

GM 67716

IRON ORE LOCATION AND VOLUME ASSESSMENT USING AIRBORNE MAGNETIC AND GRAVITY GRADIOMETER DATA, SILICATE BRUTUS LAKES PROJECT

Documents complémentaires

Additional Files



Licence



License

Cette première page a été ajoutée
au document et ne fait pas partie du
rapport tel que soumis par les auteurs.

Énergie et Ressources
naturelles

Québec 



**ABITIBI
GEOPHYSICS**

NORTHFIELD METALS INC.

IRON ORE LOCATION & VOLUME ASSESSMENT USING
AIRBORNE MAGNETIC & GRAVITY GRADIOMETER DATA

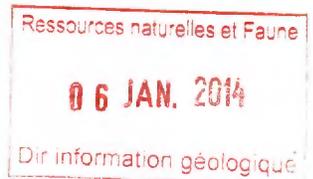
SILICATE BRUTUS LAKES PROJECT

FERMONT DISTRICT, QUÉBEC, CANADA

INTERPRETATION REPORT

13N037

JULY 2013



GM 67716



1341054

TABLE OF CONTENTS

Abstract	1
1. The Mandate	2
2. The Silicate Brutus Lakes Project.....	3
3. GPR International Airborne Survey	5
4. Fugro Airborne Survey	6
5. Data Processing and Deliverables	7
6. Geophysical Interpretation.....	8
7. Conclusion.....	12

LIST OF FIGURES

Figure 1. General location of the Silicate Brutus Lakes Project	2
Figure 2. Northfield Metals claims and GPR (in green) & Fugro (in grey) airborne coverage over the Silicate Brutus Lakes property.....	4
Figure 3. Total magnetic intensity map (left) and the calculated residual anomaly (right) of the Silicate Brutus Lakes Project	13
Figure 4. Vertical gradient contours map (left) and the total gradient amplitude (analytic signal) map of the Silicate Brutus Lakes Project.....	14
Figure 5. Airborne vertical gravity-gD (left) and the vertical gravity gradient-gDD (right) contour maps of the Silicate Brutus Lakes Project.....	15
Figure 6. Geophysical interpretation map showing the distribution of magnetic amplitude contours possibly related to magnetite rich-zones	16
Figure 7. Geophysical interpretation map showing the distribution of vertical gravity gradient amplitude contours related to dense masses	17
Figure 8. Super position of the magnetite contour zones (black contour) on the gDD amplitude contours related to dense masses	18
Figure 9. Recovered subsurface magnetic susceptibility distributions of the Silicate Brutus Lakes property ..	19
Figure 10. Top views of the magnetic susceptibility distributions at elevations of 400 m, 300 m, 200 m, 0 m, -200 m and -400 m, Silicate Brutus Lakes property	20
Figure 11. Longitudinal Magnetic susceptibility vertical sections at 5 752 500 mN, 5 753 000 mN, 5 753 500 mN, 5 754 000 mN, 5 754 400 mN & 5 754 700 mN.....	21
Figure 12. Transverse Magnetic susceptibility vertical sections at 570 600 mE, 571 000 mE, 571 500 mE, 572 500 mE, 573 000 mE & 574 700 mE.....	22
Figure 13. Perspective view showing magnetic susceptibility isosurfaces rendered at 0.35 SI, highlighting magnetically susceptible zones.....	23
Figure 14. Recovered subsurface density distributions from Voxi Earth Modelling inversion of the AGG gradients.....	24
Figure 15. Perspective view showing density isosurfaces rendered at 0.15 g/cm ³ , highlighting dense masses probably corresponding to iron ore	25
Figure 16. Relation between the magnetic susceptibility and the density distributions at the Silicate Brutus Lakes property.....	26

ABSTRACT

*At the request of MRB & Associates Geological Consultants, Abitibi Geophysics Inc. has undertaken to **interpret the GPR & Fugro airborne geophysical data** collected over the Silicate Brutus Lakes property located within the Fermont Iron Ore District of Québec. The objectives of the geophysical interpretation is to produce a model of the architecture that should assist in the identification of the unoxidized and oxidized ferrous mineralization, therefore helping target generation and planning follow-up exploration work.*

*The interpretation included in this report is primarily based on analysis of the combined GPR & Fugro airborne magnetic data, and the airborne gravity gradiometer (AGG) data collected by Fugro in **July, 2011**. Initially the geophysical interpretation had a qualitative character focused on the definition of the iron ore contacts (surface projection) and the location of the dense masses contour area using the vertical gravity gradient (gDD) anomaly. Thereafter, a quantitative interpretation (3D inversion / modelling) was performed on the magnetic data and gravity gradients in order to generate a possible 3D geometry model for the unoxidized and oxidized iron formation.*

A volumetric calculation of the magnetite ore was also given for the Silicate Brutus Lakes property based on the discrete isosurface values of the magnetic susceptibility.

1. THE MANDATE

- PROJECT ID* **Silicate Brutus Lakes Project**
 (Our reference: **13N037**)
- GENERAL LOCATION* Fermont Iron Ore District, Québec
- CUSTOMER* **Northfield Metals Inc.**
 20 Adelaide Street, Suite 301
 Toronto, ON M5C 2J6
 Telephone: (416) 360-8006
- REPRESENTATIVES* **Mr. Réjean Gagnon**
 Coordinator / G.I.S. Specialist
 MRB & Associates
rejean@mrweb.com
 Cell: (809) 874-8768
- Mr. Bruce Mitton, P. Geo.**
 Vice President Exploration
bmitton@championminerals.com
- SURVEY TYPES* **High-sensitivity aeromagnetic & FALCON™ Airborne Gravity Gradiometer (AGG) surveys**
- GEOPHYSICAL OBJECTIVES* • To delineate magnetic & gravity highs possibly related to magnetite / hematite mineralization.
 • To assist in planning a follow-up drilling program.



Figure 1. General location of the Silicate Brutus Lakes Project

2. THE SILICATE BRUTUS LAKES PROJECT

- LOCATION* **Fermont Iron Ore District**, Québec, Canada
 Latitude: 51°55' 20" N, Longitude: 67°55 25" W
 UTM : 574 000 mE, 5 753 000 mN (NAD83, zone 19N)
 NTS sheet: **23O/13**
- NEAREST SETTLEMENT* **Fermont**: approximately 180 km to the NE.
Baie Comeau: approximately 380 km to south.
- ACCESS* From Fermont township, drive southwest on 389 road for about 180 km until you reach the old Gagnon village. The Silicate Brutus Lakes is located 13 km north the vacated Lake Jeanine mine.
- GEOMORPHOLOGY* The studied area has a sub-arctic, continental taïga climate with very severe winters. Daily mean temperature average -24°C in January and +12°C in July. The sub-arctic terrain of the property consists of a rolling glacial peneplain from 471 m to 727 m above sea level, with local relief in the order of 560 m. The glacial deposits dominate the local topography and control most of the surface drainage. Lakes and swamps fill bedrock and drift depressions.
- CULTURAL FEATURES* No cultural features have affected the quality of the collected geophysical data.
- MINING LAND TENURE* The location of the studied property is illustrated on the following page. The Silicate property is 100% owned by Northfield Metals Inc.
- SURVEY GRID* **GPR survey:**
 Seventy-two (72) traverse lines (L 13010N to L 13720N) oriented 45°N pass through the studied area at 150 m spacing interval. Five tie-lines spaced at 1500 m complete the survey grid. The traverses vary in length from about 2000 m to roughly 6000 m.
- Fugro survey:**
 The airborne magnetic survey consists of fifty-five (55) lines regularly spaced at 200 m and oriented 45°N. Inside the selected area, seven (7) tie lines spaced at 2000 m complete the survey grid. The traverse lines are greater than 15 km in length.
- COORDINATE SYSTEM* Projection: Universal Transverse Mercator (UTM), zone 19N
 Datum: NAD 83

