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SCINTREX TURAIR 1356

SEMI-AIRBORNE ELECTROMAGNETIC

SYSTEM

MT. MYE

(18)

by

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SUMMARY

The Turair semi-airborne electromagnetic system is designed to permit electromagnetic reconnaissance prospecting for large subsurface conducting bodies which are beneath the operational depth penetration of present day airborne electromagnetic systems or which occur in areas of rugged topography. Effective depths of detection for such conducting bodies of up to 500' subsurface are readily to be expected, under appropriately low geologic noise. The system employs a helicopter for laying of the primary field loop and for transporting the measuring apparatus. Some examples are shown from a production survey with this sytem, where conductors believed to be arising from this order of depth have been detected.

The statistics of this production survey indicate line mile costs at least five times smaller than comparable ground survey costs and a rate of survey coverage at least fifty times that of a ground party of comparable size.

SCINTREX TURAIR
SEMI-AIRBORNE ELECTROMAGNETIC SYSTEM

PART I

EQUIPMENT

The Scintrex Turair is a fixed source, semi-airborne electromagnetic system designed for helicopter operation.

The system embodies a fixed transmitter on the ground and a receiver carried in the helicopter. The transmitting loop is approximately square and 2 miles on each side but other shapes and sizes can be used depending on survey conditions. It is laid out by helicopter. The present system utilizes a 400 Hz primary field, excited by means of a 7.5 kW motor driven generator which supplies a current of 4 amperes into the transmitting loop. The system can operate at any other desired frequency (see fig. 4)

The receiver system includes 2 horizontal coplanar or 2 vertical coaxial air-cored coils, rigidly mounted 15 feet apart in a "bird". This bird is towed approximately 100 feet below the helicopter by means of a cable which also carries the electrical signals from the bird. The horizontal coplanar coil system is the one preferably used. In areas where conducting overburden, etc. might tilt the primary electromagnetic field from a mainly vertical to a more horizontally directed one, the vertical coaxial coil system may have to be used. The present Turair receiving system is designed to detect signals stronger than 1 μV in the coils (phase lock principle). The system has a noise level of less than 3 μV. Thus, from a 2 miles x 2 miles loop, energized by 4 amperes, an area of about 24 square miles can be covered in a region underlain by e.g. several hundreds of feet of overburden or deep weathering of moderate conductivity.

The quantities measured with this dual coil (gradient) measuring electromagnetic system include the ratio of the field strength and the phase differences of the alternating magnetic field at the two coils. The changes in amplitude ratio and phase difference are expressed in percent and degrees respectively. The sensitivities of the system are 0.1 percent and 0.1 degrees respectively.

Both parameters are recorded in analogue form on a dual channel recorder. Digital output can be employed as well.

The following recorder scale sensitivities are commonly employed:

amplitude ratio	4" = 5%	
phase difference	4" = 3°	(see fig. 1)

Flying towards or away from the loop the strength of the field detected at the coils changes gradually but considerably. For this reason, a switch connected to the signal detector amplifier is manually activated to keep the amplified output of the preamplifiers within the signal strength limitations necessary for the equipment operation. These switching markers are shown on the recorder charts as short duration "spikes" with appropriate notation and are easy to interpret as such (see fig. 1).

At one or more points during each flight, the scale sensitivities and zero levels are checked by means of calibration and zeroing signals respectively. The reference or zero level for each Turair electromagnetic trace is an arbitrary one, and is obtained empirically from the regional level of each section of a trace between the switching markers. These levels may drift slowly during a flight because of temperature changes. The drifts are very gradual and are readily distinguishable from local changes due to conductors of a geologic origin.

Since the gradients of the signals recorded close (i.e. within about 600') to the loop sides are too strong, it is not possible to distinguish field changes due to conductors of geologic origin lying in those "blind zone" regions. From a statistical point of view the chances of missing a significant conductor in those "blind zone" regions are very small, since those regions constitute only about 8% of the area surveyed from each loop.

