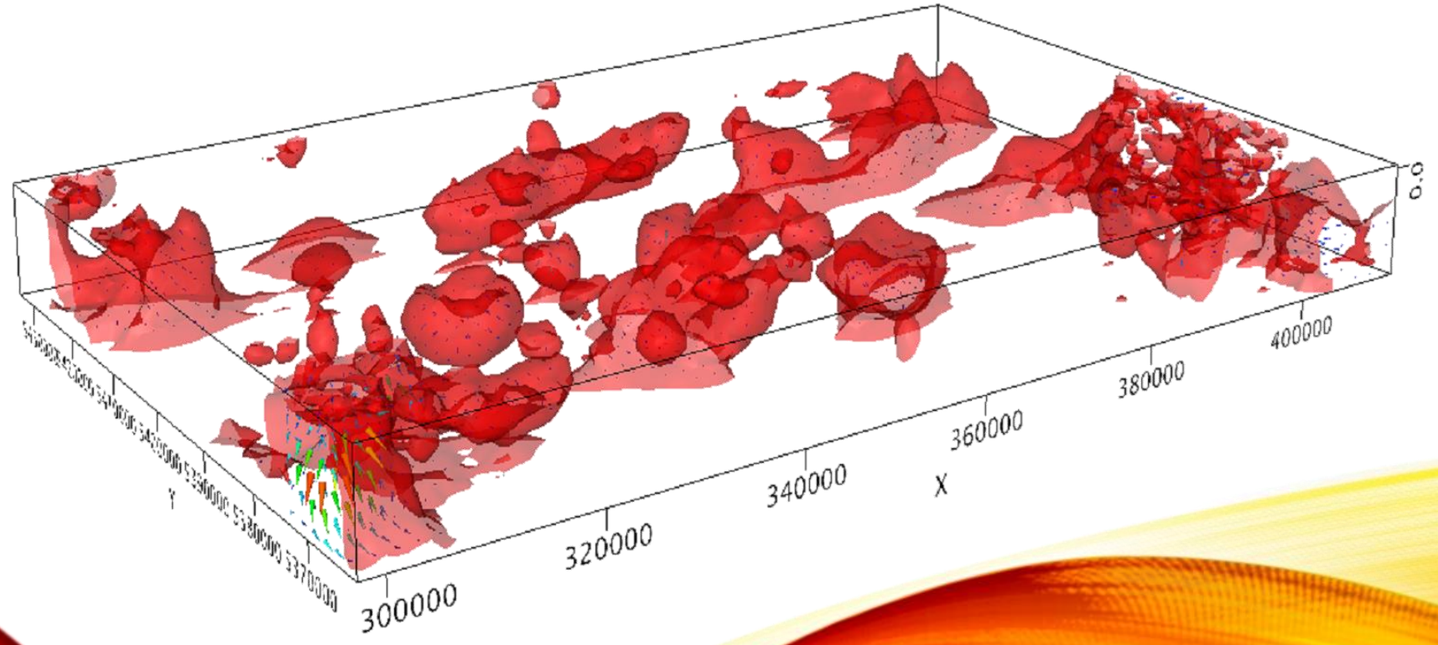
Applying Magnetic Vector Inversion (MVI) on Aeromagnetic Data in the Thunder Bay Region of the Mid-Continent Rift

Shokouh Riahi, James E. Mungall , Richard E. Ernst

Department of Earth Sciences, Carleton University, Ottawa, Ontario, Canada



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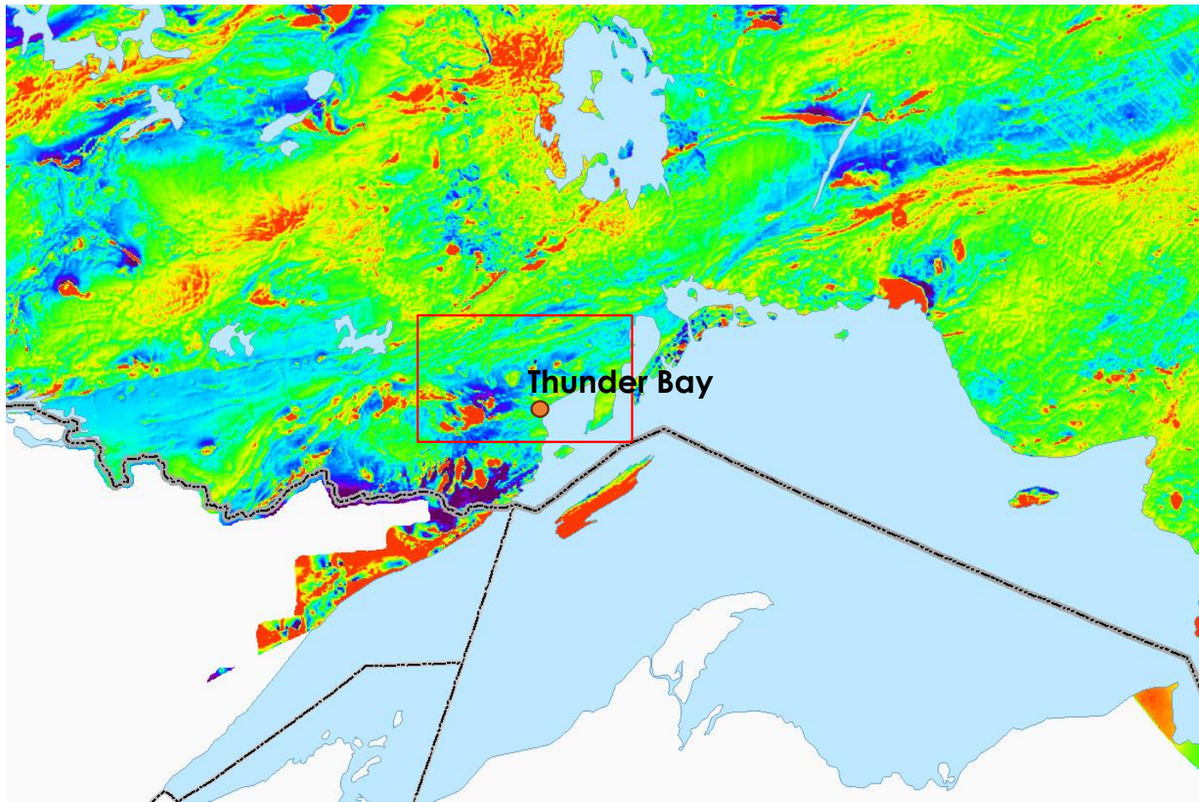
Introduction

