COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Petroleum Search Subsidy Acts

PUBLICATION No. 72

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South Canning Basin Aeromagnetic Survey

Western Australia, 1962-1963

BY

WEST AUSTRALIAN PETROLEUM PTY LIMITED

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Minister for National Development
1966

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

SECRETARY: R. W. BOSWELL

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DIRECTOR: J. M. RAYNER

THIS REPORT WAS PREPARED FOR PUBLICATION IN THE PETROLEUM EXPLORATION BRANCH

ASSISTANT DIRECTOR: M. A. CONDON

Published by the Bureau of Mineral Resources, Geology and Geophysics
Canberra A.C.T.

FOREWORD

Under the Petroleum Search Subsidy Act 1959-1961, agreements relating to subsidized operations provide that the information obtained may be published by the Commonwealth Government six months after the completion of field work.

The Bureau of Mineral Resources, Geology and Geophysics is required, on behalf of the Department of National Development, to examine the applications, maintain surveillance of the operations, and in due course prepare the reports for publication. The growth of the exploration effort has greatly increased the number of subsidized projects and this increase has led to delays in publishing the results of operations.

The detailed results of subsidized operations may be examined at the office of the Bureau of Mineral Resources in Canberra (after the agreed period) and copies of the reports may be purchased.

This Publication deals with an aeromagnetic survey conducted by Aero Service Limited over an area in the northern part of Western Australia. It contains information furnished by West Australian Petroleum Pty Limited and edited in the Petroleum Exploration Branch of the Bureau of Mineral Resources. The final report, dated July, 1963, was written by K.N. Isaacs of Aero Service Limited for West Australian Petroleum Pty Limited. The methods employed in the survey and the results obtained are presented in detail.

J.M. RAYNER
DIRECTOR

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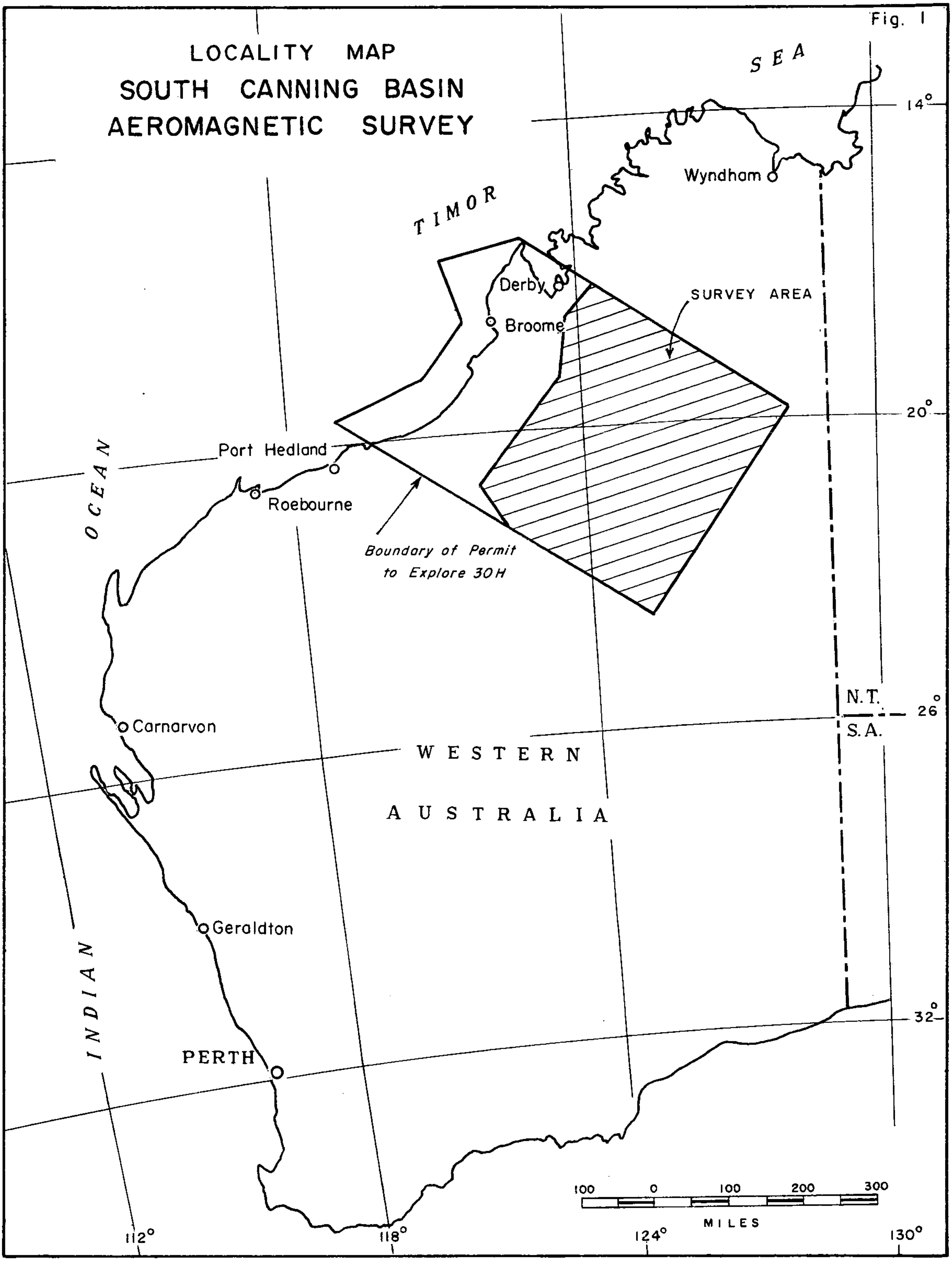
Fig. 1
LOCALITY MAP
SOUTH CANNING BASIN
AEROMAGNETIC SURVEY
TIMOR
SEA
INDIAN
OCEAN
Wyndham
Derby
Broome
SURVEY AREA
Port Hedland
Roebourne
Boundary of Permit
to Explore 30H
Carnarvon
WESTERN
AUSTRALIA
N.T.
S.A.
Geraldton
PERTH
14°
20°
26°
32°
112°
118°
124°
130°
100
0
100
200
300
MILES

SUMMARY

An airborne magnetometer survey was carried out by Aero Service Limited for West Australian Petroleum Pty Limited between November, 1962 and January, 1963. The survey covered an area of approximately 105,000 square miles of the Canning Basin, in northern Western Australia. The project area lies within Permit to Explore 30H.

The objective of the aeromagnetic survey was to delineate the depth and configuration of the Canning Basin, and to reveal, if possible, other structural features in the area.

A Douglas DC-3 aircraft was used for the 1962-1963 survey and it was equipped with a Gulf Research and Development Company Mark III continuously recording total intensity fluxgate magnetometer. Auxiliary equipment consisted of an Aeropath AS-5 35 millimeter continuous strip exposure camera, and an STR 30-B1 radio altimeter. Navigation was by reference to image-matched strips of 1:50,000 aerial photographs. Navigational aids consisted of a Kearfott N-1 gyrosyn compass and a B-3 drift meter. On the ground, a Gulf Research and Development Company magnetic storm detector was continuously monitored so that no aeromagnetic data would be obtained during periods of abnormal magnetic disturbance. The survey data were compiled by Aero Service Corporation, Philadelphia, Pa., U.S.A.

