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Ground very low frequency (VLF) and magnetic survey results at the Copperman site, near Snow Lake, Manitoba

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MINERAL RESOURCES DIVISION

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GROUND VERY LOW FREQUENCY (VLF) AND MAGNETIC SURVEY RESULTS AT THE COPPERMAN SITE, NEAR SNOW LAKE, MANITOBA

A.K. Sinha

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Contents

Abstract

This Open File presents results of ground very low frequency electromagnetic (VLF-EM) and magnetic total field and gradiometer surveys over the Copperman site, near Snow Lake, Manitoba. This area is one of the four investigated by ground geophysical techniques as part of the EXTECH project. The results from the other three areas (Linda-2, Cook Lake North and Joanie Option) are being released through separate Open File reports. The field surveys were performed by Dr. A.K. Sinha of the Electrical Methods Section, Mineral Resources Division in June/July, 1990 assisted by Mr. Donald Henderson, a summer student. The results were compiled and processed by Mr. Henderson in Ottawa under Dr. Sinha's supervision. The geophysical data were interpreted in Ottawa by Dr. A.K. Sinha of the Mineral Resources Division.

The instrument used for the VLF-EM and magnetic survey was EDA OMNI-PLUS system, manufactured by EDA Instruments Inc., Toronto and maintained by Scintrex Ltd., Toronto. The system was used in the combined VLF/magnetometer mode during our survey. Surveys were taken along several parallel lines, 50 m apart, oriented at 144°E. The VLF results are presented as plots of the various measured parameters, such as total field, in-phase, quadrature, tilt angle and apparent resistivity with distance for all three frequencies. The magnetic results consist of total field and vertical magnetic gradient values measured at each station on all lines.

The survey results are expected to be useful in mineral exploration and structural mapping. Several weak conductors trending N-S to NE-SW were detected in the area from the VLF survey. Some of these coincide with the locations of known conductors detected by previous surveys using DEEPEM, Turam and vertical loop EM systems. The magnetic response is generally weak over the area, and the magnetic trends do not coincide with VLF responses except in one area where a large magnetic gradiometer anomaly is obtained near a Cu-Zn showing at the northern end of the survey area. Several magnetic anomalies were recorded near drill hole collars and other large steel objects, such as pipes, mostly near the baseline. Preliminary interpretation of the geophysical anomalies are included in this Open File. More rigorous interpretation of individual anomalies will be presented in a future publication.

1. Introduction

Results of ground very low frequency electromagnetic (VLF-EM) and magnetic surveys which are released in this Open File report are part of the EXTECH (Exploration Technology) project, which was initiated by the Mineral Resources Division in 1989. The aim of the project 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, Joanie Option (Anderson Lake), Linda-2, and Copperman (locations 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 extremely difficult. Geological mapping of target areas is planned during the summer of 1991.

The Copperman property is located at the southwestern end of Wekusko Lake, about 25 km south of Snow Lake (see Figure 1). The access to the site is good, since Highway 391 runs across the property. The area is underlain by mafic to felsic metavolcanic rocks and Paleozoic sedimentary rocks. The metavolcanic rocks are predominantly flows, tuffs and fragments of basaltic composition with minor amounts of massive and cherty rhyolite. The property has rather poor outcrop - only about 10% of the ground. A Cu-Zn showing is present near the southern tip of the Wekusko Lake (Figure 2), which comprise several old trenches and pits in and around a gossan showing extensive hematite and limonite staining. The mineralization consists mainly of sphalerite veins, with associated pyrite with traces of chalcopyrite, pyrrhotite and arsenopyrite.

The Copperman deposit consists of two zones of high-grade Cu-Zn mineralization. The first zone (so-called A Zone) consists of 165,000 tons averaging 3.1% Cu and 3.1% Zn, while the second zone (the B Zone) has 25,500 tons of ore averaging 1.88% Cu and 15.2% Zn. The two zones appear to consist of narrow lenses, stringers and pods of a massive sulphide, possibly representing a feeder to a larger sulphide body, as yet undiscovered. Good ore-grade intersections with up to 8% Cu and 7% Zn have been made in boreholes, which makes this area an interesting one for further study.

The area has been surveyed earlier by various companies and contractors using several ground and airborne geophysical methods, such as resistivity, vertical loop EM, Turam, magnetics, DEEPEM transient EM, induced polarization and Dighem II airborne EM. The resistivity and vertical loop EM surveys detected anomalies near the Cu-Zn showing. A follow-up drilling located significant Cu-Zn mineralization at that site. A magnetic high was also detected over the Cu-Zn showings. The Turam survey detected two short strike-length conductors south of the showing, in addition to a long NE-SW trending conductor, about 500 m east of the showing, which turned out to be graphitic horizon. Dighem II airborne EM results located the graphitic conductor well, but only a weak EM response was obtained over the Cu-Zn showing, and a resistivity low. The

DEEPEM results located the graphitic conductor and a short conductor, about 50 m east of the showing, running NE-SW. Similar results were obtained with an IP survey with a McPhar P-660 frequency-domain system, (Kenny, 1983).

A ground VLF survey over 4 lines, passing near the Cu-Zn showing (Band, 1990 Personal Communication) indicated good tilt angle anomaly on two lines. This single frequency VLF system detected the presence of a short strike conductor, about 50 m east of the showing. All previous surveys indicated that the conductance of the conductor is low, and in view of the promising results with the VLF survey, it was hoped that a more extensive ground VLF survey with an updated instrument capable of operating at 3 frequencies simultaneously, and measuring ground resistivity and total VLF field in addition to the tilt angle parameter will shed more light on the disposition of poorly conductive targets in the area. A follow-up ground magnetics and gradiometer survey was also planned to supplement the ground VLF results.

