Final report

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Abstract

The purpose of this report is to discuss the results from a 2-day geophysical survey conducted in the Calabogie region. This survey was conducted to determine if the area contained any geophysical anomalies, what these anomalies were, and if they could potentially be mineral deposits that are economically feasible to mine. Using Resistivity (RES)/Induced polarization (IP), magnetic and electromagnetic survey methods, an anomaly was found striking NW-SE in the southern portion of the survey site that could potentially be due to metallic ore deposits at the site. Further surveys must be conducted to determine the exact extent of the anomaly and precisely what is the material causing the anomaly.

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Introduction

Geophysical survey methods allow researchers to learn about the properties of the subsurface, which can be used for exploration, environmental, and engineering purposes among others. Over 2 days at the Calabogie survey site in the Renfrew area of Ontario, a group of Queens and Western students were tasked with carrying out various geophysical surveys. The objectives of these surveys were to locate geophysical anomalies in the subsurface and to determine the extent and type of anomaly. Another objective was to determine if the area could have mineral or ore deposits that are economically feasible to mine using this information. With the information gathered through the surveys conducted we were then to suggest future exploration tools and targets in the area.

Geographic/Geological setting

The Calabogie site is located near Renfrew, Ontario. The site is heavily forested, with poor road access to the site besides small tracks that are suitable for off-road vehicles. From these roads, 5 survey lines were cut into the forest, as seen in figure 1. These lines are the areas the geophysical surveys were conducted on, due to ease of accessibility. The surrounding forest is dense and makes surveys outside these pre-cut lines difficult.

Figure 1: A map of the Calabogie site area. The yellow lines are precut lines where the surveys were conducted (credit:Vanderhoeff).

The site is located near the Ottawa valley, but is geologically very different. The study area is located in the central metasedimentary belt (CMB), inside the Ontario Grenville province. The CMB was created during the Shawinigan orogeny about 1.19-1.14Ga (Cousens et al). The Grenville province makes up the remnants of the Grenville mountains and as a result of this, the province contains highly sheared and metamorphosed rock (Cousens et al). Figure 2 shows the CMB particularly is a belt of calcite and dolomite marble in the Grenville province with many intrusions consisting of gabbro, diorite and tonalite. There are also northwest and northeast trending faults in the area (Dube-Borgeois et al). The study area is shown in figure 3. This section of the CMB is in an area characterized by mafic to ultramafic plutonic rocks as well as mafic to felsic metavolcanics rocks and metasedimentary rocks (Dube-Borgeois et al).

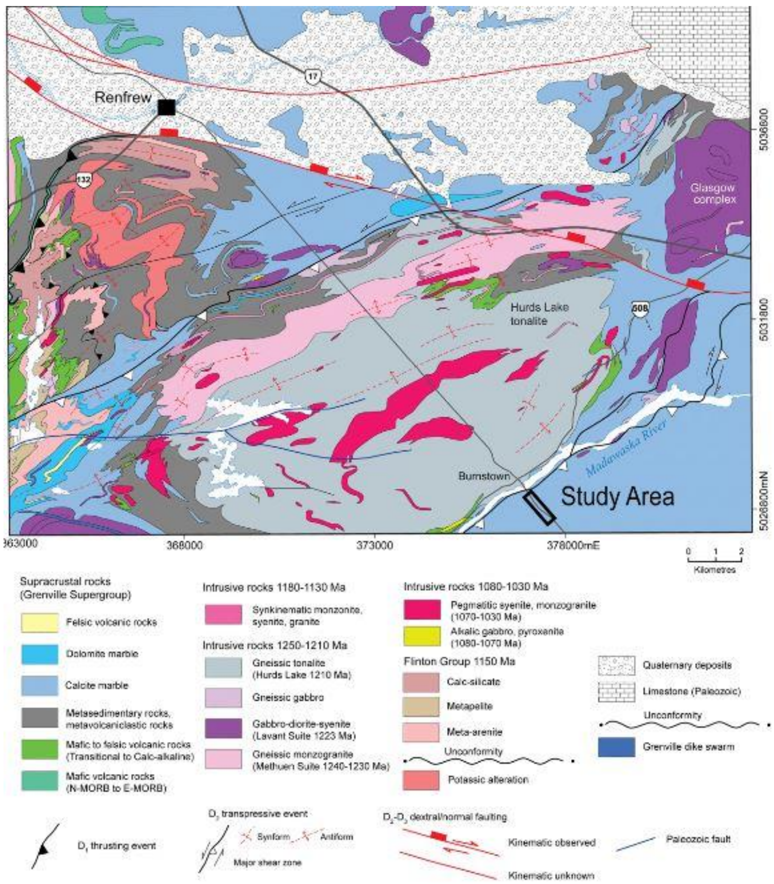

Figure 2: Geological map of part of the Grenville province where the geophysical surveys took place (Dube-Borgeois et al).

Figure 3: Geological map of Calabogie site. The light green is mafic to felsic metavolcanics rocks while the dark green is mafic to ultramafic plutonic rocks (credit: Pedro).

