# CROSS-HOLE RADIOWAVE SURVEYS WITH THE FARA SYSTEM IN THE SUDBURY IGNEOUS COMPLEX 2008





# REPORT ON SURVEY AT FROST LAKE AREA, WISNER AREA AND PARKIN AREA

WALLBRIDGE

By

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#### I. INTRODUCTION

The current report presents the work conducted by the team of geoscientists from the GEOFARA Ltd, St-Petersburg, Russia on behalf of FARA Systems Canada Ltd. The work conducted under agreement between FARA Systems Canada Ltd and Wallbridge Mining Ltd.

The team was contracted to conduct the cross-hole radio frequency electromagnetic survey at Wallbridge Mining properties in Sudbury region, Ontario, Canada. The work included study of Wisner area, Frost Lake area and Parkin offset area. The main goal was to identify and delineate ore zones or establish their absence.

The field measurements were carried out using FARA system on the frequencies of 312.5, 625, 1250 and 2500 kHz and in a depth range from 150 up to 1480m. The measuring was totally computerized. Received data were processed and presented on tomography images of cross-hole conductivity.

The «FARA» is Russian abbreviation for Phase Amplitude Radio Propagating Equipment. This word, which initially was applied only for the instrumentation using in the Radio Image Method (RIM), became the trade-name of the team: many important designs and adjustment of tools as well as methods of obtaining and processing of results have been done under this name.

The team of Russian geoscientists (further – FARA team) was headed by Klim Ratnikov, P.Geo, and included Alexey Fedorov, Anatoly Yushmanov, Andrey Lovchikov, Ivan Kholodov and Alexander Sobolevskiy. Dr. Walter Peredery, P.Geo, President of FARA Systems Canada Ltd, supervised field works, logistics and provided help with translation.

Tania Brzozowski, Wallbridge Project Geologist, organized and supervised works at Norman area.

Mark Croteau, Wallbridge Field Geologist, organized and supervised works at Wisner area and Parkin offset area.

#### II. APPLIED METHODS

#### 1. General description

Radio waves are differently attenuated in rocks according to the electrical conductivity of the medium between transmitter and receiver. Most sulphide minerals are more conductive than the country rock and therefore attenuate radio waves at a greater rate than barren, non-sulphide bearing rocks; it follows then the greater the percentage of sulphide mineralization, the attenuation rate of the radio wave passing through the mineralized zone.

The cross-hole radio frequency electromagnetic method in metalliferous mines offers a cost-effective means to discover conductive ore zones that have not been intersected or to define the extent of those which have. It also can be used to delineate such important features as faults, geological contacts, and underground cavities.

Cross-hole tomography provides a visual image of the distribution of various geoelectrical parameters in a cross-hole space which can be incorporated into the orebody modeling process.

Surveys by the cross-hole radio-wave method need a pair of drill holes. The casing of drill holes should not be conductive.

#### 2. Equipment

The Figure 1 is photograph which shows the FARA equipment used during 2005 works. The Figure 2 shows in the explicit detail the using equipment and the way it is connected.

FARA equipment, as one can see on the Fig.2, consist of:

- ✓ down-hole receiver and transmitter units
- ✓ surface receiver and transmitter units
- $\checkmark$  the cable and winch for connecting the down-hole probe with surface instruments;
- ✓ a depth counter attached to wellhead pulley for keeping track of the location of the probe in the hole;
- $\checkmark$  a computer connected with the central control unit;
- ✓ a reference telephone line between two drill-cites.

The FARA team is continuously working on the advancement of the equipment; the current parameters are:

Operating frequencies:	312.5; 625; 1250; 2500 kHz
Range of measurable voltages:	0,03-1000 mkV
Output power of the transmitter:	1 W
Range of measurable phase parameters:	0-360 degrees
Diameter of borehole investigated:	more than 40 mm
Depth of boreholes investigated:	to 3000 m



Fig. 1 FARA equipment and field scenes

The complete FARA set includes also antenna systems tailored for the proper working frequencies and a system of unique down-hole and surface filters, which allows substantially reduce losses of electromagnetic field along the cable and the reference line.