The survey area was hit by a forest fire in 1989, which burnt down most of the trees and also the picket posts from previous ground surveys. The NE-SW trending baseline was, however, located with the help of Falconbridge Ltd. geologists, along with one of the survey lines (4+00N) from the previously established imperial grid. A new metric grid was established using this line as our line 0+00N. New lines 50 m apart were cut and chained by Dr. A.K. Sinha and his assistant using chain saws, axes, etc. Although initial plans called for survey lines at least 1 km long, the rough terrain, presence of large numbers of burnt and dead trees on the ground and limited time and manpower available did not make that possible. As a result, the lines varied in length from 1.1 km to 750 m as shown in Figure 2.

2. Surveying of the Target Area

An existing baseline, oriented at 54°E was chosen to be the baseline for this survey. Hence all survey lines at Copperman are oriented at 144°E, in a generally NW-SE direction. The seven survey lines vary in length from 1.1 km to 750 m, and are 50 m apart. The layout of the survey lines in relation to the Wekusko Lake and the Cu-Zn showing are shown in Figure 2. An existing line from the previous imperial grid (in ft.) (4+00N) was taken to be line 0+00N for this survey. Positions along the line are identified by their distance from the baseline; e.g. station 200 W is located 200 m west of the baseline. The line numbers identify the distance of that line from line 0+00N; e.g. line 1+00S is 100 m south of the line 0+00N. The following lines were cut, chained and surveyed: 1+00N, 0+50N, 0+00N, 0+50S, 1+00S, 1+50S, and 2+00S.

3. Very Low Frequency Electromagnetic Surveys

The OMNI-PLUS combined magnetometer/VLF system, designed and manufactured by EDA Instruments Inc., Toronto is one of the new generation of ground geophysical instruments for multiparameter surveys. It is a portable, microprocessor-based system, capable of measuring changes or contrasts in physical properties by two different types of geophysical sensors: magnetic and electromagnetic. Therefore, the system can take simultaneous measurements of both magnetic and VLF-EM signals and store them internally in as little as 4 seconds. The instrument can be used singly as a magnetometer, a VLF receiver or as a combined magnetometer/VLF system. The instrument is capable of measuring the magnitude of the total magnetic field, its vertical gradient, as well as secondary field components from up to three VLF sources simultaneously (Scintrex, 1988).

Measurements are obtained by the use of two types of sensors; a pair of proton precession sensors carried on a pole to measure the magnetic field and its gradient, and a three-component sensor worn on the back of the operator to measure the magnetic components of the VLF secondary field. In addition, VLF electric fields can also be measured using an attachment to the VLF measurement circuitry. An electronic console is worn on the front of the operator to select, view, and store the data in an internally protected memory. A real-time clock powered by a lithium battery is also present inside the console.

The OMNI-PLUS stores the raw data inside its memory. Corrections for the magnetic diurnal variations and VLF primary field variations are performed internally using either a tie-line method (looping) or a compatible base station unit. It also monitors the data quality each time a measurement is taken by displaying DECAY bars through an LCD display. Data with less than 2 DECAY bars are normally not acceptable. VLF readings were taken every 25 m.

In standard ground VLF measurements, a uniform direction is maintained while taking readings in order to maintain consistent signs on all in-phase, quadrature or tilt angle values. Since OMNI-PLUS has no orientation system, a convention is followed that maintains that North and East are positive. Hence profiles plotted looking east (i.e. S to N) or north (i.e. W to E) will have the proper crossover sign. If during a survey, the operator notices that a station has "gone off the air", he can change one or all frequencies without losing previously recorded data. The standard OMNI-PLUS can store data for up to 1300 stations before they must be dumped to a computer. After each dumping, the system resets itself and will overwrite on existing data.

The system measures the following parameters at up to three frequencies simultaneously

a) Vertical in-phase component (percent)

b) Vertical quadrature component (percent)

c) Total VLF field strength (units)

d) Tilt angle (degrees)

e) Magnetic primary field direction

f) Apparent resistivity (ohm-m)

g) Phase angle (degrees)

The last two parameters require orthogonal electric field measurements using two sets of electrodes. For the Copperman survey, three VLF stations, NAA (Cutler, Maine -

24.0 kHz), NSS (Annapolis, Maryland - 21.4 kHz) and NLK (Jim Creek, Washington - 24.8 kHz) were used, since they were the strongest ones in that area.

In very rugged terrain, a terrain correction should be used to the VLF data. However, the topography in the survey areas was mostly flat or undulating. Hence no corrections were needed. The internal memory can hold VLF and magnetic data for several days before dumping to a computer. However, due to an unfortunate accident during the dumping of the last set of data over the two northernmost lines, the VLF data over those two lines were lost.

The processing of the data was done in Ottawa. In the first stage of processing, corrections are applied for the variation of the VLF primary field and is done internally using the tie-line (looping) method. The various VLF parameters such as the total field, in-phase, quadrature, tilt angle and apparent resistivity are plotted against distance for different survey lines. Data from all three VLF frequencies are plotted on the same sheet for comparison.

4. Magnetic Surveys

Magnetic surveys were carried out with the EDA OMNI IV magnetic gradiometer. The following lines were surveyed: 1+00N, 0+50N, 0+00N, 0+50S, 1+00S, 1+50S and 2+00S. Readings of the magnetic gradient and the magnetic total field were taken every 25 m. Data were recorded using the internal memory of the instrument. 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 one-point and spiky anomalies of unknown origin were recorded during the magnetic survey, but all were repeatable anomalies and hence should be considered real. It was noted that some of the anomalies were in close proximity with drill hole collars, and hence are to be considered cultural in nature.

The magnetic surveys were considered as a secondary tool to EM investigations. The basic goal of magnetic data interpretation was to establish whether there was a correlation between bedrock conductors and magnetic signatures. Once geology of the area becomes better known, magnetic data can be reinterpreted with a view to correlating them with lithological units.

