BARBARA INVESTMENTS PTY. LTD.

MAGNETIC BASEMENT INTERPRETATION

E.P.3 NORTHERN TERRITORY

By: J. SLADE & ASSOCIATES PTY. LTD.

On behalf of: KEVRON GEOPHYSICS PTY. LTD.

Date: September 1987

ABSTRACT

The magnetic data over survey area defined a belt of Antrim Plateau Volcanics. These were adjacent to the Fitzmaurice Mobile Zone and preserved on top of the Lower Cambrian or older basement. This is the only section of the survey where magnetic and economic basement are at the same depth. Elsewhere, magnetic basement is at a far greater depth and covered by a thick sequence of older, non-magnetic sediments. It is not possible to magnetically differentiate the Proterozoic Legune Basement Formations, to the east of the Moyle River Fault, from the sediments of the Bonaparte Gulf Basin.

A series of northerly striking basement faults, parallel to the Moyle River Fault, have been recognised in the magnetic data. Magnetic basement depth estimates across these faults indicate that they are down thrown to the west.

Depths to magnetic basement over the Bonaparte Gulf Basin vary from less than 200 metres below sea level, over the Antrim Plateau Volcanics in the south-east of the area, to greater than 7000 metres below sea level in the central western portion of the survey area.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

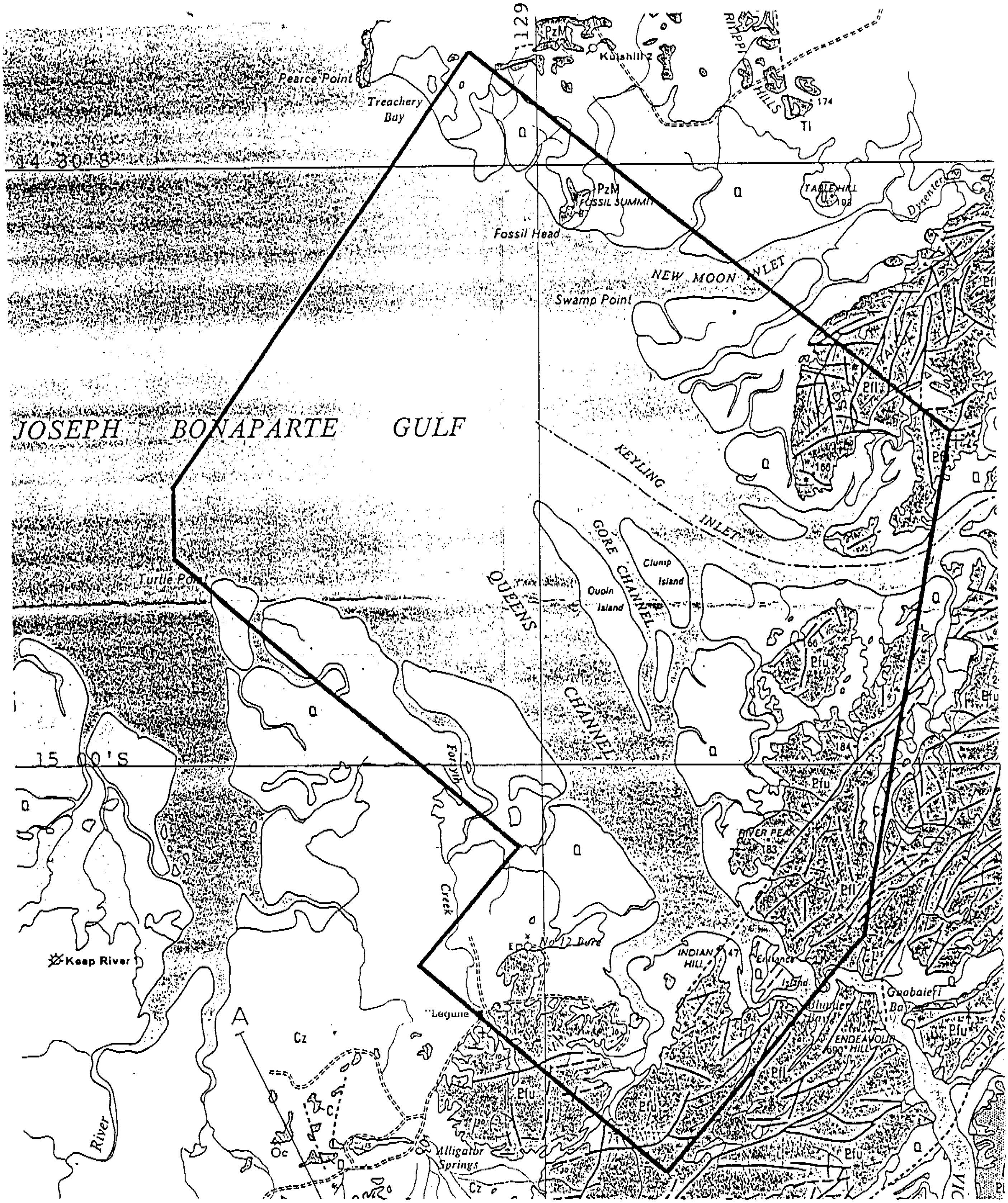
LIST OF DRAWINGS

1 INTRODUCTION

The south-eastern portion of the Bonaparte Gulf Basin, held under licence Northern Territory E.P.3 by Barbara Investments Pty. Ltd., was flown with detailed, high sensitivity aeromagnetics (Figure 1-1). The survey was carried out by Kevron Geophysics Pty. Ltd. and the data compiled by Exploration Computer Services Pty. Ltd. The survey specifications are set out in Appendix 2.

The aim of the survey was to investigate the area (Figure 1-1) by using aeromagnetic methods to identify basement structures. The flight line profiles were processed using two, independent, computerised methods to estimate the depth to magnetic basement. The results have been integrated with a regional review of the geological and gravity data.

The Bonaparte Gulf Basin is a broad, northerly plunging, syncline which extends from the mouths of the Ord and Victoria Rivers, in northern Australia, under the Timor Sea. The formations in the Basin consists of thin Cretaceous cover (approximately 100 metres thick), over Upper Carboniferous and Permian sediments (approximately 2000 metres thick), which in turn, overly Upper Devonian and Lower Carboniferous conglomerates, sandstones, limestones, siltstones and shales (approximately 5000 metres thick), Laws et al (1974) and Laws et al (1976). At the base of these formations are the Antrim Plateau Volcanics which covered the entire area at one stage. These are laid down on PreCambrian to Lower Ordovician basement.



Survey Location Map. Scale: 1;500.000

FIGURE 1-1

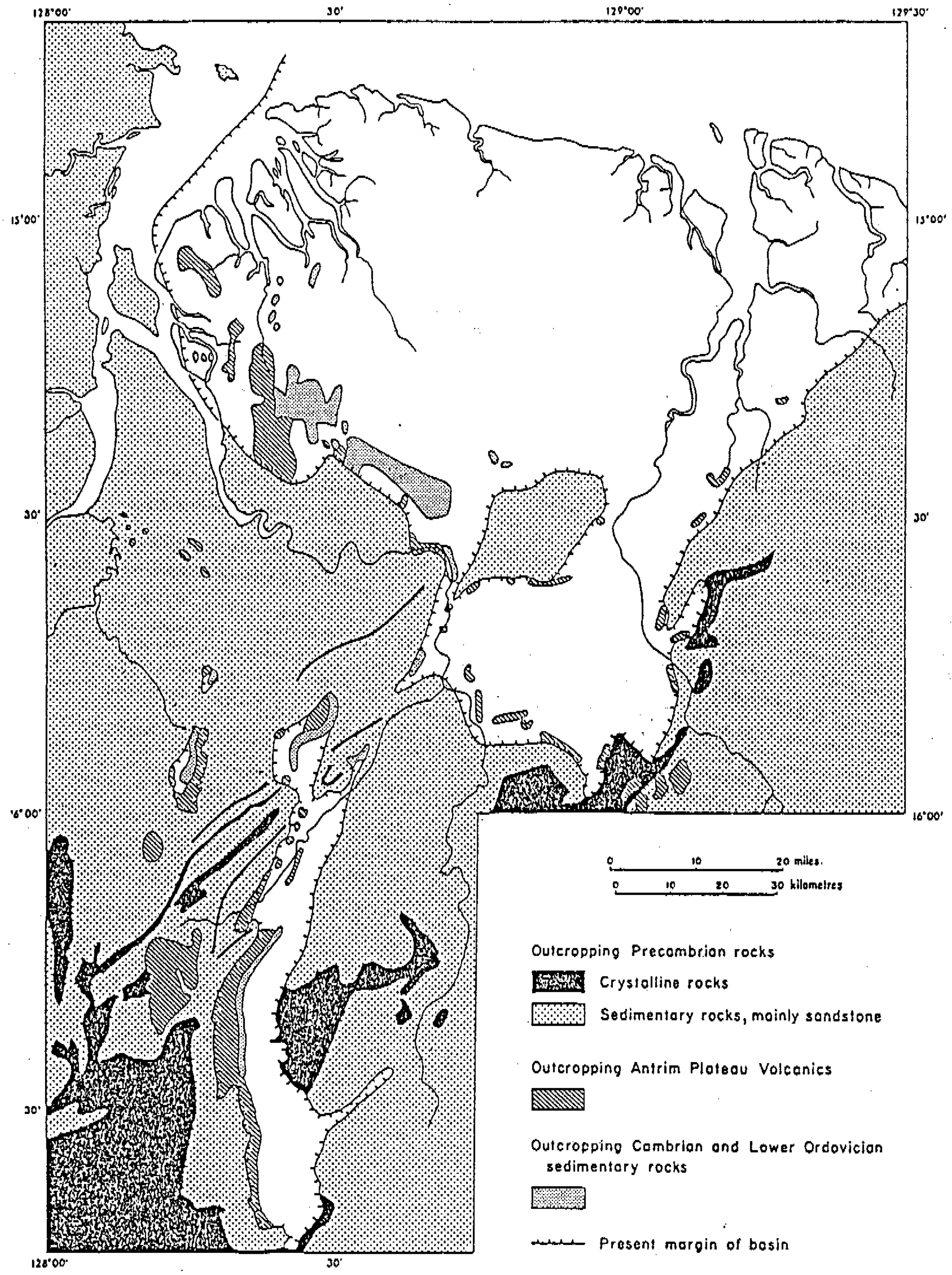
2 GEOLOGICAL AND GEOPHYSICAL BACKGROUND

The geology of the Bonaparte Gulf Basin and the underlying basement has been described by a number of authors including Veevers et al (1968), Morgan (1972), Pontifex et al (1972), Laws et al (1976), and Sweet (1977).

2-1 Basement

The basement, which encloses the Bonaparte Gulf Basin in the east, south and west (Figure 2-1a), is divided into two groups: an ancient complex of plutonic and metamorphic rock, and unconformably on this, a succession of tilted, sedimentary rocks. The plutonic rocks form a linear belt, about 50 kilometres wide, which intrudes the Fitzmaurice Mobile Zone. The PreCambrian formations comprise gently tilted sediments of the Kimberley Basin, to the west, and the Victoria River Basin, to the east. These are well sorted sandstones, siltstones and shales, with minor, acid and basic volcanics.

