UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Interpretation of an aeromagnetic survey of parts of Shannon, Carter, Oregon, and Ripley Counties in southeastern Missouri

by

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With an Introduction by Gerda Abrams

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INTRODUCTION

This report was prepared under contract by Allan Spector and Associates Limited, Toronto, Canada, for the U.S. Geological Survey. It was used in a geophysical investigation conducted by the U.S. Geological Survey of the Irish Wilderness Study Area, Missouri. The principal objective of the contract work was to resolve the topography of the buried Precambrian basement surface, and to obtain information concerning lithology and structure of the basement rocks.

The survey area is located in southeastern Missouri, bounded by latitude 36°38′, longitude 91°, and latitude 37°, longitude 91°20′. The aeromagnetic survey was flown by the U.S. Geological Survey in late 1979 and early 1980. The data was acquired using a Geometrics Proton Magnetometer G-803 installed in a Heli-Porter aircraft, flown at barometric altitude 1200′ ASL. The survey was flown in a north-south direction at a mean spacing of .5 mile (805 m).

The conclusions reached in this report are the sole responsibility of Allan Spector and Associates Limited, Toronto, Canada.

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REPORT ON

AEROMAGNETIC INTERPRETATION

IRISH WILDERNESS PROJECT

SOUTHEAST MISSOURI

For

UNITED STATES GEOLOGICAL SURVEY

By

ALLAN SPECTOR AND ASSOCIATES LIMITED
TORONTO CANADA

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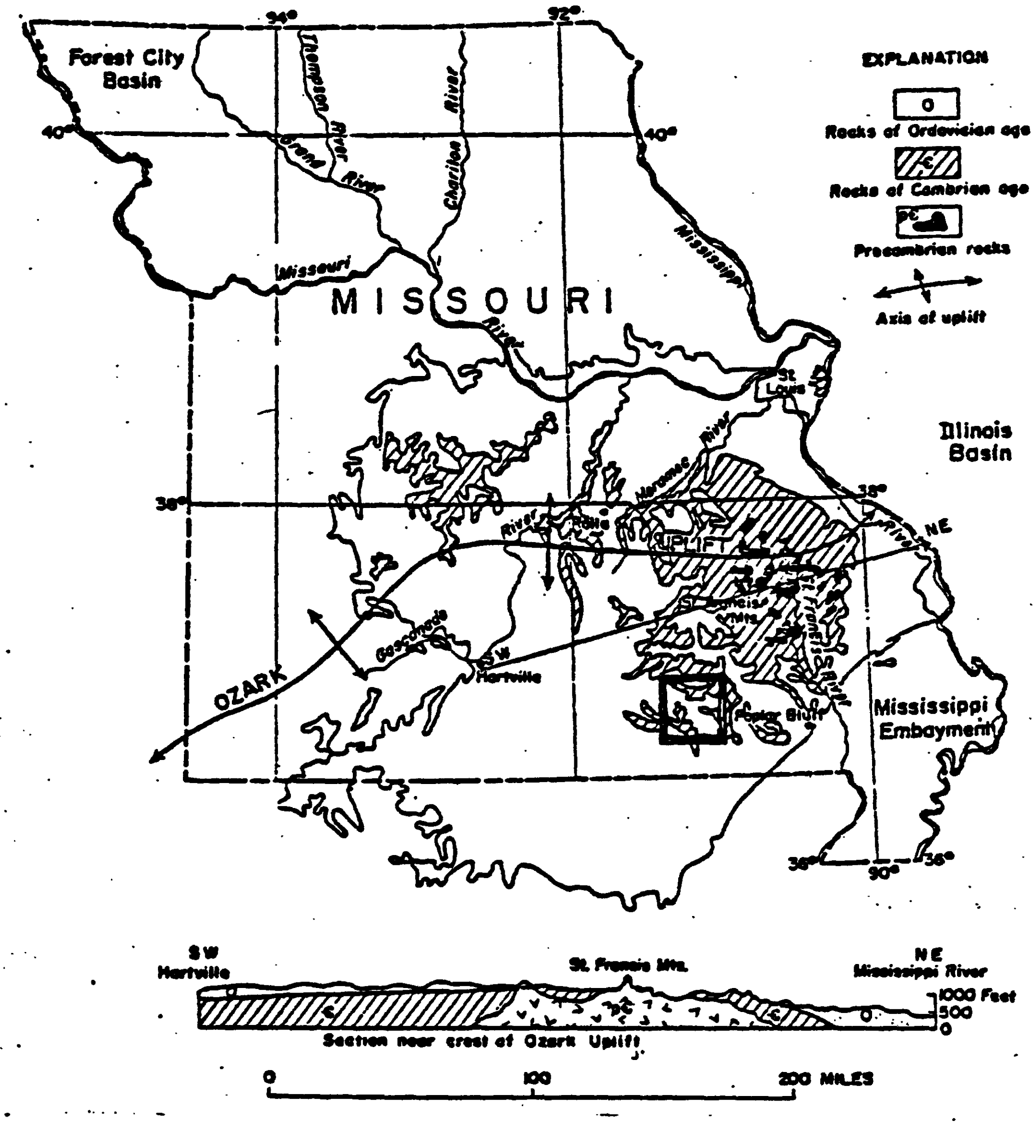


