Data Science Pty. Limited
Orb House 97 Wollongong St.
Post Office Box 484
Fyshwick ACT 2609 Australia
Telephone (062) 80 4770

INTERPRETATION of CURTIN SPRINGS AEROMAGNETIC SURVEY OP214 N.T.

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by

Bruce W. WYATT
DATA SCIENCE PTY. LIMITED

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Top Left : Oblique aerial view looking north over Curtin Springs homestead.

Top Right : Oblique aerial view looking south from Curtin Springs towards Mt Conner.

Bottom : Shrike Commander survey aircraft at Ayers Roack.

Abstract

An airborne magnetic survey was flown over an area of approximately 1600 square kilometres in the northeast of the Ayers Rock 1:250 000 Sheet area. The survey areas is a north-south strip in the western part of Block OP 214.

The survey has defined many magnetic anomalies, most of which have been interpreted and used to produce maps showing the structure of a significant unit at the top of the Bitter Springs Formation. This unit has been folded into a series of synclines and anticlines with axes which strike from north-south in the southwest of the area, through northeast, to west-northwest in most of the centre and north of the area. The axes are broadly concentric about Mount Conner in the south, and elsewhere are west-northwest parallel to the main Amadeus Basin structural trends and margins.

Tertiary and Quaternary sediments appear to be less than one hundred metres thick over the entire survey area.

The depth to the top of the Bitter Springs Formation varies from near surface down to at least 1700 metres near the central part of the area, and deeper in the southeast and north. The area in the centre may contain structural traps and more prospective Palaeozoic sediments.

Several structural traps have been indicated. Some of these could be better defined by more detailed seismic work. Seismic work should however only be considered in areas where the magnetic interpretation indicates sources due to deeper anticlines and domes, which may reflect structural traps higher in the sequence.

Several smaller circular structures may be related to diapirs. A shallow drilling program could test these at relatively minor cost and provide stratigraphic information in an area with no outcrop but with considerable magnetic detail.

Further work is required to establish the source rock potential in the area (particularly of the Precambrian sequence), to determine the extent and thickness of Palaeozoic rocks in the central part of the area, and to establish the eastward limit of the interpreted sub-basin.

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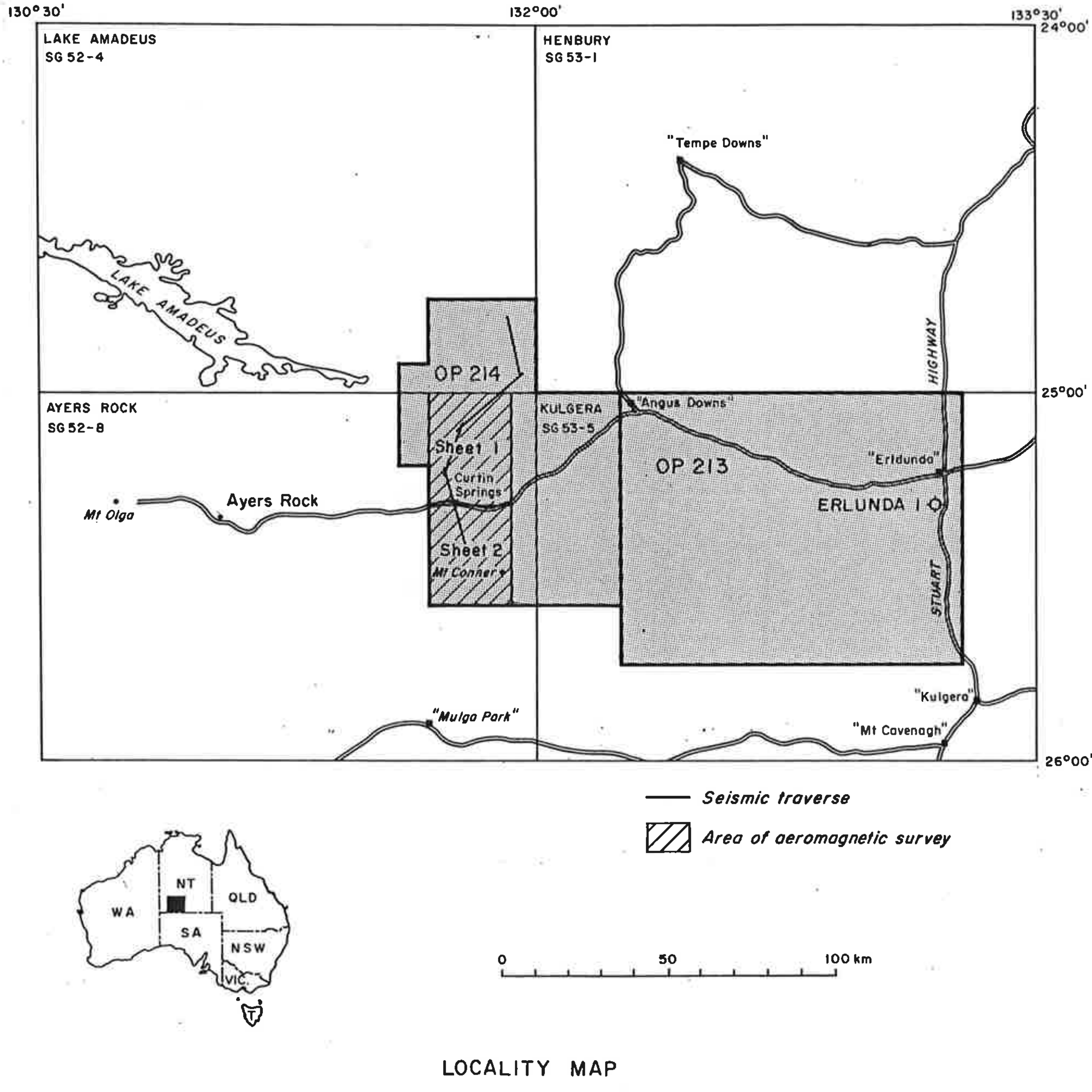
INTRODUCTION	CHAPTER 1

An airborne magnetic survey was flown over an area of approximately 1600 square kilometres in the northeast of the Ayers Rock 1:250 000 Sheet area. The survey area is a north-south strip in the western part of Block OP 214. Block 213 (8361 sq. km) lies in KULGERA 1:250 000 sheet area. Block 214 (4300 sq. km) is part of LAKE AMADEUS, AYERS ROCK, and KULGERA sheets (plate 1).