Flying commenced on 30th November, 1962 and was completed on 4th January, 1963. A total of 18,129 line-miles of traverses was flown at a barometric altitude of 2000 feet above mean sea level. The profile flight direction was 030° and the tie lines 120°. These directions and altitude were consistent with a previous survey flown over portions of the Basin. In the earlier survey, the direction of the profile flight lines and the altitude were chosen to obtain the maximum information from the geological structures. The flight line interval was 1.5 miles, flown in bands of three profiles. Tie line separation was approximately 25 miles.

The study of the aeromagnetic data resulting from the survey indicates that the Canning Basin is subdivided into four separate depressions, each of which is a major basin in itself with regard to areal dimension, and thickness of the sedimentary section.

In the north, the Fitzroy Trough has been outlined as a long, relatively narrow basin trending northwest-southeast. It appears to be a geosynclinal trough with 25,000 to 30,000 feet of sediments in its deeper regions.

The existence of the Kidson Basin in the south-central part of the survey area and about 200 miles south of the Fitzroy Trough has been confirmed by the study of the survey data. The Basin is similar in shape to the Fitzroy Trough; it trends northwest-southeast, and has a maximum thickness of between 30,000 and 35,000 feet.

A third major basin is delineated in the east-central area. This depression is on the same trend as the Fitzroy Trough, but its orientation is apparently north-south rather than northwest-southeast. Here, the maximum depth to basement is estimated to be about 30,000 feet below sea level.

Finally, a fourth major basin, outlined by the magnetic interpretation, is shown in the central part of the project area, situated to the north of the Kidson Basin. It trends east-west and attains a maximum depth of over 20,000 feet below sea level.

The several basement depressions, ridges, and faults indicated by the magnetic study all require further confirmation and modification by other, more detailed, geological and geophysical methods.

This Publication is accompanied by a composite reduction of the total magnetic intensity maps at a scale of 1:1,000,000 to which have been added the interpreted data.

The aeromagnetic survey undertaken in the Canning Basin area of Western Australia was subsidized under the Petroleum Search Subsidy Act 1959-1961.

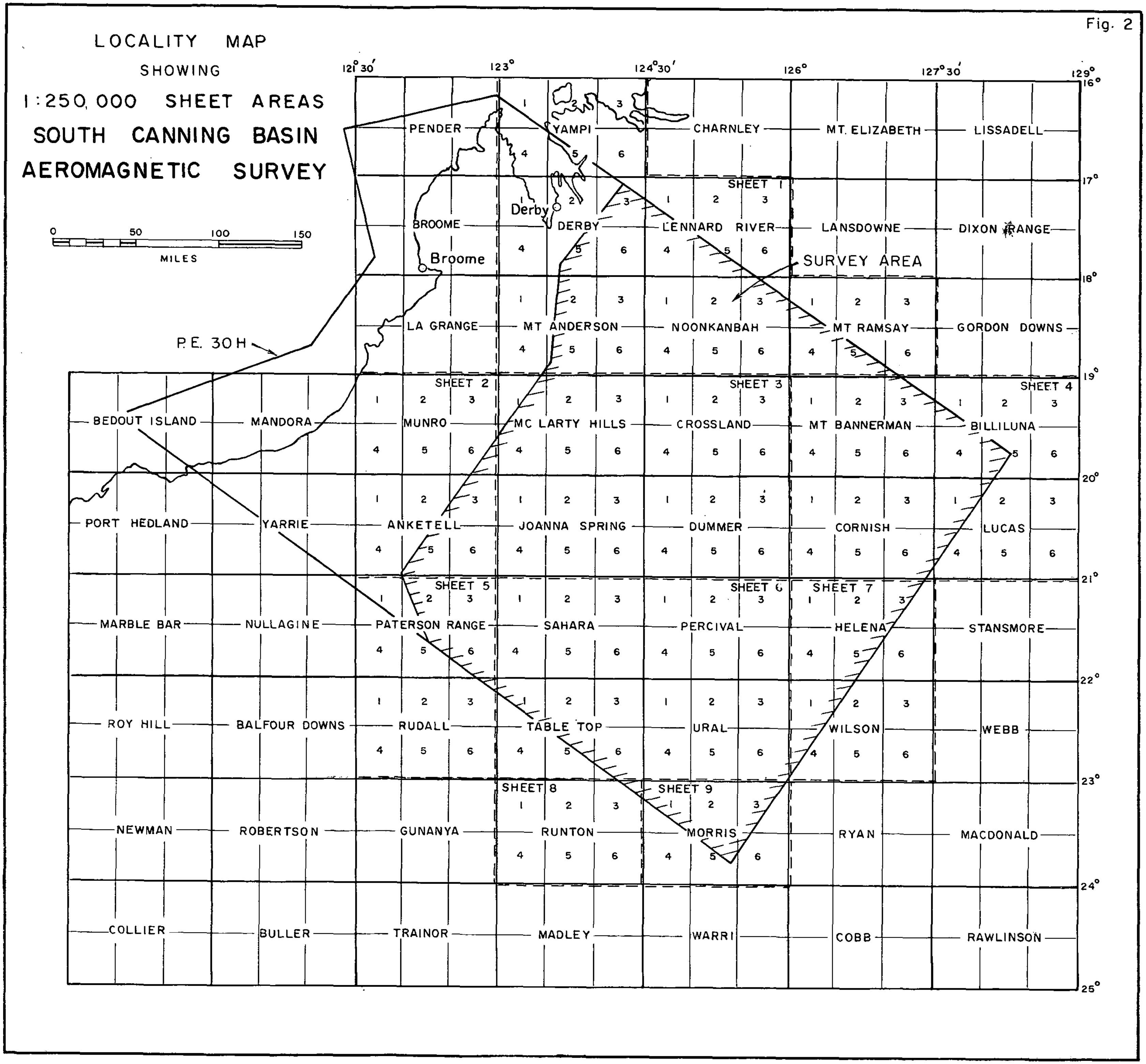
Fig. 2
LOCALITY MAP
SHOWING
1:250,000 SHEET AREAS
SOUTH CANNING BASIN
AEROMAGNETIC SURVEY
0 50 100 150
MILES
P.E. 30H
SURVEY AREA
Broome
Derby
121°30′
123°
124°30′
126°
127°30′
129°
16°
17°
18°
19°
20°
21°
22°
23°
24°
25°
PENDER
YAMPI
CHARNLEY
MT. ELIZABETH
LISSADELL
BROOME
DERBY
LENNARD RIVER
LANSDOWNE
DIXON RANGE
LA GRANGE
MT ANDERSON
NOONKANBAH
MT RAMSAY
GORDON DOWNS
BEDOUT ISLAND
MANDORA
MUNRO
MC LARTY HILLS
CROSSLAND
MT BANNERMAN
BILLILUNA
PORT HEDLAND
YARRIE
ANKETELL
JOANNA SPRING
DUMMER
CORNISH
LUCAS
MARBLE BAR
NULLAGINE
PATERSON RANGE
SAHARA
PERCIVAL
HELENA
STANSMORE
ROY HILL
BALFOUR DOWNS
RUDALL
TABLE TOP
URAL
WILSON
WEBB
NEWMAN
ROBERTSON
GUNANYA
RUNTON
MORRIS
RYAN
MACDONALD
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BULLER
TRAINOR
MADLEY
WARRI
COBB
RAWLINSON
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INTRODUCTION

An aeromagnetic survey was carried out during 1962-1963 over the Canning Basin area in Permit to Explore No. 30H in the northern part of Western Australia (Fig. 1), by Aero Service Limited for West Australian Petroleum Pty Limited.