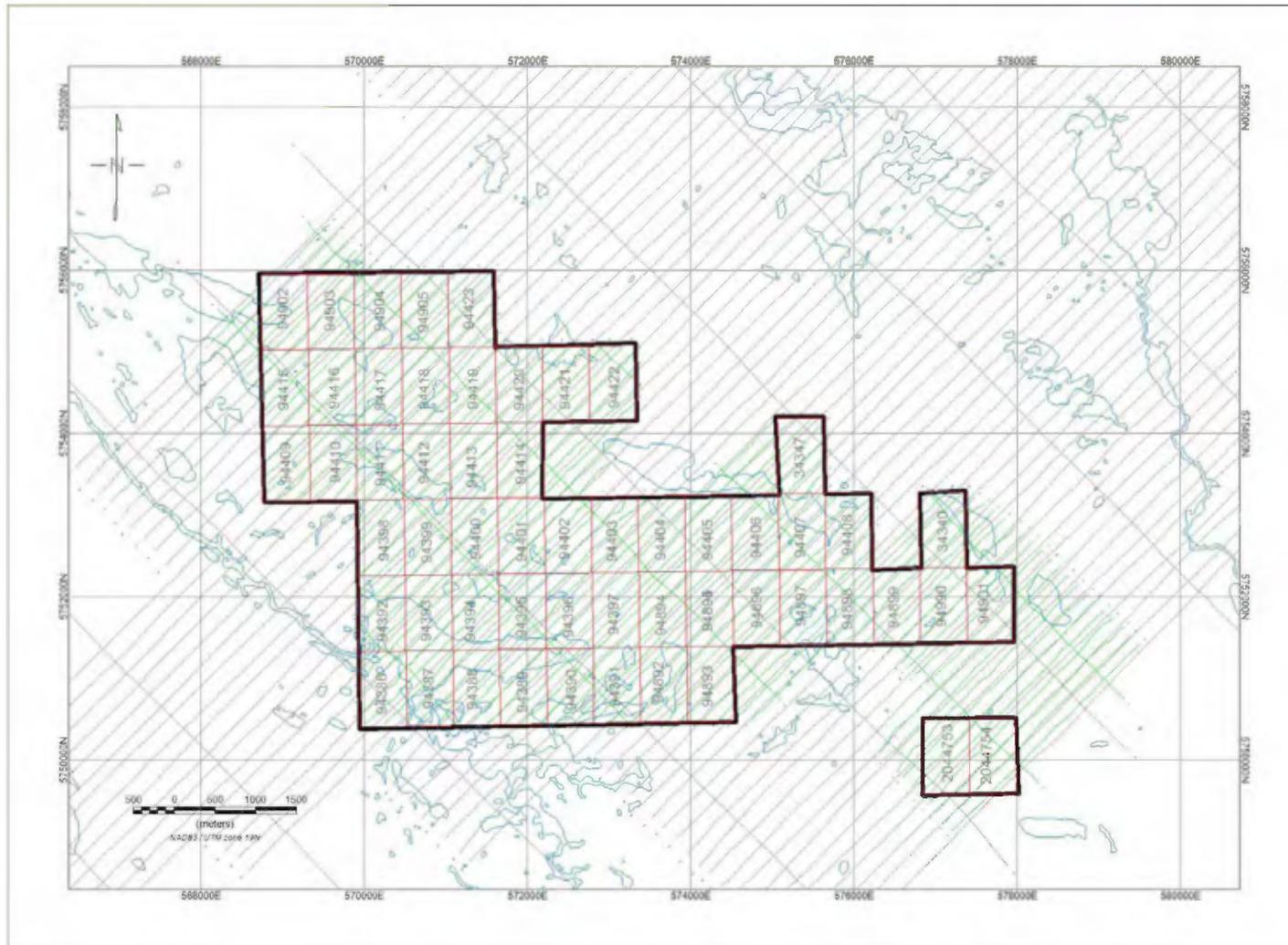


Figure 2. Northfield Metals claims and GPR (in green) & Fugro (in grey) airborne coverage over the Silicate Brutus Lakes property

3. GPR INTERNATIONAL AIRBORNE SURVEY

- DATA ACQUISITION* August 2008
- SURVEY COVERAGE* **277 km**
- AIRCRAFT* The survey aircraft was a Bell 206BH-L helicopter, callsign: C-GVHX
- SURVEY SPECIFICATIONS*
- Line spacing: 125 m and 150 m
 - Line direction: 45°N
 - Tie-line direction: 135°
 - Aircraft elevation (MTC): 60 m (nominal)
 - Average aircraft speed: 24.0 m/s
- MAGNETOMETER SPECIFICATIONS*
- Geometrics G-823A** caesium vapour
Cable length: 30 m
Sample rate: 10 Hz
Sensitivity: 0.002 nT

4. FUGRO AIRBORNE SURVEY

- TYPE OF SURVEYS* High-sensitivity aeromagnetic and Falcon™ Airborne Gravity Gradiometer (AGG) surveys.

- MEASUREMENTS*
 - Total Magnetic Field
 - Curvature components of the gravity gradient tensor namely G_{NE} & G_{UV} , where $G_{UV} = (G_{EE} - G_{NN}) / 2$.
 - Five independent tensor components (G_{EE} , G_{NE} , G_{ED} , G_{NN} , G_{ND}) were extracted from the 2 measured components. In addition, the vertical gradient (Gdd) and the reconstructed vertical gravity field (Gd) were calculated.
 - Digital Terrain Model from Laser scanner.

- AIRCRAFT* The survey aircraft was a Cessna C208B turbo prop.

- DATA ACQUISITION* June 28, 2011

- SURVEY COVERAGE* **1874 km** (block: Cluster 3b)

- SURVEY SPECIFICATIONS*
 - Line spacing: 200 m
 - Line direction: 45°
 - Tie-line direction: 135°
 - Aircraft elevation (MTC): 109 m (nominal)
 - Aircraft speeds: 70 – 130 knots

- MAGNETOMETER SPECIFICATIONS*

GScintrex CS-2 caesium sensor
 Sample rate: 10 Hz
 Sensitivity: 0.002 nT

- QC PROCESSING* Fugro Airborne surveys Pty Ltd has carried out quality control and processing of the data.

5. DATA PROCESSING AND DELIVERABLES

- TOTAL MAGNETIC FIELD**

The total magnetic field was gridded using a minimum curvature algorithm with grid cell size of 30 m. Two passes of a 3 x 3 Hanning filter were then applied to this grid to improve the overall appearance of the final *total magnetic field contours* map (figure 3.A).
- REDUCTION TO THE POLE OF THE RESIDUAL TMF**

The TMF incorporates the geometric effect of the Earth's magnetic field (i.e. inclination and declination). At the Silicate Brutus Lakes property the magnetic field inclination and declination are likely to be 74.2° and -20.7°, respectively.

Reduction-to-pole (RTP) applies a transformation that alters the anomaly geometry so that it becomes a magnetic high centred over the source, without any flanking lows. This process simplifies interpretation and makes the location of contacts more accurate. The RTP operation assumes that the observed TMF is due only to the induced field, with no remanent magnetization.