The survey was planned to provide information regarding subsurface structure. In particular it was designed to define anomalies related to a volcanic unit occuring at the top of the Bitter Springs Formation. This volcanic unit was found, from drilling by BMR, to be the source of a magnetic anomaly further west. The current survey area was positioned over several similar magnetic anomalies detected by the BMR regional aeromagnetic survey (see plate 3, Young and Shelley, 1977). It was designed to provide the necessary resolution to outline structural features within the volcanic unit.

The stratigraphic position of these beds is important as they occur at the top of the Bitter Springs Formation which has a decollement surface at its base. Irregularities in the thickness of the Bitter Springs Formation are reflected in the overlying younger sediments as anticlinal structures and sometimes as diapers, both with associated hydrocarbon potential.

Plate I



LOCALITY MAP

GEOLOGY (after Wells and others, 1970)	CHAPTER 2

2.1 Physiography

The area is mostly arid desert with extensive areas of salt lakes and sand ridges. Most of the area is about five hundred metres above sea level. Mount Conner, in the southeast of the survey area, is 863 metres above sea level. In the north of the area, strike ridges are up to a few tens of metres above plain level. The Ayers Rock road traverses the area from east to west.

2.2 The Amadeus Basin

The geology of the Amadeus Basin is described by Wells and others (1970) and in the Explanatory Notes accompanying the BMR 1:250 000 geological map series.

The Amadeus Basin contains Adelaidean, Cambrian, Ordovician, Silurian?, Devonian, and Carboniferous? sediments resting unconformably upon predominantly crystalline Precambrian basement rocks. The basement is made up of all rocks older than the Adelaidean Heavitree Quartzite.

About 9000 metres of sedimentary rocks are preserved. The only known volcanics interbedded with the sediments occur in the northeast and southwest in dolomite, siltstone, and evaporite sequences.

Extensive overthrusting and folding of basement and cover uplifted the southwestern margin during the Petermann Ranges Orogeny late in the Precambrian or early in the Cambrian.

Possible petroleum source rocks include carbonate and shale in the Adelaidean and Cambrian sequences, and shale in the Ordovician sequence. The Ordovician sandstone beds are proven reservoirs. Cambrian sandstone is a potential reservoir. One gas and oil field (Mereenie) and one gas field (Palm Valley) have been discovered in the Amadeus Basin. The main producing formation in both these fields is the Cambro-Ordovician Pacoota Sandstone, with smaller gas production from the Ordovician Stairway Sandstone and Ordovician Horn Valley Siltstone in the Palm Valley Anticline.

2.3 Stratigraphy

The formations and units which crop out in the survey area, or are inferred to occur in the subsurface, are described briefly below and summarised in Table 1. Some of the units of the Cambro-Ordovician Larapinta Group are thin or possibly non-existent in the survey area but are included because of their importance as known source and reservoir rocks further north. More complete descriptions of individual units and their lateral extent and thickness are given in Forman (1965) and Wells and others (1970).

2.3.1 Older Precambrian

Basement is presumably composed of igneous and metamorphic rocks of the Musgrave-Mann complex. This complex crops out further south and includes gneisses, schists, amphibolites, migmatites, and granites.

2.3.2 Proterozoic Heavitree Quartzite (Dean Quartzite)

This formation does not crop out in the survey area but is inferred to unconformably overlie the older Precambrian basement. It consists predominantly of white slabby silicified quartz sandstone, with minor conglomeritic sandstone, siltstone, and conglomerate.

Table 1 : STRATIGRAPHY

Age	Name	Symbol	Minumum Thickness (metres)	Lithology, Comments
Quaternary		Q		Alluvial, gypsum, evaporites, sand, and travertine
Tertiary		T		Limestone, conglomerate, laterite, sandstone and siltstone
~~ UNCONFORMITY ~~~~				
Devonian-Carboniferous	Finke Group	Pzf	??	
	Pertnjara Group	Pzf	??	Siltstone
Silurian?-Devonian	Mereenie Sandstone	Pzm	30?	Silty sandstone and sandstone
Cambrian-Ordovician	Larapinta Group:	€-Ol	330	
	(Carmichael Sandstone	Oc	)	
	(Stokes Siltstone	Ot	100)	
	(Stairway Sandstone	Os	(30))	
	(Horn Valley Siltstone	Oh	)	Source rock, with oolitic ironstone near the top
	(		)	
	(		)	
	(Pacoota Sandstone	€-Op	)	
Cambrian	Pertaoorrta Group	€p	?	Sandstone
~~ UNCONFORMITY ~~~~				
Proterozoic	Winnall Beds	Puw	400?	Sandstone, siltstone, and minor conglomerate
~~ UNCONFORMITY ~~~~				
Proterozoic	Inindia Beds	Pun	1000-2300	Siltstone, chert, sandstone, and some dolomite
---- DISCONFORMITY ----				
Proterozoic	Bitter Springs Formation	Pub		Basalt at top over dolomite and evaporites
Proterozoic	Heavitree Quartzite,	Puh	330?-360?	
	Dean Quartzite	Pud		Quartzite
~~ UNCONFORMITY ~~~~				
Precambrian				Gneiss, schist, amphibolite, migmatite, and granite

2.3.3 Proterozoic Bitter Springs Formation

This thick sequence of calcareous and arenaceous rocks conformably overlies the Heavitree Quartzite. The formation consists of interbedded crystalline dolomitic limestone, dolomite, and limestone, dololutite, dolarenite, calcarenite, shale, siltstone, gypsiferous siltstone, and sandstone. It is commonly intensely folded, brecciated, and faulted. The incompetent nature of this formation has resulted in the formation of decollement surfaces and complex folding and thrusting of the overlying sediments. Evaporites within the Bitter Springs Formation are associated with diapiric intrusions over much of the Amadeus Basin.