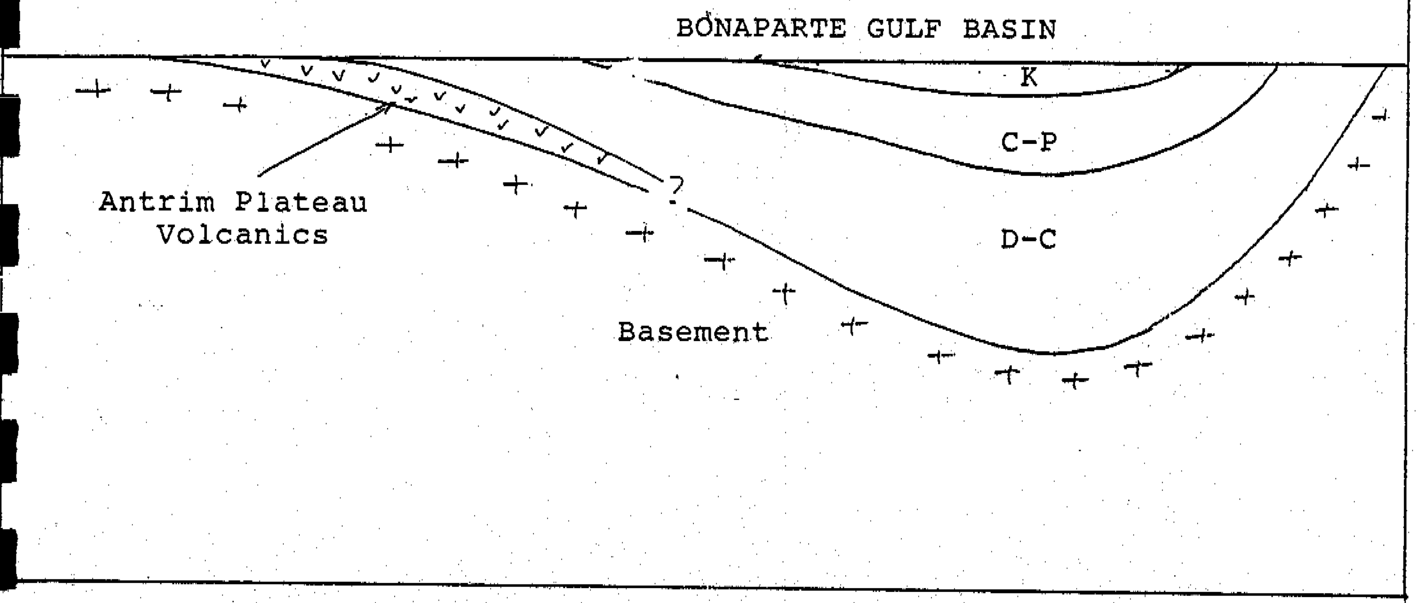
Included in the Lower Cambrian group are the Antrim Plateau Volcanics which, at one point in time, covered the entire area. The Antrim Plateau Volcanics consist of an amygdaloidal basalt, 100 metres thick. Over the western, on-shore portion of the Bonaparte Gulf Basin, Veevers et al (1968) indicates that the basalt could underlie much of the Basin and the basalt may mark the start of the sedimentary sequences (Figure 2-1b). The closest outcrop of these basalt flows is at the ochre mine on the Auvergne 1:250,000 Sheet, Pontifex et al (1972). West of the Basin, basalts have been mapped extensively, however along the eastern margin, along the Moyle River and the Indian Hill Faults, there is no indication of this formation at surface.



Distribution of pre-Upper Devonian rocks

(after Veevers 1968)

FIGURE 2-1a



Idealised section across the Southern Bonaparte Gulf Basin

FIGURE 2-1b

There are no petroleum wells within the aeromagnetic survey area. The water bores, which have been drilled north of Legune on the Auvergne 1:250,000 Sheet, were not drilled to basement.

The only formations, in these basement rocks, which are likely to have a magnetic signature, are the basal volcanics and the plutonic intrusives. Where Antrim Plateau basalt flows exist at surface, to the south of the area, there are coincident magnetic responses in the regional coverage by the B.M.R.

2-2 Sediments

The sediments in the Bonaparte Gulf Basin are divided into three sequences: approximately 5000 metres of Lower Ordovician to Lower Carboniferous shallow marine sandstones and carbonates; approximately 2000 metres of Upper Carboniferous to Lower Triassic sandstones and shales, and a thin cover, approximately 100 metres thick, of Lower Cretaceous siltstones, sandstones and conglomerate. Summary logs from Kulshill No.1 and No.2 and Moyle No.1, (Table 2-1 & Figure 2-2) show the sedimentary sequence to the north of the survey area.

No formations within these sequences of rocks have a recognisable magnetic response, however there are two types of anomalies which may occur; those associated with the lateritic remains of a weathered basalt, and furruginous sediments derived from the transported weathered volcanic detritus. Both types of intrasedimentary anomalies appear as noise in the magnetic data and depths of these responses are ignored.

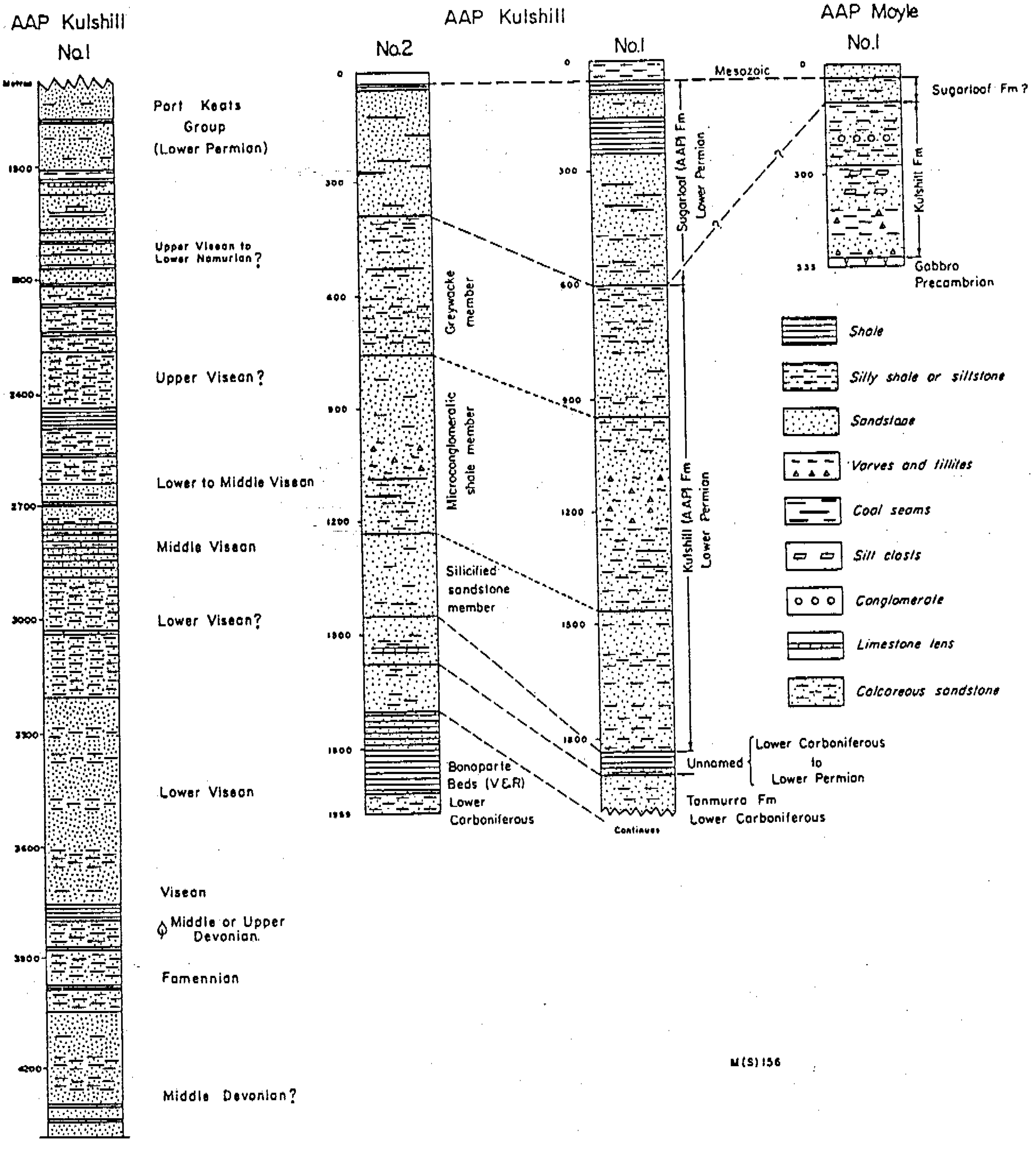
An extensive layer of salt which covered the Basin in Upper Devonian times or earlier, has moved to the Upper Permian, Crist et al (1973). The salt will not be detectable in the magnetic data although it will greatly influence the gravity responses.

Age	*Name and Symbol*	*Thickness (m)*	*Lithology*	*Remarks*
Cainozoic	Qa	Up to 10	Mud, silt, and fine sand near Victoria River and main tributaries. Sand and gravel in creeks	Extensive flats with tree-covered pressions of former ox-bow lakes
	Qc		Coastal deposits: mud, silt, evaporites	Tidal flats
	Qt	Up to 15	Mud, sand, gravel	One terrace forming banks up to m above present river level
	Czs		Sand, soil, colluvium	Much of the area mapped as s rock outcrop has a mantle of commonly as a skeletal soil
	Czb		Dark grey and black clay, minor clayey silt	River and coastal flats. Few resid black soils—mostly alluvial
	Czg	Up to 5	Gravel, sand, colluvium	Piedmont deposits adjacent to N castle Range or river terraces
	Czl	5	Massive, vesicular, and pisolitic laterite capping mottled and pallid zones	Formed on Mullaman Beds
retaceous	Mullaman Beds Klm	10+	Friable argillaceous sandstone and siltstone	Unconformably overlie Auvergne Lateritized
Upper Carboniferous	Border Creek Formation Cub	120	Quartz sandstone, conglomerate, siltstone	Contains *Phyllotheca*-like plant
ower Carboniferous	Burvill Beds Clr	Up to 85	Sandstone, shale, and sandy limestone	Fauna includes brachiopods, gas pods, ostracods, and conodonts
	Milligans Beds Clm	120	Silty shale, siltstone	Varied shelly fauna (marine). Mc subsurface; poor outcrop at Spirit
	Zimmerman Sandstone Clz	140	Quartz sandstone and siltstone	Shelly fauna includes brachiop pelecypods, and polyzoans
	Septimus Limestone Cls	180?	Limestone, minor calcareous sandstone	Marine shelly fauna. Mostly confo able on Enga Sandstone
ower Carboniferous	Enga Sandstone Cle	135	Calcareous quartz sandstone	Brachiopods, pelecypods, and w tubes
	Burt Range Formation Clb	610	Limestone, minor shale and sandstone	Marine shelly fauna. Conform overlies Duc
Upper Devonian	Cockatoo Formation Duc	1 220+	Sandstone, conglomerate	
	Kellys Knob Sandstone Member Duk	305+	Quartz sandstone, pebbly in part	Brachiopods, ostracods, and p stems
	Ragged Range Conglomerate Member Dur	305+	Cross-bedded conglomerate and sandstone	Overlies Antrim Plateau Volca Interfingers with and overlain Kellys Knob Member
Lower? Cambrian	Antrim Plateau Volcanics -Cla	60+	Massive and vesicular basalt	

UNCONFORMITY

PHANEROZOIC STRATIGRAPHY (after Pontifex 1972)

TABLE 2-1



Sections in oil wells. (after Morgan 1972)

