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DIGITAL HIGH SENSITIVITY AEROMAGNETIC SURVEY

FOR GOOD HOPE - FORT McPHERSON

NORTHWEST TERRITORIES

FOR

MOBIL OIL CANADA , LTD.

BY

GEOTERREX LTD.
Project G68-33

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INTRODUCTION

From July 18 to September 24, 1968, a digital high-sensitivity aeromagnetic survey was flown over a region east of the Richardson Mountains and north of the Mackenzie Mountains in the Northwest Territories. The program originally called for three main areas to be flown using a one by three mile grid spacing. All three blocks were tied together by a larger reconnaissance grid network. During operations, an extension was added to the western block to be flown using a line spacing of 1½ miles and a tie line interval of 5 miles. Because of the proximity of the mountain ranges both to the south and to the west, the survey was flown at three different altitudes. The most southern portion was flown at 4,200 ft., the north-western extension was flown at 4,500 ft. and the remainder of the survey, by far the largest area, was flown at an altitude of 2,500 feet above sea level.

The vastness of the area necessitated an attack from two sides; the eastern part was surveyed using Norman Wells and Fort Good Hope as bases while Inuvik and Fort McPherson served as centres for the western half. Both Norman Wells and Inuvik provided the base of operations for the aircraft and also served as secondary ground magnetometer stations. The purpose of Fort Good Hope and Fort McPherson was to provide closer monitoring of the variations of the earth's magnetic field. The ground monitor magnetometers at Norman Wells and Inuvik allowed the crew to judge whether diurnal conditions were acceptable for flying, while the other monitor stations would be used to control the results obtained. The diurnal variations will be the subject of a supplement to the present report.

A Queenair, owned and operated by Kenting Ltd., was used as the survey aircraft. A C.S.F. caesium-vapour magnetometer operated in a towed bird was used to record the total intensity of the earth's magnetic field digitally on magnetic tape in units of 0.01 gammas. The recording interval was one second, controlled by crystal clock. An analogue monitor was recorded in unison with the digital system. Similar units were used as ground monitors.

Flight path was recorded on a 35mm continuous strip camera and flight altitude by a Rosemount recording barometer. Fiducial marks, controlled by the crystal clock, were set on the film and analogue records at 50 second intervals.

I DATA PROCESSING AND COMPILATION

Data compilation included the following steps:

1. Flight path recovery and locating intersections of lines and tie-lines.
2. Reading X-Y coordinates of intersections and intermediate points on the maps in units of 10 meters on a standard UTM grid.
3. Punching IBM cards showing times and coordinates of these points.
4. Finding and correcting location errors by computing aircraft ground speed between intersections.

5. Converting airborne and ground magnetometer readings from magnetic tape to punched cards and correction of any recording errors.
6. Computing differences of magnetic values at each intersection and adjustments to level the data together.
7. Computing final magnetic values, including regional correction and X-Y coordinates for points at intervals of 5 seconds.
8. Transcribing, contouring and drafting the final maps at a scale of 1 inch to 1 mile with composite maps at a scale of 1 inch to 4 miles.
9. Preparing profiles of each line using a vertical scale of 20 gammas per inch.
10. Preparing profiles of lines scrubbed for diurnal reasons to aid in a study of diurnal effects.
11. Preparing vertical gradient profiles for areas that warranted a more detailed study.

II INTERPRETATION BACKGROUND

In the early stages of the survey, a geophysicist stationed in Norman Wells directed the flying program. By inspecting the analogue records in the field it was possible to plan the flight line directions in such a way so as to obtain the maximum magnetic response from bodies by flying over them at right angles to their strike direction.

A detailed interpretation of the data has been based on a close study of the total field calcomp profiles and contour maps. In some areas the total field profiles yielded very little information in the way of depth estimates. As a consequence, it was decided to compute vertical gradient values and produce profiles which together with the total field calcomps formed the basis for a more exhaustive usage of the digitally recorded data. Consistency of interpretation on both total field and gradient was checked on the best defined anomalies and proved to be satisfactory.