2.3.4 Proterozoic Inindia Beds

The Inindia Beds are present in subcrop over much of the survey area. They disconformably or unconformably overlie the Bitter Springs Formation and are unconformably overlain by the Winnall Beds in the southeast at Mount Conner, and by the Pertaoorrta and Larapinta Groups elsewhere in the area. The Inindia Beds include siltstone, chert, and sandstone beds with some dolomites.

2.3.5 Proterozoic Winnall Beds

The Winnall beds comprise four units - a basal siltstone, followed by sandstone, siltstone, and sandstone. The resistant sandstone beds form the mesa of Mount Conner (see frontispiece) and other prominent topographic features in the southern part of the Basin.

2.3.6 Cambrian Pertaoorrta Group

The southern limit of the Pertaoorrta Group occurs near the northeastern corner of the survey area where rocks from this Group unconformably overlie Winnall Beds and are faulted against Ordovician Carmichael Sandstone. The Group is mainly sand with some shale and siltstone at this locality.

2.3.7 Cambrian-Ordovician Larapinta Group

The Larapinta Group includes five formations :
the Pacoota Sandstone (at the base),
the Horn Valley Siltstone,
the Stairway Sandstone,
the Stokes Siltstone, and
the Carmichael Sandstone.

The Group is conformable or unconformable with both the Pertaoorrta Group below and with the Mereenie Sandstone above. In the survey area, the Pacoota Sandstone, Horn Valley Siltstone, and lower part of the Stairway Sandstone are apparently absent, and the Group has a total thickness in the order of three hundred metres.

The Pacoota Sandstone, Horn Valley Siltstone, and Stairway Sandstone are the main producing formations for the Mereenie and Palm Valley Fields.

The Pacoota Sandstone is predominantly quartzose sandstone with some siltstone interbeds and with thin ferruginous beds at the top and base in some areas.

The Horn Valley Siltstone comprises siltstone, claystone, limestone, and minor sandstone. A thin but distinctive band of oolitic ironstone near the top of the unit extends over thousands of square miles. The upper unit of the Stairway Sandstone is an arenite sequence about thirty metres thick in the survey area.

The Stokes Siltstone is up to one hundred metres thick in the survey area and consists of a sequence of grey and green siltstone and claystone with minor limestone and sandstone interbeds.

The Carmichael Sandstone is a sequence of predominantly brown cross bedded sandstone and silty sandstone, with siltstone and claystone interbeds.

2.3.8 Siluro(?)-Devonian Mereenie Sandstone

The Mereenie Sandstone consists of cross-bedded, fine grained sandstone. Maximum thickness in the northern part of the survey area is about thirty metres.

2.3.9 Devonian-Carboniferous(?) Finke and Pertnjara Groups

Thin outliers of continental siltstone, sandstone, and conglomerate of the Finke and Pertnjara Groups may be present (in the subsurface) within synclines in the northern and possibly central parts of the survey area.

2.3.10 Tertiary

Thin Tertiary deposits in the area include limestone, conglomerate, laterite, sandstone, and siltstone.

2.3.11 Quaternary

Quaternary alluvial, sand, evaporites, travertine, and gypsum cover most of the surface of the survey area.

2.4 Structure

The sediments of the Amadeus Basin are strongly folded, with major unconformities between the late Proterozoic and Cambrian, and between the Devonian-Carboniferous(?) and Permian sediments.

2.4.1 Petermann Ranges Orogeny

The late Proterozoic folds are often close or tight canoe shaped structures with flat plunges. Many of these folds were formed during northward tectonic transport over a decollement surface within the Bitter Springs Formation.

2.4.2 Alice Springs Orogeny

The Carboniferous(?) folds are regular and up to 240 kilometres long. The synclines are generally more gentle and open than the anticlines which are commonly crumpled, faulted, and thrusted. Many of the anticlines have cores of isoclinally folded Bitter Springs Formation while some have brecciated gypsum and blocks of carbonate.

2.4.3 Diapirism

The thick beds of evaporites within the Bitter Springs Formation form diapirs in quite a few areas, particularly within the cores of anticlines.

2.4.4 Curtin Springs Area

In the survey area, outcrop mapping and photo-geological interpretation has defined the surface structure around Mount Conner in the southeast, where the Winnall and Inindia Basin form a local basin, and also in the north where a sequence of east-west folds contain Proterozoic Inindia Beds in the anticlinoria and Palaezoic sediments within the synclinoria. The limbs of the folds have shallow to steep dips and in places are overturned.

PREVIOUS GEOPHYSICAL SURVEYS	CHAPTER 3

3.1 Magnetic

The results from two previous airborne geophysical surveys are available.

The Charlotte Waters Aeromagnetic Survey was flown by Aero Service Limited for Exoil (NSW) Pty Limited in 1963 (Exoil, 1966). The survey was flown at 915 metres above mean sea level along north-south traverses spaced 3.2 kilometres apart. The lines were flown in bands of three lines, with 6.4 kilometres between adjacent bands. Results are presented as total magnetic intensity contours and interpreted basement depths.

