Sub-Phanerozoic Geophysics in the Flin Flon – Snow Lake Belt Manitoba and Saskatchewan

EMinar

Presented by Bob Lo

May 2023

Outline of talk

- Brief section on Flin Flon – Snow Lake Belt and mines
- Case History – Reed Mine
- Case History – McIlvenna Bay
- Closing remarks

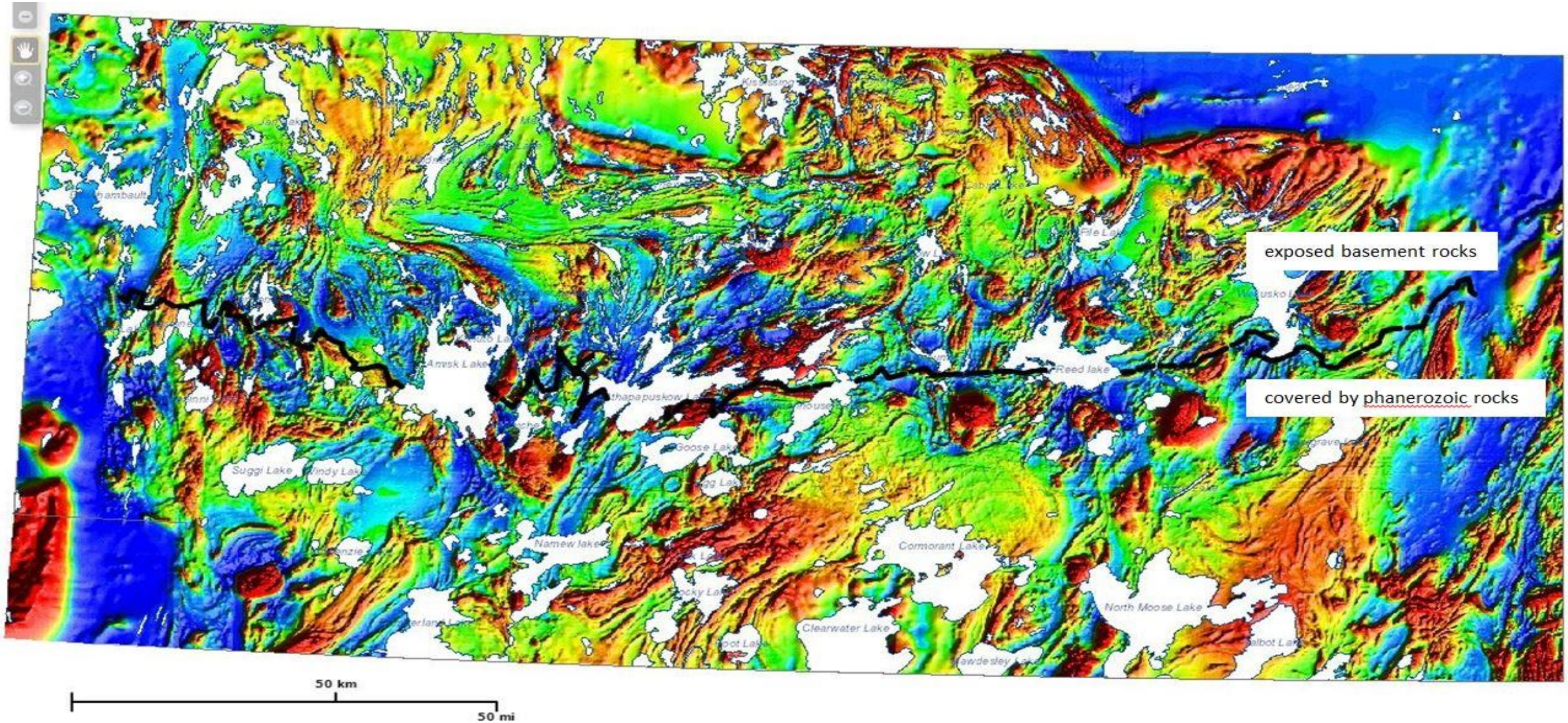
General location and background

FLIN FLON – SNOW LAKE PROTEROZOIC VMS BELT

Flin Flon – Snow Lake Proterozoic VMS Belt

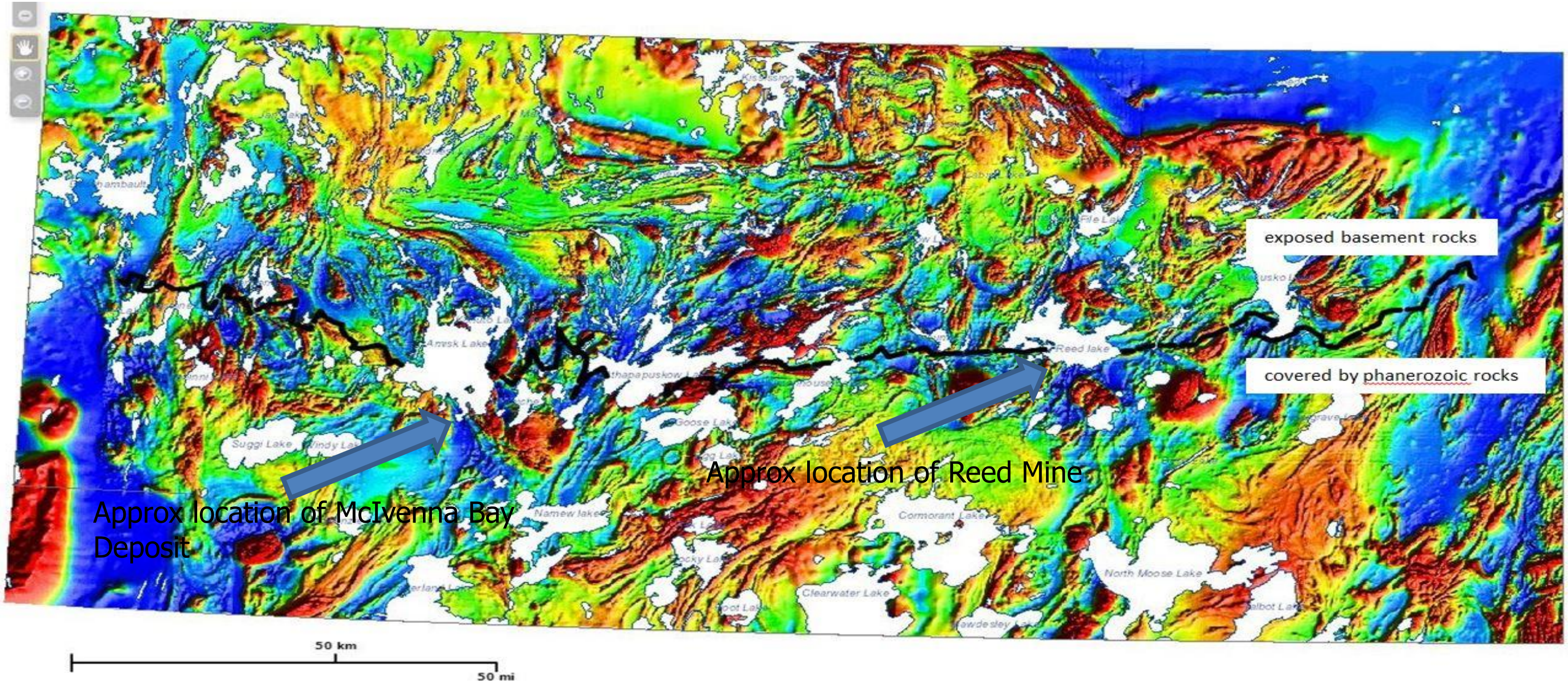
- The Flin Flon – Snow Lake Proterozoic VMS Belt is one of the most prolific VMS Belts in the world. It hosts over 400 million tonnes of sulphide ore from 27 copper-zinc mines (Gibson et al, 2013). Most of these mines are in the exposed portions of the belt which is approximately 250 km long and 75 km wide. The two most recent mines found in the belt are the Reed Mine (discovered by VMS Ventures) and the Lalor Mine (discovered by Hudbay), both in 2007 and both operated by Hudbay. Reed Mine is now mined out.

Flin Flon – Snow Lake VMS Belt



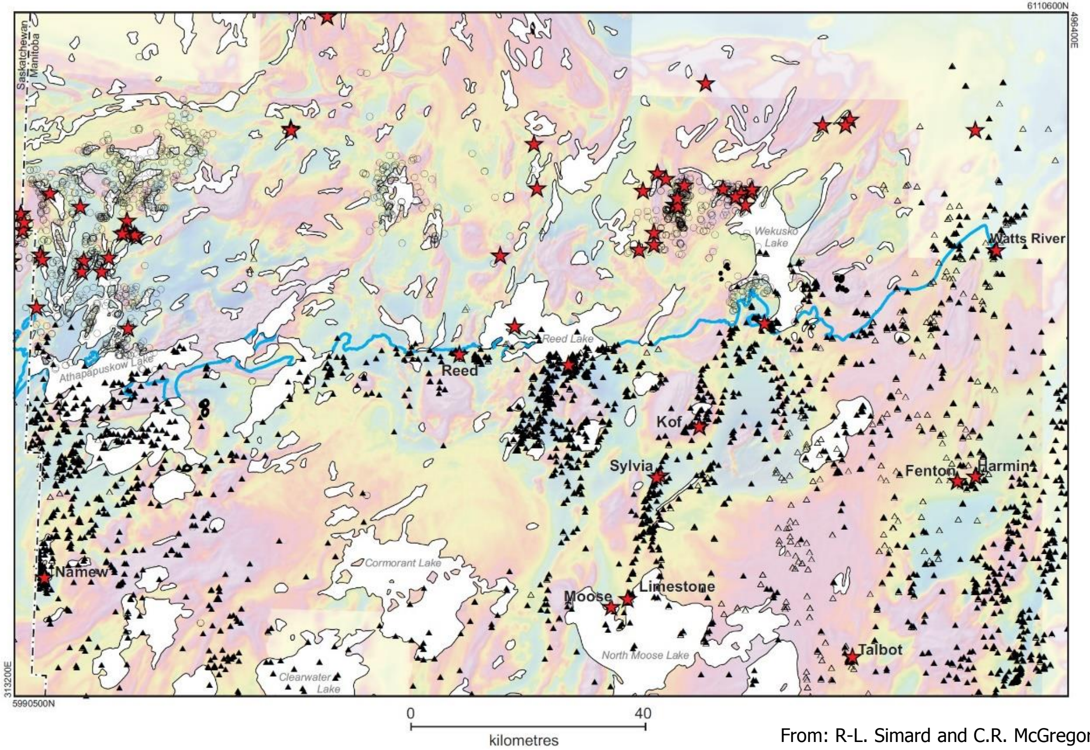
Aeromagnetic data of the Flin Flon –Snow Lake Belt. The Paleozoic boundary is drawn in a thick black line. (After: Manitoba Mineral Resources 2013: Natmap Shield Margin Project, Manitoba. The Flin Flon – Snow Lake Belt, located in Manitoba and Saskatchewan, is in the juvenile internal zone, of the Trans-Hudson Orogen. It consists of Paleoproterozoic volcanic, plutonic and minor sedimentary rocks. The areal extent of the exposed portion of the belt is approximately 250 km East-West X 75 km North-South. It is in tectonic contact with the gneissic Kisseynew Domain to the north, and is unconformably overlain by Ordovician aged dolomite to the south.

Flin Flon – Snow Lake VMS Belt



Beneath the Phanerozoic cover, without the crystalline bedrock host being exposed, geophysical methods played the crucial first step in detecting the mineral deposits. The VMS deposits of the Flin Flon – Snow Lake Belt are conductive and, in most cases magnetic, making them ideal targets for airborne electromagnetic and magnetic surveys.

