UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Airborne Electromagnetic and Magnetic Survey of parts of the Upper Peninsula of Michigan

By Geoterrex Limited

With an Introduction by William D. Heran

U.S. Geological Survey

Open File Report 82-60A

1982

This report was prepared under contract to the U.S. Geological Survey and has not been reviewed for conformity with USGS editorial standards and stratigraphic nomenclature. Opinions and conclusions expressed herein do not necessarily represent those of the USGS. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

Introduction

by

William D. Heran

The data presented in this report are from an airborne electromagnetic INPUT (Registered trademark of Barringer Research Ltd.), and total field magnetic survey conducted by Geoterrex Limited of Ottawa Canada. The survey was flown in the Upper Peninsula of Michigan within the Iron River 2° quadrangle. (See location map in Geoterrex Report.) This quadrangle was being studied as part of the U.S. Geological Survey (USGS) CUSMAP (Conterminous United States Mineral Appraisal Program) project. The survey was designed to provide geophysical information which will aid in the integrated geological assessment of the Iron River 2° quadrangle.

Specifically the two areas in this survey were flown to better define the contact between Proterozoic Jacobsville Sandstone and older adjacent rocks, which are covered by substantial amounts of glacial overburden. This contact is thought to be, in a general sense, favorable for uranium mineralization (Kalliokoski, 1977).

The funding for the collection of geophysical data in area A was provided by the Department of Energy as part of their study of world class uranium deposits. The areas flown are additions to a previous survey flown in the same region. For a description and data from the other eight survey areas refer to U.S. Geological Survey Open-File Report 81-577A and U.S. Geological Survey Open-File Report 81-577B (Geoterrex Ltd., 1981). Data from areas A-1 through A-5 described in the above open-file reports have been interpreted at Michigan Technical University in a Masters Thesis by Paul S. Ensign (1981).

This report is accompanied by the INPUT maps (Plates 1-5) of each of the survey areas (see Table 1), showing locations of fiducial points, the flight lines, location of anomalies and conductive zones; all plotted on an air photomosaic. The analog records of the INPUT data in microfische form are available in U.S. Geological Survey Open File Report 82-60B.

TABLE 1.

PLATES AS THEY CORRESPOND TO SURVEY AREAS.

SEE LOCATION MAP

PLATE NO.	AREA	TOPOGRAPHIC SHEET NAME
PLATE 1	AREA A-7	SIDNAW N.
PLATE 2	AREA A-7	ROUSSEAU N.
PLATE 3	AREA A-7	ROUSSEAU S.
PLATE 4	AREA A-6	WATERSMEET N.
PLATE 5	AREA A-6	THAYER N.

References

Ensign, P.S., 1981, An INPUT Electromagnetic Investigation of the Southern Margin of the Jacobsville Sandstone, Upper Peninsula of Michigan: Michigan Technological University Thesis.

Geoterrex Ltd. with an introduction by Heran, W. D., 1981, Airborne electromagnetic and magnetic survey of parts of the Upper Peninsula of Michigan and Northern Wisconsin: U.S. Geological Survey Open File Report OF 81-577A.

Geoterrex Ltd., with an introduction by Heran W. D., 1981, Analog records from an airborne electromagnetic and magnetic survey of parts of the Upper Peninsula of Michigan and northern Wisconsin: U.S. Geological Survey Open File Report OF 81-577B (in microfische only).

Geoterrex Ltd., with an introduction by Heran W. D., 1982, Analog Records from an Airborne electromagnetic and magnetic survey of parts of the Upper Peninsula of Michigan: U.S. Geological Survey Open File Report OF 82-60B (in microfische only).

Kalliokoski, J. O. K., 1977, Uranium, thorium and potassium content of Precambrian rocks, Upper Peninsula of Michigan and northern Wisconsin: Bendix Field Engineering Corp. Grand Junction Colo. (U.S. Energy Research and Development Admin.; GJBX 43 77)

Report by Geoterrex Ltd., Ottawa Canada*

*The material in this report is the sole responsibility of the contractor. It does not necessarily express the views of the U.S. Geological Survey.

ADDENDUM

COMBINED AIRBORNE
ELECTROMAGNETIC and MAGNETIC SURVEY
BARRINGER "INPUT" SYSTEM

LOGISTICS REPORT

OF

SELECTED AREAS
IN THE
UPPER PENINSULA, MICHIGAN

FOR

UNITED STATES GEOLOGICAL SURVEY
(U.S.G.S.)