5. Interpretation of Geophysical Data

The ground VLF anomalies at the Copperman area are due to shallow bedrock conductors containing sulphides or graphite, or due to fracture or shear zones containing fluid or conductive sediments. These may also be due to bedrock depressions which have been filled up with conductive overburden.

The VLF anomalies may be interpreted using the model of a steeply-dipping two-dimensional conductor, located in a highly resistive host rock (Sinha, 1990). The tilt angle and total field VLF response parameters can be used to determine the location of the conductors. The tilt angle anomalies in the area are generally of small amplitude, and irregular in shape, thus implying that the conductors are probably limited in strike direction and not highly conductive. The poor conductivity of the bodies agrees with the results of horizontal loop EM surveys at three other sites in the Snow Lake area.

Figure 3 shows the interpreted locations of conductors from the tilt angle response. It shows a number of conductors, trending from north to NE-SW west of the baseline (0+00E). Two weaker conductors are mapped east of the baseline which turn eastward in their northern end. Another conductors crosses the baseline on line 0+00N. The extent of its northern continuation is unknown since the VLF data on lines 0+50N and 1+00N were lost due to an accidental erasure. However, this conductor would pass close to the Cu-Zn showing, if extended northward. The magnetic anomalies are also shown in Figure 3. Generally, the positions of the EM and magnetic anomalies do not match except for the anomaly passing through the baseline. This magnetic anomaly also passes close to the Cu-Zn showing. Figure 4 shows the interpreted locations of VLF conductors derived from the total field anomalies. There is a slight discrepancy between mapped conductor locations east of the baseline, but the match is better to the west of the baseline and for the conductor passing through the baseline. However a short E-W trending conductor is detected in Figure 4 between lines 2 + 00 S and 1 + 50 S at the extreme west end. The forking out of the westernmost conductor at the north end is shown clearly in both diagrams. The magnetic anomalies are also shown in Figure 4.

Figure 5 shows the contoured apparent resistivity values in the area using data from station NAA (24.0 kHz). The low resistivity of the ground at the western end of lines 1+00S to 2+00S is due to extensive soil and moss cover with vegetation in that area. Several high resistivity-zones are found at locations where the bedrock is exposed at the surface, or when resistive basaltic dykes meet the surface. Since the VLF conductors in the area appear to be of low conductance, their presence do not affect the apparent resistivity values significantly.

The contours of total field magnetics and magnetic gradiometer values are shown in Figures 6 and 7 respectively. The total field anomalies show a magnetic high somewhat south of the Cu-Zn showing. Another large magnetic high is seen at the western end of line 1+00N, and should be studied carefully. The gradiometer contours show two highs at the same locations as seen in Figure 6. Several anomalies of smaller amplitude are also seen which seem to correlate with the presence of the bedrock on the ground. The location of the first magnetic anomaly agrees well with the location of the known mineralization near 0+50W, 0+50N. On the other hand, the other anomalous area seems to represent a conductor detected by earlier Turam and DEEPEM surveys.

6. Conclusions

The ground multifrequency VLF method proved useful in detecting shallow conductors in the Copperman area. Since the azimuths of the primary VLF field from stations NLK, NAA and NSS are different, the simultaneous use of all three stations should enable detection of conductors with a wide range of azimuth values. In fact, however, the azimuths from NAA and NSS were rather close at the Snow Lake area, which is borne out by the similarity of response using NAA and NSS. The magnetic anomalies in the area generally do not coincide with EM anomalies, indicating that the two methods respond differently to the subsurface inhomogeneities. An exception to this is the conductor passing through the baseline whose location from the EM and magnetic anomalies is almost identical.

Due to an accidental erasure of VLF data from the two northern lines, the VLF coverage over the Cu-Zn showings is missing. The presence of the conductor passing through the baseline is mapped continuously from 1+50S to 0+00N, and its extension towards north would pass very close to the position of the Cu-Zn showing. An evidence for the possible presence of a conductor comes from the apparent resistivity contours (Figure 5) using NAA which shows a zone of low resistivity in that area. The magnetic results show a strong anomaly almost coincident with the position of the VLF conductor. The magnetic results show another strong anomaly at the western edge of line 1+00N. Although we do not have any VLF data at this site due to the accidental erasure, the position of this anomaly seems to agree with the location of a conductor detected by earlier Turam and DEEPEM surveys.

Acknowledgments

The author is indebted to members of the EXTECH group, Mineral Resources Division, Geological Survey of Canada who helped in selection of this site and providing geological information. Mr. R.B. Band, Exploration Manager, Falconbridge Ltd., Winnipeg provided information about previous surveys at Copperman and allowed us to inspect proprietary company data. The work could not have been undertaken without the help and enthusiasm of Mr. Donald Henderson, a summer student, who not only helped with the field work, but was also responsible for initial processing of the data.

References

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Scintrex Limited, 1988, Operations Manual OMNI-PLUS VLF/Magnetometer system.

Sinha, A.K., 1990, Interpretation of Ground VLF-EM Data in Terms of Inclined Sheet-Like Conductor Models, Pure and Applied Geophysics, 132, 733-756.

