GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2463

Results of Ground Magnetic and Electromagnetic (Multifrequency, Horizontal-loop) Measurements in the Cook Lake North area, Snow Lake, Manitoba

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RESULTS OF GROUND MAGNETIC AND ELECTROMAGNETIC (MULTIFREQUENCY, HORIZONTAL-LOOP) MEASUREMENTS IN THE COOK LAKE NORTH AREA, SNOW LAKE, MANITOBA

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Contents

Abstract

This Open File 2463 presents digital results of magnetic gradiometer and multifrequency horizontal-loop (HLEM) surveys in the Cook Lake North area. This area is one of four investigated by ground geophysical techniques in the course of the EXTECH project. The results from other areas (Joannie, Linda-2, Copperman) are being released as separate open file reports. The field measurements were performed by Geoterrex Ltd. in March 1990. The surveys were supervised in the field by Dr. A.K. Sinha, Electrical Methods Section, Mineral Resources Division, who was the Scientific Authority for the contract. EM data were interpreted by Dr. G.J. Palacky, Head of the Electrical Methods Section, Mineral Resources Division.

The multifrequency horizontal-loop APEX MaxMin I manufactured by APEX Parametrics Ltd. of Uxbridge, Ontario, was used in all ground EM surveys. Two coil separations were used in the surveys: 200 m over the whole grid (10 km) and 150 m over the centre portion (6 km). Magnetic surveys were carried out with the EDA Omni IV instrument. Vertical gradient and the total field were measured. The results of geophysical field measurements are presented as edited data files on a diskette.

The survey results will be of use in mineral exploration, structural mapping, and Quaternary geological studies. Weak HLEM and magnetic anomalies appear to be associated with Cook Lake North deposit. Previously unknown bedrock conductors and shear zones were detected as a result of HLEM surveys. All bedrock conductors have low conductance (0.1 to 1.2 Siemens). Horizontal layering interpreted by means of EM data inversion provides information on the nature and thickness and Quaternary sediments covered by the lake. Because of the multitude of users and potential applications, each requiring a different approach, only limited interpretation is provided in this Open File.

