Geophysical case study of the Iso and New Insco deposits, Québec, Canada: Part II, modeling and interpretation

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Abstract

The MEGATEM^{II} data collected over the Iso and New Insco bodies have been modelled using three modeling packages. The EMQ package is a quick inversion tool which indicates that the Iso body is a dipping plate-like body. The New Insco body is inferred to have a geometry somewhere between a dipping plate and a sphere. The Maxwell package was used to refine the properties of the plate-like body at Iso. The EMIGMA package was able to identify which parts of the New Insco orebody were more conductive. It was observed that the most conductive parts correspond to the copper-rich zones and the next most conductive to the pyrite-rich zone. The EMIGMA package was also used to show that a thick-prism model might be a more appropriate model for the New Insco ore body.

Gravity modeling constrained by the known geology was successful in identifying the denser sulphide zones. The densest zones appear to be pyrite rich. Magnetic modeling identified diabase dykes. Over New Insco, a small magnetic anomaly was attributed to pyrrhotite-rich sulphides. There was only a weak magnetic anomaly over the Iso body, consistent with the non-magnetic sulphides logged in the holes drilled at that location.

Résumé

Les données MEGATEM^{II} recueillies au-dessus des dépôts d'Iso et de New Insco ont été interprétées en utilisant trois outils de modélisation différents. L'outil EMQ a été utilisé comme un outil d'inversion rapide suggérant que le dépôt Iso peut être assimilé à une plaque inclinée, et que le dépôt de New Insco se situe quelque part entre une plaque et une sphère. L'outil Maxwell a été utilisé pour raffiner les propriétés du dépôt Iso. L'outil EMIGMA nous a permis d'identifier les différences de conductivité à l'intérieur du dépôt Iso. Il a été observé que la partie la plus conductrice correspond à la zone riche en cuivre, suivie par la zone riche en pyrite. L'outil EMIGMA a aussi permis de montrer qu'un modèle de prisme épais pourrait être plus approprié pour décrire le dépôt New Insco.

La modélisation des données gravimétriques, contrainte par la géologie connue, définit bien la zone de sulfures massifs. La zone de pyrite apparaît être la plus dense. La modélisation des données magnétiques identifie bien les dykes de diabase. Au-dessus du dépôt New Insco, on observe une faible anomalie magnétique correspondant aux sulfures non-magnétiques observés dans les carottes de forages à cet endroit.

Introduction

As part of a research project, a test survey using the MEGATEM^{II} airborne electromagnetic system was flown over the Iso and New Insco ore bodies. These two deposits are conductive and they lie in a resistive geological background so the responses of the target are prominent and clearly distinguishable. There are a number of historical surveys acquired over the deposits and these data were compared with the MEGATEM^{II} data (Cheng et al., 2004, hereafter referred to as "Part I"). Other tests were performed to quantify the noise levels of the MEGATEM^{II} system and to illustrate the advantages of collecting data at a base frequency of 30 Hz (Part I). Height attenuation tests were used to infer that the MEGATEM^{II} system would be able to detect the Iso deposit even if it were 230 m below the ground surface (Part I).

As part of the project, we compiled all available geological information for the Iso and New Insco deposits and reconstructed the geology in three dimensions. Data from more than 200 drill holes, 33 cross sections and 117 lithogeochemical locations were used in building the 3D model. Owing to the recent development of computer applications in the earth sciences, we can now visualize full 3D images of the geology; and undertake 3D quantitative interpretation of geophysical data. In this paper we will undertake 3D modeling of the MEGATEM^{II} data to determine how well the data can characterise the deposit.

As well, the magnetic and gravitational data are modelled, with the intention of identifying zones of different density and magnetic susceptibility.

This paper (Part II) shows the potential of the MEGATEM ^{II} airborne system and the appropriate modelling tools to describe the geometry and the distribution of physical parameters characterising these massive sulphide deposits. It is our hope that this study will give explorers a better understanding of the usefulness of geophysical methods when exploring for massive sulphides similar to the Iso and to New Insco deposits.

Geology

The Iso and New Insco massive sulphide deposits are within the Abitibi greenstone belt in western Québec (Figure 1). In the immediate vicinity of the deposits, geological mapping (Figure 2) indicates a general east-west strike of the surrounding felsic to intermediate volcanics (rhyolite, dacite and andesite). These volcanic flows were subsequently intruded by diorite, gabbro, quartz feldspar porphyry and finally diabase dikes (Crossley et al., 1974). The Iso and New Insco sulphide zones lie close to the contact between felsic volcanic rocks (rhyolite) and mafic volcanic rocks (andesite) that strikes east-west and dips to the south. In the Abitibi camp, the zone close to the rhyolite/andesite boundary is considered highly prospective for sulphide deposits.

Extensive drilling has established that the Iso deposit, which is situated on the western side of the test site, consists of massive fine-grained pyrite-sphalerite-chalcopyrite with minor amounts of galena, magnetite and silver and gold. The massive sulphide body is sheet-like, dipping south at 45^o to 50^o, and striking east-west over a distance of more than 500 m. The thickness is up to 35 m and the down-dip extent is at least 800 m.

The New Insco deposit, which is situated to the east, consists of massive pyrrhotite-pyrite-chalcopyrite. The deposit is more tabular, dips to the south at about 50^o, and strikes east-west over a distance of about 117 m. The thickness varies from 5 m to 38 m and the down-dip extent is at least 250 m.

In order to build a common geological reference base, all the available geoscientific data has been compiled and used to construct a detailed 3D geological model. This data comes from both the public and private domains and includes information from more than 200 drill holes. The construction of the geological model permits evaluation of the geophysical interpretations presented here.

Experience in the Abitibi camp is that in broad terms the rhyolite/andesite boundary is generally a more favourable location for ore bodies. Analysis of lithogeochemical data indicates a number of distinct zones of the Iso deposit with varying metal content (Figure 3).

The Iso deposit has not been mined. There has been some open cut mining activity at New Insco: in the period 1976-1977 Noranda mined 103,574 tons grading 2.64% Cu from a small open pit (about 10 m deep).

Interpretation of MEGATEM^{II} data

In resistive environments, the electromagnetic response of a sulphide body is relatively independent of the background geological model. Hence, to a first approximation, we can use a simple model. Commonly used models are the plate or the sphere in a resistive background (Dyck and West, 1984), which are used to estimate a physical property of the conductor, such as size and conductance or conductivity. As the response of a conductor is a combination of its size and conductivity, a similar response could be produced by a bigger plate with a lower conductivity as well as a smaller plate with a higher conductivity. However, this ambiguity only exists within a certain range of parameter choices; and there should normally be a combination of properties which defines the amplitude and time constant that is consistent with all the observed data. For example, using data from adjacent lines will help to resolve the dimension in the strike direction.