Geophysical survey methods

Over 2 days at the Calabogie site, 2 separate RES/IP surveys were completed. There was also a UTEM survey, several EM surveys, and several magnetometer surveys completed using the PPM and fluxgate magnetometers. Figure 4 shows a map of the EM, UTEM and RES/IP surveys in the area that were conducted. Figure 5 shows a map of the fluxgate magnetometer survey conducted. The data collected in figure 9 of the results section shows us the path the PPM magnetometer survey was taken on.

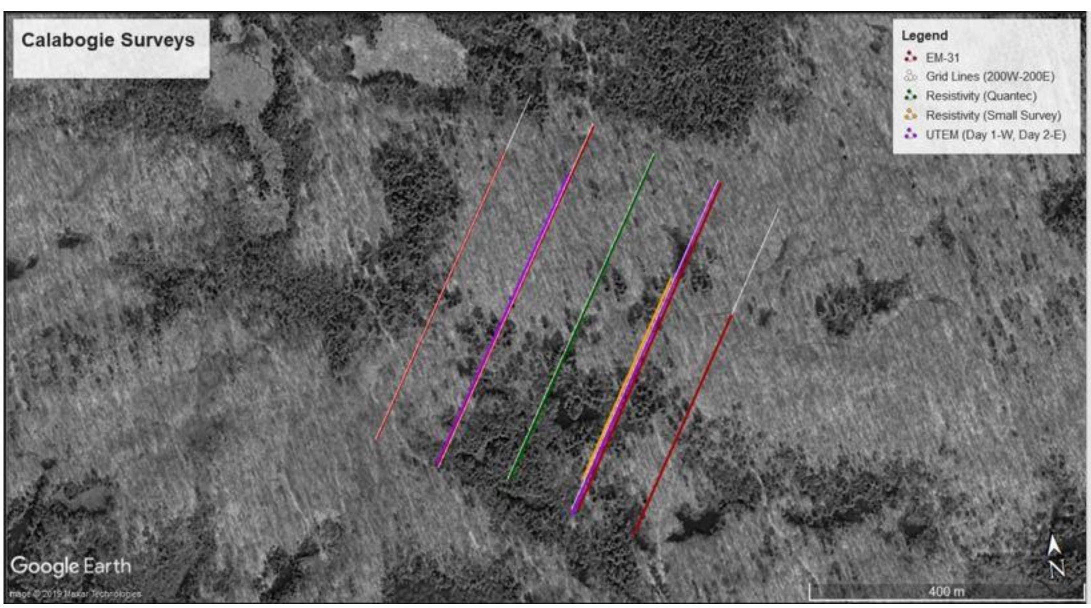

Figure 4: a map of survey locations at the Calabogie survey site. This map does not include the magnetic surveys, as they did not stay strictly on the pre-cut lines (credit: Bourassa).

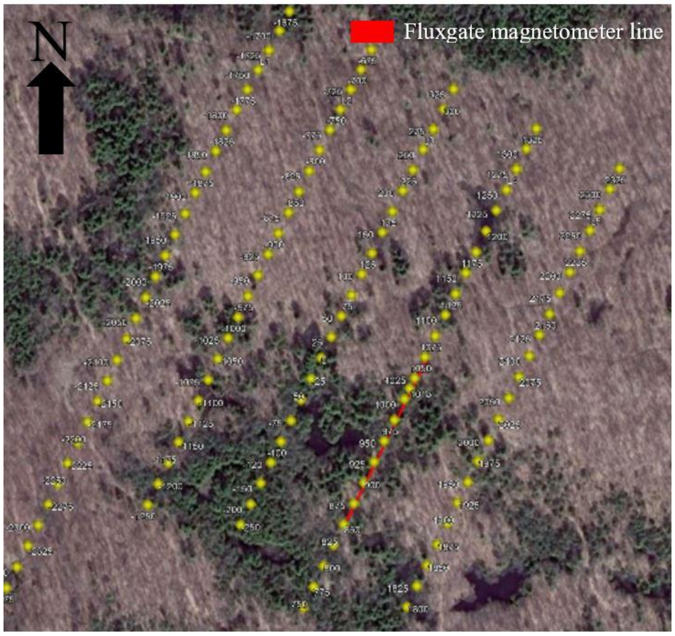

Figure 5: A map of the fluxgate magnetometer line (credit: Vanderhoeff).

It was thought that these surveys that seek to determine the electrical and magnetic properties of the subsurface would be more valuable at Calabogie than seismic methods, which is why no seismic methods were employed and only electrical and magnetic methods were. The reason for this is because the terrain is very rough, with lots of rock and tree roots, making it difficult to deploy geophones along a line. The bedrock depth, which seismic methods excel at finding, is also irrelevant to our study because the depth to bedrock is shallow and it was not what we were tasked with finding. It was more important to not only find anomalous objects in the subsurface, which seismic methods could do, but learn about it's electrical and magnetic properties to determine if it could be a sulphide or metallic ore deposit. We also did not think seismic methods would help with this given the terrain, because there is so many different intrusions and faults in the area, it would be difficult to distinguish which anomalies could be worth further investigation and which are not worth the time investment it would take to investigate. There would also be large error in the seismic methods due to topographic effects from all the elevation changes at the site, so the results would not be reliable.