The Amadeus Basin airborne magnetic and radiometric survey was flown by BMR in 1965. The survey was flown at 240 metres above ground level along east-west lines 3.2 kilometres (South of 25 30') and 6.4 kilometres apart. Results are presented as north-south and east-west profiles, total magnetic intensity contours, and basement depth contours (Young and Shelley, 1966, 1977).

The magnetic interpretations indicate maximum basement depths to almost 6000 metres below sea level. In Block 214, smaller wavelength magnetic anomalies were presumed to be due to dyke swarms or volcanics within the sediments. These anomalies are not properly resolved by the coarse flight lines.

Basement features produce magnetic trends to 40, 90, 110, and 140 degrees. Basement depths interpreted by Aero Service (Exoil, 1963) are generally about 30 percent shallower than those interpreted by BMR (Young and Shelley, 1977).

One of the short wavelength aeromagnetic anomalies to the west of the survey area was investigated by BMR with ground magnetic traverses and drilling in 1981. The strike of the anomaly was irregular with an interpreted dip of forty degrees, width of forty metres, and magnetic susceptibility of .0045 cgs units. The two drill holes intersected dipping volcanics at about ninety to one hundred metres below the surface. The volcanics were underlain by interbedded grey shale and evaporite. (D. Stuart, BMR, personal communication). The inference that the magnetic sources correspond to volcanics near the top of the Bitter Springs Formation, and the existence of similar sources in adjacent parts of the Amadeus Basin provided the rationale for the current low level survey to assist structural mapping of the sedimentary sequence.

3.2 Seismic

A comparison of seismic (Exoil,1966) and magnetic results from the KULGERA Sheet to the east, highlights the different but complimentary nature of the methods. The deepest reflector, interpreted as being near the top of the Bitter Springs Formation, varies from about 1000 to 3000 metres below the surface. The depth to magnetic basement is generally about 4000 metres below the surface, the difference being attributed to the combined thicknesses of Bitter Springs Formation and Heavitree Quartzite. The seismic line along the eastern boundary of OP214 indicates three half troughs separated by thrusts. The thrusts trend approximately west northwest with the southern block being thrust over the trough in each case.

Seismic reflection profiles were shot for Weeks Australia Limited in 1982. One of these traversed the aeromagnetic survey area, approximately north-south along an existing track. The information derived from the profiles was minimal, due possibly to the presence of the shallow layer of volcanics near the top of the Bitter Springs Formation or to the lack of section. An area between two and five kilometres north of the Curtin Springs homestead shows a reflector at a depth of between about 800 and 350 metres, shallowing to the north.

3.3 Gravity

The area has been covered by BMR helicopter-borne gravity surveys in 1961 (Langron, 1962) and in 1962 (Lonsdale and Flavelle, 1963).

The gravity data show east-west gradients. The regional low corresponding to the Amadeus basin contains a smaller gravity ridge which extends across the northern part of the survey area. This possibly corresponds to a basement high, or hinge line seperating areas of greater Proterozoic sediment development to the south from the main Palaeozoic Basin to the north.

3.4 Radiometric

Airborne radiometric data show a general correlation between radiometric highs and sediments of the Larapinta and Pertaoorrta Groups. A correlation also exists between the radiometric highs and anticlinal axes, though this may be partly due to associated topographic effects.

3.5 Geochemistry

Northeast of the survey area, some anticlinal structures have also been broadly outlined by gas geochemical surveys aimed at detecting gas seeps. These anomalous areas follow anticlinal crests east-west then west-northwest into the Walker and Mereenie anticlines.

3.6 Drilling

No drilling has been undertaken in the survey area. One BMR stratigraphic well was drilled in the Lake Amadeus 1: 250 000 sheet area, just northeast of the survey area.

AEROMAGNETIC SURVEY SPECIFICATIONS	CHAPTER 4

The airborne magnetic survey was flown from Ayers Rock between the seventh and thirteenth of February, 1982. The data was acquired by Geoterrex Limited and processed by Exploration Computer Services Pty Limited.

The survey covered 1600 square kilometres and comprised sixty five north-south lines each sixty five kilometres long, and twenty three east-west ties each twenty six kilometres long (total 4800 line kilometres). Lines and ties were four hundred metres and three kilometres apart respectively (plates 2 and 3).

The data were acquired using a Rockwell Shrike Commander, VH-PWO, flying at an average ground clearance of eighty metres everywhere except around Mount Conner. The aircraft was equipped with an alkali vapour magnetometer recording to 0.04 nanoteslas every 0.2 seconds, a radio altimeter, a strip camera, and a digital data acquisition system. Visual navigation and flight path recovery utilised RC9 airphotographs enlarged to 1: 25 000 scale.

Data are presented as pairs of 1: 50 000 maps for flight path (plates 2 and 3) magnetic profiles (plates 4 and 5), and magnetic contours (plates 6 and 7). The interpretation of these maps is described in the following section and illustrated in plates 8 to 11.

The magnetic profiles have been levelled using tie lines, corrected for the earth's regional field (IGRF, 1975), and are presented at a scale of twenty nanateslas per centimetre. The magnetic data have been interpolated onto a one hundred metre square grid before machine contouring at two nanoteslas interval.

MAGNETIC INTERPRETATION	CHAPTER 5

5.1 Methodology

The data have been interpreted both quantitatively and qualitatively to obtain maximum information regarding geology and structure in the area (plates 8 to 11).

Depths to most anomaly sources have been determined using various graphical methods, including those described by Peters (1949) and Vacquier and others (1951), and computer modelling techniques (McGrath and Hood, 1970 ; Talwani and Heirtzler, 1964; Grant and West, 1965) where applicable.

The upper surfaces of dipping magnetic sources are delineated, along with the edges of some sub-horizontal sheets. In many cases a direction of dip has also been determined.

