DEPARTMENT OF MINES AND ENERGY
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AN INTERPRETATION OF MAGNETIC AND GRAVITY DATA IN THE MUSGRAVE BLOCK IN SOUTH AUSTRALIA

GEOLOGICAL SURVEY

By

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DEPARTMENT OF MINES AND ENERGY
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ABSTRACT

The Musgrave Block is a large area of Precambrian crystalline basement situated in the northwest corner of South Australia and extending into Western Australia and the Northern Territory. Geological mapping has revealed large areas of granulite and amphibolite facies metamorphic rocks. These are intruded by basic to ultrabasic layered norites and gabbros, younger granites, and dolerite dykes.

Structurally, the area is dominated by major east-west to northeasterly trending faults and thrust zones which controlled the initial uplift of the exposed deep seated metamorphic rocks. Later reactivation of the Mann Fault and other related structures produced two Adelaidean graben structures. Regional gravity and aeromagnetic data have been obtained over most of the Musgrave Block, while some more detailed geophysical exploration programmes have been undertaken in specific localities.

Interpretation of the regional magnetic data has defined five main features, viz. large zones of complex magnetic relief; discrete source anomalies; linear anomalies; dislocations; and outcropping granite.

The regional gravity data indicate that the Musgrave Block lies within a gravity ridge of continental significance. Gravity maxima apparently coincide with areas of maximum metamorphic grade and these are equated to areas of maximum tectonic uplift.

The region shows overall compatibility with base metal sulphide mineralization and several host environments are specified. The area has considerable potential for detailed exploration for economic mineralization.

1. INTRODUCTION

The Musgrave Block is defined (Thomson, 1976) as a Precambrian crystalline basement feature located in the northwest of South Australia and adjacent areas of Western Australia and the Northern Territory. The Block is elongated east-west (approximately 750 km long and 270 km from north to south) but its limits are in many cases not known precisely. The Musgrave Block is bounded to the north by younger Precambrian sediments of the Amadeus Basin, to the east by the Great Artesian Basin and to the south and west by the Officer Basin. The sub-parallel Arunta Block to the north appears to be tectonically related.

Specific regions within the Musgrave Block (e.g. Giles Complex) have been studied in great detail by various workers and there are numerous publications relating to many aspects of the geology of this area. Regional geological mapping at 1:250 000 scale has been completed over most of the South Australian portion but many questions remain to be answered. Poor exposure over much of the central and southern portions has hindered geological mapping and even in areas of good exposure interpretation is often unresolved.

Regional gravity and aeromagnetic surveys now cover most of the Musgrave Block, particularly in South Australia, although data density is variable and sometimes inadequate. This report is an attempt at a regional interpretation of these data, with detailed geophysical work in some areas incorporated in the interpretation. Where possible, reference has been made to published geological maps and some detailed geological work, published and unpublished. However, many features remain unexplained and interpretation can only be speculative.

Most of the available aeromagnetic data have been presented as contours on base maps at a scale of 1:250 000 or 1:63 360 and geological mapping is usually available at one or both of these scales. Accordingly the text of this report makes frequent reference to locations by the name of 1:250 000 or 1:63 360 map sheet areas. Names in block type (e.g. WOODROFFE) refer to 1:250 000 sheet areas, names underlined (e.g. <u>Permano</u>)

refer to 1:63 360 areas. Locations of these map sheet areas are illustrated in Fig. 1 (1:250 000) and Fig. 2 (1:63 360).

2. GEOLOGICAL NOTES

The following summary of the geology of the Musgrave Block in South Australia is an attempt to sort and classify the rocks of the area into simple groupings with emphasis on geophysical characteristics wherever possible. The data used have been derived from available mapping and explanatory notes on six 1:250 000 map sheets (MANN, WOODROFFE, ALBERGA, BIRKSGATE, LINDSAY and EVERARD) supplemented by discussion with people who have worked in the area and several more recent papers and publications (e.g. Thomson 1975; Thomson et al., 1976).

As a first step, the rocks of the Musgrave Block are divided into six main groups.

2.1 Musgrave-Mann Metamorphics (dated 1600-1700 m.y.)

This term is generally used to describe the widespread zone of metamorphic rocks which are the oldest in the area. These include granulite facies and transitional granulite-amphibolite facies variants; they are well layered, of variable composition and are considered to be metasediments including iron formations, carbonate rocks and probably some basic sills or flows.

The Musgrave-Mann metamorphics extend across the entire Musgrave Block from the Blackstone Ranges in WA to Mount Howe on the eastern margin, in SA. The principle areas of Musgrave-Mann Metamorphics are on MANN and WOODROFFE, the western part of ALBERGA (Ernabella area) and the northwest corner of EVERARD. They have been intruded by younger granites, the basic rocks of the Giles Complex and numerous dolerite or microgabbro dykes. The metamorphics have also been extensively distorted and sheared by a system of major faults (e.g. the Mann

Fault) and thrust zones (e.g. the Woodroffe Thrust).

Because of the extremely variable composition of the metamorphics, their magnetic character is difficult to predict. Certainly they may be expected to have some magnetic expression but it is also likely to be quite variable. A significant grain or texture might be anticipated due to the well developed layering. However, it may not always be detectable at the scale of regional magnetic surveys and would also be disrupted by the numerous faults and intrusions of younger rocks.

2.2 Wataru Gneiss and equivalents

These rocks mainly occur south and west of the Musgrave-Mann metamorphics. They are generally described as amphibolite facies biotite-hornblende granitic gneisses. Their age relative to Musgrave-Mann Metamorphics is unknown; they could be the same but of lower grade and partly metasomatised, more prone to granitisation. They may be equivalent to migmatites in WA and are possibly equivalent to the Olia Gneiss in NT (and north of the Woodroffe Thrust on WOODROFFE).

These rocks are found mainly on BIRKSGATE and LINDSAY. They are of lower metamorphic grade than the Musgrave-Mann Metamorphics with foliations generally oriented north to north-east. An outline of the zones of lower metamorphic grade is included in a study of the area by Forman and Shaw (1973).

Magnetic properties are again likely to be variable (perhaps less so than for the granulites) with a defined grain or texture which may be highly deformed or distorted by faulting and intrusions.

2.3 Giles Complex

Mafic and ultramafic intrusives of the Giles Complex mainly extend across the northern part of the Musgrave Block in an east-west zone associated with the major fracture system, e.g.

Mann Fault. Rock types include norites, gabbros, anorthosites, etc. in layered masses of variable sizes and shapes. Some of these masses are overturned (Nesbitt and Talbot, 1966). The masses are generally considered to be roughly equidimensional discrete blocks rather than the surface expression of pipes extending to great depths.

Rocks of this composition would be expected to have a high density and a marked magnetic expression. Although a significant density contrast has been demonstrated by extensive gravity work in the northwest corner of MANN (Steele, 1966; Rowan, 1967), no major magnetic anomalies have been observed in their vicinity. Measurements by Steele gave a range of 3.0 - 3.2 g/cm^3 for the specific gravity based on fourteen samples from Mount Davies and ten samples from Gosses Pile. A study of the magnetic properties of these rocks demonstrated significant remanent magnetisation tending to oppose the present earth's magnetic field (Facer, 1969). The age of the Giles Complex rocks is not certain (Nesbitt et al., 1970). It may be approximately 1100 m.y. The Complex may have approximately the same age as the Kulgeran Granites, however, the observed remanent magnetisation would suggest at least a different age of final cooling.

2.4 Kulgeran granite (1100 - 1140 m.y.)

The widespread granites and adamellites present in the area are all considered to be the same age, although of somewhat variable composition, and are collectively known as the Kulgeran granites (Thomson, pers. comm.).

This term includes the hypersthene granites and adamellites (charnockites) identified on WOODROFFE and ALBERGA, and widespread coarse grained, porphyritic, hornblende, biotite, granite (often with accessory allanite) and leucogranites and lucoadamellites noted on LINDSAY. The granites often occur as roughly equidimensional masses of varying size or as elongate zones parallel to faults or structural lineaments. On Eateringinna is an extensive group of microgranite dykes which trend west-northwest. In the same general area on ALBERGA are several circular masses of granite 3-5 km in diameter.

Many and perhaps all of the Kulgeran granites are considered to have formed by anatexis of the older metamorphics. Magnetite is a common accessory mineral (up to 10%) in most of the granites and it has been suggested that it may have developed during anatexis from either biotite or pyroxenes (Conor in prep. and pers. comm.). In any case the Kulgeran granites commonly contain several per cent magnetite and are associated with major magnetic anomalies.

Since the formation of anatectic granite has been gradational, and has occurred at various levels within the crust (i.e. charnockites at deeper levels and biotite adamellites at high levels), one might expect magnetic properties of the resulting granitoids to be variable and somewhat unpredictable.

There is some evidence to suggest that the formation of granites and adamellites has been fault controlled (at least on Kenmore and Eateringinna). This has resulted in both micro-granite dykes and broad zones of granites parallel to major faults (e.g. Ferdinand Fault), (Conor pers. comm.).

2.5 Dolerite Dykes

Dolerite or microgabbro (and micronorite) dykes are present throughout the Musgrave Block in various concentrations and attitudes. The main strike orientation seems to be northwest with apparently a secondary group striking northeast and many local variations. The dykes are of variable width (in excess of 100 m in some cases) and most have steep or vertical dips (Kreig, 1973).

These dykes might be expected to be magnetic, probably with significant remanent magnetisation, but their dimensions may be too small for detection by regional airborne surveys.

2.6 Cover rocks

This term includes the Levenger Arkose and the Moorilyanna Conglomerate, both thought to be Late Precambrian or possibly Cambrian.

These rocks consist of conglomerates, arkosic grits, etc. deposited in fault bounded depressions, within the crystalline rocks. The Levenger Arkose or Levenger Formation occupies the Levenger Graben on WOODROFFE and the Moorilyanna Conglomerate occupies a similar structure, the Moorilyanna Graben, on ALBERGA. Neither of these formations have any significant magnetic expression but their position may be marked by absence of magnetic relief.

2.7 Structure

The northern part of the Musgrave Block in S.A., close to the Northern Territory border, is dominated by a series of major east-west faults and thrust zones (e.g. the Mann Fault and Woodroffe Thrust). Further east, these structures trend more northeasterly (e.g. Ferdinand Fault). It is generally accepted that the deepseated metamorphic and other rocks now exposed in the Mann Ranges and Musgrave Ranges were thrust upwards and northwards along the Woodroffe Thrust Zone and associated fault structures during the Musgravian Orogenic Cycle (Thomson, 1969). These faults may have been reactivated many times.

Later movements (Late Precambrian) of the Mann Fault and other related faults produced the Levenger and Moorilyanna Grabens.

The southern margin of the Musgrave Block is generally less exposed and not as well understood as the northern margin.

There is evidence that on EVERARD the Everard Ranges (Ill-billies Adamellite of the Kulgeran Granites) have been thrust southwards over younger sediments of the Officer Basin. The age of this overthrust is thought to be at least post-Ordovician (Milton and Parker, 1973).

3. HISTORICAL NOTES

During the period 1950-1975, various geophysical surveys were carried out in the vicinity of the Musgrave Block in SA, NT and WA. These were primarily airborne magnetic surveys (sometimes accompanied by radiometrics) ranging from preliminary reconnaissance on irregular lines to detailed low-level surveys on regular grids. Regional gravity surveys now cover all of Australia on a coarse grid and detailed surveys have been conducted in selected areas on the Musgrave Block. Other miscell-aneous methods have been utilized in exploration by SADME and companies.

This chapter summarizes some details of previous surveys in the area. Since most of the work was carried out prior to metric conversion, imperial units were used and have been retained in this description.

3.1 Airborne Magnetics

Initially, during the 1950's, the Bureau of Mineral Resources (BMR) flew various reconnaissance surveys on irregular lines which were the forerunners of later systematic surveys over most of Australia. The various sedimentary basins surrounding the Musgrave Block; Amadeus Basin; Officer Basin; etc. were later covered by oil companies and the BMR with broadly spaced surveys to assist petroleum exploration, and the WA portion of the Officer Basin was surveyed on contract to the BMR during 1976, 1977. Each of these surveys extended onto the fringes of the Musgrave Block and the recent survey in WA covered a significant portion of shallow basement area which is virtually all of the WA portion of the Musgrave Block. In addition, the major part of the Musgrave Block in SA was covered by semi-detailed BMR surveys in 1967 and 1969 and this included some extensions into NT. A summary of these aeromagnetic surveys is included below and the areas covered are illustrated in Fig. 3. No other airborne surveys in the area are known to the author and it seems unlikely that any extensive work of this type would be unreported.

1954 (Ref. BMR Record 1958/87)

At the request of Frome-Broken Hill Company Pty. Ltd., the BMR carried out a reconnaissance survey of parts of the Eucla Basin and beyond. The survey consisted of an irregular pattern of lines, some of which crossed portions of the Musgrave Block. It was flown in a DC3 (VH BUR) at an altitude of 1500 ft. above ground level and navigation was by dead reckoning. Results were recorded on analogue charts.

The survey results were used to estimate approximate depths to magnetic basement in four broad ranges (0-500 ft. below surface, 500-2000 ft. below surface, approximately 2000 ft. below surface and greater than 2000 ft. below the surface). These depth estimates then permitted a rough outline of areas where a significant thickness of sediments could be anticipated and secondly of shallow basement areas, including the Musgrave Block.

1957

Additional, similar survey flights were made in the same aircraft (VH BUR) at the same altitude (1500 ft.). These flights extended from Kalgoorlie to Alice Springs via Blackstone Range and the Tomkinson Ranges and included several short flights in the Mount Davies area of the Tomkinson Ranges. Results were similar to those obtained in 1954 and were summarized briefly in BMR Record 1961/137.

1960 (Ref. BMR Record 1961/137)

Additional, similar lines were flown in the vicinity of Giles, WA and on long traverses from Alice Springs to Giles and Giles to Kalgoorlie. These flights were made in a DC3 aircraft (VH MIN) fitted with a fluxgate magnetometer, again at an altitude of 1500 ft. Navigation was by visual observation and dead reckoning and data were recorded on an analogue chart recorder.

The results of these flights were compiled together with those from 1954 and 1957 surveys and used to update the previous map of depth to basement. These surveys confirmed the existence of a significant area of shallow basement rocks in the northwest of SA and extending into NT and WA and a crude attempt to outline the margins of the Musgrave Block was possible.