The plan for this geophysical survey was to first map the rocks magnetic susceptibility and electrical conductivity using magnetic surveys and EM surveys respectively. The goal was to get data using the magnetometers (both fluxgate and PPM) and EM31 along all pre cut lines the first day, then determinine which would be most useful for additional investigation for the second day. Unfortunately, not all pre-cut lines could be surveyed in the first day, so the line with the largest magnetic field strength anomaly found the first day was investigated using a small RES/IP survey the second day. The RES/IP survey used the dipole-dipole array geometry, since the goal was to find anomalies in the subsurface by inverting the data collected to form a resistivity and chargeability model of the subsurface. Only dipole-dipole was able to do this. The electrode spacing was 10m and the line length was 45m. There was a 10m overlap between lines in the RES/IP survey. The survey took place over lines 100E and 200E, with each RES/IP line being about 140m long.

While the magnetometer, EM31 and small RES/IP surveys were ongoing, a larger RES/IP survey was being conducted with the aide of Quantec geosciences, and a UTEM survey was being conducted with the aide of Lamontagne geophysics. The larger RES/IP survey was conducted along the centre line (the green line in figure 4) over both days while the UTEM survey was conducted on 100W and 100E lines over both survey days.

The reason the magnetometer surveys were conducted was to locate any magnetic anomalies in the subsurface, since the magnetic anomalies could correspond to areas where there is a large concentration of metallic rocks, since these have high amounts of magnetic minerals. It was done on the first day because it was fast and could narrow down the areas where further study was needed. The EM surveys were conducted because these surveys measure electrical conductivity of the subsurface rock, which could again tell us if there is an area with a high concentration of metallic minerals, since these would have high electrical conductivities. The Resistivity survey would inversely tell us where there are anomalies in the subsurface resistance. This could tell us where metallic minerals are since these minerals would have a low resistivity. The IP survey could tell us areas where there may be disseminated mineral deposits, since these areas would have a high chargeability, meaning the voltage decay would be slow in these areas (Pratt & Smith).

Data reduction/results

After the data was collected using the geophysical survey methods over the 2 days at the Calabogie site, the data was then processed using various software packages by the whole group. Figure 7 shows the results of the fluxgate magnetometer survey along the 100E line. The plot shows a large increase of nearly 10000nT in the magnetic field strength to about 61000nT at about the 145m mark along the 100E line from the road. This increase was followed by a large decrease in the magnetic field strength to about 45000nT about 20m after the increase in field strength.

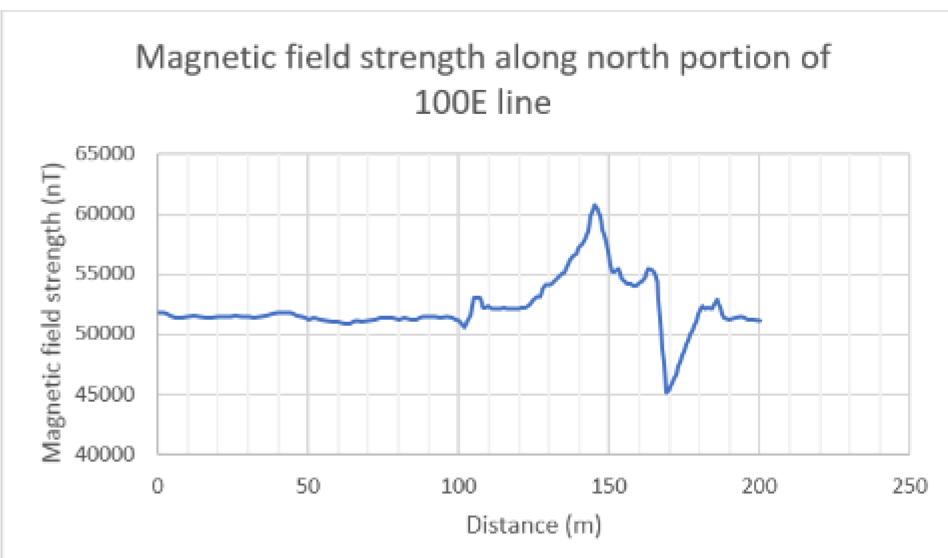

Figure 6: magnetic field strength data collected using the fluxgate magnetometer along the north portion of the 100E line. An anomaly is seen at the 145-175m mark (credit:Vanderhoeff).

The magnetic field data from figure 8 was collected and processed in a previous year. Even so, this data shows that there is an anomaly at about the 150m mark from the road along 100E, confirming the fluxgate magnetometer survey. Figure 8 shows that there are magnetic field anomalies striking NW-SE along the southern portions of the lines. These magnetic anomalies range in strength from about 54850nT-68890nT.