1. Introduction

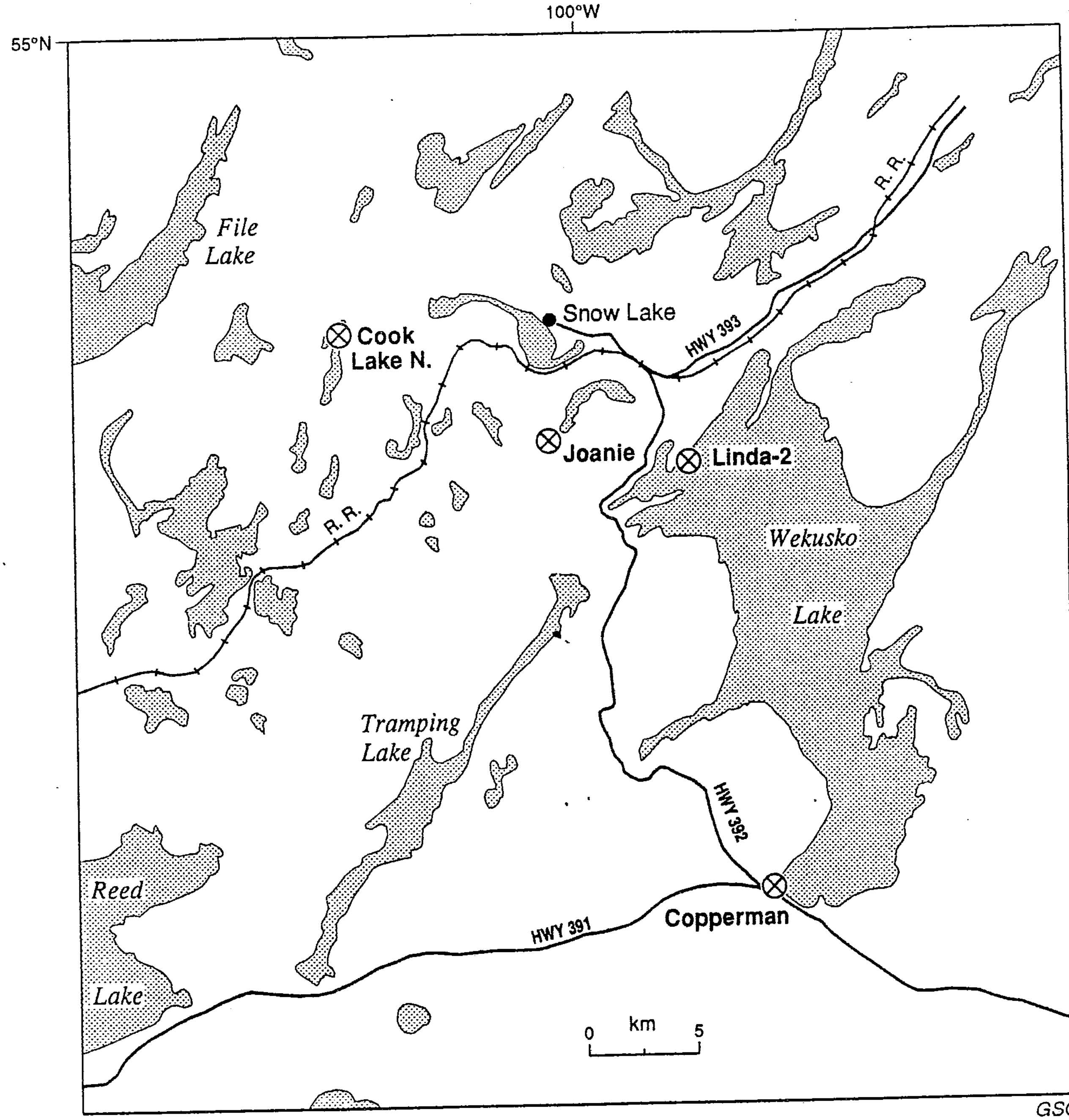
The ground magnetic and electromagnetic (EM) surveys, the results of which are released as this Open File report, were funded by the EXTECH (Exploration Science and Technology) project. The aim of the project, which was initiated by the Mineral Resources Division in 1989, is to assess existing and experimental geological, geophysical and geochemical techniques in test areas and make recommendations for more efficient and cost-effective mineral exploration programs. The Snow Lake greenstone belt in Manitoba was selected as one of the test areas.

After a discussion with other members of the EXTECH group, four areas were selected for ground geophysical investigations: Cook Lake North, Joannie Option (Anderson Lake), Linda-2, and Copperman (location given in Figure 1). The purpose of geophysical surveys was to investigate in situ physical properties (electrical conductivity, magnetic susceptibility) of massive sulphide deposits representing different types of polymetallic mineralization. Because of the nature of EM measurements which are negatively affected by man-made structures, operating mines had to be excluded. The ideal targets would be mineralized bodies with extensive geological information obtained from drilling and ground investigations. While this selection criterion sounds attractive, in reality it was extremely difficult to satisfy. In the Snow Lake area, the amount of geological information on subeconomic deposits is limited and the local access is usually extremely difficult.

Unlike sulphide bodies under the southern and central portion of Cook Lake (Bomber Zone), the target denominated Cook Lake North is poorly known and no geological description exists in literature. For this reason it was not included in the original EXTECH proposal and surveys here were recommended only when no other suitable areas could be identified. In 1983, drilling by Falconbridge Ltd. at the northern end of Cook Lake intersected a 10 m wide sulphide zone at a depth of 300 m. The distance from the surface to the top of the sulphide body is unknown. Exploration strategy of the company has been based on drilling anomalies detected in the course of ground time-domain EM surveys, but this approach resulted in investigating many graphitic zones without base metal potential. It was hoped that detailed geophysical studies would define petrophysical signature of the body.

Geophysical field surveys were carried out by a contractor, Geoterrex Ltd. of Ottawa, between March 4 and 27, 1990 (DSS contract # 23226-9-1332/01-SZ). The field party consisted of Party Chief/Geophysicist P. Beingessner, geophysicist B. Weststrate, and geophysical assistants G. McAuley, S. Jackson and J. Mayner. Line cutting and chaining was done by a subcontractor, J.W. Campbell Services of Winnipeg. Scientific Authority for the survey was Dr. A.K. Sinha, Electrical Methods Section, Mineral Resources Division.