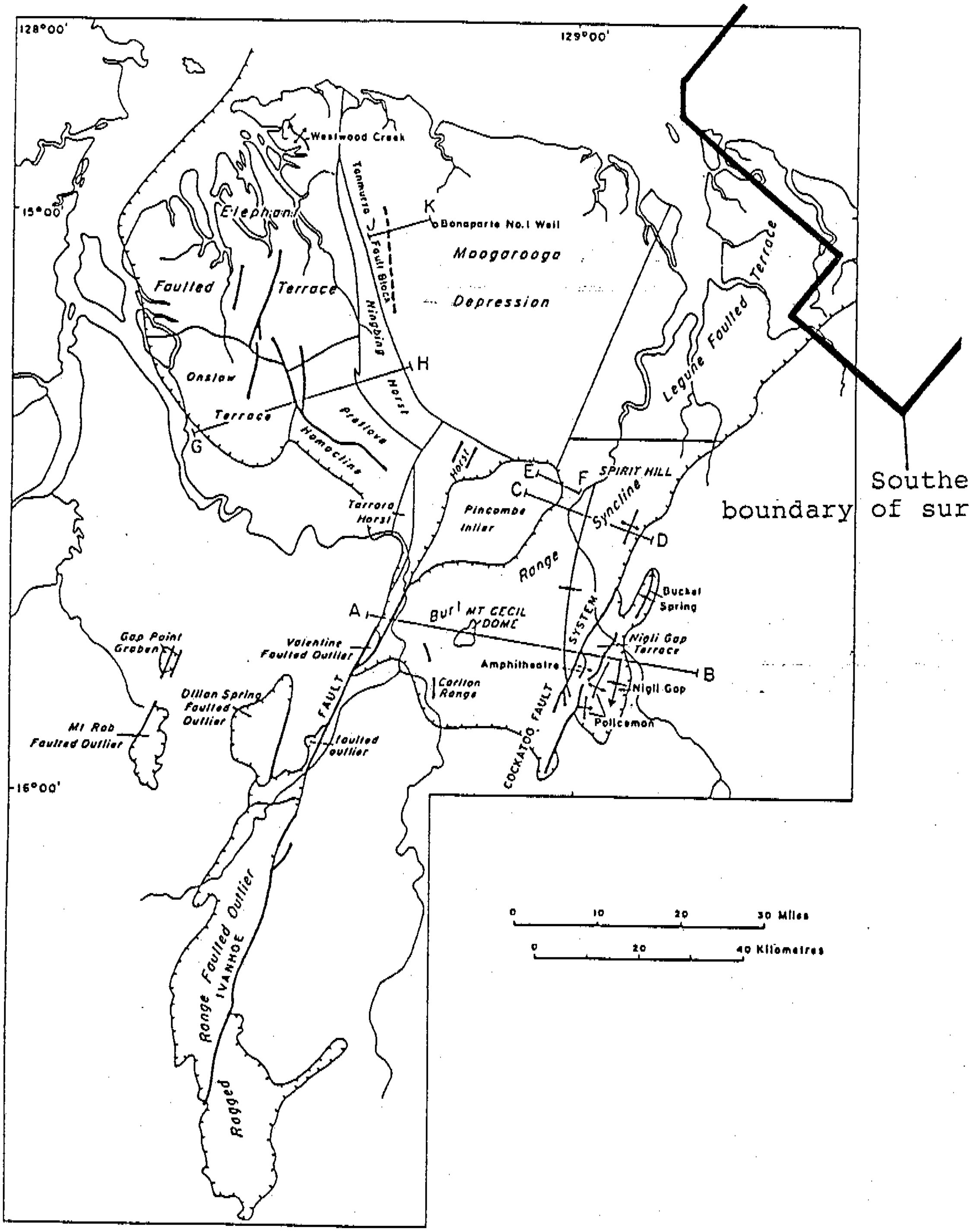
FIGURE 2-2

2-3 Structures

The main structural elements recognised in the Bonaparte Gulf Basin, Veevers (1968), (Figures 2-3a and 2-3b), locate the survey area on the Legune Faulted Terrace, bounded to the east by the Fitzmaurice Mobile Zone. To the west of the area, the Moogarooga Depression forms the central deep of the Basin. Very little has been published about the Legune Faulted Terrace which is described as a north-westerly sloping platform crossed by north striking faults. No major off shore structures have been mapped which could be extended, with any degree of confidence, over the survey area. One possibility is that the underlying basement is structurally complex, similar to the Hyland Bay Area (Figure 2-3b).

Lee et al (1988) and Gunn (1988) have proposed that the Bonaparte Gulf Basin overlies a failed Devonian rift. This is not the first time a rift system has been theorised for the Basin. Veevers (1984) cites previous interpretations which suggested the Bonaparte Gulf Basin as part of a failed Early Cambrian rift, extending south from the Tethys Sea (Figure 2-4a). These interpretations assumed the Wickham Gravity High, over the depocentre of the Basin, (Figure 2-4b) to be associated with crustal thinning, and that the Antrim Plateau Volcanics were fed from vents under the Bonaparte Gulf. More recently, Lee et al (1988) and Gunn (1988) postulated a triangular or pivot-type rift model to explain the Wickham Gravity High and magnetic activity over the depocentre of the Bonaparte Gulf Basin. They interpreted the proposed rift as a triangular shaped fault system, rather than a linear fracture pattern, opening about a pole (Figure 2-5). They do not substantiate with an example of a triangular or pivot-type rift system elsewhere in the world.

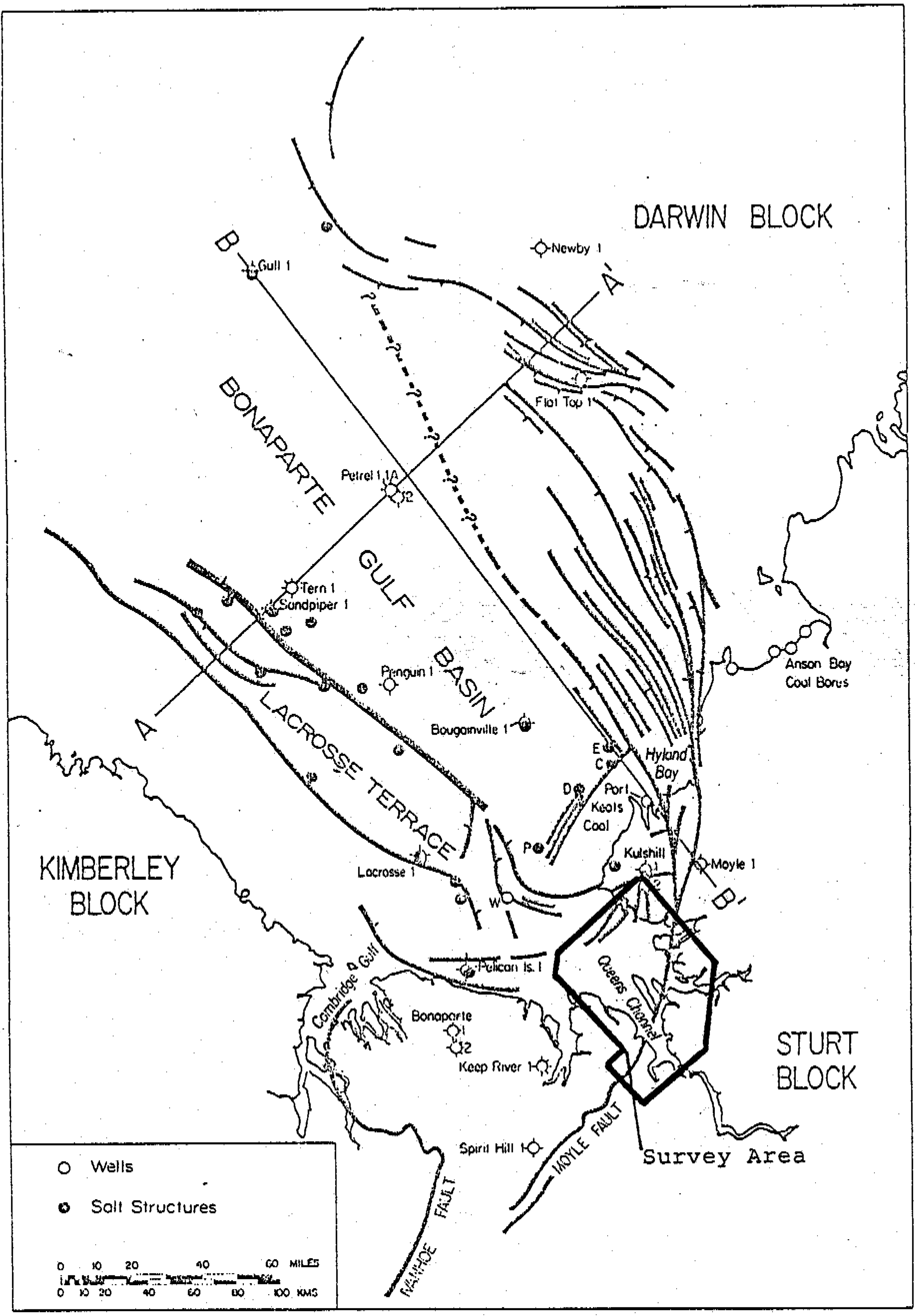
In the author's opinion it is extremely difficult to reconcile this pivot-type rift model from the available data. There is no evidence on-shore of any basement faulting with a north, north-westerly strike, parallel to the rift faults. Secondly, if the rift had been a linear system,



Southern
boundary of survey

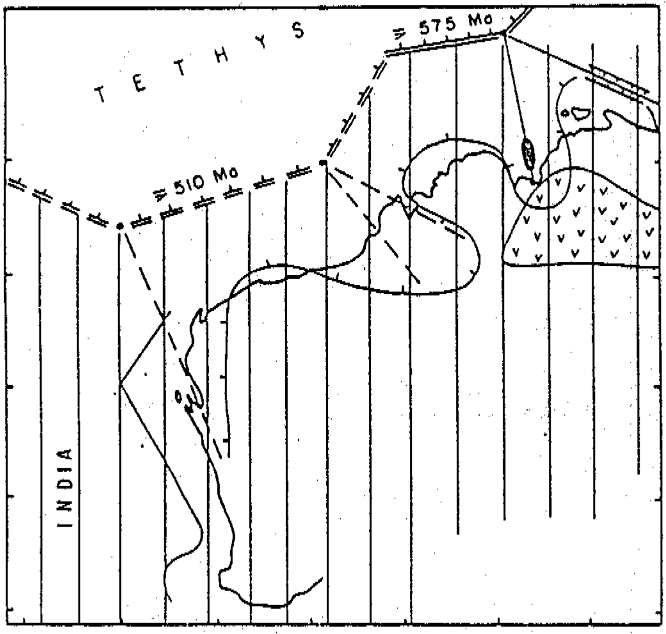
Structural subdivisions of Bonaparte Gulf Basin (on shore)
(after Veevers 1968)

FIGURE 2-3a



Tectonic framework of the Southeast Bonaparte Gulf Basin. (off shore)
(after Edgerley 1974)

FIGURE 2-3b



Failed-arm stage, during the Cambrian and Ordovician, with failed arms radiating from nodes at re-entrants, of continental margin adjacent to Tethyan Ocean, with Money Shoal Graben and Bonaparte Gulf Basin stemming from oldest margin, and the Canning and Carnarvon Basins from the younger margin. Continental lithosphere shown by vertical lines, oceanic lithosphere clear. Solid black ellipse in the southern Bonaparte Gulf Basin represents an intense positive gravity anomaly.

FIGURE 2-4a (after Veevers)