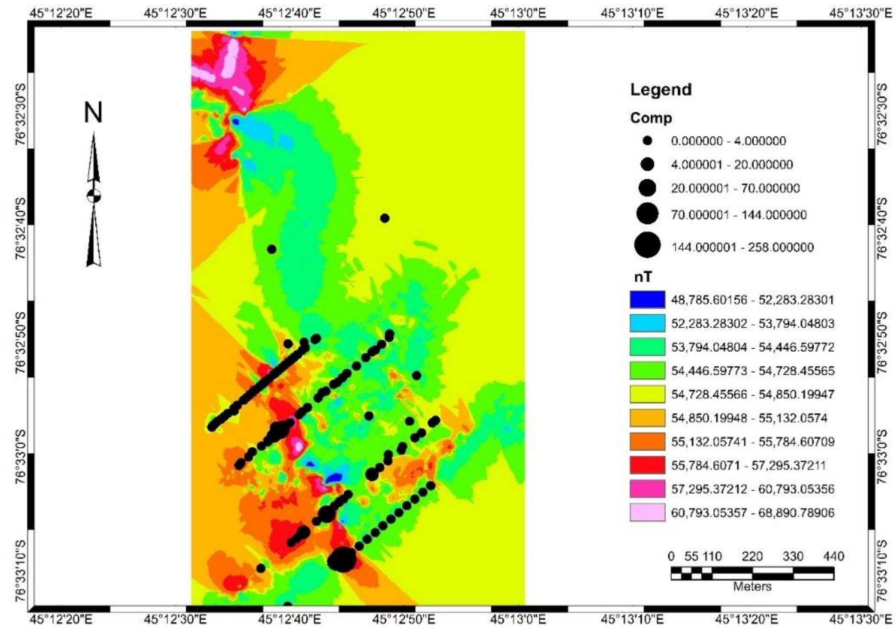

Figure 7: Magnetic field strength data collected at the Calabogie site in a previous year. The magnetic anomalies appear in red, orange and pink (credit: previous years field school).

Figure 9, which is the magnetic field strength data collected using the PPM magnetometer, shows the same trend in the magnetic field strength data as figure 6 does. It again shows magnetic anomalies located along the southern portions of the pre-cut lines striking NW-SE.

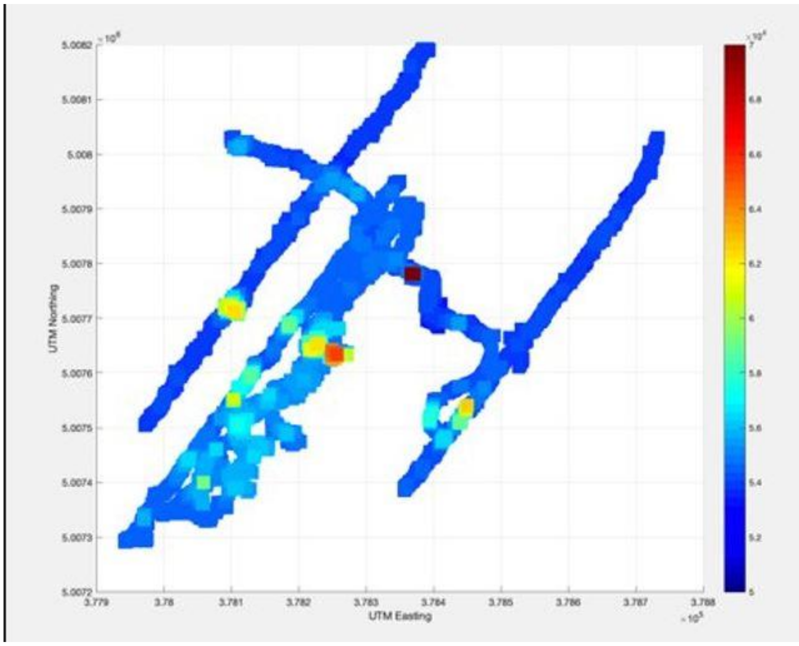

Figure 8: Magnetic field data at the Calabogie site. The yellow, green and red show areas where high magnetic field strength values were detected (credit: open source).

EM methods allows us the measure the electrical conductivity of the subsurface (Pratt & Smith). Many of the rocks containing high concentrations of metallic minerals display high levels of magnetic susceptibility can also good electrical conductors. Because of this, if the rock contains high concentrations of metals, we expected to see anomalies in the electrical conductivity data collected using the EM31. This is shown in the conductivity data in figure 10, where the conductivity spikes about 300m down the 200W line. This is about the location the magnetic field strength data shows an anomaly along the 200W line.

