Performance Comparisons of Helicopter Time-Domain Systems

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Summary

Comparison data between the VTEM and AeroTEM II and between VTEM and HeliGeoTEM II systems are presented. The effects of each system's waveform and dipole moment in the data are shown and compared. B-field data at 30 Hz is shown to be able to resolve higher conductance targets than on-time 150 Hz data. A symmetrical system produces data which can be interpreted easier. Having both the transmitter and receiver closer to the ground aids in the detection of near surface and smaller conductive features.

Introduction

In the past decade, a number of helicopter towed time-domain electromagnetic systems have been developed and commercialized. They include the VTEM system from Geotech, HeliGeoTEM from Fugro, and AeroTEM (versions II, III, and IV) from Aeroquest.. These systems have different system geometries, transmitter waveforms, dipole moments for example. Direct comparison of the systems is difficult due to the lack of overlapping data in the public domain. What comparison data that does exist is often confidential to the exploration companies that sponsored the tests.

Geotech has assembled comparison data between VTEM and AeroTEM II, and AeroTEM IV, and between VTEM and HeliGeoTEM II.

AeroTEM II and VTEM System Comparison

Geotech's VTEM data over the Delta Deposit in the Raglan Belt demonstrates the advantages of using a low base frequency and calculated B-Field in the search of massive nickel sulphides and other excellent conductors.

The Delta Deposit is located in the Raglan Belt in Northern Quebec where Xstrata Nickel has operating mines and where Canadian Royalties is planning to put their Nunvavik Nickel Project into production.

The Delta Deposit consists of three bodies termed D8 south, D8 north and D9 Zones. The three sulphide zones total 817,000 tons at 3.05% Ni, 1.2% Cu, 222 ppb Au, 1007 ppb Pt and 1647 ppb Pd. An additional 205,200 tons of low grade – less than 1% Ni and low PGE is also indicated as disclosed in assessment reports by Falconbridge (GM48413).

The D8 south zone is mostly disseminated with higher grade net-textured and semi-massive to massive sulphides rarely exceeding 10 feet horizontal distance. The D8 north and D9 zones consist of massive and semi-massive sulphides, some 600 metres (2000 feet) apart. The sulphides occur along a steeply dipping contact zone. Numerous faults, breccia and low grade sulphides are found throughout the contact zone. The D8 north zone dip steeply and plunge eastward at -40o to about 200 metres beneath the surface. The thickness decreases outward and down plunge into disseminated sulphides. The D9 zone is narrower than the D8 south zone and plunges nearly vertically.

Geotech overflew the Xstrata claims as part of a much larger survey in 2007 and retained the rights to the data. Previous exploration companies also overflew the same area in 2003 with the AeroTEM system and that data was released in assessment files (GM60799). This provided the opportunity to compare the systems over the same deposit. The VTEM flight lines were 50 metres apart as compared to AeroTEM's at 100 meter separation. Every other one of the VTEM lines were directly over the AeroTEM lines.

In quantitative analysis of time-domain EM systems and their conductivity aperture, it is the resolvable time constant that is of importance. The time-constant is the length of time that it takes for induced currents to decay to 1/e of their initial value. The better the conductor in terms of size and conductance, the higher the time constant. Nickel sulphides and the associated sulphides of pyrrhotite are the most conductive sulphide species. Some of the nickel sulphides in Sudbury have time-constants which are estimated to be in the 1000's of milliseconds and greater. Measuring long time constants require lower base frequencies to allow for the induced current to decay sufficiently that it is measurable. It also helps to have a low noise system so that a smaller change from decay can be measured. VTEM has arguably the industry's best signal to noise ratio, and it operates at the lowest available frequency of airborne systems at 30 Hz.

Figure 1 and 2 shows the images of the grids of an early to mid-time VTEM B-Field channel (bottom) and AeroTEM (top) from the claims which hold the Delta Deposit.

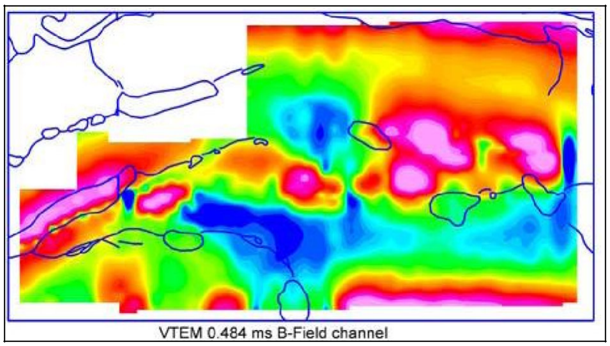

Figure 1 – VTEM's 0.484 ms B-Field channel with every other line removed for comparison with the AeroTEM data below.