List of Profile Plots

2+00S	VLF total field variations at 3 frequencies
	VLF in-phase field component at 3 frequencies
	VLF quadrature component at 3 frequencies
	VLF tilt angle variations at 3 frequencies
	VLF resistivity variations at 3 frequencies
	Magnetic total field and gradiometer variations
1+50S	VLF total field variations at 3 frequencies
	VLF in-phase field component at 3 frequencies
	VLF quadrature component at 3 frequencies
	VLF tilt angle variations at 3 frequencies
	VLF resistivity variations at 3 frequencies
	Magnetic total field and gradiometer variations
1+00S	VLF total field variations at 3 frequencies
	VLF in-phase field component at 3 frequencies
	VLF quadrature component at 3 frequencies
	VLF tilt angle variations at 3 frequencies
	VLF resistivity variations at 3 frequencies
	Magnetic total field and gradiometer variations

0+50S	VLF total field variations at 3 frequencies
	VLF in-phase field component at 3 frequencies
	VLF quadrature component at 3 frequencies
	VLF tilt angle variations at 3 frequencies
	VLF resistivity variations at 3 frequencies
	Magnetic total field and gradiometer variations
0+00N	VLF total field variations at 3 frequencies
	VLF in-phase field component at 3 frequencies
	VLF quadrature component at 3 frequencies
	VLF tilt angle variations at 3 frequencies
	VLF resistivity variations at 3 frequencies
	Magnetic total field and gradiometer variations
0+50N	Magnetic total field and gradiometer variations
1+00N	Magnetic total field and gradiometer variations

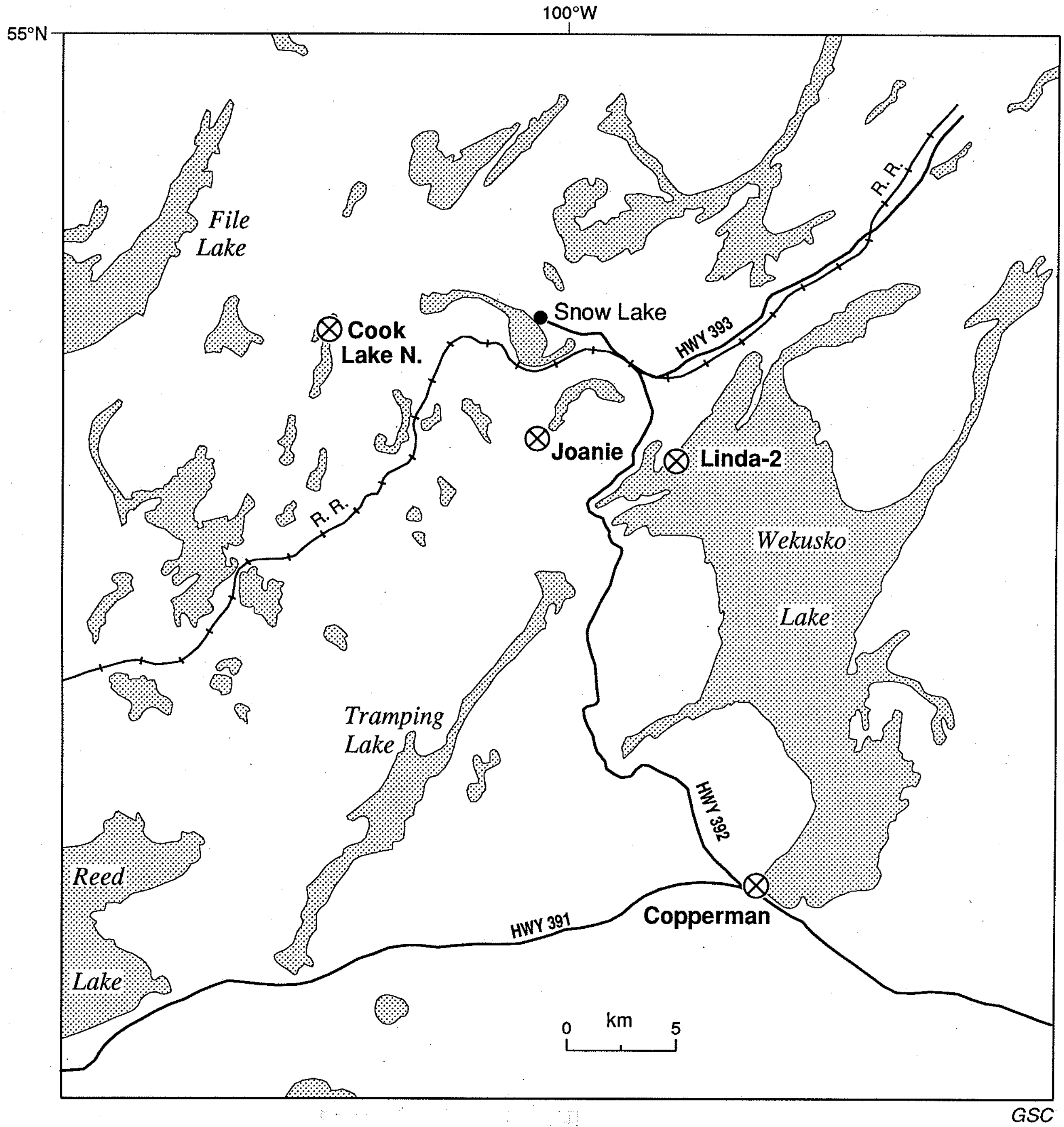
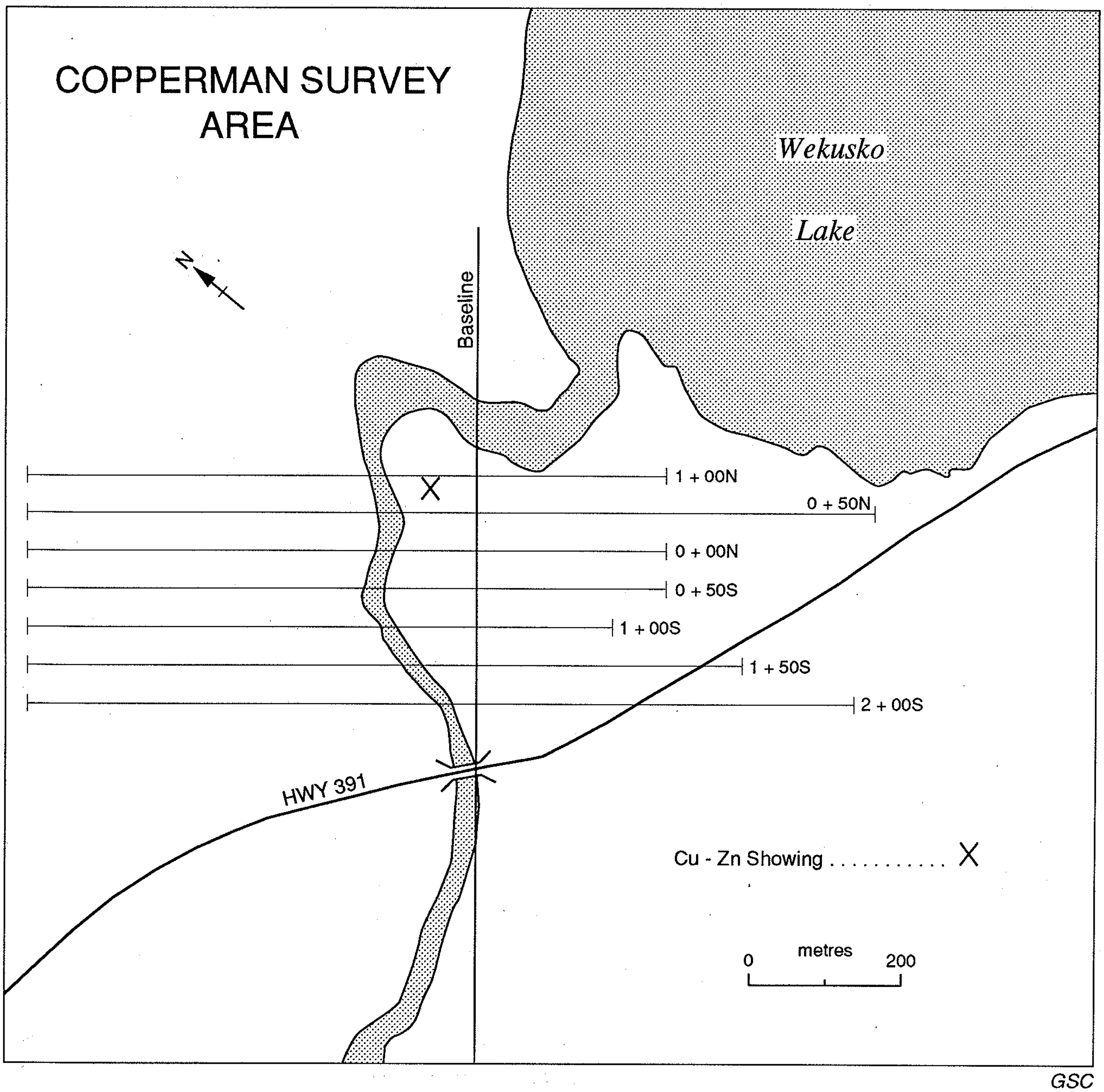