The airborne magnetometer coverage included approximately 18,000 linear miles of operational survey, over an area of about 105,000 square miles. The pattern of traverses was established in two stages. A survey was flown in 1955 by World Wide Aerial Surveys (Australia) Pty Limited, consisting of bands of three parallel traverses, spaced 1.5 miles apart, separated from adjacent bands by an average distance of about 27 miles. Between November, 1962 and January, 1963, the 1955 survey was augmented by additional traverse lines, again in bands of three and spaced midway between the old bands, so that the separation between adjacent groups of three traverses was reduced to about twelve miles. In addition to this, new control lines were established at right angles to the traverse direction approximately every 25 miles and many of the old traverses were extended to the north-east and south-west.

The traverses of the subject survey were oriented 030° - 210° at intervals of 1.5 miles within groups of three; between adjacent groups of three parallel traverses, the distance was approximately twelve miles. The distance between the tie lines, flown at right angles to the traverses, was approximately 25 miles. The survey was flown at a barometric altitude of 2000 feet above mean sea level.

A Douglas DC-3 aircraft was used for the 1962-1963 survey and it was equipped with a Gulf Research and Development Company Mark III continuously recording total intensity fluxgate magnetometer. Auxiliary equipment consisted of an Aeropath AS-5 35 mm continuous strip exposure camera, and an STR 30-B1 radio altimeter. Navigation was by reference to image-matched strips of 1:50,000 aerial photographs. Navigational aids consisted of a Kearfott N-1 gyrosyn compass and a B-3 drift meter.

The contoured total magnetic intensity maps were presented at a scale of 1:63,360 on one hundred and sixteen map sheets, corresponding in scale and organisation to the Four-mile Sheet Series of northern Western Australia. The four-mile sheets so involved include all or portions of the following (see Fig. 2):

Anketell	Lennard River	Paterson Range
Billiluna	Lucas	Percival
Cornish	McLarty Hills	Rudall
Crossland	Morris	Runton
Derby	Mt Anderson	Sahara
Dummer	Mt Bannerman	Tabletop
Helena	Mt Ramsay	Ural
Joanna Spring	Munro	Wilson
	Noonkanbah	Yampi

In addition to the presentation scale of 1:63,360, the total intensity contours were submitted at two reduced composite scales 1:253,440 and 1:633,600, to facilitate study of the maps from a regional standpoint.[1]

(1) Footnote by Bureau of Mineral Resources

The map (Plate 1) presented with this Publication has been re-drafted at a scale of 1:1,000,000 by West Australian Petroleum Pty Limited. On the total magnetic intensity map contours have been extrapolated across the spaces between the groups of traverses.

The 1:253,440 scale composite series was used for the presentation of the interpretation maps. This composite series was subdivided into nine map sheets, as follows:

- Sheet 1: Yampi, Derby, Lennard River, Mount Anderson, Noonkanbah, and Mount Ramsay;
- Sheet 2: Munro and Anketell;
- Sheet 3: McLarty Hills, Crossland, Joanna Spring, and Dummer;
- Sheet 4: Mount Bannerman, Billiluna, Cornish, and Lucas;
- Sheet 5: Paterson Range and Rudall;
- Sheet 6: Sahara, Percival, Tabletop, and Ural;
- Sheet 7: Helena and Wilson;
- Sheet 8: Runton;
- Sheet 9: Morris.

Within the survey area, the general intensity of the earth's field ranges between about 49,500 gammas in the north to about 54,000 gammas in the south, and the inclination from 47°S. to 57°S. from north to south. The declination is about 3°E. of True North in the centre of the survey area.

The objective of the airborne magnetometer survey was to delineate, as an aid to the search for oil in the area by West Australian Petroleum Pty Limited, the depth and configuration of the Canning Basin, and to reveal, if possible, other structural features.

The interpretation maps display the following: contour lines indicating the depth to basement as determined from study of the magnetic anomalies, the locations and magnitudes of individual depth estimates, and the extent of rock units and faults in the basement indicated by the magnetic pattern. These features are delineated as being continuous between groups of lines for convenience in studying the report; however, it should be understood that the position and continuity of features between groups of lines is problematical.

The discontinuous nature of the survey data introduces a high degree of uncertainty in correlating between magnetic features from band to band, and in determining the true strike of the feature so that a cosine correction can be applied to its depth estimate. For this reason, the depth-to-basement contour interval is 5000 feet; a closer contour interval would give an illusion of accuracy which is precluded by the twelve-mile separation between bands of traverses. The depth-to-basement contours should be regarded as indicators of the probable basement surface configuration and magnitude of depth, rather than accurate depths. They are in the nature of form lines rather than precise depth contours.

SUMMARY OF GEOLOGY

The Canning Basin is located in the northern part of Western Australia. The north-western margin (on land) is the coastline, extending approximately from King Sound to about 30 miles east of Port Hedland, and inland from these points for at least 450 miles. It embraces therefore, a roughly rectangular area of at least 130,000 square miles, the long axis of the rectangle being oriented northwest - southeast, normal to the coastline. The south-eastern margin of this Basin has not been conclusively defined.

Palaeozoic, Mesozoic, and Cainozoic sediments crop out in the Basin. However, along the north-eastern side and in the centre and east, Permian clastic sediments, to a great extent glacial in origin, predominate; in the north-west central part the bedrock is generally Jurassic sediments, and all along the south-western edge the bedrock is mainly Cretaceous, finally succeeded by Permian again immediately against the Basin margin. Bedrock outcrops are sparse and discontinuous throughout, as the Basin is covered by a widespread blanket of Quaternary dune sand.

The subsurface geology of the Canning Basin is known in partial detail along the accessible coastal region. The controlling structural feature is the Broome Platform, a broad asymmetrical basement ridge that trends south-east from Roebuck Bay. Thangoo No.1, drilled on top of the Broome Platform, penetrated basement at about 4500 feet below sea level. To the south-west, along the coast, the basement surface descends gradually. Samphire Marsh No. 1, near the south-western edge of the Basin, penetrated basement at about 6600 feet below sea level; however BMR 4A (Wallal), very close to the basin edge, reached basement at only 2200 feet below sea level; most of the Palaeozoic section was missing, and it is presumed that a major fault is present uplifting the basement between the two wells.

The Dampier Fault marks the northern edge of the Broome Platform and the down-faulted portion north of the Broome Platform has been named the Jurgurra Terrace. The depth to basement on the Jurgurra Terrace is not known, but a refracting horizon having a velocity compatible with basement is present at about 15,000 feet. The lateral extent of the Jurgurra Terrace is also unknown.

The Fenton Fault forms the northern edge of the Jurgurra Terrace, and beyond this fault, between the Jurgurra Terrace and the north-eastern edge of the Canning Basin, is a long, relatively narrow portion of the Basin called the Fitzroy Trough. The Fitzroy Trough is believed to contain 25,000 to 30,000 feet of sediments. Grant Range No.1, drilled in the axial part of the Trough, went to a depth of almost 12,700 feet below sea level, terminating in the Carboniferous.