The FARA system has the following advantages:

- Simultaneous measurements at four operating frequencies. The frequencies can be changed as required by presented geological challenge. The radio waves of lower frequencies are recommended for
  - a) regional works with long distances between drill holes;
  - b) highly conductive cross-hole medium;
  - c) as a first stage in complex cases, before conducting more detailed investigation on the radio waves of higher frequencies.
- 2) Measurement of the signal phase of the receiver in the reference to the transmitter. Combined phase and amplitude measurement provide reliable source of valid data and increase resolution capacity of the method. In addition to that the phase measurements allow define the time delay of an electro-magnetic wave during its propagating through the medium. That may be used for calculation of additional parameters, such as the length of the wave and dielectic permittivity.
- 3) Continuity of measurement which considerably increases productivity of survey.
- 4) Special system of filters virtually eliminates the loss of electromagnetic wave via connecting cable and prevents it from being the upper transmitting antenna.
- 5) Acute sensitivity of the instrumentation allows obtain reliable data between drill holes located far from each other: up to 1km, provided that specific resistance of the country rocks in this case is about 5000 Ohm m.



Scheme of measurements by the radio-wave method with the FARA system

#### 3. Measuring procedure

Four independent receivers constitute a single down-hole module. This module together with an antenna system and a surface receiver are designed for measuring amplitudes and phases of the electrical field intensity in a drill hole simultaneously at four frequencies emitted by a four-frequency down-hole transmitter. Two unique systems of filters meant for suppressing electromagnetic energy losses along the cable permit to employ both armored carrying cables and those with an insulating sheath.

A transmitter placed in one drill hole emits electromagnetic energy at specific frequencies. In the other drill hole, a receiver records the electromagnetic wave emitted by the transmitter after its passage through rocks. In a general case, radiation and recording of electromagnetic waves are made using electric or magnetic dipoles, which direction coincides with the direction of the drill hole at the dipole location. We used the following procedure for tomography surveys: a transmitter is fixed, while a receiver is moved and makes measurements at specific intervals. Then the transmitter is moved at the next station and the measurement process is repeated. The depth range for transmitter and receiver movements is determined by the set task conditions and is, generally, somewhat wider than that of a study space. The FARA team always performs a reciprocity test by interchanging the transmitter and receiver.

The investigation range depends on electromagnetic characteristics of a cross-hole region, sensitivity of the system's receiving path, power and frequency of an emitted signal. The table below gives approximate values of the maximum distance between transmitter and receiver drill holes (in meters), as well as approximate minimum size of investigated conductive targets (in meters) versus  $\rho$  (in Ohm m) for the FARA system.

	312.5	kHz	625	kHz	1250	kHz	2500	kHz
Resistivities of enclosing rocks, Ohm·m	Maximum distance	Minimum size of targets						
10000	1800	150	1600	80	1500	50	1400	40
5000	1000	120	900	70	800	35	700	25
1000	400	50	250	40	200	30	180	16
100	100	15	90	12	60	10	40	12
10	30	5	25	4	-	-	-	-

The FARA system's software support allows automated field data accumulation, processing of materials and presentation of the obtained result. The programs operate being controlled by MS Windows 95/98/ME/NT4/2K/XP systems and meet all the standards adopted in this sphere. Figure 3 shows the real-life picture of receiving survey data.

The operator can keep track of the quality of incoming amplitude and phase information at all the frequencies in real time, as well as review any previous measurement. The program provides the operator with all on-line information, so that he can decide whether it should be necessary to make checking measurements, to increase or decrease the depth range of the receiver movement, to concentrate the grid of transmitter stations or to repeat the data reading.

#### 4. Processing

Figure 4 presents the main steps in the processing of obtained data.

We should emphasize the following adventures of the FARA processing program.

#### Data preparing:

✓ Differentiation and smoothing of the initial materials.

