UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# Airborne Electromagnetic and Magnetic Survey of parts of the Upper Peninsula of Michigan and Northern Wisconsin

Conducted and Prepared by Geoterrex Limited

With an Introduction by William D. Heran

U.S. Geological Survey



Open File Report 81-577A

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

The data presented in this report is 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 is located in eight areas in the Upper Peninsula of Michigan and one area in Northern Wisconsin. The accompanying report describes the basic parameters for the areas surveyed (figure 1). All of the areas except area E (figure 1) are within the Iron River $2^{o}$ quadrangle. This quadrangle is being studied as part of the U.S. Geological Survey (USGS) CUSMAP (Conterminous United States Mineral Appraisal Program) project. The survey was done in order to provide geophysical information which will aid in the integrated geological assessment of the Iron River $2^{o}$ quadrangle.

Specific objectives for each of the survey areas are as follows. Areas A-1 through A-5 were flown over the contact between Proterozoic Jacobsville Sandstone and older crystalline basement. The geologic setting is thought to be, in a general sense, favorable for uranium mineralization (Kalliokoski, 1977). In a somewhat analogous geologic setting, uranium mineralization in the Athabasca Basin in Canada is preferentially associated with graphitic units within the crystalline basement (Hoeve and Sibbald, 1978). Because these graphite units are usually good conductors, data from airborne electromagnetic methods may indicate their presence beneath the covering glacial drift and sandstone. Several such conductors are defined by the survey. The INPUT data for this area is being interpreted at Michigan Technical University. The funding for the collection of geophysical data in area A was provided by the Department of Energy as a part of their study of world class uranium deposits.

Area B (Figure 1) comprises part of a gneiss dome complex (Cannon. 1978) that includes meta-volcanic, graphitic, gneiss, iron formation and metasedimentary units. There are known uranium and basemetal occurrences in this area. Funding for the survey was provided through the USGS CUSMAP project.

Area C (figure 1) is a region of structural complexity within the Jacobsville Sandstone that is being studied and funded by the CUSMAP project and the Geology Department at Michigan Technical University at Houghton, Michigan.

Areas D and E (figure 1) are wilderness study areas. Flying in these areas was funded by the USGS Wilderness program.

The airborne electromagnetic data was supplemented by an airborne radiometric survey. Data from this survey is unpublished at present. Other INPUT data for the southeast corner of the Iron river quadrangle has been released by Heran and Smith (1980).

This report is accompanied by the INPUT maps (Plates 1-22) of each of the survey areas, showing locations of fiducial points, the flight lines, locations 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 81-577B.

| | |
|---|---|
| Plate 1 | Areas A-1 & A-2 |
| Plate 2 | Area A-2 |
| Plate 3 | Area A-2 |
| Plate 4 | Area A-2 & Area D |
| Plate 5 | Area D |
| Plate 6 | Area A-3 |
| Plate 7 | Areas A-3 & A-2 |
| Plate 8 | Areas A-2 & A3 & Area D |
| Plate 9 | Area D |
| Plate 10 | Area A-4 |
| Plate 11 | Area A-3 |
| Plate 12 | Area A-3 |
| Plate 13 | Area C & Area A-4 |
| Plate 14 | Area A-4 |
| Plate 15 | Areas A-3 & A-4 |
| Plate 16 | Area A-5 |
| Plate 17 | Areas A-4 & A-5 |
| Plate 18 | Area B & Area A-4 |
| Plate 19 | Area B |
| Plate 20 | Area A-5 |
| Plate 21 | Area A-5 |
| Plate 22 | Area E |

## Selected References

Barringer, A. R., 1965, The Barringer INPUT airborne electromagnetic exploration system: Barringer Research Limited, Toronto, Canada.

Cannon, N. F., 1978, Geologic map of the Iron River $1^{o} \times 2^{o}$ quadrangle, Michigan and Wisconsin: U.S. Geological Survey Open File Report 78-342, scale 1:250,000.

Heran, W. D., and Smith, B. D., 1980, Description and preliminary map of airborne electromagnetic survey of parts of Iron, Baraga, and Dickinson Counties, Michigan: U.S. Geological Survey Open-File Report 80-297, 8 p.

Heran, W. D. and Smith, B. D., 1980, Instrument specifications and geophysical records for airborne electromagnetic survey of parts of Iron, Baraga, and Dickinson Counties, Michigan: U.S. Geological Survey Open-file Report 80-296, 15 p.

Hoeve, J. and Sibbald, T.I.I., 1978, "On the genesis of Rabbit Lake and other unconformity-type uranium deposits in northern Saskatchewan, Canada", Bull. Soc., Ec. Geol., vol. 73, no. 8., pp. 1450-1473.

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).

Mishra, D. C., Murthy, K. S. R. and Narain, H., 1978, Interpretation of time-domain airborne electromagnetic (INPUT) anomalies: Geoexploration, 16, p. 203-222.