In the central and south-eastern parts of the Canning Basin, little is known of the subsurface structure. Examination of the previous airborne magnetic records and gravity traverses have suggested the existence of a large basement depression in the south, centred in the Sahara map sheet; this feature has been tentatively named the Kidson Basin.

The history of geological work in the area is recounted by J.J. Veevers and A.T. Wells (1961), and is not repeated here.

PREVIOUS GEOPHYSICAL WORK IN THE AREA

Aerial photography of most of the Canning Basin was undertaken by the R.A.A.F. in 1947 and 1953; these photographs form the basis for the location of the present survey.

The Bureau of Mineral Resources flew a few single aeromagnetic lines over the periphery of this area in 1954. This work is discussed by J.H. Quilty in BMR Record 1960/11. Most of the area in the present survey is beyond that covered by the BMR aeromagnetic survey. The amount of coverage and the control of the present survey is superior to the earlier BMR work. The depth interpretations are generally compatible (considering the uncertainties involved) although the present survey generally indicates slightly greater thicknesses of section.

West Australian Petroleum Pty Limited flew an aeromagnetic survey over part of this area in 1955; bands of lines consisting of three parallel traverses spaced about 1.5 miles apart were flown, the bands being spaced about 27 miles apart. The data from this survey are incorporated with the present survey both on the total intensity maps and in the interpretation.

The Bureau of Mineral Resources has also obtained regional gravity data over much of the area involved in the present survey. These gravity data are reported by A.J. Flavelle and M.J. Goodspeed in BMR Record 1962/105. These data are also generally compatible with the results of the present survey, in delineating the same major structural units.

West Australian Petroleum Pty Limited has done considerable gravity and seismic work over the Lennard Shelf and Fitzroy Basin portions of the survey area and several wells have been drilled by the Company and others in these areas. The Bureau has also done some seismic work in parts of the Fitzroy Basin. Only scattered BMR regional gravity work had been done over the remaining part of the area prior to this survey. However, the Company began both seismic and gravity operations in the Sahara and Joanna Spring quadrangles in 1963.

INTERPRETATION THEORY

The interpretation of airborne magnetometer data can be conveniently separated into its two main aspects: the qualitative recognition of structural and petrological units from magnetic anomalies, and the quantitative assessment of anomalies or groups of anomalies with regard to depth, dimension, and susceptibility of the source body.

The rock units delineated are based on differences in the frequency of occurrence, extent, shape, orientation, local magnetic relief, and general intensity levels of the magnetically anomalous zones. These rock units will not, in all cases, correspond to contacts mapped in the field on the basis of observed stratigraphic criteria (that is, rock units mapped on the basis of chronological relationships). The reason for this is that different formations having similar magnetic concentration and distribution will be expressed by similar magnetic patterns, while conversely, lithological contrasts within the same geologically mapped unit will give rise to contrasting magnetic patterns.

With few exceptions, the sedimentary rocks are virtually non-magnetic. The local distortions in the natural magnetic field are considered to arise primarily from the igneous and metamorphic bedrock. In general, the stronger the local magnetic relief and intensity, the greater the proportion of magnetic minerals (chiefly magnetite) that is in the rock unit influencing the magnetic pattern; by further inference, the more likely it is to have a more basic composition.

Faults may be manifested magnetically by dislocations or disruptions in magnetic pattern or by persistent changes in pattern over long distances. Plugs, dykes and other igneous phenomena are inferred from the shape and intensities of the associated magnetic features. Recognition of such features is, to some extent, subjective.

Individual anomalies are amenable to quantitative study with regard to depth, dimension, shape, and susceptibility contrast. Many methods have been developed and are in use. All of these depend on the following general characteristics of the anomalous features:

(i) The horizontal attenuation of the anomaly amplitude normal to the strike is related to the depth and width of the body causing the anomaly;

(ii) The profile shape (relationships of the peak, trough, and inflection points) is related to the attitude of the body causing the anomaly; and

(iii) The amplitude of the anomaly is related to susceptibility contrast.

To amplify these three points:

(i) The magnetic field, as a potential field, obeys the inverse square law (in modified form because the contributions of both positive and negative poles exert influence). With increasing distance between an idealized magnetic source and the plane of observation, the anomalous field will be present over a predictably greater horizontal area, although it will be diminished in amplitude. In addition to this, the non-neutralized positive and negative poles are located at the edge surfaces of the magnetic source, so that the width of the anomaly is also a function of the width of the source.

(ii) The shape of a magnetic anomaly is critically dependent on the magnetic inclination, or the angular relationships between the anomaly source and the direction of the external field. A tabular source, striking east-west and dipping 90^{o}, will express itself as a positive anomaly at magnetic inclination 90^{o}, and as a half positive-half negative anomaly at inclination 45^{o}. If, at inclination 90^{o}, the dip of the tabular body source is shifted to 45^{o}, the angular relationships between field direction and source will be the same as those obtaining between the vertical source and the 45^{o} field, so that the anomaly will be the same as that observed from a vertical body at 45^{o} inclination, with the plane of observation inclined 45^{o}. Similarly, if a vertical body at inclination 45^{o} is shifted to a dip of 45^{o}, the anomaly will be the same as that observed at 90^{o} or the magnetic equator (depending on the direction of the dip), again with the plane of observation inclined 45^{o}. Therefore it can be seen that the anomaly shape is critically dependent on the attitude of the source body as well as the magnetic inclination.

(iii) The secondary magnetic field induced in a body by an external field is defined as :

$$H' = 4\pi \; kH$$

where:

H' = secondary induced field, in oersteds,

H = primary inducing field, in oersteds, and

k = susceptibility, in dimensionless c.g.s. units.

From this relationship it can be seen that the amplitude of the anomalous field is directly proportional to the magnetic susceptibility of the source body.

The most versatile magnetic model in quantitative interpretation is that of the tabular body. The general case equation for the magnetic expression of a tabular body of infinite length and depth is :

$$T = K (\sin (2I-D) \phi + \cos (2I-D) \ln (R_2/R_1))$$

where:

- K = function of susceptibility contrast, intensity of the earth's field, and the angular relationships between the attitude of the body and the magnetic inclination,
- I = projection of the magnetic inclination in the plane normal to the strike of the body,
- D = dip of tabular body,
- ϕ = angle subtended at the point of observation by the upper corners of the tabular body,
- R_1, R_2 = distances from the point of observation to the upper corners of the tabular body, and
- ln = natural logarithm.

In the study of this survey, a rigorous method of quantitative interpretation was employed, to estimate the dimensions and depth of the rock units in the basement manifesting themselves as major magnetic anomalies approximating the tabular body case, or its corollary, the vertical interface (fault). The principle of this method is to separate the observed magnetic profile of the anomaly into two components by graphical methods; a component symmetrical on either side of the centre of the anomaly cause, and a component inversely symmetrical on either side of the centre of the anomaly cause. The former corresponds to the term $\sin (2I-D) \phi$ and is the analogue of the vertical component of magnetic intensity, and the latter corresponds to the term $\cos (2I-D) \ln (R2/R1)$ and is the analogue of the horizontal component of magnetic intensity.

The relationships of amplitude and horizontal distance of peaks, troughs, and arbitrary critical points on the two curves extracted from the observed anomaly profile are then referred to prepared charts and tables yielding the depth and dimensions of the feature causing the anomaly.