Locations of mineralized zones - Manitoba



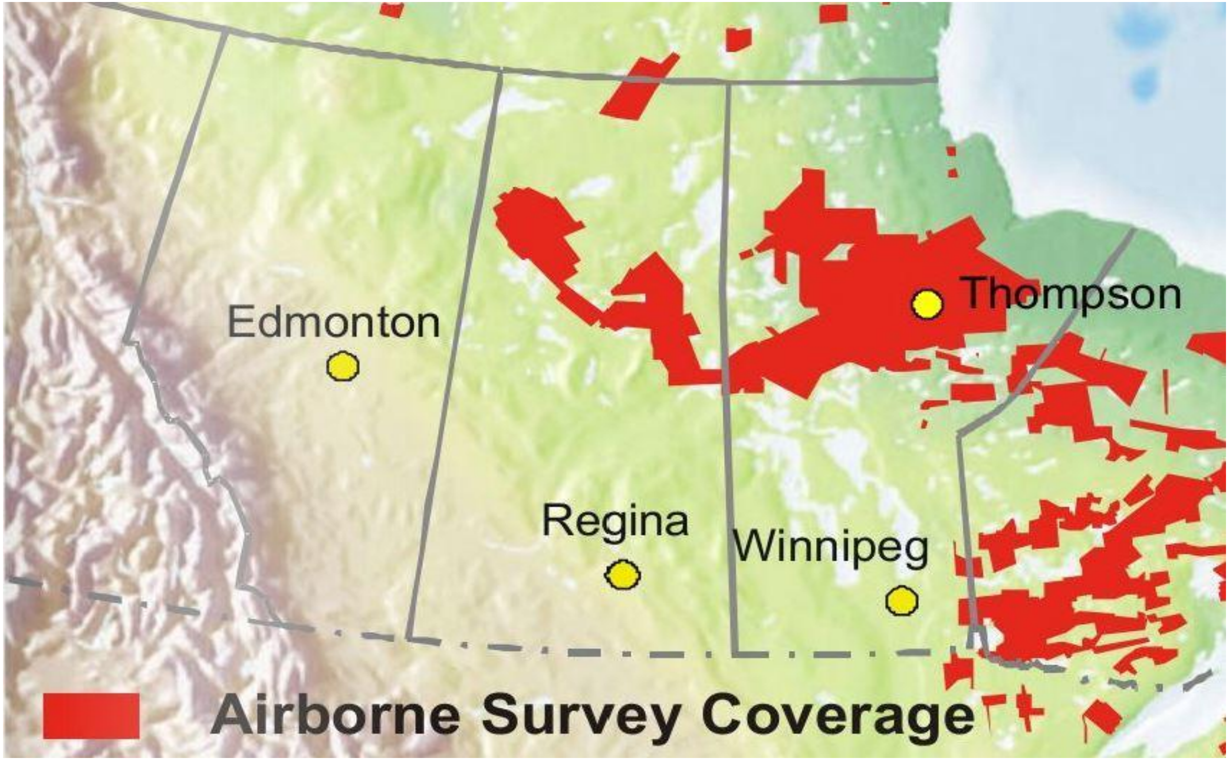
From: R-L. Simard and C.R. McGregor, 2009

Blue line is the limit of the Phanerozoic cover. Red stars show the locations of various ore/mineral deposits in the Flin Flon Belt (only the sub-Phanerozoic deposits are labelled for clarity).

Early stage geophysics

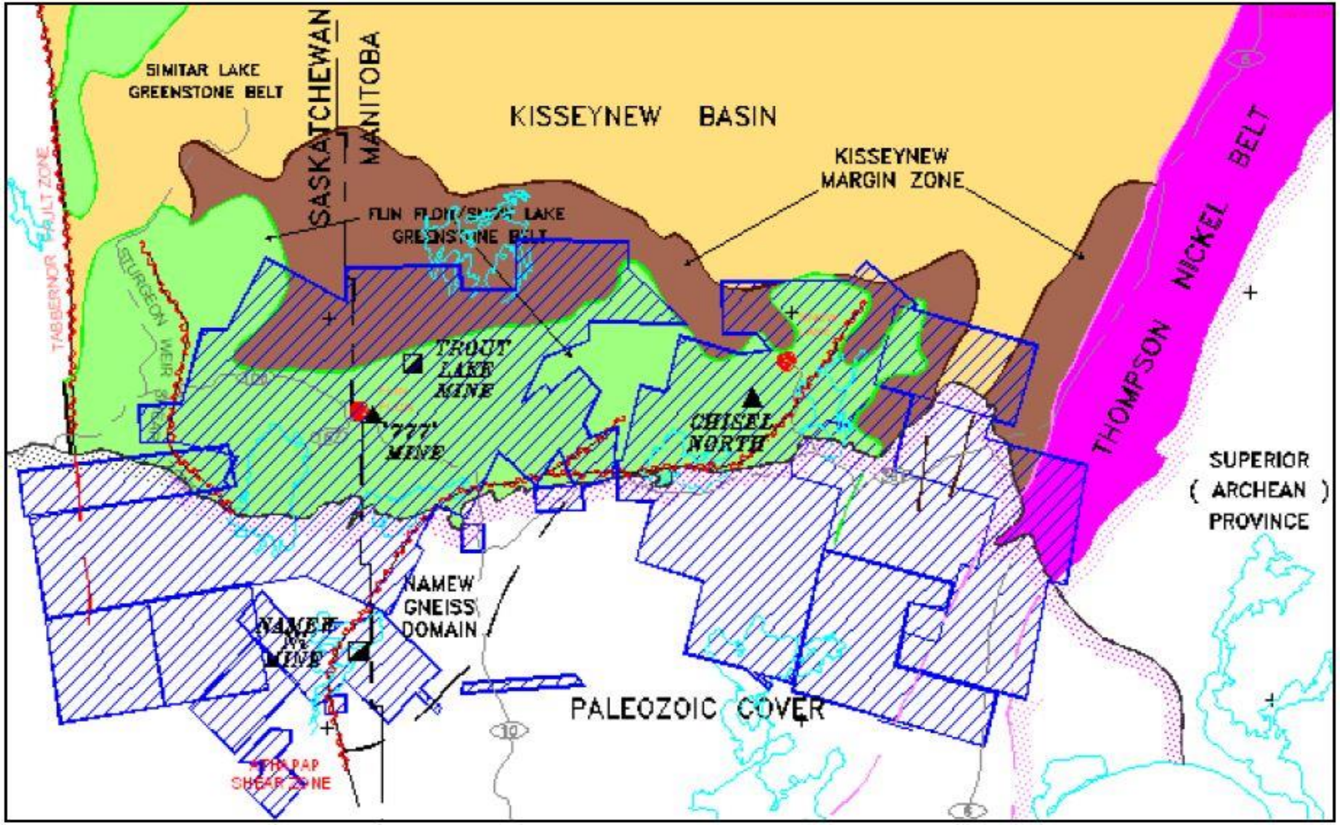
- In general, the land packages in the sub-Phanerozoic are large, and airborne EM methods have played an important first step in the exploration process, after land position has been decided. From the aeromagnetic maps, say, those published by the GSC, the various areas which had magnetic patterns suggestive of volcanic flows were initially targeted. Now, with more drill holes into the basement and additional geophysical information from previous explorers in certain areas, geological criteria has a greater input into ground selection. However, some of the very large airborne surveys, especially in the earlier days of airborne EM, suggests that a more blanket approach to exploration beneath the Phanerozoic, in which large areas are flown, evaluated, then the land positions obtained, is the norm.

INCO AEM coverage



Inco's proprietary AEM coverage over Flin Flin-Snow Lake area (from Bengert, 2002).

HudBay Spectrem coverage

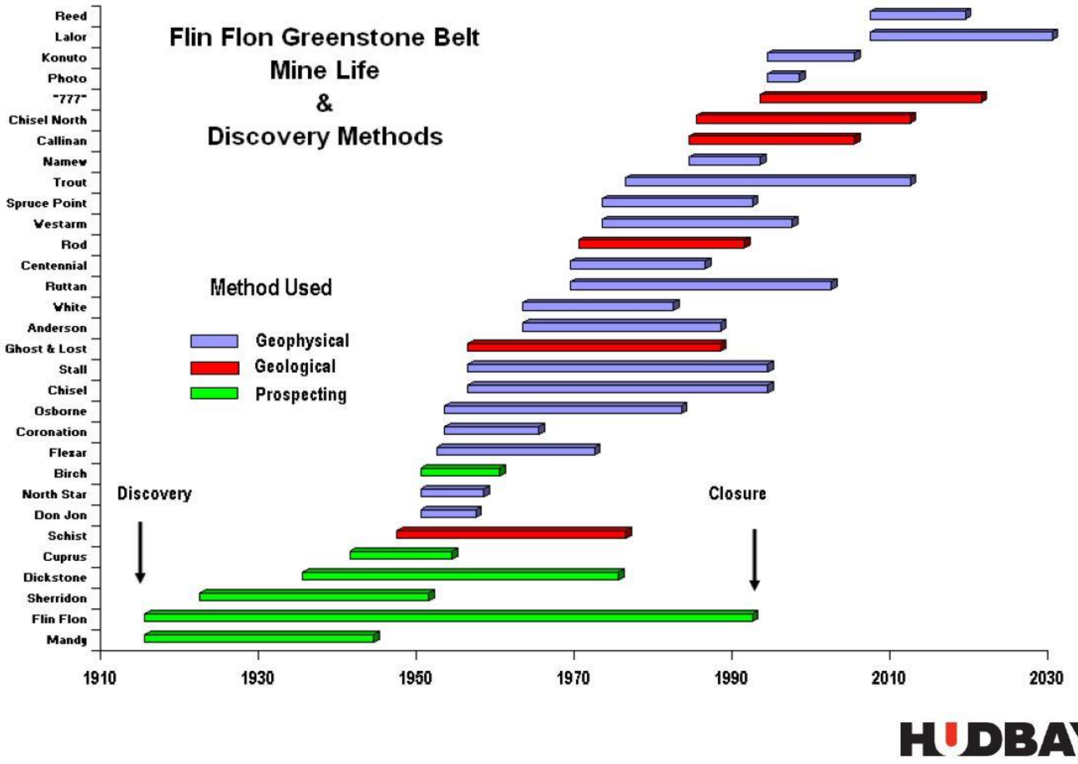


Hudbay's Spectrem airborne survey coverage (from Gilmore and Wood, 2012).

Previous Discoveries beneath the Phanerozoic cover

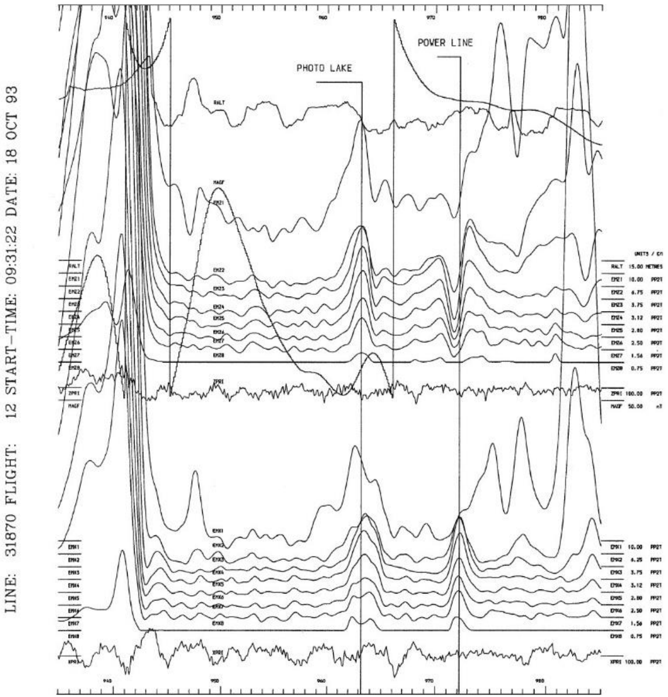
Prior to the Reed Mine, only two other mines, Spruce Point Mine discovered in 1972, and Namew Lake Mine discovered in 1984, both by Hudson's Bay Mining and Smelting (Hudbay), were discovered beneath the Phanerozoic cover. The Namew Lake Mine produced 2.6 million tonnes of 0.9% Cu and 2.44% Ni from 1988 to 1993 (Nickel in Manitoba, 2018). It was found by Hudbay's proprietary in-house airborne electromagnetic system with ground geophysics follow-up and diamond core drilling. Spruce Point Mine (1.593 million tonnes of 2.35% Cu and 2.185 Zn produced – Bamburak, 1990) was an airborne electromagnetic (AEM) INPUT (Baringer, 1962) anomaly, followed by ground EM follow-up prior to drill testing.