1960 (Ref. BMR Record 1962/98)

The BMR conducted an airborne magnetic and radiometric reconnaissance survey of MANN from a base at Giles in WA. The survey was carried out in a DC3 aircraft (VH MIN) on north-south lines at 5 mile intervals with two east-west tie lines. Survey altitude was 500 ft. above ground level with visual navigation along predetermined flight lines.

Instrumentation consisted of an MFS-4 fluxgate magnetometer recording total magnetic field and a scintillometer with remote detector towed 300 ft. below the aircraft. Flight path was recorded by a 35 mm strip camera and an air position indicator and altitude was monitored by a radio altimeter. Altitude, magnetic field and scintillometer readings were all recorded on analogue chart recorders and correlated by fiducial marks.

The survey results were reduced and compiled by the Department of Mines, South Australia. They have been presented as stacked profiles at scales of 1 inch = 2 miles and 1 inch = 60 chains (Dept. of Mines, SA, 1972).

1961/62 (Ref. SADM Env. 202)

A regional aeromagnetic survey was conducted in 1961/62, primarily over the sedimentary basins to the east of the Musgrave Block but extending onto some shallow basement areas on ABMINGA. This survey was flown by Aero Service Corporation for Delhi Australian Petroleum Ltd.

The survey was flown in a Piper Apache aircraft at an altitude of 1500 ft. (barometric) on east-west lines spaced five miles apart with north-south tie lines at intervals of 20 miles. Instrumentation consisted of a Gulf Research and Development Company Mark III fluxgate magnetometer mounted in a tail boom and data were recorded on analogue charts. Navigation was visual and was monitored by a 35 mm strip camera.

Survey results were reduced and compiled by Aero Service Corporation in Philadelphia and presented as contour maps at a scale of 1:240 000. An interpretation report was presented by Aero Service Corporation but since the survey was designed to provide reconnaissance data on basin structure little attention was paid to shallow basement areas near the margins of the basin; e.g. the Musgrave Block.

1965 (Ref. BMR Record 1966/230)

During 1965 the BMR flew an airborne magnetic and radiometric survey over the greater part of the Amadeus Basin and the surrounding Precambrian basement in the Northern Territory. This survey covered portions of the Musgrave Block on PETERMANN RANGES, AYERS ROCK and KULGERA, although it was primarily designed to determine basement structure beneath the sedimentary basins.

The survey was conducted in a DC3 aircraft (VH MIN) along east-west lines spaced at intervals of 2 miles and 4 miles and at an altitude of 800 ft. Navigation was by aerial photographs and flight paths were recorded by a 35 mm strip camera.

Instrumentation consisted of an MFS-5 fluxgate magnetometer mounted in a tail boom and a scintillometer with two inboard detectors and one suspended on a cable 200 ft. below the aircraft. Altitude was monitored by a radio altimeter and all data were recorded on analogue charts.

The results were reduced and presented as profiles for discussion and interpretation in BMR Record 1966/230. At a later date, the results were also used to compile contour maps of total magnetic intensity and radioactivity at a scale of 1:250 000, and these were published by the BMR.

1965 (Ref. BMR Record 1967/89)

A low level aeromagnetic survey was conducted by the BMR over a narrow strip (approximately east-west) extending through MANN and WOODROFFE. This strip contained known outcrops of ultrabasic intrusives included in the Giles Complex and these were considered prospective for nickeliferous laterites. It was hoped that the survey would indicate whether these ultrabasic rocks were continuous beneath cover.

The survey was flown in a Cessna 180 on lines approximately 1 mile apart with a detector ground clearance of 250 ft. Flight lines were oriented northwest and northeast. Instrumentation consisted of a MNS-1 proton precession magnetometer and a radio altimeter recording on analogue charts. Navigation was visual and was monitored by a 35 mm, single frame type camera with 180^{o} fish eye lens.

The data were reduced and plotted by the South Australian Department of Mines and presented as both flight line profiles and contours. Preliminary interpretation indicated that the flight line separation (1 mile) was excessive for this altitude over shallow basement and line to line correlation was difficult and subjective. Magnetic response of known basic and ultrabasic rocks appeared variable and the data appeared unlikely to contribute significantly to knowledge of the continuity of these rocks beneath cover.

It appears that little consideration was given to the possible magnetic remanence of the Giles Complex rocks which, together with the three dimensional nature of some of the occurrences (i.e. isolated blocks rather than extended linear features), could result in unusual magnetic response patterns. When surveyed with such widely spaced lines it becomes easier to understand the apparent lack of correlation between outcrop and observed magnetic response.

1965 (Ref. SADM Env. 527)

During 1964/65 an airborne magnetic survey was also carried out over Oil Exploration Licence 28 in SA by Adastra Hunting Geophysics Pty. Ltd. for Exoil Pty. Ltd. This survey covered a portion of the Eastern Officer Basin and was designed to outline the Basin and interpret depths to magnetic basement (and hence the thickness of sediments in the basin). It also extended onto the southern portion of the Musgrave Block on BIRKSGATE, LINDSAY, EVERARD and WINTINNA.

The survey was flown in a Lockheed Hudson aricraft along north-south flight lines in groups of three (1.5 miles between lines and 10 miles between groups) with east-west tie lines (single lines spaced 20 miles apart). The survey was flown at an altitude of 2000 ft. (above sea level). Instrumentation consisted of a Gulf Research and Development Mark III (total field) magnetometer and radio altimeter both recording on analogue charts. Navigation was visual and flight paths were monitored by a 35 mm camera.

Data were reduced and plotted as contours of total magnetic intensity (1" = 2 miles and 1" = 4 miles) by Adastra Hunting

Geophysics Pty. Ltd. An interpretation report was then prepared by Geophysical Associates Pty. Ltd. and maps of magnetic basement contours were prepared. These maps effectively outline the southern margin of the Musgrave Block.

1967 (Ref. BMR Record 1968/51)

A systematic, regional aeromagnetic and radiometric survey was carried out by the BMR over the eastern portion of the Musgrave Block in SA. The survey covered portions of WOODROFFE, ALBERGA, ABMINGA, LINDSAY, EVERARD and WINTINNA and extended from the NT border south to the approximate southern limit of shallow magnetic basement. The aim of the survey was to assist in geological mapping of the region and indicate possible areas where rocks of the Giles Complex might approach the surface.

The survey was flown in a DC3 aircarft (VH MIN) on north-south lines spaced 1 mile apart with east-west tie lines at 15 mile intervals. The survey altitude was 500 ft. above ground level.

Instrumentation consisted of an MFS-5 fluxgate magnetometer mounted in a tail boom, radar altimeter and both inboard and outboard scintillation detector heads. All data were recorded on analogue charts. Visual navigation was assisted by an Air Position Indicator and monitored by a BMR 35 mm strip camera.

The survey data were initially presented as profiles along the flight lines and a preliminary interpretation was prepared from a consideration of these profiles (BMR Record 1968/51). Subsequently the South Australian Department of Mines compiled contour maps of the relevant map sheets at scales of 1:250 000 and 1:63 360. In addition the data have been included in a magnetic contour map of SA at a scale of 1:1 000 000.

The results from this survey comprise the best available data over most of the eastern portion of the Musgrave Block at this time.

<u>1969</u> (Ref. BMR Record 1971/19)

During 1969 a systematic, regional aeromagnetic survey was carried out by the BMR over the western portion of the Musgrave Block in SA. The survey covered portions of MANN, WOODROFFE, BIRKSGATE, LINDSAY and PETERMANN RANGES (NT). It filled the gap between the 1967 survey and the WA, NT borders and extended into a small portion of the Northern Territory. The aim of the survey was to assist in geological mapping with particular emphasis on locating areas of shallow Giles Complex rocks.

The survey was flown in an Aero Commander (VH BMR) along north-south flight lines spaced 1 mile apart with east-west tie lines at 15 mile intervals. Survey altitude was 500 ft. above ground level.

Instrumentation consisted of a MNS-1 proton precession magnetometer with the sensor in a towed bird and a radar altimeter. All data were recorded on analogue charts. Navigation was visual by aerial photographs and flight lines locations were monitored by a 35 mm single frame camera and "fish-eye" lens.

Survey data were originally presented as profiles along the flight lines and these profiles were used in a preliminary interpretation (BMR Record 1971/19). Subsequently the South Australian Department of Mines compiled contour maps of the relevant map sheets (together with data from the 1967 survey) at scales of 1:250 000 and 1:63 360. The data have also been included in the SA state aeromagnetic map at a scale of 1:1 000 000.

The results of this survey now comprise the best available data over most of the western portion of the Musgrave Block (in SA) at this time.

<u>1970</u> (Ref. SADM Env. 944)

A low level, detailed aeromagnetic survey was carried out by McPhar Geophysics Pty. Ltd. on SML 226 for T.S. Minerals Pty. Ltd. SML 226 was located adjacent to the NT border near 133°E (on ALBERGA) occupying an area of approximately 200 km^2.

The survey was flown in a Beaver aircraft along north-south lines spaced 1000 ft. apart at an altitude of 300 ft. In addition, one east-west tie line was flown. Instrumentation consisted of a Varian proton precession magnetometer and radar altimeter recording on analogue charts (and possibly also on digital film). Visual navigation was monitored by wide angle photography from the aircraft. The magnetic data were processed by Engineering Computer Services Pty. Ltd. to produce contour maps at a scale of 1 inch = 1000 ft. An interpretation report was prepared by McPhar Geophysics Pty. Ltd. but its scope was limited by lack of geological control. Magnetic relief of approximately 2000 gamma was observed and linear anomalies were thought to correlate with the numerous basic dykes known to exist in the area.

These data have been recontoured by the South Australian Department of Mines and presented as contour maps (on two sheets) at a scale of 1:25 000.

1976

During 1976, regional airborne magnetic surveys were flown by Austral Geophysics Pty. Ltd. covering BENTLEY, SCOTT, TALBOT, and COOPER (and other areas in WA). These surveys were flown on contract to the BMR as part of a regional survey of the Officer Basin but also included the WA portion of the Musgrave Block.

The surveys were flown at an altitude of 150 m above mean terrain along north-south lines spaced 1.5 km apart. Measurements of total magnetic intensity were made at intervals of 60 m with a proton precession magnetometer.

Results were recorded and processed digitally and preliminary contour maps of total magnetic intensity at a scale of 1:250 000 were released by the BMR late in 1977.

3.2 Gravity

Regional gravity surveys by the BMR and private companies cover the entire Musgrave Block on approximately a 4 mile x 4 mile grid. These data have been processed by BMR on MANN, WOODROFFE, ALBERGA, BIRKSGATE, LINDSAY and EVERARD and by SADM on ABMINGA and WINTINNA. Similar data have been collected by BMR on adjacent areas in WA and NT. The data have been presented as contours of Bouguer gravity anomalies at scales of 1:250 000 and 1:500 000 on individual map sheets and incorporated in the gravity map of Australia published by the BMR at various scales. A summary map at a scale of 1:1 000 000 is included with this report (see Fig. 5).

The station spacing for these regional surveys is generally too great for correlation with mapped lithologies. However, broad structural features are apparent and have been reviewed by several authors (e.g. Mathur, 1976; Anfiloff and Shaw, 1973). More detailed surveys as discussed below have been conducted in specific areas by various workers but this work has generally not been incorporated in the regional surveys (Fig. 4).

(1) During May-July, 1953 several road traverses were surveyed with magnetics and gravity by officers of the SADM (Knapman, 1953). Gravity measurements were hindered by a lack of suitable base maps but two traverses - Tieyon to Abminga and De Rose Hill to Granite Downs - were completed and the data reduced and presented as profiles. Little could be done with these two profiles in isolation, although they did appear to outline the limits of the shallow basement areas to the east and southeast of the Musgrave Block.

The Tieyon to Abminga traverse has now been superseded by regional surveys on ABMINGA, and the De Rose Hill to Granite Downs traverse has been superseded by regional surveys on ALBERGA.

(2) During 1960, officers of the SADM undertook gravity surveys over Claude Hills and Scarface (areas of Giles Complex rocks on MANN) to examine zones of nickeliferous ochre (Pegum, 1961). Negative gravity anomalies of up to 2 mgal appeared to correlate with the low density ochre and a regional positive anomaly of up to 70 mgal outlined the region of Giles Complex rocks.

(3) Regional gravity surveys were also conducted during 1961, from Fisher (on the Transcontinental railway) north to Mount Davies (northwest corner of MANN) and east through Granite Downs to Oodnadatta. This work was summarized by officers of the SADM (Mumme, 1961).
Magnetic measurements were made simultaneously with the gravity measurements and the results helped to confirm the existence of a deep sedimentary basin - the Officer Basin - south of the Musgrave Block.

(4) The work of Pegum (1961) in the Claude Hills area was extended in 1965 by B.E. Milton and J. McG. Hall of the SADM (Hall, 1966). The objective of this work was to locate additional zones of nickeliferous ochre which had been shown to cause negative gravity anomalies.
Measurements were made over several areas of known Giles Complex rocks (Claude Hills, Scarface, Gosses Pile) and drilling on negative residual anomalies was successful in locating additional deposits of nickeliferous ochre at Claude Hills and Scarface.

Reconnaissance lines further east on MANN were designed to test for continuing occurrences of Giles Complex rocks to the east. A positive anomaly coincided with mapped Giles Complex rocks at Hanging Knoll but generally the lines were too short to be interpreted with any confidence. This early work did detect a strong regional gradient decreasing to the north and it was generally considered to indicate extensive masses of basic - ultrabasic Giles Complex rocks. Subsequent regional surveys have confirmed this feature but it is now thought to be part of a major regional pattern of continental significance (Mathur, 1976; Anfillof and Shaw, 1973).

(5) Some limited gravity measurements were made over the Ewarara Intrusion (part of the Giles Complex) in 1965 by officers of the SADM, but this work was not included in Hall, 1966. The survey is mentioned briefly in a review of the geology of Ewarara (Goode and Krieg, 1967) but no data are presented. Apparently only one profile was surveyed and little interpretation was possible.

(6) During 1966, a gravimetric investigation of the Mount Davies and Gosses Pile intrusions of the Giles Complex was carried out as a B.Sc. Honours project in the Department of Economic Geology, University of Adelaide (Steele, 1966).
One traverse was surveyed over each of Mount Davies and Gosses Pile with stations at 500 ft. intervals and detailed modelling was done in an attempt to interpret the subsurface configuration and extent of these intrusive bodies. Results indicated a steep southerly dip for both bodies with depth extent of 9000-14000 ft. for Mount Davies and 3000 ft. for Gosses Pile.