The residual RTP anomaly was generated in a straightforward way by subtracting the upward regional field (upward continuation to 4000 m elevation) from the *total magnetic field* grid (figure 3.B).
- CALCULATED FIRST VERTICAL DERIVATIVE**

The first vertical derivative (FVD) of the RTP total magnetic field was computed to enhance small and weak near-surface anomalies and provided an aid to delineate the lithological contacts having contrasting susceptibilities (figure 4.A).
- TOTAL GRADIENT AMPLITUDE**

The total gradient amplitude (Analytic Signal) is defined as the amplitude of the horizontal and vertical gradients of the total magnetic field. It has an important property as it locates the edges of the magnetic sources, regardless of any geometric or remanence effects. Consequently, this is an indicator for the location of magnetic formations (figure 4.B).
- SOURCE EDGE DETECTION**

To determine the lithological contacts having contrasting susceptibilities a *Source Edge Detection* program with the help of the normalized derivative were used in this study.
- VERTICAL GRAVITY (GD) & VERTICAL GRAVITY GRADIENT (GDD)**

Final grid products of the Fourier derived gD & gDD with applied terrain correction density 2.67 g/cm³ were used in this study because they most closely relate to the geology.

A grid cell size of 50 m was used to create the *spatial* maps (figures 5.A & B).

6. GEOPHYSICAL INTERPRETATION

The area of investigation is located between longitudes 68° 01' to 67° 51' W, and latitudes 51° 53' to 51° 57' N. The magnetic survey method is a useful mapping tool, outlining both lithological and structural trends. The principal aim of this study is to outline the magnetic and gravity highs which could be related to unoxidized and oxidized ferrous mineralization (such as magnetite & specularite / hematite, respectively), and to produce a detailed 3D geometry model for the iron ore to evaluate the potential of the Silicate Brutus Lakes property (reserve estimation).

MAGNETIC FIELD MAP

The total field magnetic responses reflect major changes in the magnetite content of the underlying rock units. The amplitude of the magnetic responses relative to the regional background helps to assist in identifying specific magnetic and nonmagnetic units. To achieve the geophysical objectives of this project the following steps were carried out:

- ✓ Process the magnetic data to provide a high quality image of the total & residual RTP magnetic field.
- ✓ Generate a range of high resolution normalized derivatives and illustrate their effectiveness for structural mapping.
- ✓ Delineate magnetic and gravity anomalies which exhibit high amplitude values to investigate them as possible iron rich-zones of magnetite and hematite.

Analysis of the enhanced TMI map (figure 3.A) and its derived products allowed the identification of two distinctive magnetic signatures over the Silicate Brutus Lakes property:

The most dominate feature on the Silicate Brutus Lakes property is a high magnetic lineament trending NW-SE for more than 9 km in length. In the center of the property the delineated magnetic lineament seems disrupted by a strike-slip fault trending NE-SW, which resulted in forming the two outlined structures. The eastern lineament appears mostly folded and shows high amplitudes reaching 50 000 nT above a background of 55 700 nT. For the western lineament, recorded amplitudes generally vary from 17 000 to 42 000 nT above a background of 55 800 nT. To the south of the western lineament a high arch-shaped magnetic anomaly of 2.0 km length has been detected. The folded structure shows amplitudes ranging from 10 000 to 22 000 nT above a background of 57 000 nT.

Using the zero contour of the vertical gradient of the RTP total magnetic field, with the help of the *Source Edge Detection* algorithm of Montaj, the lithological contacts of the possible iron orebodies are well defined. The inferred surface projections are reported on the Geophysical Interpretation map (figure 6), and graded (coloured) according to their relative amplitudes.

UNCONSTRAINED 3D MAGNETIC INVERSION

The principal aim of this interpretation is to produce a subsurface magnetic susceptibility model for the Silicate Brutus Lakes property. The resulting 3D map will provide a model of the architecture that should assist in the identification of favourable magnetite rich-zones, therefore helping in the design of a follow up drilling program.

In this study, an unconstrained magnetic inversion has been performed on the airborne magnetic data. Geosoft GridKnit™ was used to stitch together the high resolution GPR magnetic data with the high sensitivity Fugro magnetic data. A residual magnetic grid (figure 3.B) was calculated and used as input file for producing a 3D magnetic susceptibility model. The topography is included in the modelling process and Gaussian noise of 2.5% which may represents an estimate of all possible sources of data uncertainty was assigned to the input data.

The modeled grid is about 10.0 km by 6.0 km. There are 17 315 observed data points in the grid. To invert these data, a 3D earth-mesh is built and discretized by 60 x 60 x 30 m. In the vertical direction the thickness of the cells has been increased by a factor of 1.4 from the depth 1500 m. The processing resulted in mesh with 176 x 107 x 80 cells including the padding to account for the off-area regional effects.

The 1 506 560 cells below the surface define the magnetic susceptibility model for the Silicate Brutus Lakes property, and the inverse problem is therefore formalized.

The final inversion result is illustrated in figure 9, as three-dimensional perspective block view. Pixel image in these rectangular cells convey quantitative information about the intrinsic magnetic susceptibility values. Complementary information is obtained by viewing the subsurface models in plan views (figure 10), in vertical cross sections (figures 11 & 12), and also presented in 3D isosurfaces with different susceptibility cut-off values (figure 13).

As shown in figures 9 to 13, the unconstrained inversion reveals the 3D geometry of the major structures of the Silicate Brutus Lakes Project and provides guidance to the location and delineation of potential zones for magnetite rich-zones. The recovered model susceptibilities range from 0.35 SI up to 1.5 SI. High susceptibility values exceeding 0.5 SI could correspond to the magnetite iron orebodies, and from the vertical sections (figures 11 & 12) the dip of the iron structures can be determined.

The final 3D magnetic susceptibility model is delivered in the Autocad dxf file for the geophysical / geological data integration.

Due to the unconstrained character of the 3D magnetic inversion and the non-uniqueness of potential field modeling, any parametric calculation resulting from this study is only one possible solution, and only sampling by drilling through the rock formation may give the final answer to the nature of the magnetic anomalies.

ISOSURFACE VOLUME ASSESSMENT OF THE UNOXIDIZED IRON ORE

Volumetric analysis from the unconstrained magnetic inversion of the unoxidized iron ore (such magnetite) was carried out to a depth of 230 m (from level 630 m to level 230 m). The estimate volume is based on discrete isosurface values of subsurface magnetic susceptibility (refer to the table 1 at page 11). The volumes provided in this table can be a useful guide, but should not be relied upon for reserve estimation. A 0.4 SI isosurface is used as a minimum cut-off, representing the unoxidized iron zone in this study.

□ AIRBORNE GRAVITY FIELD MAP

The airborne gravity gradient (AGG) survey allows the identification of a broad gravity anomaly (gD) of 4 x 2.4 km in size trending NW-SE in the NW part of the studied grid. The delineated gravity high is about 12.0 mGal in amplitude and correlates well with the outlined western magnetic lineament. To the SE of this anomaly the AGG survey highlights a second gravity anomaly of 1.7 x 0.8 km in size. This feature is almost elliptical in shape, correlates well with the eastern magnetic anomaly and exhibits an amplitude of 5.70 mGal (figure 5-A). To better distinguish the dense masses which could be related to the ferriferous mineralization, the vertical gravity gradient (gDD) map was created and analysed (figure 5-B).