Palacky, G. J. and West, G. F., 1973, Quantitative interpretation of INPUT AEM measurements: Geophysics, v. 38, no. 6, (Dec. 73), p. 1145-1158.

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.

# LOGISTICS REPORT

for a

COMBINED

ELECTROMAGNETIC BARRINGER INPUT AND MAGNETIC

AIRBORNE SURVEY

in the

UPPER PENINSULA of MICHIGAN
and
NORTHERN WISCONSIN

for

UNITED STATES GEOLOGICAL SURVEY

by
GEOTERREX LIMITED
83-375

OTTAWA, CANADA
OCTOBER 1980

J. ATKINS
Geophysicist

## TABLE OF CONTENTS

## LIST OF FIGURES

## I. INTRODUCTION

Geoterrex Limited conducted an airborne survey for the United States Geological Survey in the period from April 21 to April 26 and May 20 to May 25, 1980.

The purpose of the survey was to provide digital and analog recorded total field magnetic and INPUT electromagnetic data in eight areas in the Upper Peninsula of Michigan and one area in Northern Wisconsin.

The areas are depicted on the location map in Figure 1 and are as follows:

| Area | Name | Mileage |
|---|---|---|
| A-1 | Jacobsville Contact | 138.0 |
| A-2 | Jacobsville Contact | 402.0 |
| A-3 | Jacobsville Contact | 660.0 |
| A-4 | Jacobsville Contact | 354.0 |
| A-5 | Jacobsville Contact | 349.9 |
| | Tie Lines for A1 to A5 | 148.9 |
| B | Northern Cusmap | 181.0 |
| C | Limestone Mountain | 51.5 |
| D | Sylvania Wilderness | 175.9 |
| E | Wisconsin Wilderness | 169.9 |
| | Total | 2631 miles |