BY

GEOTERREX LIMITED
83-375

OTTAWA, CANADA
JANUARY, 1981

R. HETU
Geophysicist

TABLE OF CONTENTS

		PAGE
I.	SUMMARY	1
II.	INPUT TECHNIQUE	3
III.	LOCATION MAP	
	a) Area A-6 and A-7	4
IV.	INSTRUMENT SPECIFICATIONS	
	a) Mark V INPUT System	5
	b) Geometrics Magnetometer	5
	c) Sperry Altimeter	5
	d) Intervalometer	6
	e) Madacs Format	6
	f) Archive Format	8
V.	PERSONNEL	9
VI.	DATA PRESENTATION	10
VII.	GENERAL RECOMMENDATIONS	13
	APPENDIX A - INPUT Equipment and Procedures	

Accompanying this Report

EM Plan Maps - Scale 1:24,000 - 5 sheets

I. SUMMARY

During the month of November, 1980, Geoterrex Limited conducted a combined magnetic and electromagnetic survey for the U.S.G.S. in the State of Michigan. This is part of a mineral appraisal program being conducted by the U.S. Geological Survey in various parts of the United States. The purpose of the airborne surveys in the Upper Peninsula region of Michigan is to provide the U.S.G.S. with unprocessed geophysical data, in the form of both digital and analog records. The two areas flown at this time are a continuation of the survey conducted during April and May in the same region. For a description of the original eight survey areas, the reader is referred to the "Logistics Report" by J. Atkins, 1980.

Two new areas, designated Area A-6 and Area A-7 are outlined, along with the previous eight survey blocks, on the accompanying location map. The total mileage flown in Areas A-6 and A-7 is 372 and 410 respectively. Survey lines were oriented perpendicular to the long axis of each area and spaced 1/4 mile apart.

Under mutual agreement, the additional U.S.G.S. areas were included as part of a broader flying program undertaken by Geoterrex Ltd, for the fall 1980. The U.S.G.S. survey was completed in five flights from Rhinelander, the last base of operations. Flights 13, 14, 15, 17 and 18 were flown on November 2, 3, 4, 24 and 25, respectively.

The aircraft presently equipped by Geoterrex for INPUT surveys in the U.S.A. and utilized for this survey, is a Super Canso PBY-5A aircraft under registration N4760C. It is also owned and operated by Geoterrex Limited. The equipment on board the aircraft consists of a Barringer "INPUT" system, a Geometrics G-803 nuclear precession magnetometer, a Honeywell

Visicorder, a Sperry radar altimeter, a 35mm continuous strip tracking camera, a 60 Hz powerline monitor and a Geoterrex Madacs digital acquisition unit.

A drafted anomaly map and a digital magnetic tape was completed in Ottawa, Canada, but final compilation and analysis of the INPUT data is to be carried out in Denver, Colorado, U.S.A. by the U.S.G.S.

II. INPUT TECHNIQUE

The electromagnetic data is presented on the analogue records in the form of 6 INPUT channels. These represent six sample periods during the off-time of the aircraft's transmitting system and measure relative intensities of the secondary electromagnetic field created during the on-time. Ground currents are induced at a rate of 288 times per second by a discontinuous pulse lasting one millisecond. The resultant signal is measured between pulses for a time period of 2.47 milliseconds. An analysis of the decay patterns indicate the variations in ground conductivity or resistivity.