FIGURE 1

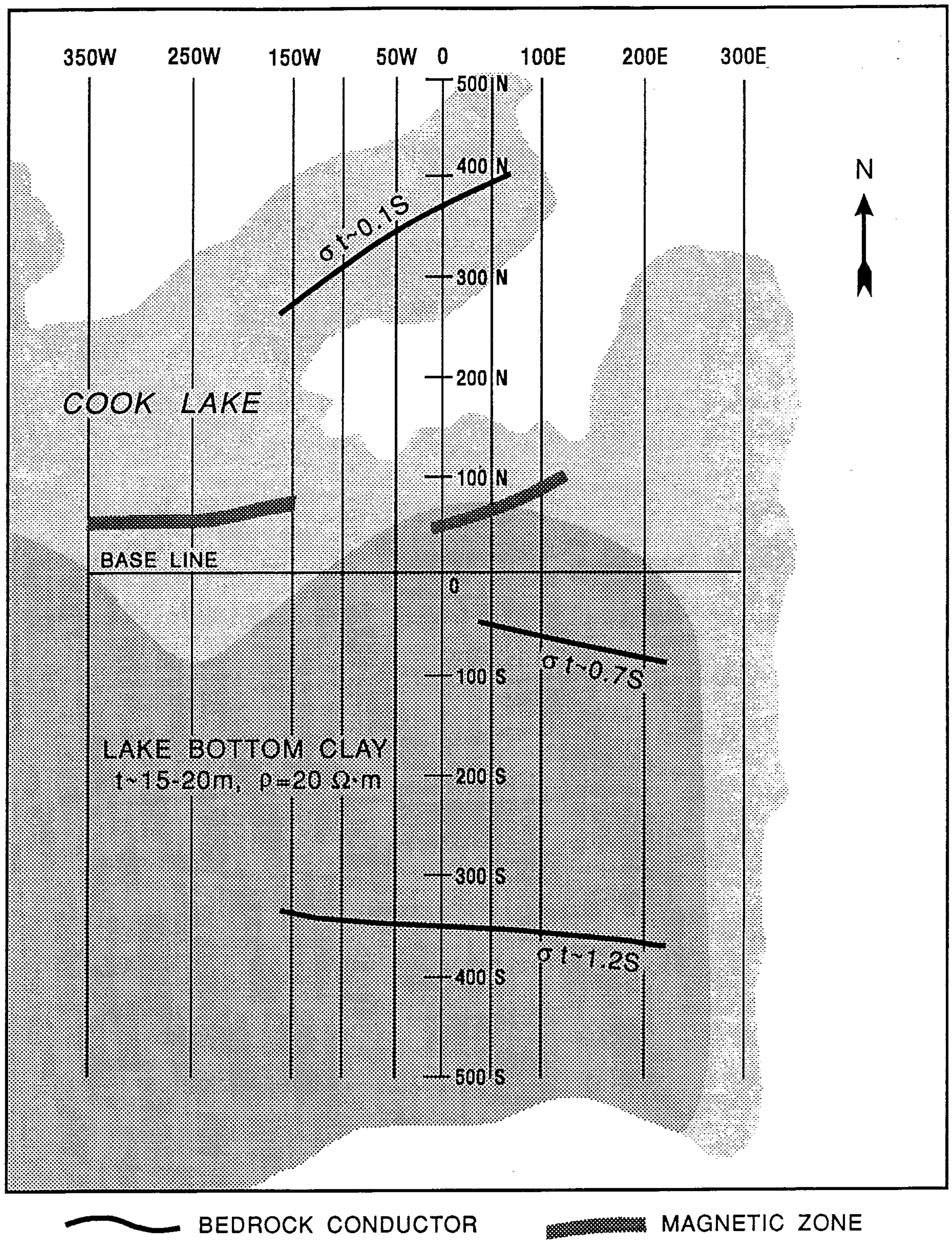

100°W
55°N
File Lake
Cook Lake N.
Snow Lake
HWY 393
R.R.
Joanie
Linda-2
R.R.
Wekusko Lake
Tramping Lake
HWY 392
Reed Lake
Copperman
HWY 391
0 km 5
GSC

2. Surveying of the Target Area

All survey lines in the Cook Lake North area are 1 km long and have a north-south orientation. Basic topography (outline of Cook Lake) and the layout of survey lines are drawn in Figure 2, where geophysical interpretation is also depicted. The locations are described using a metric grid system; e.g. line 300W is 300 m west of line 0, line 150E is 150 m east of line 0. Points along the line are also identified by their distance from the base line; e.g., station 125S lies 125 m south of the base line. A total of ten lines was surveyed: 350W, 250W, 150W, 100W, 50W, 0, 50E, 100E, 200E, and 300E. Stations were pegged every 25 m along the lines.