The amplitude ratio and phase difference are recorded in such a way that flying "towards" the loop using the horizontal coplanar coil system, a normal anomaly shows a positive sign (i.e. upward deflection) for the former and a negative sign (i.e. downward deflection) for the latter parameter (anomaly A fig. 1 and 2). While flying "away" from a loop these signs are reversed (anomaly B fig. 1). Reversed anomalies can also be the result of particular geometric situations, e.g. when the source is located on the hanging wall side of a flatly dipping conductor (Bosschart, 1964, p. 22 and fig. 9) * (see anomaly C, fig. 1 and 2). Man-made disturbances including power lines, pipe lines, metal fences, railways, etc. may cause spurious anomalies. The former are recognizable as such when they appear as cyclic noise of irregular shape and phase relationship.

Non-energized, grounded power lines (e.g. 3 phase systems) sometimes give rise to anomalies that are more difficult to identify. Such indications as well as those from pipe lines and metal fences, etc. are however, of short duration and can be distinguished from most geologic sources except for very narrow, near-surface conductors. In some instances, ground investigation may be necessary in order to resolve the ambiguity of possible sources. Although the airborne geophysical crew attempts to note visible man-made conductors of the above type, the ground moves by so rapidly at the low flight elevation employed that 100% recognition of such sources cannot always be expected from the air.

The normal terrain clearance of the bird is 100-200 ft. depending on the surface topography, tree cover, etc., with the helicopter 100 ft. above. The established useful depth of detection of the system for moderate-to-large conducting bodies, i.e. 1000' or more in plan length, is at least 600 ft. sub-bird under conditions of low extraneous geologic noise, i.e. where the general level of conductivity of the overburden and rock types of the area is low. The useful depth of detection of the system is therefore at least 400-500 ft. beneath the ground surface under these conditions.

PRESENTATION OF RESULTS

The electromagnetic records (see sample traces fig. 1 and 2) are interpreted to determine the presence of conducting bodies and to obtain some information relating to their character. The intervalometer time marks are synchronized with the positioning camera film strip and thereby permit the relating of the conductors with appropriate ground locations. The terrain clearance is obtained from the altimeter data, presented in the form of sidepen markers whose separation is nearly proportional to the helicopter-terrain clearance.

A plan is prepared, either using a subdued photo-mosaic ("grayflex") or an overlay from a mosaic or topographic plan as base (fig. 3) The flight path of each survey line is obtained by means of "tie points", which are features on the mosaic or topographic plan which are identified on the positioning camera film. The flight path is interpolated between these tie points.

For each conductor the following quantities are measured and recorded:

a) Peak Location

The peak location of the amplitude ratio (using the horizontal coplanar coil system or the cross over in case the vertical coaxial coil system is used) is shown on the plan by a circle in the appropriate location. In the case of broad conductors or closely spaces multiple conductor zones there may be more than one peak, in which event all major peaks are shown. A conductor which is likely man-made will be indicated by an X rather than by a circle.

b) Conductor Half Width

The "half width", i.e. the distance between the points of half the maximum response amplitude is for simple line current sources, using the horizontal coplanar coils approximately equal to the depth of the source under the detector. In case the vertical coaxial system is used the peak to peak separation is for dike like bodies equal to 1.15 times the depth of the source under the detector. Flat-lying conductors (e.g. overburden) characteristically give rise to very large half widths, combined with rather irregular curve shapes and, often, "dipolar" curve forms on the horizontal coplanar coils.

The conductor half width, or peak to peak separation, is indicated on the plan by an open bar symbol along the flight line. If a conductor is of short half width there may be no room for a half width bar and only the peak circle will be shown.

c) Amplitude Ratio and Phase Difference

Amplitude ratio and phase difference are scaled from the electromagnetic traces and noted in percent and degrees respectively. On the flight plan, opposite each peak location (circle) will be given the peak amplitude ratio and the peak phase difference as well as the calculated depth of the conductor under the surface (see below).

INTERPRETATION

Where field distortion occurs the curves indicate the location and the depth of the main current flow. The "current axis" is well defined when the current is concentrated as, for instance, in thin, steeply dipping conductors. In wide, banded conductors, or in horizontal conductors such as overburden, the current is usually more dispersed and the anomalies will yield less positive information.

As a rule the current axis is located right below the maximum field strength ratio deflection or the maximum negative phase shift, for the horizontal coplanar receiving coil system. For the vertical coaxial coil system the current axis is located right below the cross over. Its depth under the traverse is indicated by the shape of the anomaly.