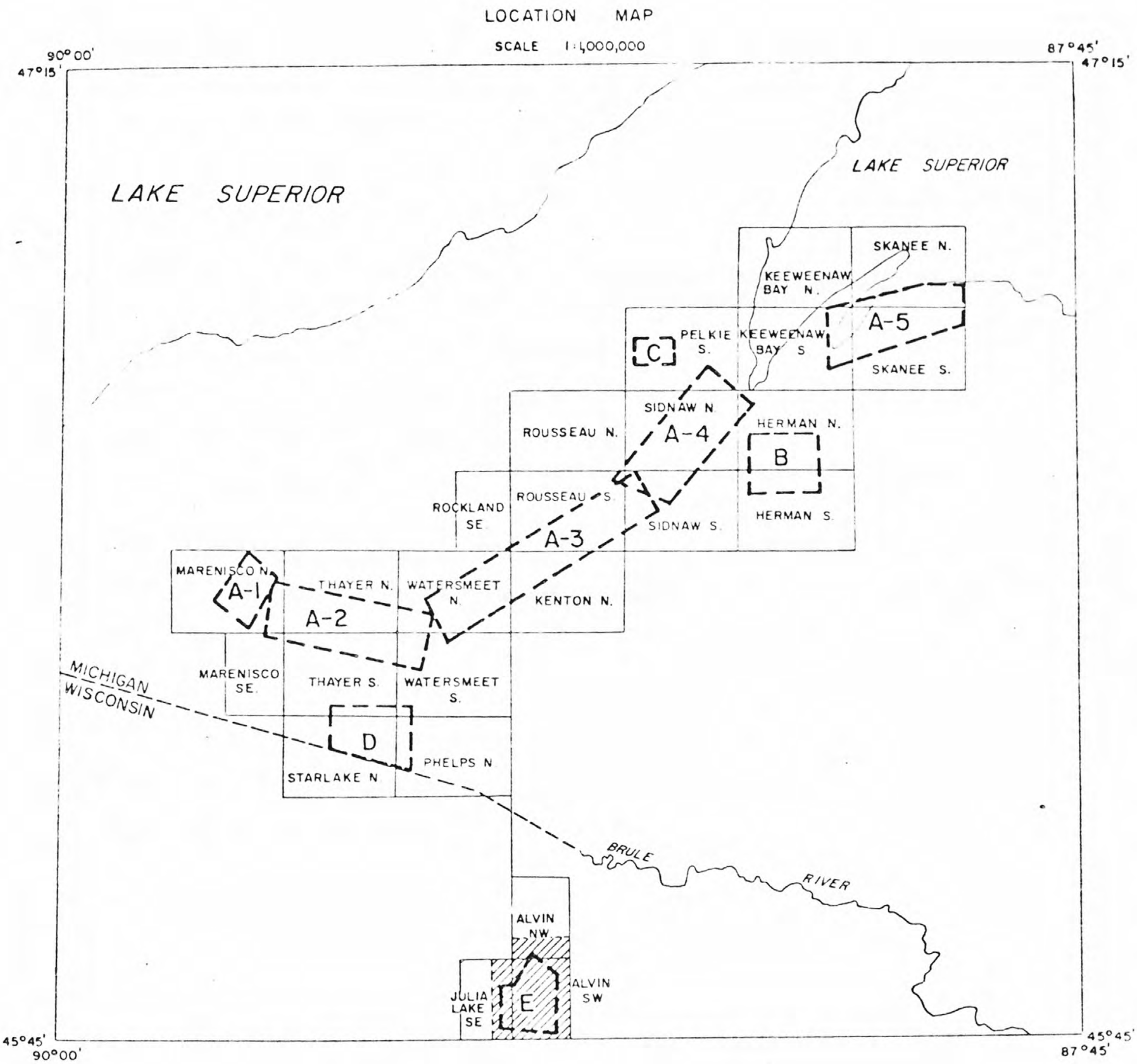

LOCATION MAP
SCALE 1:1,000,000
90°00'
47°15'
87°45'
47°15'
LAKE SUPERIOR
LAKE SUPERIOR
SKANEE N.
KEEWEENAW BAY N.
A-5
PELKIE S.
KEEWEENAW BAY S
C
SKANEE S.
SIDNAW N.
HERMAN N.
ROUSSEAU N.
A-4
B
ROUSSEAU S.
ROCKLAND SE.
SIDNAW S.
HERMAN S.
A-3
MARENISCO N.
THAYER N.
WATERSMEET N.
KENTON N.
A-1
A-2
MICHIGAN
WISCONSIN
MARENISCO SE.
THAYER S.
WATERSMEET S.
D
STARLAKE N.
PHELPS N
BRULE RIVER
ALVIN NW.
JULIA LAKE SE
E
ALVIN SW
45°45'
90°00'
45°45'
87°45'

FIGURE 1

# II. FIELD OPERATIONS

## II.1 Schedule of the Survey

| | |
|---|---|
| April 21 | Flight 17 - First flight of Geoterrex Project 83-375, based in Rhinelander, Wisconsin. Areas A-1 and A-2. |
| April 23 | Flight 18 - Areas A-2 and A-3 |
| April 25 | Flight 19 - Area A-3 |
| April 26 | Flight 21 - Area A-3<br>With client's approval, operations postponed due to weather conditions |
| May 20 | Flight 33 - Areas A-3 and A-4 |
| May 21 | Flight 34 - Areas A-2, A-4, B and C |
| May 22 | Flight 35 - Area 5 |
| May 22 | Flight 36 - Areas D and E |
| May 23 | Flight 37 = Area C |
| May 24 | Flight 38 - Area D |
| May 25 | Flight 40 - Area E |

## III. GEOPHYSICAL EQUIPMENT

The following items of geophysical equipment were utilized during the survey:

-Barringer Mark V INPUT system

Transmitter: Pulse width - 900 microseconds
Pulse separation - 2572 microseconds
Frequency - 288 cycles/second
Average Primary Field Strength - 1.0 volt at the receiver.
Average Loop Current - 40 amperes

Receiver:

| CHANNEL | GATE CENTRE (microseconds) | GATE WIDTH (microseconds) |
|---|---|---|
| 1 | 420 | 200 |
| 2 | 620 | 200 |
| 3 | 820 | 400 |
| 4 | 1120 | 400 |
| 5 | 1520 | 600 |
| 6 | 2020 | 600 |

See Appendix A for a general description of the INPUT method.

-Geometrics G-803 magnetometer

| | Sensitivity | Scale |
|---|---|---|
| Fine Scale: 200 $\gamma$ full scale | $\pm$ 2 $\gamma$ | 1 inch = 40 $\gamma$ |
| Coarse Scale: 20,000 $\gamma$ full scale | $\pm$ 200 $\gamma$ | 1 inch = 4000 $\gamma$ |

-Sperry radar altimeter RT220

Approximate scale: 1 inch = 100 feet
Altitude increases downwards.

-Intervalometer controlled fiducial numbering system.

1 fiducial = 2 seconds = 2 magnetometer readings
INPUT lag - 4.0 seconds = 2 fiducials

-Honeywell Visicorder

-35mm Camera (strip film)

## IV. PERSONNEL

The following Geoterrex personnel participated in the survey:

### A. Field Crew

| | |
|---|---|
| Geophysicists | R. Hetu<br>R. Yee<br>J. Atkins |
| Pilot and Project Manager | J. Devalk |
| Co-pilot | R. Mott |
| Electronic Technicians | K. Kurokawa<br>D. Armstrong |
| Engineers | B. Coder<br>M. Pelko |
| Datamen | R. McDonald<br>F. Makuch |

### B. Office Compilation

| | |
|---|---|
| Compilation | G. McDonald |
| Computing | R. Wasylechko |
| Drafting | R. Schingh |
| Geophysics | J. Atkins |

The representative for the United States Geological Survey was B. Smith.

## V. GENERAL SURVEY PARAMETERS

The survey was performed according to the following specifications:

### Line Spacing

The nominal line spacing was ¼ mile.