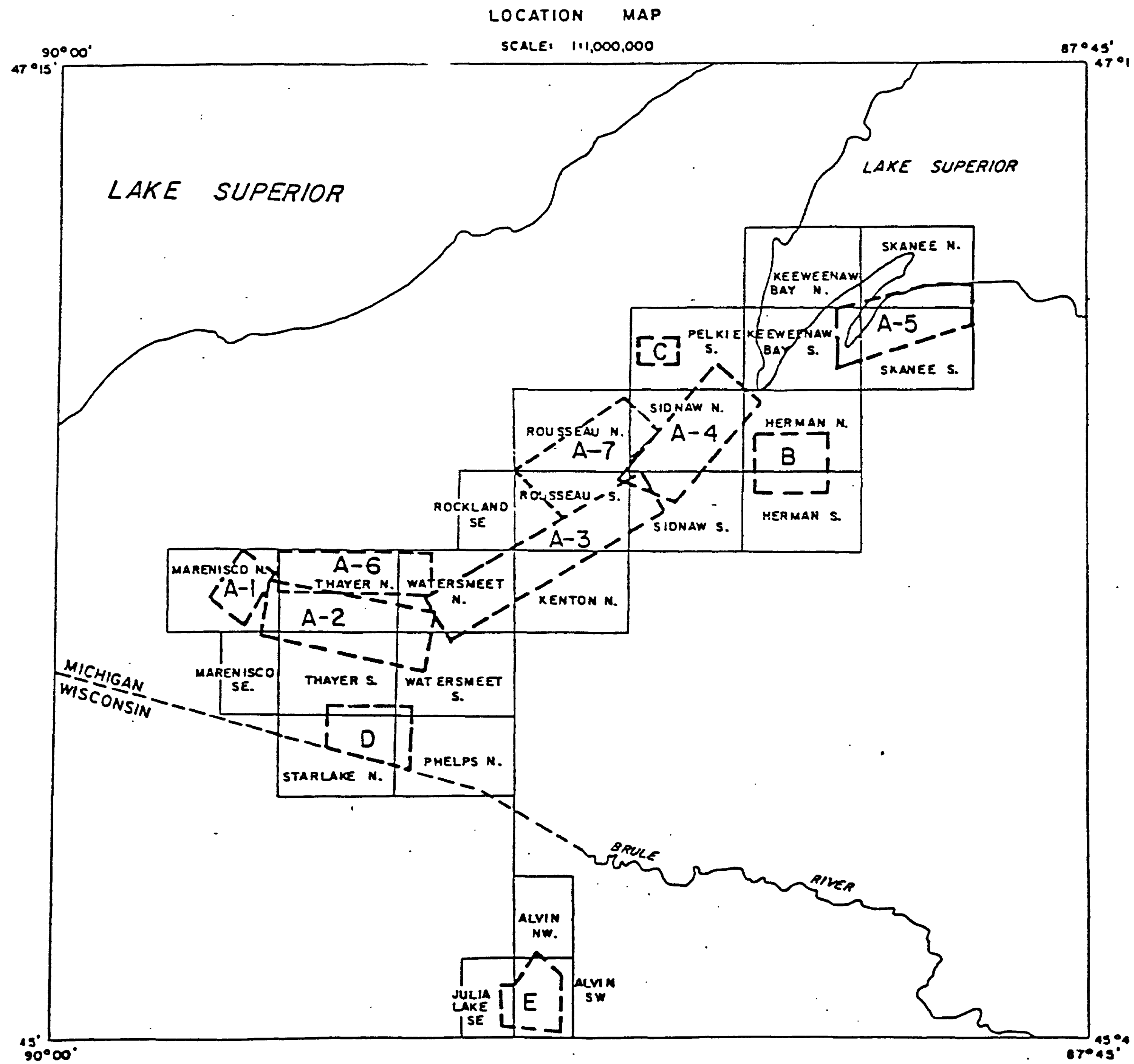
On the analogue record, the decay rate is expressed by the anomaly amplitudes usually measured from a zero background level. A residual base level can be used as well. The system is calibrated at the start of each flight and checked for drift at the end. This involves establishing background levels for each channel in the absence of ground conductors by flying at a high altitude and determining the relative signal strength at the bird or receiver. For this survey a 2 mv signal was set to cause a 3 inch chart deflection. The channel positions with zero deflection, are half an inch apart.

In theoretical studies the decay rate is often expressed by graphical presentations of channel amplitude in ppm versus conductivity in mhos or mhos/m. Using fixed parameters, family curves can be created for specific conductive models; for example, the vertical half plane model or the homogeneous half space model. These nomograms are very useful for quantitative interpretation.

For a more complete description of the Barringer INPUT system and our standard procedures, the reader is referred to Appendix A at the back of this report.

III LOCATION MAP

a) Areas A-6 and A-7



IV. INSTRUMENT SPECIFICATIONS

a) Mark V INPUT System

Transmitter: Pulse Width - 1020 microseconds

Pulse Separations - 2472 microseconds

Frequency - 288 cycles/second

Average Primary Field Strength - 1.0 volt at the receiver

Average Loop Current - 70 amperes

Receiver:

CHANNEL	GATE CENTRE	GATE WIDTH
1	500 microseconds	200 microseconds
2	700 microseconds	200 microseconds
3	900 microseconds	400 microseconds
4	1200 microseconds	400 microseconds
5	1600 microseconds	600 microseconds
6	2100 microseconds	600 microseconds

The gain settings of the INPUT channels were set to assure that a 2 millivolt signal caused a 3 inch chart deflection.

b) Geometrics Magnetometer, Model G-803

Two channels are recorded. The fine scale has a 200 gamma full scale deflection over 5 inches, a sensitivity of plus or minus 2 gammas and calibration of 40 gammas per inch. The coarse scale is only increased by a factor of 100.

The total field increases downward. Magnetic values are recorded once every second.

c) Sperry Altimeter, Model R7-220

The approximate scale is 100 feet per inch of chart deflection or 30 metres per inch. Altitude increases downward.

d) Intervalometer

Major and minor fiducials are shown on the analogue record and film by means of timing lines flashed at 2 second intervals. Each minor timing line is synchronized by the Madacs system. These are identified with a whole number representing seconds after midnight.

Each major fiducial equals twenty seconds or ten minor fiducials or twenty magnetic readings.