STOP   1E7	5587	180	8
RECORD			
RESET			
Dep: 1894	2500 kHz, 2	-160	Phase 2500 kHz,
Station: 8 1127 Point: 1775	186509	180	.15
Save station			
100	1250 kHz, 4	-180	Phase 1250 kHz.
Duput lienans: 1E7 Nrd55_53.1ar	449521	180	-17
T Inversed			
100	625 kHz, 5	-180	Phase 625 kHz.
167	58575	160	
Parameters			
? About			
🖉 Graph			
EXIT 100	312.5 kHz 3	-180	Phase 312 5 kHz

Fig. 3 Screen of FARA data reading software



Fig. 4 Processing of obtained FARA data

FARA detects four readings per seconds, but the depth of probe is located with an accuracy of one turn of the wellhead pulley. Thus, depending of the velocity of receiver movement, every measurement of depth corresponds to 5-100 signal



Fig. 5 Screen of FARA processing software

readings. We calculate only one value from all this set at the very first stage of the processing, thus decreasing the noise and curves steepness.

- ✓ Automatic phase correction. Initial data may be complicated when a phase is jumping over 360 degrees. Our system of processing automatically eliminates these jumping.
- ✓ Conversion to 3D coordinate system. The real position of a transmitter and a receiver is calculated with respect to drill holes deviations.
- ✓ Backed by knowledge of true locations of a receiver and transmitter the real life geometry of ray path is calculated.

#### Data editing:

- ✓ Determination of normalization coefficients for amplitude and phase. These factors allow convert the measured values of amplitude and phase to the actual characteristics of electromagnetic wave. They may be defined by comparison of theoretical curve and the one backed by field data.
- ✓ Manual editing of field data. The interpreter checks field data, determining and eliminating the obviously erratic values

Creating of tomography image:

- ✓ A cross-hole region is divided into rectangular cells. The value of specific resistivity shall be calculated for every cell.
- ✓ The specific rays passing through every designated cell from the whole set of generated electromagnetic waves.
- ✓ All rays passing through the every designated cell undergone statistical analysis of their physical properties.
- ✓ The resistivity for every cell is calculated.

Results presentation:

✓ The FARA team usually presents tomography images in the Golden Software Surfer 7 package using OLE technology. It is possible, however, to create and present the tomography images in the packages of 3D presentation and analyses of geological data provided by Gemcom and DataMine. Figure 5 shows examples of tomography images on different frequencies.

Description of an every cross-hole section has the following pattern:

- 1) A table which summarizes parameters of measurements, processing and geometry of the drill holes relative position:
  - ✓ Work type surface or underground
  - ✓ Measuring frequencies frequencies which have been used in the measurements
  - ✓ Transmitter antenna length length of a transmitting antenna
  - ✓ Receiver antenna length length of a receiving antenna
  - ✓ Transmitter step transmitter station spacing down a drill hole
  - ✓ Receiver step receiver station spacing down a drill hole
  - $\checkmark$  Station number total number of station from the both sides
  - ✓ Distance between boreholes approximate distance between drill holes on the level of an intersected orebody
  - ✓ Depth range depth range of an investigated region
  - ✓ Processing frequencies the frequencies best fitted to the particular environment; the data obtained on these frequencies were successfully processed and presented in the current report.
  - ✓ Processing type basic algorithm or iterative algorithm
  - ✓ Tomography cell size geometrical size of a ray-path matrix cells which are elementary units of a cross-hole region
  - ✓ Resistivity range a range of resistivity displayed on the tomography image.
- 2) Correlation of obtained conductive anomalies with geological structures intersected by investigated drill holes.
- 3) Shape and attitude description of obtained anomalies of conductivity.
- Comments Results presentation:
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Description of an every cross-hole section has the following pattern:

- 4) A table which summarizes parameters of measurements, processing and geometry of the drill holes relative position:
  - ✓ Work type surface or underground
  - ✓ Measuring frequencies frequencies which have been used in the measurements
  - ✓ Transmitter antenna length length of a transmitting antenna
  - ✓ Receiver antenna length length of a receiving antenna
  - ✓ Transmitter step transmitter station spacing down a drill hole
  - ✓ Receiver step receiver station spacing down a drill hole
  - ✓ Station number total number of station from the both sides
  - ✓ Distance between boreholes approximate distance between drill holes on the level of an intersected orebody
  - ✓ Depth range depth range of an investigated region

