure 3: Observed TMI data with IGRF removed (top left), predicted TMI data with IGRF removed from the inversion (top right) and the difference normalized by the standard deviation, between observed and predicted data (bottom). Units (nT).

Several views of the 3D magnetic susceptibility model are shown in the following figures.

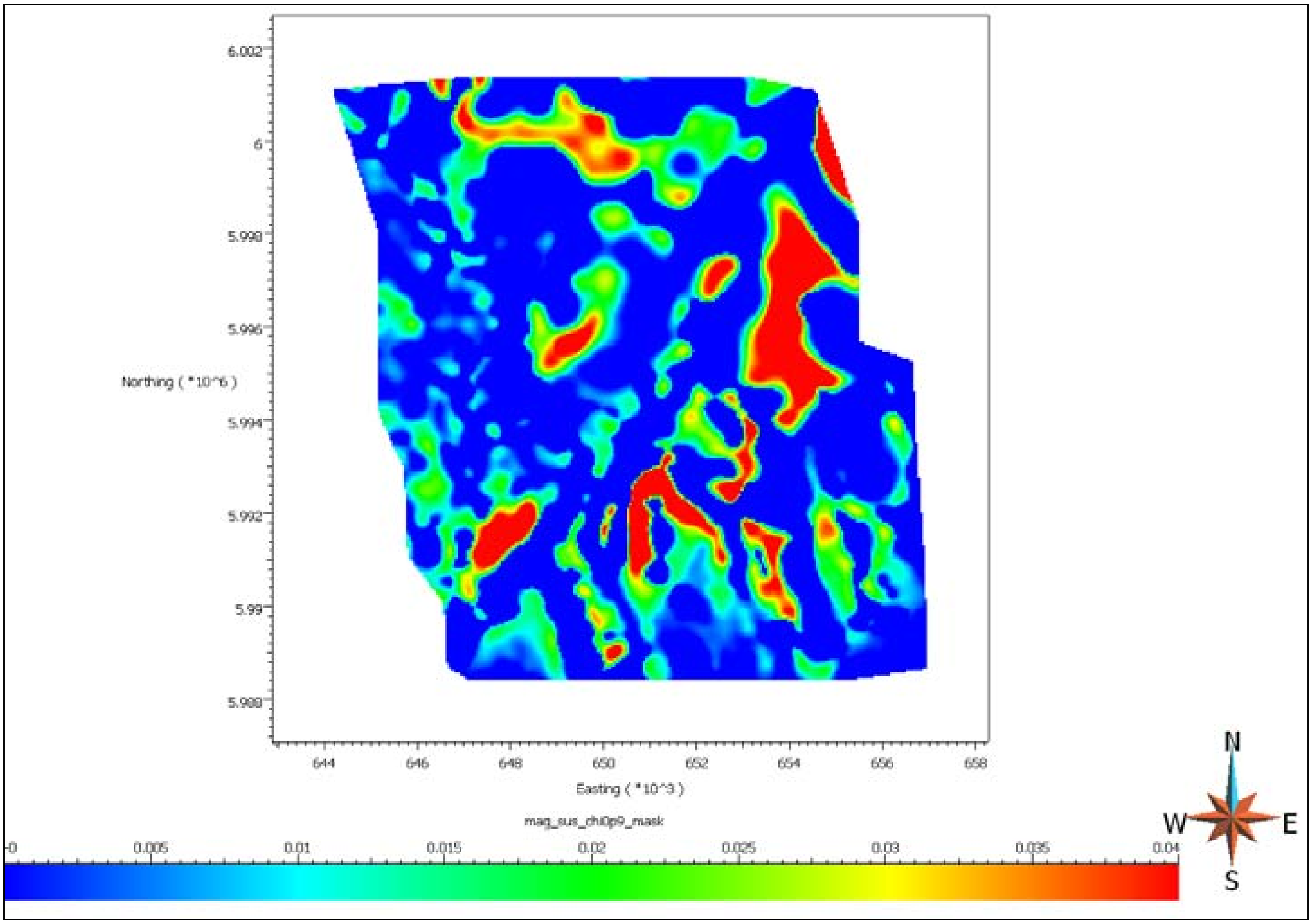

Figure 4: Magnetic susceptibility (in SI) plan section at an elevation of 612.5 m (approximately 105 m below the mean topography).