### Line direction

For Areas A-1 to A-5 lines were orientated perpendicular to the long axis of each sub-area (NS or NW-SE trending lines). Flying in the other areas was N-S.

### Tie Lines

A tie line was flown for each area.

### Flight Elevation

Mean terrain clearance was 400 feet or 120 metres.

### Flight Path Recovery

Spacing between picked points is 2 kilometres or less except over terrain where no features can be recognized.

## VI. CALIBRATION PROCEDURES

1. Flight at 400 feet (120m) at airport to check radar altimeter.
2. Calibration for maximum gain, 2 mv. is applied to each INPUT channel to give a deflection of 3 inches.
3. Verification of zero level for the INPUT channels at high altitude.(2000').
4. Electrical compensation adjustments for minimum manoeuvre noise
5. Magnetometer calibration - Check for 0 deflection and full-scale deflection.
6. Check of digital recording system.
7. Check of cable length for towed bird (400').

### OTHER TESTS

1. Magnetometer Heading Test

| Magnetometer Heading Test | Direction | Altitude | Relative Magnetometer Reading |
|---|---|---|---|
| May 24 - Flight 38 | EAST | 470' | 0 |
| | WEST | 530' | 8% less |
| | NORTH | 490' | 1% less |
| | SOUTH | 470' | 5% less |

2. Altitude Tests of

300', 400', 500', 600', 700', 800', over the Crandon Orebody These were carried out on April 21, 1980 during Flight 17 but due to poor weather conditions, the results were not satisfactory. In consultation with the USGS, it was decided to refly these tests during a future survey.

3. Reflights of Selected Test Lines

At the end of certain flights, an earlier line was reflown to check for repeatability. These tests were carried out, survey conditions permitting.

## VII PRESENTATION OF DATA

Figure 2 shows a typical record obtained from the analogue recorder in the aircraft.

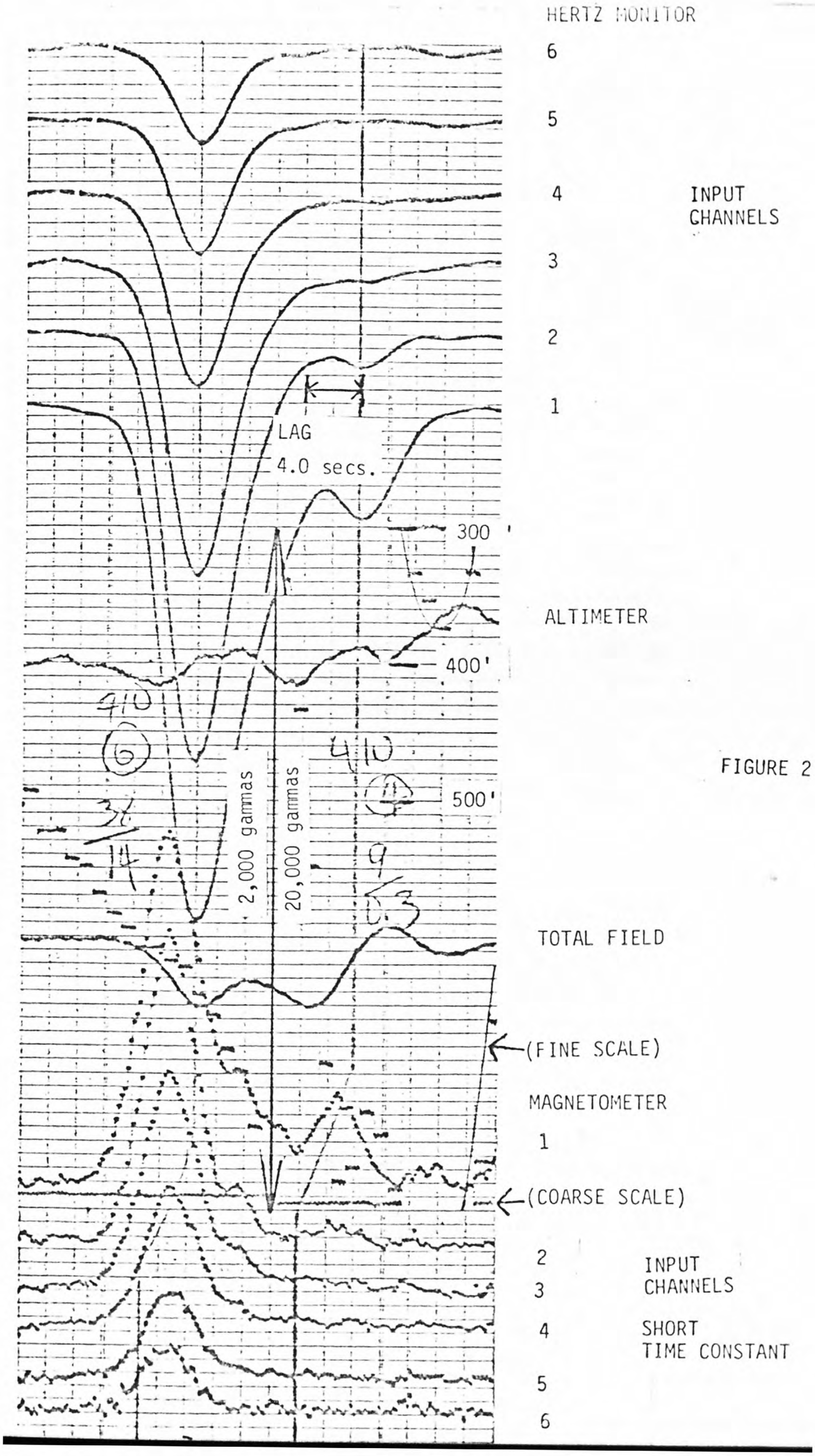
The electromagnetic results are presented in the form of Electromagnetic Anomaly Maps. These maps are plotted on base maps prepared from orthophotos or in some cases from a topographic base. Map scale is 1:24,000.