1. INTRODUCTION

1.1 The Project Area

This report contains an interpretation of the geological significance of aeromagnetic data in the southeast Missouri Mining District. Principal objective of this work is to resolve topography and structure on the buried Precambrian basement surface.

The location and geological setting of the study area is described in Figure 1. The 450 mile^2 study area includes 15 townships; 23N, 24N, 25N, 26N, 27N and from range 1W to range 3W extending into Ripley, Oregon, Shannon and Carter Counties. The town of Alton is located in the southwest part of the area. Primary interest is focussed on township 24N, range 2W.

St. Louis is 100 miles northeast of the study area. Overall topographic relief in the area is about 500 feet with elevations ranging from 600 to just over 1000 feet above sea level.

1.2 The Aeromagnetic Data

This report concerns aeromagnetic data taken from the southern part of a survey done in December, 1979 and January, 1980 by the U.S.G.S. The 900 line mile survey consisted of north-south oriented lines at 1/2 mile spacing and orthogonal tie lines at 12 mile spacing, all at 1200 foot A.S.L. (barometric) altitude. A 10 gamma magnetic contour map (minus geomagnetic gradient) was compiled at a scale of 1:62,500.

A Geometrics proton magnetometer G803 with 1/8 gammas sensitivity was used in the survey.

The data was recorded in both analog and digital form. The digital data was later used to present the data in rectified form. Magnetic diurnal variations were recorded; this data was applied in the survey data reduction.

The data as expressed in the magnetic contour map is considered accurate to about ±5 gammas because of the following factors:

(a) inaccuracies in correction for magnetic diurnal variation, ± 1/2 gamma,

(b) inaccuracies in survey flight path positioning, ± 1/4 gamma,

(c) sensitivity of the magnetic measurements, about ± 1/4 gamma,

(d) system noise, e.g. during radio transmission by the pilot, ± 1/4 to ± 1/2 gamma,

(e) ground effect, ± 2 gammas (estimated).

Regional characteristics of the earth's magnetic field for the project area (1975) are as follows:

intensity:	57,000 gammas
inclination:	68°
declination:	5° east of north
gradient:	+ 8.0 gammas/mile in a northery direction

Although the aeromagnetic maps are useful for delineating rock units of distinguishable magnetization and also structure, they are not to be used for accurately determining depth to magnetic basement rocks. This is mainly a result of the fact that a great deal of smoothing of magnetic texture has resulted from the compilation procedure.

A much more definitive or more accurate means of depth determination is provided from the survey measurements recorded in profile form. Thirty-seven rectified profiles of the residual magnetometer data (minus diurnal variation and geomagnetic gradient) at a constant horizontal scale of 1;62,500 and 1" = 25 gammas vertical scale were made available for the analysis.

1.3 Program of Work: Geology of the Study Area

Objectives of this study given in this report may be described as follows:

(a) map magnetic basement elevation to resolve basement highs in the vicinity of which base metal mineralization may be developed,

(b) map basement fault structures which may have influenced the topography of the basement surface and also the attitude and lithologic facies of overlying sedimentary rocks,

(c) distinguish crystalline lithologic units on the basis of contrasting magnetization.

Materials made available by the U.S.G.S. for this study consisted of the location of two drill holes in the east-central part of the area:

T25N, R2W, Sec. 22SE; collar +905 feet, t.d. 2342 feet (into Precambrian)

T25N, R1W, Sec. 18SE; collar +880 feet, t.d. 2665 feet (in Paleozoic)

Geological Setting

As seen in Figure 1, the project area is situated on the south flank of the St. Francois Mountains, the crystalline, igneous core of the Ozark Uplift, a broad west-trending area of thin sedimentary cover. The Bonne Terre area has yielded about 9 million tons of lead since 1960. Most of the ore has been mined within 600 feet of the surface from shaly dolomite in the lower part of the Bonne Terre dolomite.