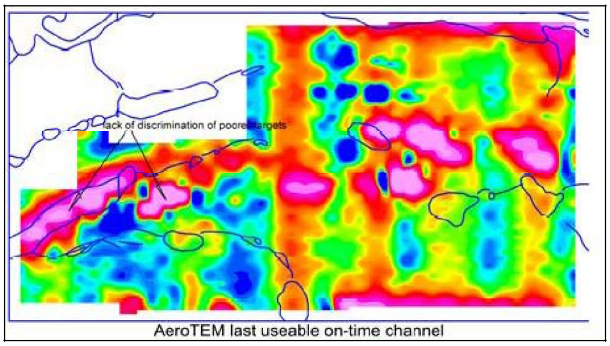

Figure 2 – AeroTEM's Zon15 on-time channel.

We immediately see that VTEM data is better leveled as evidenced by the lack of stripping in the grid caused by level shifts in the base lines values of the EM data.

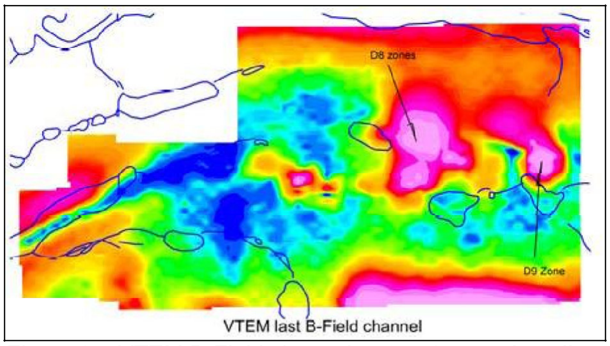

Figure 3 – VTEM B-Field channel at 6.578 ms using all the survey lines.

Figure 3 shows VTEM's last B-Field data using every line. The Delta deposits are clearly seen in all three datasets. However, due to VTEM's higher conductivity aperture, it can discriminate between the high conductance responses of the nickel sulphides and the other conductors in the survey area. The AeroTEM data has similar looking responses over the long lake to the west and other similar looking targets in the survey area. This is due to AeroTEM's much smaller conductivity aperture which causes it to "see" the moderate conductors as the same as good conductors. VTEM's early time 0.484 ms VTEM B-Field data sees these weaker responses as well, but they are not what the explorationist was targeting here. Thus the targeting of high conductance responses is vastly superior for the VTEM system.

Another example of VTEM's conductance discrimination is seen in a detailed examination of the D8 zone. Figure 4 shows 444 Hz MaxMin II data over the zone. The amplitudes, and the inphase to quadrature ratio clearly shows that the conductor is weaker near the lake and that the better target is about 6 lines to the east where the D8 zone is.

Figure 4 – 444 Hz MaxMin survey over the D8 zone (data from assessment file: GM34807).

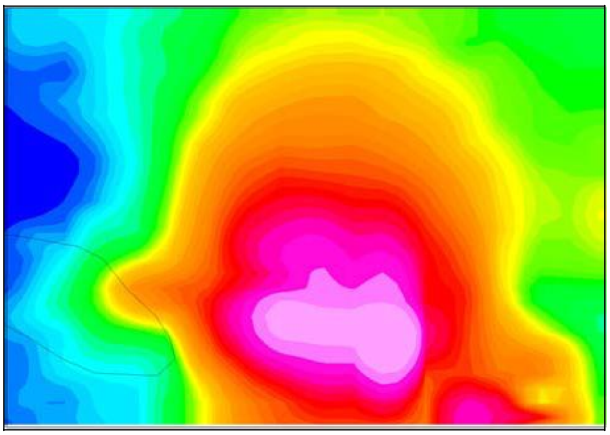

Figure 5 - VTEM B-Field channel at 6.578 ms over the same area as Figure 4. Note the better late time response some 200 metres east of the lake corresponding to the D8 Zone.

The VTEM data of the same coverage and scale is shown in Figure 5. The VTEM data is able to show that the higher conductance related to the D8 Zone was some 200 metres to the east of the small lake, as opposed to either being on the shore of the lake. This was not resolved by the AeroTEM II data.