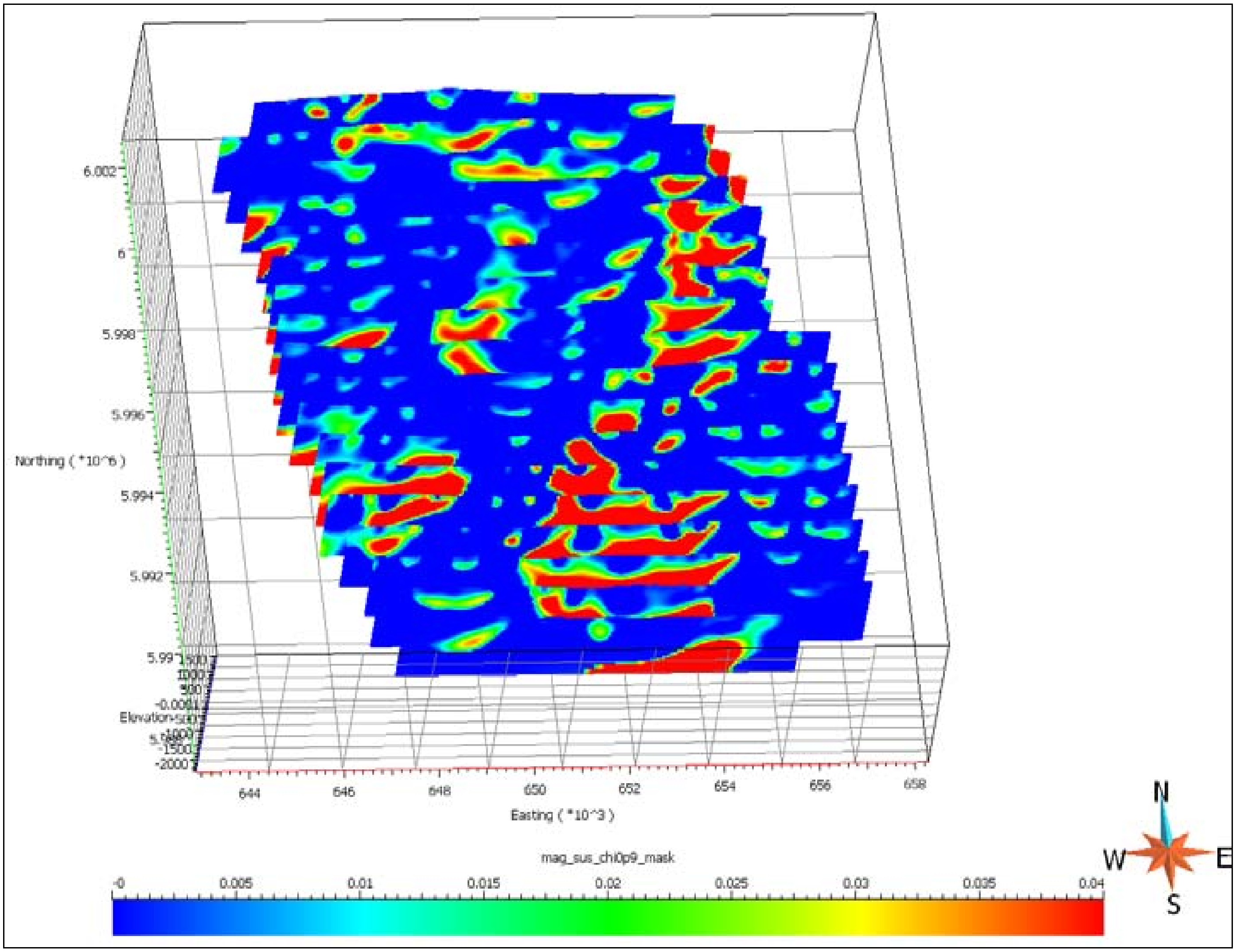

Figure 5: Perspective view of magnetic susceptibility E-W vertical sections (in SI).