Preceeding the interpretation, a study of the diurnal records was necessary in order to determine the validity of subtracting the ground magnetic values. Results of this study showed that magnetic events arriving at Norman Wells often arrived at Fort Good Hope with a phase shift as much as twenty seconds. The distance between the two stations is approximately 90 miles. The significance of this phase shift is that subtracting ground values recorded at Fort Good Hope from air values that are recorded 90 miles away could easily introduce false anomalies into the data. Since some parts of the survey are over 90 miles from the nearest ground station, and the radius of effective ground control is unknown, no subtraction of ground from airborne data was performed. However, to aid the interpretation, all lines that were rejected for diurnal reasons were processed for comparison with the accepted data. This technique allowed the interpreter to decide whether an anomaly was due to geologic conditions or due to variations in the earth's magnetic field. The criterion was simple: If the anomaly was evident on both profiles, it was real; its appearacne only on one, however, indicated that it was not due to geological conditions. In some cases, anomalies of doubtful validity appeared in the data, on calcomps or maps. These are usually features shown by one line only. They are marked on the maps by queries.

Anomaly locations were transferred from the profiles to the maps and traced from line to line. Three types of anomalies are presented on the interpretation maps; both positive and negative basement anomalies above basement anomalies and intrabasement anomalies. The latter, constitute the large regional anomalies which yield depth estimates in the vicinity of 25,000 feet sub-sea, while basement features are in the neighbourhood of 6,000 to 12,000 feet sub-sea. Above basement anomalies are considered to originate within the sedimentary section or close to the ground surface. These features, generally recognized by their amplitude, width, character and depth, often present problems such that their origin is questionable. In cases where it is difficult to decide whether a feature originates at the basement surface or within the section, the axis is shown with an interrogation mark, and the preferred interpretation is shown by the anomaly symbol used.

This classification is necessarily arbitrary. On the basis of present data we cannot be sure which magnetic horizon is the actual basement. It is quite possible that the deep features, classed as intra-basement, mark the real igneous basement surface, while the features marked as basement may sometimes reflect a metamorphic level in Precambrian or other sediments in some places.

The primary method used for determining depths has been the Inflection Tangent Intersection method developed by the

Compagnie Generale de Geophysique*. Depth estimates are shown in feet below sea level and are, in general, accurate to within ±10% relative to flight altitude. Considering the reliability of the estimates, and their density, an interval of 1,000 feet has been used in the depth contours. On the eastern part of the survey, basement was interpreted at around 6,000 feet deepening westward where the magnetic pattern takes on the effect of large regional features. Depth estimate for these features reveal that their source lies somewhere in the range of 20-35,000 feet below sea level. Their size and estimated depth is such that they have been interpreted as originating from below the basement surface, consequently, their depth values are not contoured.

III INTERPRETATION

For simplicity and coherence in the discussion of the interpretation, the survey is divided into four principal sections; the eastern block (sheets 12 to 17), the southern block (sheets 21 to 26), the centre block (sheets 9 to 11 and 18 to 20) and the western block (sheets 1 to 8).

III.1 THE EASTERN BLOCK (sheets 12, 13, 14, 15, 16, 17)

From the total field contours, the dominant magnetic features present in this area are as follows: The regional magnetic low situated near the middle of the area; the northwesterly trending low in the northern half, the magnetic high near the western edge and the three general zones of activity,

*GIRET, R. and NAUDY, H., 1963. Methodes actuelles d'interpretation des etudes aeromagnetiques en recherche petroliere: World Pet.Congress Section 1.

one in a northwest trending belt extending across the northern area, one occupying the southeastern quarter, and another in the southwestern corner. The broad magnetic highs and lows are attributed to changes in composition of the material within the basement. Their amplitudes and resulting gradients tend to obscure smaller anomalies that may be superimposed. As a consequence, such smaller anomalies might not yield reliable depth estimates and often are difficult to identify as being basement surface features or intrasedimentary anomalies. Several of these anomalies can be found in the northern half of the area.

Many anomalies throughout the area have yielded reliable depth-estimates, especially over sheets 12, 15, 16 and 17. Over these sheets the depth estimates are the most abundant and likely the most reliable.