Finally, the validity of the analysis is verified by introducing the parameters obtained into the general case equation and re-computing. In practice, it is usually convenient to construct the graphic derivative of the observed profile (the slope curve) and then subject it to separation into the $\sin (2I-D) \phi$ and $\cos (2I-D) \ln (R_2/R_1)$ curves; in this case, the former will have inverse symmetry and the latter will have direct symmetry. The reason for this is that treatment of the inversely symmetrical curve is easier, and in high magnetic latitudes it is the $\sin (2I-D) \phi$ curve that is dominant.

The method of quantitative interpretation referred to above is applicable to only a few of the magnetic anomalies in the survey area. Most of the depth-to-basement estimates are drawn from measurements of the horizontal extents of the steep uniform magnetic gradients, averaged together in groups, and multiplied by a correction factor calculated from the more rigorous method of anomaly separation analysis.

The computed susceptibility contrast of the source of an anomaly is a function of the proportional amplitude of the anomaly in the earth's total magnetic field, the length, width, depth, and strike of the source, and the inclination of the earth's field. The higher the figure for the calculated bulk susceptibility, the greater the concentration of magnetic minerals, and by inference, the more basic its composition.

All methods of quantitative study require assumptions of homogeneity and idealized shape. Inasmuch as rock bodies cannot be expected to satisfy these assumptions except under the most unusual circumstances, quantitative conclusions should be regarded as estimates of magnitude rather than precise depths.

GEOPHYSICAL INTERPRETATION

SHEET 1

Yampi, Derby, Lennard River, Mount Anderson, Noonkanbah, and Mount Ramsay

Sheet 1 is located in the northern portion of the survey area, and includes all the magnetic data north of latitude 19°S. Over most of the sheet, the magnetic pattern is very gentle, departing only slightly from the regional magnetic slope. Along the northern edge, in the south-east, and to a lesser extent in the south-west, the anomalous pattern changes to a series of relatively intense, abrupt, high-frequency features with amplitudes ranging up to 150 gammas.

The chief geological feature interpreted on this sheet is a long basement depression, oriented northwest-southeast. It is obviously correlatable with the Fitzroy Trough. The depression is interpreted as having a maximum depth in excess of 30,000 feet below sea level in south-eastern Mount Anderson 3. The location of this greatest depth estimate, and others in the basin, suggests that the basin is roughly triangular in shape, and asymmetrical in profile cross-section. However, it should be noted that anomalies amenable to depth estimation are few on the north-eastern flank of the depression, and the depth-to-basement contours have simply been interpolated evenly along this flank. Additional conclusive depth information from other sources may alter the delineated configuration considerably.

In the northern part of the sheet there is an abrupt magnetic gradient, succeeded to the north by a more intense pattern of anomalies. The gradient is interpreted as the expression of a fault or fault system defining the north-eastern limit of the Fitzroy Trough with significantly more shallow basement, of the order of 5000 feet below sea level, north of the fault system. In Lennard River 5, the magnetic pattern indicates that the basement is exposed or near surface, and this conclusion is in accord with the mapped geology. The fault system itself is apparently offset to the south-west about four miles on Derby 3, as indicated by the location of the gradient on Traverses 121 - 123.

In the south-eastern corner of Sheet 1 (Noonkanbah 3 and 6, and Mount Ramsay 4) there is another zone of strong magnetic gradient, succeeded to the north-east by a series of relatively intense, high frequency anomalies. This area, also, is interpreted as a profound fault with a considerably uplifted basement on the north-eastern flank. In this case, the fault can be correlated with the Pinnacle Fault. The minimum depth-to-basement calculated north of the fault is 3300 feet below sea level; this figure is in disagreement with the geological mapping, which shows exposed basement in this area, but it may be that none of the magnetic traverses crossed the exposure. The obvious alternative explanation is that the magnetic depth estimates are too deep.

On Noonkanbah 3, there is a transition in pattern between Traverses 201-203 and Traverses 211-213, indicating much greater depth-to-basement on Traverses 201-203 than on the 211-213 band. For this reason, a fault line has been inferred between the two bands of traverses, trending northeast-southwest, to indicate that some type of structural discontinuity exists between the two. The nature, complexity, and location of this structural break are problematical.

In the south-western part of the sheet, on Mount Anderson 2, 4, and 5, depth-to-basement estimates are relatively shallow, deepening to the east. An inferred north-south fault is delineated in Mount Anderson 2 and 5 to account for this great change in basement depth (about 3000 feet). Evidence for this fault is somewhat more conclusive than for the northeast-southwest fault on Noonkanbah 3; strong anomalies on Traverses 131-133 and 141-143 also suggest that it exists. The area immediately north-west of this postulated fault on Mount Anderson 2, the Jurgurra Terrace, probably has a depth-to-basement of the order of 10,000 feet below sea level.

The deepening basement east of the north-south fault in Mount Anderson 2 and 5 forms a salient to the Fitzroy Trough, which controls the triangular shape it assumes from the airborne magnetometer data. The overall basement dip demanded in south-western Mount Anderson 3 and north-western Mount Anderson 6 is improbably high (about 11 degrees) and it is likely that the basement in this area is complicated by additional faulting.

The Fenton Fault which passes through this area, probably is involved in this steep-dipping zone. An anomaly on Traverses 141-143, located on the junction of Mount Anderson 3 and 6, may be a manifestation of this fault; however, as it is not conclusively expressed magnetically, it is not delineated on the magnetic interpretation map.

SHEET 2

Munro and Anketell

Sheet 2 is located in the western part of the survey area. The magnetic pattern in the northern and central part of the sheet displays a series of broad anomalies trending about 285°, having probable continuity from band to band. In the south, the magnetic features are more irregular and continuity between adjacent bands of traverses is not likely.

The depth-to-basement estimates in the northern part of Sheet 2 (Munro 6 and most of Anketell 2 and 3) indicate that the depth of the basement is generally between 5000 and 10,000 feet below sea level. In eastern Anketell 3, the contouring suggests that the depth to basement is over 10,000 feet. This contour line is controlled by depth estimates on adjacent Sheet 3; there are no depth estimates on Anketell 3 in excess of 10,000 feet.

In the south-western corner of the sheet (the western half of Anketell 5) the magnetic depth estimates indicate exposed or near surface igneous or metamorphic rocks. It should be noted that this is not in agreement with the Canning Basin geological map, which shows Permian sediments covering this area, with the edge of the basement exposed about fifteen miles to the south.

In Anketell 6, the magnetic data indicate the existence of a small basin developing a maximum depth of over 15,000 feet below sea level. This feature is controlled by only two depth estimates, so that it may be spurious. North of it, in south-western Anketell 3, is a feeble basement ridge.

In the south-central part of the sheet, two anomalous trends are correlated across three bands of traverses, and these are delineated as broad rock units in the basement having a relatively basic composition. Both of these trend approximately 295^{o}.

SHEET 3

McLarty Hills, Crossland, Joanna Spring, and Dummer

Sheet 3 includes the central and north-central parts of the Canning Basin survey, between latitudes 19^{o}S. and 21^{o}S. and longitudes 123^{o}E. and 126^{o}E.

The magnetic pattern on the sheet is variable. In the north-centre, on Crossland 1, there is an intense, abrupt anomaly displaying apparent continuity across three bands of traverses. In the western, southern, and south-eastern portions of Sheet 3 there are a number of broader, lower amplitude features having continuity from band to band. The general trend of these aligned features is northwest - southeast.