Quite a few linear magnetic discontinuities have been delineated by the colinear termination and occurence of anomalies, and by abrupt changes in interpreted source depths. Many of these are assumed to correspond with normal or transcurrent faults, shear zones, thrust planes, and anticlinal axes (plates 8 and 9).

The interpreted dip directions, along with symmetric or asymmetric source distributions, have been utilised to infer the positions of several anticlinal crests and, to a lesser extent, synclines.

The inferred fold axes, interpreted source depths, and interpreted faults have been combined to produce a composite interpretation defining the shape of a magnetic volcanic surface at the top of the Bitter Springs Formation (plates 10 and 11).

5.2 Magnetic Sources (plates 8 and 9)

5.2.1 Volcanics

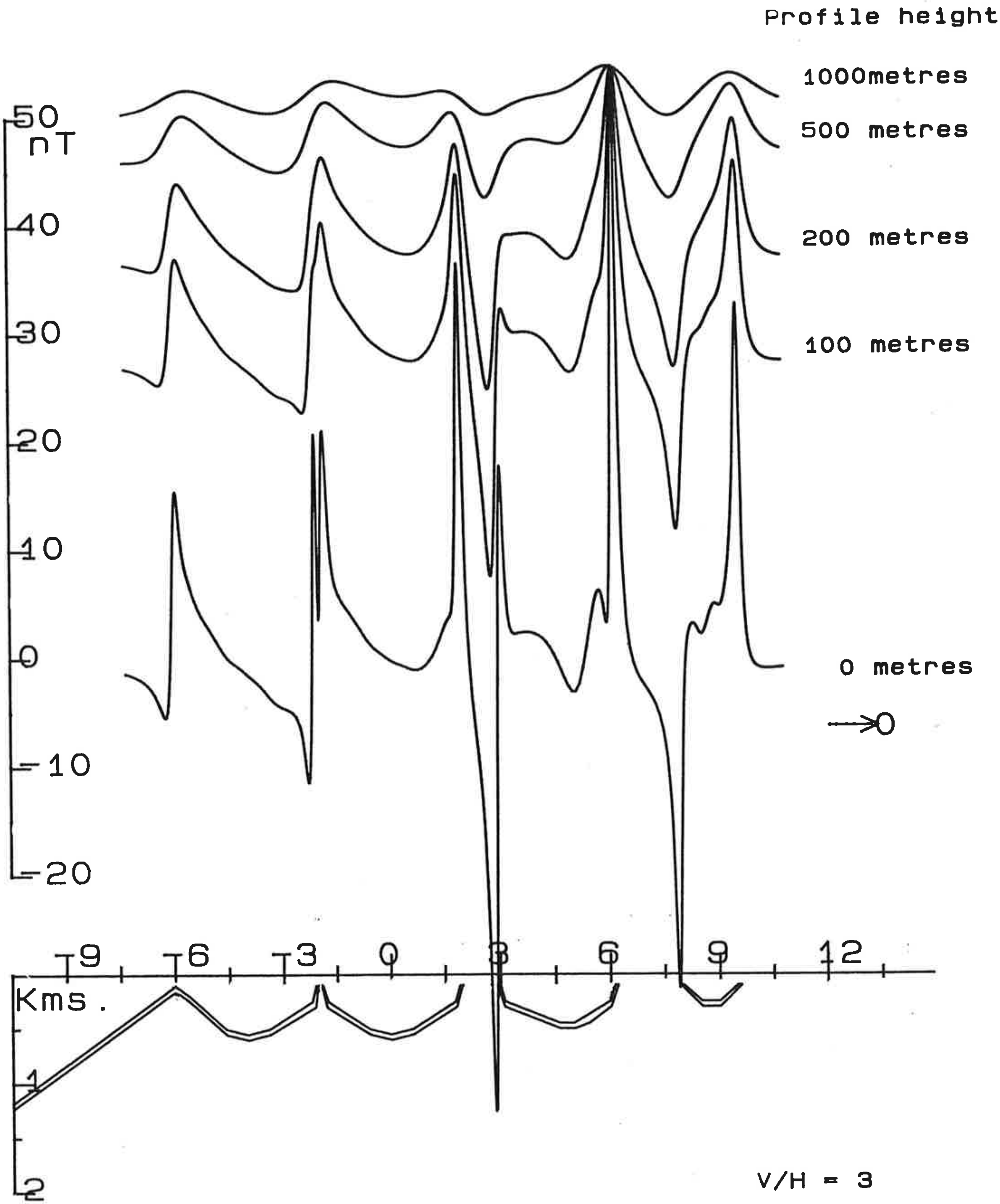
The major magnetic source is interpreted to be a layer of basic volcanics near the top of the Bitter Springs Formation. This unit is presumably the source of all anomalies with amplitudes between a few tens and a few hundreds of nanoteslas, and also some of the smaller ones. These anomalies generally occur within broad complex zones (e.g. L on plate 10), or as broader single anomalies (e.g. H on plate 10).

In most cases the complex zones can be resolved into a series of overlapping anomalies due to discrete parallel sources. The directions of dip can be ascertained from the anomaly shapes. Most of the complex areas are interpreted as representing the crests of complexly folded anticlinal structures with westerly trending fold axes. Interpreted depths over these areas imply they are generally shallow (less than one hundred metres below the surface). The anomaly source traces indicate that most have been truncated at an unconformity surface, presumably at the base of the Tertiary and Quaternary sediments.

The interpreted anticlinal structures could quite conceivably be correlated with the thrust zones indicated on the seismic lines further east. The trend directions and separation between features is similar in both cases. While the magnetic data generally indicate dips away from the complex zones, the possibility of extensive thrusting is not ruled out. Indeed the existence of multiple sources within the zones suggests repetition of the volcanic unit by short wavelength folding or thrusting.