The code for presentation of these anomalies is shown on each map and is repeated in Figure 3.

The original geophysical INPUT records and calibrations and a full scale copy are presented in book form. An additional copy is supplied on 16mm film.

The negative 35mm tracking film is delivered in 11 rolls.

One can refer to the flight logs or to the information which is recorded on each of the records in order to relate the film to the geophysical records and maps.



HERTZ MONITOR
6
5
4
INPUT CHANNELS
3
2
1
LAG
4.0 secs.
300 '
ALTIMETER
400'
500'
2,000 gammas
20,000 gammas
TOTAL FIELD
(FINE SCALE)
MAGNETOMETER
1
(COARSE SCALE)
2
INPUT CHANNELS
3
4
SHORT TIME CONSTANT
5
6


FIGURE 2

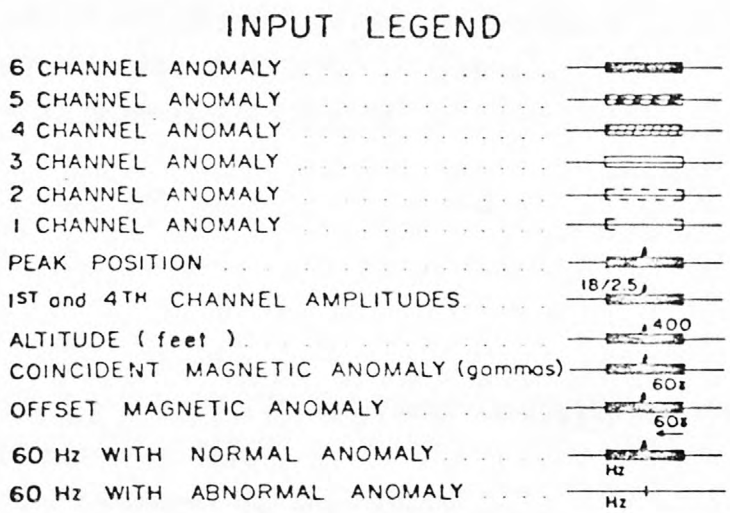

INPUT LEGEND
6 CHANNEL ANOMALY
5 CHANNEL ANOMALY
4 CHANNEL ANOMALY
3 CHANNEL ANOMALY
2 CHANNEL ANOMALY
I CHANNEL ANOMALY
PEAK POSITION
1ST and 4TH CHANNEL AMPLITUDES
18/2.5
ALTITUDE ( feet )
400
COINCIDENT MAGNETIC ANOMALY (gammas)
60
OFFSET MAGNETIC ANOMALY
60
60 Hz WITH NORMAL ANOMALY
Hz
60 Hz WITH ABNORMAL ANOMALY
Hz

FIGURE 3

## VIII. DESCRIPTION OF DIGITAL DATA

### VIII.1 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 | Time of day after midnight in seconds x 10 |
| 25-32 | Magnetic intensity x$10^2$ in gammas |
| 33-40 | INPUT channel 1 in digital measuring units |
| 41-48 | " 2 " " |
| 49-56 | " 3 " " |
| 57-64 | " 4 " " |
| 65-72 | " 5 " " |
| 73-80 | " 6 " " |
| 81-88 | " 7 (total field in digital units) |
| 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 | |

## VIII.2 Field Magnetic Tapes

| | |
|---|---|
| Tape Density | 9 track, 800 BPI |
| Block Size | 438 Bytes |

### Description of a Single Physical Block

Each physical block is composed of a single 358 byte 'header' record followed by five sequential 16 byte records of input data.