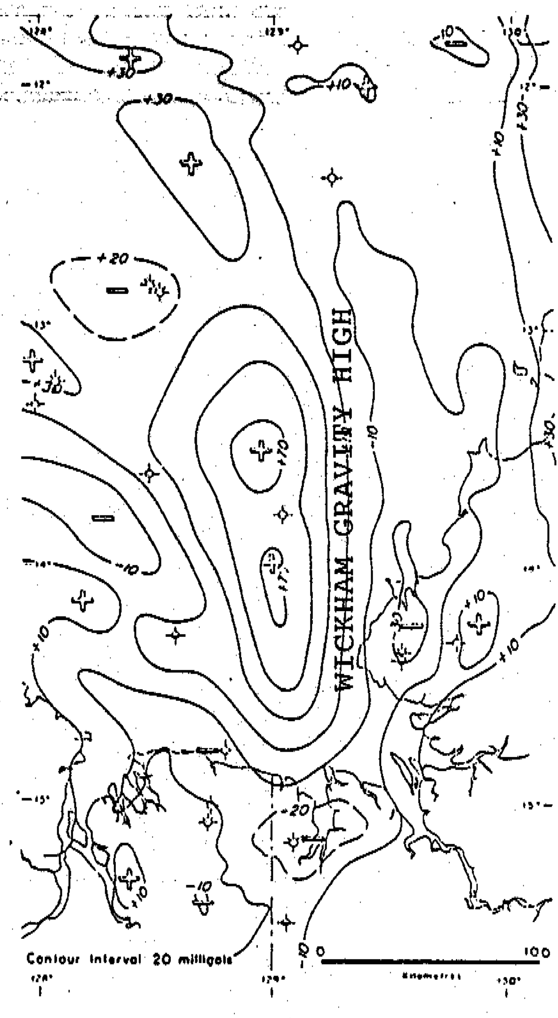
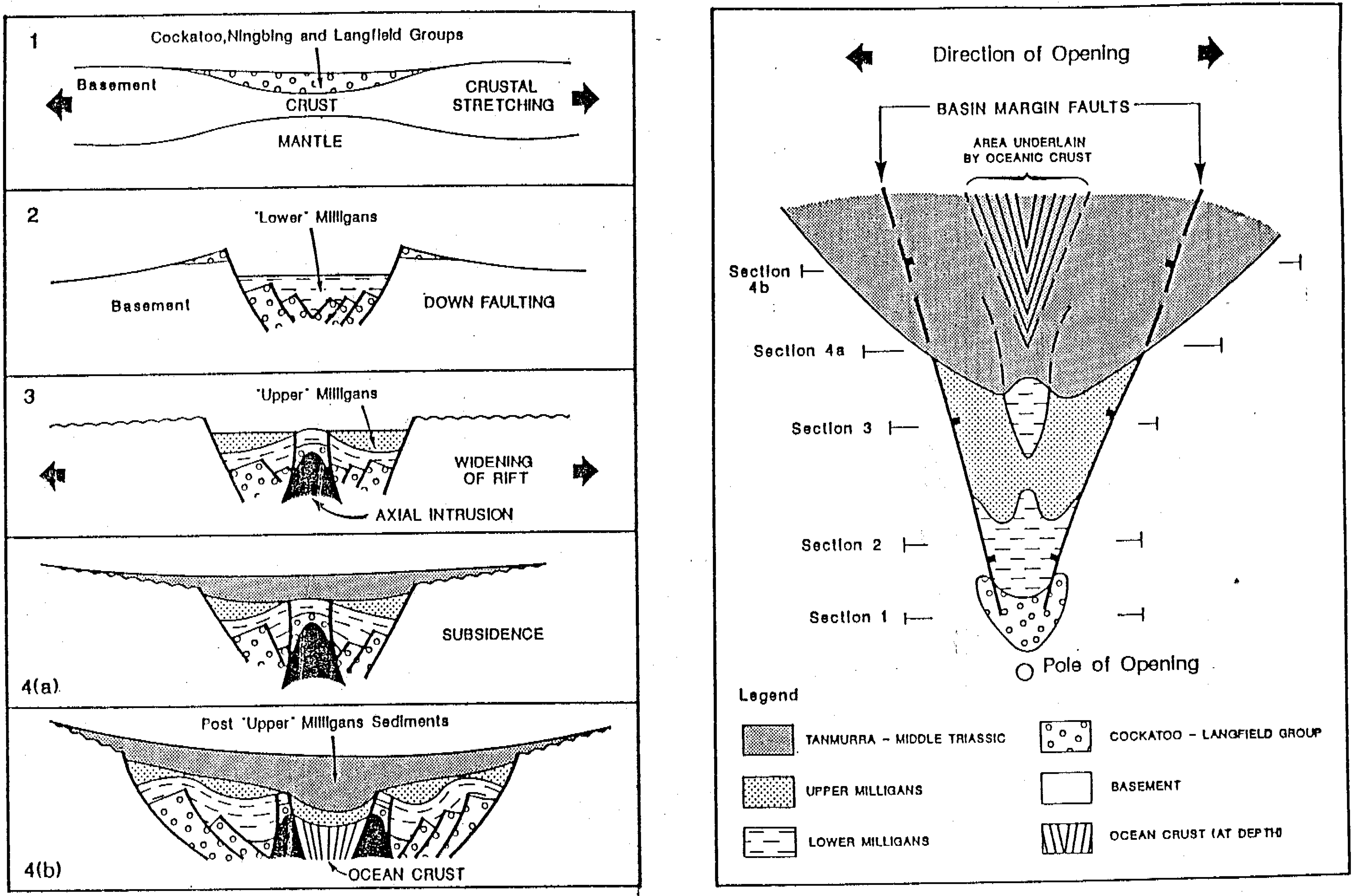


FIGURE 2-4b

Bouguer Anomaly Map over the Bonaparte Gulf Basin.



Pivot-type Rift (after Gunn 1988)

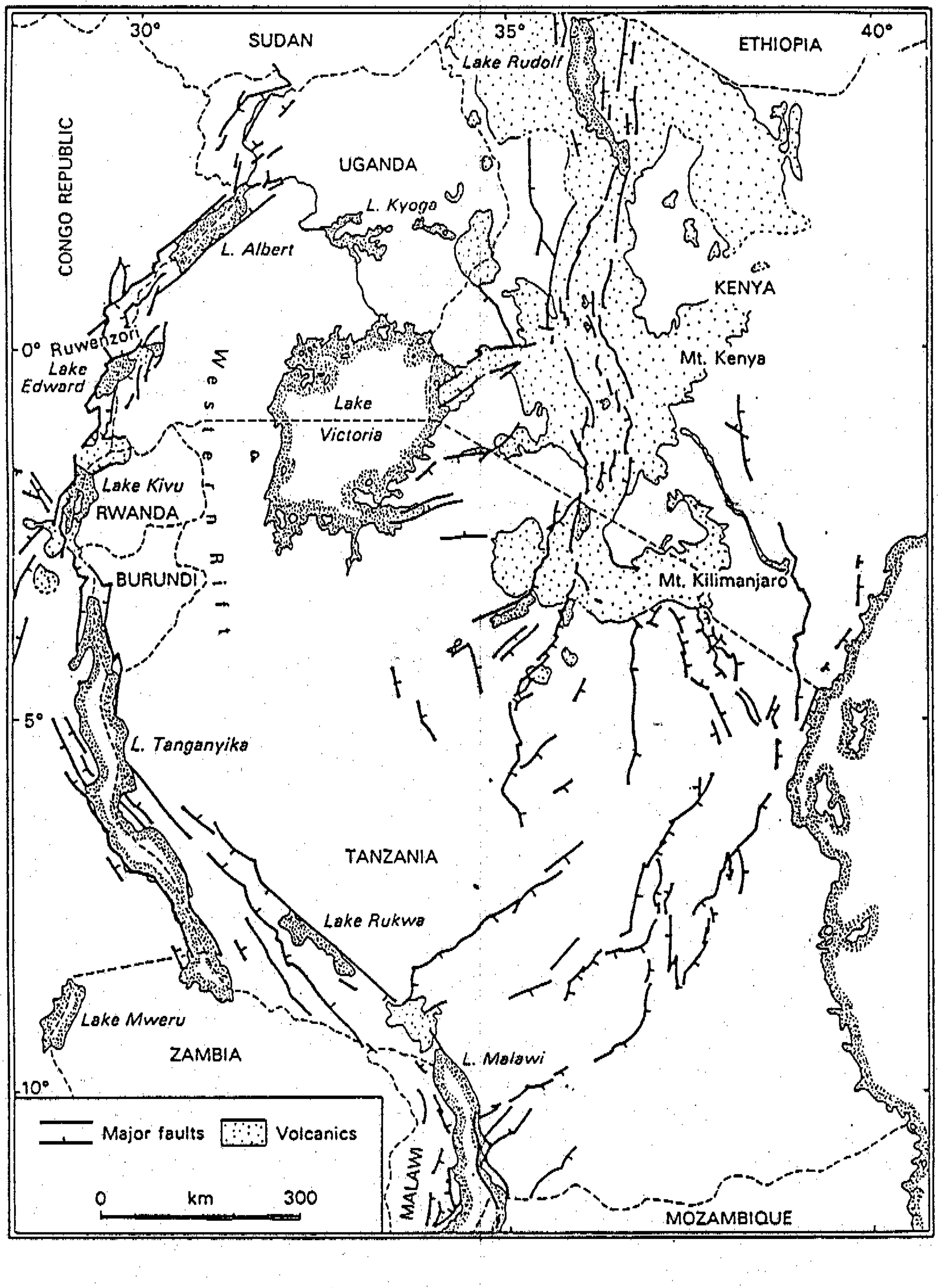
FIGURE 2-5

rather than a pivot-type, there should be a general fanning out of faults as the rift system dies, similar to the East African Rift, south of Mt. Kilimanjaro (Figure 2-6). There is no evidence of these fan-like structures in the older basement formations to the south of the Bonaparte Gulf Basin. In fact, the Victoria River Fault (Figure 2-7) is described as a compressional thrust fault.

2-4 Previous Surveys

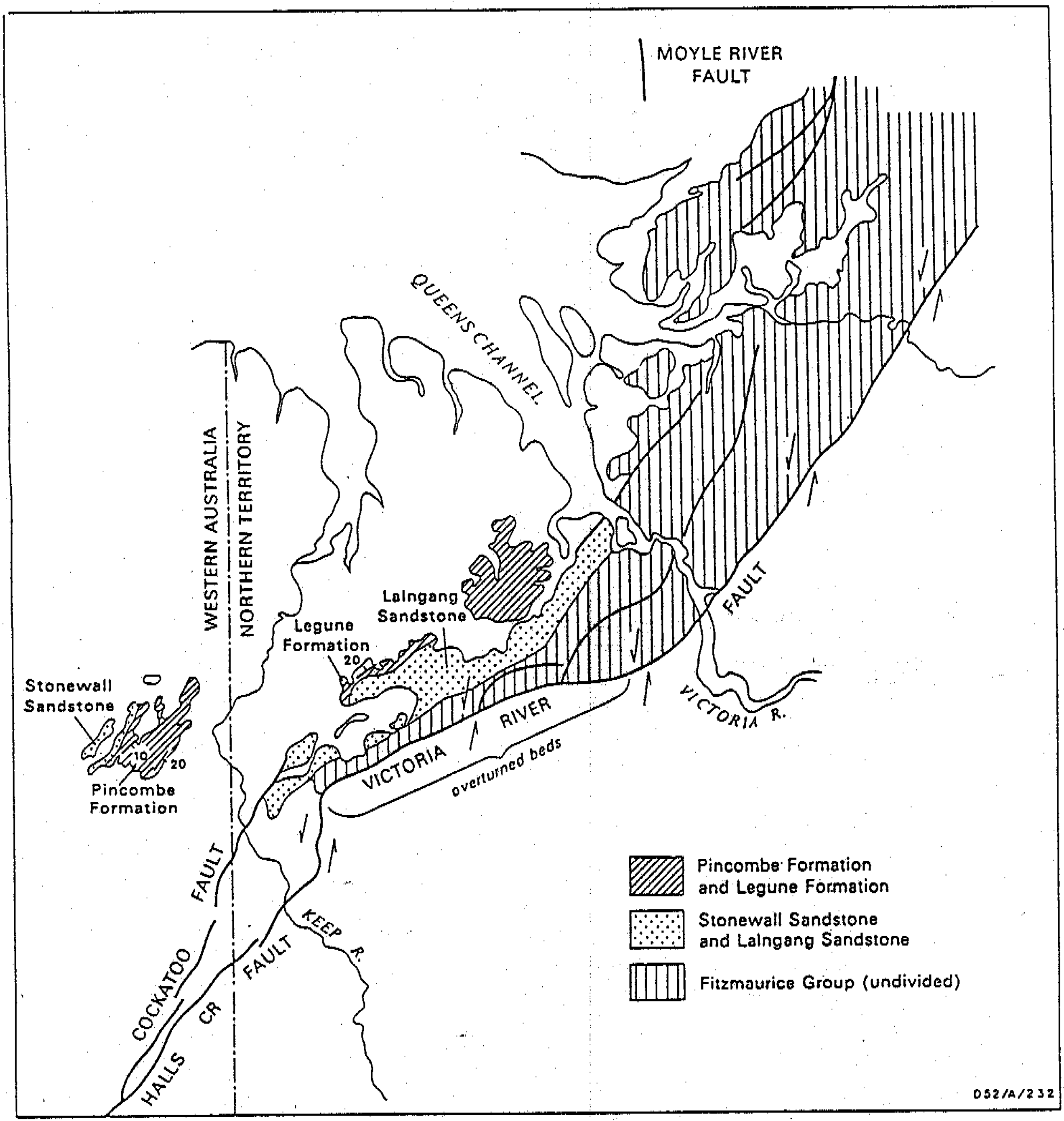
The B.M.R. has carried out two aeromagnetic surveys over the Port Keats and Auvergne 1:250,000 Geological Sheets. The first, flown in 1958, over the on-shore and near off-shore portion of the Bonaparte Gulf Basin, included this survey area. The data were recorded at an altitude of 1500 feet (460 metres) above sea level, using a fluxgate magnetometer, and contoured at a 20nt interval. The lines were approximately 2 kilometres apart. Over the survey area on the Port Keats Sheet there was no magnetic relief. The second survey, carried out by the B.M.R., was over the Auvergne 1:250,000 Geological Sheet and published in 1984. This survey was flown at a mean terrain clearance of 150 metres, with lines spaced at 1.6 kilometre intervals. A fluxgate magnetometer was used to record the variations in the field and the data were contoured using a 20nt interval. Over the survey area there are a number of minor disturbances in a zone which is otherwise magnetically inactive.