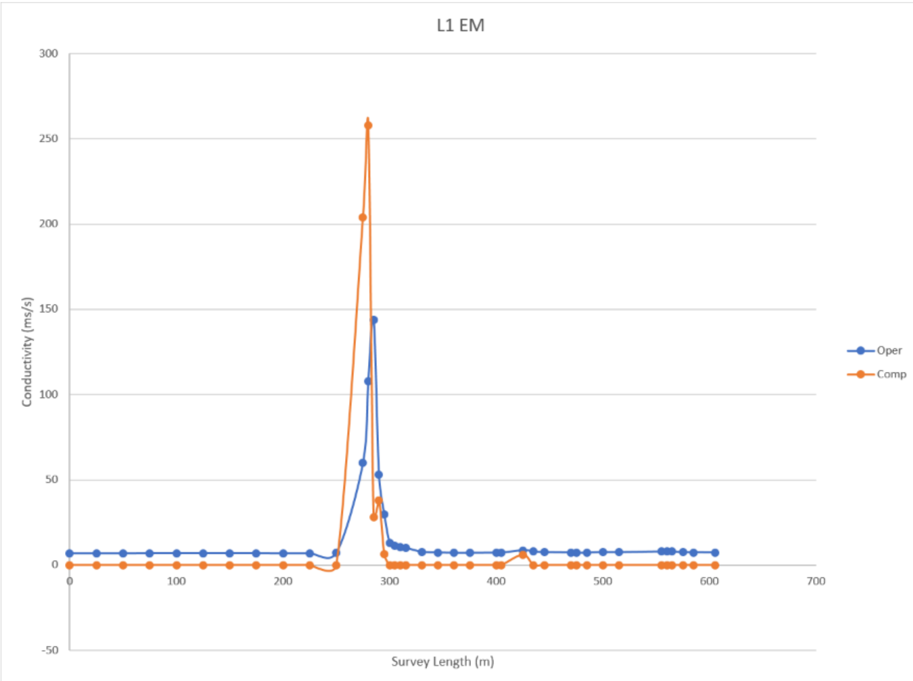

Figure 9: Conductivities measured along line 200W using EM31. The high conductivity values represent an anomaly (credit: open source).

Figure 11 shows the electrical conductivity data along the 100E line. Comparing this plot to the plot of the magnetic field strength data collected by the fluxgate magnetometer in figure 7, we see that the plots are in very good agreement with each other as to where the location of the anomaly is along the 100E line, both showing significant anomalies around the 170m mark.

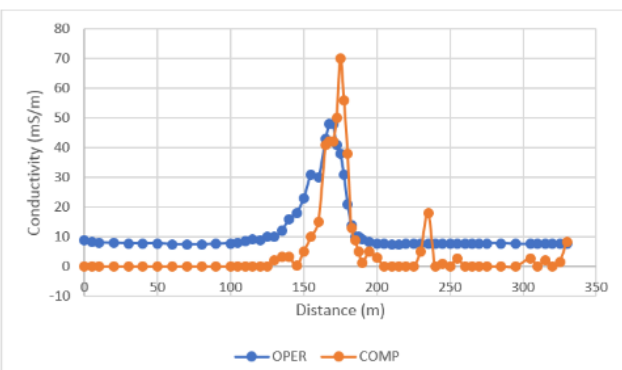

Figure 10: Conductivities measured along line 100E using EM31 (credit: Meredith and Caroline).

Figure 12 shows the electrical conductivity along the 100W line. This data shows several small increases along with larger increases. This could be due to small local intrusions or large rocks underneath the EM31 that have high concentrations of metal. Because of this, the data in figure 10 is not reliable.

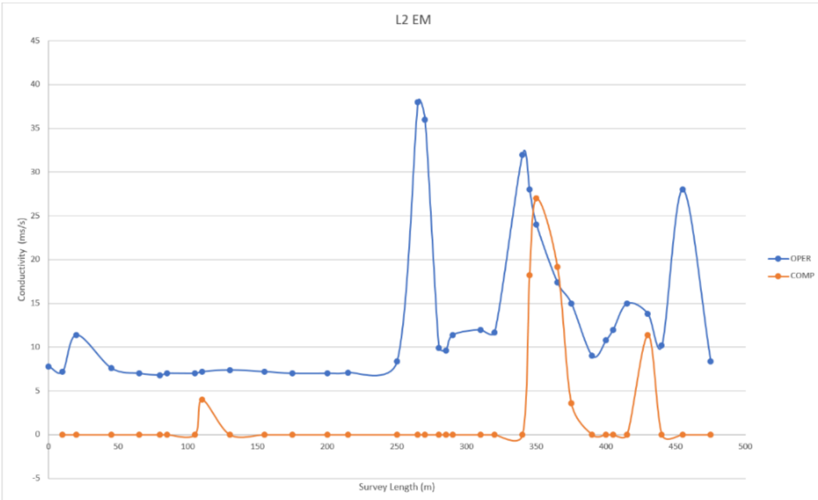

Figure 11: Conductivities along the 100W line measured using EM31 (credit: open source).

Figure 13 is a plot of the electrical conductivity along the 200E line. This plot shows a large increase in electrical conductivity at about the 370m mark. Besides a spike in conductivity at the beginning of the line, this data shows no other outliers and can be considered reliable.

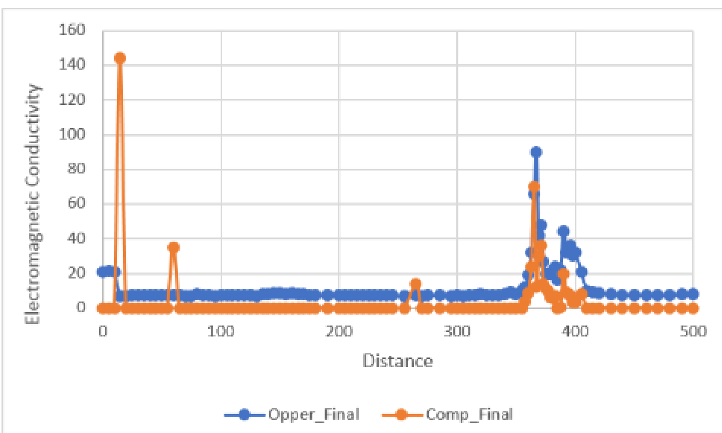

Figure 12: Conductivities along the 200E line measured using EM31 (credit: Meredith and Caroline).