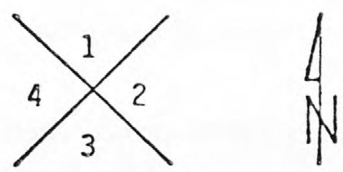
### Contents of a Single 'Header' Record

| 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 (*1) |
| 13-16 | 4 | Magnetics (*2) |
| 17-18 | 2 | Thorium |
| 19-20 | 2 | Uranium |
| 21-22 | 2 | Auxilary Uranium |
| 23-24 | 2 | Potassium |
| 25-26 | 2 | Total Count |
| 27-28 | 2 | Cosmic sum |
| 29-30 | 2 | Live Time (milliseconds) |
| 31-34 | 4 | Scan Time (tenths of seconds past midnight) |
| 35-36 | 2 | Fiducial Number |
| 37-38 | 2 | Frame Picture Number |
| 39-158 | 120 | Channels 0-59 (2 bytes/ channel) |
| 159-354 | 196 | Channels 60-255 (1 byte/ channel) |
| 355-356 | 2 | Doppler track |
| 357-358 | 2 | Distance travelled in sample period |
| | 358 | |

Contents of a Single INPUT Record

| 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 | Input Total Field |
| 15-16 | 2 | Radar Altimeter (feet) |

(*1) The convention Geoterrex uses to denote the direction is as indicated below:




(*2) Magnetics are recorded in 1/100ths of gammas. Also a constant of $2X10^6$ must be added to each measurement to obtain the correct total field value.

## IX. GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The survey areas in Michigan reflect an increasing density of conductors towards the northeast. Fairly large areas of resistive rocks can be seen in Areas A-1, A-2 and D, while Areas A-3, A-4, A-5 and C reflect widespread conductivity. The contrasts and variability in this conductivity indicate varying thicknesses of overburden material, as well as highly conductive bedrock sources.

2. Bedrock conductors, were detected in all areas, with the possible exception of Area E in Wisconsin, where only two INPUT responses were noted, both with apparent low conductivity.

3. Highly conductive, formational conductors appear to be present in all the Michigan areas. The prevailing strike is E-W and NE-SW but anomalous trends reflect interesting structural features in some areas, for instance the arcuate shaped conductor near the south boundary of Area B.

4. The electromagnetic data is presented as electromagnetic anomaly maps, as requested by the USGS. Detailed interpretative mapping of these areas will undoubtedly reveal conductors of interest.

RESPECTFULLY SUBMITTED

J. Atkins

J. Atkins

## APPENDIX A

## 'INPUT' EQUIPMENT AND PROCEDURES

### I. BARRINGER 'INPUT' SYSTEM

#### a) General

The INPUT (Induced Pulse Transient) method is based upon the study of the decay of secondary electromagnetic fields created in the ground by short pulses generated from an aircraft. The time-varying characteristics of the decay curve are analyzed and interpreted in terms of information concerning the conductivity characteristics of the terrain.

The principle of separation in time between the production of the primary field and the detection of 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. It also makes the INPUT system relatively independent of air turbulence.

At a normal survey altitude of 400 feet (120 metres) above terrain, the typical effective depth penetration is estimated at about 400 feet (120 metres) below surface, depending on the conductivity contrast between the conductive body and surrounding rocks, the size and attitude of the conductor and the presence or lack of conductive overburden. In optimum conditions, a penetration of 600 feet (185 metres) subsurface can be achieved.

One of the major advantages of the INPUT method lies in good differentiation between flat-lying surface conductors and bedrock conductors, so that the latter can be detected even under a relatively thick overburden such as glacial or pedological formations (laterite, weathered zone, etc.).

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

b) Equipment

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

The transmitted primary field is discontinuous in nature (Fig. 1A) with each pulse lasting one millisecond; the pulse repetition rate is 288 per second. The electromagnetic pulses are created by means of powerful electrical pulses 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.

The secondary field reception is made by means of a receiving coil wound on a ferrite rod and mounted in a "bird" towed behind the airplane on a 400-foot (122 metre) co-axial cable. The axis of the pickup coil is horizontal and parallel to the flight direction. Gaps of two and a half milliseconds between successive primary pulses (Fig. IB) 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 several 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 INPUT system has six sampling gates, the centres of which are commonly at a mean delay of 420, 620, 820, 1120, 1520 and 2020 microseconds after time zero (Fig. 1D).

The signals received at each sampling gate are processed in a multi-channel receiver to give six analog voltages recorded as six continuous analog traces on a Honeywell Visicorder direct-reading optical galvanometer