The basement generally dips westwards and its depth below sea-level averages 4,000 feet on the eastern boundary of sheets 15 and 16, and 8,000 feet on the western boundary of sheet 12. In between, several interesting structures of the basement have been revealed by the contouring of the basement surface. The main ones are the following:

Anticline A1 (Sheet 15). This anticline appears to be limited to the south by fault F1, trending approximately N60°West. Depth of basement at the top of the anticline was found to be 3,800 feet b.s.l.

Anticline A2 (Sheet 15), is trending approximately NW-SE. Depth of basement at the top is the same as for A1.

Another fault, F2, could constitute the southern boundary of this anticlinal area; this fault follows a marked discontinuity in the magnetic pattern suggesting a lateral displacement in the range of 2 to 3 miles and a possible downthrow to the south.

Anticline A3 (Sheet 15) is only a plunging "nose", with a depth of basement some 4,500 feet b.s.l. at its axes. This structure, therefore, appears to be less interesting than A1 and A2.

Anticline A4 (Sheets 14-15) is located on the same trend as A1, but in a less favourable position since it is structurally lower. Average depth to the surface of basement ranges from 5,500 to 6,000 feet below sea-level.

An additional broad basement high has been interpreted in the southeastern corner of sheet 12. This is a large area where the depth-estimates range between 5,500 and 6,000 feet. The closure of this structure to the east is not well ascertained due to the absence of anomalies in this direction.

The quantity and intensity of magnetic anomalies are decreasing to the north, on sheets 13 and 14. For this reason, the contouring of basement could not be extended north of line 17. It is possible to estimate, however, that the basement dips to the north on sheet 14 and to the west on sheet 13.

Most of these basement highs are associated with individual magnetic anomalies of basement type, striking north-south. There are a number of these anomalies spread throughout these sheets. Some are too weak to give reliable depth estimates, but they may be important indicators of structure on the basement surface and deserve further exploration. Others may be stronger, but local complications hindered depth calculations. A prime example is the circular magnetic high in the centre of sheet 14 (on line 22 between tie line 218 and 221). This could indicate a small plug lying on a deeper-seated north-south axis.

In the north end of this block (sheets 13-14), several sharp, but weak magnetic anomalies were noted. These arise from magnetic material above the basement, possibly near the ground surface. They are short and irregular, and unlikely to be important.

As a conclusion, it is possible to assert that in the eastern block of the survey area the thickness of the sedimentary section ranges from 4,500 to 9,000 feet. Good prospects for further geophysical investigation have been found, especially along a trend stretching across sheet 15, with individual structures in A1 and A2.

III.2 <u>CENTRE BLOCK</u> (Sheets 8 to 11, 18, 19 and 20)

The centre block, bounded by 66°00" N to 67°00" N latitude and 129° E to 133°00" E longitude, is partly covered by a detail grid network of 1 by 3 miles (sheets 8, 9, 10), a reconnaissance grid of 3 by 9 (sheets 11, 19, 20) and a tie-in network of 9x9 miles (sheet 18).

The total field contours illustrate the predominance of large regional "highs" and "lows". These anomalies may be the result of changes in the rock composition within the basement and, consequently, may influence neither the topography of the basement surface nor the sedimentary section.

But possibly, they could reflect the real igneous basement surface, at depths of 20,000 to 40,000 feet, for there is obviously little magnetic material in the overlying rocks. However, certain weak magnetic features give much shallower depths, ranging from 8,000 to 15,000 feet. We have chosen to call this horizon the basement surface, since it fits well with the stronger features to the east. But obviously it does not represent a basement of normal Precambrian igneous type. It could be a metamorphic surface.

If we consider, for example, the field contours on sheet 8, only a strong gradient decreasing from NE to SW can be seen. This is one of the deep seated effects that has been called intrabasement, but vertical derivatives or graphical residuals show a residual anomaly, the axis of which is located approximately along tie line 353, between lines 40 and 49. Quantitative interpretation of this anomaly yields depth estimates ranging from 12,000 to more than 14,000 feet below sea-level. In the same way, another anomaly appearing on lines 60 and 61 near tie line 350 yields depth estimates averaging 11,000 feet. This, and another short north-south feature are related to more persistent east-west anomalies in such a broken manner that faulting is implied. As for the huge magnetic gradient stretching over the whole sheet, its source may be located at 35,000-40,000 feet below sea-level.