Although the agreement between observed and calculated gravity results is excellent, the interpretation is based on very limited field data and other solutions may also be possible.

(7) The reconnaissance gravity measurements on MANN, commenced in 1965 by B.E. Milton and J. McG. Hall (Hall, 1966) were extended in 1966 by Rowan of the SADM (Rowan, 1967).
This programme partly defined the major gravity ridge which extends east-west across MANN and WOODROFFE. Rowan considered this ridge to be an extension of the Anketell Regional Gravity Ridge which had been defined in WA (Fraser, 1976). Rowan's interpretation would make this ridge continuous from the Indian Ocean in the west to the Great Artesian Basin in the east, at the eastern margin of the Musgrave Block.
Although there is a suggestion of a continuous ridge, there is a change of both direction and amplitude west of the Blackstone Ranges in WA. The east-west ridge extending through the Musgrave Block is now generally considered as a separate feature, named the Blackstone Regional Gravity Ridge (Fraser, 1976).
Rowan suggested that this gravity ridge was a major structure and this has been confirmed by subsequent work on the regional gravity map of Australia. Local anomalies superimposed on the regional structure were apparent over Giles Complex rocks at Mount Davies and Hanging Knoll and these were explained by the density contrast between the basic-ultrabasic Giles Complex rocks and the surrounding granulites of the Musgrave-Mann Metamorphics.

(8) The results of extensive geophysical, geochemical and geological programmes in the North West Province were

summarized in a report by P.G. Miller (1969). This includes some gravity data not included in previous reports and is mainly devoted to an evaluation of the significance of nickeliferous ochres in the Mount Davies area and some exploration for nickel sulphides associated with the ultra-basics of the Giles Complex. This work was initially carried out by exploration companies during 1954-1959, and subsequently by officers of the SADM 1959-1967.

In general, the various detailed and semi-regional gravity surveys described above have not been adequately tied in for inclusion in the gravity map of Australia. The summary gravity map included with this report (Fig. 5) is based on regional surveys by the BMR and does not include the various detailed measurements in specific areas.

3.3 Miscellaneous

3.3.1 During the period 1954-1959 extensive exploration for nickel (primarily nickel sulphides) was carried out by Gold and Mineral Exploration N.L. (SML 20) and Southwestern Mining Ltd. (SML's 21, 25, 33) on the north and west of MANN. They employed a variety of geophysical methods without much success. The following summary is extracted from Miller, (1969).

Resistivity profiles	31
Magnetometer traverses (ground)	66 miles
Electromagnetic Surveys (ground)	4 square miles
Electromagnetic Surveys (airborne)	197.5 miles
Airborne E.M. anomalies tested	77
Airborne E.M. anomalies drilled	5.

In general, these methods were applied as direct tools in the search for nickel sulphides. Predictably, the electro-magnetic methods were masked by deep conductive overburden and the five anomalies which were drilled were attributed to saline groundwater. Any magnetic response due to sulphide mineralisation was expected to be masked by the stronger responses associated with concentrations of magnetite. Resistivity surveys did offer some hope as an aid to geological mapping beneath cover and they confirmed the presence of conductive overburden which hindered the electromagnetic measurements.

These detailed surveys are not generally relevant to a regional study of the Musgrave Block and only limited reference to them is made in this report. Any future detailed exploration for metalliferous mineralisation may benefit by the experience of these workers but in any case significant developments in instrumentation and methods have largely superseded their work.

3.3.2 During the period 1967-1973, extensive geological, geochemical and geophysical work was done by officers of the SADM in the Kenmore Park area of ALBERGA. This work was initiated as a search for nickel sulphide mineralisation associated with ultrabasic rocks following the discovery of green chalcedony by aboriginal prospectors. During these years several nickel and copper prospects were located and investigated.

Geophysical investigations included ground magnetics (both detailed and reconnaissance), induced polarization, resistivity and VLF electromagnetic methods. A number of anomalies were detected and tested by drilling but no economic mineralization was revealed.

The results of geophysical surveys in this area are summarized in numerous unpublished and some published reports by officers of SADM. The main reports which summarized this programme are listed below.

Warne	1967
Miller & Gerdes	1970, 1972
Gerdes	1971
Taylor	1971(a) and (b)
Barnes, Conor, Pain & Taylor	1971
Nelson & Taylor	1972
Wightman & Taylor	1973

Measurements of specific gravity and magnetic susceptibility on drill core and surface samples of various lithologies are included in Gerdes (1971).

Detailed geological mapping of Kenmore and Eateringinna was completed as part of this programme and an interpretation report is in preparation (Conor, 1978). Thirteen samples of granitoid rocks collected on Eateringinna by C. Conor in 1975 were submitted to the BMR for physical property measurements and the results were recently made available (Wilkes, pers. comm.).

3.3.3 Parts of ALBERGA and ABMINGA were held by Kennecott Explorations (Australia) Pty. Ltd. during 1969-1971 as SML's 357, 358, 363, 417, 418 and 510. Exploration in these areas included extensive geological mapping of Alcurra, Marryat, Echo, De Rose, Paroora and Moorilyanna (all on ALBERGA) and Tieyon on ABMINGA.

Exploration included limited geophysical work, mainly ground magnetic measurements over the Wanka Wanka ultramafic dyke near 132°45'E, 26°47'S. The data are available as open file reports at the SADM (Envelope Nos. 1281, 1476, 1477 and 1597).

3.3.4 During 1969-1970, Australian Aquitaine Petroleum Pty. Ltd. held SML 342 covering parts of De Rose and Indulkana on ALBERGA.

Exploration included geological mapping on De Rose and Indulkana and extensive ground magnetic traversing. Some correlation was possible between the magnetic results and the mapped geology. In addition measurements of magnetic susceptibility were made on a number of samples of various lithologies. Results are available as open file reports at the SADM (Envelope No. 1215).

3.3.5 During 1970, T.S. Minerals Pty. Ltd. carried out ground investigations on SML 467 (formerly SML 226) in the northern part of ALBERGA as a follow up to an airborne magnetic survey by McPhar Geophysics Pty. Ltd. (SADM Envelope 944). These investigations included ground magnetic measurements in an attempt to confirm the source of airborne magnetic anomalies. Results are available as open file reports at the SADM (Envelope No. 1484).

These detailed surveys (sections 3.3.2 and 3.3.5 above) do contribute some knowledge of the physical properties of various rock types, both from laboratory measurements and from comparisons of field measurements and mapped lithology. The observed complexity of local geology also serves as a warning against sweeping generalisations in a regional interpretation.

4. SUMMARY OF PHYSICAL PROPERTY MEASUREMENTS

Over a period of ten to fifteen years, several workers have attempted measurements of physical properties of various rock types within the Musgrave Block. These measurements, mainly of specific gravity or magnetic susceptibility (together with some paleomagnetic work) are from diverse localities and not all are fully documented.

They are by no means conclusive but do indicate that, firstly, a significant density contrast exists between the rocks of the Giles Complex and the granites and metamrophics and, secondly, that the Kulgeran Granites are the most susceptible rocks in the region. The granites are believed to be anatectic and quite variable in composition; this is apparent in the range of susceptibility values measured and also in the observed association between magnetic anomalies and outcropping granite.

4.1 Specific Gravity

Fifteen samples of granulite country rock from near Mt. Davies were tested by Steele (1966) and gave an average specific gravity of 2.74. This might be anticipated to vary with the local granulite composition and Rowan (1967) assumed a range of 2.7 - 2.9 for metasediments based on the measurements by Steele and other additional samples.

More recent measurements by Gerdes (1971) on seventeen samples of metasediments from the Kenmore Park area gave an average value of 2.66. Metasediments in this area have been described as granulite - amphibolite transition rocks (Conor, in prep.) while those at Mount Davies are described as granulites (Mirams, 1964).

Steele (1966) also tested fourteen samples of Giles Complex rocks from Mount Davies and ten samples from Gosse Pile. He obtained an average specific gravity of 3.0 for gabbro and norite at Mount Davies and 3.2 for pyroxenite at Gosse Pile.

Additional measurements by Gerdes (1971) for various lithologies on Kenmore are listed below:

lithology	number of samples	mean specific gravity
dolerite	13	3.04
amphibolite	6	2.95
serpentinite	2	2.4

The amphibolite should possibly be included with the meta-sediments and this would give an average of 2.74 for twenty three samples, in good agreement with Steele (1966).

The serpentinite may have been weathered; in any case only two samples were tested so that the result is probably unreliable.

Thirteen samples of granite from Eateringinna were collected by C. Conor in 1975 and sent to the BMR for physical property measurements. These gave an average specific gravity of 2.70 (Wilkes, 1976).

These results suggest that the following ranges should be reasonably representative.

	Specific Gravities
Metasediments (granulites-amphibolites)	2.7 - 2.9
Granites	approx. 2.7
Giles Complex	3.0 - 3.2
Dolerite (dyke rocks)	approx. 3.0

4.2 Magnetic Susceptibility

Magnetic susceptibility, particularly in the metasediments, depends critically on sample lithology and wide variations have been noted. The following tables show ranges of typical values but usually both the number of samples and description is inadequate for firm conclusions to be drawn.

Rock type	No. of Samples	Susceptibility ($\times 10^{-3}$ c.g.s. units)
Waller, (1968)		
metasediments	2	0.05
microgabbro (dyke?)	1	0.52
norite	1	0.48
granite	6	0.28
Aquitaine, (1970)		
gneiss	7	0.2
serpentinite	4	1.0-13.0
amphibolite	4	0.39-9.0
chert	2	5.3-9.0
gabbro	1	0.5
dolerite	1	0.5
Miller and Gerdes, (1970)		
metasediments	5	0.1
quartz-orthoclase	16	0.01-0.33
quartz biotite gneiss (some magnetite)	26	3
granite*	10	0.03
granite*	9	0.04
metasediments	7	0.76
quartz biotite orthoclase	39	3.4

*These samples are probably gneisses of granitic composition and could be classified as metasediments (Gerdes, pers. comm.).

dolerite	2	7.2
serpentinite	5	4.6
Gerdes, (1971)		
metasediments	7	1.9
amphibolite	2	3.5
serpentinite	2	0.5
dolerite	10	2.5
Wilkes, (1976) (samples collected by C. Conor, 1975)		
granitoids from Eateringinna	13	50

Most of the rocks described above are presumably part of the Musgrave-Mann Metamorphics. The susceptibility measured in these samples is quite variable but generally in the range 0.1×10^{-3} to 10.0×10^{-3}.

The basic to ultrabasic rocks which may be either part of the Musgrave-Mann Metamorphics or, more probably, younger intrusives, also have a wide range of susceptibilities in the few samples tested. They have ranged from 0.5×10^{-3} to approximately 7×10^{-3}, within the range of values obtained for metasediments.

True granites have only been tested by Waller (1968) and Wilkes (1976, pers. comm.). There is a wide disparity between these two sets of results but in any case, the granites sampled by Conor and measured by Wilkes gave the highest susceptibility (50×10^{-3}) of any rocks from the Musgrave Block. This is in good agreement with the observed magnetite content and the apparent association between magnetic anomalies and outcropping granite.

The range of values encountered for all of these rocks is so wide that the results are only of limited use. Certainly, it is clear that some (and perhaps all) of the younger granites are strongly magnetic. The older metamorphics including basic and ultrabasic rocks and the younger basic intrusives have variable magnetic properties but generally appear less magnetic than the granites.

5. INTERPRETATION

The interpretation procedures used in this report have been mainly qualitative and the results are summarized on Figs. 7, 12, 13, 14 and 15 and in the descriptive notes in this chapter. Gravity interpretation has been very limited; it has entailed mainly a comparison of broad interpreted features with zones defined by magnetic results. Magnetic interpretation has involved scanning the available contour maps (at a scale of 1:63 360 or 1:250 000) and attempting to identify discrete magnetic anomalies, e.g. linear dyke-like features, roughly circular or equidimensional bodies, etc. Where possible these anomalies have been correlated with the mapped geology in an attempt to identify the source.

In addition to the published magnetic contour maps, the contour compilation sheets and original analogue records were available for detailed checking. In some areas, the magnetic data were re-contoured to conform better with known geology.

The analogue chart records demonstrate the complex magnetic relief present in this area and it is hardly surprising that contouring between 1 mile flight lines becomes very subjective. Many anomalies could not be traced on more than one flight line, and little could be interpreted about the shape of the source. East-west trending linear anomalies were the most easily recognised features together with complex zones of high magnetic relief usually associated with granites.

In general, after removing a regional gradient, background values of total magnetic intensity were between 2 000 and 3 000 gamma. Positive anomalies usually exceeded 3 000 gamma and negative anomalies were usually less than 2 000 gamma.

Some computer modelling has been done in an attempt to simulate specific features, e.g. Mount Davies basic-ultrabasic block, east-west dykes, southern overthrust, etc. but the results are incomplete and they are not included here. Additional modelling is suggested in the future.

The broadest regional features of the Musgrave Block are illustrated in Fig. 5 and Fig. 6, maps of Bouguer gravity contours and total magnetic intensity respectively at a scale of 1:1 000 000. A number of interpreted features, e.g. zones, lineaments, dislocations etc., are superimposed on the magnetic contours in Fig. 7.

In addition Figs. 8-11 and 12-15 show total magnetic intensity contours and interpreted features at a scale of 1:250 000 on MANN-BIRKSGATE, WOODROFFE-LINDSAY, ALBERGA-EVERARD and ABMINGA-WINTINNA respectively.

Interpreted magnetic features shown on figures 12-15, superimposed on simplified magnetic contours, have been classified as described below. Any such classification is subjective and because it attempts to group a wide range of anomaly types into discrete categories it is unlikely to be universally acceptable. There are some cases of overlap between anomaly types and many anomalies where insufficient detailed information is available for confident assessment. The notes in this section of the report are intended to supplement and clarify the features illustrated.

In general, major zones of high magnetic relief are associated with granitoid masses which often have gradational boundaries and therefore poorly defined magnetic boundaries. Discrete anomalies arise from a number of identified sources and these are individually classified. Positive anomalies are generally attributed to isolated intrusions or fault controlled intrusions of granitic material. Discrete negative anomalies are generally associated with remanently magnetised rocks of the Giles Complex. Major faults and thrust zones are usually reflected in the magnetic data as linear, negative anomalies, the lack of magnetic relief along a linear trend or the dislocation of otherwise recognisable trends. Some dyke-like bodies have similar magnetic expressions. The final classification refers to boundaries between areas of high magnetic relief over non-magnetic, sedimentary sections. Many anomalies do not conform to this broad classification and these are discussed individually.