Arco Ltd. and Australian Aquitaine Petroleum Pty. Ltd carried out an aeromagnetic survey over the Bonaparte Gulf Basin in 1965, Reford (1983). The survey concentrated on the off-shore portion of the Basin (Figure 2-8) and consisted of a series of widely spaced (3.2 Kms) flight lines. A high sensitivity cesium vapor magnetometer was used. The interpretation indicated a broad synclinal structure at a depth of 4500 metres (15000 feet), shallowing to the south and east (Figure 2-9). The data were too widely spaced and covered such a large area that it was impossible to map structures in any detail.



East African Rift: showing the fault fanning out south of Mt. Kilimanjaro.

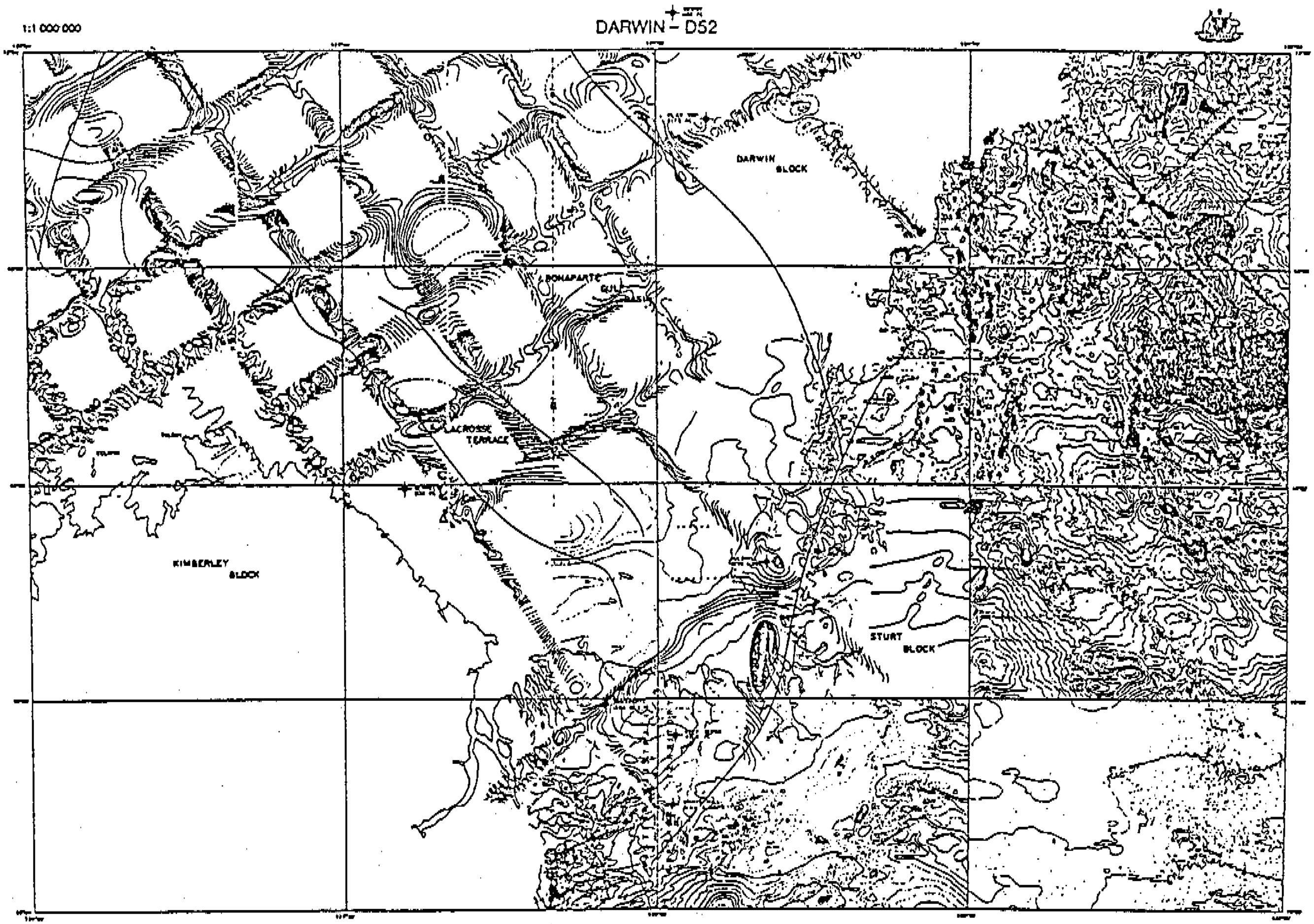
FIGURE 2-6



The Victoria River Fault. Arrows show the probable movement and the zone of pronounced overthrusting.

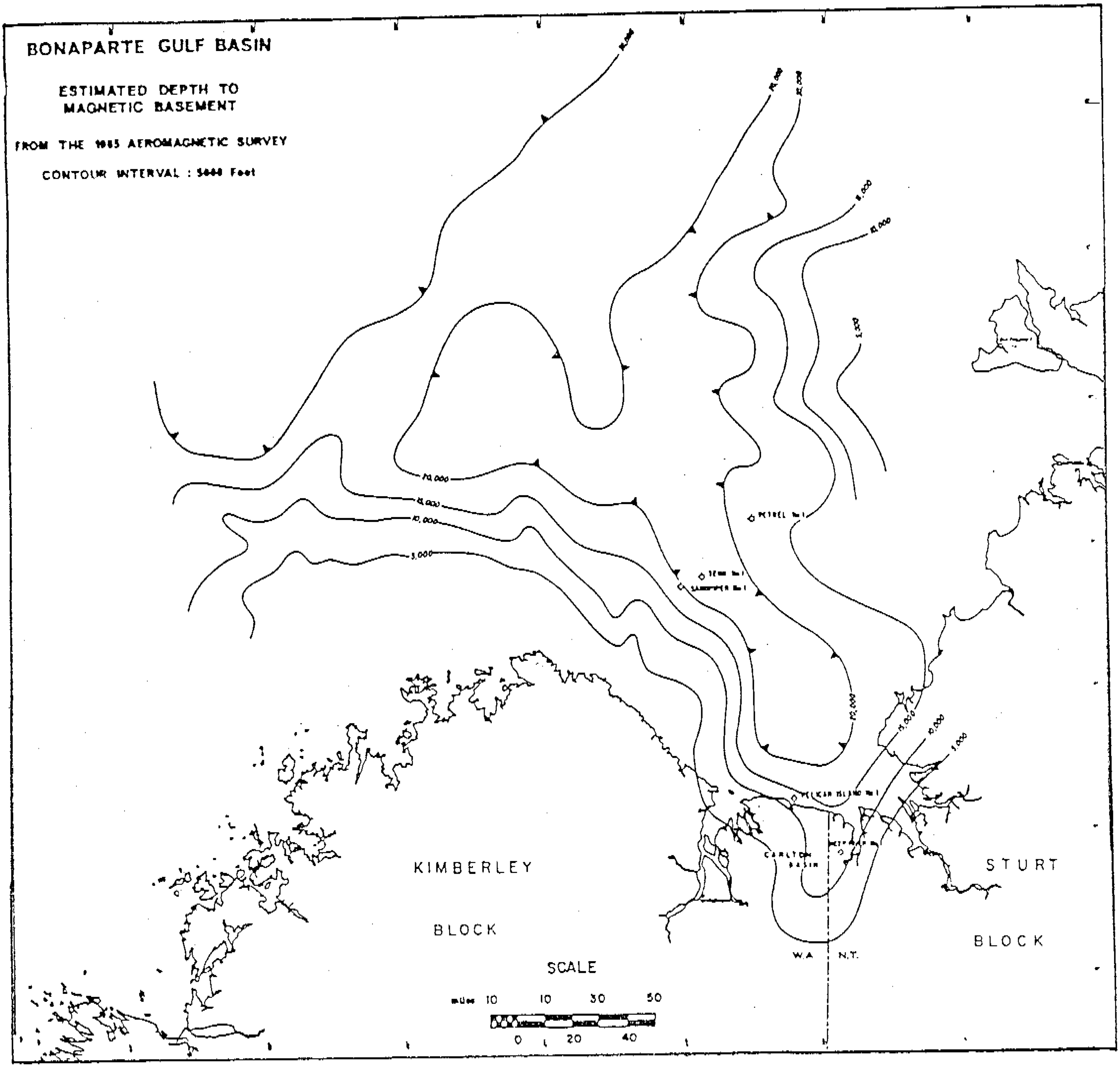
(after Sweet 1977)

FIGURE 2-7



Previous Aeromagnetic Coverage (after Reford 1983)

FIGURE 2-8



Aeromagnetic Map of the area showing probable depths to magnetic basement. (After Crist et al 1973)

FIGURE 2-9

3 GRAVITY INTERPRETATION

The gravity data over the area shows a number of distinctive features which can be related to various subdivisions within the Basin.

(a) The Wickham Gravity High, coincident with the approximate depocentre of the Basin (Figure 2-4b), can be explained in four ways: as crustal thinning at this location; the triangular rift, as proposed by Lee et al (1988) and Gunn (1988); salt diapirs which have migrated to the east and west, Crist et al (1973); or there is a thick section of high density limestones in the sequence.

Crustal thinning on a small, localised scale is unlikely. This type of response, usually, is only recorded along plate margins, as is the case in New Guinea. When the plate margins become inactive the amplitude of the gravity highs and lows associated with the subduction zone return to equilibrium.

The triangular rift model, proposed by Gunn (1988), assumes the gravity high to be associated with the axial dyke of the rift. The dyke consists of dense magma, the source of the gravity high.

Prior to the proposed model of a rift system, the accepted explanation for the Wickham Gravity High was that it had been enhanced by salt diapirs which had migrated to the east and west, Crist et al (1973).

This type of gravity high, over the depocentre of a basin, is not uncommon. It has been recognised over the Bowen Basin in Queensland and the Papuan Basin in New Guinea. In the Papuan Basin the gravity high is due to a thick sequence of dense limestones which have been intersected in wells, Bowen (1984).

The Wickham Gravity High, over the depocentre of the Bonaparte Gulf Basin, is interpreted by J.C.Slade as being due to a thick sequence of dense limestones, plus the migration of salt diapirs.

(b) There is -30 milligal low over the Port Keats portion of the Basin which, in this area, represents a deep section of low density sediments, including a number of salt diapirs adjacent to the Moyle River Fault. The alternative explanation for a gravity low is a granite intruding basement, however igneous intrusions are not common in the exposed basement to the south-east.

(c) A -25 milligal low, coincident with the Keep River estuary, similarly represents a deep section of low density sediments.

(d) The Moyle River and Indian Hill Faults are both evident as gradients in the data with gravity highs to the east over the older, higher density, basement formations.

There is insufficient coverage in the data to form any definite conclusions. Density logs from the Kulshill and Moyle Wells should be analysed and if there is sufficient density contrast between the Lower Permian and Carboniferous sediments it may be possible to map structures at this interface using gravity methods.

4 AEROMAGNETIC INTERPRETATION

The aeromagnetic survey was flown using a cesium vapor magnetometer which had a sensitivity of 0.01nt (Appendix 2). The magnetic data over the area was compiled as contour maps (Dwg. No. 1), and stacked profiles at a scale of 1:100,000. The aeromagnetic data were contoured using an interval of 1nt. The preliminary contours of the unfiltered data were extremely complex with a large number of small amplitude and short wavelength anomalies dominating the data. The final contour maps were compiled from data which had been filtered to remove some of this noise. The stacked profiles of the magnetic data, which are not included as part of this report, show the unfiltered traces. The most probable source of the noise is transported intra-sedimentary volcanic detritus or laterites.

A qualitative interpretation has been prepared to identify the magnetic formations and major structures evident in the data (Dwg. No. 2). This interpretation is integrated with the quantitative interpretation, based upon both a Werner deconvolution, Werner (1955) and the analytic signal, Nabighian (1972). Appendix 1 outlines the Werner deconvolution method. Depths to magnetic basement (Dwg. No. 2) are in metres below sea level. Depths suffixed with `W' were estimated by the Werner method while depths suffixed with `N' were estimated from the analytic signal.