Flin Flon – Snow Lake Mines



Discovery, production and method of discovery of Flin Flon – Snow Lake Mines (from Gilmore and Wood, 2012). Chisel North was a BHEM discovery – so maybe a purple bar – M. Holden, personal comms)

Spectrem flight line over Photo Lake



From Leggatt et al, Geophysics, 2000

Image downloaded from Mining Weekly

Photo Lake was not beneath the Phanerozoic, but beneath a lake. 1993 Spectrem Air survey – Z component upper profiles, X component lower profiles (different scales were used for each channel). The Photo Lake deposit should have been detected in all of the previous airborne EM surveys which flew over it, due to its high conductivity and relatively near surface location. It was covered by a lake of almost the same size as the surface expression of the ore body, and there is always the suspicion that the EM responses over lakes are due to conductive lake bottom sediments and possibly due to the lake water (which under certain conditions can be conductive).

Geophysical data

- From assessment files, very old to fairly recent airborne EM responses of two sub-Phanerozoic cover massive sulphide deposits can be found.
- Reed Lake Mine was flown with INPut and Spectrem prior to 2007. It was flown in 2007 and again in 2008 with VTEM (Manitoba Assessment Reports: 74580, 74793)
- McIlvenna Bay was flown in 1977 with Aerodat (Saskatchewan Mineral Assessment Report #63L10-0076). and again in 1986 with helicopter INPut (Saskatchewan Mineral Assessment Report #63L10-0092).

A story of near misses.

REED MINE CASE

Reed Mine Deposit

The Reed Lake Mine is located some 80 km from Flin Flon, just off of Provincial Highway 39. The published resource estimate is 2,550,000 tonnes of 4.52% Cu, 0.91% Zn, 0.64 g/t Au and 7.86 g/t Ag of indicated resource and 170,000 tonnes of 4.26% Cu, 0.52% Zn, 0.38 % Au/t and 4.55 g/t Ag inferred resource (Allen and Carter, 2011).

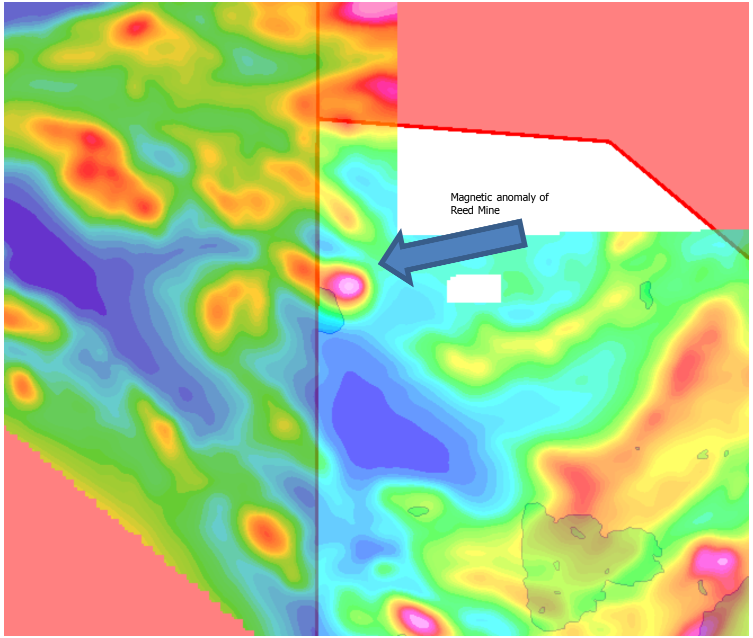
The sulphides are contained and underlain by weak to moderately altered felsic volcanic rocks. A fine- to medium-grained gabbro intrudes the sequence locally (Fedikow, 2009). The Proterozoic basement is overlain by 3 to 7 m of overburden, 15 to 20 m of dolomitic sandstone and 1 to 2 m of semi-consolidated to consolidated quartz-rich sandstone. The top 5 to 25 m of the basement rocks are deeply weathered (Allen and Carter, 2011).

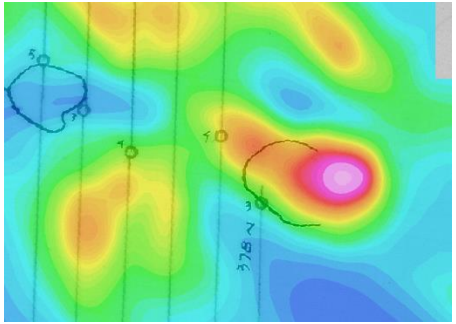
The mineralization is described by Allen et al.(2011) as being generally fine- to medium-grained, disseminated to solid sulphides. The ore mineralization consists of pyrrhotite, pyrite, chalcopyrite, sphalerite and magnetite. Solid sulphides are more prevalent closer to the surface.

Reed Lake Mine – Geophysical Exploration History

The area had been explored by Freeport Canadian Exploration Company Canada and by Hudson’s Bay Mining and Exploration (Manitoba Assessment Work Report #99449). The nearby Spruce Point Deposit, some 15 km to the east, was discovered in 1972. Freeport Canadian Exploration Company commissioned an airborne geophysical survey by Questor in 1972 and staked ground in the area. Drilling by Freeport identified a small VMS type deposit that is known as the ‘Highway Zone’.

Hudbay's Hunting's 1968 survey – First near miss

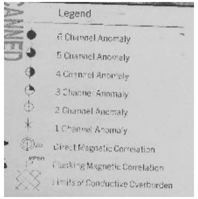


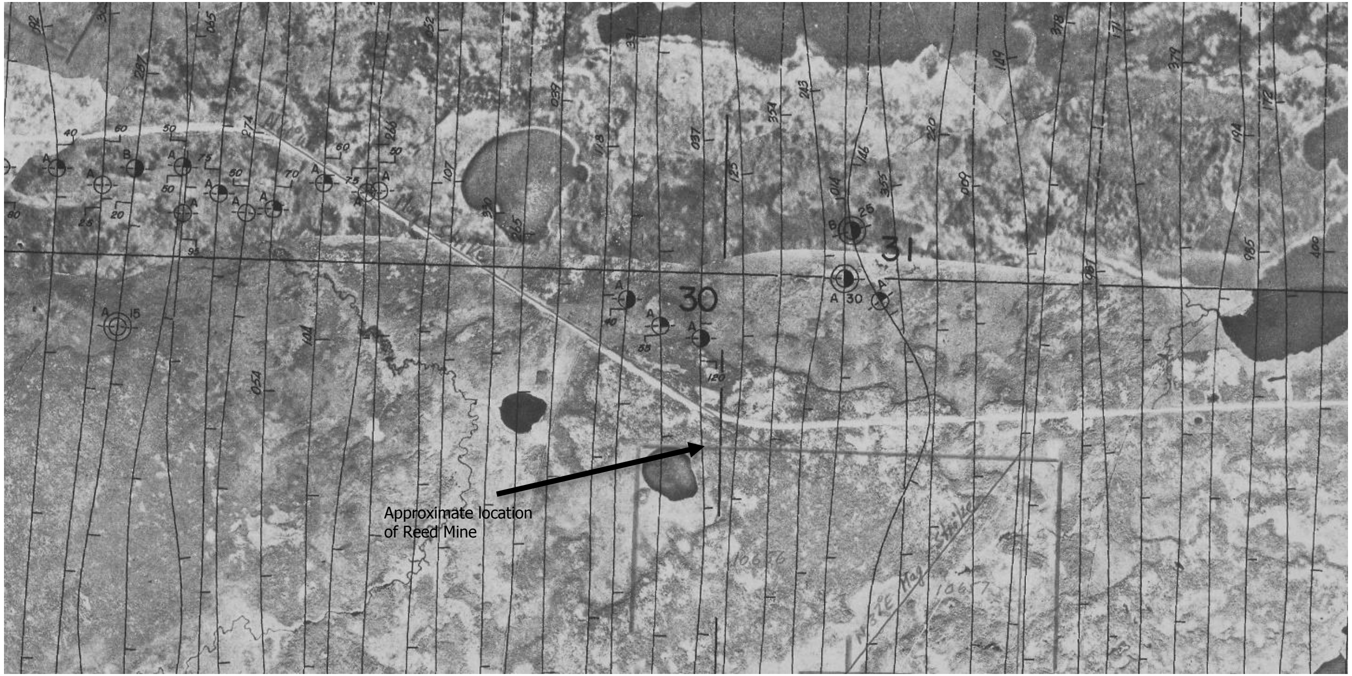


Close up of magnetic anomaly of Reed Mine and
Hunting's survey lines. Flight lines of the Hunting EM system with fids -
not a perfect georeference but close enough to show no coverage.

Spruce point was identified on the 1968 Hunting system EM maps but looks like it wasn't followed up until it was detected by Freeport's 1972 INPUT survey. The red outlines below show the coverage of the Hunting EM system (Assessment file 99449) with the VTEM magnetics, just missed the Reed Lake deposit in 1968 & 1970.

InPUT survey over Reed Mine (1972)





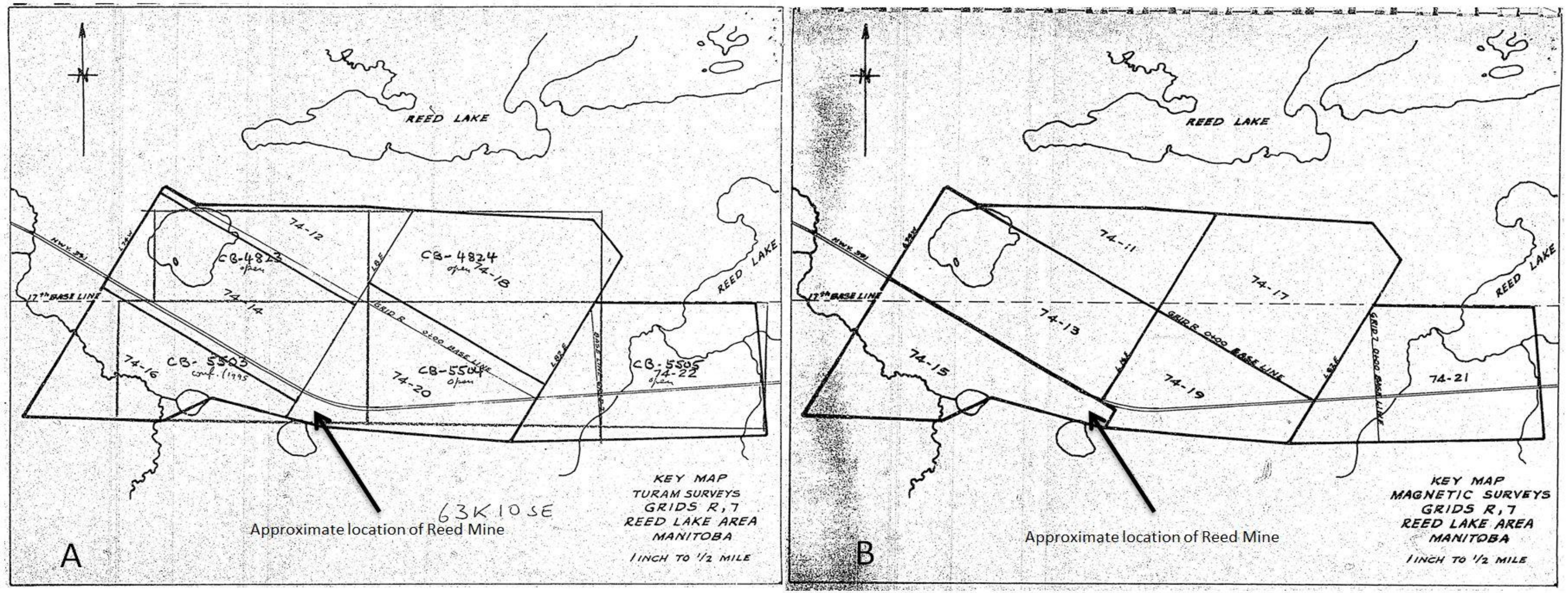
Part of EM anomaly sheet on photomosaics from INPUT survey over the Reed Mine Deposit (rescanned Manitoba Assessment Work Report #99449 copy, curtesy of Hudbay). A circular symbol would be plotted from the strip chart recording if an EM anomaly was interpreted. Note the deviation in the flight path five lines to the east. It is caused by the pilot avoiding a communications tower in that location. Notice the interpretation of the magnetics as annotated on the map.