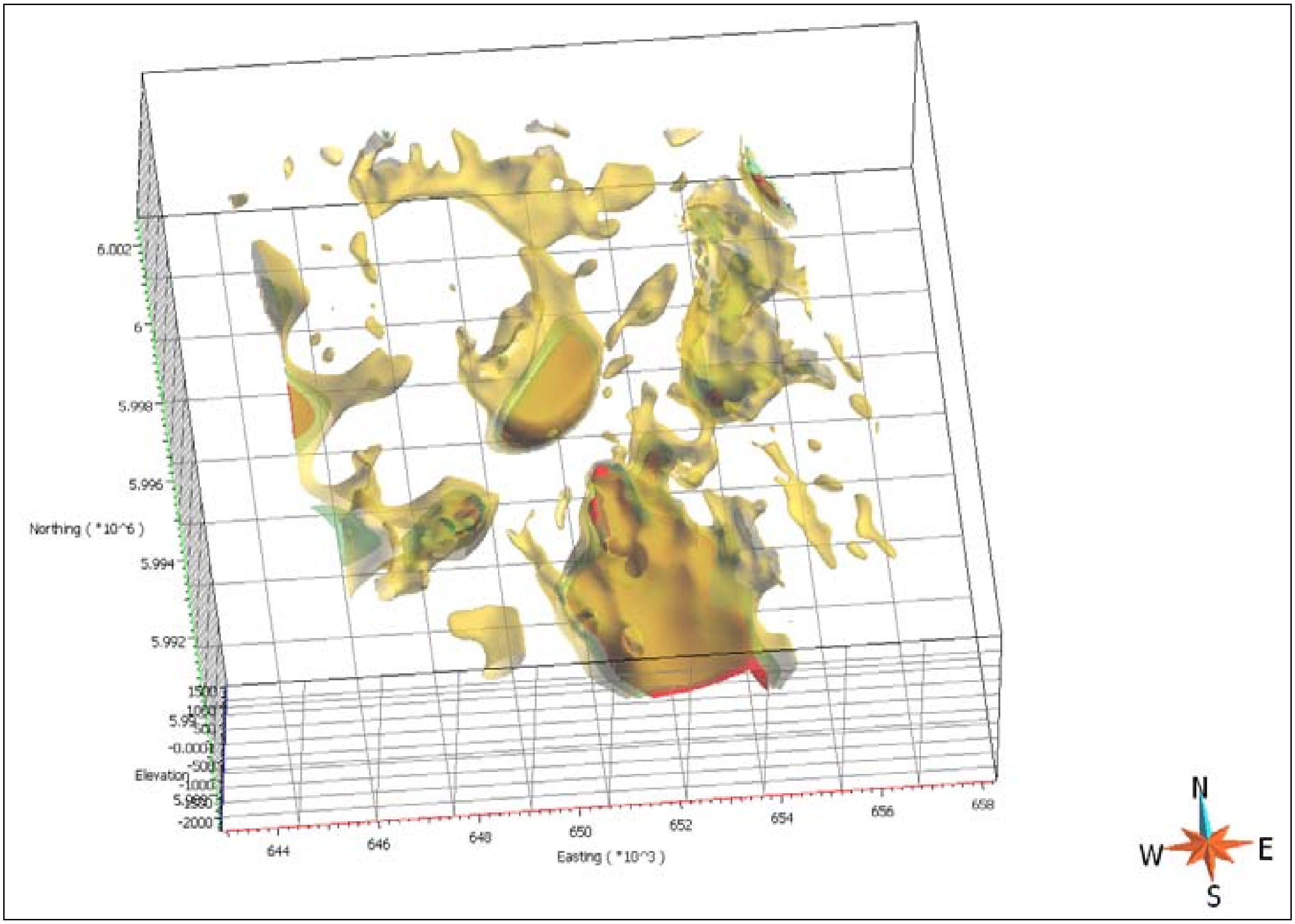

Figure 6: Perspective view showing magnetic susceptibility iso-surfaces rendered at 0.02 SI (gold), 0.06 SI (green), and 0.1 SI (red), highlighting magnetically susceptible regions.