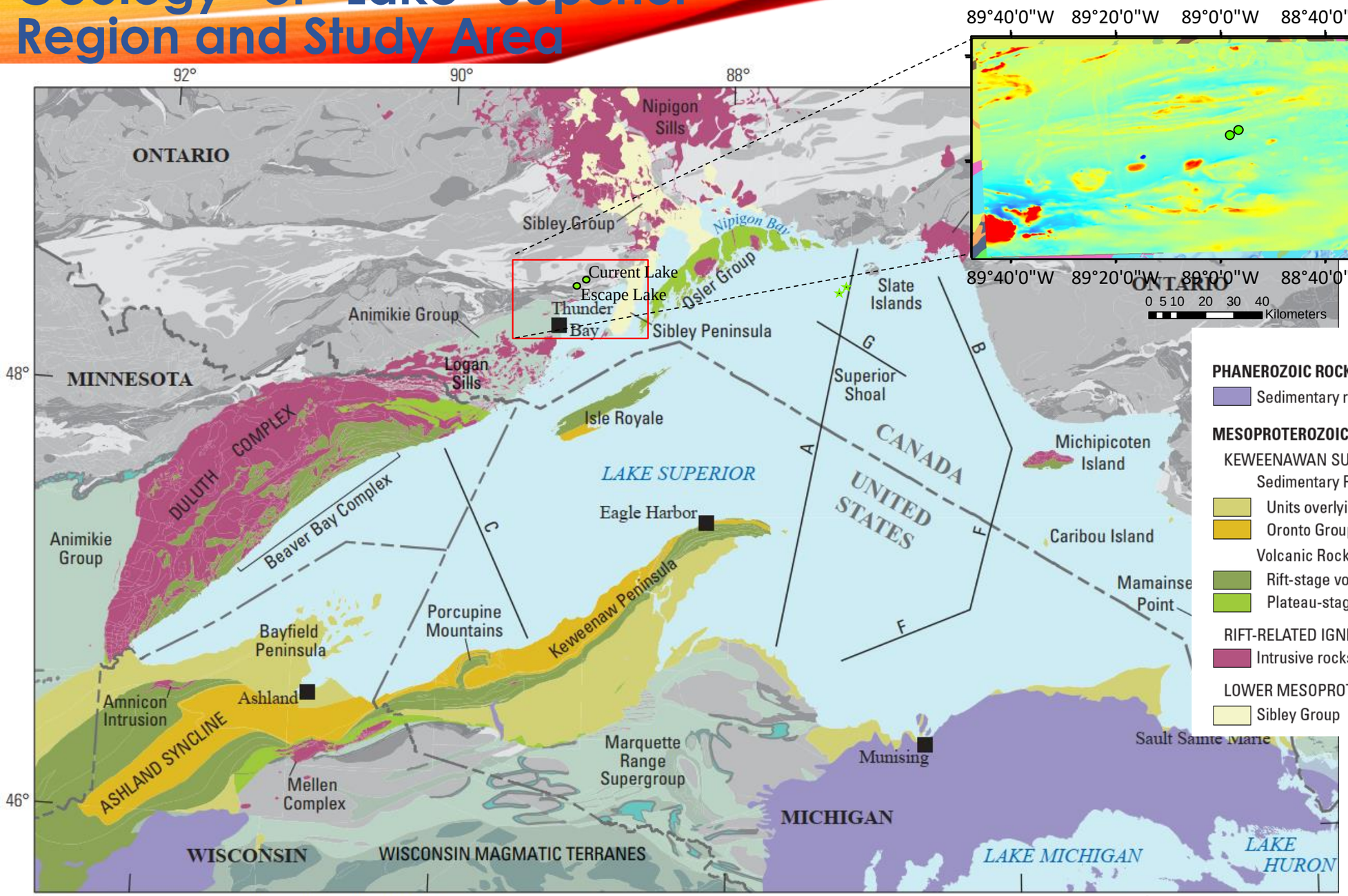
This research focuses on applying Magnetic Vector Inversion (**MVI**) to aeromagnetic data collected in the Thunder Bay North (**TBN**) region to generate geologically plausible targets for further testing through modeling or drilling.