Ground EM (Turam) follow-up

The Reed Mine was covered by ground geophysics in 1974 of Turam EM (by Geosearch Consultants) and ground magnetometer survey that was conducted in Freeport Canadian Exploration Company's exploration of the area detected the Reed Mine Deposit. It is not known why the anomaly was not drilled by either Freeport or Hudson's Bay Mining and Exploration who took over the project area. Perhaps having map sheets at a scale of 1 inch to 200 feet made for a lot of maps, and the Turam anomaly was at bottom right corner of one map, and the corresponding magnetic anomaly was on the bottom left corner of a different map (Kelly Gilmore – retired Hudbay Chief Geologist – personal communications). The four assessment reports filed on this project by Freeport (Manitoba Assessment Work Report # 99449, 98523, 98467, and 92716) had a total of 1,400 line km of Turam and slightly more for the magnetics.

Surveying with 400 foot spaced lines and plotted at 1:2,400 scale for Turam and magnetic separately made for a lot of paper maps.

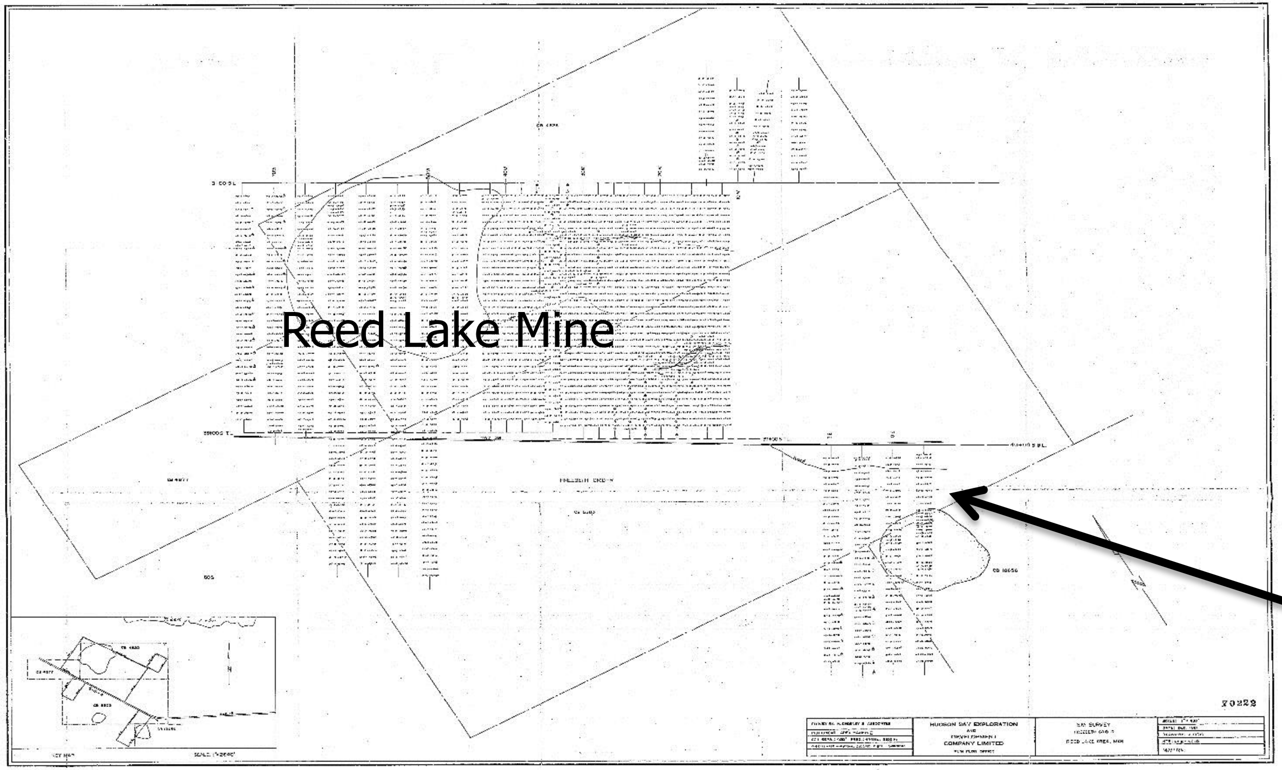
Turam and magnetics survey over Reed Area



Layout of the Turam and ground magnetometer map sheets from Freeport's 1974 ground surveys. Figure 6A shows the Turam data being plotted on map sheet 74-20 and Figure 6B shows that the ground magnetics being plotted on map sheet 74-15. In the days of light tables for correlation of different parameters, and the search of coincident EM and magnetic responses, and lots of targets, it could be possible that this map layout caused the Reed Mine Deposit to be overlooked.

Hudbay’s ground follow-up - 1

HBED conducted additional ground geophysical surveys and drilling after acquiring the property from Freeport. Hudbay, in 1981, conducted an HLEM survey to follow up on their own in-house airborne EM system (EM-30) anomalies and to better define previously located Turam trends. The HLEM surveying just missed the massive portion of the ore body (Manitoba Mineral Assessment Work Report # 70222). The HLEM survey data was not presented as profiles and the numbers are difficult to read, but it does show that the survey did not pick up a conductor on Line 14E, the easternmost line. With a coil separation of 400 feet and using frequencies of 444 Hz and 3555 Hz, the survey should have detected the mineralization of the Reed Mine Deposit if the HLEM coverage had been extended by one or two lines to the east.



Approx location of Reed Mine

Hudbay’s ground follow-up - 2

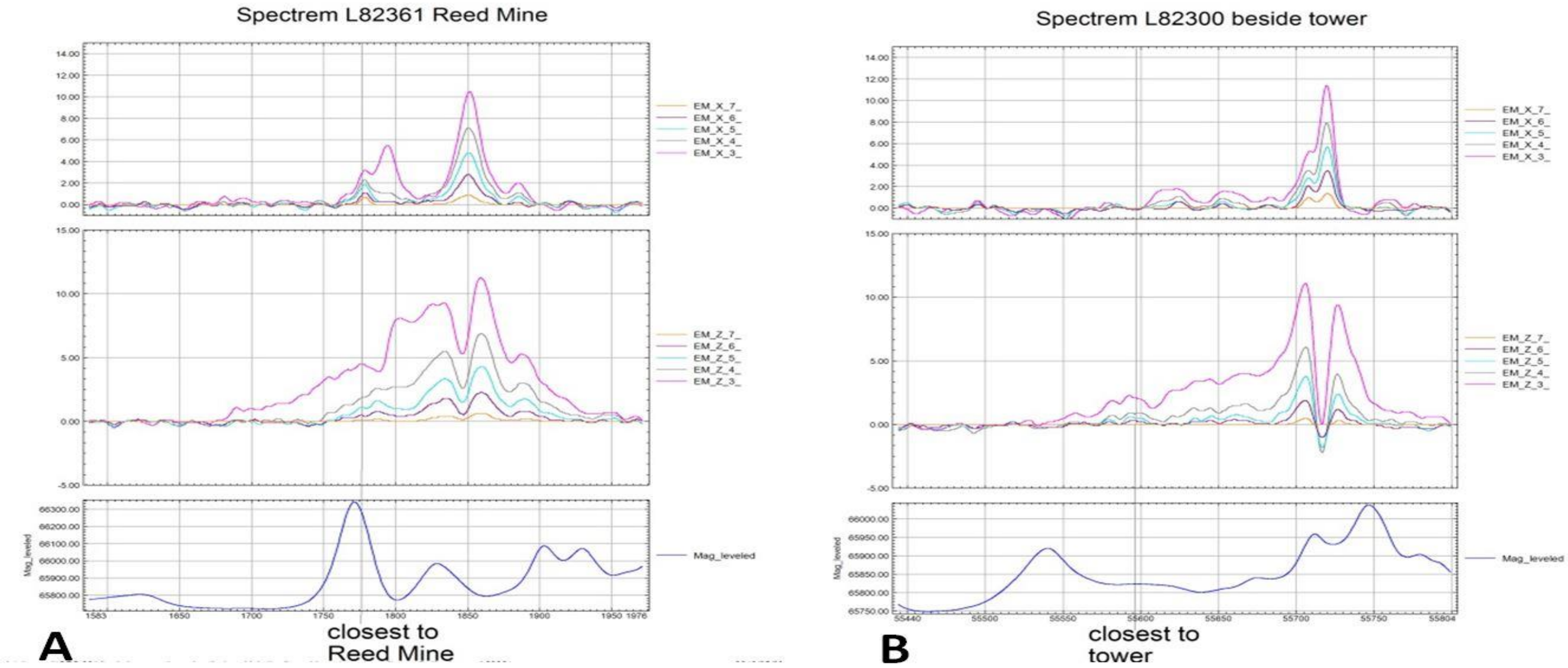
The rationale for Hudbay’s 1981 HLEM grid lines that just missed is not known. This could be due to a number of reasons, including plotting errors from their in-house EM-30 survey, or from a reinterpretation of the 1972 Questor airborne survey data, or perhaps from the line cutters who established the grid in the incorrect place.

Homestake explored in the area and flew an airborne geophysical survey in 1988, with ground geophysical surveying follow-up work just to the north of the Reed Mine Deposit.

Hudbay’s ground follow-up - 3

The Reed Lake orebody was also covered by a large Spectrem survey that was flown by Hudbay in 1995 (Manitoba Mineral Assessment Work Report# file 73859). The deposit was detected by the Spectrem survey in their Reed Lake A flying block, but the EM response was attributed to the response of the communications tower nearby which, judging by the responses on the map, affected the Spectrem system for quite a few lines.

Spectrem survey over Reed



Spectrem data over the Reed Mine Deposit (A) and data close to the communications tower (B). Top panel is the X component, middle panels are Z component and bottom panel shows the total magnetic Intensity. Both lines were flown from south to north. Digital data curtesy of Hudbay.

VMS Ventures Exploration – 1

In 2006, VMS Ventures embarked on an exploration program beneath the Phanerozoic cover, with the Reed Lake area as one of many prospective areas that were obtained by staking or options. Their rationale was that there were 29 mines found in the Flin Flon Belt with only one of those (of VMS type deposit) beneath the Phanerozoic cover, which made the covered area underexplored. The exploration team recognized that advances in geophysics and geochemistry provided the targeting required to explore beneath the cover rocks (J. Roozendaal, President – VMS Ventures – personal communications).