Three modeling tools (EMQ, MAXWELL, and EMIGMA) have been used to quantitatively interpret the MEGATEM^{II} data in order to obtain a credible estimation of the physical properties as well as the depth and dimensions of the Iso and New Insco massive sulphides.

EMQ modeling

EMQ is a very fast inversion tool for determining properties like the depth to a sphere-like conductor or the depth and dip of a small "dipping" spherical conductor. The latter body is approximated by constraining the current in the sphere to flow in a plane with a specific orientation. This 3D inversion program uses the concept of moments and is described in Smith et al. (2003). The model assumes that the exciting field is uniform over the spherical body. The calculated response is dependent on multiple variables, such as the dimension, conductivity and depth of the conductor. If the conductor is plate-like, the response is also dependent on the dip and strike of the current flow. A feature of the inversion is that if the initial guesses are reasonable, EMQ can determine a refined model in a few seconds. Because of the simplicity of EMQ, we start the interpretation with this tool.

For the Iso body, we have modelled the second-order moment (Smith and Lee, 2002) derived from the *x* and *z* components on line 100501 (Figure 4a). The blue data are the measured moments and the red is the calculated or fitted data. The final model is a dipping plate-like conductor centered at 96 m depth below surface and dipping 50 degrees to the south. The strike of the body is east-west. The very good agreement between the measured and calculated data on line 100501 suggests that the Iso body is a plate like conductor.

For the New Insco body, the second-order moment anomaly on line 101601 can be modelled, albeit poorly, by both a plate-like model (Figure 4b) and a sphere-like model (Figure 4c). The fact that the anomaly on line 101601 is modelled to some extent by both the plate and sphere models, implies that the properties of the real conductor lies between these two extremes. The properties of the plate-like model is very similar to the model used for Iso (striking east-west), dipping 50 degrees to the south centered at about 42 m depth). The key difference is that the New Insco model is more conductive than the Iso model, which is consistent with the decay rates seen on Figure 13 of Part I.

MAXWELL plate model of the Iso body

Maxwell package is better able to simulate the response of a large plate in a very resistive environment, than does the EMQ method. The plate size and its conductance, and the total number of ribbons used to approximate currents in the plate play an important role in the result obtained. Maxwell is suitable for modeling a single plate or multi-plates. Although multiple lines can be modelled simultaneously, it is difficult to visualize the model and response profiles, so that practically, we found that we could only conveniently model a single profile at a time. As with EMQ, the user adjusts the plate parameters and can examine the modeling results almost instantaneously. Maxwell also analyses the decay to estimate a time constant or a power-law decay where appropriate. Unlike EMQ, the field is not assumed to be uniform at the plate. Maxwell can also be used as an inversion tool to find the best fitting model given some initial estimate of parameters.

Figure 5 shows a good fit between the measured response (black) and the model response (red) for the *z*-, *x*- and *y*-component. The measured data is on line 100501 over the Iso body. The plate-like conductor has a conductance of 55 S, a strike length of 200 m and a depth extent of 500 m and is dipping 50 degrees to the south. This is consistent with geological information and other geophysical interpretations.

Our EMQ modeling indicates that the New Insco body is not well approximated by the plate model used by Maxwell. We therefore preferred to use the more complex modeling algorithm EMIGMA (discussed in the following section) to model New Insco.

EMIGMA Plate model of Iso body

The EMIGMA package can be used to estimate the response for a specified model (forward model). It is not able to iteratively improve the model to find the best model (inverse modeling). Thus, more trial and error work is required to obtain a satisfactory fit. The advantage of EMIGMA is that it allows the user to design models comprising multiple (albeit non-interacting) plates and to simulate the response on several profiles. This is important as it allows us to examine the consistency between the measured and the modelled anomalies on all relevant profile lines (even those profiles offset some distance from the centre of the body). Furthermore, it is the only commercial EM modeling tool that can model a thick prism model (vertical and dipping) as well as a thin plate. Our modeling was done with the GeoTutor II implementation of the EMIGMA algorithms VHPLATE (for plates) and ILNprism (for thick prisms).

The Iso massive sulphide response is simulated by a model comprising four thin plates which are shown superposed on a cross section of the ore body in Figure 6. Figure 7 shows a close similarity between the measured anomalies (left) and the modelled responses (right) along three flight lines (100301, 100401 100501). Plate 3, situated under flight lines 100401 and 100501, is the plate with the highest conductance, 55 S. The conductance of Plate 2, below lines 100301 and 100401, is 40 S. Plate 1 has the lowest conductance (20 S) and is at the extreme west end of the Iso deposit (below lines 100201 and 100301). At the extreme east end (below lines 100601) the conductance of Plate 4 is about 30 S. The time constant of the response increases with the conductance, being greatest in the high conductance zone near line 100501. Table 1 summarizes the parameters used in modeling and compares the amplitudes of the field data and the simulation results (measured in time window 8). Because the thin rectangular plate model is an approximation, we would not expect an exact fit of the model data to the field data. For this example, the early-time amplitudes are close, but the decay rate of the model data is a little too slow, particularly on line 100301.

These four thin plates are situated in a medium where the resistivity is about 5000 Ωm. For this specific model, the modeling results agree quite closely with the measured data (table 1). Increasing the resistivity of the host rock produces no change in the response; however, decreasing the resistivity produces a larger discrepancy between the modelled and measured data. Hence, we conclude that the resistivity of the background is about 5000 Ωm or higher.

Table 1

Parameters of Model

Plate size (m)				**Conductance (S)**
No	**Strike length**	**Dip extent**	**Dip angle (degrees)**	
1	100	200	50	20
2	153	620	50	40
3	200	470	55	55
4	200	150	50	30

Electromagnetic response (nT) for unit dipole transmitter, base frequency 90 Hz, resistivity of bedrock is 5000 ohm-m							**Time constant (ms) (90 Hz)**	
line	Xmax (window 8)		Ymax (window 8)		Zmax (window 8)			
	obs	model	obs	model	obs	model	obs	Model
301	1.4E-7	1.4E-7	6.8E-8	9.8E-8	1E-7	1E-7	0.46	0.89
401	1.7E-7	1.67E-7	-3E-8	-1.6E-8	2.6E-7	2.1E-7	1.091	1.032
501	3.4E-7	3.4E-7	-6.2E-8	-7.2E-8	2.8E-7	2.8E-7	1.506	1.233

There is a good agreement between the model derived from the $MEGATEM^{II}$ data and the known geology. It is observed from the overlay of the EMIGMA model on the mapped geology (Figure 6), that different conductances correspond to specific compositional zones. For example, the high conductance of 55 S relates to the copper-rich zone, the pyrite-rich zone corresponds to the plate with a conductance of 40 S, and low conductance zones (20 to 30 S) probably correspond to the other sulphides or thinner zones. Also, the depth extent of the plates suggests that the Iso deposit might be more conductive in the upper and middle part from 50 m to 650 m depth. If the high conductance is correlated to high copper content, the modeling result could indicate that the more economic zone of the deposit is in the top 550 m. In fact, the geology below 500 m is not well constrained by drill holes. By the same token, the depth attenuation results in Part I indicate that the MEGATEM system will be less sensitive to the deeper parts of the body.