INPUT SIGNAL

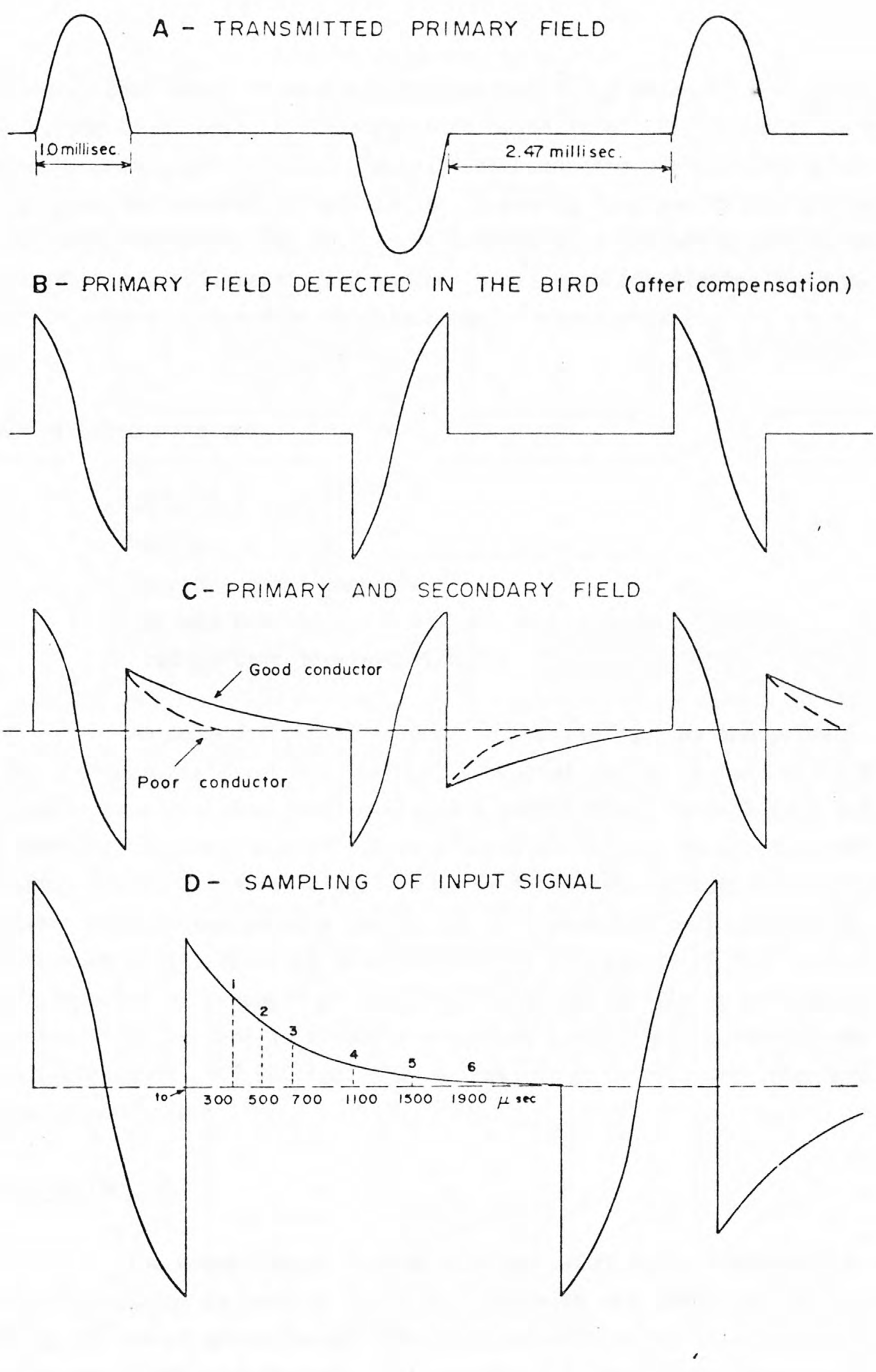



FIGURE I

recorder. Each trace represents the coherent integration of the transient sample, the time constant of integration being about 2.4 seconds on the analog recording and 1.0 second on digital recording. This integration delay, plus the separation between the receiving bird and tracking camera installed in the aircarft, introduces a delay of 4 seconds which has to be taken into consideration and corrected prior to correlating the electromagnetic data with the other simulatneously recorded data.

Other recorded data are:

- -fiducial marks
- -altimeter trace
- -earth's total magnetic field
- -Hz monitor
- -radiometric levels (optional)

An eddy current is 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 compnesation adjustment is a simple procedure carried out during flight 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. The