MVI

- Advanced tool for subsurface exploration
- Effective where magnetization deviates from the Earth's magnetic field
- Looks beyond induced magnetism
  - magnetic remanence
  - self-demagnetization
  - Magnetic anisotropy due to geological structure
- More reliable depiction of subsurface geology compared to susceptibility inversion.



Geology of Lake Superior Region and Study Area



Legend

Faults_OGS_Superior

Area Lithology

RegionClas

- Clastic metasedimentary
- Granitoids
- Granitoids and Gneisses
- Mafic and Ultramafic Intrusions
- Mafic and ultramafic intrusions
- Metasedimentary Units
- Metavolcanic

EXPLANATION

PHANEROZOIC ROCKS
- Sedimentary rocks

MESOPROTEROZOIC ROCKS

KEWEENAWAN SUPERGROUP

Sedimentary Rocks
- Units overlying Oronto Group
- Oronto Group

Volcanic Rocks
- Rift-stage volcanic rocks
- Plateau-stage volcanic rocks

RIFT-RELATED IGNEOUS ROCKS
- Intrusive rocks

LOWER MESOPROTEROZOIC ROCKS
- Sibley Group

PALEOPROTEROZOIC ROCKS
- Sedimentary and metasedimentary rocks
- Iron Formation
- Volcanic rocks
- Plutonic rocks

ARCHEAN ROCKS
- Metasedimentary rocks
- Greenstone
- Granite and granitic gneiss

A — **GLIMPCE seismic reflection line**

(E. Anderson, after C. Dicken, U.S. Geological Survey, written commun., 2018).

Physical Rock Properties

Understanding of petrophysical properties of an exploration target, its host rock, and the surrounding geological formations is essential for interpreting and optimizing geophysical surveys.

- Magmatic Ni-Cu ore bodies composed of pyrrhotite, chalcopyrite, and pentlandite.
- Notably, pyrrhotite in this area is magnetic.
- Serpentinized ultramafic intrusives are rich in magnetite.
- Magnetic susceptibility of each lithology should be measured, though typical values are available in the literature.
- Metamorphism significantly influences rock properties.

Aeromagnetic Data Acquisition and Processing

Data Acquisition

USGS website compilation of survey and industry data

1

Data Processing

Extending the analysis by RMI and upward continuation to a surface covering 150 m and 300 m above the ground then organizing it into grid cells of sizes 250 m and 500 m, respectively