The modeling also indicates that the Iso body becomes less conductive on its eastern and western edges. The high signal to noise ratio of 90 Hz data allows us to identify and model these more weakly conductive parts of the deposit. This would be more difficult using the 30 Hz data.

The EMIGMA modeling indicates that the MEGATEM^{II} data is very good for identifying the conductive body and estimating geometric parameters such as the strike extent and the dip. The airborne EM data have been able to identify the more conductive zones, but it cannot determine their mineralogy (e.g. copper-rich). The conductance estimate is a conductivity-thickness product and is not an estimate of the conductivity.

EMIGMA Prism model of New Insco body

If the geometry of the New Insco body is similar to the Iso body (plate-like, dipping to the south), then the shapes of the *x*- and *z*-component response measured over New Insco should be similar to those measured over Iso. However, negative features are absent from the measured data at New Insco (left panels of Figure 8). Whereas plate models (right panels of Figure 8) have responses with strong negatives in the *z* component. However, the response from a 35 m thick plate, calculated with the EMIGMA ILNprism algorithm, does not have a strong negative. Although the responses of the thick plate do not resemble the measured data on all profiles, we can infer that the thickness of the New Insco body is significant. This is consistent with the fact that our EMQ models also indicated that New Insco might be thick (spherical).

The parameters for the New Insco thin plate and thick prism are shown in Tables 2a and 2b respectively. The prism model has a conductivity of 3 S/m and a thickness of 35 m (equivalent to a conductance of 105 S) while the plate model has a conductance of 130 S. Both these conductances are significantly higher than the modelled conductances for the Iso body. The prism/plate has a depth to top of 55 m below surface and is situated between line 101501 and 101601, but lies closer to line 101601. A quantitative analysis of metal concentration on thirty-nine core samples (from 13 boreholes) shows that New Insco is richer in copper and there is a higher concentration (10 to 90%) of pyrrhotite between 50 to 100 m depth. Pyrrhotite is not readily identified in the analysis of the Iso body. This is consistent with our interpretation. However, there are discrepancies between the model responses and the observations, particularly on the *y* and *z* components. We were unable to resolve these discrepancies by using EMIGMA, but suspect that they could be due to the influence of shallow conductors or inadequacies in the ability of the simple plate/prism models to model complex geology.

Table 2b

Model parameters of New Insco deposit – Thick plate								
Prism size (m)							**Conductance (S)**	
Strike length	**Dip extent**	**Dip angle**	**thickness**					
70	100	60	35				105	
Electromagnetic response (nT) for a unit dipole transmitter, base frequency 90 Hz, Resistivity of bedrock is 5000 ohm-m							**Time constant (ms) (90 Hz)**	
line	Xmax (window 8)		Ymax (window 8)		Zmax (window 8)			
	obs	model	model	obs	obs	model	obs	model
1501	2.36E-8	2.33E-8	1.28E-8	1.28E-8	1.7E-8	1.23E-8	1.162	1.011
1601	2.77E-8	2.77E-8	5.7E-9	1.4E-8	3.14E-8	2.4E-8	1.204	1.182

Table 2a

Model parameters of New Insco deposit – Thin plate								
Plate size (m)							**Conductance (S)**	
No	**Strike length**	**Dip extent**	**Dip angle**					
1	70	90	50				130	
Electromagnetic response (nT) for a unit dipole transmitter, base frequency 90 Hz, Resistivity of bedrock is 5000 ohm-m							**Time constant (ms) (90 Hz)**	
line	Xmax (window 8)		Ymax (window 8)		Zmax (window 8)			
	obs	model	model	obs	obs	model	obs	model
1501	2.36E-8	2.34E-8	1.28E-8	1.79E-8	1.7E-8	1.8E-8	1.162	1.046
1601	2.77E-8	2.8E-8	5.7E-9	1.4E-8	3.14E-8	3.4E-8	1.204	1.106

Interpretation of gravity data by 3D inversion

Bouguer gravity anomalies reflect heterogeneities in the density of the earth. The inversion of gravity data therefore defines a density model that provides the best fit of the model data to the observed data. Modeling gravity data is considered to provide a non-unique solution, because different models can yield the same response.

The inversion algorithm we use (GRAV3D) was developed at the University of British Columbia (UBC) (Li and Oldenburg, 1998), and then integrated into Gocad, which is a computer aided design system for 3D visualization and modeling. The volume representing the area of investigation is defined by a finite set of rectangular cells, and the physical properties of these cells are estimated. The usefulness of Gocad is that all available geological information can be combined in a single model, which is used later as a reference model for geophysical inversion. The distribution of density or susceptibility within the set of cells is determined by minimizing the difference between the observed anomaly and that generated by the synthetic model. The non-uniqueness issue is therefore addressed by seeking a solution that is consistent with the geological information incorporated into the reference model.

Massive sulphide bodies usually have a density that is higher than the surrounding material. By modeling the gravity data, we expect to get additional information about the density of the Iso and New Insco deposits. Unfortunately, there are a limited number of gravity measurements (3 profiles over the Iso body and 3 profiles between Iso and New

Insco). Even so, there is a distinct 0.2 mGal residual anomaly over the Iso body that is oriented along the known strike direction (Figure 9a,b). The density of host rocks such as rhyolite, dacite and andesite is normally less than 2900 kg/m^3, while the density of massive sulphide is more than 3500 kg/m^3.