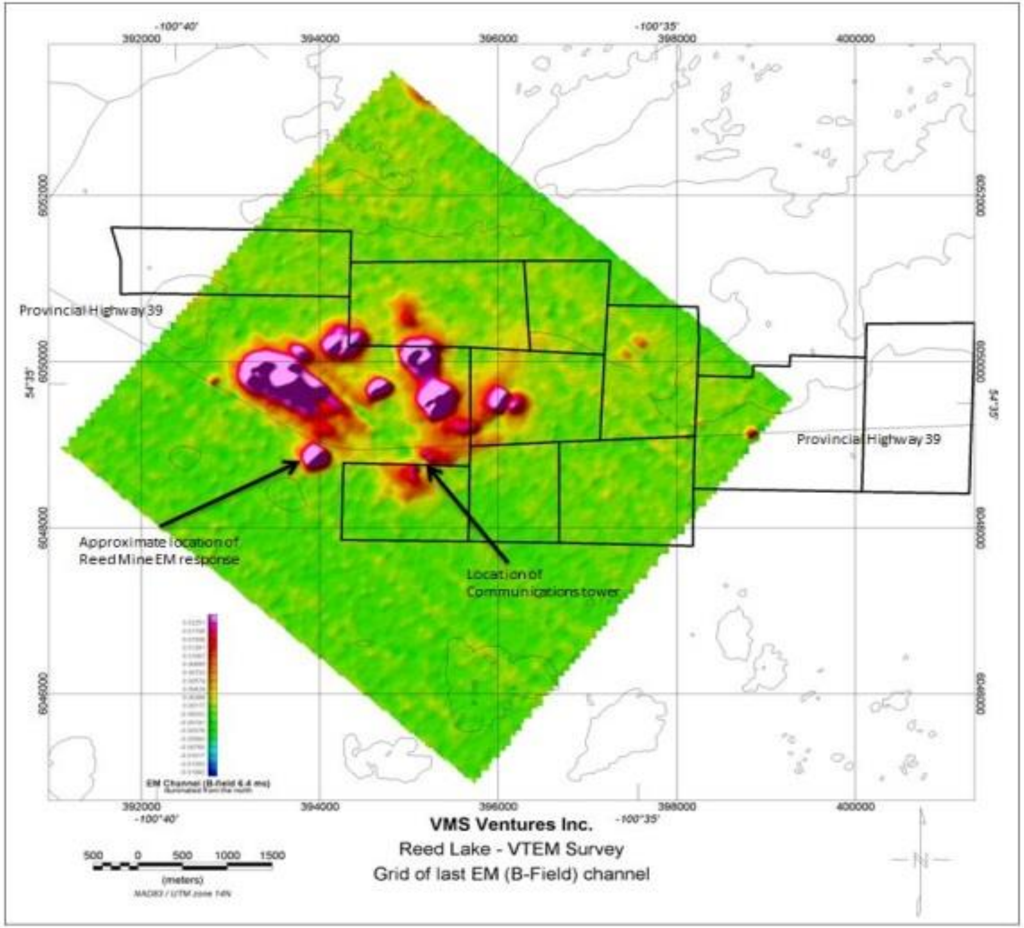
VMS Ventures Exploration – 1

The Reed Lake area was of interest due to the Spruce Point Mine, mined by HBMS from 1982 to 1988, some 15 km away and the Highway Zone (discovered in 1972, 73 – 250,000 tonnes of up to 2.5% Cu), just north of the highway which runs through the property. The previous 40 years of exploration in the immediate area had drill core which showed good alteration (J. Roozendaal – personal communications).

VMS Ventures Exploration – 2

VMS undertook an airborne geophysical survey over the property in early 2007 using Geotech's VTEM system. The VTEM system at the time was a vertical component receiver system. Survey lines were flown 100 m apart in a NW to SE direction. Interpretation of the data consisted of EM anomaly picking on a profile-by-profile basis followed by a ranking of the anomalies based on conductor length, conductance, correlation to magnetic anomalies, and complexity. A number of well-defined conductors were identified.

VTEM survey over Reed

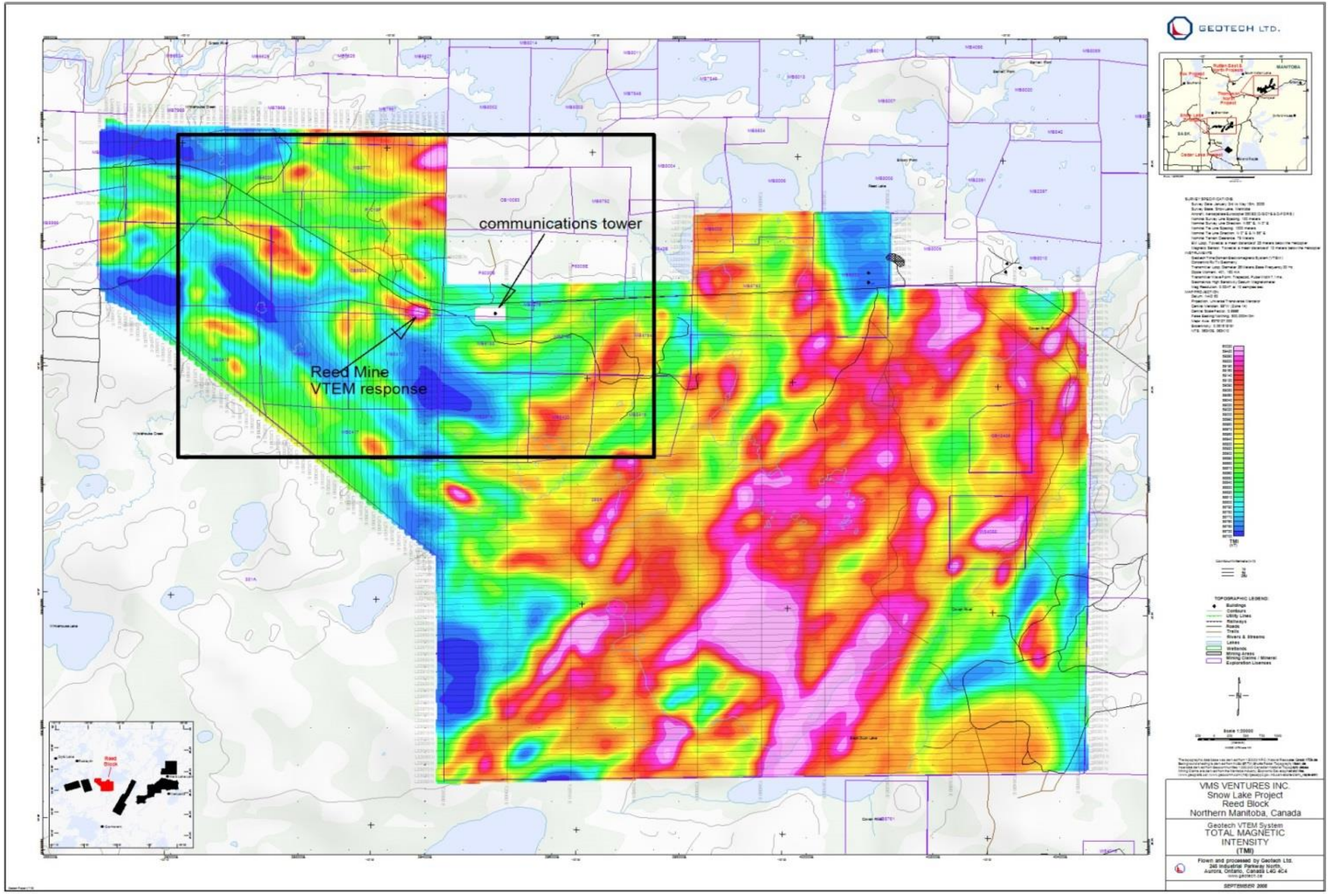


Map of gridded last EM channel with topographic overlay. Note the small EM responses directly on the highway. The Reed Mine Deposit is positioned close to the highway, near to a communications tower, raising some doubts as to whether the EM response was valid. Data taken from digital portion of Manitoba Mineral Assessment Work Report# 74580.

VMS Ventures Exploration – 3

The Reed Lake Deposit responded as a moderately conductive three line anomaly within an 800 m long, and much weaker, conductor. It was not selected as a high priority target by the consulting geophysicist to the project (personal recollection of the author who was the geophysical consultant to VMS Ventures at the time) as there were other more geophysically intriguing targets located on the survey block, and it was downgraded due to its proximity to the bend in the highway and the communications tower to the east.

Reed Lake Mine



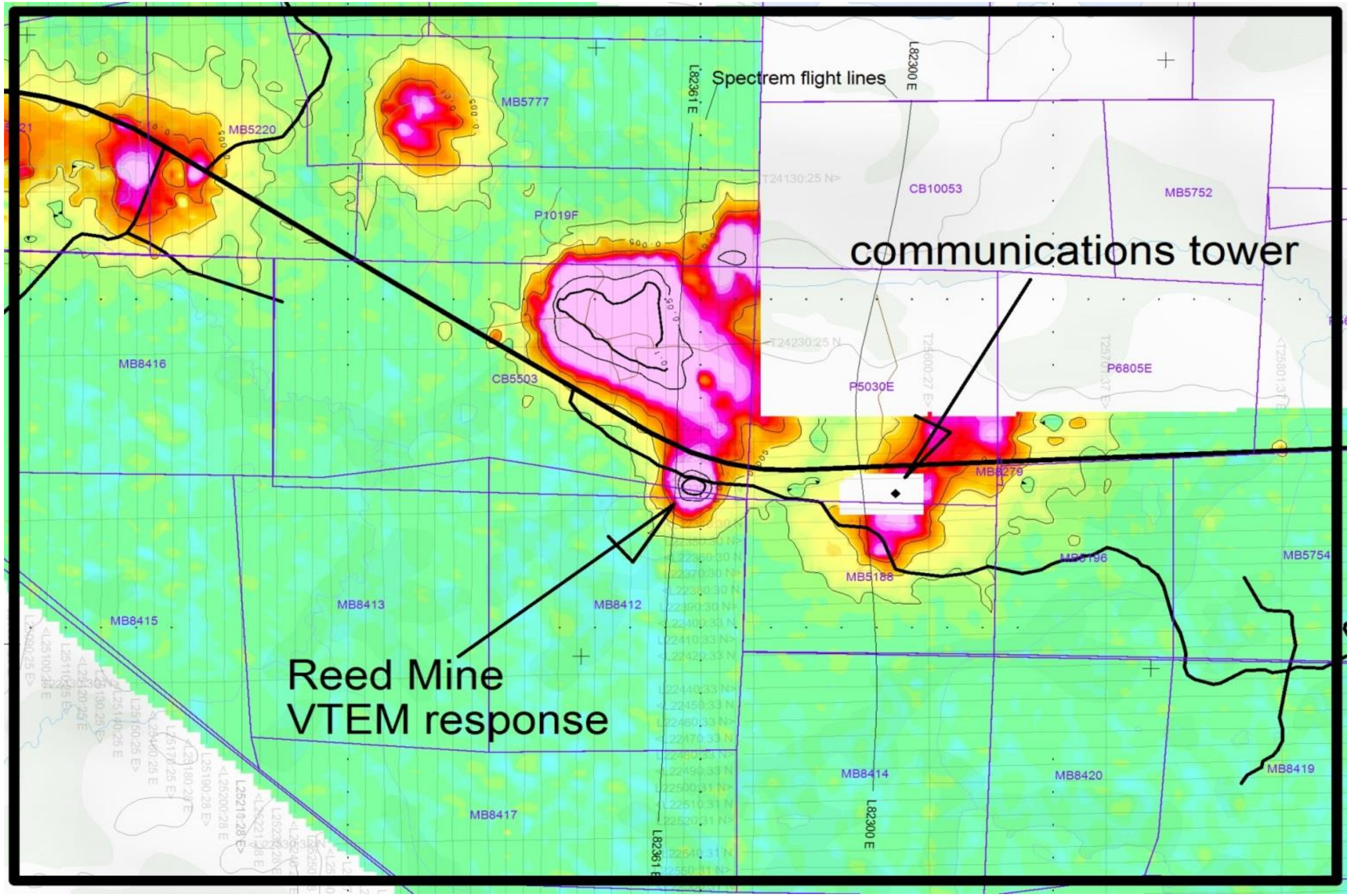
The Reed Mine was covered in a larger survey using VTEM in the following year. The image is of the TMI.

B-Field – next slide

B-Field channel 30 (time gate 3.911 ms) of the rectangular area shown in the previous figure. The EM data is also affected by the communications tower. Also shown on this map are the flight path of the two Spectrem lines presented in previous slides.