# TYPICAL INPUT RECORDING

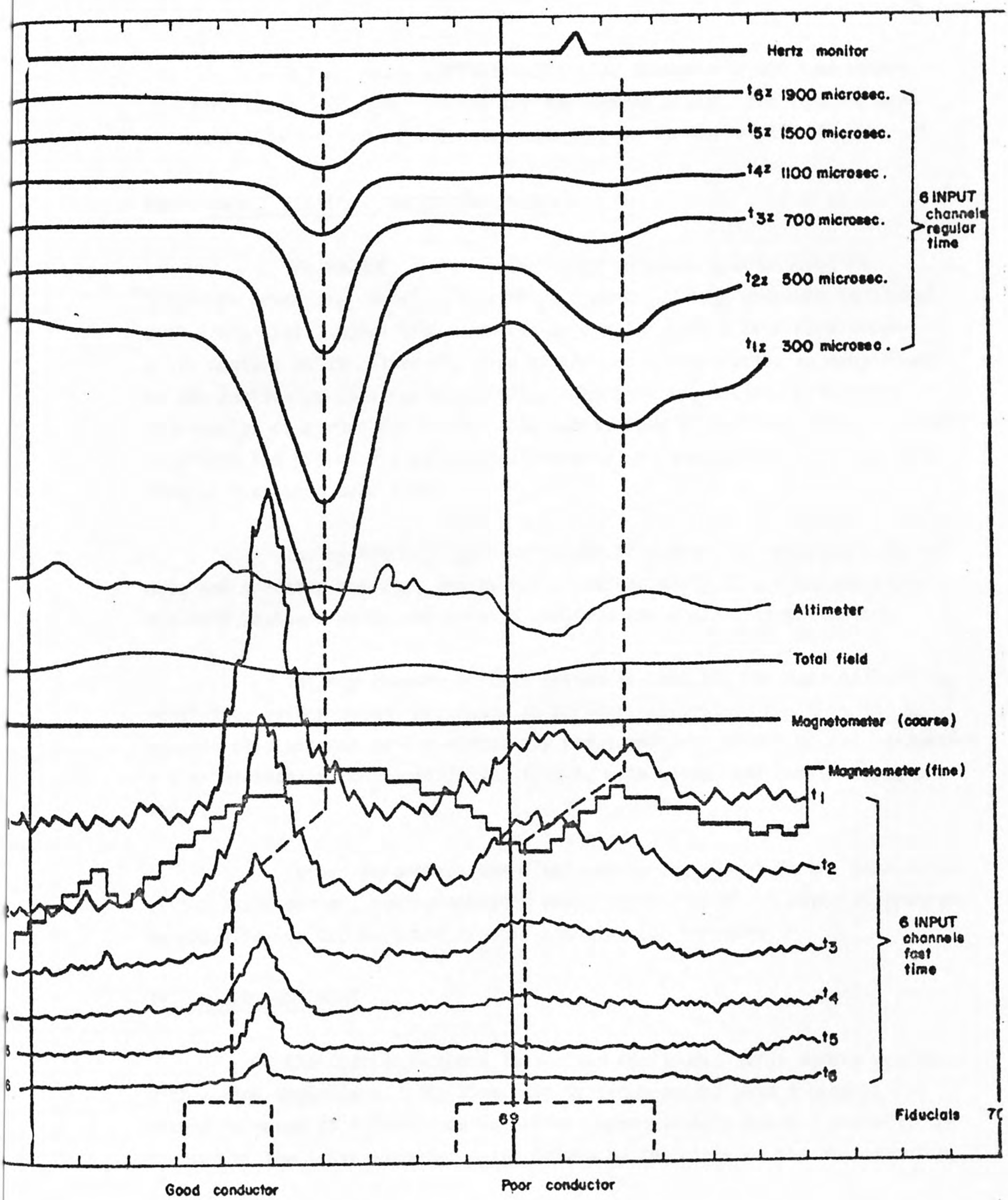



FIGURE 2

A full scale deflection is five inches or 2,000 gammas for the fine scale and 20,000 gammas for the coarse scale. The sensing head is mounted at the end of a 3 metre stinger, on the tail of the PBY aircraft.

## III. MADACS DIGITAL ACQUISITION SYSTEM

The MADACS is a computer based software system using an Interdata processor, model 6/16 with 32 K 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 alpha-numberic 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.

## IV. OTHER EQUIPMENT

The tracking camera is a 35 mm continuous strip camera equipped with a wide-angle lens. The 35mm film is synchronized with a geophysical record by means of fiducial marks printed approximately every 2 seconds, the counter of the intervalometer being driven by the clock of the magnetometer.

An APN-1 or a Sperry Altimeter is used, and its output is recorded on the chart.

In most cases, a Hz monitor tuned to the local domestic power distribution frequency, is employed to assist in the detection of power lines.

A Geometrics G-806 magnetic ground station coupled with a Moseley 7100 paper recorder is operated at the survey base to monitor the diurnal variation of the earth's magnetic field in the event of any magnetic storm. Recordings are taken approximately every 5 seconds with a sensitivity of plus or minus 1 gamma. The recording speed is 0.5 inch per minute.

## IV. PROCEDURES

### a) Field Operations

The flight line spacing is ¼ mile (1320 feet). During survey flights, the altitude of the aircraft is maintaned 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 orthophotos or in some cases, on topographic maps.

Just after take-off, the calibration of the altimeter is checked by flying straight and level over the runway at a barometric altitude AGL of 400 feet (120 metres). The compensation adjustment is checked during ferry from the base to the survey area.

### 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 marks common to both 35mm 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 of the record).

c) Digital Processing

The digital data recorded in the field is reformated to provide a residual archive tape for each of the areas to provide INPUT, magnetometer, radio altimeter and fiducial data.