100°W
55°N
File
Lake
Cook
Lake N.
Snow Lake
HWY 393
R. R.
Joanie
Linda-2
R. R.
Wekusko
Lake
Tramping
Lake
HWY 392
Reed
Lake
HWY 391
Copperman
0
km
5
GSC

Figure 1



COPPERMAN SURVEY AREA
Wekusko
Lake
N
Baseline
1 + 00N
0 + 50N
0 + 00N
0 + 50S
1 + 00S
1 + 50S
2 + 00S
HWY 391
Cu - Zn Showing X
0
metres
200
GSC

Figure 2

COPPERMAN AREA, MANITOBA
Interpreted conductors from VLF tilt angle data

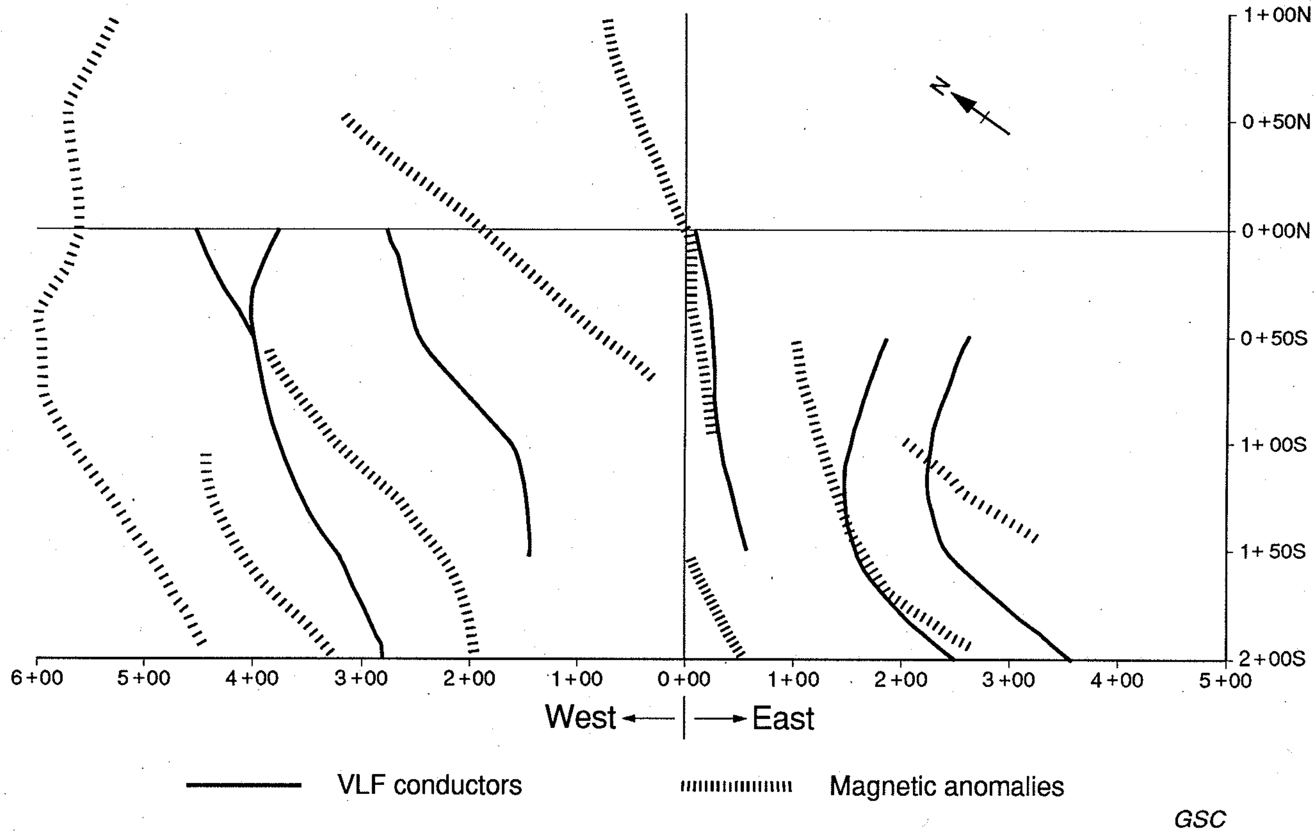


Figure 3

COPPERMAN AREA, MANITOBA