4-1 Qualitative Interpretation

Magnetic noise, which is evident in the data and was filtered out prior to contouring, is interpreted as iron rich horizons in the sediments, or alternatively, as buried laterites rich in ferromagnetic minerals. In some instances it is possible to use this type of response to map a certain furruginous formation. This noise, however, is across the entire area and does not correlate with known geological features.

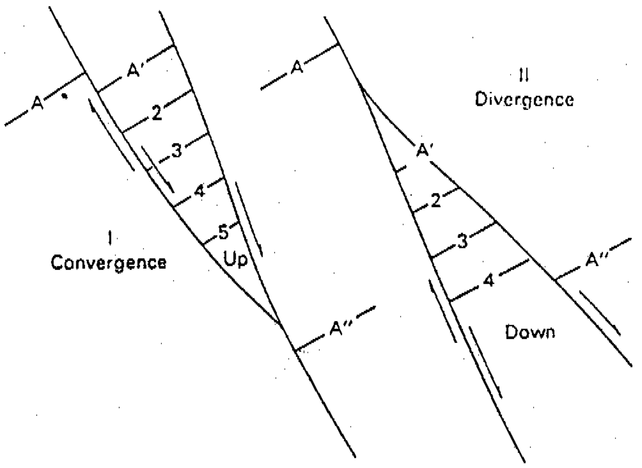
Three anomalous features are evident in the magnetic data: areas of magnetic activity in the south of the block (Dwg. No. 2); the northerly striking structures; and the north-easterly striking basement fault.

(a) The area of magnetic activity in the south of the block is interpreted as remanent outliers of Antrim Plateau Volcanics (Dwg. No. 2). The Antrim Plateau Volcanics, an extrusive basalt which covered the entire area at one stage, has been subsequently removed by weathering, from most of the area. The areas of magnetic activity correlate with low lying, swampy areas either side of the Victoria River. The responses are interpreted as down thrown blocks associated with the movement along the Indian Hill and Moyle River Faults (Figure 4-1). Antrim Plateau Volcanics are preserved on the down thrown blocks. These faults must have been active post the episode of extrusive volcanism and prior to the deposition of the Carboniferous sediments when the volcanic cover was removed from the upthrown blocks. The faults may have been reactivated recently as they are evident in the current topography. Magnetic basement, over these magnetically active areas, correlates with economic basement.

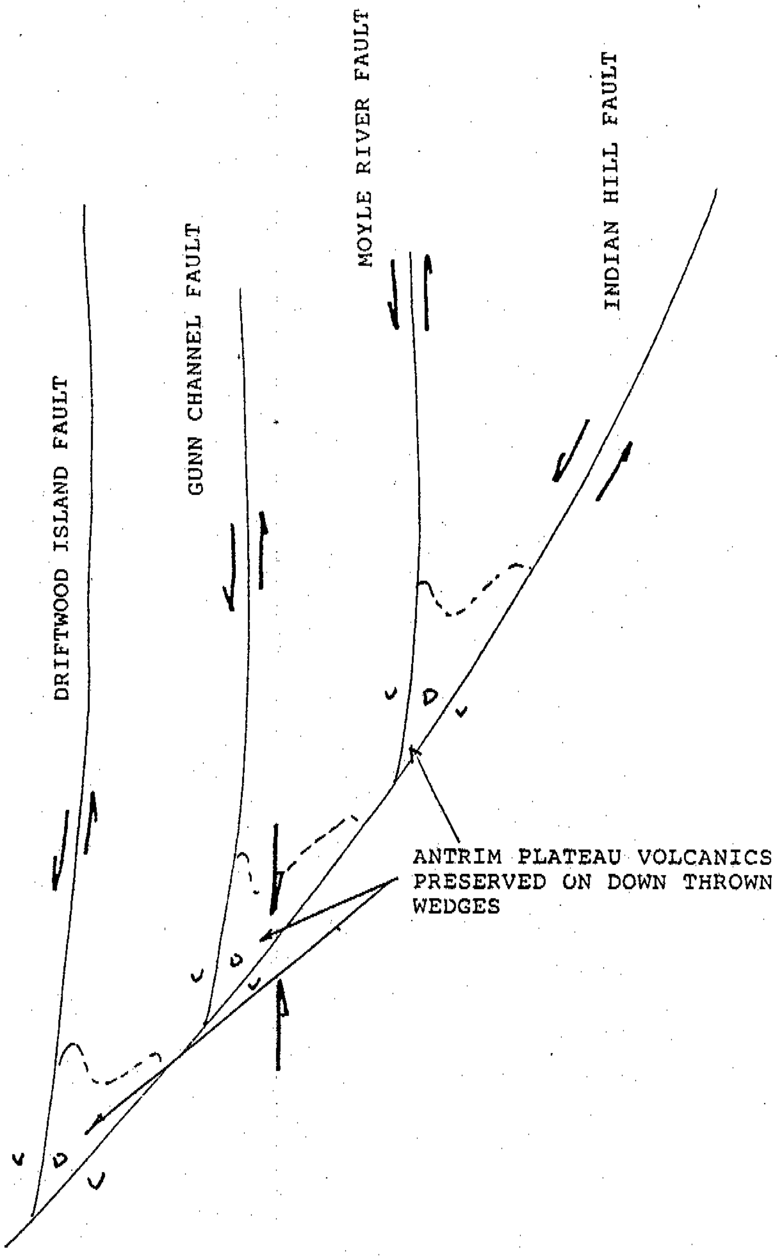
(b) A series of northerly striking, magnetic linears are mapped in the data (Dwg. No. 2); the Moyle River Fault in the east of the area, the Gunn Channel Fault, the Driftwood Island Fault and the Steele's Bore Fault.

(c) The Indian Hill Fault, to the south of the area, is barely evident in the data, (Dwg. No. 1).

The Proterozoic Legune basement sandstones, siltstones and dolomites, to the east of the Moyle River and Indian Hill Faults, cannot be recognised in the magnetic data.



Sketch map to show uplift at convergence and subsidence at divergence of strike-slip faults



Divergent Strike-slip Faults

Figure 4-1

Over the zones of Antrim Plateau basalts, magnetic basement correlates with economic basement. For the remainder of the area magnetic basement is at a greater depth.

The most important basement structure, defined by the magnetic data, is the Clump Island Basement Shelf, (Dwg. No. 2), which plunges to the north and is a continuation of the Legune Platform. It is bounded by the Moyle River Fault to the east and the Driftwood Island Fault to the west. The Shelf may be displaced in the centre by the Gunn Island Fault.

4-2 Quantitative Interpretation

The Quantitative interpretation is based upon two independent methods; the Werner deconvolution (Appendix 1), and the analytic signal, Nabighian (1972). Every tenth line and all tie lines were analysed, using both methods, and the results compared. Magnetic basement depth estimates (Dwg. No. 2) are suffixed with `W' for Werner deconvolution solutions and `N' for Nabighian analytic signal results.

Over the deeper part of the survey area the Werner depths are more accurate and these have been favoured. The deconvolution was applied, using a 50 metre sample interval, and calculating the depth for levels 2 to 6 (1000 to 16000 metres). Level 7 (32000 metres) could not be used due to the short length of the flight lines. Lines 10000 to 11600, at 2000 metre spacings, were analysed by this method.

The analytic signal, Nabighian (1972), was designed as a method to positively identify the corners and depths of magnetic sources. The output of the calculation is plotted on the multiplots of the magnetic data. Unfortunately the method enhances shallow features, therefore noise associated with the furruginous horizons dominates the profile over low magnetic gradients. The method is most useful over the volcanics, in the south of the area, where the depths are often shallower. Lines 10600 to 11200 were processed using the analytic signal.

To test accurately the depth of a magnetic source, using the Werner deconvolution method, it is necessary to have a profile over the maximum response and the anomaly completely defined. As the wavelength of the response is directly related to the depth of burial, deep sources near the ends of lines are not always resolved. Depth to magnetic basement, in the northwest of the survey area, could be far greater than the maximum resolvable by level 6, which is approximately 8000 metres.

Basement contours (Dwg. No. 2) represent an interpreted shape to the top of magnetic basement. All anomalies have been tested and those interpreted as intra-sedimentary sources have been rejected. The remaining depth solutions are either from the top of basement or intra-basement sources. When the shallowest solution in the area is established the basement is contoured with a maximum slope of approximately 30 degrees. If the slope exceeds this, a vertical fault is inferred.

Depth to magnetic basement contours (Dwg. No. 2) show the following.

(a) Over the Legune Basement, to the east of the area, depths between sea level and 1000 metres have been estimated. The shallow depths correlate with the zones of minor magnetic activity, such as intrusives in the fault zones.

(b) Depths to magnetic basement over the Antrim Plateau Volcanics vary between 0 to 200 metres below sea level. These plunge to the north where the maximum depth is approximately 500 metres below sea level.

(c) Turtle Point is recognised in the data as a basement formation with a similar magnetic response to the Legune basement, east of the Indian Hill Fault.

(d) To the north of the area, two magnetic basement troughs have been mapped; one open to the north, west of Table Hill and the second open to the west, coincident with the Keyling Inlet.

5 CONCLUSIONS AND RECOMMENDATIONS

A series of northerly striking basement faults has been mapped parallel to the Moyle River Fault. These are interpreted as pre Carboniferous faults which displaced the Antrim Plateau Volcanics. Some reactivation is possible as the faults are identifiable in present day topography.

Depths to magnetic basement over the survey area vary from less than 200 metres below sea level, over the Antrim Plateau Volcanics, to greater the 7000 metres in the north west of the area. The magnetic data does not define the Legune Proterozoic Basement Formations, to the east of the area, as these older sediments are non-magnetic. Elsewhere, if basement consists of similar non-magnetic rock types, magnetic basement will be at a greater depth than economic basement. Only over the Antrim Plateau Volcanics, in the south of the area, do economic basement and magnetic basement correlate.

Recent interpretations of the regional magnetic and gravity data over the Bonaparte Gulf Basin indicate the Basin to be part of a rift system which has separated about a pole located in the south-east of the area. There is no evidence in the detailed aeromagnetic survey to support this theory.

Detailed gravity surveys may be an alternative method of mapping economic basement structures. This would be dependent upon a density contrast between the Lower Permian and Carboniferous lithologies.

6 REFERENCES

Bowen E.A. (1984) `Magnetic and gravity in the search for hydrocarbons in the Papuan Basin, Papua New Guinea' ASEG 2nd. Australian Petroleum Symposium, Melbourne.

Crist R.P. and Hobday M. (1973) `Diapiric features of the offshore Bonaparte Gulf Basin, northwest Australian shelf' Bull. Aust. Soc. Explor. Geophys. Vol-4 p43-66

Edgerly D.W. and Crist R.P. (1974) `Salt and Diapiric Anomalies in the Southeast Bonaparte Gulf Basin' The APEA Journal 1974 p85-94

Gunn P.J. (1988) `Bonaparte Rift Basin: Effects of Axial Doming and Crustal Spreading' ASEG Bicentenary Publication (in Press)

Laws R.A and Kraus G.P. (1974) `The Regional Geology of the Bonaparte Gulf, Timor Sea area' The APEA Journal, 1974, p77-84.

Laws R.A. and Brown R.S. (1976) `Bonaparte Gulf Basin southeastern part' Economic geology of Australia and Papua New Guinea, Vol 3 Petroleum, AIMM Monograph 7, p200-208.

Lee R.J. and Gunn P.J. (1988) `The Bonaparte Basin' Petroleum 1988, APEA Bicentenary Publication, (in press)

Morgan C.M. (1972) `1:250,000 Geological Sheet-Explanatory Notes PORT KEATS, Northern Territory'

Nabighian M.N. (1972) `The analytic signal of two dimensional magnetic bodies with polygonal cross-section: its properties and use for automated anomaly interpretation' Geophysics Vol. 37 pp 507-517

Pontifex I.R. & Sweet I.P. (1972) `1:250,000 Geological Sheet-Explanatory Notes AUVERGNE, Northern Territory'

Sweet I.P. (1977) `The Precambrian Geology of the Victoria River Region, Northern Territory' B.M.R. Bulletin 168

Veevers J.J. & Roberts J. (1968) `Upper Palaeozoic Rocks, Bonaparte Gulf Basin of Northwestern Australia' B.M.R. Bulletin 97.

Veevers J.J. (1984) `Phanerozoic earth history of Australia' Clarendon Press.