In the north-western, north-central, and south-eastern portions of Sheet 3 (all of McLarty Hills, Crossland 1, 4, and 5, and Dummer 2, 3, 5, and 6) the depth-to-basement estimates indicate the existence of a long, irregularly shaped zone of shallow basement. Its deoth generally ranges between 5000 and 10,000 feet below sea level on McLarty Hills and Dummer, but rises to less than 5000 feet on Crossland 1 and 4, where it is apparently complicated by transverse faulting. This regional basement uplift is tentatively identified as the south-eastward extension of the Broome Platform. However, its location is considerably to the south of where the extrapolated position of the platform would be from its known trend and extent in Mount Anderson 1; presumably (if this structure is related to the Broome Platform), it has been offset to the south by a strong system of transverse faulting, previously unsuspected. The north - south fault suggested on Sheet 1, Mount Anderson 2 and 5, and two interpreted faults on this sheet, might be part of such a system.

Toward the north-eastern corner of the sheet, the basement drops gradually to a maximum depth of over 25,000 feet in Crossland 3. This is the southern part of a depression also observed on Sheet 1, in Noonkanbah 6. This depression is apparently a subsidiary feature of the Fitzroy Trough, separated from it by a structural saddle.

In the south-west and south-centre, on the six Joanna Spring maps and on Dummer 1 and 4, a broad basin area is delineated. Its orientation is roughly east - west, divergent from the general northwest-southeast trend of the Canning Basin as a whole. The maximum estimated depth of this basin is over 20,000 feet below sea level, in Joanna Spring 6. Its configuration and extent are probably modified by north - south faulting on its eastern end in Dummer 1 and 4.

Several anomalous trends display marked continuity across two or more adjacent bands of traverses, and these are delineated and interpreted as large scale rock units in the basement of inferred relatively basic composition. A few aspects of these basement rock units are notable.

In Crossland 1, a series of anomalies is present, of shallow origin and sufficiently abrupt and intense to suggest that they possibly express basic intrusion along a line of faulting. The postulated fault trends about 335^{o} and forms the north-eastern edge of the uplifted area tentatively correlated with the Broome Platform extension. It is possible that this feature has some relationship to the Fenton Fault.

Of the several basement rock units in the southern part of Sheet 3, one displays strong continuity, clearly correlating across nine bands of traverses. Its trend is almost east - west, conforming to the trend of the basin in the south-west, and (less distinctly) to the presumed Broome Platform in the north-west, and diverging from the general trend of the Canning Basin.

Between the Joanna Spring and Dummer map sheets, there is a fairly abrupt dislocation in the continuity of the basement rock unit anomalies, and this is interpreted as weak evidence for transverse faulting. As on Sheet 1, the suggested discontinuity is largely located between bands, and it is not amenable to direct interpretation.

SHEET 4

Mount Bannerman, Billiluna, Cornish, and Lucas

Sheet 4 includes the eastern part of the survey. The magnetic contour pattern is one of broad, low amolitude anomalies except in the north-west, on Mount Bannerman 2, and in the extreme east, on Billiluna 5 and Lucas 2. In the latter areas the pattern is one of small high-frequency anomalies of irregular amplitude. The western part of the sheet is dominated by an extensive, broad anomaly of unusually high amplitude, 800 gammas.

Depth-to-basement estimates indicate the presence of another major basement depression, in Mount Bannerman 5 and 6, and Cornish 2, 3, 5, and 6. The greatest depth estimate is 33,000 feet below sea level in Mount Bannerman 6. To the west and north-west, the contours show a large area of horizontal basement surface, between 15,000 and 20,000 feet deep. To the east, the basement is contoured as rising gradually to its area of outcrop on Billiluna 5 and Lucas 2. The basin itself is delineated as having a general north - south orientation.

However, anomalies suitable for depth estimation are sparse on Sheet 4, so that the contouring is very uncertain on this sheet. This is especially true of the monoclinal surface delineated in western Cornish and eastern Lucas, the broad flat area in eastern and central Mount Bannerman and Cornish, and the improbable steep southward dip (about seven degrees) in Mount Bannerman 6.

In the north-west, a group of abrupt, high frequency features is interpreted as the extension of the Pinnacle Fault and the uplifted basement to the north-east of it, previously noted on Sheet 1.

Basement rocks are indicated to crop out in Billiluna 5 and Lucas 2. The location of the contact on Billiluna 5 indicated by the magnetic data is in slight disagreement with the geological map, which shows the contact to be about ten miles farther west.

Two large scale basement rock units are delineated on the basis of anomalous continuity between adjacent bands of traverses. The northern-most of these is located on Mount Bannerman 1, 4, 5, and 6 and it trends 300°. The southernmost one, on Cornish 1 and 2, trends 285° and is particularly intense (800 gammas). The calculated susceptibility contrast between this unit and adjacent rocks is 0.0025 c.g.s. unit, a figure characteristic of an ultrabasic rock mass.

SHEET 5

Paterson Range and Rudall

Sheet 5 is in the south-western part of the survey. In general the magnetic contours display an irregular pattern of anomalies of moderate size and frequency on the eastern half of the sheet, with no discernible orientation or continuity. Along the western margin of the survey (the south-western end of most of the traverses), the magnetic anomalies are abrupt and frequent.

The edge of the zone of abrupt anomalies is interpreted as the margin of the outcropping or near surface basement rocks. This contact runs across the north-eastern corner of Paterson Range 2, then southward across Rudall 3. The geological map is in good agreement with this boundary except in Paterson Range 2, where the margin of the exposed basement is delineated about ten to fifteen miles farther south-west. On Traverses 191 and 192, a single depth estimate suggests minor development of a sedimentary inlier.

East of the basement outcrop, the basement surface apparently dips gently basinward, with an average depth-to-basement of about 5000 feet below sea level on Paterson Range 3 and 6. One basement rock unit - the western end of a feature on adjacent Sheet 6 - is recognized on this sheet.

SHEET 6

Sahara, Percival, Tabletop, and Ural

Sheet 6 includes the south-central part of the survey area, and is bounded by latitudes 21^{o}S. and 23^{o}S. and longitudes 123^{o}E. and 126^{o}E. It is similar to some of the previous sheets in that the magnetic contour pattern displays a succession of broad, gentle anomalies over most of the sheet, characterized by a fair degree of continuity from traverse band to traverse band, and a recognizable magnetic trend ranging from east - west to north-west - southeast. Only in the extreme south-west do the anomalies assume the high frequency and variable intensity associated with surface or near surface crystalline rocks.

The chief interpreted feature on Sheet 6 is a long basement depression traversing the sheet from the north-western corner to the south-eastern corner. The deepest part of the depression however, is oval shaped, with some irregularities, and is located in Sahara 5 and 6, and Tabletop 2 and 3. The maximum estimated depth to basement in Sahara 6, is more than 35,000 feet below sea level. The position of this basin area coincides exactly with the Kidson Basin, a regional feature deduced from previous study of the gravity and airborne magnetic data, but not conclusively established.

The basement dips calculated from the depth contours on the northern and southern flanks of the Kidson Basin are improbably high, as in several other areas of the survey. This may be because of longitudinal faulting, but nevertheless, caution should be exercised in accepting the depth-to-basement estimates too literally in these areas.

In the north-east, on Percival 2, 3, 5, and 6, the north-eastern flank of the Kidson Basin culminates in an elliptical basement uplift with a minimum depth of less than 10,000 feet below sea level.