- ✓ Processing frequencies the frequencies best fitted to the particular environment; the data obtained on these frequencies were successfully processed and presented in the current report.
- ✓ Processing type basic algorithm or iterative algorithm
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- ✓ Resistivity range a range of resistivity displayed on the tomography image.
- 5) Correlation of obtained conductive anomalies with geological structures intersected by investigated drill holes.
- 6) Shape and attitude description of obtained anomalies of conductivity.
- 7) Comments on specific characteristics of applied measuring and processing.
- 8) Cross-hole tomography images.
- 9) Accompanying pictures
- 10) Specific characteristics of applied measuring and processing.
- 11) Cross-hole tomography images.

## III. SURVEY AT FROST LAKE AREA

The property is strategically located in the footwall on the East Range of the Sudbury basin, adjacent to the Capre 3000 Cu-Ni-PGE zone discovery announced by the Vale Inco/Lonmin PLC joint venture on Jan. 23, 2007. The further exploration program was aimed to test the belt of Sudbury breccia that hosts an extensive zone of low-sulphide PGE mineralization, which is called Amy Lake PGE zone, discovered by Wallbridge in 2005. The Amy Lake zone is in the same belt of rocks, which hosts the Capre 3000 discovery zone, located just 600 metres south of Wallbridge's property boundary.

The area is located on the East Range of SIC and can be reached by travelling 4km eastwards on Cote blvd (Hanmer), and then about 15km north on old Pourpore road.

The RIM surveys were a part of investigation for the Footwall in search for copper ore developments, as soon as previous FARA RIM have shown a good potential of its use in discovering mineralized zones in contact type as well as in Footwall environments around Sudbury area.

Both boreholes have difficult access and required skidder transportation.

The survey on the property was carried out on 625, 1250 and 2500 kHz. For the reason of boreholes geometry as well as general conductivity of the sections the length of antennas was 10m for all the surveys on the property. The step of the transmitter we chose was 30 m with accordance to survey setups and boreholes geometry.

# 1. Pair WC031 – WC032

Work type	Surface
Measuring frequencies, kHz	312.5, 625, 1250, 2500
Transmitter antenna length, m	10
Receiver antenna length, m	10
Transmitter step, m	30
Receiver step, m	1
Stations number	41
Distance between boreholes, m	435 ÷ 490
Depth range, m	250 ÷ 1210
Processing frequencies, kHz	625 1250, 2500
Processing type	iterative algorithm
Image projection azimuth, Deg.	99.3
Tomography cell size, m	10 × 10
Resistivity range, Ohm m	2000 ÷ 5000
Figures	6, 7, 8

Survey was carried out on all frequencies available for the system -2500, 1250, 625 and 312.5 kHz. Lowest frequency of 312.5 kHz was found not suitable for processing because of low general conductivity of the section. Because of the same reasons the confidence of sections in 625 kHz should be considered as low.

Section can be characterized as low conductive. No essential strong conductive zones were found. Some zones of slightly increased conductivity can be noticed on the images.



RIM tomography reconstruction Apparent resistivity, 625kHz

Fig. 6



RIM tomography reconstruction Apparent resistivity, 1250kHz

Fig. 7

RIM tomography reconstruction Apparent resistivity, 2500kHz



Fig. 8

# 2. Summary

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As a result of the surveys at Frost Lake area, tomographic images from 1 pairs of boreholes were acquired.

Localization and expansion problems for conductive objects in the area were solved well in terms of tomography.

The survey discovered the absence of high conductive zones within the cross-hole space, but some local zones of slightly increased conductivity were outlined.