In a more quantitative study, we can look at the decay curves and the time constants over the D8 Deposit. The flatter the curve, the longer the time constant that we are seeing.

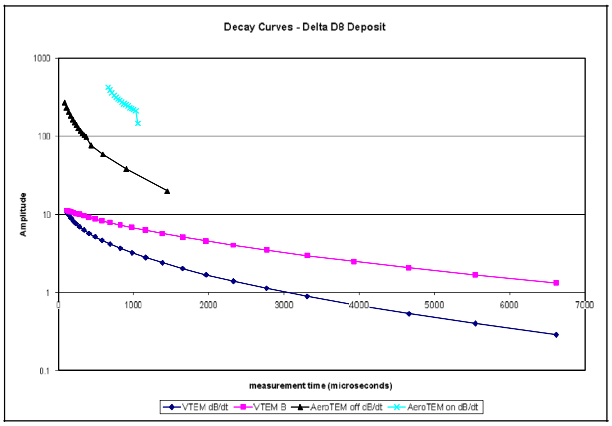

Figure 6 – plots of the amplitudes versus time of responses over the D8 deposit. AeroTEM off-times have been shifted to start at the end of the off-ramp as per normal convention.

Examination of the plots shows how much longer VTEM measures the decay of the signal. It shows that until AeroTEM runs out of time windows, that their off-time behaves much the same as VTEM. But notice that the curve flattens out as time increases, showing that the early time was only seeing weaker conductivity as opposed to the main sulphide body. The time constant that the AeroTEM off-time measured is 1.8 milliseconds as opposed to 7.7 milliseconds for VTEM off-time.

AeroTEM's on-time has been widely touted as being able to detect excellent conductors. As can be seen in Figure 6, that is not true. Their triangular waveform and short pulse causes problems in detecting excellent conductors as the response from the turn on portion of pulse cancels out a portion of the response from the turn off portion of the pulse where their on-times are located. As the entire pulse is only 1.1 milliseconds long, this cancellation effect is seen even for moderately good conductors. It gets worse for AeroTEM the better the conductor. The time constant from the on-time is 1.9 milliseconds, as opposed to the B-Field time constant of 11.5 milliseconds.

As an aside, VTEM B-Field has been able to detect and resolve targets of up to 23 milliseconds in the Fox River Sill area.

AeroTEM III

Aeroquest also operate a larger and more powerful version of their AeroTEM series of systems in the AeroTEM III. The AeroTEM III is a 10 metre transmitter loop and has a transmitter peak dipole moment of 230,000 NIA and is able to operate with a base frequency of 30 Hz.

In the summer of 2008, a comparison block of data was acquired by Geotech over the same block flown by AeroTEM III a few weeks earlier.

At the time of the writing of this extended abstract, the final AeroTEM III data was not available. The comparison will be made during the presentation.

HeliGeoTEM II and VTEM System Comparison

A comparison of actual survey data from VTEM and HeliGeoTEM over the Archean Shield of Canada is presented. Both data sets were flown in the spring of 2008.

System Comparison- overview

	VTEM	**HeliGeoTEM**
Dipole Moment	Maximum: 625 000 NIA Typical: 400 000 NIA	Maximum: 750 000 NIA
Geometry	Symmetrical in-loop	Asymmetric out-of-loop
Receiver coils	Z-axis (X and Y axis as beta versions by request)	X, Y and Z-Axis
Current Pulse Shape	Polygonal	Half-sine (Input-like)
Current Pulse Width	7.4 milliseconds	4 milliseconds
Transmitter ground Clearance	30 meters	30 meters
Receiver ground Clearance	30 meters	70 meters (40 metres above transmitter)
Magnetometer ground Clearance	50 metres	80 metres
Sampling rate	10 Hz	4 Hz
Base Frequency	30 or 25 Hz	30 or 25 Hz

Table 1 – system comparison

Table 1 shows the system comparison. Only in the case of the multiple receiver orientations, does HeliGeoTEM hold the advantage. We argue that due to their poor geometry, that they require all three receiver components to resolve the target geometry. In all other parameters VTEM hold the advantage or is more or less the same.

Symmetry

Part of the success of VTEM is its symmetric response. Having a symmetric response allows for rapid and accurate conductor location picks and interpretation of dips based on simple rules of thumbs. Also, contouring the EM response at any channel will yield images which can be interpreted with ease.

But the most important advantage of a symmetrical system is that the conductor picks are located sufficiently well that they can be drilled directly, without the use of ground geophysics to confirm the targets. This may not be the case with HeliGeoTEM.