RES/IP surveys allow us to measure the electrical resistivity and the chargeability of the subsurface (Pratt & Smith). Using this survey method, the measured and calculated pseudo sections as well as an inversion are shown in figure 14 and figure 15 along the 100E and 200E lines respectively. Figure 14 shows a high chargeability for the rock at about the 160m mark along the survey line. This lines up with approximately the same area the data from the fluxgate magnetometer found an anomaly. Since a high chargeability could potentially mean there is a disseminated mineral deposit (Pratt & Smith), we can conclude there is a possibility of a mineral deposit at this location. Figure 15 shows an anomaly in chargeability, but has a very high degree of error, so the data in this figure is unreliable.

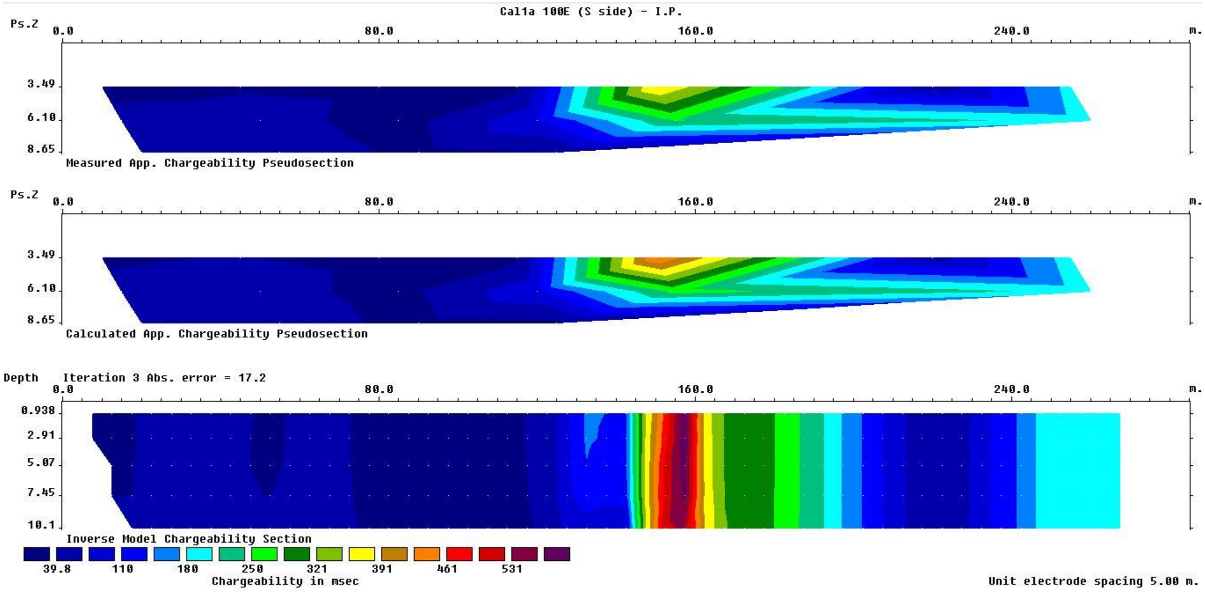

Figure 14: Measured and calculated pseudo sections and an inversion of the chargeability along the 100E line (credit: open source).