Despite the fact that the vertical gravity gradient (gDD) highlighted several small and weak near-surface anomalies (affected by high-frequency noise), the dense zones have still been successfully defined. The surface projection of the dense iron structures could probably be located by the three contours: 50, 60 and 100 eotvos. The inferred surface projections are reported on the Geophysical Interpretation map (figure 7) and graded (coloured) according to their relative magnitude.

Figure 8, shows the super position of the probable magnetite surface (black contour) over the defined gDD contours likely representing the dense iron sources. It can be seen that most of the strong magnetic anomalies (> 10 000 nT in amplitude), show strong correlation with the 50-70 eotvos Gdd contour (red coloured areas). It must be noted that there is no good correlation between the 50 eotvos gDD contour and the determined magnetite zone in the northwestern part of the Silicate Brutus Lakes property. The nature of the rock formations located in the areas shaded light brown colour where the vertical gravity gradient amplitudes reach 50 eotvos especially in the northwestern side of the grid must be verified by drilling.

□ UNCONSTRAINED 3D GRAVITY INVERSION

To extract further information about the dense masses which may correspond to the oxidized and unoxidized iron ore, their depth-to-top, depth extension and density contrast; a 3D inversion was performed on the AGG gradients (A_Gne, A_Guv, B_Gne and B_Guv) using the program library **Voxi** developed by Geosoft in 2012.

A polygon file that defines the area to be modelled is created using a mesh grid of 130 x 105 x 32 cells, the 3D mesh is discretized by 100 x 100 x 50 m. The 436 800 cells below this surface define the density model and the inverse problem is therefore formalized by inverting 17 480 data points to recover the density distributions in those cells.

The final inversion result is illustrated in figure 14, as a 3D perspective block view showing the subsurface density contrast distributions. Complementary information is presented as 3D iso-surfaces with different density contrast cut-off values (figure 15). An Autocad DXF file is also delivered for geological data integration purpose.

Inspection of the results from the Voxi AGG inversion allow the understanding of the 3D geometry model for the dense masses of the Silicate Brutus Lakes property. The calculated gravity model shows important near-surface sources caused by the high-frequencies that affected the gravity gradiometer input data.

Overall the morphology of the dense target is well defined by this modelling (figure 15). The dense material, with isosurface $\geq 0.20 - 0.25 \text{ g/cm}^3$, may correspond with the iron formation and shows a good correlation with the 0.35 SI shell of the magnetic susceptibility (figure 16).

It's important to note that the gravity anomalies are a volumetric function, i.e. all masses manifest themselves in the field of gravity, while a magnetic field only indicates the presence of magnetic minerals. Hence, the shape of models resulting from the modelling will be somewhat different.

ISOSURFACE VOLUME ASSESSMENT

The volume assessment was not done for the gravity because of the high-frequency noise which severely contaminated the near-surface geological signal in the first 100 m.

Table 1. Voxel statistics for visible cells truncated at 230 m level

CUT-OFF (SI)	VOXEL STATISTICS FOR VISIBLE CELLS				
	Volume (m ³)	Magnetic Susceptibility (SI)		Mean Value (SI)	Standard deviation
		Minimum	Maximum		
Silicate Brutus Lakes property Truncated at 230 m level (ground surface level:~630 m)					
≥ 0.40	1 056 240 000	0.40	2.533	0.835	0.370
≥ 0.50	881 064 000	0.50	2.533	0.912	0.358
≥ 0.60	718 956 000	0.60	2.533	0.994	0.347
≥ 0.70	571 320 000	0.70	2.533	1.083	0.335
Note: 1 km ³ = 1 000 000 000 m ³ ;					

7. CONCLUSION

Despite the generic nature of the unconstrained magnetic inversion carried out on the Silicate Brutus Lakes property, this 3D interpretation has shown a possible 3D geometry for the Iron Formation zones having high magnetic susceptibility values (≥ 0.4 SI). The resulting inversion model, therefore, may be used as a guide for determining where the mineralized zones might appear at depth with determining their spatial geometry and the portions with increasing iron content (high grade content). This result has strong implications for target generation and for planning future exploration drilling work to better define the iron targets, therefore helping in the estimation of mineral resources.

Thus, volume assessment of the iron ore for the Silicate Brutus Lakes property based on discrete isosurface values of the magnetic susceptibility has been produced.

A limitation in the interpretation of these volumes may come from the following sources:

- ✓ Unconstrained character of the magnetic inversion.
- ✓ The presence of high susceptibilities and the resulting self-demagnetization effect.
- ✓ The ambiguity in picking a representative magnetic susceptibility shell that is consistent with the susceptibility of the iron formation.

The airborne Gravity Gradient (AGG) survey has successfully outlined most of the dense sources within the studied grid. Although the vertical gravity gradient has been severally affected by high-frequency noise, this did not prevent the location of dense masses which could be related to the iron formation.

The interpretation of the aeromagnetic and gravity gradiometer data embodied in this report is essentially a geophysical appraisal of the Silicate Brutus Lakes Project. As such, it incorporates only as much geoscientific information as the author had on hand at the time. Geologists thoroughly familiar with the area may be in a better position to evaluate the geological significance of the various interpreted geophysical signatures. Moreover, as time passes and data provided by follow-up programs are compiled, the priority and significance of exploration targets reported in this study may be downgraded or upgraded.

Respectfully submitted,
Abitibi Geophysics Inc.



Madjid Chemam, P. Geo.
Geophysicist
OGQ # 1259

MC/mw



NUMÉRIQUE

Page(s) de dimension(s) hors standard numérisée(s) et positionnée(s) à la suite des présentes pages standard