Similar magnetic features may be seen on sheets 9 and 10; the huge anomalies or gradients several hundreds of gammas in intensity are intrabasement features which conceal smaller anomalies hardly visible on the total field records. Those again were interpreted mainly from vertical derivative records; however slight these anomalies may be, some of them can be correlated over long distances. For example, a small anomaly may be followed across the whole sheet Nº9 along tie line 311; the computed depths range from 8,700 to 9,800 feet, which suggests that the area is comparatively flat.

The most interesting prospect in this central area could be the area mapped as A6 in the southern part of sheet 19. Although the density of profiles is small in this area, the depth estimates point to an anticline trending approximately east-west. Depth of basement at the top of the anticlinal could be less than 8,000 feet, whereas to the north and to the south it is more than 11,000 feet. This feature is related to a magnetic anomaly of moderate strength, probably striking northwest, that might be intrusive.

Although strong intrabasement anomalies obscure the basement magnetic features, depth contours of the basement were tentatively drawn over the whole area. The basement is slightly dipping to the west on sheets 8, 9, 10 and 11 and to the south-west on sheets 18, 19 and 20. A possibly closed structure, A6, is indicated on the southern edge of sheet 19.

III.3 THE SOUTHERN BLOCK (Sheets 21 to 26)

The area covered by sheets 24, 25, 26 and the southern part of sheets 21, 22, 23 was flown at an altitude of 4,200 feet A.S.L., and the remainder of this block at an altitude of 2,500 feet A.S.L.

Two large east-west trending anomalies occur within the area; one of these features is located along the southern boundary of the survey area - its depth to source averages 30,000 feet and the anomaly may be regarded as "intrabasement". The other large feature is located more to the north and yields depth estimates in the range of 25,000 - 30,000 feet, again it is intrabasement.

A careful examination of the profiles disclosed that there are anomalies, generally not visible on the field contour map, that can be related to the supposed surface of the basement. Such are two small anomalies on line 106 (sheet 22) which yield depth estimates of 7,800 feet and 8,000 feet. More to the south, the estimated depths are in the range of 12,000-14,000 feet, suggesting that the basement dips to the south in the northern half of sheet 22. More to the east (sheet 23) the basement also dips to the south, or southwest, from 9,000 to 12,000 feet in depth. There is a suggestion of basement rising to 9,000 feet below sea level in the southeast corner of the survey

In this block some of the anomaly axes may well be related to local structure on the basement surface. The north-south axis in the north end of sheet 22 could indicate a nose related to the basement high A6 to the north. Other anomalies have east-west strikes.

The intrabasement magnetic maximum along the southern boundary has an intriguing break about line 300 on sheet 25. In the southeast corner of this same sheet, the axis lies beyond the survey boundary, but is replaced by a shallower feature - possibly on basement surface, but more probably of sedimentary origin. This lies over an east-west mountain separated from the main ranges.

III.4 WESTERN BLOCK (Sheets 1 to 7

The area north of 66°56" latitude, covered by sheets 1, 2, 3 and 4, was flown at an altitude of 4500 feet above sea level. Within this area, the total field contours indicate the existence of a very large regional anomaly, the centre of which probably lies just east of the survey area. This feature, a reflection of intrabasement compositional changes, is so large that it tends to suppress total field deviations that might be attributed to weaker and shallower features.

In the extreme northwest corner, a feature of very different type lies right on the survey boundary. The amplitude is moderate, some tens of gammas, and the axis clearly breaks between lines 572 and 574. Note that the magnetic contours show a peak offset from the anomaly axis, resulting from the effect of the huge regional maximum to the east. This feature yields depths around 6000 feet. It has been tentatively ascribed to basement surface, although it could be intrusive.