Figure 7 shows the same anomaly as measured by HeliGeoTEM and VTEM. Close examination of the responses shows that there isn't a characteristic point on the HeliGeoTEM response that one can use to find the conductors. There is a 30 meter difference between the cross-over in the x-coil, and the local minimum in the z-coil. VTEM has a sharp local minimum directly over the plate-like response allowing for ease of interpretation and confidence in directly drilling VTEM targets without having to conduct ground geophysics to better locate the conductor.

EM Receiver and magnetometer ground clearance

HeliGeoTEM's receiver is 40 metres higher than the transmitter coils. This significantly reduces the amplitude from outcropping or subcropping conductors. It may even lead to small conductors being missed. Figure 8 shows a situation where VTEM picks up a small one-line conductor, whereas the HeliGeoTEM II response is barely above noise levels.

Also note that VTEM's magnetometer is 30 metres closer to the ground than HeliGeoTEM's magnetometer. The added spatial resolution of VTEM's magnetometer data is evident by inspection of the magnetometer trace (top panel) in Figures 7 and 8.

Current Pulse Shape and Length

VTEM uses a polygonal waveform as opposed to a half-sine waveform that HeliGeoTEM uses. The VTEM waveform approximates the square wave more and is more efficient. Following the method of Liu in 1998, we convolve transmitter waveform with a single exponential decay target response. This yields the effect of waveform shape from which we can add the effect of dipole moment and pulse width. The waveforms are presented as a function of pulse width divided by target time constant (Δ/τ).

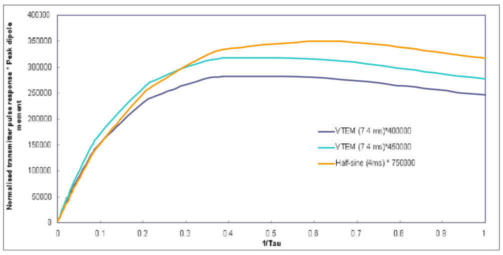

Figure 9: Comparison of VTEM and HeliGeoTEM responses taking into account pulse shape. 1/Tau = 0 is an infinite conductor.

Figure 9 shows the effect when pulse shape and peak dipole moment is taken into account. We note that for VTEM at 450,000 NIA (a fairly standard dipole moment for VTEM), that VTEM outperforms HeliGeoTEM II for the better conductors which are the targets of interest in base metal exploration.

Data Comparison

Showing data yields a good visual estimate of the signal to noise ratio. Figure 10 shows HeliGeoTEM data and Figure 11 shows VTEM data over the essentially the same line.

Conclusion

VTEM's longer transmitted pulse, lower noise and higher power is better suited to airborne EM exploration. In particular, the higher conductivity aperture allows for better discrimination of the excellent conductive targets from, say, unwanted lake bottom/overburden or weakly mineralized areas. The VTEM data, both off and B-field, were able to resolve higher conductance targets than the on-time of AeroTEM II.

Systems with a symmetric response produce data that is easier to interpret. The images generated from grids of the EM channels are free of herringbone effects and there are diagnostic portions of the system response which can be used to locate the anomalous responses. Also, having the transmitter and receiver as close to the ground as possible yields better results for near surface and smaller targets.

The peak dipole moment may be a misleading parameter. Other important factors include transmitted pulse length, pulse shape have to be taken into account to compare transmitter performance.

The receiver performance is often overlooked in system comparisons. But it is as important as the transmitter in determining signal-to-noise of the system.