#### IV. SURVEY AT PARKIN AREA

The Parkin property covers a 2.5 kilometers strike length of the Whistle-Parkin Offset Dyke and is located about 3 kilometers north of the Whistle Embayment situated along the North Range of the SIC. The Whistle Embayment and Whistle-Parkin Offset Dyke are highly prospective as they are known to host mineralization at:

CVRD Inco's Whistle deposit, which was mined out in 1999 and produced from a resource of 6 million tones grade 0.9% Ni and 0.3% Cu, FNX's Podolsky Mine, The Milnet Mine now owned by Wallbridge, Wallbridge's Parkin resource, which has seen historical exploration since 1934 and 22,447 meters of resource drilling in 121 holes by Wallbridge between 1999 and 2001.

As a part of investigation at Parkin Offset a down-hole geophysical RIM surveys were carried out to test for conductive objects on the property.

All borehole sites were accessible from tractor roads, and a part of the gear was transported by 4WD and the rest by the skidder.

All three surveys were carried out on four frequencies: 312.5, 625, 1250 and 2500 kHz. For the reason of boreholes geometry as well as general conductivity of the sections we chose the length of antennas was 10m for all surveys on the property. The step of the transmitter we chose was from 25 to 30m with accordance to survey setups and boreholes geometry.

#### 1. Pair WMM005 – WMM010

Work type	surface
Measuring frequencies, kHz	312.5, 625, 1250, 2500
Transmitter antenna length, m	10
Receiver antenna length, m	10
Transmitter step, m	30
Receiver step, m	1
Stations number	72
Distance between boreholes, m	380 ÷ 440
Depth range, m	250 ÷ 1480
Processing frequencies, kHz	625, 1250, 2500
Processing type	Iterative algorithm
Image projection azimuth, Deg.	12.50
Tomography cell size, m	10 × 10
Resistivity range, Ohm m	2000 ÷ 5000, 400 ÷ 5000
Figures	9, 10, 11, 12, 13, 14

The survey was carried out on all four frequencies available for the system -2500, 1250, 625 and 312.5 kHz. The lowest frequency 312.5 kHz was found not suitable for processing because of relatively low general conductivity of the section and low resolution of the frequency. Because of the same reasons images in 625 kHz should be considered as not reliable enough.

Image for highest frequency of 2500kHz appeared to be optimal for this section because of the best resolution.

Two main conductive zones and some weak zones can be found on tomography images.

The first conductive zone can be found in right top part of section. In intersects WMM-010 hole at about 400m depth and dips towards WMM-05 for about 100m.

The second zone is also concentrated at WMM-010 hole and intersects it at about 1150-1360m interval. It pinches out on about 150-200m distance from WMM-010.

Some weaker zones can be found on image for 2500kHz. Particularly there is a weak zone on about 900m depth in the right part of section.

# RIM tomography reconstruction Apparent resistivity, 625kHz



# RIM tomography reconstruction Apparent resistivity, 1250kHz



# RIM tomography reconstruction Apparent resistivity, 2500kHz



# RIM tomography reconstruction Apparent resistivity, 625kHz



RIM tomography reconstruction Apparent resistivity, 1250kHz



# RIM tomography reconstruction Apparent resistivity, 2500kHz



#### 2. Pair WMM010 – WMM011

Work type	surface
Measuring frequencies, kHz	312.5, 625, 1250, 2500
Transmitter antenna length, m	10
Receiver antenna length, m	10
Transmitter step, m	25 ÷ 30
Receiver step, m	1
Stations number	80
Distance between boreholes, m	260 ÷ 380
Depth range, m	200 ÷ 1480
Processing frequencies, kHz	625, 1250, 2500
Processing type	iterative algorithm
Image projection azimuth, Deg.	-1.70
Tomography cell size, m	10 × 10
Resistivity range, Ohm·m	2000 ÷ 5000, 400 ÷ 5000
Figures	15, 16, 17, 18, 19, 20

The survey was carried out on all four frequencies available for the system -2500, 1250, 625 and 312.5 kHz. The lowest frequency 312.5 kHz was found not suitable for processing because of low resolution.