The time delay or INPUT lag equals four seconds or two minor fiducials. There is no electronic delay when the magnetic values are recorded.

e) Madacs Format

The tape structure used on this survey is set to record INPUT and magnetic data along with a 256 channel spectrometer system. Because no radiometric information was required for this survey, these byte positions were not used.

The following is the tape description for a single physical block. Each physical block or reoord is composed of a 358 byte "header" representing values incremented every second followed by five sequential 16 byte "scans" of INPUT data representing five values per secood.

Field Tape Description

Tape Density	9 track, 800 BPI
Block Size	438 bytes
Recording Mode	Binary (IBM compatible)

Contents of the "header"

Byte Position(s)	Number of Bytes	Description
1-4	4	Block number
5-6	2	Flight number
(7-8)	(2)	Line number **
(9-10)	(2)	Part number **
(11-12)	(2)	Direction code **
13-16	4	Magnetic intensity *
(17-18)	(2)	(Thorium) **
(19-20)	(2)	(Uranium) **
(21-22)	(2)	(Auxiliary Uranium) **
(23-24)	(2)	(Potassium) **
(25-26)	(2)	(Total count) **
(27-28)	(2)	(Cosmic sum) **
(29-30)	(2)	(Live time in milliseconds) **
(31-34)	(4)	Scan time; tenths of seconds past midnight **
35-36	2	Fiducial number
(37-38)	(120)	Frame or picture number **
(39-158)	(196)	(Channels 0-59; two bytes/ channel) **
(159-354)	(2)	(Channels 60-255; one byte/ channel) **
(355-356)	(2)	(Doppler track) **
(357-358)	(2)	(Distance travelled in sample period) **

Contents of a Single INPUT Scan

Byte Position(s)	Number of Bytes	Description
1-2	2	INPUT Channel 1
3-4	2	INPUT Channel 2
5-6	2	INPUT Channel 3
7-8	2	INPUT Channel 4
9-10	2	INPUT Channel 5
11-12	2	INPUT Channel 6
13-14	2	HZ Monitor
15-16	2	Radar alitmeter in feet

* The magnetic values represent the earth's total magnetic field. These values are recorded in 1/100th of gammas.

** The positions shown in parenthesis are not required for this survey. The digital print out contains zero values.

f) Residual Archive Magnetic Tapes

Bytes	Data Description
1-8	(flight number x 10^6) + (line number x 10^2) + (line segment number)
9-16	Fiducial number
17-24	These byte positions not utilized
25-32	Magnetic intensity x 10^2 in gammas
33-40	INPUT channel 1 in digital measuring units
41-48	INPUT channel 2 in digital measuring units
49-56	INPUT channel 3 in digital measuring units
57-64	INPUT channel 4 in digital measuring units
65-72	INPUT channel 5 in digital measuring units
73-80	INPUT channel 6 in digital measuring units
81-88	Hz Monitor
89-96	Altimeter in feet
97-104	UTM x in metres (Clarke 1866)
105-112	UTM y in metres (Clarke 1866)
113-120	Latitude in degrees x 10^5
121-128	Longitude in degrees x 10^5

TAPE CHARACTERISTICS

NUMBER OF TRACKS	9
RECORDING DENSITY	800 BPI
PARITY	ODD
CHARACTER TYPE	EBCIDIC

FILE HEADER

FILE HEADER EXISTS	No

DATA RECORD

BLOCK SIZE	7680	bytes
LOGICAL RECORD SIZE	128	bytes
ENCODING FORMAT	1618	bytes

V. PERSONNEL

The following Geoterrex personnel participated in the field phase of the survey:

R. Mott	Pilot
Y. Thientz	Co-Pilot
J. Ost	Aircraft Maintenance Engineer
K. Kurokawa	Electronic Technician
D. Armstrong	Electronic Technician
R. McDonald	Data Complier
R. Torrens	Geophysicist

Compilation of the data was initiated in the field and completed in Ottawa.

VI DATA PRESENTATION

The electromagnetic data is presented in the form of an anomaly map. This map in its final drafted state represents a combination of manual, digital and photographic compilation. The map scale is 1:24,000.

Prior to the start of a survey, a set of base maps is prepared for the collection of the electromagnetic data. A separate set is kept on file for the presentation of the final EM results. The term "base map" simply refers to the map showing the necessary geographic detail required to carry out the survey and to properly orientate the data in space. For this purpose, a composite mosaic of either topographic, aerial photography or orthophotoquad coverage is used. The base map for this survey was compiled from existing orthophotos. These were obtained from the United States Department of the Interior in Rolla, Missouri.