Broad magnetic highs occur in many of the otherwise undisturbed areas. These anomalies have amplitudes of up to thirty nanoteslas and spectra indicating sources at depths of 200 metres to 1700 metres. A few of these anomalies partly bifurcate into two symmetric anomalies (e.g. J on plate 10, P on plate 11). These broad anomalies are elongated between west and west-northwest, and it is likely that they also represent anticlines within the Bitter Springs Formation with deeper crests which have not been truncated at the unconformity surface.

If this interpretation model is correct, then these broad magnetic highs provide a direct method for delineating closed anticlines and domes in the Bitter Springs Formation,



Magnetic profiles over folded and eroded magnetic sheet and possibly also in overlying younger sediments.

In the southwest of the survey area, the trend directions are ambiguous (e.g. W on plate 11), but the most important one is thought to be concentric around Mount Conner.

Modelling studies for the volcanics have assumed thickness of fifty metres, susceptibility of .0045 cgs units, field inclination of -58 degrees, and various source geometries. At shallow depths an anticline will produce a smaller amplitude anomaly than a dipping sheet of similar thickness. However at depths greater than about a hundred metres this is reversed.

Maximum modelled anomaly amplitudes are as follows :

Depth from sensor (m)	10	100	200	400	600	1200	2000
Dipping sheet (nT)	250	50	20	7	3	1	0.5
Anticline (nT)	100	50	30	15	6	4	2

Plate 12 shows computed anomaly profiles over a folded and truncated sheet model, at various detector heights. Greater anomaly amplitude and increased resolution are features of the profiles computed at lower heights.

5.2.2 Discrete sources

Many magnetic anomalies appear to be due to discrete magnetic sources with no strike extent, as opposed to the more common linear anomalies due to interbedded sheetlike sources. The amplitudes of these range up to several hundred nanoteslas, and strongly suggest a common source with those due to the volcanics. No other magnetic sources have been described in the region. Some can be explained as being due to preferential thickening in the crests of folds. Others reflect linear sources that strike almost parallel to the north-south flight lines (e.g T on plate 11), and produce anomalies which cannot be adequately interpolated by the contouring program.

These discrete anomalies could also be the result of intrusive plugs which were feeders for the volcanics discussed in the previous section, or remnants of the keels of synclines preserved below an unconformity surface. One possible example of the latter is at 25 35' S, 131 43' E (Y on plate 11).

Another less likely possibility is that some of the discrete anomalies may represent blocks of the volcanic unit which have been detached and transported upwards by diapirs from the evaporites at lower levels in the Bitter Springs Formation.

5.2.3 Low amplitude anomaly sources

Short wavelength anomalies with amplitudes between one and twenty nanoteslas occur in reasonably well defined areas or as linear features over much of the survey area. These anomalies are more apparent on the stacked profiles (plates 4 and 5) than on the contour presentations. In the north of the area, many of these anomalies correspond with outcrop of Larapinta Group (e.g. A and C on plate 10). The source of the anomalies is presumably an oolitic haematite similar to that within the Horn Valley Siltstone. This unit varies in thickness up to about 1.3 metres on the LAKE AMADEUS sheet (D.Forman, BMR personal communication).

Modelling studies for the ironstone have assumed thickness of two metres, susceptibility of .0005 cgs units, field inclination of -58 degrees, and dipping sheet geometry.

Maximum modelled anomaly amplitudes are as follows :

Depth below sensor (m)	10	100	200	400	600
Dipping sheet (nT)	8	1	0.4	0.2	0.1

The Horn Valley Siltstone is the main source rock for hydrocarbons further north in the Amadeus Basin. The association with this magnetic marker bed raises the possibility of being able to map this unit further north under limited thickness of younger sediments.

Similar anomalies occur in fairly well defined areas throughout the survey area, generally in otherwise magnetically flat areas inferred to represent synclines or sub-basins in the Bitter Springs Formation (e.g. D on plate 10). Inspection of these areas has implied the existence of several younger synforms (e.g. N on plate 11), and in one case a possible truncated diapiric structure (Q on plate 11).

The sub-basin centred on Mount Conner contains at least two concentric low amplitude anomalies in an area where

Inindia Beds crop out. The anomalies occur within a radius of seven to ten kilometres from the summit of the mountain.

Several anomalies of about ten nanoteslas amplitude occur a few kilometres west, southwest, and south-southeast from Mount Conner (U on plate 11). These anomalies appear to indicate smaller near-surface structures superimposed on the main sub-basin centred on Mount Conner.

Very low amplitude (up to three nanotesla) linear anomalies are present in the central northern part of the survey area (e.g. F on plate 10). These are interpreted to represent faults. The anomaly could be the result of a small vertical step within one of the reasonably smooth magnetic units described above, or it could be due to formation of laterite within the fault plane.

If the sources of these low amplitude magnetic anomalies are stratigraphic horizons within the pre-Devonian sediments, then limits can be placed on the combined thickness of Tertiary and Quaternary sediments. Alternatively these anomalies may be related to surface weathering of the Cainozoic rocks. This explanation is not favoured because of the linear nature of many of the sources.

5.2.4 Long wavelength anomalies

A strong regional gradient (three hundred nanoteslas in sixty kilometres) is due presumably to magnetic sources within the older Precambrian basement, or representing a shallowing of the Curie isotherm to the north.

The broad circular anomaly, centred on Mount Conner and extending over most of the southern map sheet, may be explained by a pole source at a depth of about 7000 metres. This figure is slightly greater than depths interpreted from the BMR regional survey. An alternative interpretation using a disc-like model would indicate a much shallower source.