The following types of features have been identified.

1. Large zones of complex magnetic relief. These may have lateral dimensions varying from a few kilometres up to several tens of kilometres. They are usually poorly defined, often with no clear boundaries and complex shapes. These have been designated A type. They are usually associated with zones of granitoid rocks.

2. Anomalies suggesting discrete sources with well defined limits and shape characteristics. Anomaly types B, C, D and E are in this group and they are distinguished as follows:

   <u>B</u> These are positive anomalies, roughly equidimensional in shape with a typical diameter of 5-10 km. These anomalies are often associated with intrusive granite bodies (e.g. on ALBERGA).

   <u>C</u> Broad, elongate positive anomalies, with dimensions commonly several kilometres across by several tens of kilometres long. These anomalies are often associated with intrusive granitic bodies, probably fault controlled.

   <u>D</u> Discrete negative anomalies with well defined but variable shapes and dimensions. These are usually associated with basic and ultrabasic rocks of the Giles Complex.

   <u>E</u> Discrete anomalies of special interest. All of these anomalies have only limited lateral extent, they are roughly equidimensional and often defined on only one flight line.

E 1 This is a zone of granite with no magnetic expression outlined on Unmoorinna (BIRKSGATE). It is discussed in section 5.5.

E 2 Several bodies of apparent Giles Complex rocks gave a positive magnetic response - the reverse of the response observed over the main Giles Complex masses on Davies. The best example of an E 2 type is the Caroline Anomaly (see section 5.7.2).

E 3 The Moulden Anomaly is a pronounced negative anomaly on Moulden (MANN). It is discussed further in section 5.7.1.

E 4 The Harcus Anomaly is a pronounced negative anomaly on Harcus (MANN). It is discussed further in section 5.7.3.

E 5 The Crombie Anomaly is a pronounced positive anomaly on Crombie (WOODROFFE). It is discussed further in section 5.7.4.

E 6 A number of very small anomalies were defined on MANN and WOODROFFE which appear as a positive ring or annulus surrounding a centre of background or negative values. These are discussed further in section 5.7.5.

3. Elongate, linear or sub-linear anomalies. These suggest much narrower sources than type C and are often associated with major lineaments and dyke-like bodies. They may be either positive or negative or identifiable by an absence of magnetic relief (e.g. Mann Fault). These have been designated Type F.

4. Dislocations in otherwise identifiable anomaly patterns, suggesting possible faults or major lineaments, sometimes extending for many tens of kilometres.

5. Boundaries between areas of short wavelength anomalies over shallow crystalline basement and areas devoid of such features suggesting deep, non-magnetic sediments. The southern boundary of the Musgrave Block adjacent to sediments of the Officer Basin is a good example.

5.1 Regional gravity

The Bouguer gravity contours shown on Fig. 5 are compiled from regional surveys with widely spaced stations (approximately 6.5 km x 6.5 km). Although more detailed surveys have been conducted in specific areas (see Fig. 4) these measurements have not generally been tied in to a regional datum and the results are not included in Fig. 5.

The most obvious feature of the gravity map is the east-west arcuate zone of positive anomalies which generally coincides with the Musgrave Block. This feature has been designated the Blackstone Regional Gravity Ridge (Fraser, 1976). It extends across the Musgrave Block in SA and WA and may be continuous with the Anketell Regional Gravity Ridge (Rowan, 1967) which continues through WA to the Indian Ocean.

Various authors have studied crustal structure in central Australia (Forman and Shaw, 1973; Anfillof and Shaw, 1973; Mathur, 1976) and two extreme models have been proposed to explain the observed gravity anomalies.

Anfillof and Shaw (1973) have compiled a model of upthrust granulites surrounded by granite masses underlying the Officer Basin and Amadeus Basin. This model assumes uniform composition and density below the Conrad discontinuity at about 20 km and it is adequate to explain the observed gravity anomalies on a broad scale. Any model of this type necessitates general assumptions for rock densities; while these may always be debatable, the values chosen were reasonable.

A later model, proposed by Mathur (1976), suggests that the observed gravity anomalies are related to the composition of the crust down to the Mohorovicic discontinuity (at about 40 km) and that this discontinuity is not a flat interface. Recent work (Goode and Moore, 1975; Moore and Goode, 1978) suggests that high pressure basic rocks which intrude granulites of the Musgrave Block may have crystallised at depths of 30-35 km with subsequent uplift to the surface. This would tend to support involvement of the entire crust and upper mantle in deformation which has resulted in these pronounced gravity anomalies.

Both of these models (Anfillof and Shaw (1973), Mathur (1976)) would imply that the crust in Central Australia is not in isostatic equilibrium (at least for blocks of the order of $1^{o} \times 1^{o}$ in size) and large uncompensated blocks in the crust are responsible for the observed gravity anomalies. More recently a third model has been proposed (Wellman, 1978) which assumed isostatic equilibrium for $1^{o} \times 1^{o}$ blocks and appears to explain all the observed gravity features very well. It is perhaps more difficult to visualize this model geologically as the proposed uplifted blocks would need to have compensating "roots" but the agreement between observed and predicted gravity anomalies gives this model strong support.

Without resolving these differences it seems reasonable to accept the general concept of major uplift of the Musgrave Block resulting in the surface exposure of rocks which formed deep within the crust (e.g. granulites and charnockites). By some unexplained mechanism, compensating "roots" may have formed (resulting in the dipolar gravity anomaly pattern). Alternatively, this uplift has raised high density rocks of deep seated origin closer to the surface causing the pronounced gravity anomalies of the Blackstone Regional Gravity Ridge.

It is no doubt significant that the Giles Complex and similar rocks in the Caroline Intrusion (see later) coincide with the most pronounced gravity anomalies in this regional zone. This suggests maximum uplift in these areas exposing rocks from deepest within the crust, including the basic - ultrabasic rocks and anorthosites of the Giles Complex. Local anomalies due to the exposed higher density rocks of the Giles Complex and Caroline Intrusion are superimposed on the regional gravity ridge.

This model might lead us to expect that rocks of the highest metamorphic grade would be exposed near the centre of the gravity anomaly and particularly in the belt which includes the Giles Complex and Caroline Intrusion, i.e. the main mountain ranges in the area. Certainly, the main gravity ridge appears to coincide with the east-west zone of granulites.

On MANN there is a fork in the gravity ridge. The main trend extends eastward, parallel with the Mann Fault and terminates east of the Caroline Intrusion on WOODROFFE. A second zone trends southeast from Michael Hills through Tomkinson into Bryson. Scattered outcrops of anorthosite have been mapped in this area, similar to some of the Giles Complex, suggesting that this is part of the zone of maximum uplift. Several magnetic lineaments on Tomkinson and a possible zone boundary on Moulden outline this trend but they are poorly defined and intermittent (see Fig. 7).

Further east, on WOODROFFE, there is a discontinuity in the gravity ridge, and a positive anomaly further south on the boundary between WOODROFFE and LINDSAY coincides with scattered outcrops of granite. The gravity anomaly is unlikely to be due to the granite so that a major uplift in this area is proposed. This zone is approximately bounded by arcuate magnetic lineaments, the Lindsay Lineament to the south and the Wintiginna Lineament to the north. A northeast trending dislocation in the Wintiginna Lineament (and in several other subsidiary magnetic trends) suggests a fault which may bound this zone to the east.

If this zone has exposed high grade metamorphics (granulites) at the surface it would conflict with the boundary between granulites and granulite - amphibolite transition rocks proposed by Thomson (1969) and also used by Forman and Shaw (1973). This boundary is shown in Fig. 16 together with a suggested revision based on the gravity data.

The discontinuity in the gravity ridge on WOODROFFE is almost coincident with a poorly defined, northeast trending zone of low magnetic relief which is apparent on Figs. 6 and 7. This also aligns approximately with the Ferdinand Fault. At least one author (Conor, 1975) has suggested that this is part of a major northeast trending system which may extend from the vicinity of the Fraser Fault in the southeast of Western Australia to Mount Isa in Western Queensland.

North of the Wintiginna Lineament, on Eunyarinna, and further east on ALBERGA, the main gravity ridge appears to be partly bounded to the south by the Paroora Lineament and De Rose Lineament. It may also be partly bounded to the north by Gosses Lineament. The gravity anomaly diminishes in intensity to the east (i.e. on ABMINGA) and mapping in this area has been hindered by lack of outcrop. Conor (in prep.) has described the metasediments on Kenmore and Eateringinna as transitional between granulite facies and amphibolite facies. He has also noted some evidence, albeit inconclusive, for an increase in metamorphic grade to the south.

The generalized picture described here, of high grade metamorphics in areas of maximum uplift corresponding with gravity highs and bounded by aeromagnetic lineaments is no doubt imperfect. It suggests a series of uplifted and eroded blocks, bounded by arcuate faults. Maximum uplift (and hence, by inference, exposures of the highest metamorphic grade) corresponds approximately with gravity maxima.

Although some of the details of this model are highly conjectural, the broader regional picture of major crustal deformation with uplift exposing high grade metamorphics formed deep within the crust appears reasonable. The conflicting models proposed by various workers (Anfillof and Shaw, 1973; Mathur, 1976 and Wellman, 1978) could be clarified and perhaps resolved by deep seismic measurements to test crustal thickness across the Musgrave Block.

5.2 Structure and Lineaments

Several major structural features have been previously mapped, named and studied in some detail (e.g. Woodroffe Thrust, Major, 1973). Most of these have been added to the interpretation plans (Figs. 7, 12-15) although some have no apparent magnetic signature. Additional magnetic lineaments which have not previously been identified are also shown and several major features have been named. Identification of lineaments is a somewhat subjective process, and in many cases it is affected by the original contouring. Many less definite lineaments have been interpreted in this study. They are shown on Figs. 12-15 but not named. Lineaments are identified either as type F anomalies (dyke-like bodies) or as dislocations in the magnetic pattern. While type F anomalies are usually well defined, dislocations are often highly subjective.

It should be borne in mind that the airborne magnetic data were collected along north-south survey lines. East-west lineaments tend to be emphasized by the subjective contouring process while any possible north-south lineaments are only likely to be visible if they dislocate otherwise continuous east-west features. Individual features are discussed in turn below.

5.2.1 Woodroffe Thrust Zone (Major, 1973)

This is a major structural feature which has been mapped in the field and partly extrapolated by reference to the magnetic contour pattern. It is located near the northern boundary of MANN, WOODRFFE and ALBERGA and extends into the Northern Territory on PETERMANN RANGES, AYERS ROCK and KULGERA. The thrust zone is mappable as a zone of mylonites dipping shallowly to the south. It represents the northern boundary of granulite facies rocks which have thrust northwards over amphibolite facies rocks for perhaps 24 km (Major, 1973).

Although the mylonites appear to have no distinct magnetic signature, the Woodroffe Thrust Zone appears to separate a zone of low magnetic relief to the north (amphibolites and granites) from more magnetic granulites and granites to the south. In the northeast part of WOODROFFE, an outlier of granulites at Ayliffe Hill overlying the Woodroffe Thrust coincides with increased magnetic relief (see Figs. 7, 9).

5.2.2 Davenport Fault Zone

The Davenport Fault Zone is clearly mapped as an "altered basic dyke in a shear zone" (Major, 1973) but it generally appears to have no magnetic signature. The fault position shown on Figs. 7, 13 has been taken from the geological map of WOODROFFE. It appears to generally parallel magnetic trends in the area but has no coincident magnetic anomaly.

5.2.3 Ferdinand Fault Zone

The Ferdinand Fault is mapped as a mylonite zone on WOODROFFE and ALBERGA (Major, 1973; Coats, 1963), but is perhaps most apparent on Ernabella mapped by R.C. Sprigg, B. Wilson and R.P. Coats (1955). It is a broad zone and appears to have been associated with the intrusion of magnetic granitic rocks and a body of micronorite. There is no clear magnetic anomaly coincident with the Ferdinand Fault but a number of well defined magnetic trends (apparently associated with granites) enable extrapolation beyond outcrop.

The Ferdinand Fault appears to be the surface expression of a major crustal feature. This feature has possibly controlled the Woodroffe Thrust Zone and the intrusion of extensive zones of probably anatectic granites (Conor, in prep.). A possible extension of this zone to the southwest would roughly coincide with a dislocation in the east-west gravity ridge and also the poorly defined magnetic zone extending through LINDSAY and BIRKSGATE. This system has been discussed by Conor (1975).

5.2.4 Mann Fault

The Mann Fault has been mapped on MANN and WOODROFFE as a mylonite zone dipping steeply to the south. It is a major feature which extends across two map sheets and possibly further. To the east it may be collinear with the Ferdinand Fault (with a change in direction) or possibly other lineaments (e.g. the De Rose Lineament) which appear to extend beyond the eastern margin of the Musgrave Block.

The Mann Fault is apparent as a negative magnetic anomaly which can be traced from the northern margin of the Levenger Graben in the east to the southwest corner of PETERMANN RANGES and possibly further west. A number of dislocations are apparent in the southwest corner of PETERMANN RANGES.

There is some suggestion that the negative anomaly which can be traced along the Mann Fault is simply an absence of positive anomaly in an area of significant magnetic relief. It is not uncommon to observe linear magnetic minima over fracture zones (e.g. Henkel and Guzman, 1977) but the reason for the reduction in susceptibility within the fracture zone may be debatable. In addition to oxidation and hydration along linear fault zones, as proposed by Henkel and Guzman, we would certainly expect a reduction in grain size within the mylonites and possibly piezoremanence or shape factors associated with the formation of the mylonite zone.

Bell (1973) noted a significant reduction in average grain size for quartz, feldspar and biotite within mylonites of the Woodroffe Thrust Zone but although magnetite was present as an accessory, it was not studied in detail. His sample may be still available at the University of Adelaide for further study.

The Mann Fault appears to coincide with the northern boundary of the Blackstone Regional Gravity Ridge and the Levenger Graben. Further east, on ALBERGA and ABMINGA, there is no clear relationship between a magnetic lineament and the gravity ridge; possibly Gosses Lineament follows the northern boundary but it is poorly defined.

There are many similarities between the Mann Fault and Ferdinand Fault and they may be the surface expression of the more recent movements along a zone of crustal weakness which includes the Davenport Fault, Woodroffe Thrust Zone and other fragmented and less well defined features.

5.2.5 Scarface Lineament

This lineament was defined in the northwest corner of MANN by Goode (1975) as a geomorphological break between granulites formed at different pressures. The lineament was tentatively extended to the east as far as Mount Kintore.