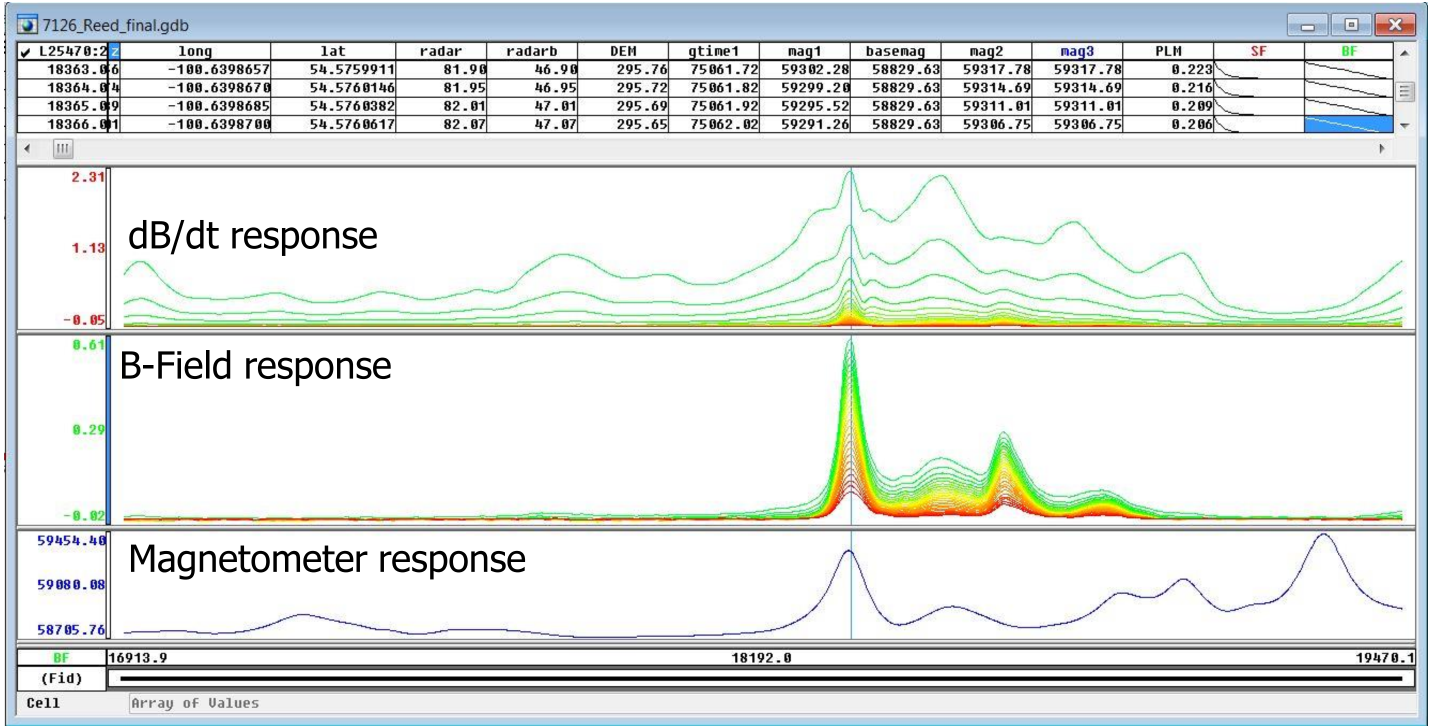
A field check plus GPS positioning of the highway and communications tower by John Roozendaal of VMS Ventures showed that the transmission tower was over one kilometer away to the east and that there were no anthropogenic sources in the vicinity of the Reed Mine VTEM responses. A fiber-optic line was laid down south of the highway, but it did not appear to produce an EM or magnetic response.

Reed Lake Mine



Reed Lake Mine, EM and magnetics Profile

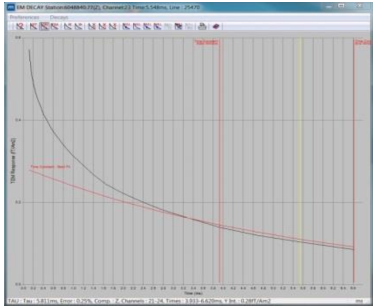
The EM and magnetics profiles are shown in the figure to the right. The vertical line shows the location of the Reed Lake Mine geophysical response.

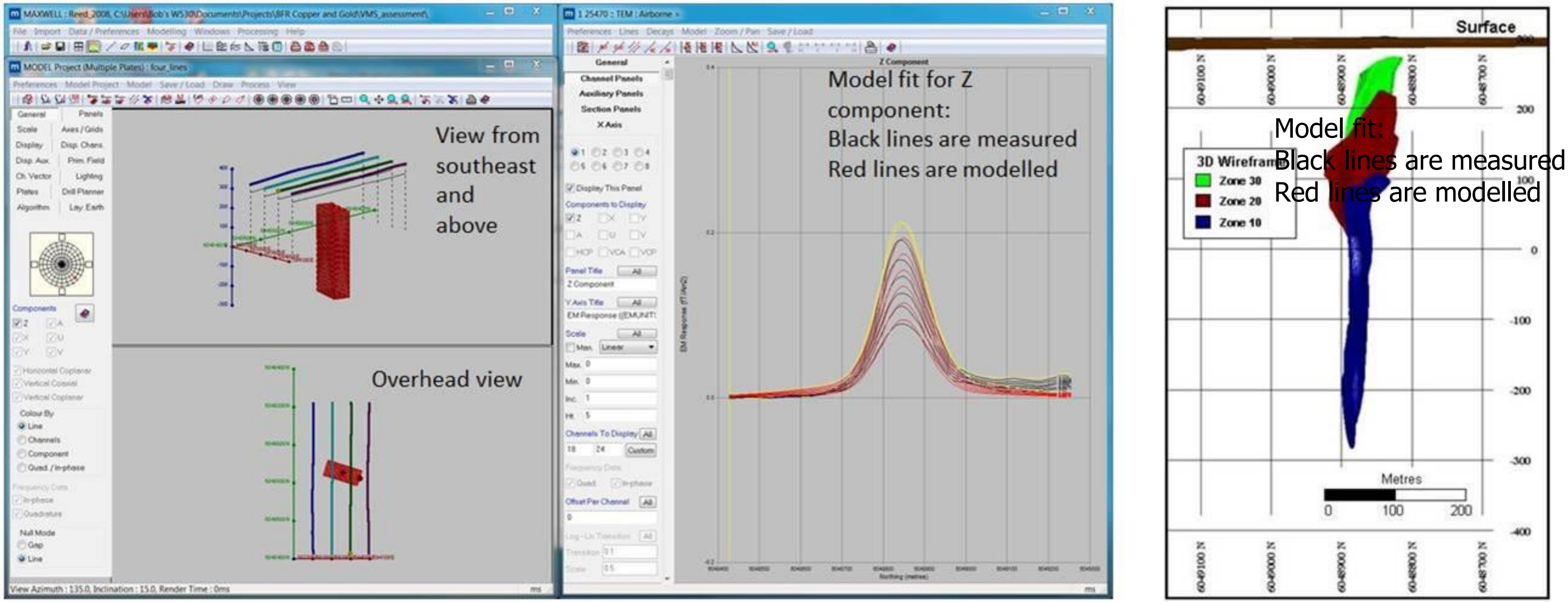


Time Constant Analysis:

The time constant is the length of time after the electromagnetic transmitter is turned off, for the induced currents in the anomalous body to decay to 1/e of its original value. Since there are usually multiple conductors (overburden is always around), we use the late time channels, after the weak conductors such as overburden have decayed away.

The time constant measured here is: 5.8 milliseconds





Reed Lake Mine – thin plate modelling (of the second VTEM survey data).

The Reed Lake Mine VTEM response was modelled over four survey lines using a thin-plate algorithm. A thick body is approximated with multiple plates close together. A very good fit to the late time response is achieved with a body of dimensions 189 metres strike length, 444 metres depth extent, and 84.4 metre thickness of total conductance of 219 Siemens. The top of the body is modelled at 131 metres beneath the surface. Note that this was not the plate modelling done to guide the discovery drillhole and subsequent follow-up drillhole.

Discovery hole

The first drill hole, collared on high ground in the vicinity, intersected 30 m of stringer sulphides with some chalcopyrite (VMS Ventures press release – Sept. 17, 2007). The follow-up drillhole, stepped 100 m to the north, also on high ground, intersected near solid sulphides with ore grade and widths.

Another case that shows that you have to have perseverance and/or be lucky to find a deposit.

MCILVENNA BAY DEPOSIT

McIlvenna Bay Deposit

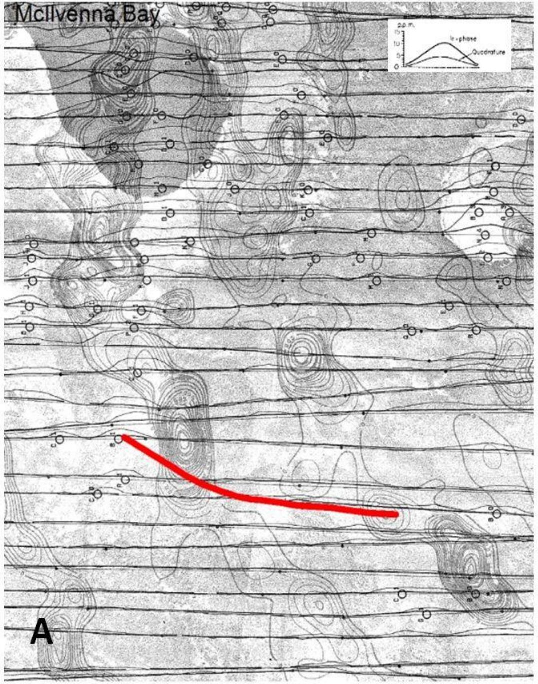
The McIlvenna Bay Deposit is located on the western edge of the Flin Flon – Snow Lake Belt. It is located a short distance from the edge of the limestone cover. Published resources are 13.9 million tonnes of 1.28% Cu, 2.67% Zn, 0.49 g/t Au and 17.1 g/t Ag indicated and 11.3 million tonnes of 1.32% Cu, 2.97% Zn, 0.43 g/t Au and 17.5 g/t Ag inferred (Rennie, 2011). An excellent case history of the discovery was published by Koziol and Ostapovitch in 1990. Rather than reproduce the case history, the author will add some exploration details not presented in the case history.

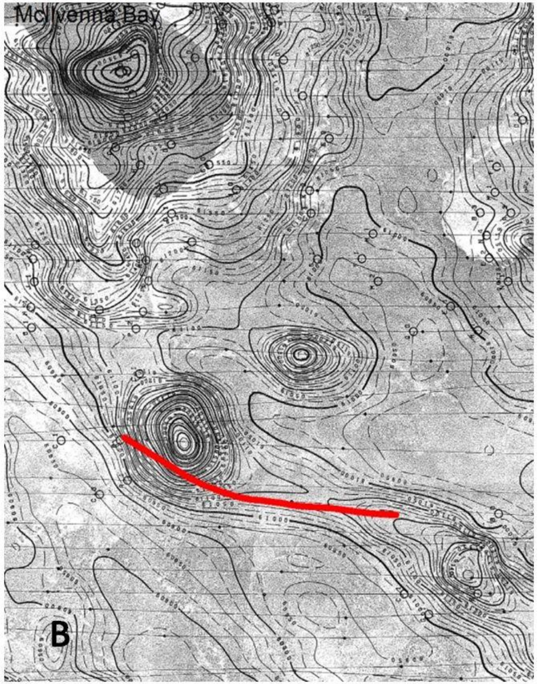
The McIlvenna Bay Formation hosts the deposit. The formation is at least 200 m thick and comprises the deposit and variably altered felsic volcanics, volcaniclastics, and/or volcanic derived sediments of rhyolitic composition (Rennie, 2011). Above the McIlvenna Bay Formation is the Cap Tuffite Formation, a sequence of intercalated felsic volcanic and cherty metasediments. Stratigraphically overlying the Cap Tuffite is the Koziol Iron Formation. It is a long continuous exhalative marker horizon, containing massive magnetite and traceable by geophysics (Rennie, 2011).