5.3 Linear Features (plates 8 and 9)

These have been inferred from the colinear termination of anomalies, from a colinear series of discrete or linear anomalies, or from abrupt changes in interpreted source depths. They are generally assumed to represent faults or unconformity surfaces.

The most obvious linear features are shown on plates 8 and 9. Many others appear to be present but have not been delineated because they are too ambiguous to display without confusing the overall picture.

Interpreted linear features show several preferred directions:

West-northwest to east-southeast (parallel to fold axes).
These features are common in the area, particularly in the interpreted anticlines, as indicated by the repetition of magnetic sources.

Northeast-southwest.
Several features have been interpreted in this direction. The most important are those which are interpreted to have formed a graben like structure through the centre of the survey area (G and M on plate 10). In the area around 25 06' S, 131 45' E (F on plate 10), linear features are defined by small but very persistent anomalies interpreted as faults (see section 5.2.3).

North-south.
Parallel features appear to have offset several of the main anticlines in the area.

East-west.
Rock outcrop and several magnetic anomalies are terminated at about 25 34' S latitude, suggesting a possible major fault at this position.

Northwest-southeast.
A few persistent discontinuities cross most of the survey area. The most obvious ones are shown on plates 8 and 9. Other related ones are parallel to these.

5.4 Folding (plates 10 and 11)

Most folding has occured about an east-west axis. Other directions include concentric folding around Mount Conner, and possible north-south folding in the southwest of the area.

Most of the fold axes interpreted as affecting the volcanics in the Bitter Springs Formation can be incorporated into a realistic surface. One area however appears to reflect a shallow synform at a higher stratigraphic level than expected. This area, around 25 21' S, 131 48' E (R on plate 11), has several possible interpretations. It may be part of an overthrust or ramp originating within the anticline immediately to the south. This interpretation may seem unnecessarily complex, but is consistent with the tectonic style and sense in other parts of the basin. An alternative interpretation is that the apparent syncline is actually an anticline with bulbous core and inward dipping limbs.

Results in the southwest of the survey area are ambiguous. There are numerous anomalies of widely varying amplitudes, but with small strike lengths (e.g. S on plate 11). Plate 9 shows some well defined trends but also indicates alternative possibilities with strike sub-parallel to the flight lines. One plausible explanation for this area is that the volcanic surface is generally within a few hundred metres of the surface and has been deformed by folding about two seperate directions to form an "egg-crate" pattern. Erosion of this surface would leave both remnant lows and local highs in the magnetic surface. The two interfering fold patterns would appear to be the concentric folding around Mount Conner, and the west-northwest axes common throughout most of the Amadeus Basin.

5.5 Interpreted Structure (plates 10 and 11)

Plates 10 and 11 show the interpreted depth below ground level to the upper surface of the Bitter Springs Formation. These plates are based on the interpreted anomaly source depths, interpreted fold axes, interpreted faults, and mapped geology. This surface is most significant as the structures within it also affect all overlying strata, whereas surfaces below the Bitter Springs Formation are of little significance because of the decollement surfaces within the Bitter Springs Formation.

Control is better where the unit is shallower (anticlinal crests and thrust zones), and poorer in those areas where the mapped unit is deeper. The depths obtained from the interpretation of these broad anomalies may be too great if they are due to gentle folds (by analogy with magnetic spheres or shells of differing radii). Because a downwarped surface produces a much less significant anomaly than a local high, the interpreted depths and resultant surface will be biased towards the crests of anticlines. Deeper troughs may well exist between and adjacent to the highs but they cannot be recognised from the magnetic data.

While the shallow anticlines are obvious potential hydrocarbon targets, they are also more likely to have been breached. Therefore more promising targets are considered to exist as subtle structures within the areas where the marker unit occurs at greater depth. Of these the most promising would appear to be the broad zone in the south-east of plate 11. In this zone the broader sources are thought to be due to deeper anticlines and domes, which may reflect structural traps higher in the sequence.

Several local structures have been interpreted from circular, sub-circular, or elongated source distributions, and from interpreted dip directions. Interpreted dome structures occur at 25 20' S, 131 48' E and at 25 23' S, 131 44.5 E (Q and E10 on plate 11). Small synclines have been interpreted at 25 18.5' S, 131 43.5' E, at 25 31' S, 131 50.5' E, at 25 32' S, 131 41' E, at 25 32' S, 131 43' E, at 25 34' S, 131 43' E (N, U, V, W, and Y on plate 11), and at other locations (see plates 8 to 11). Quite a few other local structures probably occur in the southwest of the survey area but cannot be resolved for the reasons given in the section on folding.

CONCLUSIONS	CHAPTER 6

The magnetic survey has defined many magnetic anomalies, most of which have been interpreted and used to produce maps showing the structure of a significant unit at the top of the Bitter Springs Formation.

This unit has been folded into a series of synclines and anticlines with axes which vary from north-south in the southwest of the area, through northeast, to west-northwest in most of the centre and north of the area. The axes are broadly concentric about Mount Conner in the south, and elsewhere are west-northwest parallel to the main Amadeus Basin structural trends and margins.

Tertiary and Quaternary sediments appear to be less than one hundred metres thick over the entire survey area.

The depth to the top of the Bitter Springs Formation varies down to at least 1700 metres near the central part of the area and deeper in the southeast and north. The area in the centre may contain structural traps and more prospective Palaeozoic sediments.

Further work is required to establish the source rock potential in the area (particularly of the Precambrian sequence), to determine the extent and thickness of Palaeozoic rocks in the central part of the area, and to establish the eastward limit of the interpreted sub-basin.

Several structural traps have been indicated. Some of these could be better defined by more detailed seismic work. Seismic work should however only be considered in areas where the magnetic interpretation indicates sources due to deeper anticlines and domes, which may reflect structural traps higher in the sequence.