According to a recent geological map of S.E. Missouri, published by Pratt et al (1979), Precambrian granite outcrops only 1 1/2 miles east of the northeast corner of the study area. Four miles north of the area, Precambrian alkali-rhyolites are more extensively exposed. According to Pratt et al (1979) the Precambrian rocks of the St. Francois Mountains comprise a thick sequence of relatively unmetamorphosed volcanic rocks, most of which are ash flows, intruded by a thin, sheetlike, composite granite batholith that now dips gently southwest. According to Kisvarsanyi's 1979 map, most of the study area is underlain by granite, however this map is based on drilling which is entirely exterior to the study area. Faulting and tilting of large blocks of basement rocks prior to sedimentation provided local relief. The Upper Cambrian Lamotte sandstone filled basins on the Precambrian surface. Patch and algal reefs developed along the flanks of bedrock hills. Dolomitization and recrystallization altered the original characteristics of calcareous beds within the Bonne Terre dolomite which overlies the Lamotte sandstone. These altered permeable structures controlled many lead deposits in the Bonne Terre area. Major fault structures appear to have been a controlling influence in the distribution of the deposits, i.e. they acted as channelways in which mineral-bearing fluids migrated upward.

Three important factors controlled deposition of the lead:

(1) relief on the Precambrian surface, which controlled sedimentation and some structural features in the Palaeozoic strata,

(2) an archipelago environment that produced sedimentary structures of depositional origin, mainly sand bars or spits and wavecut benches upon which algal reefs formed, and shallow depositional basins adjacent to reef facies that received clastic sediments, lime and argillaceous mud, and calcareous shaly breccias,

(3) fracture zones and permeable fault zones that were favourable for the movement of mineral-bearing fluids.

Some Precambrian hills are roof pendants; dense fine grained rocks such as rhyolite or granophyre which resisted erosion and produced isolated hills of higher relief than that over the coarse grained granite.

The example shown below is taken from Allingham (1966):

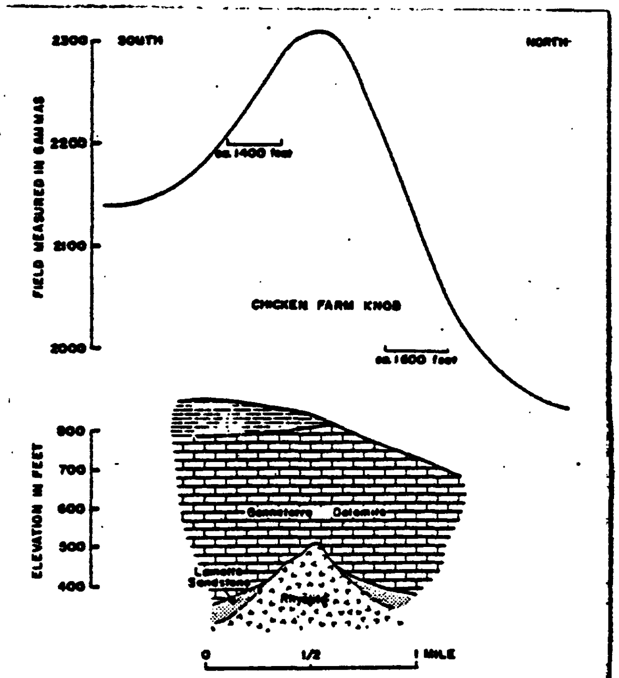


FIG. 6. Aeromagnetic profile showing the effect of topography and estimated depth to basement at Chicken Farm Knob. Subsurface information from St. Joseph Lead Co.

In addition to basement highs, attention should also be given to areas of depressed basement or basins which are filled with argillaceous strata. According to Allingham, fringing reef and inter-reef detritus, solution and slump breccias at reef margins are host rocks for many lead deposits.

2. INTERPRETATION METHOD

In the analysis of the magnetic data, described below, emphasis was placed on ensuring that the data was thoroughly assessed in order to avoid disregarding features of possible significance in terms of Precambrian relief. To accomplish this, the analysis initially involved an assessment of the data in profile or analog form. The results of this profile analysis were later synthesized using the contoured magnetic intensity maps.

2.1 Profile Analysis

The computer plotted magnetic intensity profiles from each survey line were examined to firstly identify magnetic anomalies and magnetic contacts and secondly, to measure depth to magnetic zone.

Shown in Figure 2a is a reproduction of part of a plotted chart recording of magnetic data.