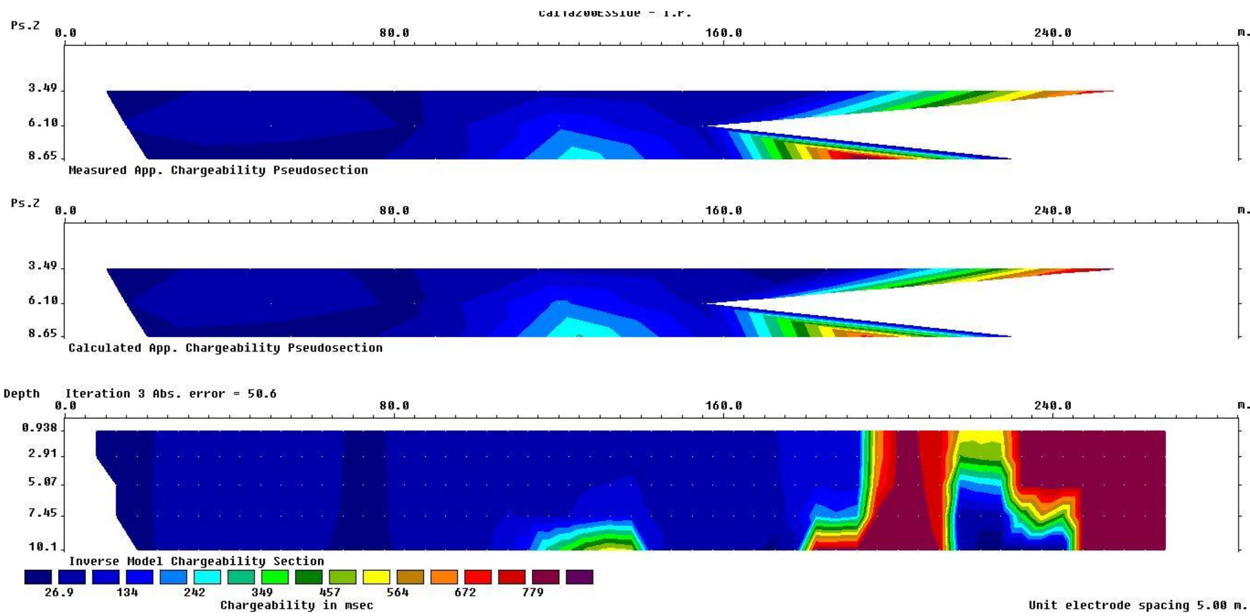

Figure 13: Measured and calculated pseudo sections and an inversion of the chargeability along the 200E line (credit: open source).

Figure 16 shows a pseudo section for the measured and calculated resistivity, along with an inversion of the subsurface resistivity for the 100E line. The inversion in figure 16 shows an anomaly in a similar location to the anomaly for the chargeability in figure 14 is. This tells us that the anomaly located in figure 16 could potentially be a disseminated deposit of metallic minerals, since the chargeability is high in the area and the resistivity is low.

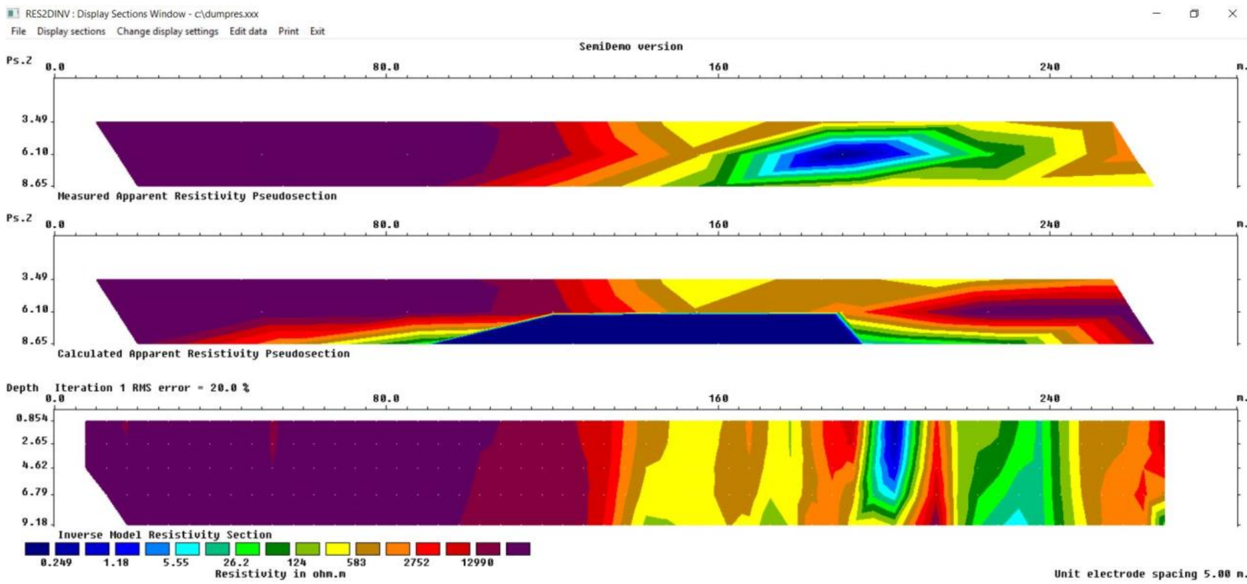

Figure 14: Measured and calculated pseudo sections and an inversion of the resistivity along the 100E line. (credit: Vanhuevelen and Norenberg).

Figure 17 is a plot of the UTEM survey results. This survey allows us to determine the electrical conductivity of the rock and the size and orientation of an anomaly. Since the crossover occurs in the vertical component along the baseline, this indicates a conductive plate in the area. This is approximately 10m south along line 100E and 0m along line 100W. The third subplot indicates to us the degree of dip of the anomaly. It shows us that the anomaly is dipping about 75-90°.