There appears to be a coincident negative magnetic anomaly in the southeast corner of Davies and southwest corner of Mann but extensions to the southeast would diverge from the direction proposed by Goode. These extensions may also represent an extension of the Hinckley Fault (Figs. 12, 20). On Deering, this arcuate feature corresponds closely with the southern boundary of the northern limb of the Blackstone Regional Gravity Ridge. All of the mapped bodies of Giles Complex rocks occur in this region and the main group occur immediately to the north of the Scarface Lineament.

5.2.6 Hinckley Fault (Fig. 20)

The Hinckley Fault is mapped as a massive mylonite zone on MANN and particularly on Davies where it coincides with a well defined negative magnetic anomaly. Its eastern extension separates Giles Complex rocks at Mount Davies from similar rocks at Dulgunja Hill and possibly separates Mount Davies from Gosses Pile. This is a very complex area and it is tempting to oversimplify the observed fault patterns. If the Hinckley Fault passes north of Gosses Pile it may coincide with the magnetic trend defined as the Scarface Lineament (5.2.5).

5.2.7 Intersection Fault

This fault was mapped on Kenmore by Conor (in prep.) and it has been extrapolated to the southwest by following magnetic trends. It possibly converges with the Echo Lineament on Eunyarinna.

Over most of its length, the Intersection Fault is coincident with a weak negative anomaly (or lack of positive anomaly). However, on Eunyarinna it is associated with a positive magnetic anomaly suggesting that it has either been intruded or possibly acted as a locus for the formation of granite, as has Ferdinand Fault.

5.2.8 Gosses Lineament

This lineament was mapped on Kenmore and Eateringinna (Conor, in prep.). While there is no clear magnetic signature in this area, a possible extension to the northeast would coincide with a poorly defined sub-linear zone of negative anomalies.

5.2.9 Marryat Lineament (and Fault) (Fig. 19)

The Marryat Fault was first noted by Coats (1963) and subsequently named and extended by Conor (1978). In addition, Conor defined the Marryat Lineament extending further east and this has been extended even further in this report (Fig. 14) by following magnetic trends.

On Kenmore the Marryat lineament appears to terminate against Gosses Lineament and Conor has defined the Marryat Fault Zone to the west as a northwards displacement of the Marryat Lineament. There is a suggestion of a zone of reduced magnetic relief along the Marryat Fault Zone but it is far from clear and no definite magnetic signature is apparent.

The Marryat Lineament coincides with a well defined negative magnetic anomaly on Eateringinna and the western part of Marryat but further east it simply parallels the magnetic contour pattern.

5.2.10 De Rose Lineament

This is a clearly defined magnetic lineament (mainly negative) apparent on De Rose and Ungalootanna. It has been suggested as a possible easterly extension of the Mann Fault but it has not been mapped on the ground (virtually no outcrop) and there is little magnetic evidence to support this suggestion.

The De Rose Lineament appears to define the northern boundary of a fault bounded depression filled with sediment. This is apparently an eastern extension of the Moorilyanna Graben.

5.2.11 Echo Lineament and Paroora Lineament

These are well defined arcuate magnetic lineaments which extend across ALBERGA and part of WOODROFFE in an area of sparse outcrop. They have not been identified on the ground.

For most of its length, the Echo Lineament coincides with a positive magnetic anomaly suggesting an intrusion, dipping south. The Paroora Lineament coincides with a negative anomaly, suggesting a north dipping intrusion. Together, these two lineaments appear to define a wedge of material which has been upthrust between two arcuate faults. It is centred south of the main gravity ridge so that it has possibly involved an overthrust to the south, perhaps related to the suspected overthrust on the southern margin of the Musgrave Block in the Everard Ranges (Milton and Parker, 1973).

5.2.12 Wintiginna Lineament and Lindsay Lineament

These are similar magnetic features to the Echo and Paroora Lineaments, although somewhat less clearly defined, located on WOODROFFE and LINDSAY respectively. This is also an area of sparse outcrop and these features have not been identified by mapping.

The Wintiginna Lineament appears to be associated with a linear negative anomaly near Anpirnga Rock Hole (on Wintiginna) but elsewhere it is mainly identified by a lack of anomaly or parallel magnetic trends. The Lindsay Lineament extends across Eterinna, Moolalpinna and Illillinna and is mainly apparent as a negative anomaly (possibly lack of anomaly) but is also associated with positive anomalies near Lindsay Pile and further to the east.

Together these two lineaments enclose a significant positive gravity anomaly, part of the Blackstone Regional Gravity Ridge, suggesting that this is another zone of maximum uplift.

Several subsidiary, unnamed magnetic lineaments are apparent trending approximately east-west within this zone and at least one northeast trending dislocation (probable fault) on Wintiginna appears to displace the Wintiginna Lineament.

The Lindsay Lineament coincides closely with the southern boundary of the main positive gravity anomaly. It may also define the southern limit of the main zone of granulite facies metamorphics. South of the lineament, mapping shows amphibolite facies metamorphics, with isolated zones of mapped amphibolite-granulite transition facies rocks at Kulinja Soak and Tarleecartagun Hill.

5.2.13 Camel Pad Lineament and Bully's Lineament (Fig. 14)

Aerial photography of Eateringinna indicates two east-northeasterly lineaments, designated Camel Pad Lineament and Bully's Lineament (Conor, in prep.), extending across the entire sheet from 132°30'E to 133°00'E. The magnetic data offer some support for Bully's Lineament as it coincides with some distortions and dislocations in the magnetic trends, but the Camel Pad Lineament is less well defined and its existence is not clearly supported by the magnetic data.

5.2.14 Southern Overthrust

The southern margin of the Musgrave Block has only been partially covered by BMR aeromagnetic surveys on the western half of BIRKSGATEand eastern portions of LINDSAY and EVERARD. The remainder has been covered by widely spaced flight lines in a survey by Adastra Hunting Geophysics Pty. Ltd. for Exoil Pty. Ltd. (SADM Env. 527). It is apparent on most flight lines that the southern boundary is an abrupt transition from shallow magnetic basement to a deep cover of non-magnetic sediments. This is supported by the steep gravity gradient with pronounced negative anomalies to the south. These negative anomalies are generally attributed to a thick cover of low density sediments.

In at least one part of the southern margin (along longitude 132°30'E) a probable overthrust has been interpreted with the Everard Ranges appearing to have been thrust south over younger sediments of the Officer Basin (Milton and Parker, 1973). Unfortunately, this is an area where the regional aeromagnetic survey does not extend over the block margin and seismic data which support this interpretation are not available elsewhere.

Although aeromagnetic data suggest a sharp block margin, presumably faulted, it is difficult to interpret a dip for the contact, which might support an overthrust. Further work may be possible in this area.

5.3 Dykes

The numerous dolerite or microgabbro dykes which have been mapped throughout the Musgrave Block are rarely associated with significant magnetic anomalies. This may be partly due to lack of thickness or continuity along strike but some continuous dykes, clearly mapped along major structural features (e.g. the Davenport Fault), have no recognisable magnetic signatures.

Conor (pers. comm.) has mapped granite dykes on Kenmore and Eateringinna and although these usually contain several percent magnetite they have not been correlated with significant magnetic anomalies in the regional survey data.

In general, survey lines 1.6 km apart and at an altitude of 152 m above ground level, do not yield sufficiently detailed data for positive identification of such small features. The detailed survey conducted by McPhar Geophysics Pty. Ltd. on parts of Kenmore and Alcurra (T.S. Minerals, 1970) might have been expected to resolve dyke anomalies but it appears to have been unsuccessful (see 5.3.6).

There are some notable exceptions to this general lack of magnetic expression over dykes and they are discussed in turn below. These are invariably classified as type F anomalies.

5.3.1 Moolalpinna Hill Dyke (see Fig. 17)

A mapped basic dyke at Moolalpinna Hill (Major, 1972) trends west-northwest and coincides with a pronounced negative anomaly. Some recontouring of the existing data is desirable in this area and results in a good correlation between magnetic data and mapped geology.

The magnetometer was driven "off scale" by this anomaly on several flight lines so that its amplitude is unknown. The reversed anomaly polarity suggests remanent magnetisation.

Although not distinguished by mapping, this dyke appears to have a significantly different magnetic character from the main dyke population and a closer examination may show a significant lithological difference.

5.3.2 Oonmooninna Hill Dyke (Fig. 13)

A northwest-southeast trending pair of anomalies near the northwest corner of Eterinna has been correlated with a dyke at Oonmooninna Hill by Major (1972). Although the dyke appears to parallel a well defined magnetic trend, it seems unlikely to be the source of the anomaly which suggests a broader, tabular source. Perhaps a suite of dykes in this locality indicates a more extensive source at depth.

These trends may be traced northwest onto Cartarlinna but outcrop is sparse and no source has been identified. There may be a correlation between a parallel negative anomaly and mapped basic dykes near Dry Hill on Cartarlinna.

There are several pronounced negative linear anomalies in this area and quantitative modelling methods could be applied to interpret source parameters.

5.3.3 Cartumooninna Hill Dyke (Fig. 13) (Major, 1976)

The basic dyke mapped at Cartumooninna Hill appears to be continuous with dykes mapped at Wintiginna Hill and Lindsay Pile. This would parallel the Lindsay Lineament and probably correlates with a parallel positive magnetic anomaly which extends northeast onto WOODROFFE.

5.3.4 Old Well Dyke (Fig. 17)

A very pronounced, linear, negative magnetic anomaly was detected on several flight lines near Old Well on Indulkana ($133^{\circ}7'$E, $26^{\circ}47'$S). The magnetometer was driven "off scale" by anomalies exceeding 6 000 gamma. The total amplitude is unknown but a tabular body is indicated with a strike length (approximately east-west) of 13 to 14½ km. Geological mapping at a scale of 1:63 360 on Indulkana describes "younger intrusives: micro gabbros" in this area intruding older granitic gneisses. Later prospecting by Australian Aquitaine Petroleum Pty. Ltd. (Aquitaine, 1970) revealed a limited outcrop of ultrabasic rock near Old Well containing an unknown magnetic mineral.

Recently (1977) samples of basic and ultrabasic rocks were collected in this area by S. Warne (pers. comm.) and submitted to Pontifex and Associates Pty. Ltd. for petrological examinations. Warne noted numerous wide dykes of non-magnetic basic rocks which were described as dolerite. In addition, less common narrow dykes (1-2 m wide) were partly exposed and samples of this material were highly magnetic. This was described as a peridotite (of hartzburgite composition) with up to 10% magnetite, probably representing a layered sill (Pontifex, confidential report).

It seems probable that a much more extensive body of peridotite is present at depth although it has not been identified in previous mapping. Although its mode of emplacement may be quite complex it is apparently intrusive with strong remanent magnetisation (causing the negative anomaly) and has been tentatively designated the Old Well Dyke because of its linear character.

It is doubtful whether a closer examination of the existing magnetic data would be useful since most lines were "off scale". This is a pronounced anomaly which could easily be investigated by more detailed airborne magnetic surveys with more modern equipment (e.g. magnetometer with automatic tuning or a wider tuning range). The anomaly at Moolalpinna Hill (on Moolalpinna) may also be due to an intrusion of this type rather than the mapped basic dyke, since its magnetic response is atypical of basic dykes elsewhere in the area.

5.3.5 Wanka Wanka Dyke (26°47', 132°45')

This basic-ultrabasic dyke, over 14 km long and up to 150 m wide has been studied in some detail by the staff of Kennecott Explorations (Australia) Pty. Ltd. (Kennecott, 1970(a), 1970(b), 1971). It has been shown to have a variable composition but might have been expected to be magnetic, at least in part.

Relatively crude ground magnetic measurements by Kennecott confirmed a pronounced linear magnetic feature over the central portion of the dyke (over approximately 460 m) but the magnetic response was erratic and variable outside this zone. Airborne magnetic results show no anomaly which clearly correlates with the Wanka Wanka Dyke although more detailed measurements may have done so.

5.3.6 Victory Downs Dyke Suite

Numerous dolerite and microgabbro dykes have been observed and partially mapped intruding "biotite and hornblende adamellites" near the northern boundary of ALBERGA on Kenmore and Alcurra. These dykes are generally a few metres thick with a shallow (e.g. 20°-30°) southerly dip (Sprigg et. al. 1959 and Conor pers. comm.). This area was formerly covered by SML 226/467, held by T.S. Minerals Pty. Ltd., and the dykes have been sampled and studied in some detail (SADM Envelope 527).

The area was initially covered by a detailed airborne magnetic survey (see Fig. 24) and several anomalies, typical of broad, relatively uniform bodies were detected (McPhar, 1970). Later ground magnetic measurements by D.J. Rudd, consultant to T.S. Minerals Pty. Ltd., were obscured by erratic magnetic relief typical of shallow sources but broad anomalies could be interpreted in general agreement with the airborne results. The most pronounced narrow magnetic anomalies appeared to correlate with exposed or interpreted magnetic dykes. Samples of these dykes were studied and variously described as gabbro-microgabbro-dolerite, invariably containing significant ilmenite-magnetite. It was concluded that the broad magnetic anomalies, mapped by airborne measurements, were due to clusters of magnetic dykes, not resolved at the survey altitude.

Although there seems little doubt that these dykes must be magnetic, there is insufficient mapping to correlate them with the broad, well defined aeromagnetic anomalies. These anomalies are much more typical of the biotite adamellites (with accessory magnetite) which have been mapped on Kenmore (see Fig. 19 and Conor, 1979) and are discussed in section 5.5 of this report.

The magnetic dyke rocks intrude both the mapped adamellite and surrounding gneissic granite (Conor pers. comm.) and do not appear to have contributed significantly to the airborne magnetic results.

5.4 Metamorphic Grade

The oldest rocks identified on the Musgrave Block are metamorphics of varying composition and metamorphic grade. These include the granulites and granulite-amphibolite transition rocks of the Musgrave-Mann Metamorphics, the amphibolite facies Wataru Gneiss and equivalents and, north of the Woodroffe Thrust Zone, the possibly retrograde amphibolites of the Olia Gneiss.

It has been suggested (section 5.1) that metamorphic grade may relate very crudely to Bouguer gravity anomalies since these in turn appear to be related to the degree of uplift. While this is a broad generalisation, it seems to work reasonably well over most of the areas where metamorphic grade has been determined. No doubt it is an oversimplification of the true situation.