Image for highest frequency of 2500kHz appeared to be more appropriate for this section because of the best resolution.

Some conductive zones can be found on tomography images.

The first zone can be found in the top part of section. Position and shape of the zone most probably reflected not reliable enough because the zone is allocated too close to the top edge of section where the rays of electromagnetic field did not penetrate the zone from above.

The next zone can be found close to WMM010 hole at about 400m depth. It dips to WMM011 hole for about 100m. Comparison of the zone imaged for different frequencies indicates that it was outlined by best way for lowest frequency 625 kHz and by worst way for highest frequency 2500 kHz. Usual situation is reversed. It indicates the zone is located not in the plane of section but apart.

Other zone is detected at about 700m depth. The zone is located close to WMM011 hole but doesn't intersect it.

The next zone is located in bottom part of section. It intersects WMM010 hole at about 1160m depth and rises towards WMM011 hole for about 300m.

The last zone can be found in bottom right part of section at the end of WMM011 hole.



# RIM tomography reconstruction Apparent resistivity, 625kHz

- 27 -



RIM tomography reconstruction Apparent resistivity, 1250kHz

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RIM tomography reconstruction Apparent resistivity, 2500kHz

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# RIM tomography reconstruction Apparent resistivity, 625kHz

- 30 -



RIM tomography reconstruction Apparent resistivity, 1250kHz



RIM tomography reconstruction Apparent resistivity, 2500kHz

- 32 -

#### 3. Pair WMP100 - P060

Work type	surface
Measuring frequencies, kHz	312.5, 625, 1250, 2500
Transmitter antenna length, m	10
Receiver antenna length, m	10
Transmitter step, m	25 ÷ 30
Receiver step, m	1
Stations number	81
Distance between boreholes, m	250 ÷ 355
Depth range, m	200 ÷ 1190
Processing frequencies, kHz	625, 1250. 2500
Processing type	iterative algorithm
Image projection azimuth, Deg.	77.30
Tomography cell size, m	10 × 10
Resistivity range, Ohm·m	2000 ÷ 5000, 400 ÷ 5000
Figures	21, 22, 23, 24, 25, 26

The survey was carried out on all four frequencies available for the system -2500, 1250, 625 and 312.5 kHz. The lowest frequency 312.5 kHz was found not suitable for processing because of low resolution.

Image for highest frequency of 2500kHz appeared to be optimal for this section because of best resolution.

Some conductive zones can be found on tomography images.

The first zone can be found in the top left part of section. It intersects WMP100 on about 300m depth and localized at this hole.

Next two zones can be found in central part of the section. They are imaged by best way for highest 2500 kHz frequency. Zones are comparatively weak, can be seen only on 2000-5000 Ohmm scale and localized on about 770 and 830m depths. Most conductive parts of the zones are allocated between holes and don't intersect them.

One more increased in conductivity, but comparatively weak zone was outlined in the bottom part of section at WMP100 hole and can be seen on the images in 2000-5000 Ohmm color scale only. The shape and boundaries of this zone might be imaged not reliably enough because of closeness to bottom part of section.



RIM tomography reconstruction Apparent resistivity, 625kHz

Fig. 21



RIM tomography reconstruction Apparent resistivity, 1250kHz

Fig. 22



RIM tomography reconstruction Apparent resistivity, 2500kHz

Fig. 23



# RIM tomography reconstruction Apparent resistivity, 625kHz

Fig. 24

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RIM tomography reconstruction Apparent resistivity, 1250kHz

Fig. 25



RIM tomography reconstruction Apparent resistivity, 2500kHz

Fig. 26

#### 4. Summary

As a result of the surveys at Parkin area, investigations were performed for 3 pairs of boreholes.

On the whole, contouring and expansion problem of mineralized zones was solved well in terms of tomography.

Only one strong in conductivity zone can be noticed on the upper part of almost all images. On two sections with WMM boreholes, this zone is positioned in the proximity to WMM010 borehole at the depth intervals of 380-450m. The high conductivity part of the zone is local and extends for not more then 120-140m. On the WMP100-P060 section the upper zone is allocated in adjacent to WMP100 borehole at 300m depth.