SMDC – Exploration Rationale

Saskatchewan Mining and Development Corp. (SMDC) chose the area to explore, because the exposed Proterozoic rocks north of the limestone cover appeared to be similar to those at Flin Flon, and so they acquired claims in the Hansen Lake area in 1976 (M. Koziol, former SMDC and Cameco project geologist for the area, personal communications). SMDC flew a 3,652 line km survey using Aerodat Ltd. over the area both north and south of the unconformity in 1977, using 100 m spaced lines, oriented East-West. The EM system was an EM33-1 frequency domain system manufactured by Geonics Ltd. and consisted of one set of horizontal coaxial coils operating at 736 Hz. Positioning was electronic (as opposed to via camera/film as other airborne surveys of this vintage) with a Motorola Mini-Ranger III system (Saskatchewan Mineral Assessment Report #63L10-0076). The Aerodat system was chosen because it had the vertical coil transmitter-receiver orientations which were deemed to be important to penetrate through the paleo weathered contact at the top the covered Proterozoic rocks (M. Koziol, personal communications). A detailed line spacing for the day of 100 m was used in the search for the typical Flin Flon type ore bodies, which were pencil or rod-like, nearly vertical bodies with a small surface expression. A number of small VMS deposits were discovered from ground follow-up of the 3652 line km of airborne EM over the survey area, including the Grid-B Zone and the Zinc Zone (discovered in 1984).

Helicopter frequency domain EM survey results





Aerodat HEM system – California, 1993)

Figure A: Aerodat EM profiles on flight path with interpreted anomalies and McIlvenna Bay INPUT conductor (in thick red line and traced out from Koziol and Ostapovitch's 1989 paper). Note that the flight lines are rather poorly flown in the area of the conductor and that only three lines crossed the conductor. The contour lines in Figure 14A are of high-pass filtered magnetics. The filtering is done along the lines in a 1D sense and then contoured. Figure B - Total Magnetic Intensity contours with flight path and interpreted anomalies. The change in direction of the conductor follows the local magnetic trend.

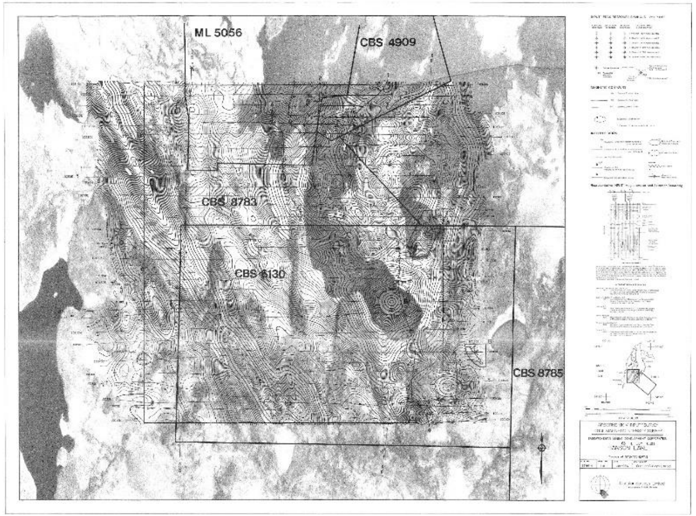
The Aerodat flight lines were oriented in the East-West direction, perpendicular to the features seen on the available Geological Survey of Canada magnetic data. It turns out that the flight lines were sub-parallel to the strike direction of the magnetics data and of the near surface conductivity due to the McIlvenna Bay Deposit. The geophysicist for the project had noted the complex EM responses in the area of the then undiscovered McIlvenna Bay deposit, and had interpreted the EM responses as possibly those from conductivity parallel or sub-parallel to the flight lines (Mike Koziol: personal communication). In the area of complex EM responses, the high resolution aeromagnetic data showed a marked orientation change which was not seen in the regional magnetic trends.

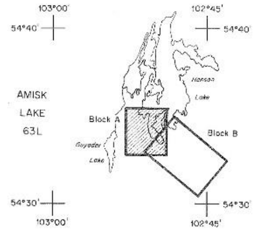
SMDC – Helicopter Input

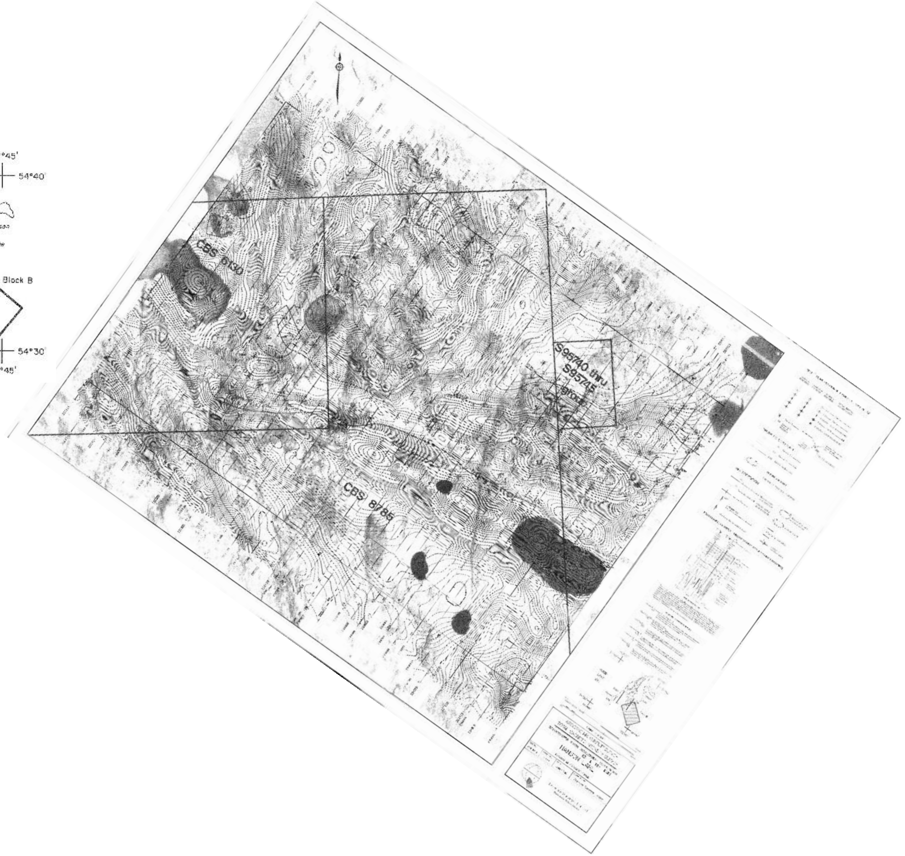
SMDC had relinquished much of the ground covered by the Aerodat survey, no longer thought to be prospective by 1985. In early 1985, a Troymin-Granges joint venture discovered the McDermott Lake-Balsam Zone Deposit approximately 7 km away on a land package to the east of the SMDC ground. The McDermott Lake-Balsam Zone was discovered by drill testing airborne EM (INPUT) anomalies. The INPUT survey was flown with a fixed-wing over five overlapping blocks with different line directions. Ground follow-up was with MaxMin (Saskatchewan Mineral Assessment Report #63L10-0090 and 63L10-0100).

This prompted a review of the geophysical data that had been acquired over the years. The decision was to re-fly in 1986 the now smaller area of interest with Questor's helicopter INPUT system. This time, the receiver coil was oriented in the vertical direction. Two line orientations were used to best couple with the trends interpreted, using the detailed magnetometer data from the Aerodat survey. The area of the complex responses was flown with both survey line orientations at 150 m line space to ensure that at least one set of survey lines would cross the conductive feature at a fairly normal angle (Mike Koziol, former Exploration Geologist for Cameco: personal communication).