Based on 33 cross-sections and data from more than 100 boreholes, we have built a 3D geological model of the Iso and New Insco deposits. The model is 2.5 km x 2 km x 1 km and the cell size varies from 5 to 10 m in width. An initial density distribution, inferred from 59 core sample measurements was used to populate the density attributes of the geological model. The values used were 5010 kg/m^3 for pyrite, 4280 kg/m^3 for chalcopyrite and 4080 kg/m^3 for sphalerite (Greason 1974). The populated geological model was used as the starting model in the inversion to refine the density estimates. Figure 9c shows us that the model anomaly after inversion fits acceptably to the observed data. According to the inversion, a high density zone is present under MEGATEM^{II} flight lines 100401 and 100501, where the density is at least 4000 kg/m^3. This high-density zone corresponds to the copper and iron-rich zones (Figures 10—top, and 6). An isodensity surface corresponding to 3500 kg/m^3 outlines the whole Iso massive sulphide body (Figure 10-- bottom). An alteration zone is indicated by the 3000 kg/m^3 isodensity surface. Variations of density modelled in the Iso area are cited in table 3.

Table 3: Densities in Iso area

Zone	Initial density (kg/m^3)	Inversion results (min-max)	Inversion results (75% of each zone are above this density value) (kg/m^3)

pyrite	5010	3850 – 4870	4610
copper rich	4280	3450 – 4480	3850
zinc rich	4080	3280 – 4810	3660
alteration	3180	2620 – 4270	3000
rhyolite	2850	2640 – 3140	2760
diorite	2850	2250 – 3500	2630
andesite/trachyte	2850	2390 – 2740	2530

Interpretation of Magnetic data by 3D inversion

Magnetic susceptibility is the parameter used to characterize the potential of a mineral or a rock to acquire an induced magnetisation. The susceptibility of crustal materials is strongly dependant on the presence of magnetite which is a common mineral in many rocks. For this reason, the susceptibility of a country rock could be superior to that of an ore mineral. For example, the susceptibilities of sphalerite, pyrite and chalcopyrite are all less than 0.001 SI (Telford et al., 1976), however the susceptibilities of andesite, basalt and diabase can be more than 0.1 SI (Keller, 1988). If a massive sulphide body formed of the aforementioned sulphide minerals is in such an environment, then the anomaly would be predominantly negative (at high magnetic latitudes such as the Abitibi). Pyrrhotite, on the other hand can have a susceptibility as high as 1 SI, so if this material is present, we would normally expect a positive anomaly.

The magnetic data were collected during the MEGATEM^{II} survey. We can see from Figure 11a that the magnetic map is dominated to a large extent by positive (red) anomalies, those trending between the Iso and New Insco bodies being associated with diabase dikes, which were emplaced during the last volcanic event in the area. There is a small positive 50 nT anomaly (red) associated with the New Insco body, but the anomaly over Iso is much weaker and is about 20 nT and it stands out as a green oval-shaped anomaly surrounded by blue shades. In both cases the anomalies are roughly circular and of limited extent. The 3D inversion (UBC code: MAG3D developed by Li and Oldenburg, 1996) has been used to invert the data without geological constraints. However, the non-uniqueness issue, apparent in magnetic interpretation also, has been addressed to some extent by seeking a solution that places greater emphasis on solutions that are deeper rather than shallower.

The results indicate that the susceptibility of the diabase dikes is about 0.01 SI, the susceptibility of the New Insco body is at least 0.0001 SI (Figure 11b), however, there is no significant value for the Iso body. Our suspicion is that the New Insco anomaly is associated with the pyrrhotite that has been identified at New Insco (but not at Iso).

Characteristics of Iso and New Insco deposits

Summarizing the above observations, we conclude that the Iso body has a lower magnetic susceptibility than the New Insco body and has a lower conductance. Also, the density of the material in the Iso body is greater than that of the surrounding volcanic rocks. We infer that the conductance within the Iso body increases where the Iso body contains more chalcopyrite. This is consistent with our observation for the New Insco body, which also has a large conductance and is rich in chalcopyrite; however, the large conductance could also be attributed to the presence of pyrrhotite in the New Insco body. This illustrates that electromagnetic surveys are useful for resolving parameters like the conductance, the dip and other parameters such as the strike and depth extents, but are not able to identify mineralogy. However, zones with differing conductance might be indicative of zones of differing mineralogy.

Conclusions

Modeling of the MEGATEM^{II} data with the EMQ package showed that a dipping plate model is appropriate for the Iso body, but not necessarily for the New Insco body. The EMQ model was able to estimate the strike, dip and the depth. Also, the EMQ results indicated that New Insco was more conductive than Iso.

Maxwell plate modeling of the Iso body shows that the measured response below one flight line (100501) can be approximated by that of a large plate having a conductance of 55 S, and dipping at 50 degrees. Using the more sophisticated EMIGMA package to model several lines, it is possible to show that the copper-rich zone corresponds to the greatest conductance (55 S), and the iron-rich zone to the plate with the next greatest conductance (40 S). The edge zones have smaller conductances corresponding either to other less conductive sulphides (zinc) or thinner, more disseminated zones. EMIGMA results indicate that a thick prism might be an appropriate model for the New Insco body.

The gravity inversion was constrained by setting the initial model to the known background geology. The results showed that the densest zone corresponds to the sulphide body at Iso. Within the sulphide zone there is some indication that the iron-rich zone is the densest. There are no gravity data over New Insco. Magnetic data have been inverted and show that the diabase dykes have the strongest susceptibilities (0.01 SI). The susceptibility for the New Insco deposit is quite high (up to 0.005 SI), interpreted to be a consequence of the pyrrhotite which has been mapped in the deposit. There is no significant pyrrhotite mapped at Iso, consistent with the inverted susceptibility being below 0.0001SI.

Interpretation, modeling and inversion of MEGATEM^{II} data provide important information about the size, geometry and conductance/conductivity of the Iso and New Insco deposits. The gravity and magnetic data have provided information about the density and susceptibility of the deposits, but geometric information is not as easy to obtain from gravity or magnetic (because of non-uniquenesses in both methods). In all cases the results are consistent with the known geology.

Because the MEGATEM^{II} results are consistent with the known geology, we can conclude that there are no significant parts of the body above 230 m depth, which are undetected by the MEGATEM system. There could be similar conductive material below

230 m depth, but the depth of investigation study in Part I demonstrates that this would not be detected by the system.

In areas where the underground structure is poorly known, it might be appropriate to use MEGATEM^{II} data to resolve the geometry of conductor and then to use this as a constraint for the gravity and magnetic inversion.

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Figure captions

Figure 1. Locations of the two study sites in the MEGATEM^{II} project.

Figure 2. Geology of the Iso and New Insco area (adapted from SIGÉOM of Ministry Geology of Québec, 2004. http://www.mrnfp.gouv.qc.ca/produits-services/mines.jsp).

Figure 3. Zoning of sulphides within the Iso deposit, data from Noranda. the zone labeled "Massive Sulphide" indicates mixed pyrite, sphalerite, chalcopyrite and gangue.