Line cutting and chaining was carried out prior to geophysical surveying by a subcontractor, J.W. Campbell Services of Winnipeg, Manitoba. The service was completed before February 26, 1990. All stations should have been chained and pegged with accuracy of 10 cm over a distance of 25 m. Such high level of accuracy is required for HLEM surveys when layered earth interpretation is carried out.

FIGURE 2


350W
250W
150W
50W
0
100E
200E
300E
500 N
400 N
300 N
200 N
100 N
0
100 S
200 S
300 S
400 S
500 S
N
σ t~0.1S
COOK LAKE
BASE LINE
σ t~0.7S
LAKE BOTTOM CLAY
t~15-20m, ρ=20 Ω·m
σ t~1.2S
BEDROCK CONDUCTOR
MAGNETIC ZONE

3. Multifrequency Horizontal-Loop Electromagnetic Surveys

The MaxMin I is the latest of the multifrequency ground EM systems designed and manufactured by APEX Parametrics Ltd. of Uxbridge, Ontario. Surveys with the system can be carried out in five modes, but in our study only MAX 1 (horizontal-loop mode) was used (Frischknecht et al., 1991). The transmitter-receiver separation can be changed for fixed distances between 12.5 and 400 m. In the Cook Lake North area, known massive sulphide bodies are deep. Therefore, it was decided to use a coil separation of 200 m for routine coverage. The following lines were surveyed with this coil separation: 350W, 250W, 150W, 100W, 50W, 0, 50E, 100E, 200E, and 300E. To obtain better resolution in the central portion of the area, six lines were surveyed also with a 150 m coil separation (150W, 100W, 50W, 0, 50E, and 100E).

The operating frequencies of the MaxMin I system are 110, 220, 440, 880, 1760, 3520, 7040, and 14080 Hz. In order to obtain a sufficient number of data points for inversion, all available frequencies were used. In mineral exploration programs, the measurements of in-phase and quadrature components are usually performed at only 2 or 3 frequencies. On occasions the noise level was too high on the low frequency surveys (110, 220, 440 Hz) because of electronic interference (Beingessner, 1990).

In the Cook Lake North area, all survey lines are located in flat areas, and therefore no topographic corrections were required. All field data were recorded using an APEX Parametrics MMC data logger. According to the specifications, raw data should have been dumped daily onto a Compaq II portable computer and the results plotted on a Bruning Zeta drum plotter for examination of data quality. Unfortunately, during most of the survey, problems were encountered with the computer hardware, and this procedure was not followed. This technical problem resulted in lower than expected quality on some lines.

The data acquired digitally in the field have been edited by the contractor to conform with the "xyz" file format, which has originally been recommended for the Geosoft 2-D Mapping System and used in the EMIX-MM Plus interpretation software (Interpex, 1988). There are two files for the target area: "cook150.xyz", which contains all HLEM data acquired with the 150 m coil separation, and "cook200.xyz" for the 200 m coil separation measurements. The data can be used directly from the diskette when interpretation is done with the EMIX-MM Plus program (see Appendix B of the manual). Survey lines have to be specified before interpretation of individual lines. Their designators are listed in the Appendix.

Principles of HLEM interpretation have been described by Frischknecht et al. (1991). Responses due to bedrock conductors (massive sulphides, graphitic layers) and shear zones were identified visually and interpreted using the EMIX-MM Plus program. In areas free of bedrock inhomogeneities, HLEM responses were analyzed using the model of multiple layers. Using the same software for a 3-layer model, EM data were inverted to obtain resistivity and thickness values along the whole profile. Some horizontal-layer interpretations were checked using phasor diagrams (Eadie, 1979). The procedure followed in interpretation has been described in detail by Palacky (1991).