A general map of metamorphic grade was prepared by Forman and Shaw (1973) and is reproduced as Fig. 16 of this report. It shows that the highest grade granulites are present near Mount Davies in the northwest corner of MANN, close to exposures of Giles Complex. Granulites are also shown close to the main gravity anomalies on Caroline and Bryson. Granulites on Illillinna are close to the gravity anomaly on Anerinna and Moolalpinna.

Further east granulite-amphibolite transition rocks have been mapped on Kenmore and Eateringinna (Conor, 1977) and metamorphic grade appears to generally diminish to the east, together with a reduction in intensity of the gravity anomaly.

On the southern part of MANN and WOODROFFE and on northern BIRKSGATE and LINDSAY, a broad zone of amphibolite facies has been mapped corresponding with the Wataru Gneiss. On the basis of correlation with gravity, this zone could be modified to exclude the gravity anomaly on Anerinna and Moolalpinna (see Fig. 16).

Since a reliable estimate of metamorphic grade must depend on examination and interpretation of numerous samples, and complex variations are likely to be present, there seems little point in extending this reasoning too far, although it is interesting to note the magnetic response in these different regions.

The northwest part of MANN (and extensions to the east and southeast) is characterized by numerous linear and sublinear anomalies trending approximately east-west, roughly parallel with major structural trends. These are frequently distorted and dislocated but the main "grain" is reasonably well defined. This texture is maintained over most of the northern part of WOODROFFE and the area enclosed by the Wintiginna and Lindsay Lineaments. A similar texture on ALBERGA may be interpreted in the area enclosed by the Echo and Paroora Lineaments but it is less clearly defined to the north and east. This texture appears to characterize the granulites of highest metamorphic grade in this area.

On Eateringinna, and to some extent on adjoining sheets, there is a well-defined group of arcuate magnetic lineaments trending approximately northeast. To the east these cross the flight lines at very shallow angles and contouring becomes very subjective. However, they do parallel geological trends mapped by Conor (1977). These magnetic lineaments appear to be due to compositional layering in the granulite-amphibolite transition rocks relatively undistorted by major structural features.

On the southern part of MANN, on BIRKSGATE and on adjacent parts of WOODROFFE and LINDSAY, magnetic lineaments trend northeast or northwest and the southern margin of the Musgrave Block appears to be controlled by a series of en echelon, northwest trending lineaments. This texture seems to be characteristic of the amphibolite facies Wataru Gneiss or at least the region in which it is known to occur.

The mode of occurrence of the Kulgeran Granite is also perhaps influenced by metamorphic grade. The Permano Adamellite and Ilbillie Adamellite form broad diffuse zones with poorly defined boundaries. A large part of the southern half of MANN is possibly underlain by Kulgeran granite similar to the Permano

Adamellite. Certainly scattered outcrops of "granitoid rocks" have been mapped but limited outcrop has hindered mapping.

Further north on MANN, WOODROFFE and ALBERGA, granites appear to form more discrete masses of limited size, either elongate along faults or as discrete circular bodies (e.g. Eateringinna). It has been suggested that the deep seated anhydrous granulites do not form granites as easily as the more hydrous amphibolites (e.g. Wataru Gneiss). Thus, granite formation is controlled by faults or perhaps fault intersections and the extensive granitoid bodies mapped on BIRKSGATE and EVERARD in areas of lower grade metamorphism do not develop so readily in areas of granulite facies rocks.

Once again this is no doubt an oversimplification, but it does appear to fit the available facts.

5.5 Granites

The term Kulgeran granite is generally considered to include all granitoid rocks within the Musgrave Block (with the possible exception of some older granitic gneisses which are included in the Musgrave-Mann Metamorphics). This includes the Permano Adamellite, Ampeinna Granite, Cartoberinna Granite, Illbillie Adamellite, hornblende adamellites and charnockites on WOODROFFE and various other unnamed granitoid rocks on MANN and ALBERGA. These have all been dated at about 1000-1150 million years by the Rb/Sr method (Major, 1972, and Thomson, pers. comm.).

The Kulgeran granites are generally considered to be anatectic. Some granites appear to have remained in situ (e.g. the granitoid rocks of the Mann Ranges) while others may have mobilized and developed into intrusive bodies (e.g. Ernabella charnockite and Illbillie Adamellite). The formation of granites has been studied in some detail on Kenmore and Eateringinna by

Conor (1977); he describes granites in this area as autochthonous or parautochthonous.

It might be expected that the granites should have variable composition and hence variable magnetic properties. Variable composition has certainly been observed. Some highly magnetic samples were collected on Kenmore and Eateringinna by Conor (Wilkes, 1976) but earlier samples measured by Waller (1968) were much less magnetic. Conor's samples were collected by blasting and were likely to be fresher - possibly contributing to the difference in magnetic properties (see section 4.2).

In many cases the Kulgeran Granites clearly correlate with well defined magnetic anomalies designated type A, B or C on Fig. 12-15. Some of these clearly coincide with areas of mapped granite, others represent interpreted granite beneath cover.

Type A1 anomalies are large ovoid or amorphous zones of complex magnetic relief. They usually occur towards the southern margin of the Musgrave Block, notably on BIRKSGATE and EVERARD, in areas of relatively lower metamorphic grade. They are associated with Permano Adamellite, Illbillie Adamellite and similar rocks interpreted beneath cover.

The large areas of massive granitoid rocks mapped in the Mann Ranges and north of the Musgrave Ranges do not fit the general pattern described above. These appear to form extensive zones of anatectic granites in an area of high grade (granulite) metasediments. There is a general correlation between mapped granitoid rocks and poorly defined positive magnetic anomalies. Mapped contacts between these granitoid rocks and the enclosing metasediments are often poorly defined also and it appears probable that physical properties are gradational. These anomalies are classified type A2.

A further sub-classification A3 has been used to designate smaller A type anomalies with irregular shapes. These are usually correlated with discrete masses of magnetic granite smaller than A1 and A2 and without the distinctive shape of B and C type anomalies. They may be due to groups or combinations of B and C type anomalies; the distinction is often artificial but convenient for anomaly classification.

Type B anomalies are typically circular or ovoid with diameters of 5 to 10 km. There is a suggestion that they may be controlled by intersecting lineaments but this is far from established. They are best developed on ALBERGA where coincident granite masses (with visible magnetite) have been mapped but they also appear to be present on MANN and WOODROFFE. They seem to be concentrated in areas of high grade, anhydrous metamorphics, and contrast with the more extensive A1 type anomalies which have formed in areas of low grade hydrous amphibolites.

Type C anomalies are typically broad and elongate close to or coincident with major faults which have presumably controlled their development. Large masses of adamellite which have developed along the Ferdinand Fault, on Kenmore, are a good example (see Fig. 19). A similar body has formed along the southern margin of the Moorilyanna Graben.

Conor (1977) suggested that faults may have assisted anatexis by the introduction of heat and water. He also suggested that during anatexis water and magnetite may be released from biotite, and magnetite may also be formed from pyroxene. In any case, the resulting granites have magnetite as a common accessory mineral and are frequently magnetic.

On BIRKSGATE, Major (1968) noted an area of "grey medium grained equigranular hornblende-biotite granite" in an area bounded approximately by Unmoorinna Hill, Yaroona Hill and Cheeseman Peak (see Zone E1 Fig. 12). He noted a lack of dolerite intrusions and suggested that this may be a younger granite (i.e. younger than the Permano Adamellite to the north-west). This certainly coincides with an area of low magnetic relief which might elsewhere be considered typical of a granite but certainly atypical of the Kulgeran Granite. Magnetically this zone is distinct from other Kulgeran Granites to the north and west but the reason for this different character is not clear.

Possibly similar granites occur on LINDSAY. Various light coloured granites (presumably lacking dark minerals e.g. magnetite), including the Ampeinna Granite have been mapped in scattered outcrops on LINDSAY but there is no clear correlation with magnetic anomalies. There are few anomalies of type A, B or C on LINDSAY and none coincide with mapped outcrops of the light coloured granite. These may be similar non-magnetic granites to that interpreted on BIRKSGATE or alternatively (but improbably) the mapped outcrops may represent discrete, isolated granite bodies between flight lines and therefore not detected by the airborne survey measurements.

Detailed mapping of Kenmore and Eateringinna (Conor, 1979 and pers. comm.) has confirmed a gradational sequence of rock types from gneissic metasediments through gneissic granite to a regular, coarse grained, porphyritic adamellite with biotite, hornblende and magnetite. The broad magnetic anomaly (classified A3) on Alcurra near 133°05'-133°10'E, 26°01'-26°04'S (see Fig. 24) clearly coincides with coarse grained adamellite while surrounding rocks including adamellites generally retain some gneissic texture and can be described as gneissic granite (Conor, pers. comm.). Similarly, the A, B and C type anomalies on <u>Kenmore</u> and <u>Eateringinna</u> (now Eateringinna 1:100 000 sheet area, Fig. 19) appear to correlate with mapped "adamellitic granites", and the large A1 type anomalies on BIRKSGATE and EVERARD correlate with Permano Adamellite and Illbillie Adamellite respectively.

It appears probable that A, B and C type magnetic anomalies, correlated with magnetic Kulgeran Granite, either mapped or interpreted beneath cover, represent an end product of anatexis. Related rocks, variously described as granitic gneiss, gneissic granite, etc. are usually less magnetic and probably result from various degrees of partial anatexis. Other non-magnetic granites or non-magnetic phases of the Kulgeran Granite may also be present but would be difficult, if not impossible, to recognize.

5.6 Giles Complex

Several basic - ultrabasic bodies of Giles Complex rocks have been mapped on MANN and studied in some detail by various authors (e.g. Nesbitt <u>et</u> <u>al</u>., 1970). The major occurrences of these rocks are mapped on <u>Davies</u> (see Fig. 20). There are a number of discrete "blocks" mapped variously as ultramafic, mafic and related rocks and several large bodies of anorthosite which are not generally included in the Giles Complex but which may have similar magnetic characteristics. Michael Hills, Claude Hill, Ewarara, Kalka, Mount Davies and Gosses Pile are the main basic and ultrabasic occurrences. Teizi (Gray, 1967) is an anorthosite which has been included in the Giles Complex by Nesbitt <u>et</u> <u>al</u>. (1970) but not on the published geological map. North and west of Teizi, several other occurrences of anorthosite are mapped and these appear to have similar magnetic expression.

These discrete bodies or "blocks" are often too small to be adequately defined by measurements on flight lines spaced one mile apart; however, a general pattern seems evident. With the possible exception of the Hinckley Range mass and the western part of Kalka, all major mapped occurrences of Giles Complex rocks coincide with negative magnetic anomalies, with positive anomalies near the southern boundary (see Fig. 21). This is the reverse of the pattern to be expected from induced magnetisation and it is presumably influenced mainly by remanent magnetisation. Paleomagnetic measurements by Facer (1969), used samples from various Giles Complex bodies in SA and WA. Most samples were from Kalka, Mount Davies and Gosses Pile (82%) and these gave a mean direction of stable remanent magnetisation displaced by 121^{o} from the earth's field (mean remanence declination 343^{o}, inclination $+62^{o}$, c.f. earth's field declination 4^{o}, inclination -58^{o}).

It appears probable that a combination of remanent and induced magnetisation can adequately explain the observed anomaly patterns although attempts to reproduce these patterns (by computer modelling of Mount Davies) have not been very successful. Lack of homogeneity and interference from adjacent magnetic bodies makes the observed patterns difficult to simulate in detail. In any case the observed negative anomalies are consistent with the reversed remanent magnetisation deduced by Facer (1969).

The Hinckley Range mass appears more complex. The northern half of this block is strongly influenced by a zone of dark coloured granulites and several discrete bodies of massive magnetite. This coincides with a positive magnetic anomaly bounded to the south by a negative anomaly over the northern margin of the Hinckley Range zone of Giles Complex rocks. To the south, the Hinckley Range is bounded by a negative anomaly associated with Hinckley Fault. The magnetic response of the intervening Giles Complex material is therefore difficult to assess.

Magnetic anomalies associated with the known bodies of Giles Complex rocks are outlined on Figs. 12 and 21 and designated type D, with numbers to identify the various named bodies as listed below.

D1	Claude Hills
D2	Ewarara
D3	Teizi
D4	Hinckley Range
D5	Kalka (Dulgunja Hill)
D6	Michael Hills
D7	Mount Davies
D8	Gosses Pile

Several other type D anomalies are shown on MANN and these presumably represent occurrences of similar rocks (Giles Complex or anorthosite) beneath cover. In several places this interpretation is supported by scattered outcrops; in others no outcrop has been mapped but the magnetic pattern suggests a discrete body with remanent magnetisation opposing the present earth's field.

An ovoid mass of similar rocks on Caroline has been investigated in some detail. This area is normally considered part of the Giles Complex but it coincides with a positive magnetic anomaly and is therefore differentiated in this report and discussed in section 5.7.2.

Further east on WOODROFFE there are several mapped occurrences of Giles Complex rocks in the area between the Davenport Fault and the Woodroffe Thrust Zone. These generally coincide with type D anomalies and some additional, unmapped Giles Complex rocks are suggested by the magnetic pattern.

Finally, on Ernabella, a zone of micronorite has been mapped immediately south of the Ferdinand Fault. Although exposure is somewhat limited, particularly to the south, this elongate body appears to be clearly associated with a negative magnetic anomaly. An associated positive anomaly to the south may overlie additional micronorite beneath cover or simply indicate a more magnetic zone within the surrounding hypersthene adamellite (Ernabella Charnockite). The negative and positive anomalies have been tentatively grouped together and classified as a type D feature but the pattern is complex and unclear.

5.7 Other Intrusions

There are many small magnetic features, often detected on only one flight line, which may represent intrusions, and other known intrusive bodies which are too small for detection with flight lines 1.5 km apart (e.g. Marryat Norites, Conor, 1977). Several major anomalies suggest roughly equidimensional intrusive bodies and they are discussed in turn below.

5.7.1 Moulden Anomaly (E3, Fig. 12)

A pronounced, circular, negative anomaly on Moulden with a diameter of approximately 10 km is unexplained. It occurs in an area of no mapped outcrop and has previously been considered to represent a large mass of anorthosite similar to mapped anorthosites to the northeast, near Krewinkel Hill (Mirams, 1964).

The mapped anorthosites tend to follow a ridge in the Bouguer gravity map (discussed earlier) and this circular anomaly would be displaced to the southwest with no apparent coincident gravity anomaly. The mapped anorthosites do not coincide with obvious type D magnetic anomalies.