DIGITAL FORMAT

Non-standard size page(s) scanned and placed after these standard pages

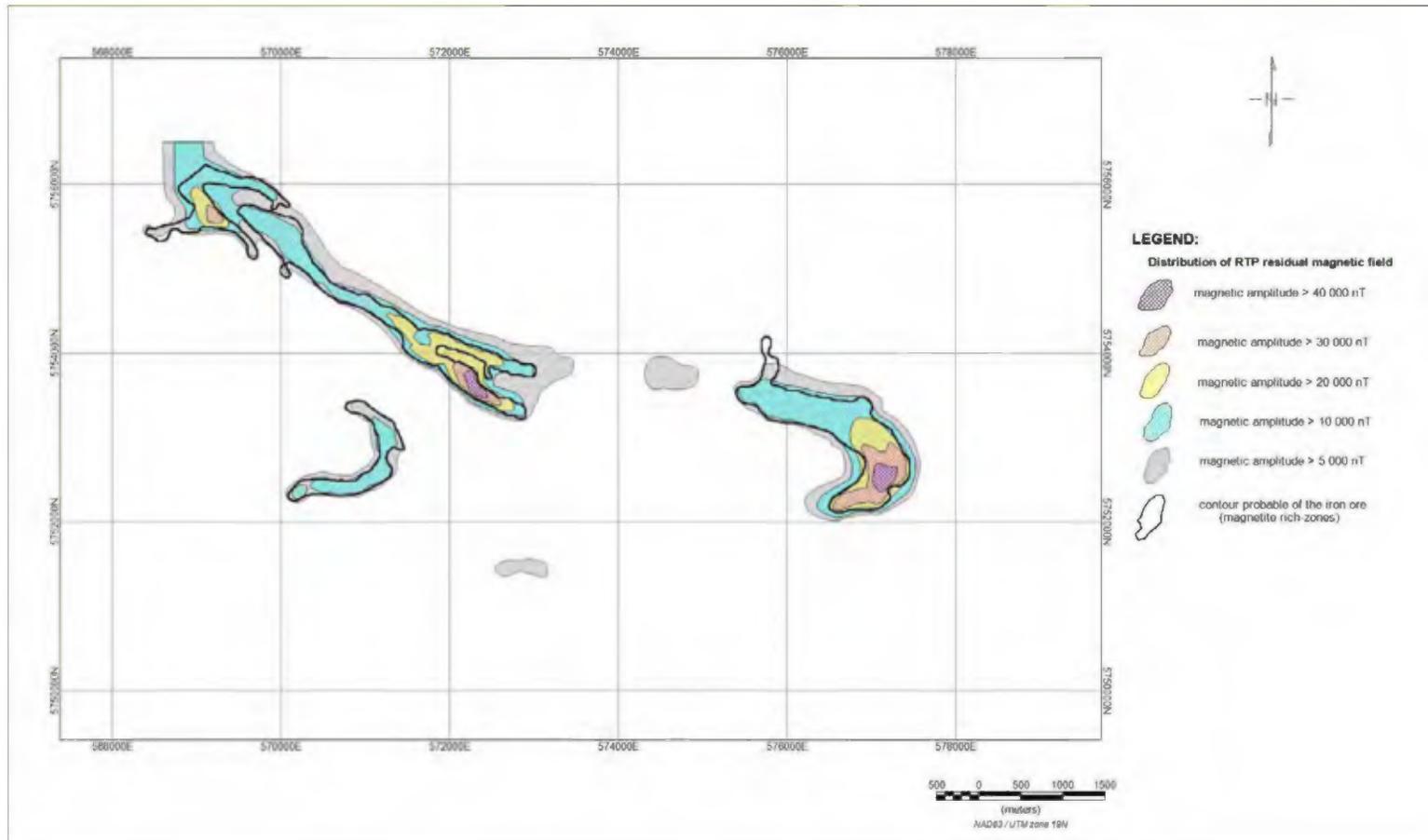


Figure 6. Geophysical interpretation map showing the distribution of magnetic amplitude contours possibly related to magnetite rich-zones

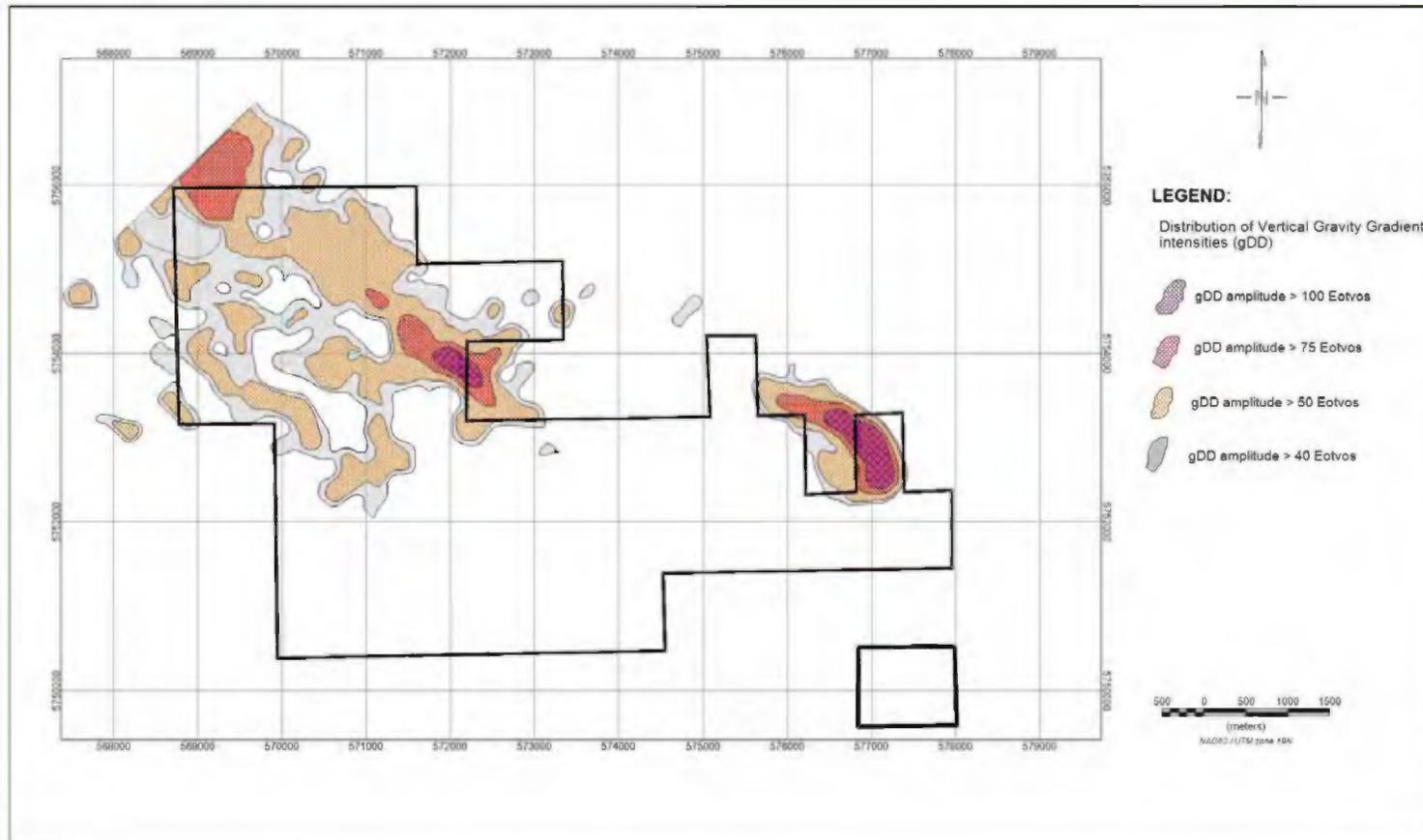


Figure 7. Geophysical interpretation map showing the distribution of vertical gravity gradient amplitude contours related to dense masses