4. Magnetic Surveys

Magnetic surveys were carried out with the EDA Omni IV magnetic gradiometer. The following lines were surveyed: 350W, 250W, 150W, 100W, 50W, 0, 50E, 100E, 200E, 300E, and the base line. Readings of the magnetic gradient and the magnetic total field were taken every 25 m. The magnetic data were recorded digitally using the instrument memory. An identical unit served as the base station, which was set up in a magnetically quiet area near Snow Lake. Field data were corrected for diurnal variations using software of the instrument. Several spikes of unknown origin were recorded during the magnetic survey, but all were confirmed to be repeatable by the contractor, and hence should be considered real.

In the office, the field data have been edited to conform with the "xyz" file format. After the station designator, the magnetic total field, the error in the data, the diurnal drift, time of the reading, a data quality indicator, and the vertical gradient values are listed. Every survey line forms a separate file, which is listed in the Appendix (e.g., "CL100E" for line 100E). The magnetic surveys were considered as a secondary tool to EM investigations. The basic goal of magnetic data interpretation was to establish whether there is a correlation between bedrock conductors and magnetic signatures. Once geology of the area becomes better known, magnetic data can be reinterpreted with focus on correlation with lithological formations.

5. Interpretation of Geophysical Data

HLEM anomalies in the Cook Lake North area are due to overburden (Quaternary sediments), bedrock conductors rich in graphite and/or sulphides, and clay-filled shear zones.

The EM response due to conductive overburden can be interpreted using the horizontal layer model. HLEM readings of in-phase and quadrature at eight frequencies were inverted at all stations where readings were not affected by lateral inhomogeneities (e.g., bedrock conductors). As mentioned in Section 3, on some lines the low-frequency data were of poor quality and could not be used. The survey area can be divided into two environments: a) conductive lake-bottom sediments (dark shading in Figure 2) where conductivity and thickness of individual layers could be determined; b) resistive areas, where such determinations were impossible or unreliable because measurable EM responses were recorded only at high frequencies (in such situations, the number of data points was insufficient for inversion).

The conductive area underlies southern half of the survey grid. Its northern boundary is irregular, but runs roughly parallel to the base line. The eastern boundary lies most likely between lines 200E and 300E (conductive response was recorded on line 200E, but not on 300E). To the south and west, the conductive area extends outside the survey grid. Estimates of layer thicknesses and resistivities were consistent in inversion of HLEM data at about 300 stations. There was no significant difference between results obtained for the two coil separations. The average resistivity of the first layer (water) was 500 Ω.m, of the second layer (overburden) 20 Ω.m, and in excess of 5000 Ω.m for the third layer (bedrock). Geologically, only the second layer resistivity is meaningful because resistivity estimates for highly resistive rocks are unreliable. The average overburden resistivity value (20 Ω.m) is typical of water-saturated lake bottom clays. It may be of interest to geologists that the extent of conductive clays does not coincide with the outline of the lake. The clays are absent (or their thickness is very small) at the northern end of the lake. From HLEM interpretation the clay thickness appears fairly constant, between 15 and 20 m. At the moment, there is no drilling information to confirm the accuracy of our interpretation.

Three conductive trends due to sources in the bedrock were identified after interpretation of HLEM data (Figure 2). According to the limited drilling information available, the Cook Lake North deposit is a short strike-length body located close to the centre of the survey area (intersection of the base line with line 0). An HLEM anomaly was detected on three lines (50E and 100E) using both coil separations. The determinations of the anomaly centre slightly vary with the coil separation; between 30S and 40S on short separation surveys and approximately 75S on L=200 m data. The conductor was also detected on line 200E, where only long coil separation surveys were carried out. Estimates of conductance (conductivity-thickness product) determined from five sets of field measurements are low - between 0.3 and 2 S (Siemens). Such values would be untypically low for massive sulphide bodies in most greenstone belt settings, such as Abitibi in Ontario and Quebec or the Bathurst camp in New Brunswick. The north-west striking body appears to continue also on lines 0 and 50W, but the HLEM response becomes so weak that no quantitative determinations were possible. In the target area, EM interpretation was made difficult by the fact that the bedrock conductor is very close to the northern margin of conductive lake bottom sediments. A well-defined anomaly of about 200 nT can be seen on total-field magnetic data, but it is centred at 50N on lines 0 and 50E and 100N on line 100E (about 75 to 100 m north of the interpreted HLEM axis). A weaker magnetic anomaly (about 100 nT) was detected along the same trend to the west (lines 150W to 350W). It is not clear whether this dislocation between EM and magnetic response is due a presumably complex structure of the deposit or due to separate anomaly sources for the two techniques.