The interesting part is the uppermost area of sections with WMM boreholes. Some images show the increasing of conductivity at the depths less then 300m. The most interesting in the list appeared to be WMM010-WMM011 section in 2500 kHz. In color scale of 2000-5000 Ohmm, the anomalous conductivity zone was outlined at the very top of the section. On the images in other frequencies (625 and 1250 kHz) this zone looks different, that is the indication to the heterogeneous character of the conductivity of the zone. The other thing that should be noticed, that the position as well as boundaries of this conductivity anomaly can not be stated to be outlined reliably because of the positioning of the zone to the uppermost limits of the section.

The other increased in conductivity structure can be found on the lower parts of sections at 700-1200m intervals. This zone is vast and very heterogeneous, but not so strong in conductivity. The lower parts of this conductive structure may not be outlined at reliable level, because the electromagnetic field did not penetrate this zone from the below.

#### V. SURVEY AT WISNER AREA

The Wisner property is located on the north range of the Sudbury basin and covers in excess of nine kilometers of highly prospective ground in the footwall to the Wisner embayment. Mineralization occurs as stringers and irregular pods of Cu-Ni-PGE-rich sulphides hosted in irregular, altered zones of Sudbury breccia at the south and southwest area showings.

RIM down a hole surveys were a part of exploration on the property in finding of mineralized zones within units of Sudbury breccias in a cross-hole space.

The conducted RIM surveys on Sudbury area in the past have shown a good correlation of the obtained data with the geology and position of ore zones.

The access to the boreholes was available by tractor roads, the use of a skidder for transportation was essential.

For the reasons of boreholes geometry as well as general conductivity of the cross-hole space on the area, we used all four standard frequencies of the system: 312.5, 625, 1250 and 2500 kHz. The length of antennas was accepted to be 10m, depending on boreholes geometry and chosen frequencies. The step of the transmitter we chose was 20m with accordance to survey setups and boreholes geometry.

#### 1. Pair WIS003 – WIS096W1

Work type	surface
Measuring frequencies, kHz	312.5, 625, 1250, 2500
Transmitter antenna length, m	10
Receiver antenna length, m	10
Transmitter step, m	20
Receiver step, m	1
Stations number	93
Distance between boreholes, m	230 ÷ 310
Depth range, m	230 ÷ 1210
Processing frequencies, kHz	312.5, 625, 1250, 2500
Processing type	iterative algorithm
Image projection azimuth, Deg.	-131.10
Tomography cell size, m	10 × 10
Resistivity range, Ohm·m	2000 ÷ 5000
Figures	27, 28, 29, 30

Survey was carried out on all frequencies available for the system -2500, 1250, 625 and 312.5 kHz. Because of the highest resolution images for highest frequency 2500 kHz represent the section by best way. Results for lowest frequencies 312.5 kHz and 625 kHz shouldn't be considered as reliable enough because relatively close position of holes.

All the images are presented in 2000-5000 Ohmm color scale because of low general conductivity of the cross-hole space.

Some relatively weak but increased in conductivity zones can be found on tomography images.

First zone is located in the upper the section. It extends from one hole to another, intersects WIS003 at about 440m depth and WISWIS096W1 at about 420m depth.

Second zone is located in central part of the section. It intersects WIS096W1 at about 740m and extends towards WIS003 on about 150m.

Third zone is located in bottom part of the section. Image for 2500 kHz indicates the zone is divided on two parts. First part is located at WIS096W1 hole and intersects it on about 1000m depth. Second part is located close to WIS003 hole at about 940m depth.