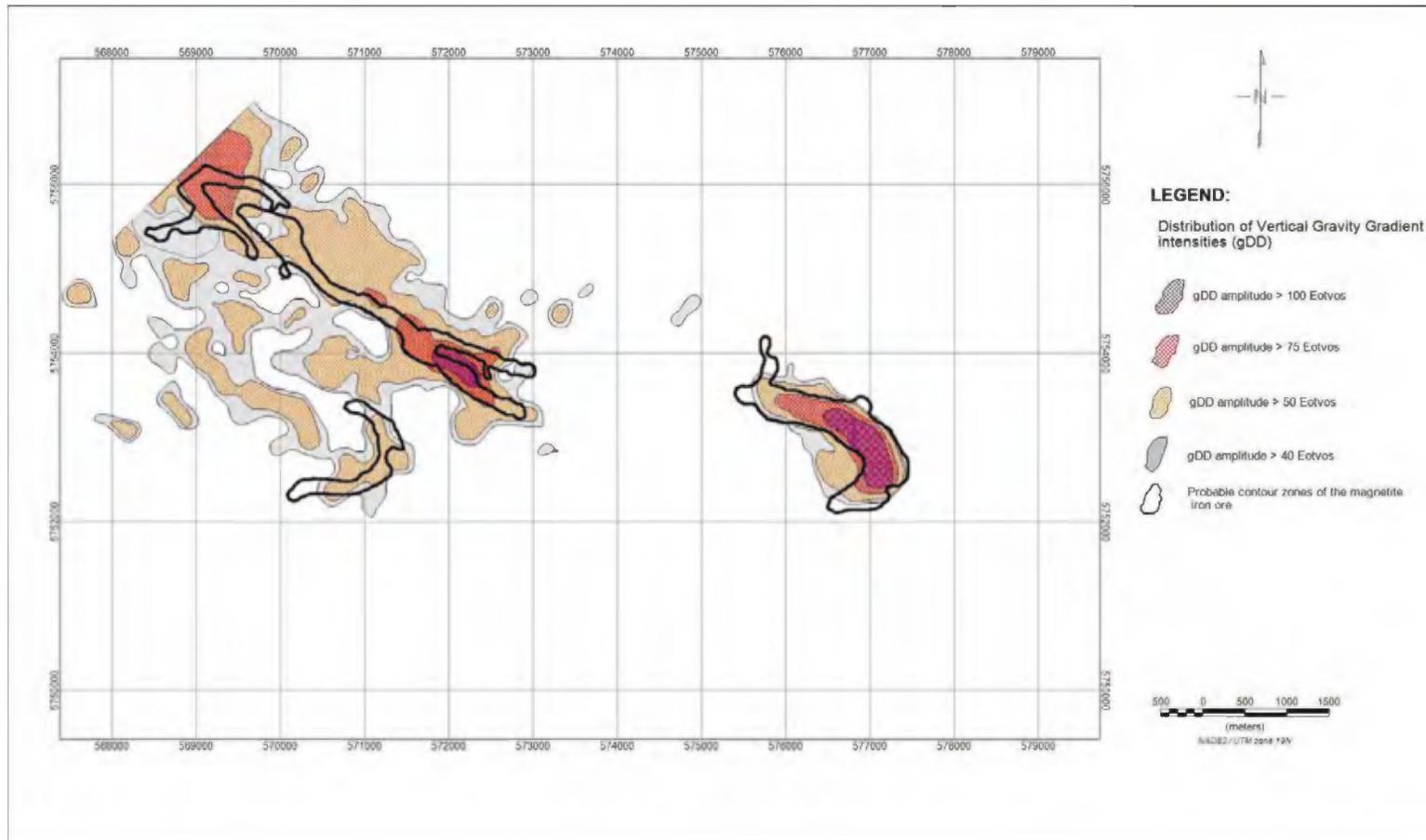


Figure 8. Super position of the magnetite contour zones (black contour) on the gDD amplitude contours related to dense masses

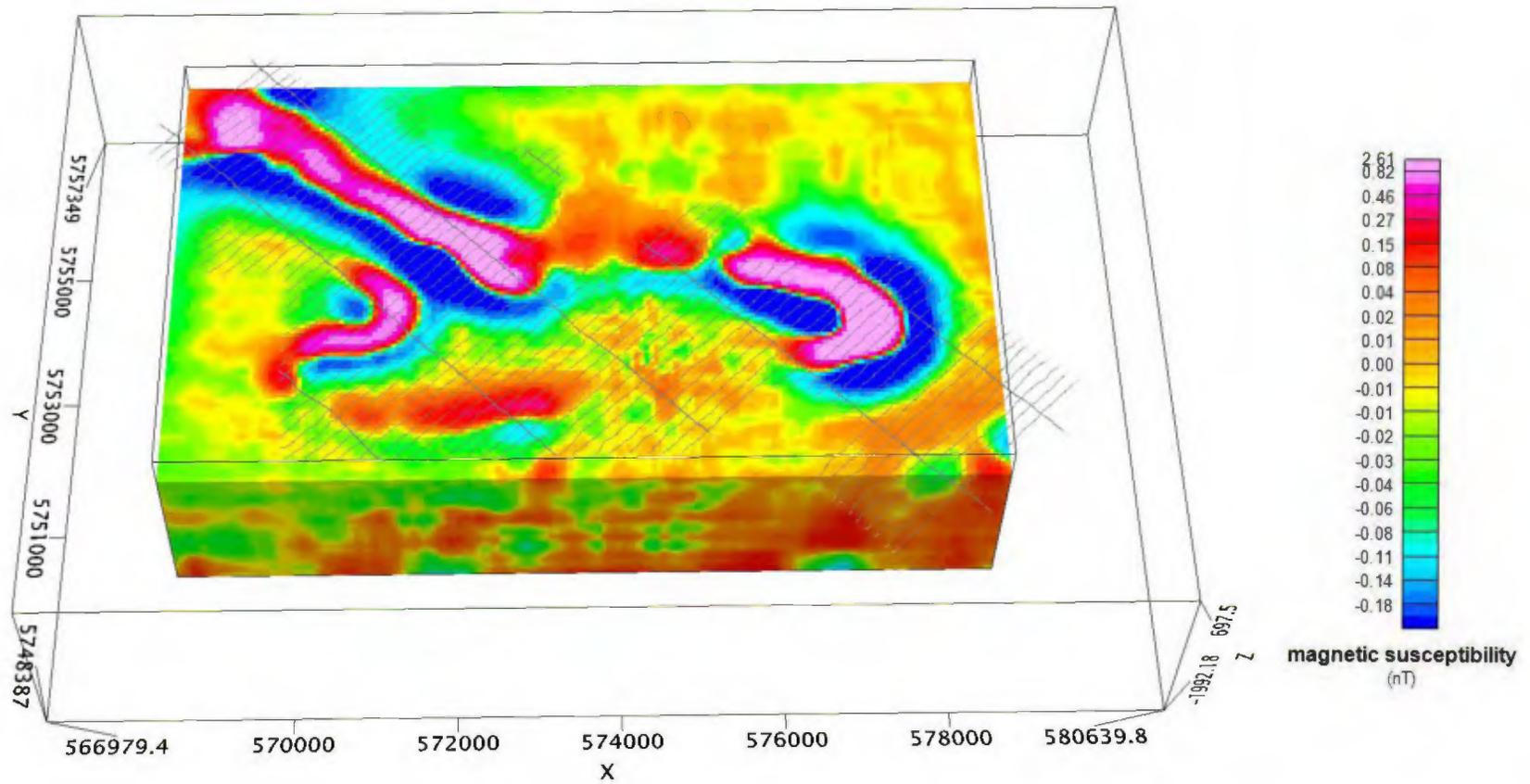


Figure 9. Recovered subsurface magnetic susceptibility distributions of the Silicate Brutus Lakes property

NUMÉRIQUE

Page(s) de dimension(s) hors standard numérisée(s) et positionnée(s) à la suite des présentes pages standard