The anomaly pattern suggests a roughly circular source with remanent magnetisation similar to the Giles Complex but with perhaps greater depth extent than has been attributed to previously mapped occurrences. It seems probable that the Moulden Anomaly represents a major intrusive "pipe" several miles in diameter whose magnetic characteristics and hence composition may be similar to the Giles Complex.

5.7.2 Caroline Intrusion (Fig. 13)

A large ovoid area approximately 18 km by 8 km of positive magnetic anomalies on Caroline coincides with a pronounced positive Bouguer gravity anomaly and mapped basic-ultrabasic rocks (mainly anorthosites and leucotroctolites). This has been classified as part of the Giles Complex by Major (1973) but has distinctly different magnetic properties from other rocks in this group.

The positive magnetic response implies different remanent magnetisation from other Giles Complex rocks suggesting a possible different age of cooling.

This area has been studied in some detail by officers of the SADM (Miller, 1969); however, the main objective was to locate concentrations of nickeliferous ochre. Drilling was usually designed to test gravity lows, which had been shown to correlate with ochre near Mount Davies, but two drill holes (CR1 and CR3) did test flanking ridges. They encountered fresh anorthosite a few feet below the surface with up to 30-35% magnetite in one hole (CR1).

If the high magnetite concentration is widespread throughout this zone, it would explain both the observed gravity and magnetic results. Miller (1969) has interpreted this zone as a late stage differentiate of the Giles Complex, more felsic than intrusions on MANN and of less economic significance as a possible host for nickel. The possibility of concentrations of vanadium bearing magnetite was mentioned but not pursued. Such concentrations may be apparent if the area was surveyed by detailed low level aeromagnetics; the present data are too widely spaced for evaluation. The gravity anomaly is superimposed on a regional feature (the Blackstone Regional Gravity Ridge) but a local anomaly of approximately 50 mgal is apparent, suggesting that the limited exposure is merely the surface expression of a larger mass of basic-ultrabasic rock with a great depth extent.

5.7.3 Harcus Anomaly (E4, Fig. 12)

A small but intense negative magnetic anomaly was detected near the centre of Harcus. This negative anomaly has a maximum amplitude of five to six thousand gamma but it is primarily defined on only two flight lines. The anomaly has two negative peaks, roughly equal in amplitude. There is no basement outcrop mapped in this area and the source is completely unknown. It appears likely to indicate a basic or ultrabasic intrusive with strong remanent magnetisation. It appears to be too far south to be related to the Giles Complex and may be unique.

Two small occurrences of basic rocks were mapped about 16 km to the northwest, near Imandi. These appear to have no significant magnetic expression but may be isolated samples of a similar rock, not detected at the survey line spacing.

5.7.4 Crombie Anomaly (E5, Figs. 7, 13)

An intense local positive magnetic anomaly was detected near the centre of Crombie. It has an amplitude of approximately 4 000 gammas but was detected on only two flight lines. This anomaly is approximately 8 km west of mapped charnockite of the Kulgeran Granite at Mt. Crombie and may be related. However, it appears more intense than anomalies usually associated with the Kulgeran Granite.

There is a possible local Bouguer gravity anomaly associated with this feature but the station spacing is too great to be certain. No outcrop has been mapped at this location but a small isolated outcrop of basic intrusive was noted about 3 km to the southwest (Major, 1973). The source of this anomaly is unknown; it may be an intrusive pipe of basic-ultrabasic rock of limited lateral dimensions.

5.7.5 E6 type anomalies and WEINNA Hill

Several discrete anomalies of similar character were identified on MANN and WOODROFFE. These appear as a ring of positive anomalies surrounding a region of negative or background values. They have been collectively designated E6 on Figs. 12 and 13. Anomalies of this type were generally defined on only one or two flight lines so the interpreted shape is highly subjective. A good example can be seen near Weinna Hill on Anerinna (Fig. 13). The significance of these anomalies is highly speculative. They may represent an alteration halo around a non-magnetic or weakly magnetic (presumably acid to intermediate) intrusive.

5.8 Grabens

Two apparently fault bounded depressions filled with Adelaidean sediments have been identified by mapping on the Musgrave Block.

5.8.1 Levenger Graben (see Fig. 22)

The Levenger Graben was suggested by Major (1973) to explain the apparently fault bounded depression on WOODROFFE containing Adelaidean shales and siltstones of the Levenger Formation. Mapping shows this depression to be bounded to the north by the Mann Fault. The other boundaries have been interpreted by this author from the magnetic results which outline a rectangular area devoid of short wavelength anomalies.

The boundaries are sometimes difficult to define. The northern margin can be interpolated between mapped exposures of mylonites identified with the Mann Fault, but the southern margin appears gradational. It may not be a fault contact, so that the depression may be a half graben.

The western or perhaps northwestern boundaries may be a set of en echelon fault contacts but the eastern boundary is again unclear.

Although few anomalies within the area of the suggested graben were suitable for quantitative evaluation, some depth estimates were attempted. Magnetometer records were presented at a very small scale and often showed excessive noise. However, a number of depth estimates were obtained in the range 200 m to 500 m. These estimates were obtained by approximate methods (e.g. straight slope, half slope and point of inflexion techniques) applied to the original analogue charts. Sources of these anomalies may represent magnetic basement but it seems more likely that they are due to magnetic intrusives within the sediments.

The depression could be more clearly defined by a detailed low level aeromagnetic survey or by ground magnetic measurements. If better data could be obtained it may then prove possible to interpret the attitude of the boundaries. In addition better estimates of the thickness of sediments may be possible from the detailed magnetic data supported by additional gravity measurements.

5.8.2 <u>Moorilyanna Graben</u> (see Fig. 23)

The Moorilyanna Graben is another fault bounded depression filled with Adelaidean sediments (Moorilyanna Conglomerate) and it is often considered equivalent to the Levenger Graben.

It has been mainly described on <u>Moorilyanna</u> and the western part of <u>Indulkana</u> (Coats, 1962, 1963) but probably extends much further to the east beneath cover. The boundaries of this depression are often unclear as faults controlling them were probably active during sedimentation (Coats, 1962).

The Moorilyanna Graben is apparent on the magnetic contour map as an area devoid of anomalies and bounded at least in part by linear (east-west) anomalies presumably associated with faults. On the eastern half of <u>Indulkana</u>, the graben appears to broaden considerably and it may extend as far north as the De Rose Lineament. This depression appears open to the east; it disappears beneath cover on ABMINGA and merges with the sediments of the Great Artesian Basin.

5.9 Younger Rocks

Although not strictly part of the Musgrave Block several magnetic features were observed in younger sediments around the margins of the area of shallow basement. Two examples are described below.

5.9.1 Wright Hill Formation

An F type anomaly was interpreted coincident with an anticlinal ridge of Adelaidean Wright Hill Formation in the Patricia Johnson Hills on Permano and Wirrildar (see Fig. 12). The amplitude of this anomaly (approximately 100 gamma) is too small for it to be clearly defined with 50 gamma contours. However, it is a quite recognizable feature.

The Wright Hill Formation includes siltstone, sandstone, quartzite and black oolitic chert (Major, 1968). The source of this magnetic expression is not known but it is presumably a slightly iron rich sediment or metasediments within this formation.

5.9.2 Wantapella Volcanics

A group of sinuous F type anomalies near the northern boundary of WINTINNA (Fig. 15) appear to correlate with the Sturtian Wantapella Volcanics which have been mapped further west on EVERARD. The anomalies, although not pronounced (less than 100 gammas) are quite clearly defined on the analogue charts and appear typical of a shallow dipping body. They presumably outline an exposed or suboutcropping edge of a flat-lying bed of volcanics. The Wantapella Volcanics, which is described as "grey green vesicular basalt" (Kreig, 1973), is the most probable source.

5.10 Mineralization

Wilson (1969(a), 1969(b)) has drawn attention to the potential for economic minerals in granulite terrains. Base metal sulphide deposits may be present in virtually any part of the Musgrave Block and several specific areas are noted here.

(i) Metamorphosed syngenetic and concordant ore bodies (Wilson, 1969(a)).

"Syngenetic sulphide and oxide concentrations associated with layered basic intrusions or concordant sulphide deposits (e.g. lead-zinc at Mt. Isa) may be metamorphosed to granulites. During metamorphism the character of the deposit may change to give a combination of hydrothermal and syngenetic features. An example might be the lead-zinc lodes at Broken Hill which occur in granulite-amphibolite facies metamorphic rocks".

The Kenmore - Eateringinna area is apparently an environment of similar metamorphic grade (Conor, 1977) and exploration by officers of the SADM has located widespread sulphide mineralisation with, so far, none of economic significance (Miller and Gerdes, 1970; Taylor, 1971; Barnes et al., 1971; Nelson and Taylor, 1972; Wightman and Taylor, 1973).

(ii) Numerous major faults have been mapped through the Musgrave Block and several phases of movement have been suggested. These could provide structural traps for deposition of metamorphosed epigenetic ore bodies (Wilson, 1969). Possible examples are numerous.

(iii) Wilson (1969(a))suggested that "disseminated sulphides and oxides may be expected in upper levels of plutons derived from partial fusion of granulite terranes. The resulting plutons will be pyroxenic and more iron rich than normal granites". This description appears to fit the magnetic granites and adamellites so widespread in the Musgrave Block and frequently identified as type B or type C magnetic anomalies.

(iv) Wilson (1969(a)) also suggested zones of retrograde metamorphism as prospective for metallic sulphide concentrations. Metamorphic rocks immediately north of the Woodroffe Thrust Zone are often considered retrograde (e.g. Thomson, 1975), and included with the Olia Gneiss. No extensive prospecting has been recorded in this area.

(v) The layered basic-ultrabasic intrusives of the Giles Complex have been studied in great detail by many workers and actively prospected for nickel. Most of this prospecting was devoted to the search for nickeliferous ochre and extensive but uneconomic deposits were located. Some electromagnetic techniques were used in the search for sulphide mineralisation but these were generally ineffective.

Nesbitt _et al_. (1970) have suggested that the Giles Complex is remarkable for its absence of economic deposits of platinum, chromium and vanadium in comparison with the Bushveld Complex of South Africa. Although their conclusions are based on a great deal of work, they cannot be assumed to have exhausted all possibilities for deposits of this type (see e.g. Miller, 1973). In addition, the possibility of concentrations of nickel sulphides has not been eliminated and further prospecting with modern methods (e.g. detailed low level aeromagnetics, induced polarization, etc.) would be desirable.

(vi) Several other known or probable basic-ultrabasic intrusions have been mapped or interpreted from the aeromagnetic results (e.g. Caroline Intrusion, Moulden Anomaly, Harcus Anomaly, Crombie Anomaly, Moolalpinna Hill Dyke, Old Well Dyke, etc.). Although the Caroline Intrusion has been prospected for nickeliferous ochre and tested by drilling in several localities, a large area of basic-ultrabasic rocks may be present beneath shallow cover and further exploration appears warranted. The other intrusions listed above have not been prospected and remain largely unknown.

The Wanka-Wanka Dyke was prospected by Kennecott (1970) and shown to be of basic-ultrabasic composition. This dyke was not detected by the regional aeromagnetic survey although ground measurements showed it to be magnetic with a strike length in excess of 14 km. Numerous other bodies of this type may exist undiscovered within the Musgrave Block.

(vii) The Adelaidean sediments within the Levenger Graben and Moorilyanna Graben may be prospective for sedimentary copper or uranium and remain untested. More extensive areas of similar sediments may be present beneath shallow cover, east of the Moorilyanna Graben on ABMINGA. Estimates of depth to magnetic basement may be possible with the magnetic results in this area.

Additional areas of Adelaidean sediments near the southern margin of the Musgrave Block, on BIRKSGATE and LINDSAY have not been prospected.

(viii) Finally, minor gold-copper mineralisation has been noted in the Indulkana fault zone north of the Indulkana Range on ALBERGA (Coats, 1963). There is no evidence be better understood if they could be surveyed in greater detail. Detailed airborne magnetic surveys would be most desirable in areas of possible economic significance (e.g. Giles Complex, Caroline Intrusion, etc.). Economic mineral concentrations are unlikely to be detected with survey lines 1.6 km apart and even broad regional features are often obscure. The dramatic increase in resolution possible with more detailed measurements is illustrated by survey results on Eateringinna and Alcurra (c.f. Figs. 19, 24).

A major part of the Musgrave Block in SA is contained in the North West Aboriginal Reserve. Access for further exploration is difficult and in any case unattractive without some real encouragement. Potential for the occurrence of economic mineral deposits in this area exists but remains relatively untested.

7. ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the contributions of the staff of the Geological Survey of SA in the preparation of this report. The project was initiated and supervised by Mr. B.E. Milton and liaison with the geophysics group was via Mr. D.C. Roberts. Geological interpretation was influenced by many valuable discussions with Messrs. B.P. Thompson, R. Major, and C. Conor. Many other staff members, both geologists and geophysicist, contributed by discussion and suggestions. All drafting was carried out with patience and forebearance by the Geological Survey drafting staff under the direct supervision of Mr. Peter Knoblauch.

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R.J. SMITH

of extensive prospecting and more extensive deposits may well remain undiscovered.

6. CONCLUSIONS AND RECOMMENDATIONS

This report covers a large area which is, as yet, only poorly understood. Large areas of granulite and amphibolite metamorphics intruded by younger granites and basic-ultrabasics have been mapped, together with structural features of possible continental significance.

Most of the Musgrave Block in South Australia has been covered by regional aeromagnetic surveys with north-south flight lines spaced 1.6 km apart. Many discrete magnetic bodies are inadequately defined with this line spacing, but a number of larger features have been recognised and described. Linear anomalies or trends oriented east-west are perhaps the most readily recognisable features and broad zones of increased magnetic relief associated with granites are readily recognizable but often have poorly defined boundaries.

An attempt has been made to classify type A, B, C and D anomalies which can be tentatively correlated with Giles Complex intrusives and various granites. This classification is often subjective and many anomalies defy such a simplistic approach.

A number of discrete features (e.g. Old Well Dyke, Moulden Anomaly, Harcus Anomaly, Levenger and Moorilyanna Grabens, etc.) could be readily studied in more detail. The existing magnetic data could be used initially but more detailed measurements with a closer line spacing would be desirable.

In the longer term, additional airborne magnetic data would be desirable to complete coverage of the southern margin of the Musgrave Block on BIRKSGATE, LINDSAY and EVERARD. Areas of great complexity or major structural significance (e.g. the apparent intersection of the Mann Fault and Ferdinand Fault) may be better understood if they could be surveyed in greater detail. Detailed airborne magnetic surveys would be most desirable in areas of possible economic significance (e.g. Giles Complex, Caroline Intrusion, etc.). Economic mineral concentrations are unlikely to be detected with survey lines 1.6 km apart and even broad regional features are often obscure. The dramatic increase in resolution possible with more detailed measurements is illustrated by survey results on Eateringinna and Alcurra (c.f. Figs. 19, 24).