Acknowledgements

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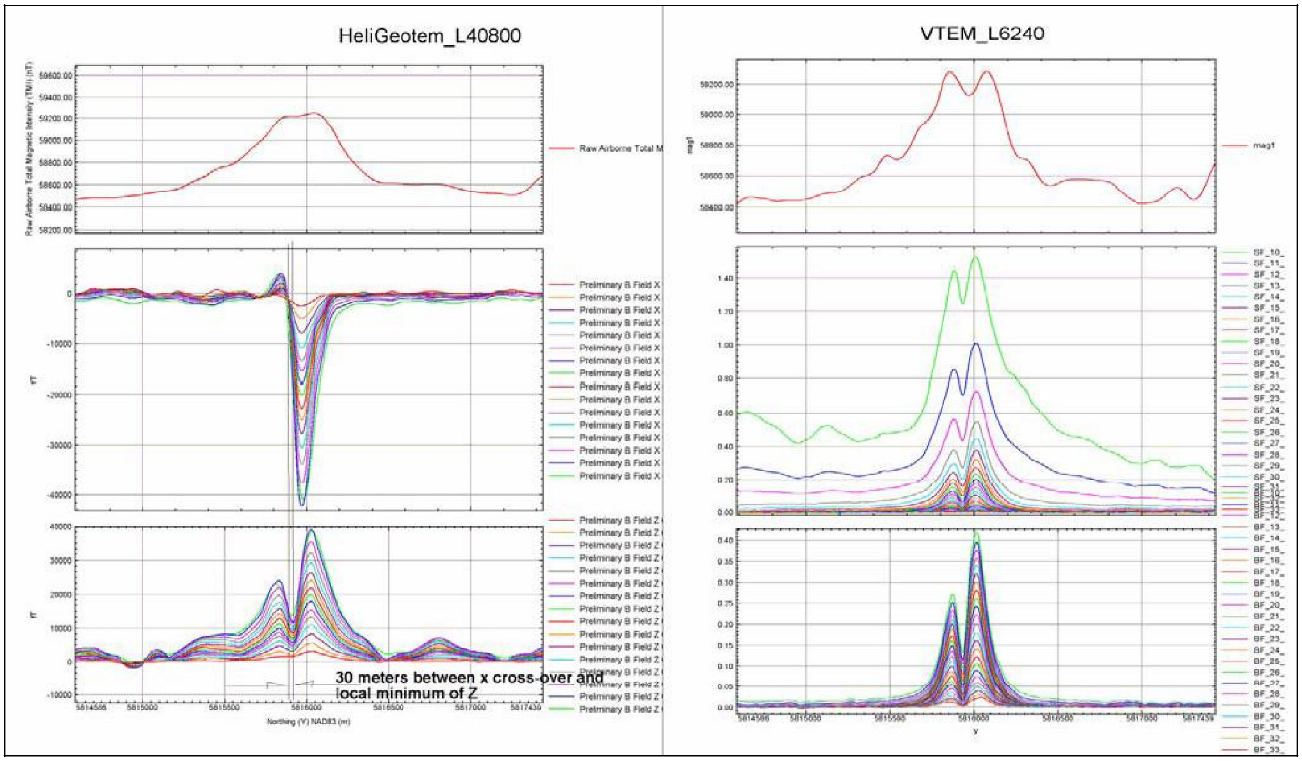

Figure 7: comparison of HeliGeoTEM and VTEM over the same anomaly.