"Flight strips" is the term referring to the base map used for navigation. Once the line direction and line spacing are specified, an imaginary flight path is traced onto the mosaic. Alternate colors are used for different line directions (i.e. visual aid for the navigator). Theoretically this is the path the aircraft follows during flight, but in practice the aircarft will deviate slightly and sometimes it is necessary to fly extra fill-in lines. The flight strips are included as part of the raw data.

"Point Picking Mosaic" is the term referring to the base map used to show the actual aircraft position during flight. Utilizing the 35mm tracking film and usually a second copy of the base map, the same physiographical features are identified and marked on the map using a time reference. The numbers used on the maps, film, flight logs, and analogue records are referred to as "fiducial numbers" and represent the number of seconds after midnight. Normally one copy of the base map would be used for navigational aid, one copy for flight path recovery and a final screened copy for drafting the results. Because the preparation time was minimal for this survey, the same set of base maps was utilized for both the flight path recovery and navigation.

In addition to the point picking/flight strip maps, we include, the tracking film (five rolls), the flight logs (five sheets), the analogue records (one book), the digital data recorded in the field (five tapes) and an archive of the digital data (two tapes) as raw data.

The processing of the geophysical data commences immediately in the field. This involves data control and preliminary data reduction. The very first step after landing is to develop both the tracking film and analogue chart, since this data is recorded on photo sensitive material. Subsequent steps include verification of the flight path, anomaly selection and plotting, digitizing, drafting, compilation and interpretation. This is a continual process from the field to final delivery of the product.

The information on the analogue records represents a cross-section of the electromagnetic activity along the flight path. In the field, anomalies or responses due to ground conductors are identified on the profiles and then they are transferred to a base map showing the actual ground locations of each source. A ground conductor may be represented by several responses depending on the length and width of the conductive source.

The EM map presented for this survey only shows anomaly positions, it does not define conductive limits. In an interpretation process, one can estimate the probable cause of the EM responses (i.e. whether the anomaly characteristics are more diagnostic of a cultural, surficial or bedrock conductor) and sometimes, general geometric parameters (i.e. strike, length, width, dip and depth) can be estimated.

The electromagnetic data is drafted on transparent cronaflex map sheets at the scale, 1:24,000. The drafting base is produced photographicly. It includes the surround, the digital flight path, the orthophoto background screened to allow the geophysical data to stand out on the map and the selected responses.

The INPUT anomalies are portrayed as follows:

a) anomaly peak positions
b) anomaly half-peak width
c) number of INPUT channels affected
d) amplitude ratio of the first and fourth channels
e) terrain clearance of the aircraft, in feet
f) amplitude of any apparently associated magnetic anomaly, in gammas
g) any associated response on the 60 cycle monitor.

A legend of the symbolism is outlined on each drafted map.

VII. GENERAL RECOMMENDATIONS

1. The anomaly map and profiles portray two dominant types of conductivity. Firstly in Area A-6, large amplitude responses with slow decay rates map highly conductive bedrock sources. Secondly, in both Area A-6 and Area A-7 numerous small amplitude responses with fast decay rates indicate surficial conductors. Formational graphite conductors and overburden conductivity appear to be the two main causes for the electromagnetic responses. Perhaps an amplitude contour map would best display these features.

2. To evaluate if additional bedrock conductors exist , perhaps a conductivity map would be useful.

Respectfully submitted

R. Hetu
J.A.

R. Hetu
Geophysicist

APPENDIX A

'INPUT' EQUIPMENT AND PROCEDURES

I. BARRINGER 'INPUT' SYSTEM

A) General

The INPUT (INduced PUlse Transient) method is based on measurement of the decay of eddy currents induced in the ground by a transmitted pulsed electromagnetic field. Variation in the decay characteristics are analyzed and interpreted to provide information about the land.

The principle of separation in time between the primary field and the measured secondary signal, gives rise to an excellent signal-to-noise ratio and an increased depth of penetration compared to conventional continuous wave electromagnetic systems. This also makes the INPUT system relatively free of noise due to air turbulence.

At a normal survey altitude of 400 feet (120 metres) above terrain, the typical effective depth penetration is estimated at about 600 feet (180 metres) below surface, depending on the conductivity contrast between the body and the surrounding rocks, the size and attitude of the conductor and the presence or lack of overburden. In Optimum conditions, a penetration of 1000 feet (300 metres) subsurface can be achieved.

One of the major advantages of the INPUT method lies in good differentiation between flat-flying surface conductors and bedrock conductors, so that the latter can be detected even under a relatively thick overburden.

The application of the airborne INPUT electromagnetic method is directed towards the solution of problems that are characterized by a resistivity contrast. The method is not considered to be applicable to the direct search for disseminated mineralization, except where a resistivity contrast exists.

B) Equipment

The INPUT system was developed by Barringer Research Limited of Toronto, Canada.