Interpreted conductors from VLF total field data

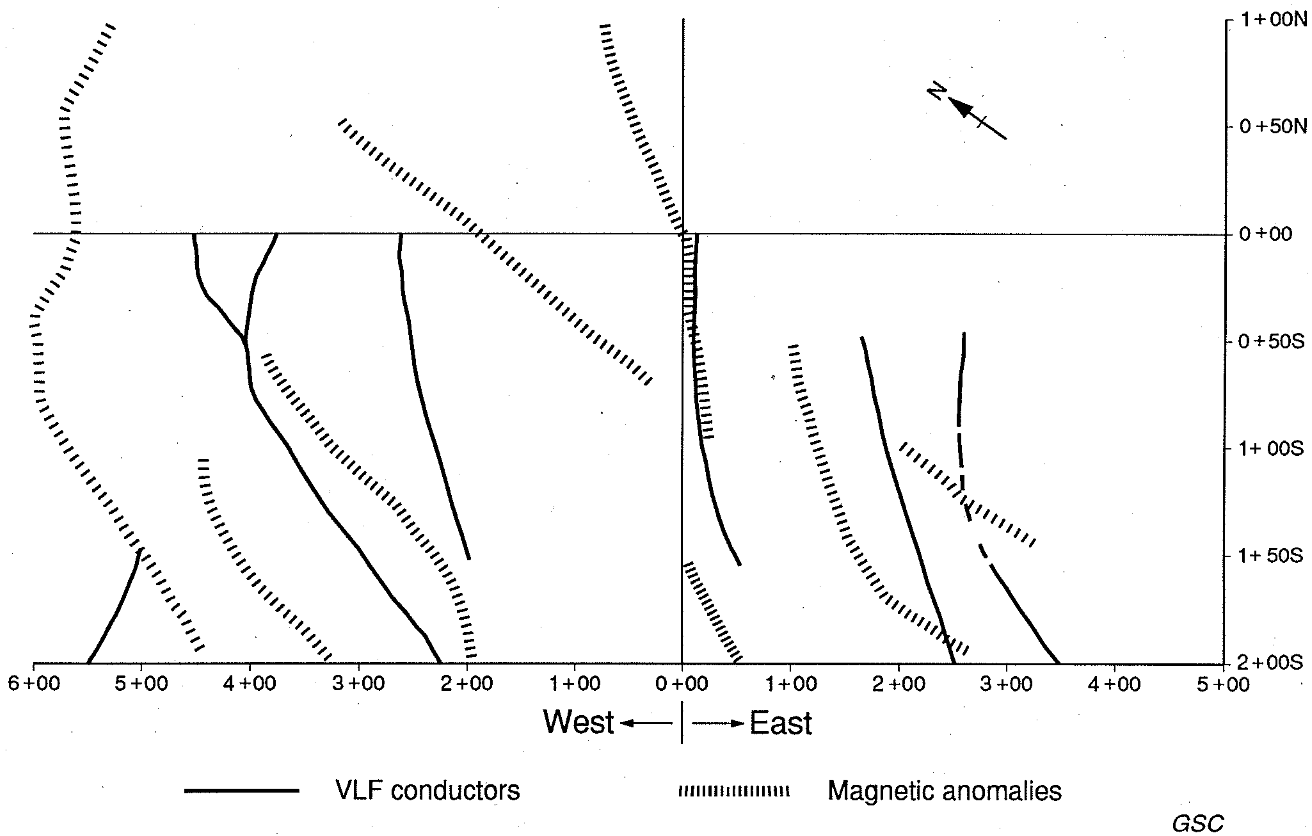


Figure 4

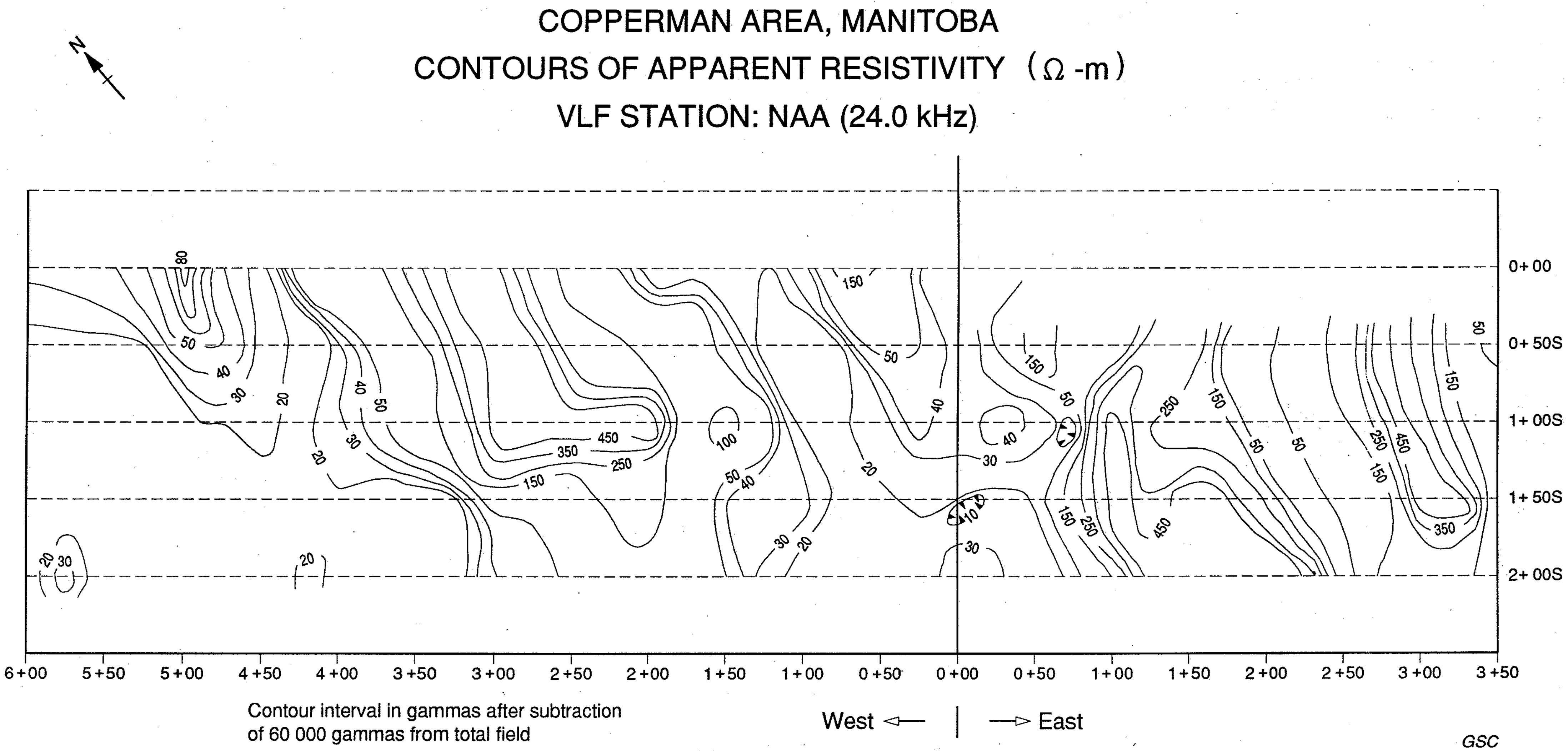

COPPERMAN AREA, MANITOBA
CONTOURS OF APPARENT RESISTIVITY (Ω -m)
VLF STATION: NAA (24.0 kHz)
N
0+00
0+50S
1+00S
1+50S
2+00S
6+00
5+50
5+00
4+50
4+00
3+50
3+00
2+50
2+00
1+50
1+00
0+50
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
Contour interval in gammas after subtraction
of 60 000 gammas from total field
West
East
GSC