Figure 4. EMQ modeling results. (a) line 100501 over Iso deposit; (b) line 101601 over New Insco deposit (dipping plate model); (c) line 101601 over New Insco deposit (sphere model).

Figure 5. Maxwell modeling result for line 100501. The measured response is shown with black lines and the model response is shown with red lines.

Figure 6. EMIGMA plate models and the mineralization zones of the Iso deposit.

Figure 7. EMIGMA modeling results for the Iso deposit. The length of the profile is 1000 m.

Figure 8. EMIGMA New Insco modeling results. The length of the profile is 800 m.

Figure 9. Gravity modeling of the Iso deposit: the left panel (a) shows the constraining volume used in the inversion (view from the east), the top right panel (b) is the measured anomaly and the bottom right panel (c) is the anomaly corresponding to the inversion results. On panels (b) and (c), north is to the top. The spacing of the gravity stations along each of the three traverses is 15 m. There are two gravity survey lines near the east end of the inversion region, which are absent from the figure.

Figure 10. The density distribution determined by 3D inversion. The top panel (section view) shows the mineralogy and in yellow the volume where the density is greater than 4.0 g/cm^3. The bottom panel (section view) shows in blue the volume where the density is greater than 3.5 g/cm^3.

Figure 11. Magnetic anomaly map from MEGATEM^{II} survey (a) and the susceptibility distributions of the New Insco body (3D model view from south) from the 3D inversion (b).

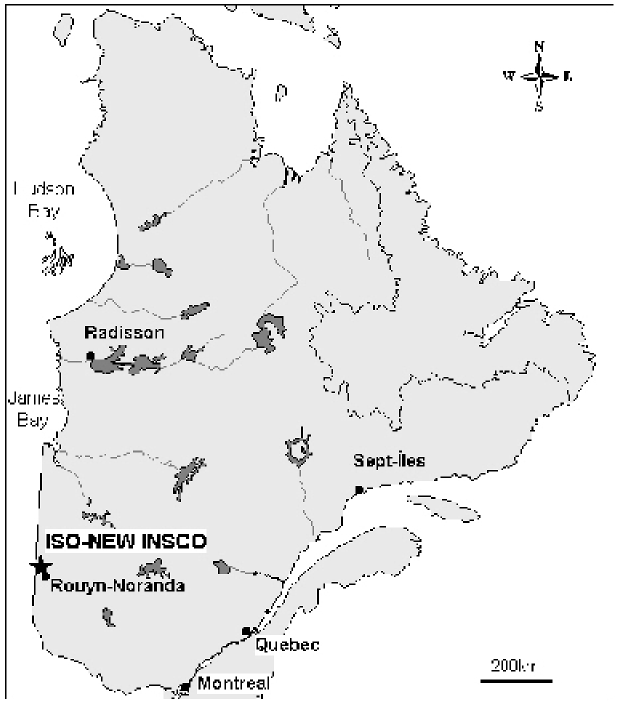

Figure 1

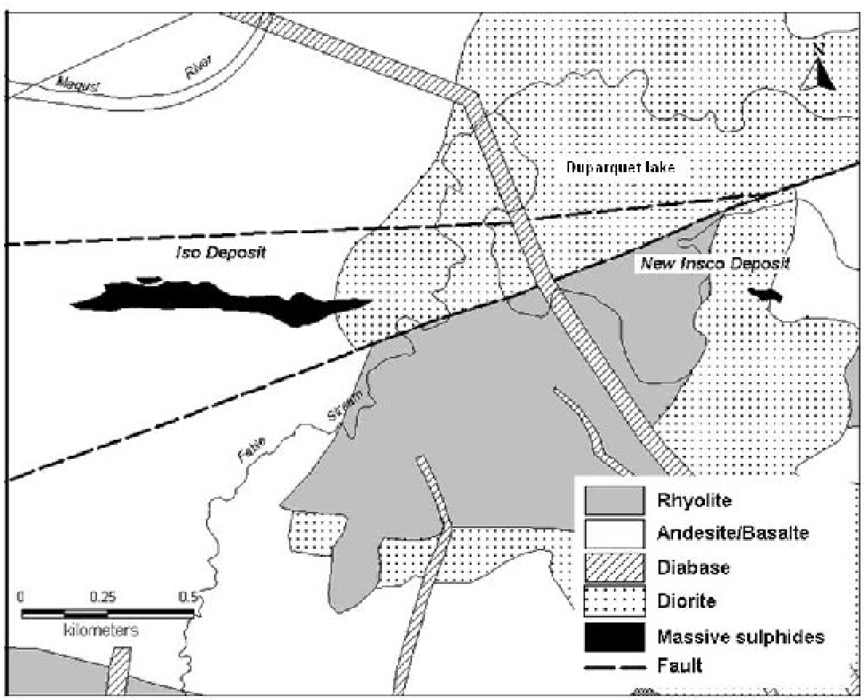

Figure 2

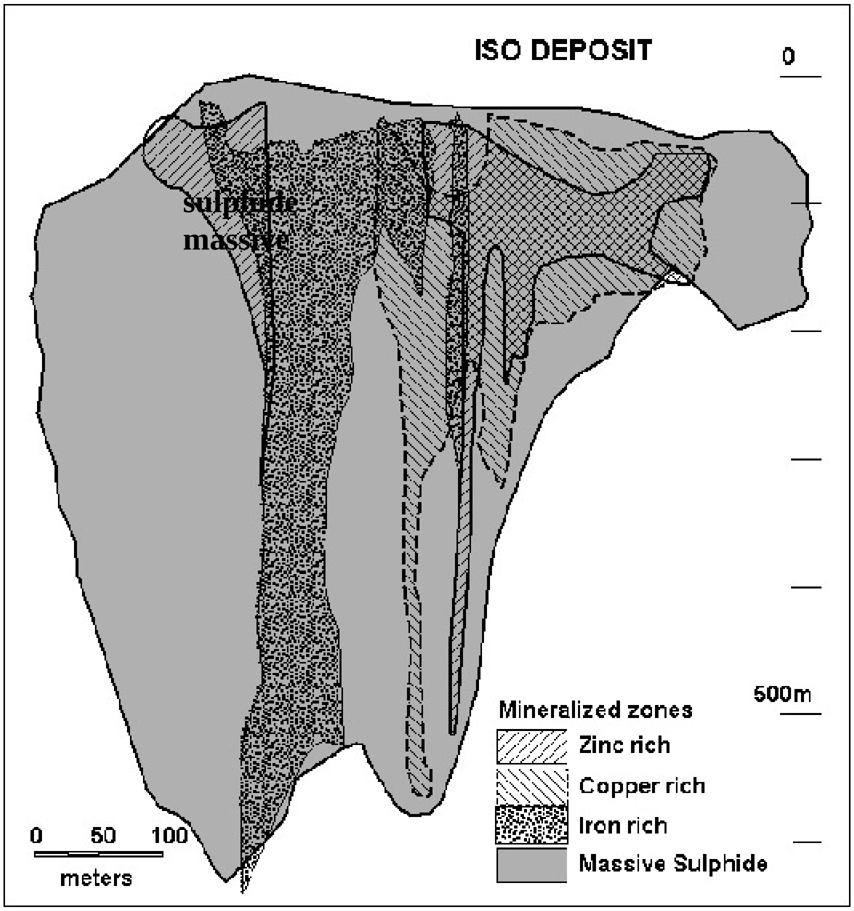
ISO DEPOSIT
0
sulphide
massive
500m
Mineralized zones
Zinc rich
Copper rich
Iron rich
Massive Sulphide
0 50 100
meters