A basis for deriving some of this information was derived from model curves. A computer program was used to generate synthetically, the anomaly of a prism (vertical contacts, horizontal top, rectangular cross-section) for the magnetic field orientation of the study area:

inclination: 67°

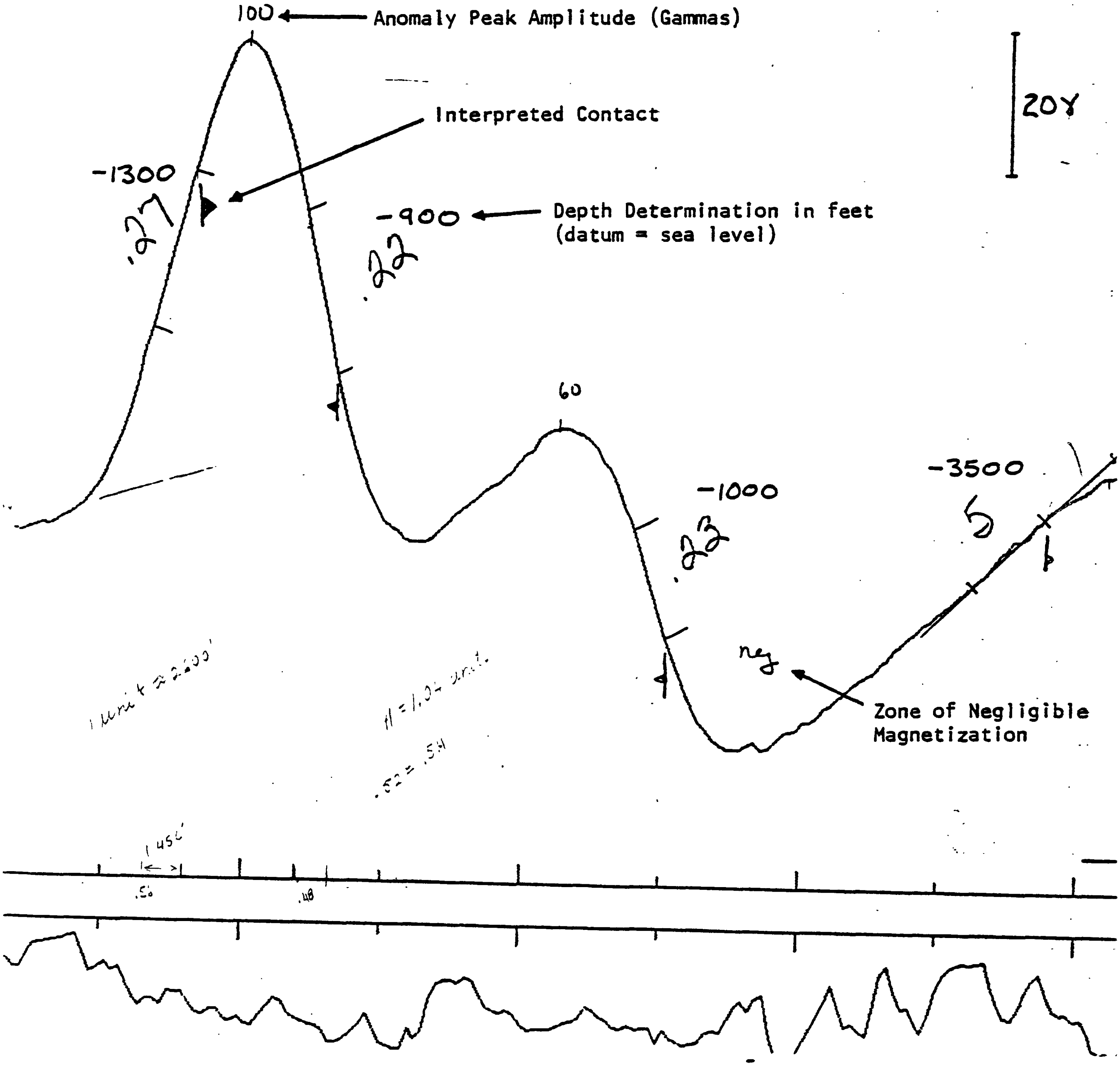
declination: 10° E of N

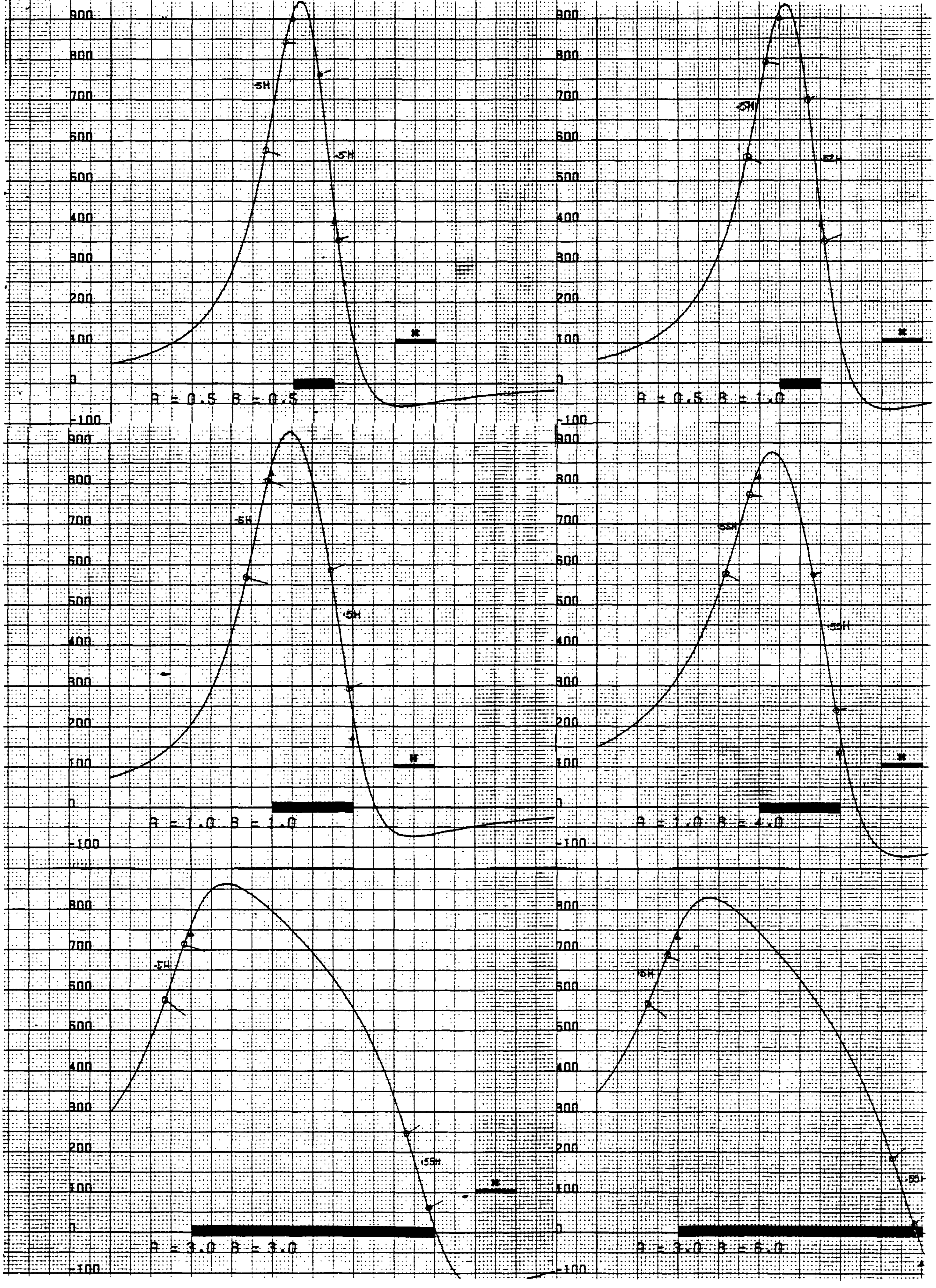
The computer program uses a mathematical expression developed by Bhattacharyya (1964). Profiles across magnetic anomalies generated for prisms with various sizes are shown in Figure 2. Prism horizontal dimensions 2a and 2b are given in units of depth to burial, i.e. H = 1.0. Anomaly amplitudes are all normalized to 1000 gammas. Also included is the anomaly over a thin plate-like body. This case is a simulation of that expected over basement topography.

Anomalies are seen to exhibit a negative component of about 10% of total amplitude off their northern contact. Magnetic anomaly peak is located near the south contact of the prism. The curves provide a valuable insight as to where to locate contacts (or faults) on the curve. They also provide an empirical basis for determining depth to source, i.e. the width of the interval of maximum anomaly gradient on either the north or south side of the anomaly maximum is a fraction of the depth of burial: 0.50H for the prism model and 0.35H for the plate model.