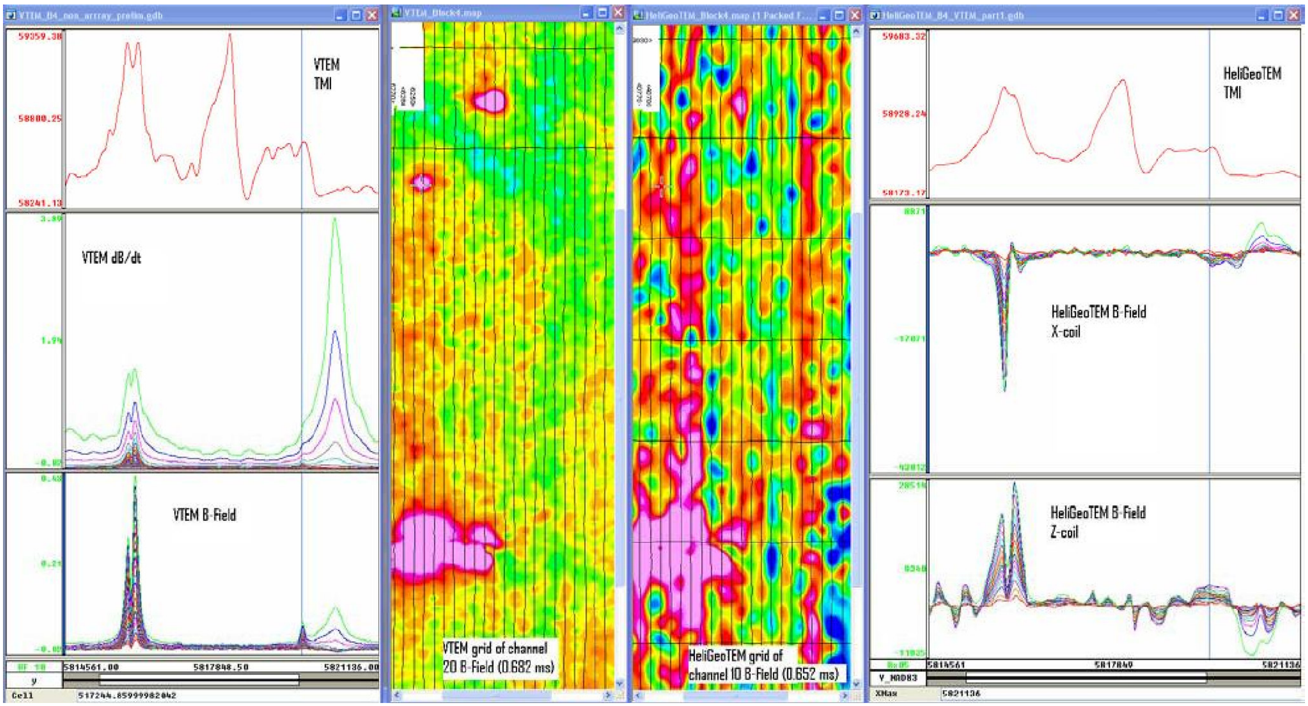

Figure 8: VTEM and HeliGeoTEM responses over a small near surface response.

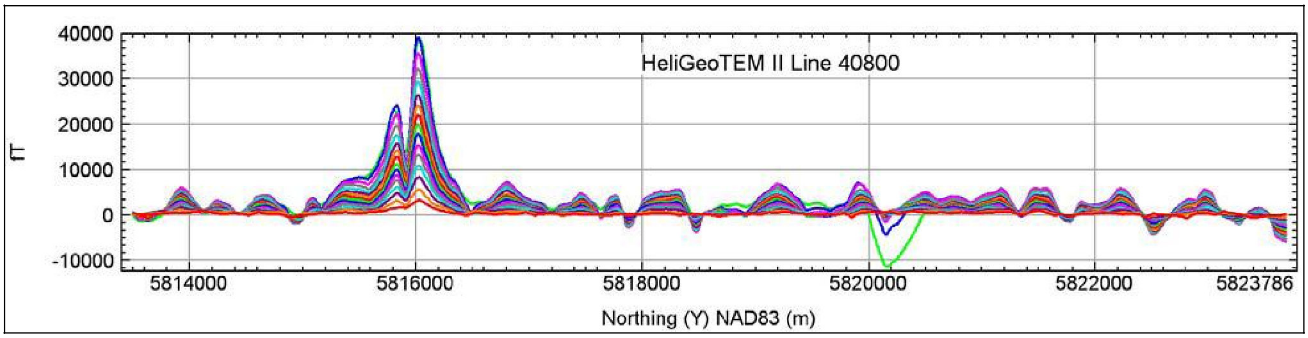

Figure 10– HeliGeoTEM II, Z-coil, B-Field, Line 40800

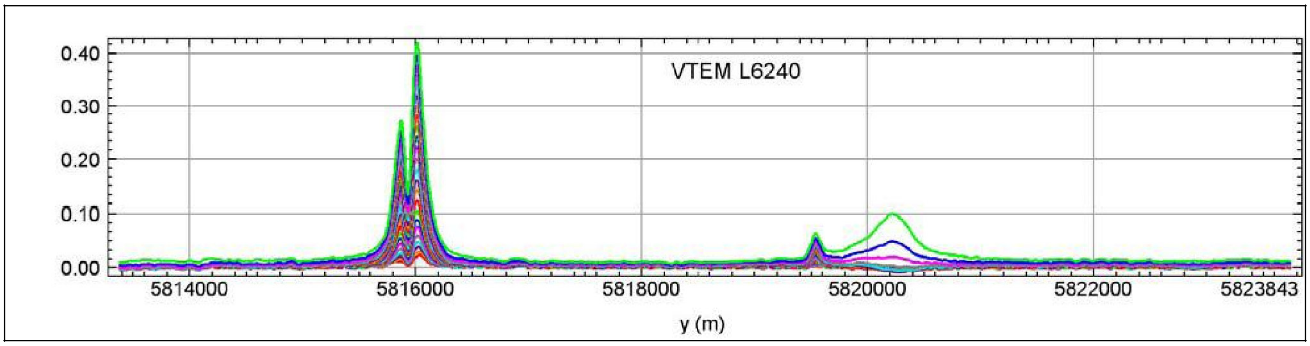

Figure 11 – VTEM, B-Field, Line 6240