Figure 3

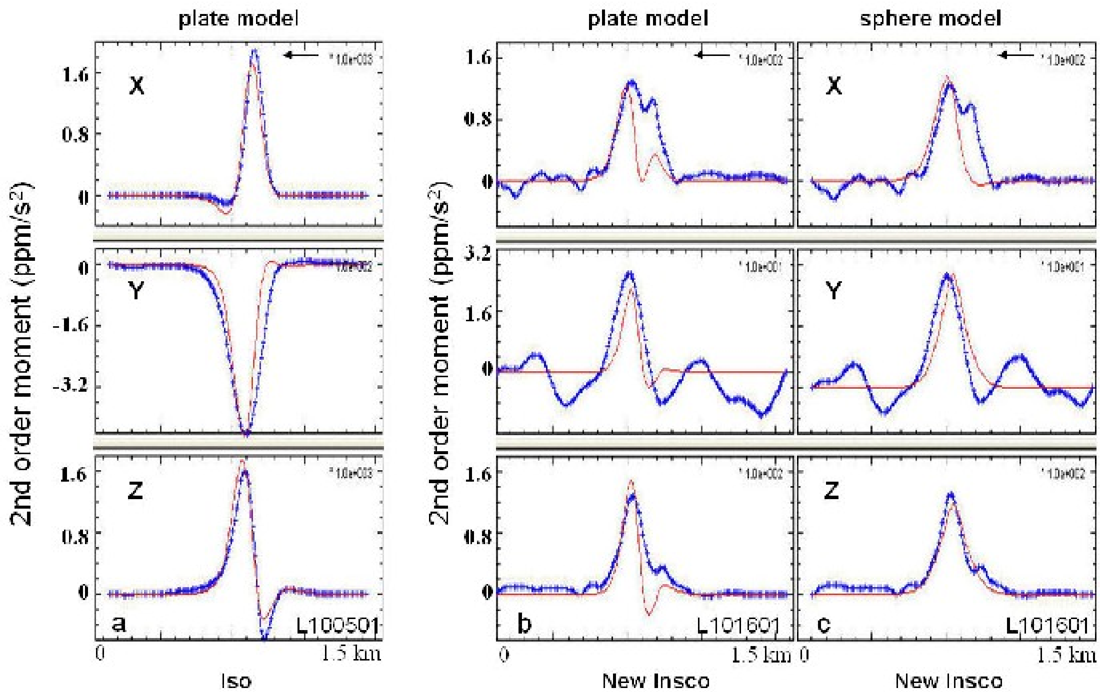

Figure 4

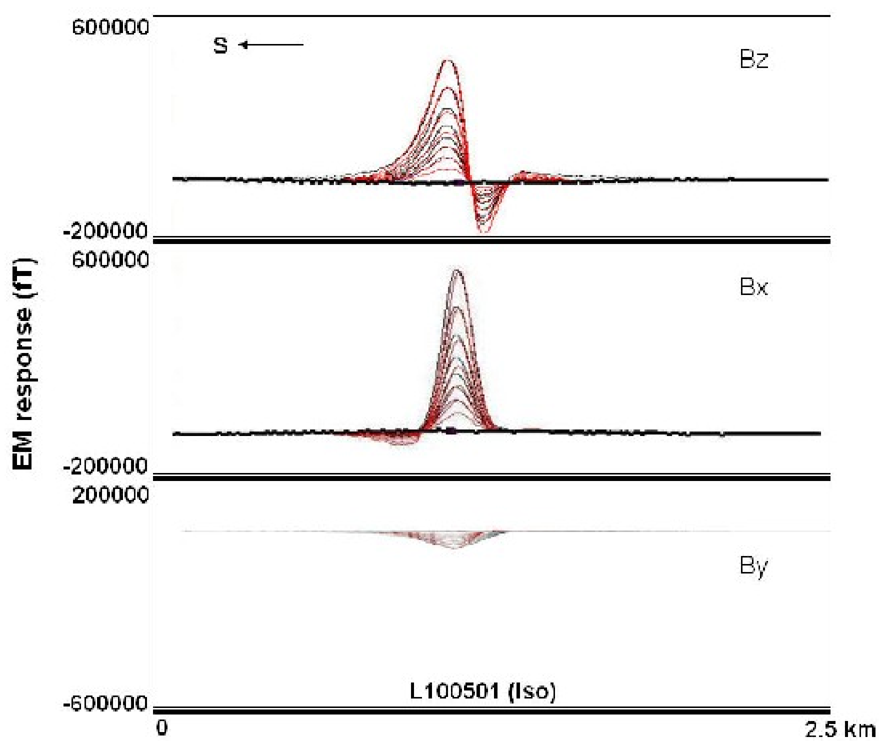

Figure 5

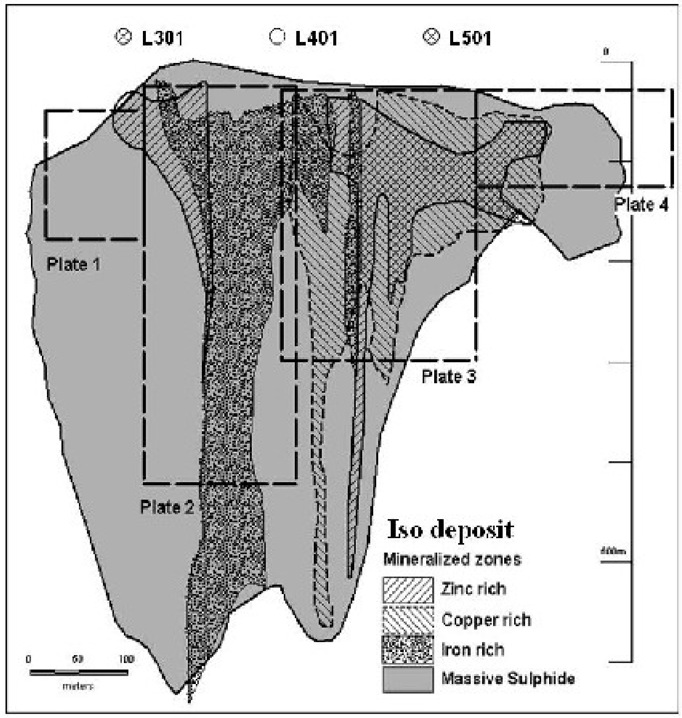

Figure 6