The amplitude ratios and phase differences provide a measure of the conductivity of the conducting bodies, i.e. good conductors are characterized by field strength distortion combined with relatively little phase shifting, whereae poor conductors affect the phase, rather than the strength of the resultant field.

For an accurate grading the conductivity-thickness factor (σt value) in most of the individual conductors can be derived from the calculated in-phase and out-of-phase components, taking further into consideration the exciting frequency and the strike length of the conductor.

To obtain the projection of the current pattern, the anomalies are connected between lines, whereby depth and σt values, as well as other characteristics of the curves are used as criteria. The strike of the formations, if known, is also taken into consideration.

Based upon the σt values, conductor intersections are graded in categories 1, 2 and 3 as follows:

Category 1 $\sigma t > 100$ mhos

2 $10 \leq \sigma t \leq 100$ mhos

3 $\sigma t < 10$ mhos

The respective peak circles are shaded to reflect these categories with category 1 fully shaded, category 2 half shaded and category 3 unshaded. Large, highly conducting bodies such as massive sulphides or graphite and seawater, etc., generally have high σt values. Moderate conductors will have σt values between 10 and 100 mhos. Poorly conducting bodies (e.g. most overburden and some sulphide and graphitic zones) will have σt values of less than 10 mhos. In areas where there is a clear differentiation in conductivity between the targets of potential economic interest and other possible conductors, the σt values may form the main basis for discrimination. When the conductivity ranges of economic and non-economic conductors overlap, the σt value can of course not be too rigidly relied upon.

MAGNETIC CORRELATION

Where magnetic data are available, preferably from a coincident magnetometer recording, any correlating magnetic activity will be noted for the pertinent conductor peak. A conductor peak with apparently direct magnetic correlation will be indicated by a double concentric circle. Although a conducting body which is appreciably magnetic is in some geologic environments more likely to be a sulphide body than one which is non-magnetic many important base metal ore bodies are known which are non-magnetic. Even when no direct correlation is evident, the magnetic data may yield significant indirect information concerning rock zones, structure and, not least of all, the depth of certain rock formations.

* (Bosschart, 1964, p. 22 and fig. 9) Analytical Interpretation of Fixed Source Electromagnetic Prospecting Data

PART II

Turair records appear rather different from most other airborne electromagnetic records. To familiarize the reader copies of typical Turair records are shown in Figures 1, 2 and 5 to 11. The field records are reduced to one half their original scale. The magnetometer traces, obtained with a Scintrex N.P.M. 1 nuclear resonance total field magnetometer, originally recorded separately, are photographically superimposed on the Turair charts.

As has been mentioned in Part I the Turair receiver system employs amplifiers which work on the "phase-lock" principal and which require at least 1 μV of primary signal for proper operation in the present equipment. This means that at relatively great distances from the transmitting loop the internal reference oscillator will not be locked to the transmitter signal. The limiting distance depends on the nature of the overburden in the vicinity of the transmitting loop, the size of the loop and the circulating current in the loop. For the present system, using a 2 mile square loop with 4 amperes at 400 Hz the limiting distance is of the order of 2 to 4 miles from the centre of the loop.

Of the profiles shown Fig. 2, 5, 7 and 8 are of Turair flight lines which were flown parallel to the loop side and about 1 mile outside the loop (see Fig. 4). The remainder of the profiles cross two sides of the loop. Each loop is approximately 2 miles in diameter (except for that of Fig. 10 which is about 3 miles) and energized by 4 amperes current.

Flying towards the loop the transmitter field will increase in strength which means a gradual increase in signal to noise ratio. This is clearly shown on all the records where directly after locking on to the transmitter signal a strong noise level still exists, which noise gradually decreases as the signal increases.

The system has an electronic noise level of about $3 \mu V$. This means in practise that it takes approximately 1500-2000 ft. after locking of the phase before the signal to noise ratio is increased to a level giving interpretable results.

During the winter of 1969 an area with up to 500 ft. of overburden and Paleozoic sediments overlaying Precambrian rocks was surveyed. Approximately twenty, 2 x 2 mile loops, energized by 4 amperes were used. From each loop an average area of 24 square miles could be surveyed with lines up to 6 miles long.