The transmitted primary field is discontinuous in nature (Fig.1A) with each pulse lasting .85 milliseconds; the pulse repetition rate is 288 per second. The electromagnetic pulses are fed into a 3-turn shielded transmitting loop surrounding the survey aircraft and fixed to the nose and tail of the fuselage and to the wing tips.

INPUT SIGNAL

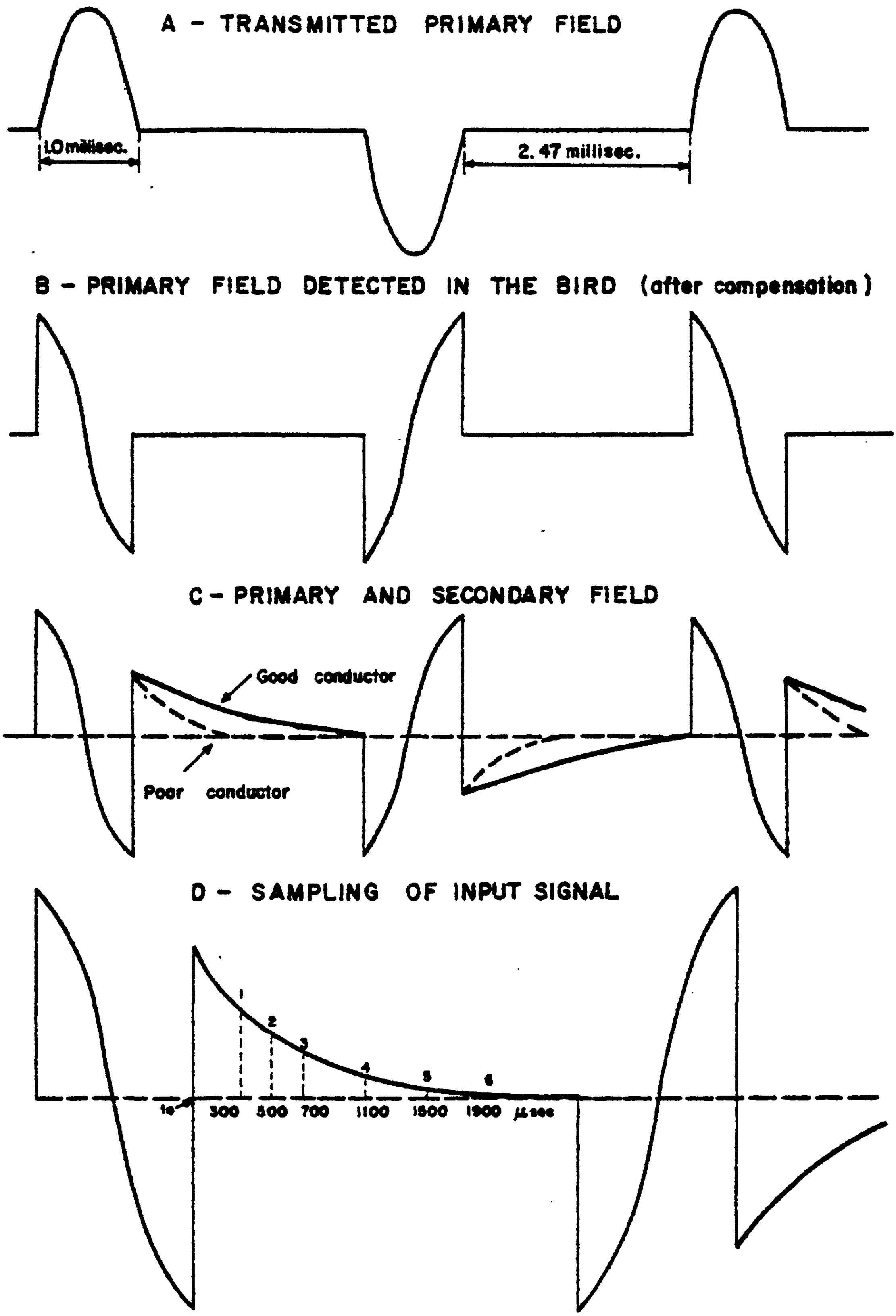


FIGURE 1

The secondary field reception is made by means of a 200 turn receiving coil wound on a ferrite rod and mounted in a feraday shielded "bird". The bird is towed behind the airplane on a 450 foot (135 metre) coaxial cable. The axis of the pickup coil is horizontal and parallel to the flight direction. Gaps of 2.62 milliseconds between successive primary pulses (Fig.1B) are used for detecting the INPUT voltage, which is a transient voltage (Fig. 1C) corresponding in time to the decay of the eddy currents in the ground.