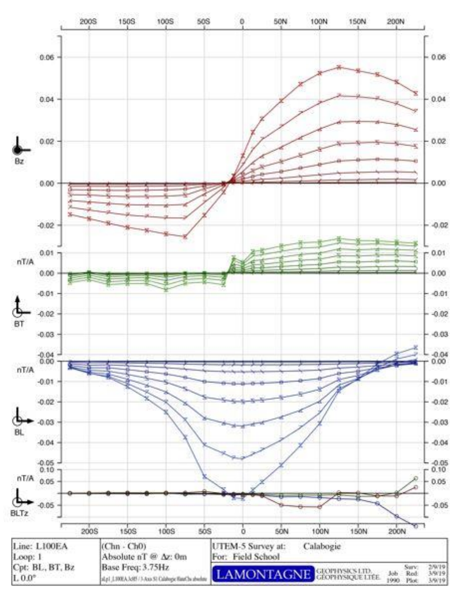

Figure 15: UTEM plot (credit: Rob)

Figure 18 shows the results of the larger RES/IP survey that was conducted along the centre line. The models created from this data show large errors and as a result, are unreliable.

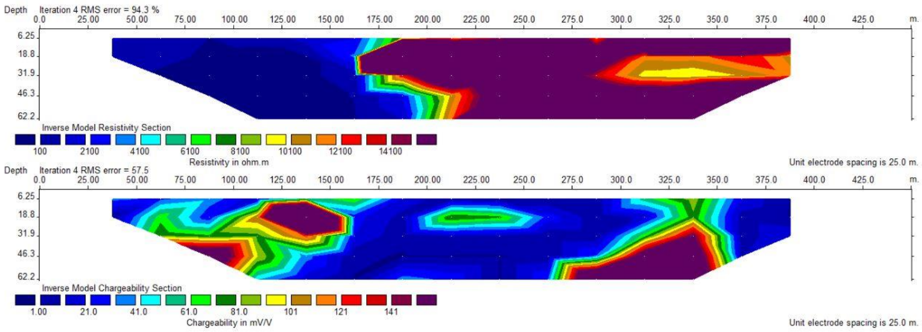

Figure 18: RES/IP survey along the centre line at the site. Large errors are found in the model and is unreliable (credit: Angelos).

Interpretation

Using the results of the data collected, we can interpret the data and determine whether our objectives for these surveys were met. The data along the 100E line all seemed to correlate and tell us that there is an anomaly located 145-180m along the line that contains a large amount of what could be metallic minerals. It could be metallic minerals at the anomaly because metallic minerals could have the high magnetic susceptibility that was shown in the magnetometer data while also having a low electrical resistivity and high conductivity that we found using the RES/IP and EM data respectively. The IP survey told us that the deposit has a high chargeability, meaning the voltage has a slow decay from the area. Disseminated mineral deposits could be one explanation for the high chargeability (Pratt & Smith). Although no RES/IP lines that created a reliable model were done on lines besides 100E and 200E, the EM and magnetometer survey data shows us that the line we saw the low electrical resistivity and high chargeability could continue along all the lines, striking NW-SE. The magnetic field strength data shown in figure 8 could show us the extent of the mineral deposit if the data follows the same trend we saw along the 100E line, where the EM, magnetic and resistivity data anomalies were in the same area. Because of the other evidence pointing towards high metal concentrations in the subsurface at that location, we conclude that there could be some sort of mineral deposit in the area that could be potentially economically feasible to mine depending on the exact extent.

Conclusions/recommendations

Using survey methods outlined in the geophysical survey methods section, a geophysical survey was conducted in the Calabogie area over 2 days. The data collected gives us an indication that there may be a mineral deposit in the area, located in the southern section of the pre-cut lines. This deposit strikes NW-SE and could potentially span 500m (the total distance spanning the lines laterally). Due to the time limitations of the surveys conducted, the whole area could not be surveyed as thoroughly as necessary using all the listed methods and as a result, the exact extent of the anomaly is unknown.

Further study must be undertaken in order to determine the extent. To do this, more magnetometer data gathered using the fluxgate magnetometer or PPM magnetometer along the entirety of the pre-cut lines would be recommended since this method is fast and proved to accurately locate anomalies in the subsurface that further surveys could more accurately image after the anomaly location is narrowed down. Collecting magnetometer data between the pre-cut lines would also be recommended, as this could tell us if the anomalies are connected or separate small, more local anomalies. Using the EM31 between these pre-cut lines would also be beneficial, as it could help to confirm the magnetometer data. The magnetic anomalies along the 100E line correlated to anomalies in electrical conductivity at the same spot along the line, so if an anomaly is shown in both datasets, the anomaly could be the same as the anomaly along 100E and be a metallic mineral deposit. This could be true for the whole area, but further surveying must be done to confirm this. More RES/IP surveys should also be conducted. The RES/IP survey, using the dipole-dipole method, created the most in-depth and accurate image of the subsurface we gathered. More RES/IP surveys should be conducted where the NW-SE striking anomaly on the magnetic field strength plot in figure 8 to confirm if they have low electrical resistivity and if they could be disseminated mineral deposits. A longer dipole – dipole array than conducted in our survey would be recommended, since we were unable to determine how deep into the subsurface the anomaly goes due to a small survey line length.

Because of limitations in time and materials, boreholes could not be drilled as part of our surveys. Drilling a borehole where the magnetic field anomalies were located would be recommended in future study, since a core of rock could then be analyzed to see the exact cause of the anomaly, as it could possibly be something besides metallic minerals creating them.

Using these recommendations and the data already collected, we believe that it would be possible to accurately determine the extent and nature of the found anomalies.

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