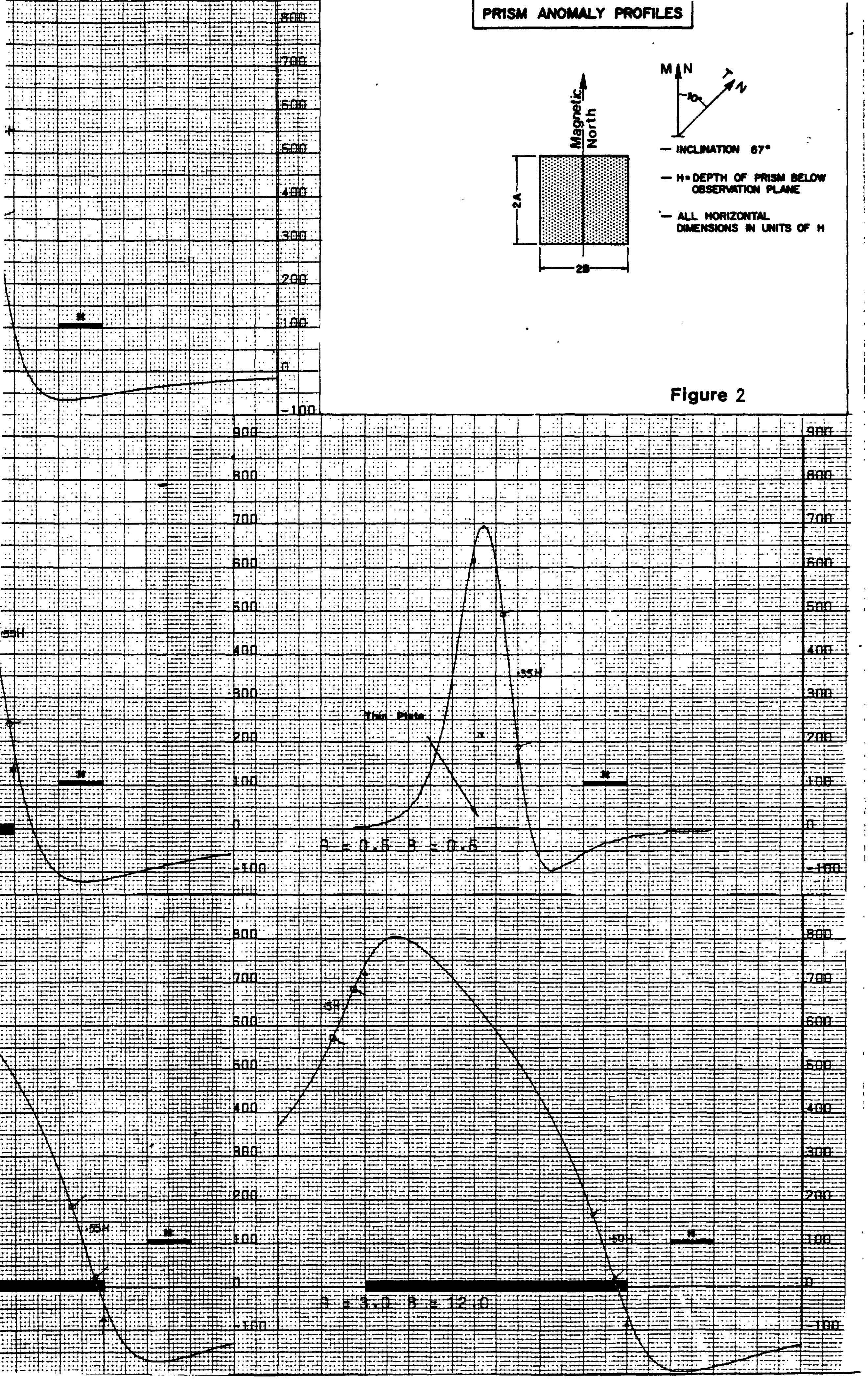
The question of which magnetic model was appropriate was decided after comparing the two sets of depth results with depth-to-basement values known from