The analysis of the signal is made in the INPUT receiver by sampling the decay curve at six points or gates, the centre and width of which have a fixed relationship with respect to time zero (t_0) corresponding to the termination of the pulses. The centres of the six INPUT sampling gates, are set at a mean delay of 450, 650, 850, 1150, 1550 and 2150 microseconds after time zero.

The signals received at each sampling gate are processed in a multi-channel reciever to give six analog voltages recorded as six continuous analog traces on a Honey Well Visicorder direct-reading optical galvanometer recorder. Each trace represents the coherent integration of the transient sample, the time constant of integration is set at 2.4 seconds. A second set of channels is often operated at a faster time constant of 1.0 seconds in addition to the normal time constant.

I Integration delay, plus the separation between the receiving bird and the tracking camera which is installed in the aircraft, introduces a day which has to be taken into consideration and corrected prior to correlating the electromagnetic data with the other simultaneously recorded data. Other data which is frequently recorded is fiducial time marks, the earth's total magnetic field, radar altimeter, a Hz monitor for the detection of powerlines an optional spectrometer data.

Eddy currents are induced in the airframe by the primary field. To compensate for this effect a special device is used which feeds into each channel of the INPUT receiver a signal equal in amplitude and waveform but opposite in polarity to the signal induced by the airframe eddy current. The compensation signal is derived from the voltage induced in the receiving coil by the primary field. It is constantly proportional to the inverse cube of the distance between the bird and the aircraft. Thus, swinging of the bird and changes of coupling are automatically corrected. The compensation adjustment is a simple procedure carried out during flight at a terrain clearance of 2,000 feet (600 metres) to eliminate the interference of ground conductors.

II. MAGNETOMETER

The magnetometer is a Geometrics G-803 nuclear precession unit especially adapted to operate in conjunction with the INPUT equipment. Readings are taken approximately every second with a sensitivity of plus or minus 2 gammas and recorded at a full scale of 5 inches for 200 gammas.