The failure of the previous seismic work to adequately define structure in this area is linked to the presence of the volcanic unit. Magnetic surveying could assist greatly in defining those areas where seismic work is unlikely to produce good data, and also areas where further seismic work is warranted.

Several smaller circular structures may be related to diapirs. A shallow drilling program could test these at relatively minor cost and provide stratigraphic information in an area with no outcrop but with considerable magnetic detail.

Modelling studies based on the magnetic data obtained from this survey suggest that the volcanic unit will produce anomalies in the order of one to five nanoteslas at a depth of two thousand metres, below the measurement plane, provided the unit has sufficient relief produced by folding or faulting. The oolitic ironstone bed (or beds) present in the Palaeozoic sequence can be expected to produce anomalies with amplitudes of about one nanotesla from depths in the order of one hundred metres below the sensor. This current survey, at eighty metres above ground level, has indicated that noise levels due to surface accumulations of magnetic material are generally less than one nanotesla in amplitude, and are not spatially coherent.

The magnetic method can be expected to provide information on discontinuities within the ironstone to a depth of only a few tens of metres, and within the volcanics at the top of the Bitter Springs Formation to depths of two or three thousand metres.

It is recommended that future work be carried out in this area to:

provide stratigraphic control in the central and southwestern parts of the survey area,

directly test shallow targets by drilling,

provide additional control to confirm the interpretation presented in this report.

RECOMMENDATIONS — CHAPTER 7

The following specific recommendations are listed in order of priority, with some being dependent on the successful completion of earlier ones.

A shallow drilling program is recommended to:

directly test the small structures interpreted as possible diapirs,

directly test discrete anomalies, which may also be related to diapirs or magnetic intrusives,

provide samples for source rock geochemical studies,

determine thickness of various stratigraphic units. The areas of highest priority are those where accumulations of Palaeozoic sediments may be present, in particular, the lower formations of the Larapinta Group.

Suggested target areas for drilling are:

Symbol	Plate	South latitude	East longitude	Interpreted Target
E1	10	25 12.5'	131 52.0'	Anticline
E2	10	25 12.9'	131 49.1'	Anticline
E3	10	25 13.4'	131 46.5'	Anticline
E4	10	25 14.8'	131 45.6'	Anticline
E5	10	25 14.9'	131 50.9'	Anticline
E6	10	25 15.3'	131 43.6'	Anticline
E7	10	25 16.5'	131 47.7'	Anticline
E8	11	25 19.0'	131 49.5'	Anticline
E9	11	25 20.0'	131 48.0'	Dome
E10	11	25 23.0'	131 44.3'	Dome
E11	11	25 23.2'	131 41.7'	Intrusive
E12	11	25 29.0'	131 43.0'	Dome

If the recommended drilling program produces promising results in the sub-basin in the central east of the area, then north-south seismic profiling is recommended to better define structural traps within this area.

Further detailed magnetic surveying in areas to the north and east is recommended to define sub-basins for further seismic profiling, and also to define areas where seismic profiling is unlikely to produce useful information because of near surface volcanics.

In the remainder of Block 214 and in Block 213, magnetic surveying should be used for the direct interpretation of structure, as has been in this area, and also as an aid to define broad areas where seismic work is or is not justified.

REFERENCES	CHAPTER 8

Exoil (N.S.W) Pty. Limited, 1966., - Charlotte Waters Aeromagnetic survey. PSSA Subsidy Report 62/1701 (unpublished report on a Commonwealth subsidised operation).

Exoil (N.S.W) Pty. Limited, 1966., - Kulgera Seismic survey. PSSA Subsidy Report 64/4595 (unpublished report on a Commonwealth subsidised operation).

Grant, F.S. and West ,G.F., 1965, - Interpretation theory in applied geophysics. McGraw Hill, New York, 584 pages.

Langron, W.J. 1962., - Amadeus Basin reconnaissance gravity survey using helicopters, Northern Territory, 1961. Bureau of Mineral Resources Australia Record 1962/24 (unpublished).

Lonsdale, G.F., and Flavell, A.J., 1963., - Amadeus and South Canning Basins reconnaissance gravity survey using helicopters, Northern Territory, and Western Australia, 1962. Bureau of Mineral Resources Australia Record 1963/152 (unpublished).

Mathur, S.P., 1976.,- Relation of Bouguer Anomalies to crustal structure in central and southwestern Australia. Bureau of Mineral Resources Journal of Australian Geology and Geophysics, 1, 277-286.

McGrath, P.H. and Hood, P.J., 1970, - The dipping dyke case - a computer curve-matching method for magnetic interpretation. Geophysics, 35 (5), 831-848.

Peters, L.J., 1949, - The direct approach to magnetic interpretation and its practical application. Geophysics, 14 (3),290-320

Talwani, M., and Heirtzler, J., 1964 - Computation of magnetic anomalies caused by two-dimensional structures of arbitrary shape. in Computers in the mining industries, Part I: Stanford University, Publications Geology Society, 9 (1), 464-480.

Vacquier, V., Steenland, N.C., Henderson, R.E., and Zietz, I., 1961, - Interpretation of aeromagnetic maps. Geological Society of America Memoir 47.

Wells, A.T., Forman, D.J., Ranford, L.C., & Cook, P.J., 1970 - Geology of the Amadeus Basin, Central Australia. Bureau of Mineral Resources Australia Bulletin 100.

Young, G.A., and Shelley, E.P., 1966 - Amadeus Basin airborne magnetic and radiometric survey, Northern Territory, 1965. Bureau of Mineral Resources Australia Record 1966/230 (unpublished).

Young, G.A., and Shelley, E.P., 1977, - Amadeus Basin airborne magnetic and radiometric survey, Northern Territory, 1965. Bureau of Mineral Resources Australia Report 187.