Within about 600' of the loop sides the recorded signals and geometric gradients are too strong and no geological conductors can be distinguished in these "blind zone" regions. Within the loops a virtually noiseless area exists making interpretation of the records easy. Each of the flight records is labelled as described in Part I (switching spikes, blind zones, conductor peak locations, etc.) and is described in turn below.

<u>Fig. 1 + 11 A</u>   A reversed anomaly marked C, showing 0.6% amplitude ratio and 0.5^{o} phase shift and an even stronger conductor

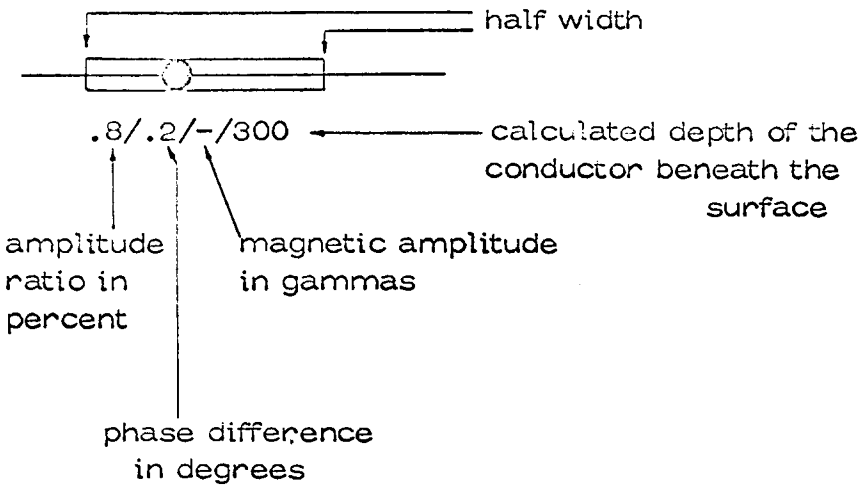
marked B are shown besides two smaller conductors marked A. In the centre of the loop a zone showing strong phase shift is encountered. This zone, which is shown on both lines (which are less than half a mile apart) reflects the same conductor (lake bottom). Zone B and zone C on these two figures correspond also. All these conductors come within 150 ft. of the ground surface.

<u>Fig. 2, 7 and 8</u> These lines are flown parallel to the loop. Twin conductors A -- C and B -- C likely each reflect a broad conductor at depth. The magnetic peak lies between the "normal" current axis A or B and the "reversed" current axis C generally somewhat closer to the former. The likely geologic source for both types of indication would be moderately conducting serpentinized ultra basic bodies at least 1000' wide.

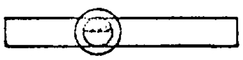
<u>Fig. 5</u> This figure shows approximately 7 miles of virtually undisturbed record.

<u>Fig. 6</u> A conductor marked A showing more than 1% amplitude ratio and negligible phase shift, together with magnetic correlation is encountered flying towards the loop. Inside the loop two smaller conductors marked A and a zone showing only phase shift (poor σt value) are shown. Flying away from the loop two conducting zones marked B are visible.

<u>Fig. 9</u> This figure shows clearly the low noise level which exists for approximately 5 miles. Three anomalies A and B all reflect conductors at less than 150-200 ft. depth.



Category one, no magnetic correlation

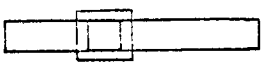


.5/.5/200/400

Category two, magnetic correlation

.1/.6/-/100

Category three, no magnetic correlation



.1/.2/200/200

Category three, reversed current flow, magnetic correlation

probably man-made conductor

Examples of Conductor Coding

Fig. 10 The character of the records reflecting conducting zone D is typical of near surface conductors with broad horizontal extent (lake bottom, swamps, etc.)

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FIG 1 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR – SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND:

- X SWITCHING "SPIKE".
- —·—·— REFERENCE OR ZERO LEVEL.
- **A** NORMAL ANOMALY FLYING TOWARDS THE LOOP.
- **B** NORMAL ANOMALY FLYING AWAY FROM THE LOOP.
- **C** REVERSED ANOMALY FLYING TOWARDS THE LOOP.