TYPICAL INPUT RECORDING

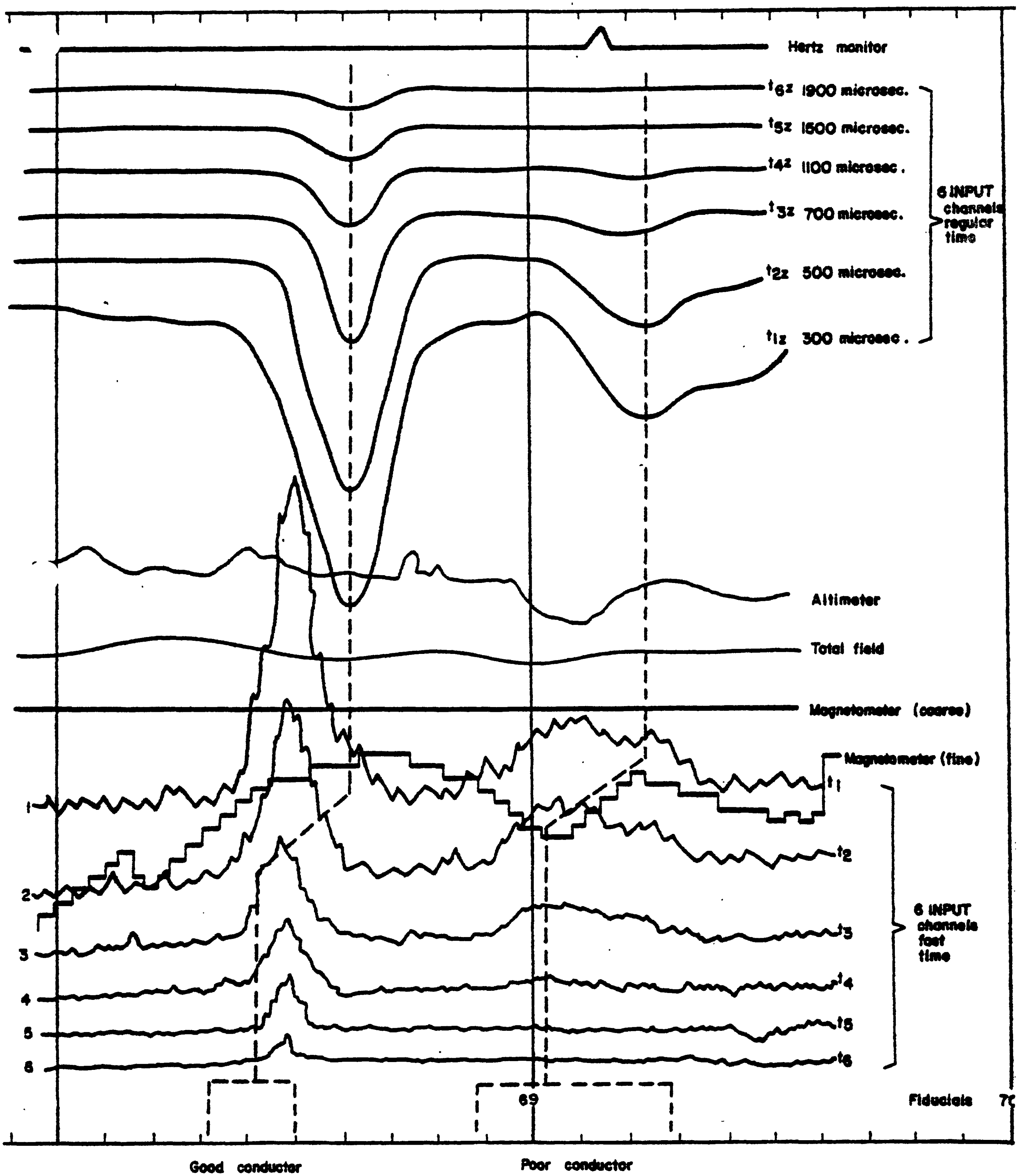


FIGURE 2

The coarse trace is recorded at a full scale of 5 inches for 20,000 gammas, or at a full scale of 5 inches for 2000 gammas. The sensing head is mounted at the end of a 3-metre stinger, on the tail of the PBY aircraft.

III. TRACKING CAMERA

The tracking camera is a 35 mm continuous strip camera equipped with a wide-angle lens. The 35 mm film is synchronized with the geophysical record by means of fiducial marks printed approximately every 2.0 seconds.

IV. ALTIMETER

A Sperry radar altimeter is used, and its output is recorded on the chart.

V. Hz MONITOR

A Hz monitor tuned to the local domestic power distribution frequency, is employed to assist in the detection of powerlines.

VI. MADACS DIGITAL ACQUISITION SYSTEM

The MADACS is a computer based software system using an Interdata processor, model 6/16 with 32K memory. This computer is linked with a Digi-Data, model 1600 magnetic tape drive with a true read after write feature which allows checking of the recording process as many times as the particular application permits. The checking procedure includes elimination of errors due to bad tape spots. Use of multiple buffers permits recording and processing data simultaneously with acquisition of new data with no resulting dead time.

The system uses an Electrohome TV monitor to display acquired data and operator messages and is fully interactive with a Cybernex alphas numeric keyboard which can be used remotely for special installations.

The key feature of this system is that all the data collecting, verifying, buffering and recording is software-controlled and thus may be economically altered to fit almost any requirements. Many critical parameters are automatically monitored during flight, with visual and aural alarms provided.

Survey parameters are displayed during flight in the same units as the basic sensor, making operator comparisons simple. A suite of programs is provided for checking and trouble-shooting the hardware.

VII. OTHER EQUIPMENT

Optional equipment can include a Doppler or other navigation system a frame camera (in addition to the strip camera) and a spectrometer.

VIII. PROCEDURES

A) Field Operations

The flight line spacing is normally in the range of 1/8 mile (200 metres) to 1/4 mile (400 metres). depending on the survey flights that altitude of the aircraft is maintained at approximately 400 feet (120 metres) above the ground with the bird flying about 200 feet (60 metres) below the aircraft.

The heading of the aircraft is such that two adjacent lines are normally flown in opposite directions. Visual navigation is based on airphoto mosaics or in some cases on topographic maps of suitable scale.

Each day after take-off, the 400 foot (120 metre) level is checked for the altimeter and compensation and gain checks are made for the INPUT system.

B) Compilation

At the end of each flight, all records and films are developed, edited and all synchronized fiducial marks are checked. Then the actual flight path recovery is made by picking visible features common to both 35 mm film and photo mosaics. Identified points with their fiducial number are plotted on the mosaic. Then, the electromagnetic anomalies are transferred from the records onto the mosaic overlay by interpolation according to their own fiducial number.

The position of the INPUT anomalies must be corrected to take into account the separation between the bird and the aircraft, as well as the delay introduced in the integration circuitry. This offset, or lag, is plotted towards the smaller fiducial numbers (to the left on the record).

The INPUT anomalies are represented on a map by means of symbols that include the most significant characteristics of the anomaly namely the location of the centre and half peak width of the electromagnetic anomaly; the number of INPUT channels affected by a noticeable deflection and the peak amplitudes of the first and fourth channels. The altitudes at which the anomalies were recorded, the amplitude of any magnetic features which coincide with INPUT anomalies and any associated response on the Hz monitor.

The only subjective elements introduced by this processing are in the decision as to whether a deflection corresponds to a genuine anomaly or to a noise source (electrostatic atmospheric discharge, compensation noise, etc.), and in the correlation of the anomalies from line to line to delineate a conductive zone.