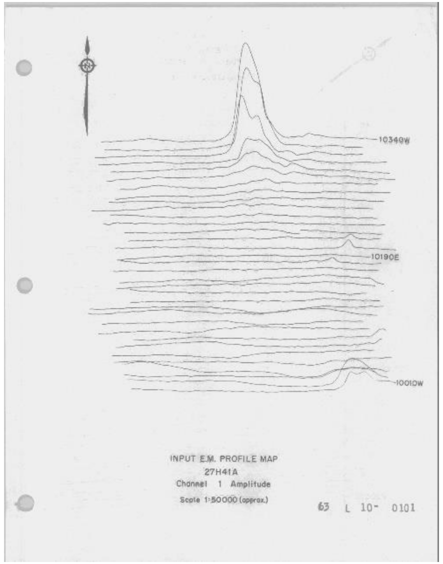
Helicopter INPut anomalies on TMI

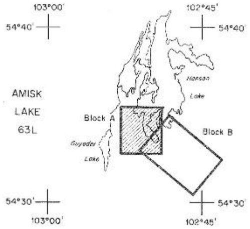


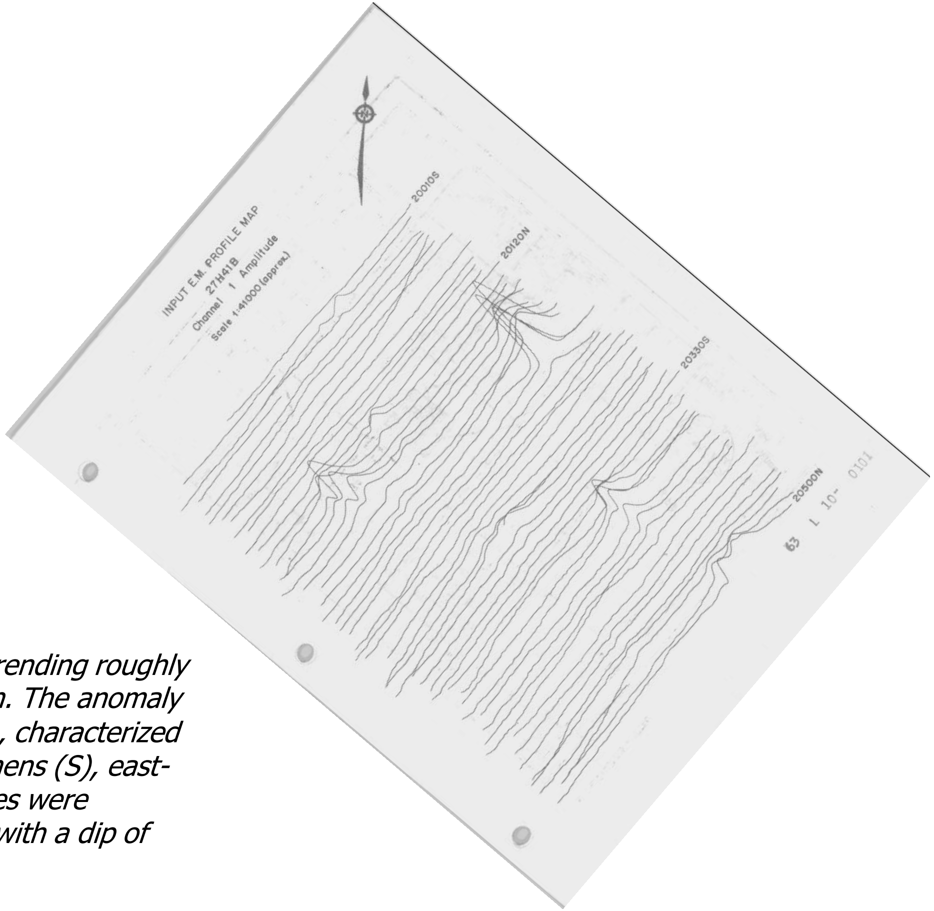




Helicopter INPut Profiles

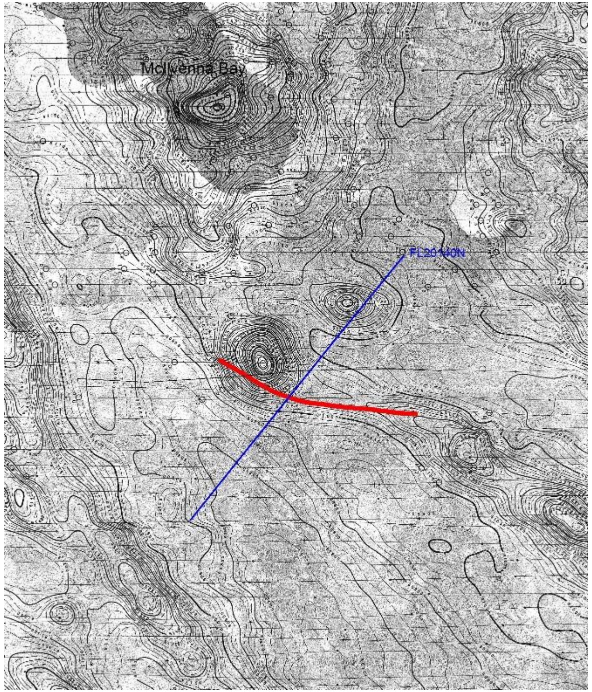


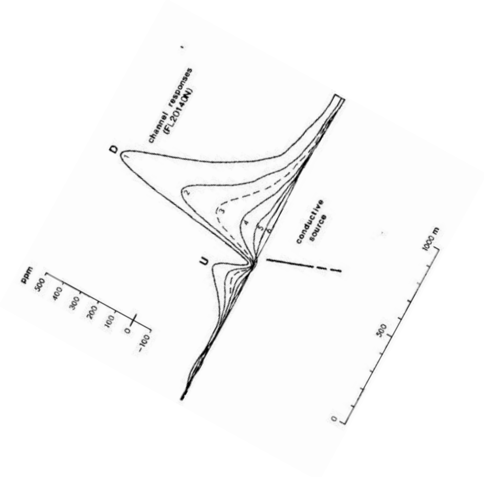




The INPUT survey outlined what appeared to be a formational conductor trending roughly 090° to 120°, flanking a linear aeromagnetic high having similar orientation. The anomaly is a 4-6 channel INPUT conductor with approximately 1200 m strike length, characterized by an estimated conductivity-thickness product ranging between 8-10 siemens (S), east-southeast of FL 20140N and 20-50S,to the west-northwest. Depth estimates were determined by Questor to fall within the 40-100 m range (below surface), with a dip of 65° to 70· to the northeast (Martyn, 1986). (from Koziol and Ostapovitch)

Helicopter time-domain EM survey results

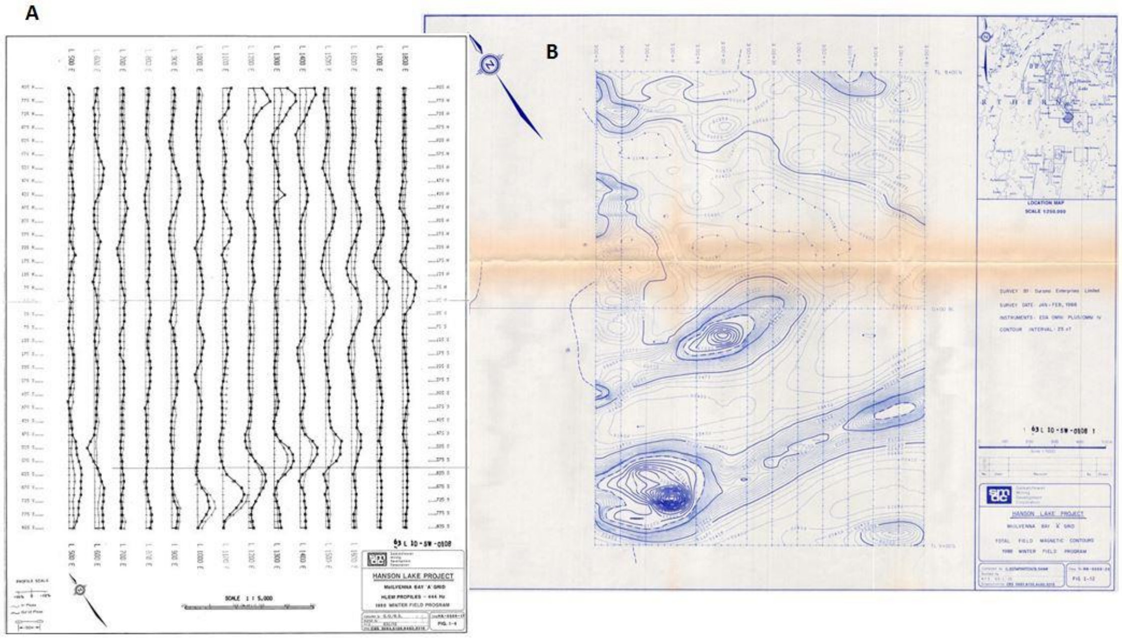




Picture from 2008 Geotech Calendar files

The INPUT stacked profile of the six EM channels on Line 20140 (path shown in blue on TMI image). The helicopter INPUT system was essentially what is now called a coincident loop geometry system. The receiver coils would be below and slightly behind the transmitter loop, giving rise to EM profiles that look the same as modern airborne time domain EM systems. (INPUT profile curtesy of Foran Mining and in Koziol and Ostapovitch, 1990).

HLEM MaxMin survey results



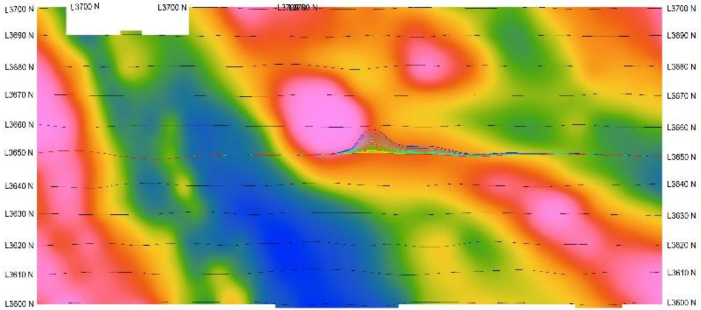
Cameco's ground geophysics in 1988 over the 1986 INPUT anomaly. A – The HLEM data (150 m cable, 444 Hz) and the total magnetic Intensity – B. Note that the grid could have been positioned more to the southwest.

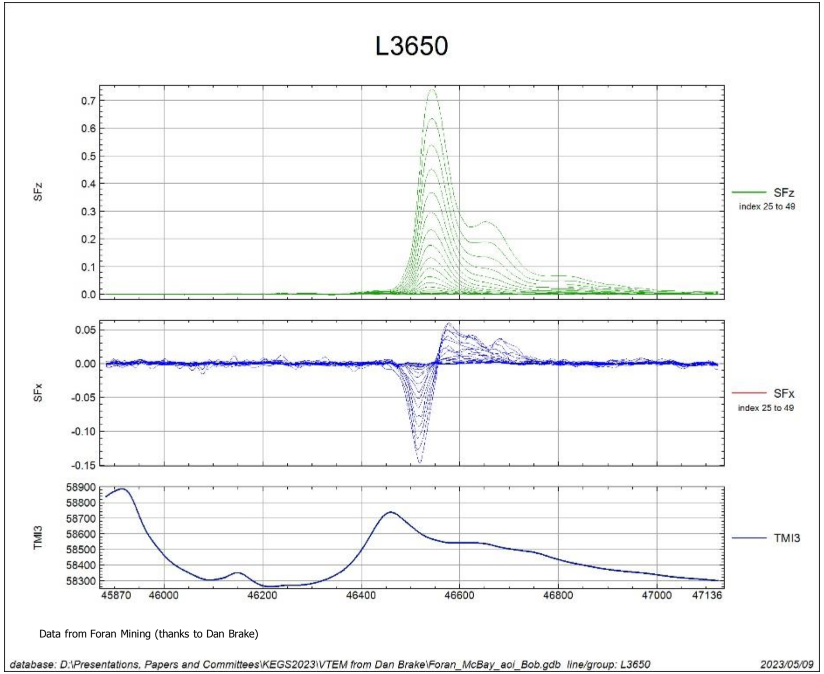
The area was covered by ground magnetometer and horizontal loop electromagnetic (HLEM) surveys. "*The interpreted HLEM conductor axis associated with the McIlvenna Bay deposit (Figure 8) has a strike length in excess of 800 m, and is characterized by moderate conductance (5-11S). The depth of the conductor was estimated at 40 m to 90 m (plunging to the northwest), and dipping 60° to 85° to the northeast*" (estimated using the technique in Nair et al., 1968) . (from Koziol and Ostapovitch)

Discovery Drillhole

A six hole diamond drill program was then carried out to test the HLEM conductor. The first hole intersected a 24 m copper stringer zone, within which was a 1 m wide massive sulphide section. The other five drill holes also intersected stringer and massive mineralization including hole HA-06, which cut 5.0 m of 3.3% Cu, 9.6% Zn, 79.9 g/t Ag and 1.02 g/t Au. An additional 48 drill holes were completed during the latter part of 1988 and 1989. (from Koziol and Ostapovitch)

VTEM Helicopter time-domain EM survey results





The area was reflown in 2011 by Foran Mining in a regional exploration effort. Survey lines are 150 meters spaced, flown east-west. The line direction is not optimal for this deposit, but still has a clear EM response over the conductor. (VTEM data curtesy of Foran Mining, expedited by D.Brake).

SUMMARY

Summary

In the two examples presented in this paper, it was good ground selection, geophysical technology of a certain level, and proper interpretation of the data that were needed to get to the discovery drill hole. The contribution of perseverance, building on other explorers' knowledge, and your own knowledge of the area, should not be overlooked.

SMDC (Cameco) had to fly the McIlvenna Bay Deposit twice before getting a believable airborne EM response for ground follow-up and then drilled on the ground geophysical results. The Reed Mine Deposit was flown at least twice and a drill road was built over the deposit to access another property and it had been surveyed with ground geophysics. Then, VMS Ventures used arguably the best airborne technology at the time to detect the deposit. They then had to convince themselves that the Reed Mine Deposit VTEM anomaly was not due to anthropogenic sources, as others thought, before drill testing.

Additional thoughts

Despite the success of finding these deposits, one of which became a mine, beneath the Phanerozoic cover, it can be argued that there is still a relatively poor success rate for the Phanerozoic covered areas, as only three mines have been found in roughly the same areal size as the exposed portion. The largest of the three mines beneath the cover is the Reed Mine. It is about average size for the belt. The largest mines in the belt (Flin Flon, 777, Trout Lake, and Lalor) are not covered by the Phanerozoic cover. Notice that in the list of mines and deposits of the Flin Flon – Snow Lake Belt, the discovery method of Callinan, Chisel North and 777 Mines are attributed to geology such as drill testing geological or structural targets in the vicinity of known mines. Also, geological input into looking for deep targets in specific locations in the Chisel Basin played a key role in determining where to place the transmitter loops for the geophysical surveys that first detected the Lalor Mine Deposit (Vowles and Dueck, 2014). It is relatively easy to fly a large land package in a covered area. Covering the same land package by ground geophysics for better information is much more difficult. Advances in airborne technologies will help with the discovery rates. But at this moment, it is for marginal gains, as a review of the assessment files shows, that most of the northern 50 km wide portion of Phanerozoic covered parts of the Flin Flon-Snow Lake Belt have been surveyed with airborne geophysics several times. As more drill holes are put into the crystalline bedrock beneath the Phanerozoic cover, the geological knowledge will increase which should help target covered areas better. This increased geological knowledge and database with improvements in geophysical techniques should increase the success rate of finding deposits beneath cover.

Acknowledgments

This author had a number of long discussions with explorers in the Flin Flon – Snow Lake VMS Belt: John Roozendall, President of VMS Ventures; Kelly Gilmore, formerly Chief Geologist of Hudbay; and Mike Koziol, former Senior Geologist with Cameco, all provided historical input into the discoveries presented in this paper. Dave Flemming and Roger March of Foran Mining supplied the helicopter INPut profile. Matthew Holden, Manager Geophysics – Hudbay Minerals, Inc. supplied valuable feedback on the paper (which formed the basis of this talk) and supplied the Spectrem data. More recently, Dan Brake helped in the release of the 2011 VTEM data over McIlvenna Bay. The editors of the paper which this presentation is derived all provided detailed editing of the manuscript which made it significantly better. Special thanks to Jean Legault, one of the editors, who convinced me to write the paper and patiently waited while the manuscript was months and months late.

End – thank you