A clearly defined conductive trend with east-west strike was detected with the HLEM method on lines 150W to 200E, at approximately 350S. Average conductance of the conductor is 1.2 S, which is marginally higher than estimates for the Cook Lake North deposit, but still very low for typical massive sulphides or graphitic layers. Conductance estimates along the trend appear fairly consistent at both coil separations. There is no associated magnetic anomaly. The geological nature of the conductor is unknown as no drilling has been carried out.

The third bedrock conductor which is located under the northern inlet of the lake has a lower conductance than the previously described bodies (average 0.1 S). The geophysical signature of the anomaly and its topographic location (following an arm of the lake) leads us to believe that its origin is a clay-filled shear zone. No magnetic signature of the conductor could be established.

5. Conclusions

The HLEM technique proved effective in detecting bedrock conductors and in mapping Quaternary sediments. The Cook Lake North deposit, which was intersected by drilling at a depth of 300 m, was detected by HLEM and magnetic surveys. However, the peak EM and magnetic anomalies do not coincide, indicating that the two techniques respond differently to the presumably complex deposit. The estimated conductance values are very low compared with those typical of Abitibi massive sulphide orebodies.

Two previously unknown bedrock conductors were detected in the survey area. One located in the northern inlet of the lake is believed to be a clay-filled shear zone, but the other, more conductive, should be investigated as the possibility of sulphide mineralization cannot de discounted.

The results obtained by inversion of HLEM data using the horizontal layer model outlined the extend of conductive lake bottom sediments. The conductive clay layer appears to be between 15 and 20 m thick, but no drilling information is available to confirm our interpretation.

Acknowledgements

Ground magnetic and electromagnetic surveys were carried out by Geoterrex Ltd. of Ottawa under a contract to Supply and Services Canada (DSS #23226-9-1332/01-SZ). Members of the EXTECH group, Mineral Resources Division, Geological Survey of Canada, helped us to select survey areas. Mr. R.B. Band, Exploration Manager, Falconbridge Ltd., Winnipeg, discussed with us previous geophysical surveys in the area and allowed us to inspect proprietary company data.

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APPENDIX

LIST OF PROFILE FILES

Files on the enclosed diskette are indicated by quotation marks (")

Negative sign before the line number in HLEM files indicates west, e.g. line 350W is listed as -350.

350W	HLEM, L=200 m (file "cook200.xyz")
"CL350W"	Magnetics (total field and vertical gradient)
250W	HLEM, L=200 m (file "cook200,xyz")
"CL250W"	Magnetics (total field and vertical gradient)
150W	HLEM, L=200 m (file "cook200.xyz")
150W	HLEM, L=150 m (file "cook150.xyz")
"CL150W"	Magnetics (total field and vertical gradient)
100W	HLEM, L=200 m (file "cook200.xyz")
100W	HLEM, L=150 m (file "cook150.xyz")
"CL100W"	Magnetics (total field and vertical gradient)
50W	HLEM, L=200 m (file "cook200.xyz")
50W	HLEM, L=150 m (file "cook150.xyz")
"CL50W"	Magnetics (total field and vertical gradient)

0	HLEM, L=200 m (file "cook200.xyz")
0	HLEM, L=150 m (file "cook150.xyz")
"CL0"	Magnetics (total field and vertical gradient)
50E	HLEM, L=200 m (file "cook200.xyz")
	HLEM, L=150 m (file "cook150.xyz")
"CL50E"	Magnetics (total field and vertical gradient)
100E	HLEM, L=200 m (file "cook200.xyz")
	HLEM, L=150 m (file "cook150.xyz")
"CL100E"	Magnetics (total field and vertical gradient)
200E	HLEM, L=200 m (file "cook200.xyz")
"CL200E"	Magnetics (total field and vertical gradient)
300E	HLEM, L=200 m (file "cook200.xyz")
"CL300E"	Magnetics (total field and vertical gradient)
"0N"	Magnetics (total field and vertical gradient) along the base line