Werner S. (1955) `Interpretation of magnetic anomalies as sheet like bodies' Sveriges Geologiska Undersokning, Ser. C.C. Arsbok 43,N:06.

APPENDIX 1

DESCRIPTION OF THE WERNER DECONVOLUTION TECHNIQUE

The Werner deconvolution theory (Werner (1955) and Ku and Sharp (1983)), estimates the depth to magnetic sources. The method assumes two models, the first of which is based upon an infinite depth and strike extent dyke or thin sheet. The second model assumes an infinite strike and depth extent contact or interface. The contact solution is calculated by processing the first horizontal derivative of the total field data.

The dyke solution uses an eleven point operator which determines a polynomial solution to the total field data. The coefficients of the polynomial can then be related to the depth, dip and magnetisation of the magnetic source. These solutions are subjected to specified tolerances and those outside the range are rejected. As well as solving the equations for a single source, an interference factor has been added to allow for adjoining or deeper sources. The eleven point operator is moved along the data at a distance equal to the depth determination interval. The procedure is then repeated. Over an anomaly, which fits inside the operator width, a number of similar solutions will be obtained. The deeper anomalies, with a wavelength longer than the operator width, will not give an acceptable solution. To process these anomalies the data is upward continued and the operator width doubled. By repeating the upward continuation a number of times, anomalies of all wavelengths are processed.

The output of the Werner calculation is a plotted section (Figure A1-1), which shows the raw data and the upward continued profiles. Depth estimates for a dyke or thin sheet model are plotted beneath the base line. Where solutions cluster, these are accepted. The examples (Figures A1-1 & A1-2) are in black and white, however the depth plots are plotted in colour, with each colour representing a different upward continuation level. This is important as it allows the interpreter to select the width of the operator which best matches the half width of the anomaly. The interpretation process is repeated for the contact model, and the first horizontal derivative of the total field data is analysed. The contact or interface solutions are plotted in a similar manner (Figure A1-2).

Before the depth estimates are transferred to a base map it is necessary to prepare a preliminary structural interpretation of the magnetic data. This is used to assist in determining whether the dyke or contact solution is the more applicable. The structural map is used to identify the strike of the source and any strike corrections necessary. After these have been applied, the flying height is subtracted, for all depths are relative to ground surface. A body with a finite strike has the depth estimate adjusted accordingly. From these corrected depth estimates, a depth to magnetic basement is prepared.

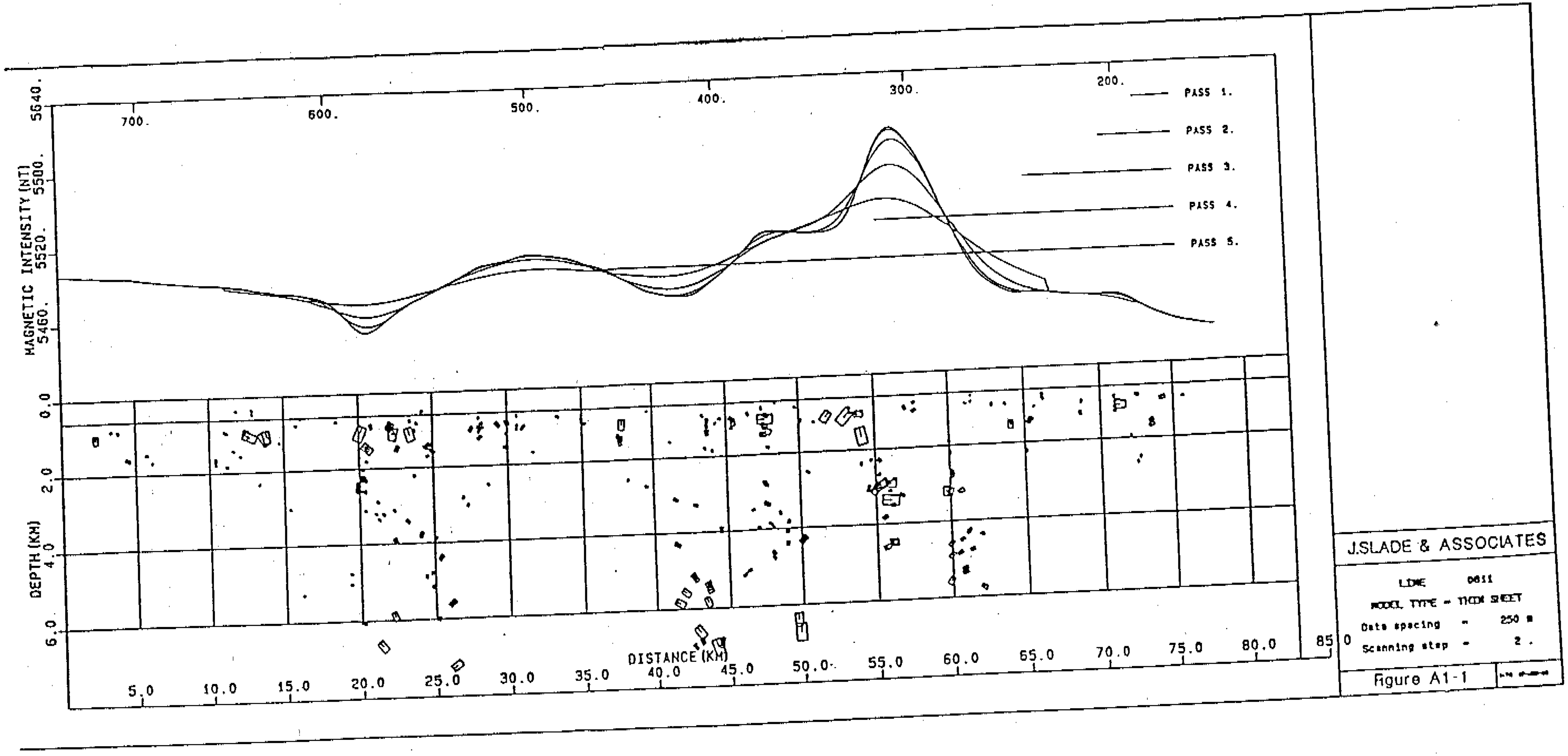

MAGNETIC INTENSITY (NT)
5640.
5580.
5520.
5460.
700.
600.
500.
400.
300.
200.
PASS 1.
PASS 2.
PASS 3.
PASS 4.
PASS 5.
DEPTH (KM)
0.0
2.0
4.0
6.0
DISTANCE (KM)
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
J.SLADE & ASSOCIATES
LINE 0811
MODEL TYPE - THICK SHEET
Data spacing - 250 m
Scanning step - 2.

Figure A1-1

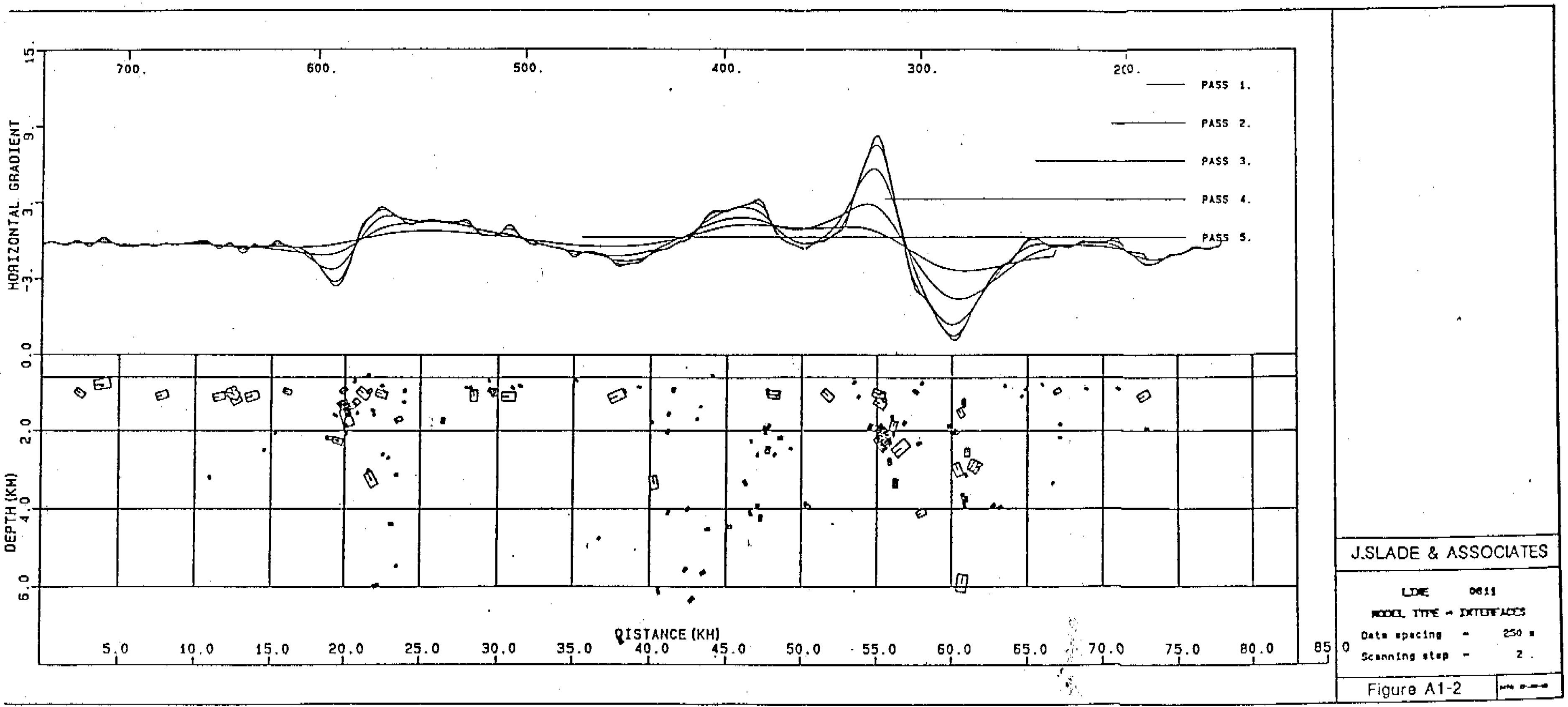

HORIZONTAL GRADIENT
15.
9.
3.
-3.
0.0
700.
600.
500.
400.
300.
2(0.
PASS 1.
PASS 2.
PASS 3.
PASS 4.
PASS 5.
DEPTH (KM)
0.0
2.0
4.0
6.0
DISTANCE (KM)
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
J.SLADE & ASSOCIATES
LINE 0611
MODEL TYPE = INTERFACES
Data spacing = 250 m
Scanning step = 2.

Figure A1-2

ANNEXURE A APPENDIX 2

A. SPECIFICATIONS FOR AIRBORNE GEOPHYSICAL SURVEY

1. SURVEY AREAS

The survey area lies within and around Exploration Permit 3 in the Northern Territory. It is centred near the mouth of the Victoria River about 150 km NE of Kununurra in Western Australia.

The purpose of the survey is to determine the general basin configuration, structure and fault patterns prior to the planning of a marine seismic survey. The survey area is to the west of the areas of Precambrian outcrop, but lines will extend 5 - 10 km over this outcrop and also beyond the western boundary of the E.P. to provide measurements of magnetic background to aid the interpretation of the data.

This quotation is based on a total survey distance of 7000 line km at a minimum line spacing of 500m. The line spacing will be varied throughout the survey area depending on the expected depth of magnetic basement. Besides compilation of the data, interpretation of the depth to magnetic basement and the structure of the area will also be carried out.

2. FLYING SPECIFICATIONS.

Flight line direction	: 130 - 310 degrees True
Flight line spacing	: 500 metres minimum
Tie line direction	: 040 - 220 degrees True
Tie line spacing	: 4000 metres minimum
Sensor mean sensor elevation	: 100 metres ASL where the terrain is less than 40 m ASL, rising to 300 metres ASL where the terrain is more than 40 m ASL
Time base for magnetics	: 0.125 seconds
Sample interval for magnetics (in still air)	: 10 metres or less

Kevron will endeavour to maintain the specified terrain clearance wherever possible, but in areas of steep terrain, the decision of the pilot in regard to a safe flying height will be final.

Sections of lines where the terrain clearance exceeds 1.20 times the nominated elevation continuously over 5 km or more will be reflown at Kevron's expense. The reflown sections will cross tie lines at their extremities.