Figure 2a: Sample of Magnetic Profile Analysis



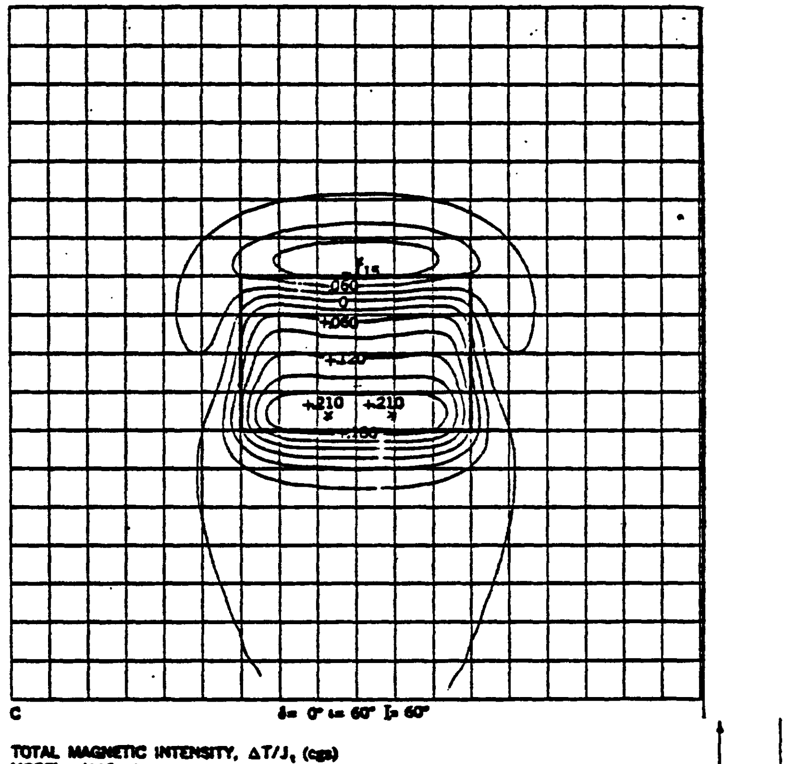


A = 0.5 B = 0.5
A = 0.5 B = 1.0
A = 1.0 B = 1.0
A = 1.0 B = 4.0
A = 3.0 B = 3.0
A = 3.0 B = 6.0


PRISM ANOMALY PROFILES
Magnetic North
2A
2B
M N
T N
— INCLINATION 67°
— H = DEPTH OF PRISM BELOW OBSERVATION PLANE
— ALL HORIZONTAL DIMENSIONS IN UNITS OF H
Thin Plate
.55H
A = 0.5 B = 0.5
.55H
.50H
A = 3.0 B = 12.0
900
800
700
600
500
400
300
200
100
0
-100
Figure 2

drilling. In about 60% of the cases, depths using the prism model yielded depths that were too shallow, i.e. a fair amount of magnetic relief is due to basement topography.

Shown below is a plan view of an anomaly due to a plate-like body. This figure is taken from U.S.G.S. Paper 666 by Andreasen and Zeitz (1969). Grid unit is equal to depth of burial, H. Plate thickness is 0.1H. The field and the polarization vector are inclined at 60°.



TOTAL MAGNETIC INTENSITY, ΔT/J, (cgs)
MODEL=4×6×.1
Grid interval=Depth of burial

MAGNETIC NORTH

Basement elevation estimates were calculated using the following formula:

$$H = H_o - s \cdot \frac{k}{A} \cdot \cos 30^\circ$$

where s is the measured horizontal width of the maximum anomaly gradient in inches (measurement accuracy ±0.02 inches)

k is the scale of the maps, i.e. 5208 feet

H_o is the aircraft altitude: 1200 feet

A is the depth factor: 0.55 and 0.35 for the prism and plate models respectively

The projection angle factor, cos 30°, gives consideration for the fact that in the majority of cases, the direction of the survey line is not perpendicular to the strike of a magnetic contact. After plotting the magnetic contacts onto the map, the projection angle was in some cases recognized to be as much as 45° and depths were adjusted accordingly.

2.2 Interpretation Overlays

Information obtained from the profile analysis was transferred directly to overlays of the 1:62,500 scale contoured magnetic intensity map. Magnetic anomaly trends, contacts and magnetization were determined using the profile information and the survey flight path recovery map.

The various overlays include:

(a) magnetic contacts, anomaly amplitude, magnetic horizon dip, zones of negligible magnetization,

(b) uncorrected basement elevation determinations,

(c) corrected basement elevation determinations,

(d) lithological and structure interpretation,

(e) basement elevation contour at 500 foot interval.

The final interpretation map is a synthesis of overlays (d) and (e).

3. GEOLOGICAL INTERPRETATION

The results of the analysis and geological interpretation of the aeromagnetic data are presented in the aeromagnetic interpretation map, Figure 3.

The following serves to elaborate on various forms of information that are given in this map.

3.1 Magnetic/Lithologic Units and Regional Structure

Three main zones of magnetic relief are expressed in the aeromagnetic map:

(1) a broad west-trending zone which dominates the south half of the map. The zone is about 7 miles in width.