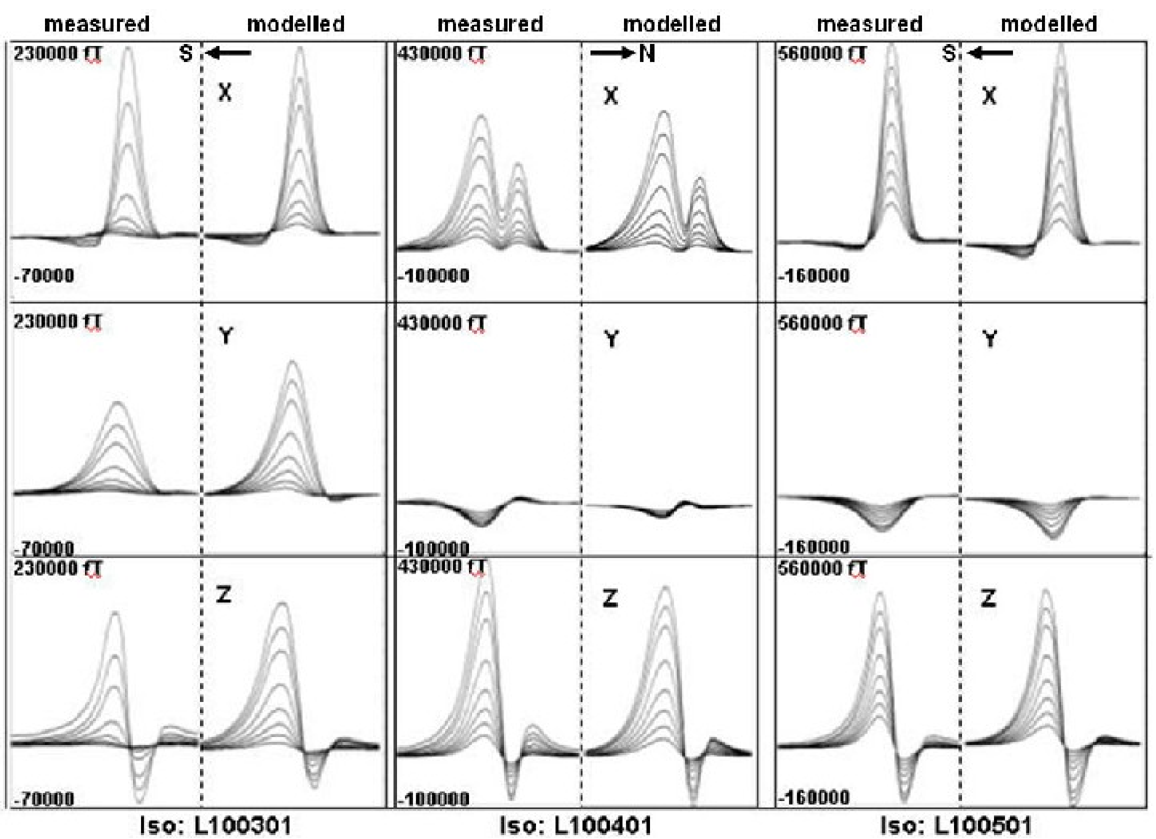

Figure 7

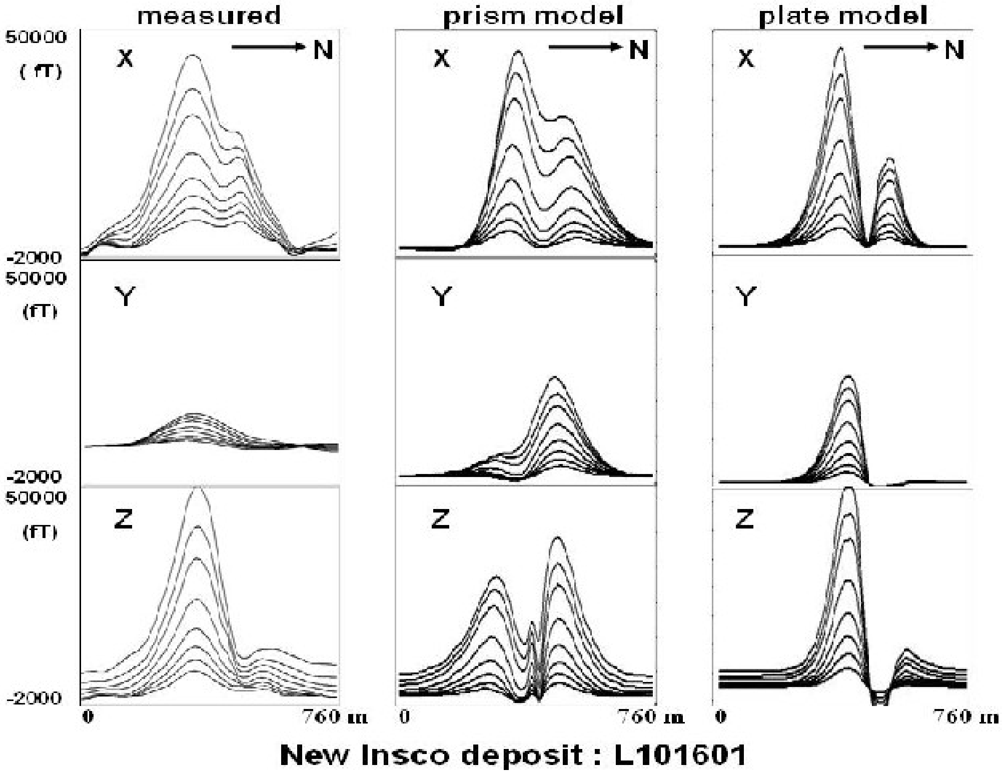
measured
prism model
plate model
50000
(fT)
-2000
X
Y
Z
N
0
760 m
New Insco deposit : L101601