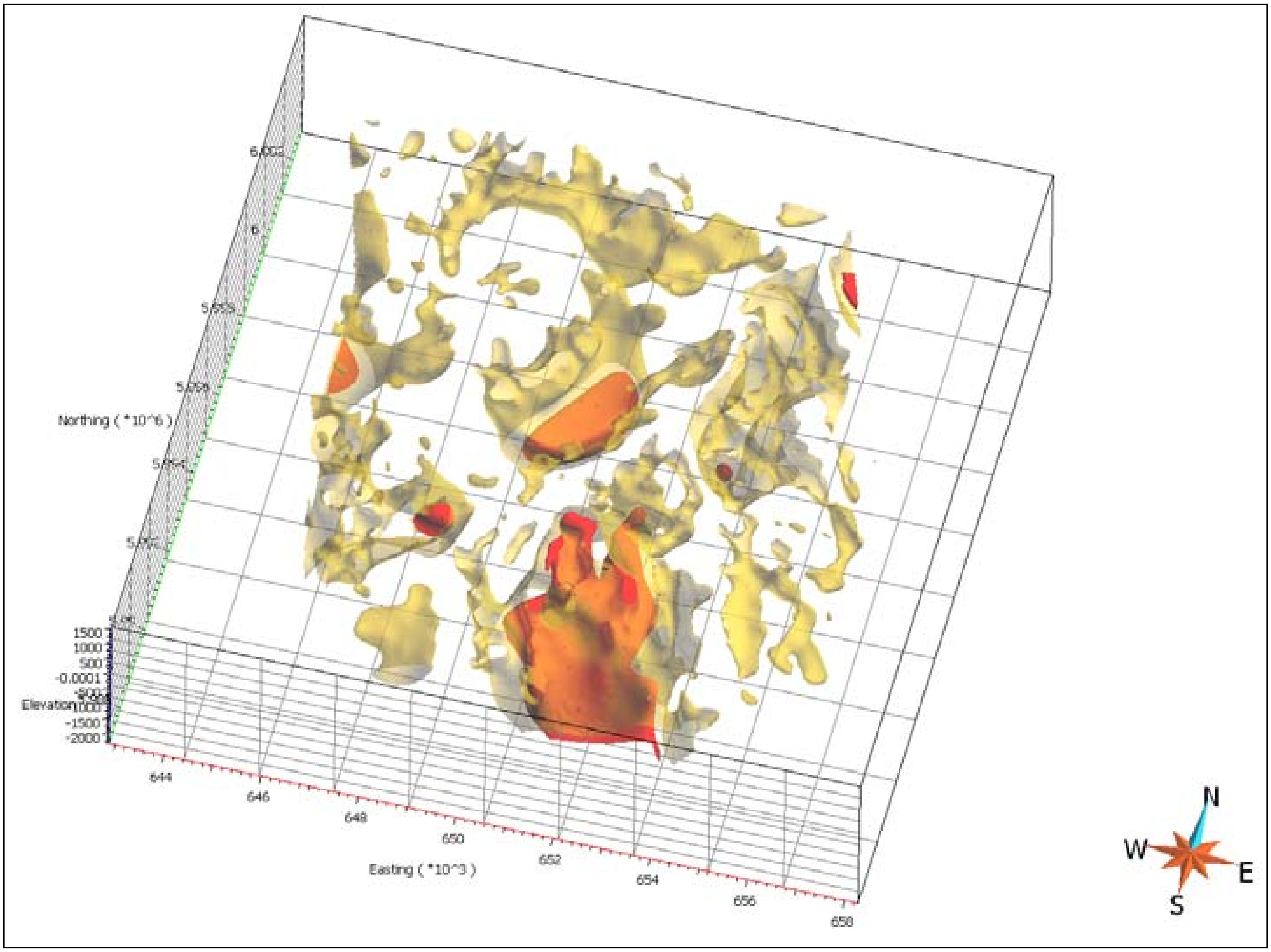

Figure 7: Perspective view looking down showing magnetic susceptibility iso-surfaces rendered at 0.01 SI (gold), 0.1 SI (red), highlighting magnetically susceptible regions.

The results of the constrained inversion show a complex geometry but reveal the 3D geometry of the major magnetic features in the project area. The model susceptibilities range from 0 up to 0.26 SI.

6. Conclusions

Unconstrained magnetic inversion has been completed on the Silver Queen survey area. The results have defined several large magnetic features and discrete anomalies over the project area.

Neither remanent magnetization nor self-demagnetisation was considered during modelling. Some demagnetization effects may be present in the results. The linear assumption of magnetization being linearly related to susceptibility made in the inversion modelling procedure can be violated in the presence of susceptibilities above ~ 0.1 or 0.2 S.I. Susceptibilities of 0.1 S.I. and higher are present in this model.

In these results, the body geometries are more characteristic of intrusive and volcanic flows, and the effect of demagnetization is not thought to be important. The unconstrained inversion model can be used to delineate limits of intrusive bodies, and to identify areas where there is destruction of magnetite in structural corridors, and where flat lying sources that may be volcanic flows exist.

Apart from very localized strongly magnetic features, all the sources have been well represented in the model as shown by a comparison between the observed field magnetic data and the data predicted by the magnetic inversion modelling result.

7. Recommendations

The magnetic inversion results should be reviewed in the context of the other available geological and geophysical data. The inversion models should be correlated with known targets and existing results from past exploration activities such as prospecting, geologic mapping, ground geophysical surveys and drilling.