DIGITAL FORMAT

Non-standard size page(s) scanned and placed after these standard pages

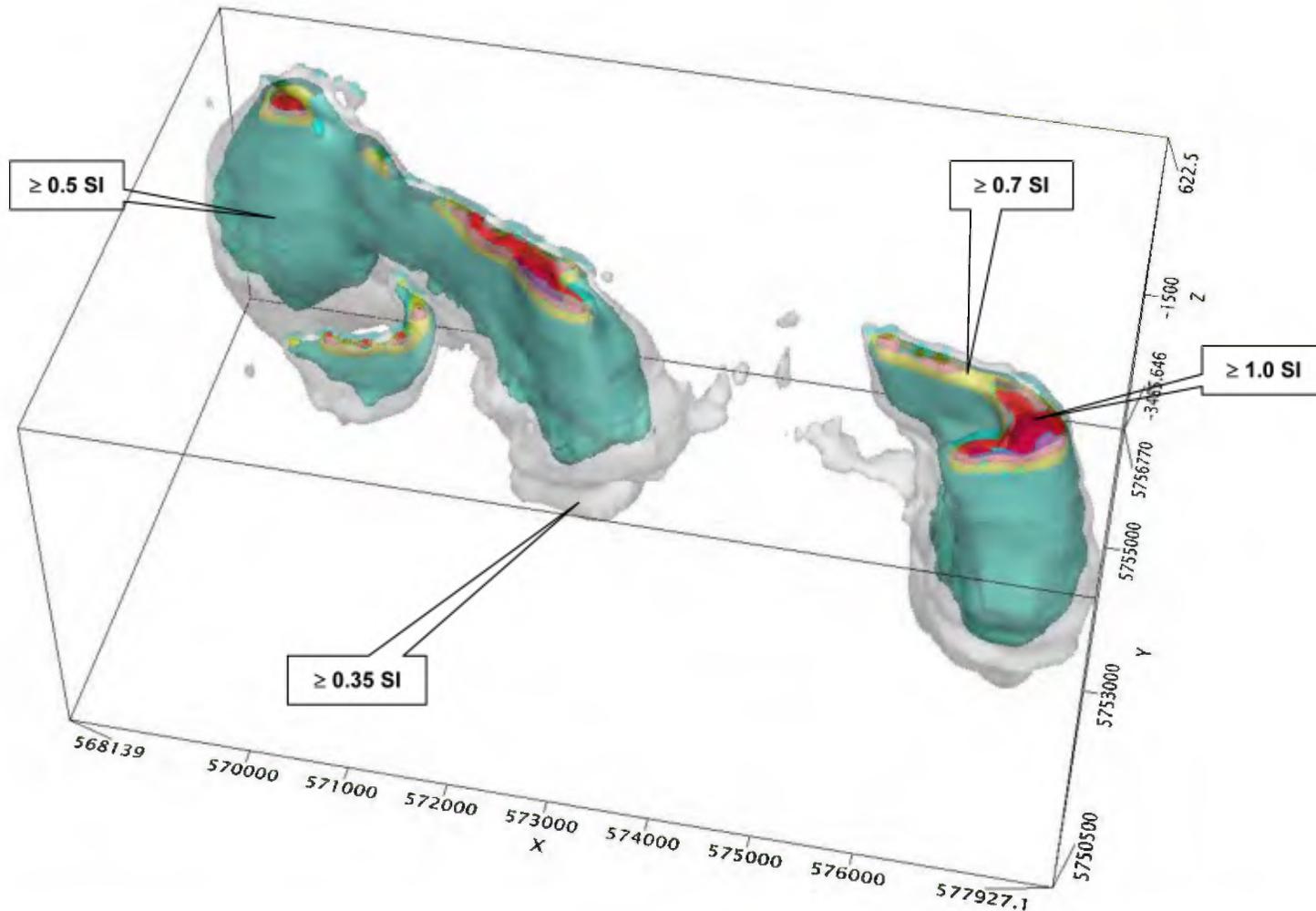


Figure 13. Perspective view showing magnetic susceptibility isosurfaces rendered at 0.35 SI, highlighting magnetically susceptible zones

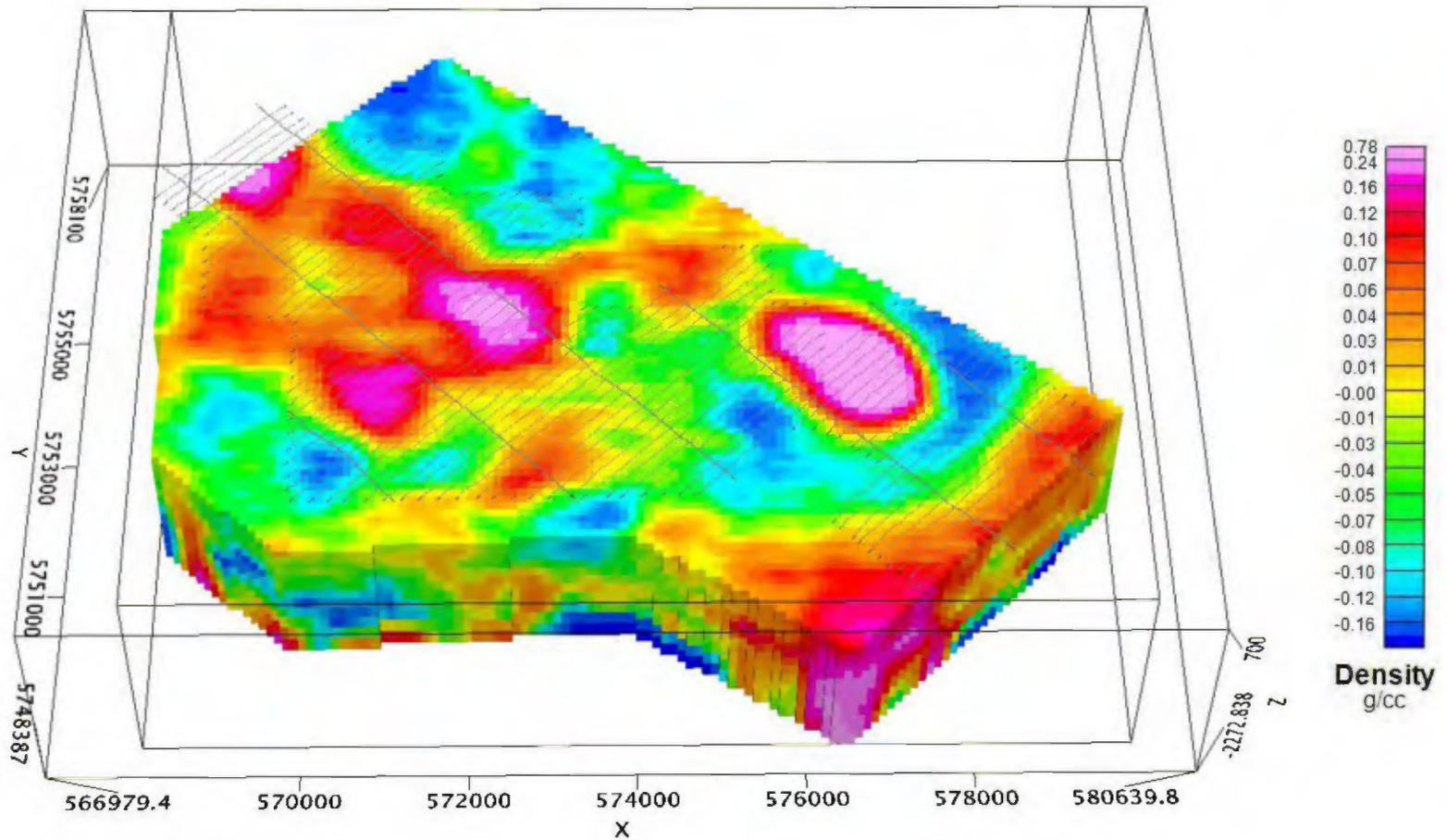


Figure 14. Recovered subsurface density distributions from Voxi Earth Modelling inversion of the AGG gradients