The basement depth contours across sheets 1 to 4 are highly speculative, assuming that this 6000 foot depth can be joined by a smooth surface to the depths obtained in the southern parts of sheets 3 and 4 which are based on magnetic features of very different character. Furthermore the group of depths in the southwest quarter of sheet 4 are not considered very reliable, and the suggestion of basement dipping east across sheet 4 is not well controlled.

Analysis of the total field calcomp profiles revealed the presence of a few features generally trending north-south. The amplitudes of these anomalies range from one to twenty gammas relative to the slope of the gradient. Alternative lines were processed to produce vertical gradient profiles which aided both in identifying anomalies and determining depth estimates. As expected, the vertical gradient profiles exposed the presence of many features that could not be observed in the total field data. Some features could be correlated from one derivative profile to the next. One unique anomaly of shallow or surface origin is marked by an 'x' in the northeast part of sheet 2.

Most of the area covered by sheets 5, 6 and 7 was flown at an altitude of 2,500' A.S.L.

The interpretation of this area is extremely frustrating, since practically all the magnetic features may be regarded as reflecting deep magnetization contrasts within the basement and therefore have no real significance in terms of defining the basement surface contours.

On sheet 6, for example, no basement anomaly at all could be found; the basement depth contours on this sheet were drawn tentatively by extrapolating the contours of the adjoining sheets.

On sheet 7, however, several anomalies could be related to the basement surface, yielding depth estimates in the range of 12,000-14,000 feet. To the north of this sheet, a depth estimate of 9,700 feet was found (on T.L. 601), which could suggest a rise of the basement to the north.

Some stronger basement features lie just outside the survey boundary on sheet 6, and give a suggestion of an eastward dipping surface.

There are some obvious effects of diurnal variations on these sheets, notably between lines 474 and 476 on sheet 6, and where the major maximum axis crosses the altitude break on sheet 5.

CONCLUSION

The results of this survey are rather disappointing, since so few magnetic anomalies have been found. Most of the region is dominated by huge regional magnetic features. These could indicate a basement surface at a depth of

20,000 to 40,000 feet. But we have preferred to consider their causes below the basement surface. This conclusion is supported by data from the eastern block, where these features are overridden by much shallower features, typical of the Precambrian crystalline rocks beneath most of the basin in western Canada.

The survey has a scientific interest which is far from negligible, since the interpretation of these huge anomalies could contribute to a study of the forces and features existing within the earth's crust.

Locally these big anomalies hinder the interpretation of smaller features which are of more immediate interest since they may be related to the basement surface. Even if the broader anomalies were removed, the residual anomalies would be scarce and generally small, except in the eastern block. This suggests that the basement is generally very homogeneous and probably of acidic composition (granitic, metamorphic, or sometimes even sedimentary).

The magnetic trends of the basement surface are generally north-south, except in the southern and south-central blocks where some of them may be east-west.

The overall pattern of the basement depth contours shows that the sedimentary section may vary in thickness from 4,500 to more than 15,000 feet. In areas where the number of basement anomalies was sufficient, closed structures could be found and mapped, suggesting possible leads for further investigation.

The thinner sedimentary section may be expected to be found in the eastern block, especially along its eastern boundary; but even there the thickness of sediments is greater than 4,000 feet. Further geophysical investigation in this area could be concentrated on structures A1, A2, A4 and A5.

Interesting prospects may be found on sheets 10, 11 and 12, where the basement contours suggest a possible east-west anticlinal trend. Sedimentary thickness in this area ranges from 8,000 to 10,000 feet.

On the southern boundary of sheet 19, the structure A6 appears to be reliable despite the comparatively small number of profiles on this area. This could be one of the most interesting areas of the whole survey.

Over most of the central and western blocks, the amount of useful information that could be obtained by interpreting the magnetic data is very small. Two kinds of data processing were made to improve the interpretation: Manual residuals of particular features were drawn in order to filter out the broader background anomalies; computed vertical gradient profiles were processed for several lines in order to enhance certain anomalies and to reveal features that could not be observed clearly on the total field profiles. However, even with the aid of these techniques, depth estimates were still too scarce for detailed contouring of the basement.

The use of digital high sensitivity equipment, however, proved to be wise since no depth estimates of the basement could have been obtained over most of the survey area with analogue records only.

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