If a more detailed magnetic inversion model is desired, a geological model can be built from geological maps, sections and drillhole information and then used to direct and constrain a revised magnetic inversion run. Additional data would produce more reliable models that are consistent with multiple data sets. This can be performed on smaller scale regions of the model if data is not available for the region as a whole.

The presence or absence of self-demagnetization in the most strongly magnetized parts of the model cannot be confirmed without further work and the collection of samples for laboratory measurements. While it may be important to consider this to rule out any possibility of it affecting the geometry of some discrete, highly susceptibility parts of the model, generally, the magnetic inversion process used here has worked well without explicitly considering the effects of self-demagnetization. The investigation of demagnetization effects is not recommended at the present time.

The results of this magnetic inversion can be combined in a 3D GIS study where all information relating to defined exploration criteria can be integrated and quantified, resulting in optimal target selection.

References and Related Reading

MAG3D Manual 2005, from http://www.eos.ubc.ca/ubcgif/ or
http://www.eos.ubc.ca/ubcgif/iag/sftwrdocs/mag3d/mag3d-manual.pdf

Appendix 1 Project Deliverables

Table 3: Project Deliverables

Format	Name	Description
Report	Report on Unconstrained Airborne Magnetic Modelling of the Silver Queen Project, British Columbia.	Logistics report detailing the unconstrained magnetic inversion.
PDF	SilverQueen_Magnetic_Susceptibility_Isosurfaces.pdf	3D PDF
Gocad	SilverQueen_Compilation_Project.gprj	Gocad compilation project.
DXF	EX: Mag_Sus_Iso_Surface_0p02SI.dxf	Magnetic susceptibility iso-surfaces.
UBC-GIF ASCII	Airborne_Data_ds3.obs, Maginv3d.pre, Maginv3d.sus, Mesh_airborne_nopadding.msh.	Observed data, Predicted data, Unconstrained susceptibility model, Mesh.