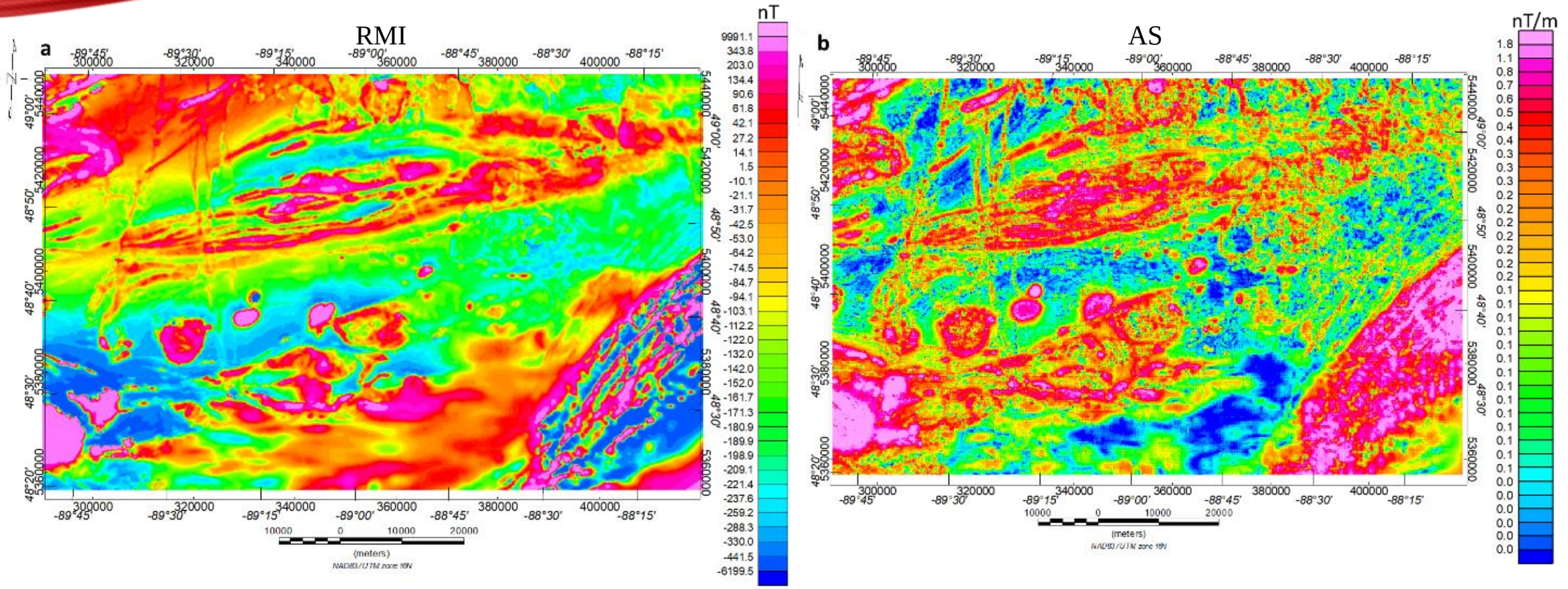
2

Data Visualization

Residual Magnetic Intensity (RMI) and Analytic Signal (AS) maps

3

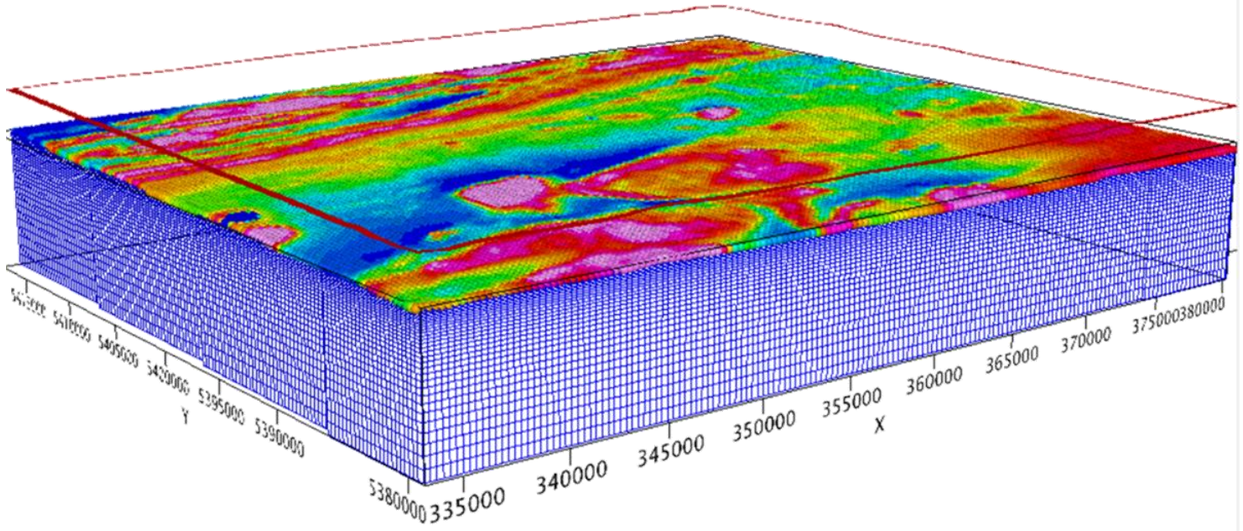
Data Visualization

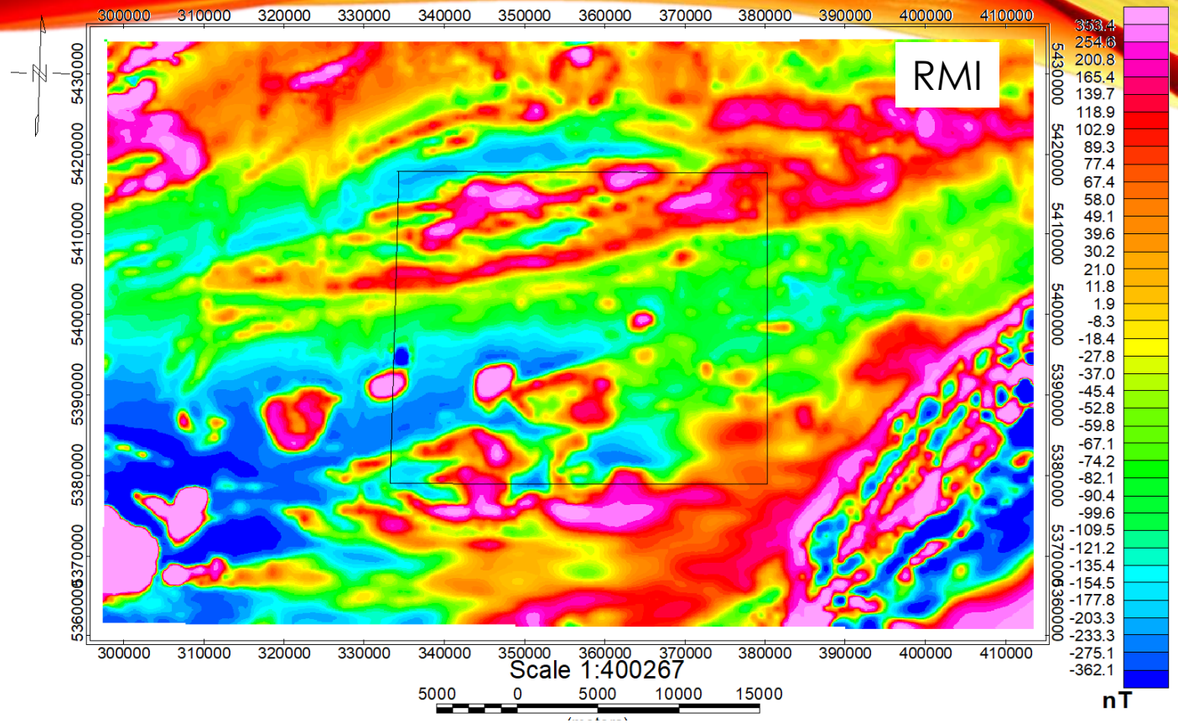