Surface or near surface basement rock is interpreted in the south-west, on Tabletop 4, 5, and 6. The geological map indicates exposed basement on Tabletop 4, but not on Tabletop 5 and 6.

Several continuous anomalies are outlined as the expressions of comparatively basic rock units in the basement. The largest of these is located along the axial zone of the Kidson Basin.

SHEET 7

Helena and Wilson

Sheet 7 includes the south-eastern part of the main survey area. In addition to this, the south-eastward extensions of Tie-lines 2, 4, 6, 8, and part of 10 are plotted on Sheet 7.

The anomalous pattern of the sheet is one of broad, low frequency anomalies of variable amplitude. Individual features tend to be irregular in shape, so that very little correlation between bands of traverses is possible.

A broad basement arch covers almost all of Sheet 7. Its most shallow part is located on Helena 2, where it apparently has a minimum depth of less than 5000 feet below sea level.

A few fairly intense anomalies are present in Helena 2 and 5, and are interpreted as moderately basic rock units. The correlation between them is not certain, but they suggest that the basement uplift consists of a heterogeneous rock mass, possibly intrusive in origin.

SHEET 8

Runton

Sheet 8 is located at the southern end of the survey, and includes only the south-western ends of a few lines on Runton 1, 2, and 3. The magnetic pattern is intense across most of the sheet, irregular, and of high anomalous frequency. The extreme ends of Traverses 272, 273, 302, and 303 are of low amplitude and high frequency.

The sheet is interpreted as being almost completely a terrain of exposed or near surface basement rocks. The northern edge of the exposed basement runs across the north-eastern corner of Runton 3. There is, in addition, the suggestion of a thin cover of sediments over a small area in Runton 3.

The transition from intense high-frequency anomalies to feeble high-frequency anomalies at the ends of Traverses 272, 273, 302, and 303 indicates a change in rock type, from basic composition to acidic, in the exposed or shallow basement. The interpreted contacts on the two traverse bands are delineated on the interpretation maps.

The magnetic map is in sharp disagreement with the Canning Basin geological map in this area. The latter map delineates the edge of the Canning Basin as swerving southward, with the exposed or near surface basement rocks present only in Runton 1. The magnetic contour map indicates that the margin of the basin, and its contact with exposed (or very shallow) basement continues to the south-east.

SHEET 9

Morris

Sheet 9 is located at the extreme south-eastern end of the survey area, and it includes the extensions of Tie-lines 10, 12, and 14. The magnetic pattern on the sheet is one of large, gentle anomalies in the north-east, gradually increasing in frequency, amplitude, and complexity towards the south-west.

Exposed basement rock is interpreted in the south-western corner of the sheet, on Morris 4. North-east of this the basement dips irregularly to the north-east, reaching a depth in excess of 25,000 feet below sea level in Morris 3.

One anomalous trend oriented 300^{o}., is delineated as a rock unit in the basement. It is located in Morris 2.

CONCLUSIONS AND RECOMMENDATIONS

The aeromagnetic data resulting from the survey indicate that the Canning Basin is subdivided into four separate depressions, each of which is a major basin in itself with regard to areal extent and thickness of the sedimentary section.

In the north the survey has outlined the Fitzroy Trough as a long, relatively narrow basin, trending northwest - southeast from Derby 5 to Crossland 3. It appears to be interrupted by a structural saddle in Noonkanbah 5, but the airborne magnetometer survey has not indicated any other changes to the previously known shape and extent of the Trough. The deepest part of the Fitzroy Trough is in Mount Anderson 3; the depth is in excess of 30,000 feet below sea level.

The existence of the Kidson Basin has been confirmed by the survey. It extends from Sahara 1 to Ural 6 (and possibly beyond to the north-western part of Ryan), although there is a structural saddle in central and north-western Ural. Its maximum development is in Sahara 6, where the sedimentary section is calculated to be over 35,000 feet thick.

A third major basin is delineated in the eastern half of Cornish and the south-eastern part of Mount Bannerman. This depression is on the same trend as the Fitzroy Trough, but its orientation is apparently north - south rather than northwest - southeast. This orientation may be influenced by the convergence of the Fitzroy Trough and the Bonaparte Gulf Geosyncline. The maximum depth to basement is probably about 30,000 feet below sea level on Mount Bannerman 6.

Finally, a fourth major basin outlined by the magnetic interpretation is present in Joanna Spring 5 and 6, and Dummer 1 and 4. This depression attains a maximum depth of over 20,000 feet below sea level in Joanna Spring 6. Its general orientation is east - west, but its shape is probably modified by a profound north - south fault or fault system close to the boundary between the Joanna Spring and Dummer map sheets.

A persistent, although irregular, basement ridge extends the length of the Canning Basin from McLarty Hills 1 to Helena 2. It seems likely that this ridge is in the extension of the Broome Platform. It is roughly parallel to the long axis of the Canning Basin, and it separates the Fitzroy Trough and the basin delineated in the eastern half of Cornish from the remainder of the survey area.

The Kidson Basin and the basin noted in Joanna Spring and Dummer are separated by a basement ridge, oriented east - west, whose axis is in Sahara 2 and 3. Farther east, in north-central Percival, the axis of this ridge turns south-east to parallel the supposed extension of the Broome Platform.

A few faults have been interpreted having a north - south trend, transverse to the Canning Basin regional strike, and there is some indirect evidence that transverse faulting may have an imoortant bearing on the structural characteristics of the region to a degree not previously expected.

The north-eastern margin of the Canning Basin, flanking the Fitzroy Trough, is probably marked by a major fault system. This does not appear to be the case on the south-western margin; however, here the magnetic data indicate that the basement contact continues to the south-east across Tabletop, and does not swerve to the south as suggested by the Canning Basin geological map.

The several basement depressions, ridges and faults indicated by the magnetic study all require further confirmation and modification by other, more detailed, geological and geophysical methods. Their priority should be dictated by economic and logistical considerations, and by the degree to which their airborne magnetometer recognition has supported previous geological and geophysical studies.

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APPENDIX 1

SOUTH CANNING BASIN AEROMAGNETIC SURVEY

OPERATIONAL INFORMATION

General

Operator:	West Australian Petroleum Pty Limited, 251 Adelaide Terrace, Perth, W.A.
Contractor:	Aero Service Limited, 232-234 Rocky Point Road, Ramsgate, N.S.W.
Area of survey:	105,000 square miles
Intensity of earth's total field:	49,500 gammas in north, increasing to 54,000 gammas in the south of the survey area
Inclination of earth's field:	47°S. in the north, increasing to 57°S. in the south of the survey area
Declination of earth's field:	2°E. to 3°E.
Spacing of traverses (combining 1955 and 1963 phases):	Groups of three traverses, spaced 1.5 miles apart, separated from adjacent groups by 12 miles. Tie-line spacing 25 miles
Traverse direction:	030° - 210°
Flight altitude:	2000 feet above sea level (barometric)

1955 Phase

Aircraft:	De Havilland Mosquito
Duration of survey:	30th May, 1955 to 31st August, 1955, inclusive
Base of operations:	Broome
Survey instrument:	Gulf Research and Development Company continuously recording total field fluxgate magnetometer, model unknown
Auxiliary instruments:	Aeropath 35 mm continuous strip exposure camera, model unknown; radio altimeter, model unknown; magnetometer recorder, make and model unknown; altimeter recorder, make and model unknown; Gulf Research and Development Company magnetic storm monitor