3. MAGNETIC READINGS

Readings of the total magnetic field intensity will be recorded to a resolution of 0.01 nT at the time base specified above. Kevron will endeavour to obtain a noise envelope not to exceed +/-0.1 nT and the client may reserve the right to reject all data with a noise envelope greater than +/- 0.1 nT for a continuous distance of greater than one (1) kilometre or for more than 10% of the flight line. All rejected data will be reflown at Kevron's expense, and these reflight lines will cross tie lines at their extremities.

4. NAVIGATION.

Navigation will be by electronic techniques using three or more shore based beacons located on points with accurately known AMG coordinates. The position of the aircraft will be recorded digitally every 10 seconds or less to a sensitivity of one (1) metre.

This navigation will be supplemented by a Doppler navigation system, the data from which will be recorded on magnetic tape to an accuracy of 10m every 1.0 second.

If the flight line separation exceeds 1.5 times the nominated line spacing over a distance of five kilometres or more, or lines cross, infill lines which cross tie lines at their extremities will be flown at Kevron's expense.

5. FLIGHT PATH RECOVERY

The flight path position of the aircraft will be recorded digitally from the electronic navigation equipment.

6. DIURNAL MONITOR

The base station magnetometer will be positioned as close as practical to the survey area and record to a sensitivity of 0.1 nT every ten seconds or less. No data will be accepted within five (5) minutes of those periods when magnetic non-linear variations greater than 5 nT occur in less than 5 minutes.

At the discretion of Kevron, supplementary base stations recording at less frequent intervals may be positioned in the general area.

7. TIMING AND DURATION

Weather and diurnal activity permitting, the flying of the geophysical survey should be completed in eight (8) days once the aircraft has mobilized to the area. Surveying could commence in late April or early May, 1987.

ANNEXURE B

B. AIRCRAFT AND INSTRUMENTATION

1. AIRCRAFT

Piper PA-31 Chieftan, registration VH-WJK

2. SURVEY INSTRUMENTATION

2.1 MAGNETOMETER SENSOR AND COUPLER

A Cesium Vapour, optically pumped and monitored magnetometer sensor, model No. V-201, manufactured by Scintrex Pty Ltd.

The sensor has a capability of recording very high gradients of up to 10,000 nT/metre, and measures to a sensitivity of 0.01 nT.

2.2 AUTOMATIC AEROMAGNETIC DIGITAL COMPENSATOR (AADC).

The AADC is a system which accepts the Larmor frequency signal from the magnetic sensor and produces, as output, magnetically compensated total field data.

The AADC compensates the total field data for the effects of the aircraft's motion and heading on the data by computing 19 interference coefficients from the data collected in the compensation flight which is carried out before the survey commences.

The AADC will supply data for digital recording to a resolution 0.01 nT and a practical resolution of 0.05 nT for analogue recording at a sampling rate of eight (8) times per second.

2.3 RECORDING ALTIMETER

A Sperry AA-210 Radar Altimeter or similar type system, being a high resolution, short pulse radio altitude system, designed for automatic continuous operation over a wide variation of terrain, target reflectivity, weather and aircraft altitude will be used to record the aircraft's terrain clearance. The radar altimeter indicator provides an absolute altitude display from 0 to 750 metres (0-2,500 feet).

2.4 DATA ACQUISITION SYSTEM

A Geometrics model G-714 geophysical data formatting/recording unit will be used to output data onto a 9 track magnetic tape for subsequent computer processing. The unit includes dual memories, two micro-processors and a tape controller. Both raw and formatted digital data are recorded in IBM compatible format onto magnetic tape at 800 BPI NRZI specifications.

2.5 TRACKING CAMERA

The aircraft's position will be recorded by a colour Video Tracking System (VHS-PAL) with wide angle lens and all necessary recovery monitoring equipment.

2.6 MAGNETIC AND RADIOMETRIC ANALOGUE RECORDER

A Printer Plotter Model RMS-33 is used to record the following in analogue form:

Radar Altimeter
Fiducial marks (correlated to those on the video film)
Aircraft generator output values

2.7 BASE STATION MAGNETOMETER

A Geometrics Base Station Magnetometer Model G-856 with digital recording will be used as a diurnal monitor and run continuously during the survey periods. The sensor of the magnetometer will be placed in a low gradient area beyond the region of expected influence of any man made interference.

No survey data will be accepted if the base station noise level exceeds 1.0 nT for more than 5 (five) minutes or when the base station has ceased to operate.

2.8 NAVIGATION SYSTEM

The primary navigation system will be a Maxiran II electronic system for which three or more beacon transponders are placed outside the survey area at points with accurately known coordinates. The range of the aircraft to each of these beacons is measured electronically to a sensitivity of one (1) metre, and the position of the aircraft is calculated in AMG or geographical coordinates. The ranges and the coordinates are recorded digitally.

At the same time, steering indication information with respect to pre-planned survey lines is displayed to the pilot to enable him to steer the aircraft along the lines accurately.

A Doppler navigation system is also carried in the aircraft. This comprises:

(i) Singer-Kearfott K510A009-01 lightweight Doppler Navigation System;
(ii) Sperry gyro-stabilised Compass;
iii) Navigation Computer.

This equipment can be used to provide along track and across track steering information as an aid to the pilot, and to provide co-ordinate information both for reference by the pilot and navigator and for recording by the digital acquisition system to a sensitivity of 10m. For this survey, its role is secondary to that of the Maxiran equipment.

ANNEXURE C

C. SYSTEM CALIBRATION AND CHECKS

1. HEADING ERRORS

The aircraft heading errors on reciprocal headings will be corrected by using the AADC, to less than +/- 1.0 nT prior to acquiring survey data and checked every 4 weeks or after aircraft maintenance.

The effects of aircraft maneouvres will also be compensated for by the AADC and corrected to +/- 0.5 nT prior to acquiring survey data.

2. PARALLAX CHECKS

Parallax effects in the data recording system will be checked and measured by flying over a sharp magnetic response on reciprocal headings.

ANNEXURE C

C. SYSTEM CALIBRATION AND CHECKS

1. HEADING ERRORS

The aircraft heading errors on reciprocal headings will be corrected by using the AADC, to less than +/- 1.0 nT prior to acquiring survey data and checked every 4 weeks or after aircraft maintenance.

The effects of aircraft maneouvres will also be compensated for by the AADC and corrected to +/- 0.5 nT prior to acquiring survey data.

2. PARALLAX CHECKS

Parallax effects in the data recording system will be checked and measured by flying over a sharp magnetic response on reciprocal headings.

ANNEXURE D

D. DATA PRESENTATION AND DELIVERABLE ITEMS

1. GENERAL DATA PROCESSING AND PRESENTATION

Compilation of data will involve the production of flight path maps, stacked profiles or multiplots of total magnetic intensity and contours of total magnetic intensity at a scale of 1:50 000, the production of digital data tapes as described below and the interpretation of the data to produce depth to magnetic basement and structure maps. Final maps and plans will be on a stable mylar base transparency.

Single noise spikes (if any) will be removed manually from the data base.

If the base station magnetometer can be placed close to the survey area, diurnal correction will be applied to the magnetic data by subtracting the base station magnetometer readings and then adding back the average base station value for the survey.

The IGRF (1985) will be removed from the data and a constant which is the value of the IGRF in the centre of the area will be added back to the data such that the magnitude of the corrected values of the magnetic field are similar to the raw values.

Tie line levelling will be applied to the magnetic data.

The mesh size of the grid used for the compilation of the contours will be 200m or as determined by consultation with the client. The grid will be parallel to the nominal traverse line direction.

The layout and orientation of each map sheet area, the sheet borders, title blocks, legends and other information thereon will be determined in consultation with the client.

1.1 FLIGHT PATH PLOTS

The flight path plots will show:

Longitude and latitude labelled at five (5) minute increments.

AMG co-ordinates labelled with their northings and eastings along two orthogonal borders at 10000 m increments.

The electronically recovered fiducials joined by a line on which the position of every twentieth (20) fiducial will be marked and every hundredth (100) fiducial numbered.

The flight lines numbered at both ends and labelled with the start or end fiducial number.

1.2 STACKED MAGNETIC PROFILES

The stacked magnetic profiles will show:

Longitude and latitude.

The line number at both ends of flight line.

For each profile the location of the base level which is the line joining the ends of the flight lines on each sheet.

On each sheet the ends of the profiles joined to the ends of the corresponding flight line as plotted on the flight path map by a line normal to the base level.

Profiles plotted at a constant vertical scale such that each magnetic value is related to its corresponding fiducial by a line normal to the base level.

A constant base level for the stacked profiles will be determined separately for each sheet based on the average level over the sheet.

The magnetic profiles will be plotted without flyback or scale change except as agreed in areas of extreme relief.

For each pair of stacked magnetic profile and flight path sheets, the corners of the sheet area will align exactly when the sheet borders are aligned.

1.3 MAGNETIC CONTOUR MAPS

The magnetic contour maps of the Total Magnetic Intensity will show:

Longitude and latitude;

Isomagnetic contours of residual magnetic intensity which have the IGFR magnetic field removed and the data levelled;

The mesh size of the grid will be 200 m or more.

The contour interval will be determined in consultation with the client after preliminary maps have been compiled.

1.4 INTERPRETATION AIDS

To assist in the interpretation of the depth to magnetic basement, automatic interpretation computer routines will be run on the data to produce Werner or Nabighian profiles which then can be used to interpret the depth to basement more efficiently than using the total field data.

1.5 MULTIPLOT PROFILES (if requested)

Multiplot profiles of corrected data and derived data will be plotted at a horizontal scale of 1:100 000. The plotted parameters may include:

Altimeter

Magnetics	fine scale
Magnetics	coarse scale
Magnetics	high pass filtered
Magnetics	horizontal derivative
Magnetics	band pass filtered

1.6 INTERPRETATION

The data acquired by the survey will be interpreted to produce a depth to magnetic basement map and a structure map. An accompanying report will also be produced.

The data interpretation shall not extend beyond twenty (20) days without the authorization of the client.

2. DELIVERABLE ITEMS

2.1 ANALOGUE DATA

All analogue data which has been collected during this project will be folded and annotated with the date, flight number, line number and chart scales.

2.2 FINAL MAPS AND INTERPRETATION REPORT

All final maps and the interpretation report will be supplied to the client as outlined in the Presentation of Data.

2.3 FIELD TAPES

All digital field tapes and/or compacted field tapes will be supplied to the client if requested.

2.4 FLIGHT LOGS

A legible set of flight logs will be delivered with the data at the end of the project.

2.5 LOCATED DATA TAPE

A located data tape will include all field data corrected and merged with locations in AMG co-ordinates and organised in line number order. It will also contain the uncorrected magnetic data as recorded in the field at each data point, and the diurnal magnetic correction (if any) which was applied to the magnetic data.

The tape format will conform to the S.A. Dept. of Mines and Energy specifications or, at additional cost, the ASEG-GDF specifications.

2.6 GRIDDED DATA TAPE (if requested)

Gridded data generated during the production of the magnetic contours will be recorded on tape in a format agreed upon by the client and Kevron.

2.7 SURVEY DATA SUMMARY

From the located data tape, a data summary will be produced for each line. This will include:

- line number
- flight number
- date
- line direction
- start and end time
- first and last fiducial
- number of readings

and for each of the data channels

- channel name
- mean reading
- maximum reading
- minimum reading
- standard deviation

2.10 LOGISTICS REPORT

A logistics report will be submitted at the completion of this contract, accurately specifying the actual parameters and techniques utilised on the survey.

2.11 WEEKLY REPORTS

A written weekly report will be submitted outlining the flying progress, the compilation's progress and the computer processing.

2.12 OTHER

All other material supplied by the client or acquired by Kevron in relation to this survey will be supplied to the client.

2.13 DELIVERY OF MAPS

The preliminary flight path and magnetic contour maps will be delivered no later than three (3) weeks after the completion of data acquisition.

Preliminaries of all these maps on paper will be submitted to the client for approval before final maps are drawn. Finals are expected to be available two (2) weeks after the approval of the preliminaries has been indicated by the client. Such approval is to be confirmed in writing.

The delivery of all other items pertaining to the survey, apart from its interpretation, will be made no later than two months after the completion of the survey.

The delivery of the interpretation maps and report will be made as soon as possible within sixty (60) days of the production of the interpretation aids described above.