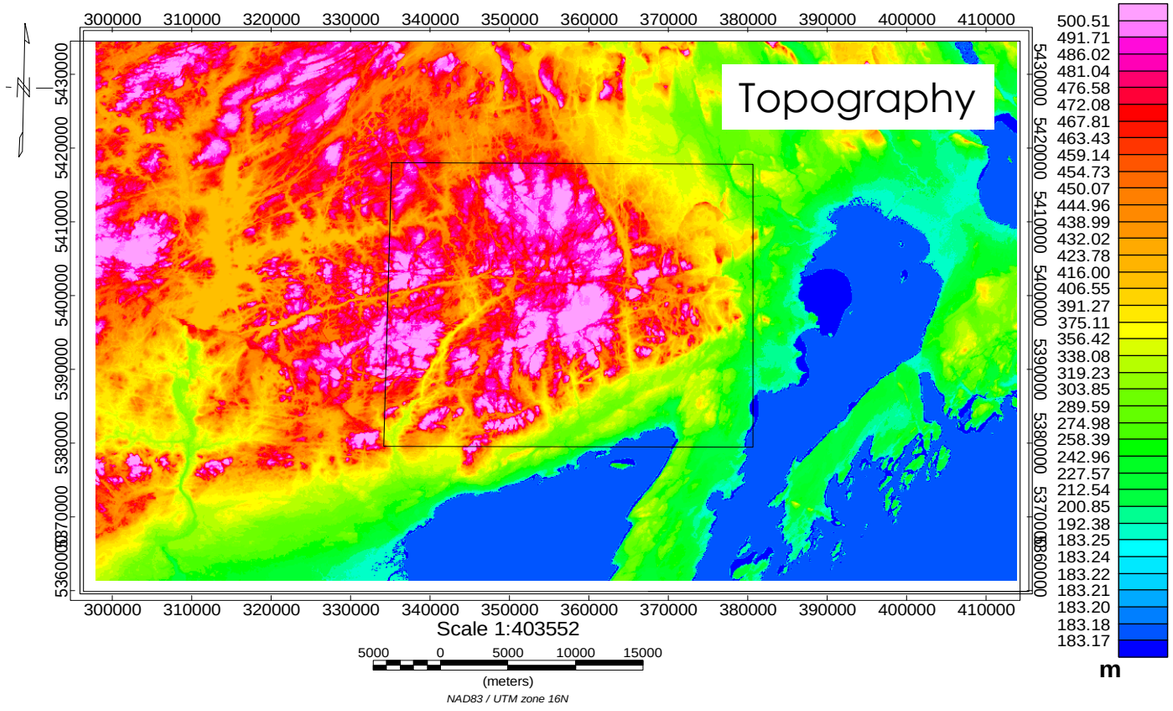
Residual Magnetic Intensity and Analytic Signal maps of the area including the Current Lake and Escape Lake areas.

Implementation MVI Using Geosoft VOXI and UBC Codes:

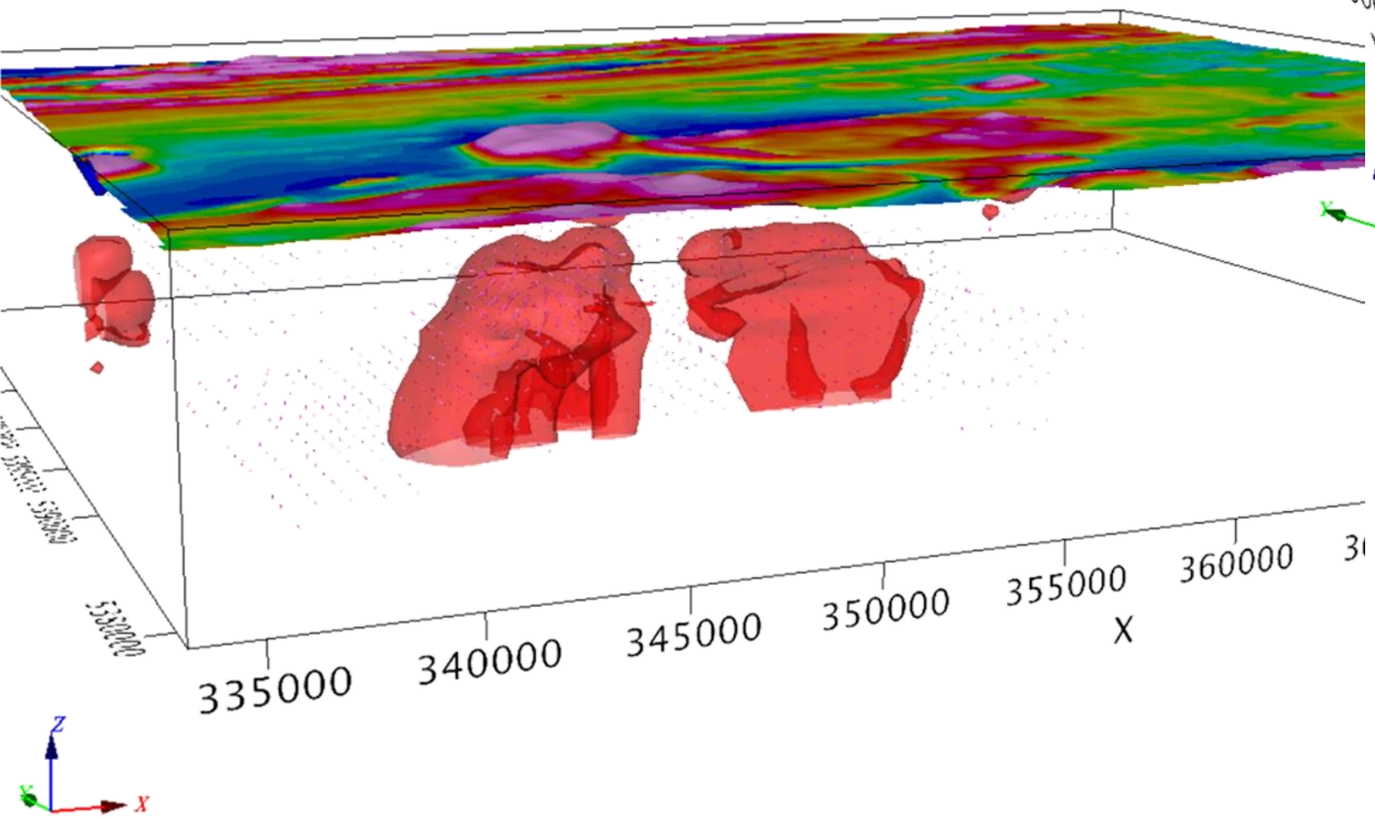
- Preparing Topographic data
- Mesh Design
- Applying Inversion

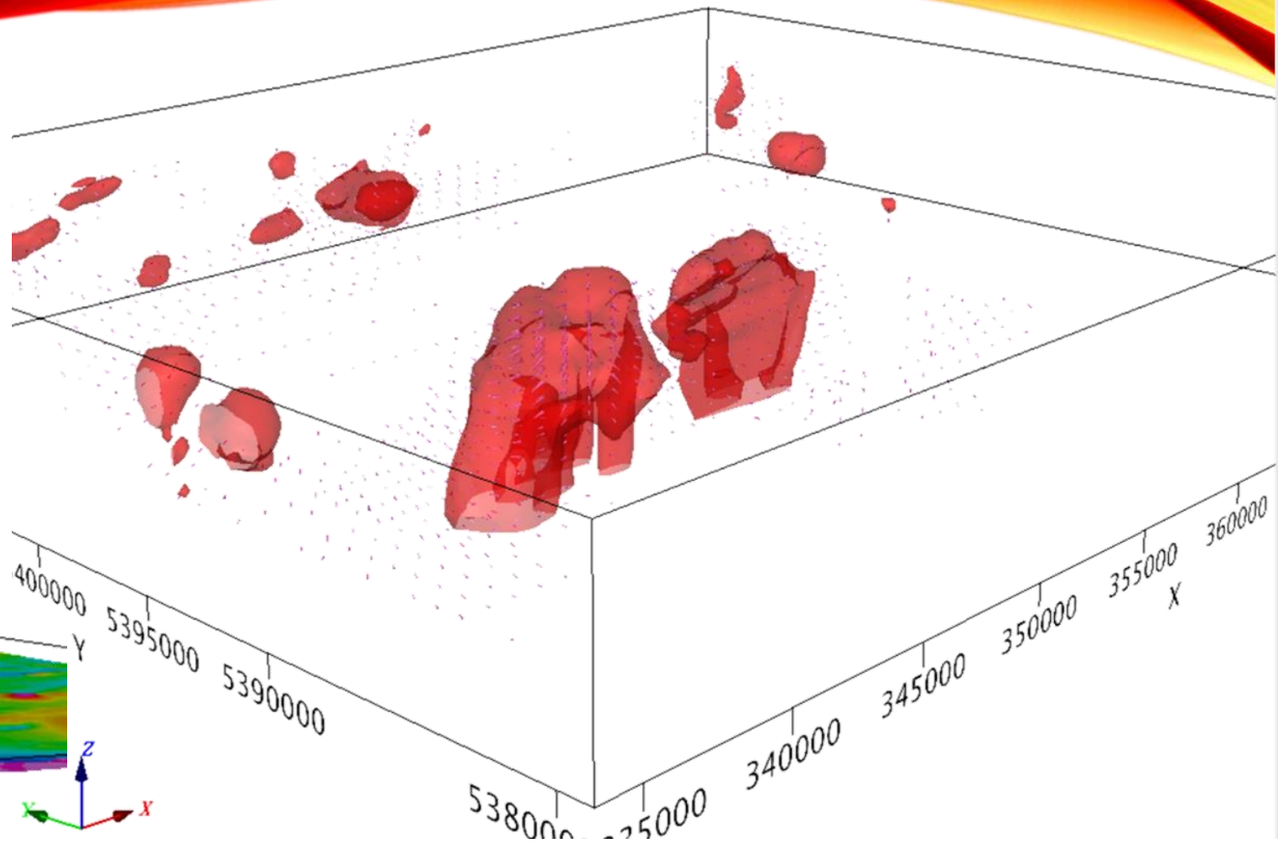






MVI using Geosoft VOXI (Oasis Montaj):