RIM tomography reconstruction Apparent resistivity, 312,5kHz

Fig. 27



RIM tomography reconstruction Apparent resistivity, 625kHz

Fig. 28



RIM tomography reconstruction Apparent resistivity, 1250kHz

Fig. 29



RIM tomography reconstruction Apparent resistivity, 2500kHz

Fig. 30

# 2. Pair WIS014 – WIS096W1

Work type	surface
Measuring frequencies, kHz	312.5, 625, 1250, 2500
Transmitter antenna length, m	10
Receiver antenna length, m	10
Transmitter step, m	20
Receiver step, m	1
Stations number	100
Distance between boreholes, m	290 ÷ 310
Depth range, m	210 ÷ 1210
Processing frequencies, kHz	312.5, 625, 1250, 2500
Processing type	iterative algorithm
Image projection azimuth, Deg.	-82.80
Tomography cell size, m	10 × 10
Resistivity range, Ohm m	2000 ÷ 5000
Figures	31, 32, 33, 34

Survey was carried out on all frequencies available for the system -2500, 1250, 625 and 312.5 kHz. Because of the highest resolution images for highest frequency of 2500 kHz reveal some details of weak conductive zones. Result for lowest frequency 312.5 kHz shouldn't be considered as reliable enough because relatively close position of holes.

Two main increased in conductivity zones can be found on tomography images.

First zone is located in the upper left part of the section. The zone intersects WIS014 at about 480m depth, rises towards WIS096W1 for about 100m. The zone is imaged by best way on 1250kHz tomography image.

Second zone is located in the central right part of the section. It intersects WIS096W1 at about 750-1000m depth. Image for 2500kHz indicates the zone consists of some separate zones.

Some weak zones were also found in the bottom part of the section close to WIS014 hole. Zones were outlined by best way on images for 2500kHz.



# RIM tomography reconstruction Apparent resistivity, 312,5kHz

Fig. 31



#### RIM tomography reconstruction Apparent resistivity, 625kHz

Fig. 32



#### RIM tomography reconstruction Apparent resistivity, 1250kHz

Fig. 33



#### RIM tomography reconstruction Apparent resistivity, 2500kHz

Fig. 34

#### 3. Summary

As a result of the surveys at Wisner area, investigations were performed for 2 pairs of boreholes.

On the whole, contouring and expansion problem of differently mineralized sulphide zones within the cross-hole space was solved well in terms of tomography.

On the whole the section of WIS014-WIS096W1 is more conductive in general, then WIS003-WIS096W1.

During the surveys at Wisner area, three main increased in conductivity structures were localized. The first upper conductive zone can be seen on both sections at the intervals of 400-500m. At the WIS003-WIS096W1 section this zone is more local and less conductive then on WIS014-WIS096W1 section, where the zone is more extensive and more conductive.

The second increased in conductivity structure was outlined in the central part of both sections at the depths of 600-900m. This zone looks much more complex on WIS003-WIS096W1 section with almost shapeless local risings of conductivity, whereas on WIS014-WIS096W1 section the zone in the central part is more homogeneous on all frequencies except 2500 kHz.

The deepest increased in conductivity zone was found at the bottom part of sections. This zone is less essential then two higher zones, but also increased in conductivity. The inner structure of this zone is highly heterogeneous, which can be noticed from the images in different frequencies.

#### VI. CONCLUSIONS AND RECOMMENDATIONS

#### Conclusions

Within the framework of the current project, the method of radiowave imaging using the FARA apparatus demonstrated a highly effective approach in discovering, in contouring, in investigation of the conductive objects associated with orebodies.

In all, the RIM investigations were conducted in 3 pairs of boreholes at Wallbridge Parkin area, 2 pairs of boreholes at Wallbridge Wisner area and 1 pair of boreholes at Wallbridge Frost Lake area.

The results of investigations allow the following conclusions to be drawn:

- 1. The contouring and expansion problem of differently mineralized zones within SIC rocks was solved well it terms of tomography.
- 2. On a whole during RIM surveys some main and some minor zones of increased conductivity were outlined. From images on different frequencies it can be seen that some zones have heterogeneous character.

#### **Recommendations**

We can recommend the prolongation of the surveys due to the insufficient information for to make reliable conclusions about a shape and contours of the conductive bodies within ore controlling rocks of SIC on the investigated or prospecting areas, which still remains very difficult.

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