Figure 5

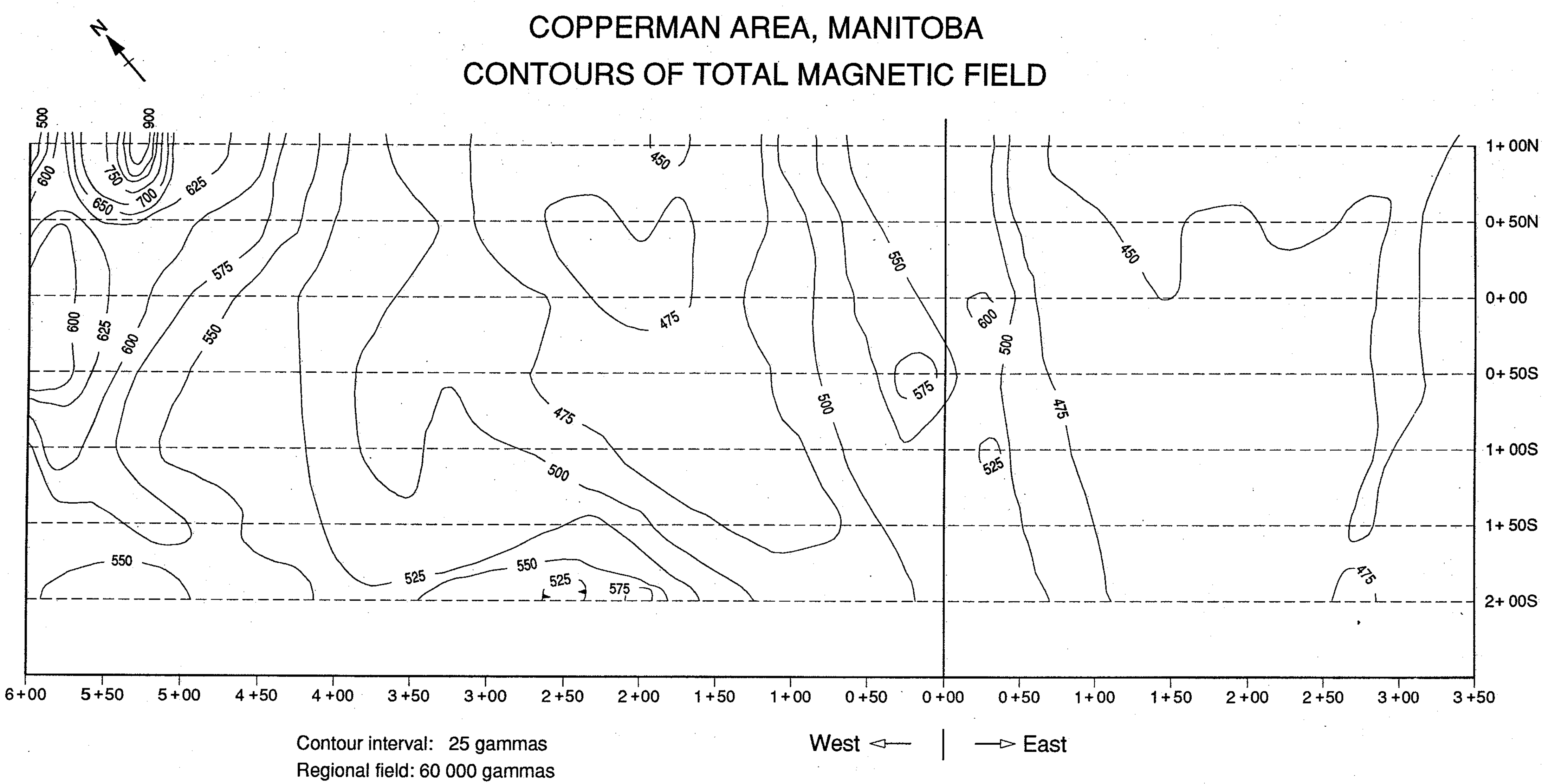
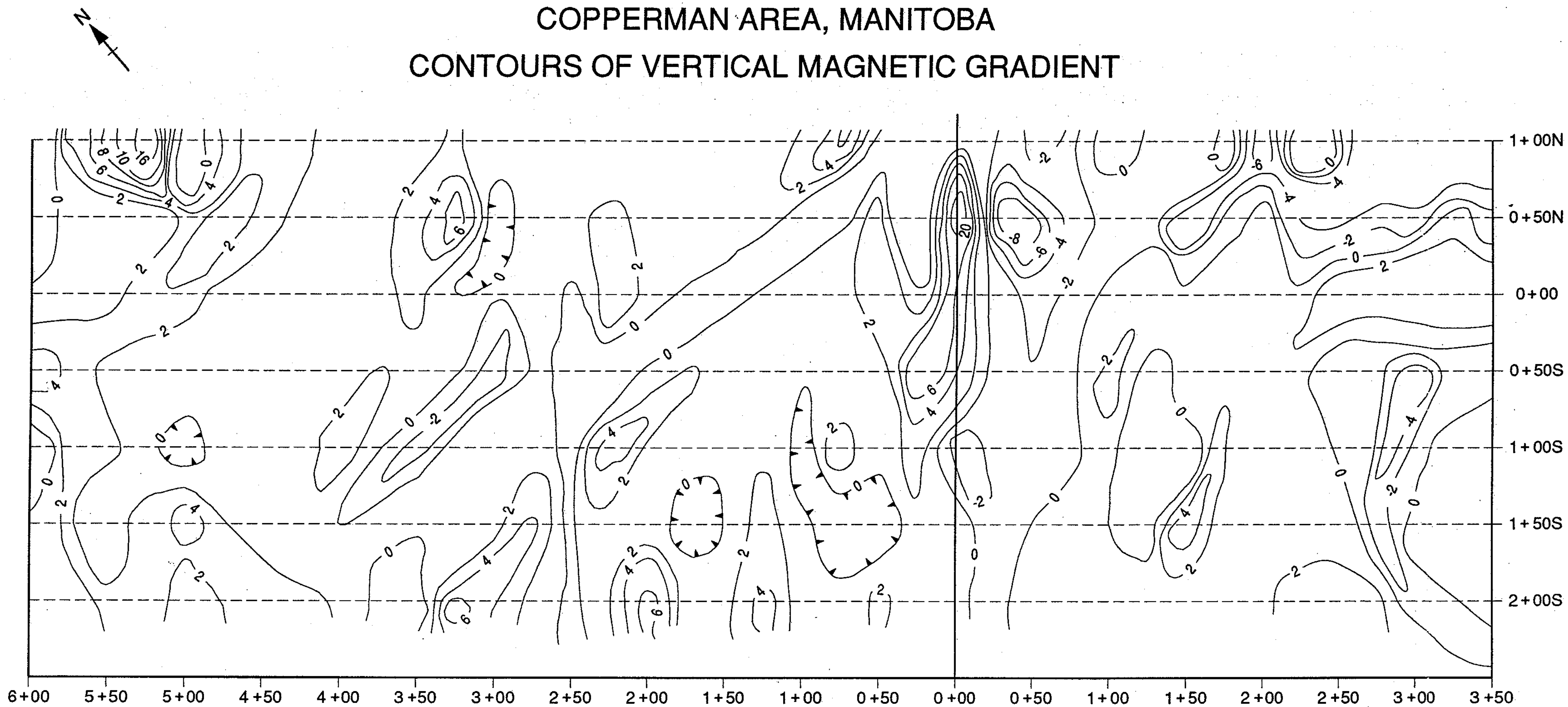

COPPERMAN AREA, MANITOBA
CONTOURS OF TOTAL MAGNETIC FIELD
N
1+00N
0+50N
0+00
0+50S
1+00S
1+50S
2+00S
6+00
5+50
5+00
4+50
4+00
3+50
3+00
2+50
2+00
1+50
1+00
0+50
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
Contour interval: 25 gammas
Regional field: 60 000 gammas
West
East
GSC

Figure 6

COPPERMAN AREA, MANITOBA
CONTOURS OF VERTICAL MAGNETIC GRADIENT



Contour interval: 2 gammas /m

West ◁— | —▷ East

Figure 7

GSC