NOTE:

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES:

TURAIR:

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1·5°
MAGNETOMETER	1" = 275 GAMMAS

FIG 2 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR - SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND :

- X — SWITCHING "SPIKE".
- —·—·— REFERENCE OR ZERO LEVEL.
- C □ REVERSED ANOMALY FLYING TOWARDS THE LOOP.
- A ◎ NORMAL ANOMALY FLYING TOWARDS THE LOOP.

NOTE :

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

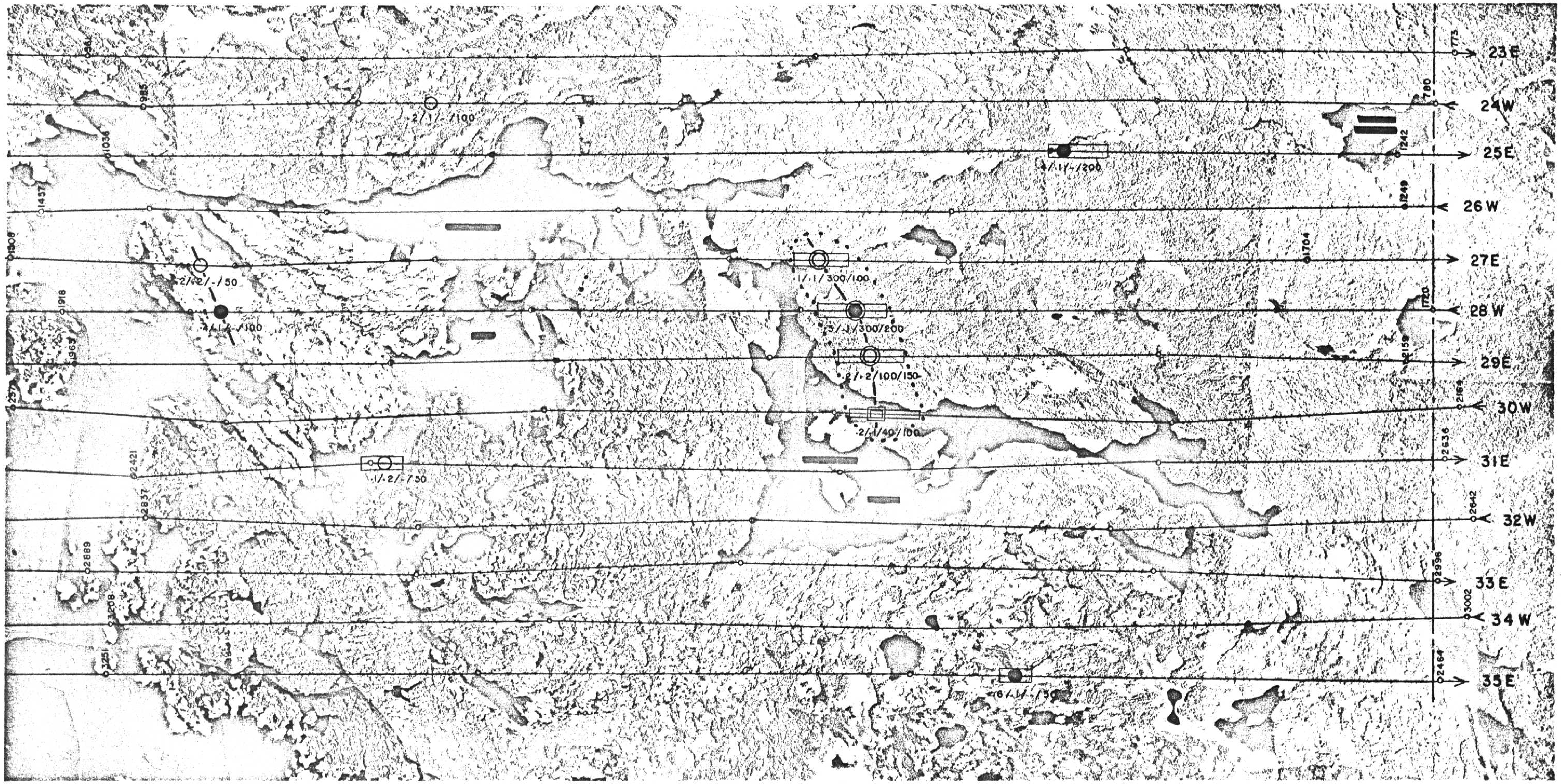
SENSITIVITIES :