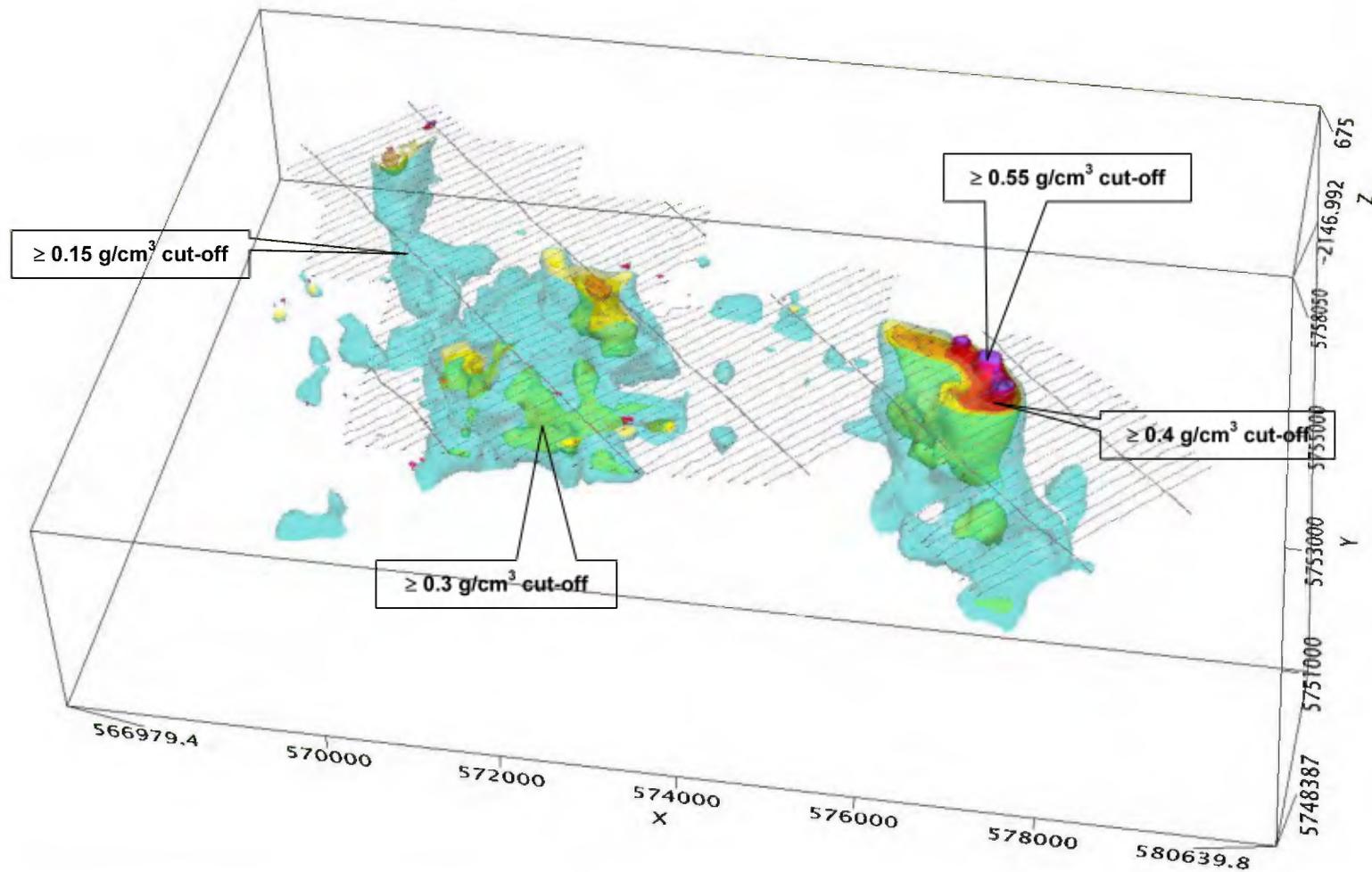


Figure 15. Perspective view showing density isosurfaces rendered at 0.15 g/cm^3 , highlighting dense masses probably corresponding to iron ore

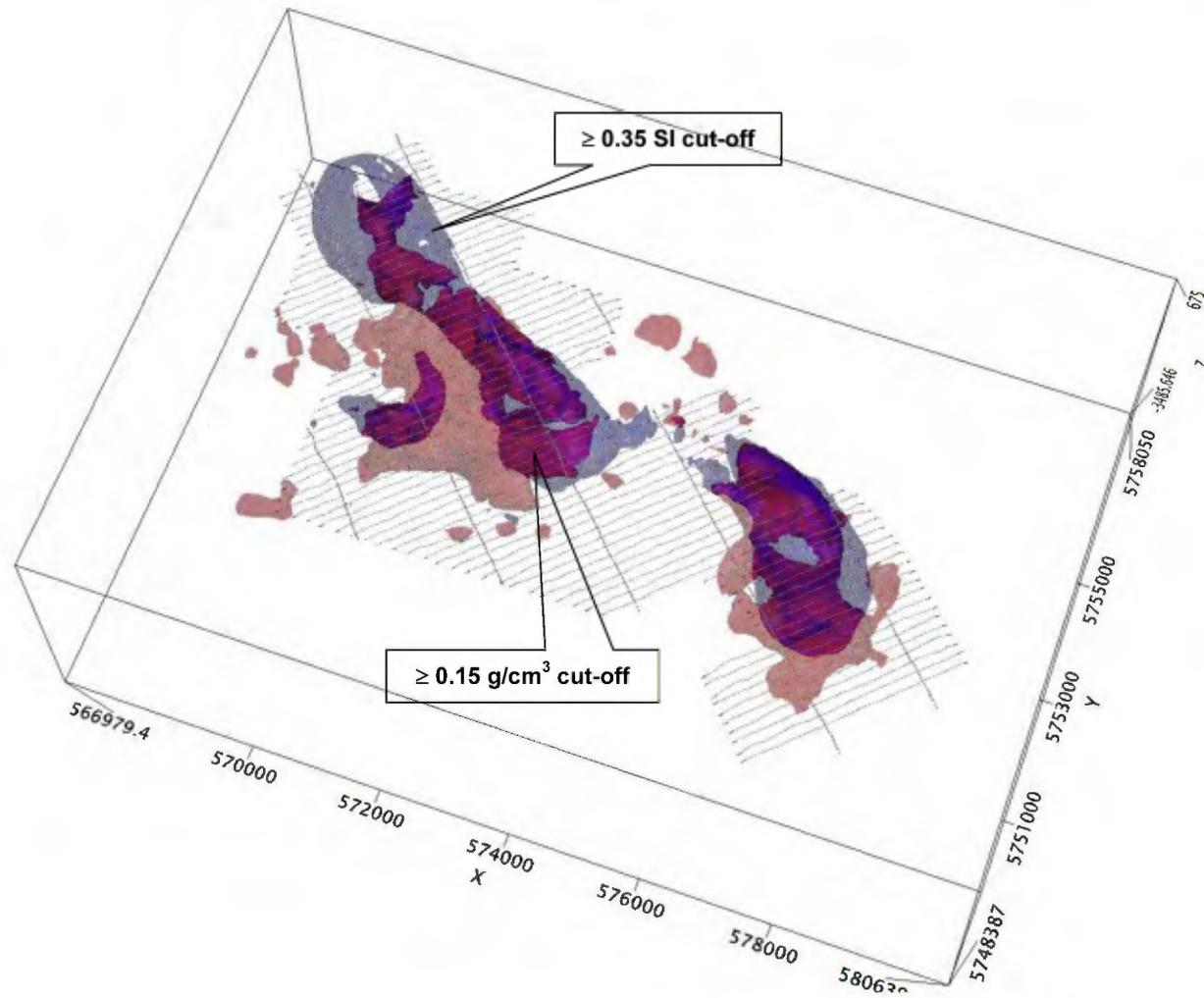


Figure 16. Relation between the magnetic susceptibility and the density distributions at the Silicate Brutus Lakes property