Recording sensitivity:	600-gamma full scale deflection
Navigation reference:	1:50,000 scale aerial photographs
Operational flight distance:	6000 linear miles (approximately)

<u>1962 - 1963 Phase</u>

Aircraft:	Douglas DC-3
Duration of survey:	30th November, 1962 to 4th January, 1963, inclusive
Bases of operations:	Fitzroy Crossing, Derby, Billiluna, Hall's Creek
Survey instrument:	Gulf Research and Development Company Mark III continuously recording total field fluxgate magnetometer
Auxiliary instruments:	Aeropath AS-5 35 mm continuous strip exposure camera, STR 30-B1 radio altimeter, Gulf 10-inch magnetometer recorder, Texas Instrument Company curvilinear altimeter recorder, Gulf Research and Development Company storm monitor, Kearfott N-1 compass, B-3 drift meter
Recording sensitivity:	600-gamma full-scale deflection
Navigational reference:	1:50,000 scale aerial photographs
Operational flight distance:	18,129 linear miles
Production days:	22 days
Time lost:	
Weather	5 days
Diurnal	0 days
Instrument maintenance	4 days
Aircraft maintenance	4 days
Ferry	1 day
Crew:	
Pilots	L. Taylor, E. Adams
Electronic engineer	R. Welshe
Aircraft engineer	J. Richmond
Chief data technician	W. Noone

APPENDIX 2

SOUTH CANNING BASIN AEROMAGNETIC SURVEY

ADDITIONAL DATA FILED IN THE BUREAU OF MINERAL RESOURCES

The following additional data relating to the South Canning Basin aeromagnetic survey have been filed in the Bureau of Mineral Resources, Canberra, and are available for reference:

(i)	Operational report by W. Noone, Aero Service Limited	18 pp.
(ii)	Total magnetic intensity contour maps, scale 1:253,440	9 sheets
(iii)	Estimated depth to magnetic basement maps, scale 1:253,440	9 sheets

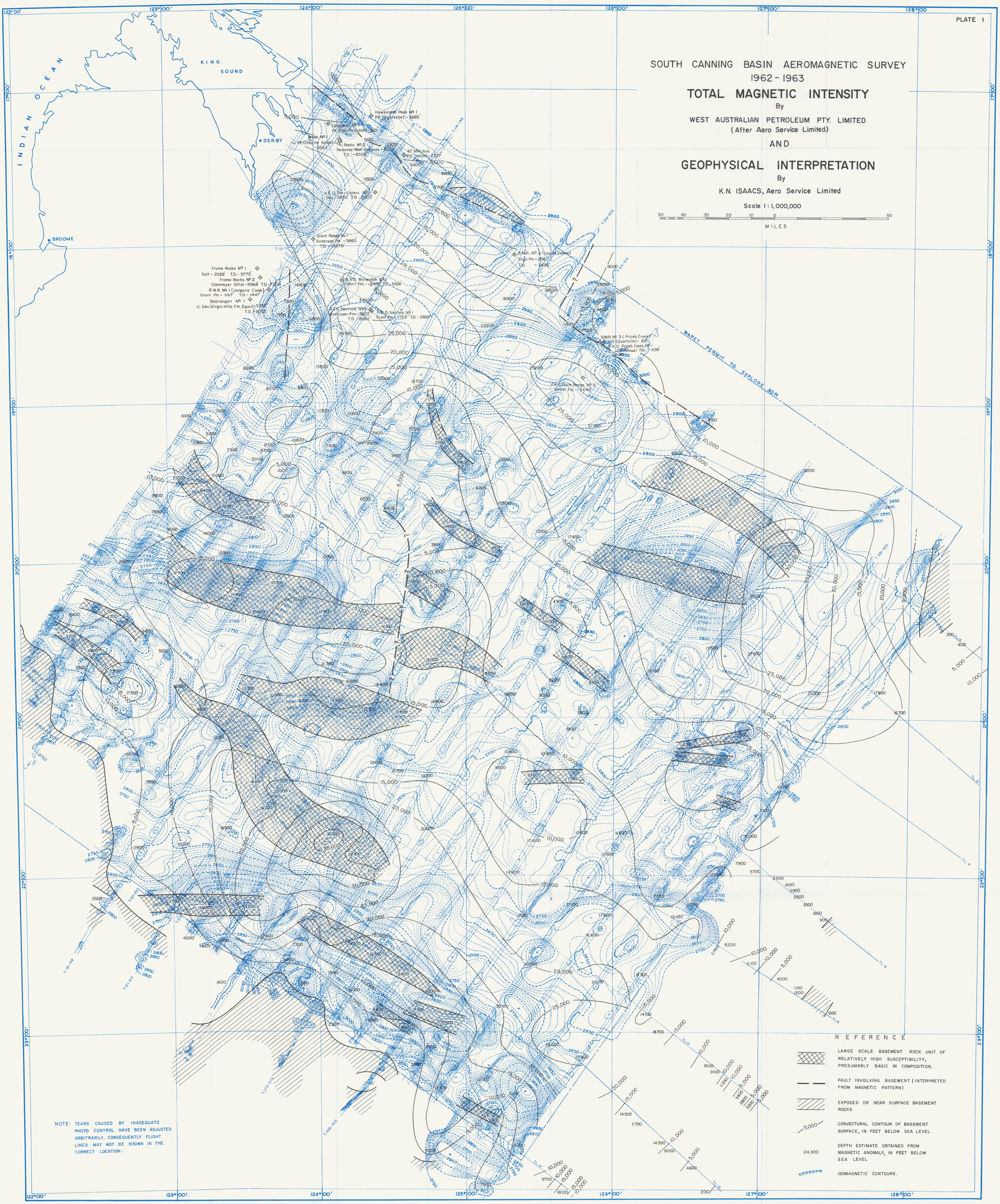

PLATE I
SOUTH CANNING BASIN AEROMAGNETIC SURVEY
1962 - 1963
TOTAL MAGNETIC INTENSITY
By
WEST AUSTRALIAN PETROLEUM PTY. LIMITED
(After Aero Service Limited)
AND
GEOPHYSICAL INTERPRETATION
By
K.N. ISAACS, Aero Service Limited
Scale 1 : 1,000,000
MILES
INDIAN OCEAN
KING SOUND
DERBY
BROOME
WAPET PERMIT TO EXPLORE 30 H
REFERENCE
LARGE SCALE BASEMENT ROCK UNIT OF RELATIVELY HIGH SUSCEPTIBILITY, PRESUMABLY BASIC IN COMPOSITION.
FAULT INVOLVING BASEMENT (INTERPRETED FROM MAGNETIC PATTERN)
EXPOSED OR NEAR SURFACE BASEMENT ROCKS
5,000
CONJECTURAL CONTOUR OF BASEMENT SURFACE, IN FEET BELOW SEA LEVEL
24300
DEPTH ESTIMATE OBTAINED FROM MAGNETIC ANOMALY, IN FEET BELOW SEA LEVEL
ISOMAGNETIC CONTOURS.
NOTE: TEARS CAUSED BY INADEQUATE PHOTO CONTROL HAVE BEEN ADJUSTED ARBITRARILY. CONSEQUENTLY FLIGHT LINES MAY NOT BE SHOWN IN THE CORRECT LOCATION.