(2) a similar broad zone seemingly offset to the north of the former zone,

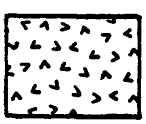
(3) the edge of an area of moderate magnetic relief along the north boundary of the area.

The three main zones are separated by non-magnetic intervals.

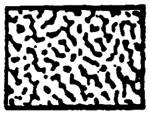
Most conspicuous however is a narrow NE-SW trending, rather linear anomaly that crosses the central part of the map. The anomaly is about 20 to 50 gammas in amplitude. This anomaly originates from much shallower depth than surrounding anomalies. It is interpreted to have great structural significance, i.e. that it is due to a fault bounded ridge 1500 to 2000 feet in relief. Major vertical and horizontal displacement is attributed to the faults that are associated with this ridge.

The first two main magnetic zones may have at one time been a single zone that has been offset 7 or 8 miles in a right lateral displacement along NE-SW trending faults.

Areas of similar magnetization (or magnetic susceptibility) texture and grain are distinguished and outlined by magnetic contacts, in the interpretation maps, as "magnetic units". These units are given a lithologic identity based mainly on the author's experience in correlating magnetic data with Precambrian rocks in North America and to some extent on information from published mapping (Kisvarsanyi, 1979) and drill hole data.



most of the rocks that are indicated to be magnetic display a moderate intensity of magnetization, i.e. 20 to 100 gammas in amplitude. This indicates a magnetite content of about 0.1 to 0.3%. These rocks presumably include rhyolite.



on the north flanks of the two main magnetic zones located in the southern and west-central parts of the map are zones of appreciably higher magnetization reflected by relief of from 200 to 400 gammas. Magnetite content in these rocks is estimated to be about 0.3 to 0.5%. The magnetization in these rocks implies the presence of a more mafic volcanic facies.

rocks displaying little or no magnetization. The broad extensive zone of nil magnetization located on the south side of the area suggests the presence of granite.

Mention has been made above of the considerable influence that NE-SW faulting has made on the structure of basement rocks. These crop faults are predominant in the study area. In the southern part of the area there is the suggestion of west-trending longitudinal or possibly thrust faults that bound the main magnetic zones. These faults may also be associated with considerable vertical displacement of the basement surface.

3.2 Magnetic Basement Elevation

Contours of Precambrian basement elevation at 500 foot interval are shown in the aeromagnetic interpretation map. Individual elevation determinations are shown. The contouring is based on elevation determinations obtained from an analysis of the survey data in profile form. Because of limitations in the use of simple magnetic models in our analysis, i.e. the plate and prism models and because of limitations in data measurement, individual depth determinations should be considered as accurate to no better than ±15% of the actual depth to basement.

This accuracy is ±300 to ±600 feet corresponding to basement elevations ranging from -1000 to -2500 feet. In consideration of this accuracy, some smoothing therefore was applied in the contouring.

Basement subsidence is indicated in various parts of the map particularly adjacent to west-trending faults. The depressions are characterized by elevations of -2000 to -2500 feet and by zones of reduced or negligible magnetization. Basement subsidence is apparent along the southern margin of the area and in two west to WNW-trending zones that cross the central part of the map.

Basement Highs

Greatest interest in the aeromagnetic interpretation results is focussed on the resolution of rises in the basement surface as favoured locations for reef development and therefore basemetal mineralization. About twenty basement highs were resolved and indicated by a ★ symbol.

Major basement uplift characterizes the narrow fault bounded NE-SW trending ridge that crosses the central part of the map. Vertical displacement of the basement surface is in places about 2000 feet.

Substantial but much more subtle basement elevation is also seen in two other areas:

- west half of T24N, R1W and east quarter of T24N, R2W elevations of -100 to -500 feet as compared to -1500 feet adjacent
- north margin of T25N, R2W and southwest corner of T26N, R2W elevations of 0 to -500 feet as compared to -1500 feet adjacent.

Quite localized "knob-like" basement rises are depicted at the following locations:

- northeast part of T25N, R2W
- north boundary of T24N, R1W (questionable)
- west side of T23N, R2W (questionable).

The interpretation of the survey data embodied in this report is essentially a geophysical appraisal of the area, as such, it can incorporate only as much geological and geophysical information as the interpreter has available at the time. It should be judiciously used, therefore, as a guide only, by geologists thoroughly familiar with the area and who are in a better position, as time passes, to evaluate the geological significance of any particular feature. With additional information such as that provided by follow-up programs, it may be possible to down- or up-grade features recognized in this study.

Respectfully submitted,

ALLAN SPECTOR AND ASSOCIATES LIMITED

Allan Spector, Ph.D., P.Eng.

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