Figure 8

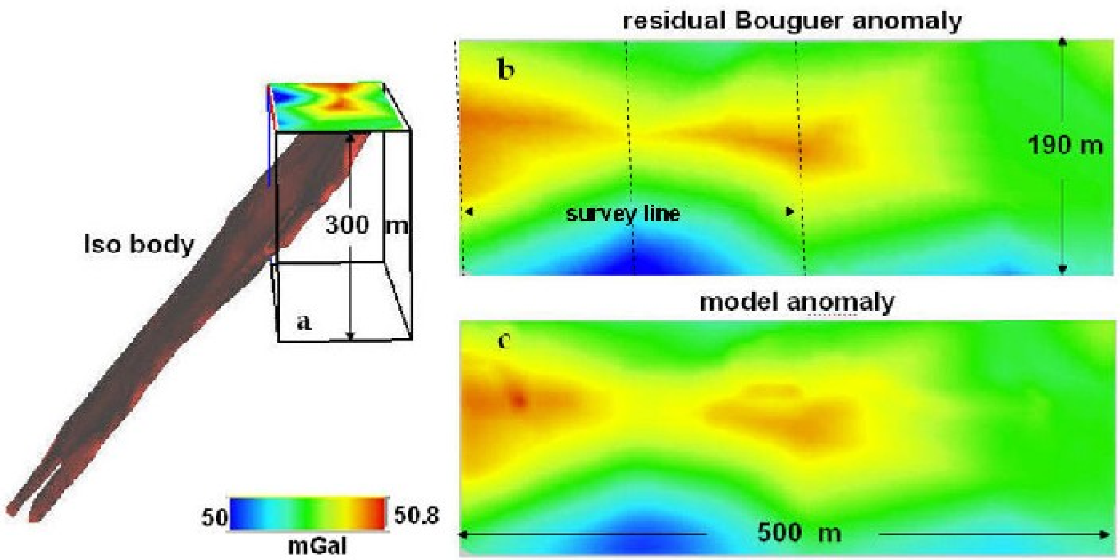

Figure 9

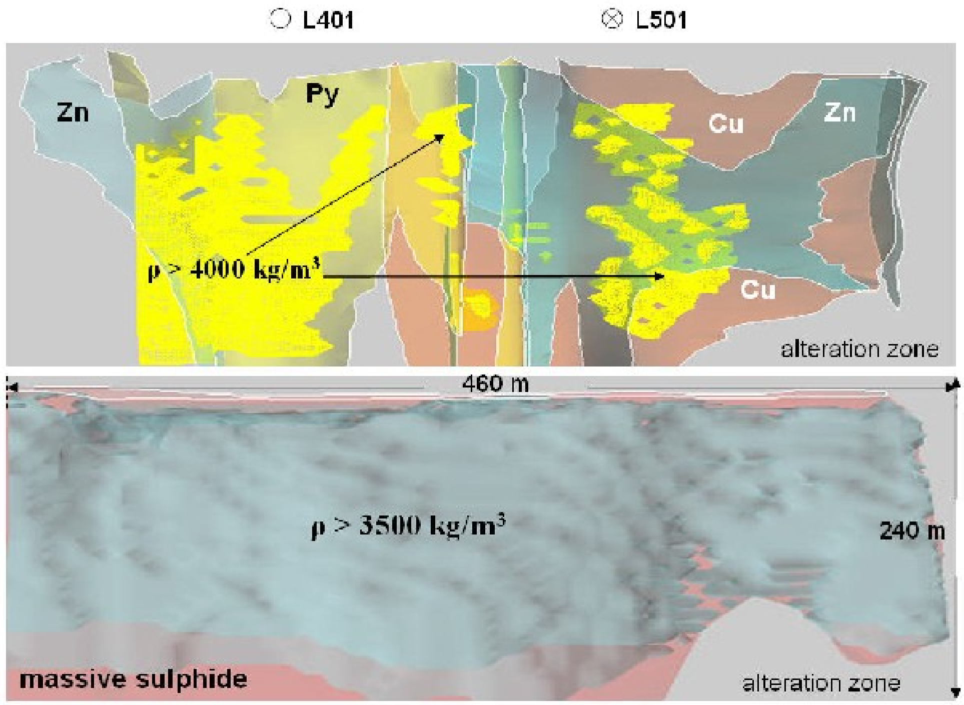

Figure 10

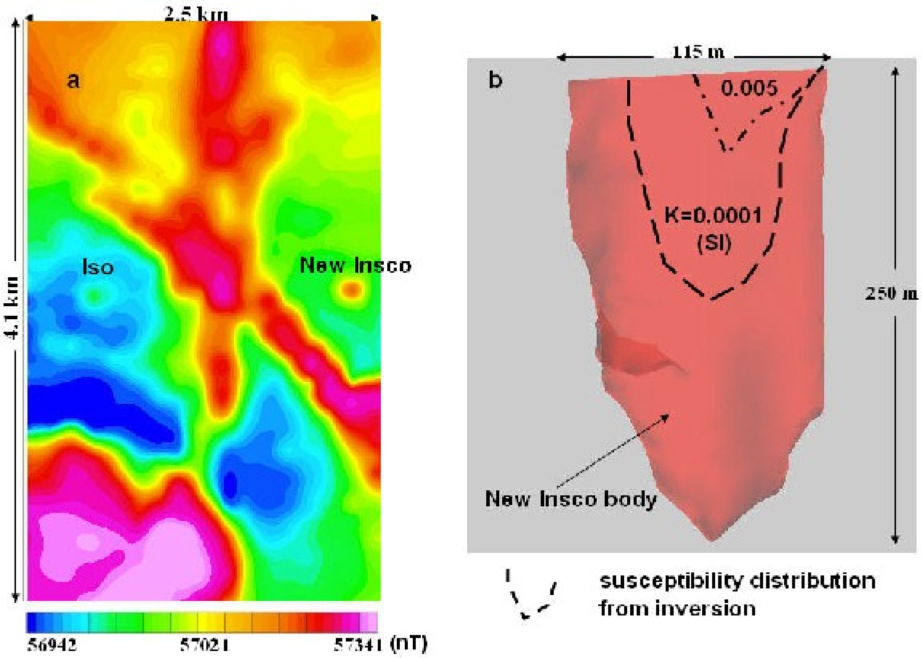
2.5 km
4.1 km
a
Iso
New Insco
56942
57021
57341 (nT)
115 m
b
0.005
K=0.0001
(SI)
250 m
New Insco body
susceptibility distribution
from inversion

Figure 11