TURAIR :

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1.5°
MAGNETOMETER	1" = 275 GAMMAS

PRESENTATION OF AIRBORNE GEOPHYSICAL SURVEY

FIG. 3



LEGEND:

1249 — 26W	FLIGHT LINE, FLIGHT LINE NUMBER AND FLIGHT DIRECTION WITH NUMBERED TIE POINT.
●	1st CATEGORY ANOMALY. ■ REVERSED ANOMALY
○	3rd CATEGORY ANOMALY. □ REVERSED ANOMALY
◎	TURAIR ANOMALY WITH MAGNETIC CORRELATION
·4/·2/100/200	·4% AMPLITUDE RATIO / ·2° PHASE DIFF. / Magnetic Correlation AMPLITUDE IN GAMMAS / CALCULATED DEPTH OF THE CONDUCTOR BENEATH THE SURFACE IN FEET.
[○]	ANOMALY EXTENT AND PEAK LOCATION
— — —	CONDUCTOR AXIS.
•••••••	CONDUCTOR OUTLINE.

inches 0 1

centimetres 0 1 2

This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.

YUKON GEOLOGICAL SURVEY

TURAIR ELECTROMAGNETIC ANOMALY PLAN

SCINTREX TURAIR

SCALE : 1" = 2640'

COMPILED BY SEIGEL ASSOCIATES LIMITED 1969

FLIGHT ALTITUDE ≃ 200'

FLIGHT LINE SPACING ≃ 1320'