MVI using UBC Codes:

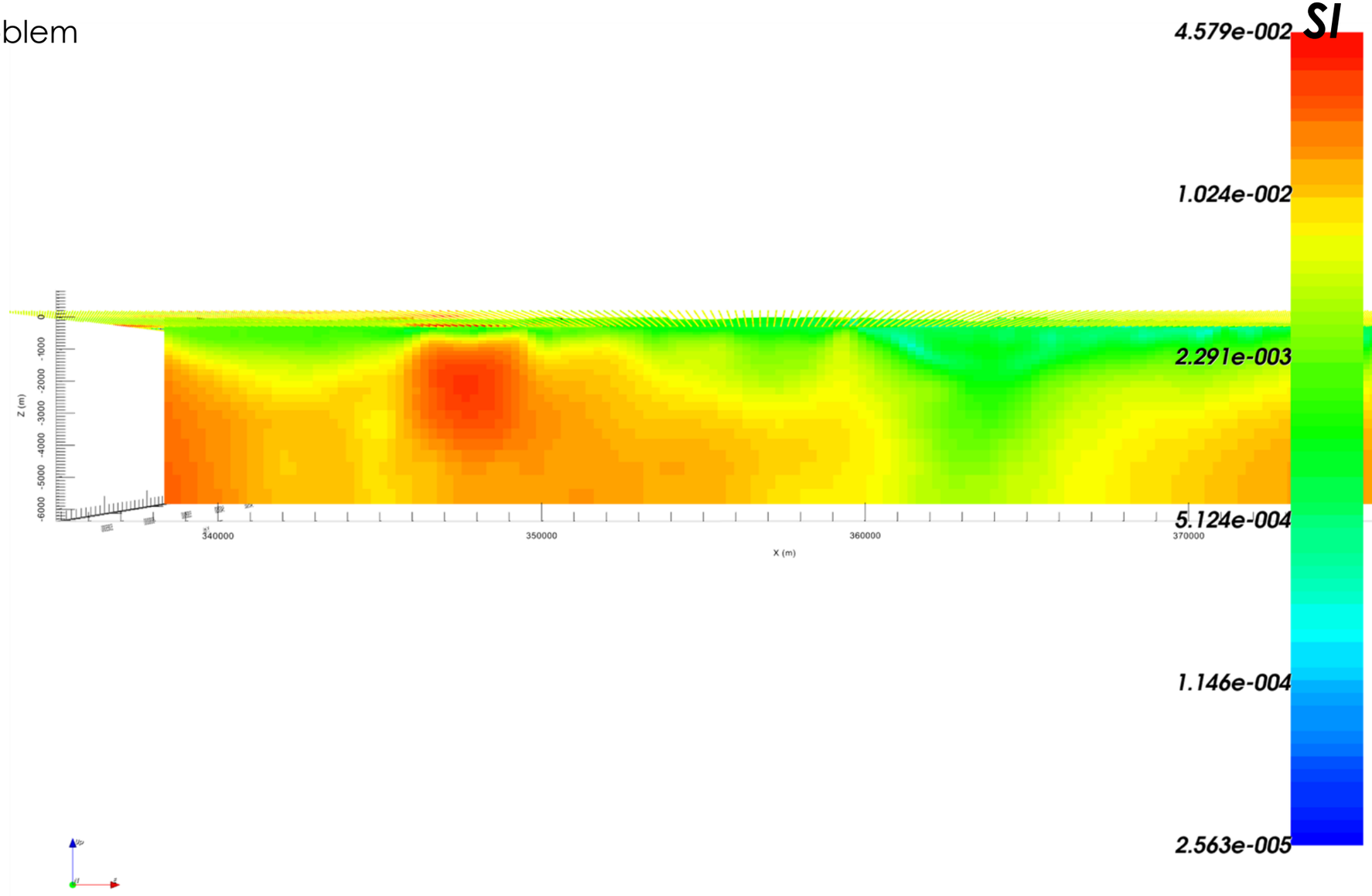
- Inverse problem is an optimization problem

- Inversion successfully recovers geological structures when:

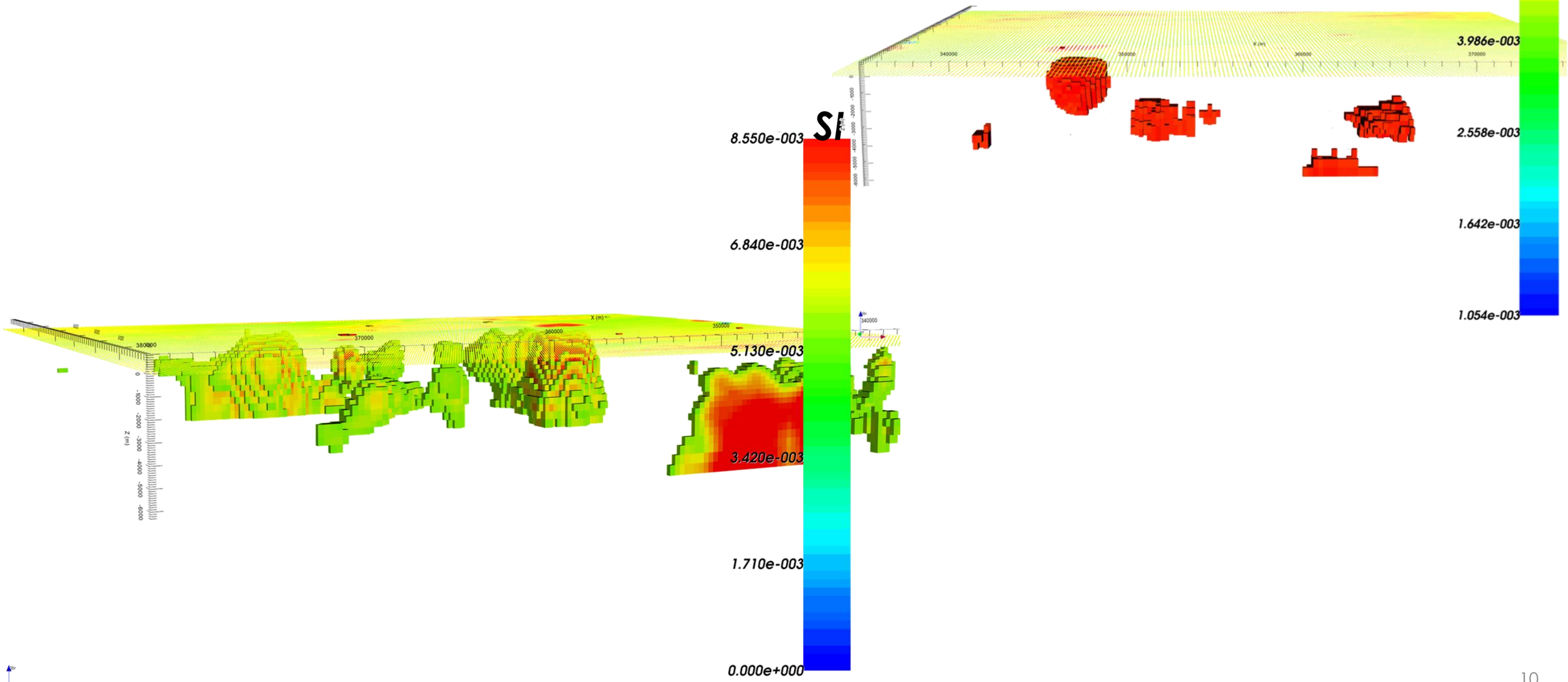
1. There is a significant contrast in physical properties between the target structure and the surrounding geology.

2. The data are sensitive enough to detect the geophysical response of the target structure.

3. The relevant inversion parameters are set correctly.



MVI using UBC Codes



Results and Interpretation

Mineralized Zones

The MVI models indicate km-scale anomalies within the study region.
These zones exhibit distinct magnetic characteristics appear to be better resolved by the UBC code

Future Research

Future research will apply these methods to high-resolution exploration data sets over recognized chonoliths, including Tamarack, Current Lake and Escape Lake once the data sets are made available.
This analysis will aim to identify distinctive magnetic vector characteristics of these small but potentially valuable intrusions.

Implications for Mineral Exploration

Target Identification

The MVI modeling identified specific targets for mineral exploration, including areas with strong magnetic anisotropy and potential mineralized zones.

Exploration Strategy

The results of the MVI modeling need to be compared with known geological features to elucidate the significance of observable anisotropy.

- Combination nonlinear susceptibility inversion results with MVI results can enhance interpretation
- Utilizing drill data, if available, to constrain high susceptibility inversion improves the reliability of the results.

Future Research Directions

High-Resolution Data

Further analysis of high-resolution exploration data sets over identified chonoliths will provide a more detailed understanding of the magnetic characteristics of these potentially valuable intrusions.

3D Modeling

3D models incorporating the MVI results and other geological data will enhance understanding of the subsurface geology and mineral distribution.

Multidisciplinary Collaboration

Collaboration with geologists, geochemists, and other experts will contribute to understanding of the study region.

The Disadvantages of MVI Method

1. Complex Geology: MVI struggles with interpreting magnetic data in the diverse geological structures of mafic and ultramafic rocks.

2. Magnetic Susceptibility Variability: Variability in magnetic susceptibility affects inversion reliability, with high susceptibility causing self-demagnetization.

3. Depth Resolution: MVI has limited depth resolution, complicating the identification of deep-seated mineralization.

4. Data Quality and Resolution: Low-quality or noisy magnetic data can lead to inaccurate results.

5. Geometric Influence: The geometry of mineralized bodies complicates the inversion process.

6. Computational Intensity: MVI is computationally intensive, requiring significant processing power and time.

Conclusion

- MVI analysis revealed strong magnetic anisotropy.
- Despite the limitations of this method, application of this technique to high-resolution data sets help guiding future exploration activities.

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