Appendix 2 Modelling Software

MAG3D

MAG3D is a program library (version 4.0 as of August 2005) for carrying out forward modelling and inversion of surface, airborne, and/or borehole magnetic data in the presence of a three dimensional Earth. The program library carries out the following functions:

Forward modelling of the magnetic field anomaly response to a 3D volume of susceptibility contrast.

Data are assumed to be the anomalous magnetic response to buried susceptible material, not including Earth's ambient field.

The model is specified using a mesh of rectangular cells, each with a constant value of susceptibility, and topography is included.

The magnetic response can be calculated anywhere within the model volume, including above the topography, simulating ground or airborne surveys, and inside the ground simulating borehole surveys.

Assumptions: This code assumes susceptibilities are "small". This means results will be wrong when susceptibilities are high enough to cause self-demagnetization.

There is no method for incorporating remanent magnetization in this code.

Inversion of surface, airborne, and/or borehole magnetic data to generate 3D models of susceptibility contrast.

The inversion is solved as an optimization problem with the simultaneous goals of (i) minimizing an objective function on the model and (ii) generating synthetic data that match observations to

within a degree of misfit consistent with the statistics of those data. To counteract the inherent lack of information about the distance between source and measurement, the formulation incorporates a depth or distance weighting term. By minimizing the model objective function, distributions of subsurface susceptibility contrast are found that are both close to a reference model and smooth in three dimensions. The degree to which either of these two goals dominates is controlled by the user by incorporating a priori geophysical or geological information into the inversion.

Explicit prior information may also take the form of upper and lower bounds on the susceptibility contrast in any cell (as of version 4.0). The regularization parameter (controlling relative importance of objective function and misfit terms) is determined in either of three ways, depending upon how much is known about errors in the measured data.

The large size of useful 3D inversion problems is mitigated by the use of wavelet compression.

Parameters controlling the implementation of this compression are available for advanced users. (MAG3D Manual).

Appendix 3 Magnetization and Modelling

Magnetization

Local magnetic anomalies in the data are due to the magnetic field produced by magnetically susceptible material beneath the surface that has been magnetized by the earth's ambient magnetic field. The majority of the response comes from shallow material due to the fast fall-off nature of the magnetic field. For low susceptibilities (< ~0.2 SI) the strength of the magnetization vector, and resulting field, is a linear relationship between the earth's field flux intensity and susceptibility. This makes interpretation relatively intuitive and modelling a less complex process.

Self-Demagnetization

For high magnetic susceptibilities (> ~0.2 S.I) the relationship between the strength of magnetization and susceptibility is non-linear. This non-linear relationship is the cause of the phenomena known as self-demagnetization where a component of the magnetization opposes the earth's field. The effect of self-demagnetization, which aligns the magnetization vector with the long-axis of the magnetic body, is to reduce the amplitude of the anomaly and change the anomaly location and shape, thus making traditional interpretation unreliable (Wallace, 2007). A typical result of considering only linear magnetization in modelling routines when non-linear magnetization is present is for the resulting dip of a magnetic body to be too shallow.

Remanent Magnetization

Remanent magnetization (or remanence) is a permanent magnetization that can be obtained by ferromagnetic material through several phenomena including thermo-, chemical and detrital remanence. Often, the remanence obtained in the past becomes oriented in a direction different from the Earth's field today; this can occur through movement of the Earth's magnetic poles or through tilting of the stratigraphic units containing the permanently magnetized material. Hence, the induced and remanent components can be oriented in different directions.

Typical magnetic inversion routines assume no remanent component exists, employ a magnetization direction aligned with the current earth's inducing field, and erroneous results can be obtained from this incorrect assumption (Lelievre et al., 2006). Typical artefacts from inversions where remanence is not accounted results in model features with very low susceptibility increasing in width with depth.