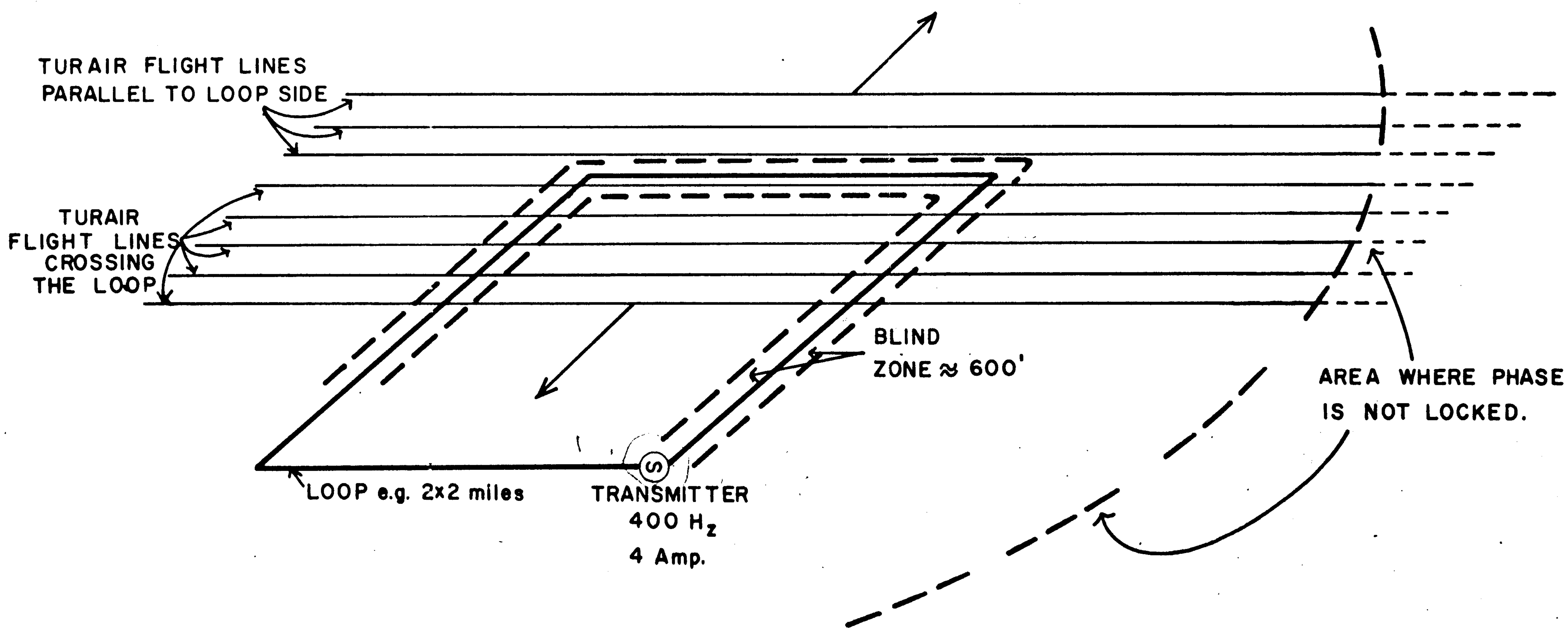


FIG. 4

TURAIR SEMI AIRBORNE ELECTROMAGNETIC SYSTEM

FLIGHT LINES IN RELATION TO THE TRANSMITTER LOOP.

RBD

FIG 5 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR - SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND:

X SWITCHING "SPIKE"

—·—·— REFERENCE OR ZERO LEVEL.

NOTE:

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES:

TURAIR:

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1·5°
MAGNETOMETER	1" = 275 GAMMAS

FIG 6 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR - SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND :

X SWITCHING "SPIKE".

REFERENCE OR ZERO LEVEL.

A ◎ NORMAL ANOMALY FLYING TOWARDS THE LOOP. WITH MAGNETIC CORRELATION.

B ⊏○○⊐ NORMAL ANOMALY FLYING AWAY FROM THE LOOP SHOWING EXTENT AND PEAK LOCATION.

NOTE :

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES :

TURAIR :

AMPLITUDE RATIO 1" = 25%

PHASE DIFFERENCE 1" = 1·5°

MAGNETOMETER 1" = 275 GAMMAS

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FIG 7 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR - SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND :

- X SWITCHING "SPIKE".
- —·—·— REFERENCE OR ZERO LEVEL.
- C □ REVERSED ANOMALY FLYING AWAY FROM THE LOOP.
- B ◎ NORMAL ANOMALY FLYING AWAY FROM THE LOOP WITH MAGNETIC CORRELATION.

NOTE :

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES :

TURAIR :

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1·5°
MAGNETOMETER	1" = 275 GAMMAS

FIG 8 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR - SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND :

X SWITCHING "SPIKE".

—·—·— REFERENCE OR ZERO LEVEL.

C □ REVERSED ANOMALY FLYING TOWARDS THE LOOP.

A ◎ NORMAL ANOMALY FLYING TOWARDS THE LOOP. WITH MAGNETIC CORRELATION.

NOTE :

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES :

TURAIR :

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1·5°
MAGNETOMETER	1" = 275 GAMMAS

FIG 9 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR - SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND :

- X SWITCHING "SPIKE".
- —·—·— REFERENCE OR ZERO LEVEL.
- **A** NORMAL ANOMALY FLYING TOWARDS THE LOOP.
- **B** NORMAL ANOMALY FLYING AWAY FROM THE LOOP.

NOTE :

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES :

TURAIR :

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1·5°
MAGNETOMETER	1" = 275 GAMMAS

FIG 10 : ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR-SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND:

X SWITCHING "SPIKE"

—·—·— REFERENCE OR ZERO LEVEL.

D ANOMOLOUS ZONE CAUSED BY NEAR-SURFACE CONDUCTION

NOTE:

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES:

TURAIR:

AMPLITUDE RATIO	1" = 25%
PHASE DIFFERENCE	1" = 1·5°
MAGNETOMETER	1" = 275 GAMMAS

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FIG 11: ORIGINAL IN-FLIGHT RECORDING OF COMBINED SCINTREX TURAIR – SCINTREX NUCLEAR PRECESSION MAGNETOMETER SURVEYS

LEGEND:

X SWITCHING "SPIKE".

–·–·– REFERENCE OR ZERO LEVEL.

C REVERSED ANOMALY FLYING TOWARDS THE LOOP.

B NORMAL ANOMALY FLYING AWAY FROM THE LOOP.

NOTE:

1. CHART IS REDUCED TO HALF ITS ORIGINAL SCALE.
2. TURAIR RECEIVER IS OF THE HORIZONTAL COPLANAR COIL SYSTEM.

SENSITIVITIES:

TURAIR:

AMPLITUDE RATIO	1" = 2.5%
PHASE DIFFERENCE	1" = 1.5°
MAGNETOMETER	1" = 275 GAMMAS