A major part of the Musgrave Block in SA is contained in the North West Aboriginal Reserve. Access for further exploration is difficult and in any case unattractive without some real encouragement. Potential for the occurrence of economic mineral deposits in this area exists but remains relatively untested.

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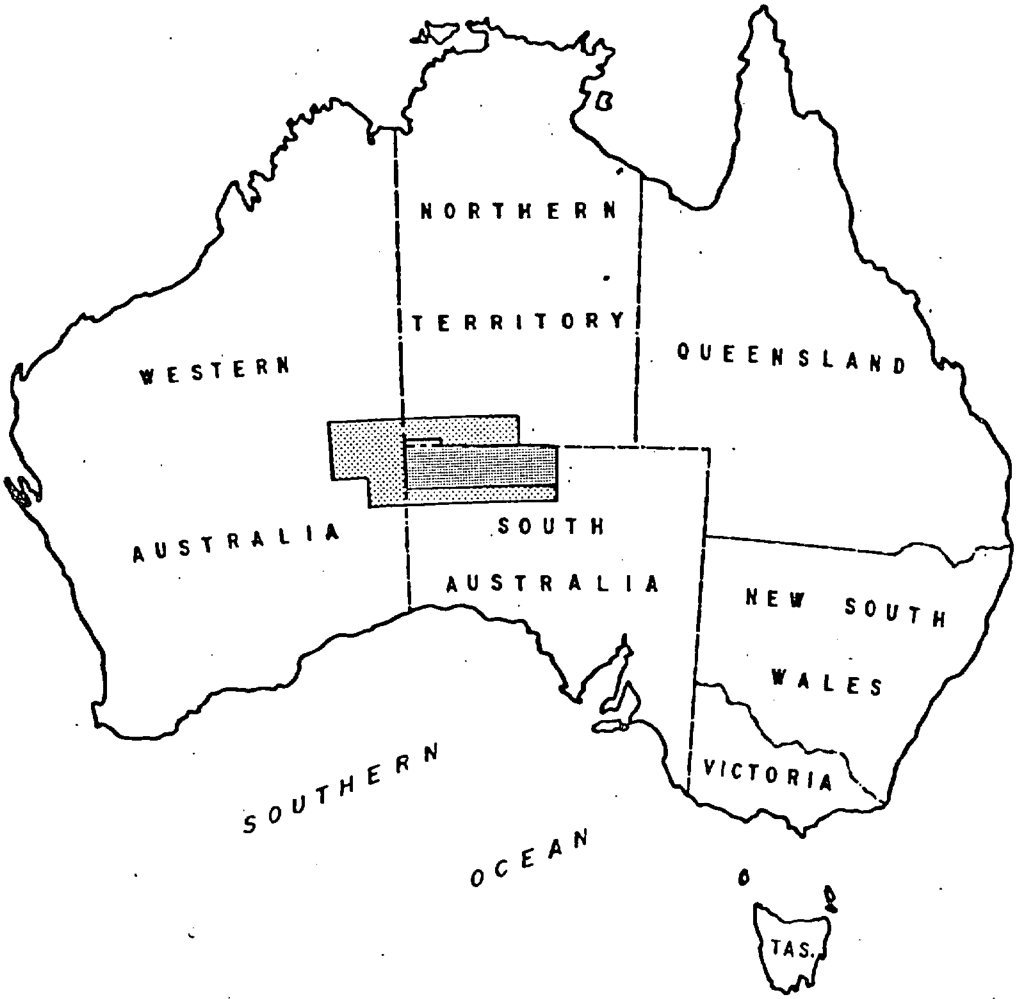


INDEX TO 1:250 000 SHEETS

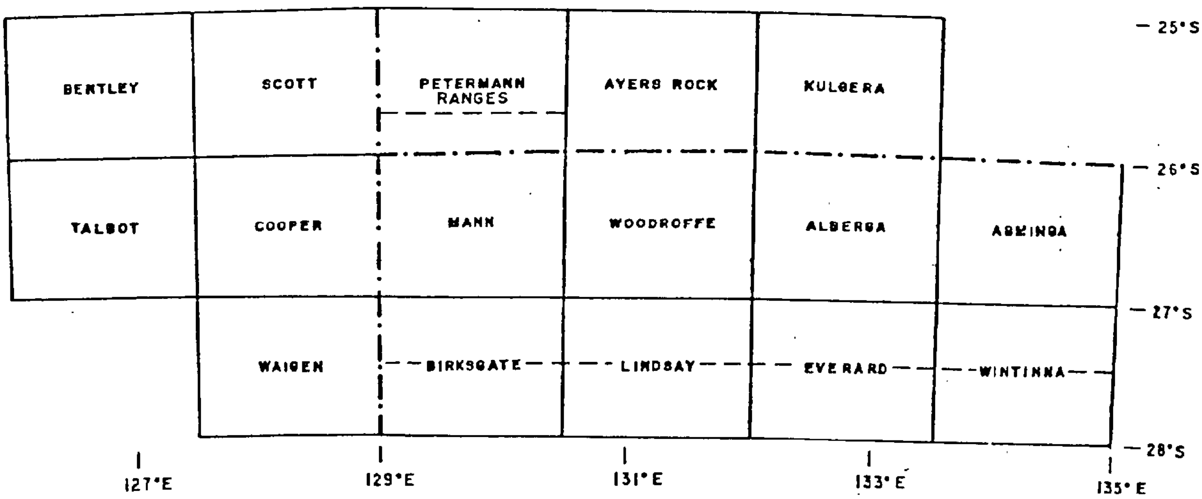


Fig. 1

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE
COMPILED: R. SMITH	MUSGRAVE BLOCK LOCALITY PLAN	DATE: 19 · 4 · 78
DRN. K.S.J. CKD:		PLAN NUMBER S 13362

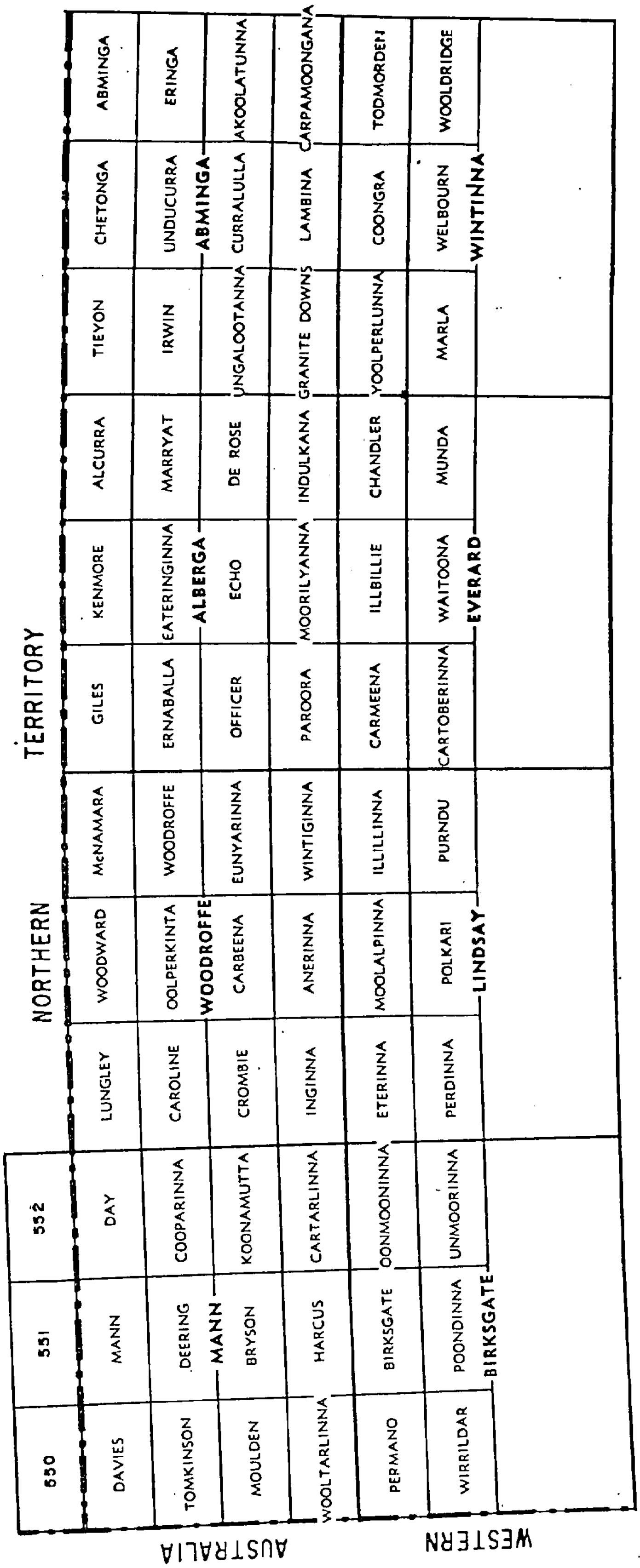


Fig. 2

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE:
COMPILED: R. SMITH	MUSGRAVE BLOCK	DATE: 6 · 12 · 78
DRN: K.S.J. CKD:	INDEX TO ADJOINING 1:63 360 SHEETS	PLAN NUMBER S 13807

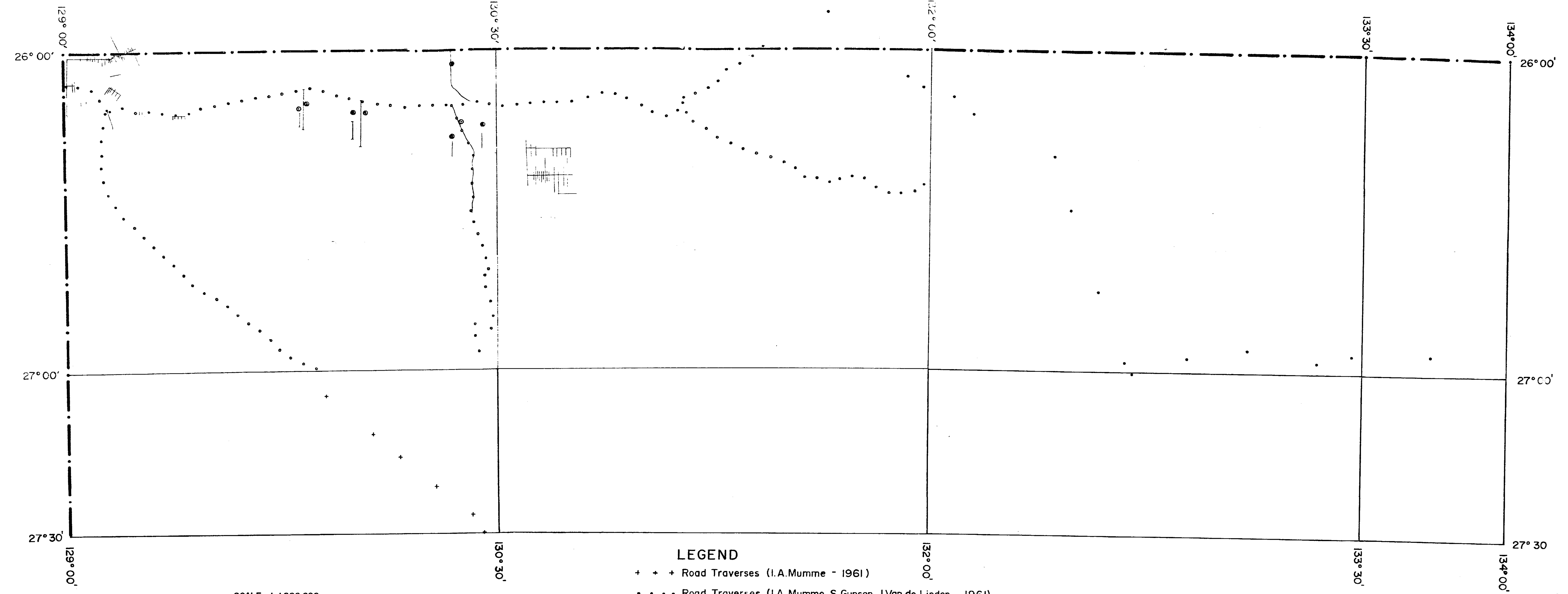
Fig.3

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

SUMMARY OF AIRBORNE MAGNETIC SURVEYS

MUSGRAVE BLOCK, S.A., W.A. and N.T.

	COMPILED: R.SMITH	DRN: M.G.	SCALE: 1:1000 000	PLAN NUMBER
DIRECTOR GENERAL		CKD:	DATE: 3-10-78	78-76



LEGEND

+ + + Road Traverses (I.A.Mumme - 1961)

• • • • Road Traverses (I.A. Mumme, S. Gunson, J.Van de Linden - 1961)

ooooooo Road Traverses (I.S. Rowan - 1967)

Detailed Survey grids. (D.M. Pegum-1961, J. Mc G. Hall -1966)

SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

Fig.4

COMPILED: R. Smith	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: 1:1000000
DRN: T. G. CKD.	MUSGRAVE BLOCK	DATE: 14 · 4 · 78
	SUMMARY OF PREVIOUS GRAVITY SURVEYS	PLAN NUMBER 78-334

Fig 5

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

MUSGRAVE BLOCK
BOUGUER ANOMALY CONTOURS
S.A., N.T. and W.A. (part only)

DIRECTOR GENERAL	COMPILED R.SMITH	DRN M.B.	SCALE 1:1 000 000	PLAN NUMBER
		CKD	DATE 18-4-78	78-341

Fig.6

DEPARTMENT OF MINES AND ENERGY– SOUTH AUSTRALIA				
MUSGRAVE BLOCK AEROMAGNETIC MAP OF TOTAL INTENSITY				
	COMPILED: R.Smith	DRN: T.G.	SCALE: 1:1000 000	PLAN NUMBER 78–463
DIRECTOR GENERAL		CKD:	DATE: 15·6·78	

INTERPRETED FEATURES

MAJOR LINEAMENTS.............. MANN FAULT

MINOR LINEAMENTS..............

BOUNDARY OF SHALLOW MAGNETIC BASEMENT..............

GILES COMPLEX.............................. D

DISCRETE BODIES.............................. A

DISLOCATIONS (POSSIBLE FAULTS)..............

SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

Contour interval 100 nT

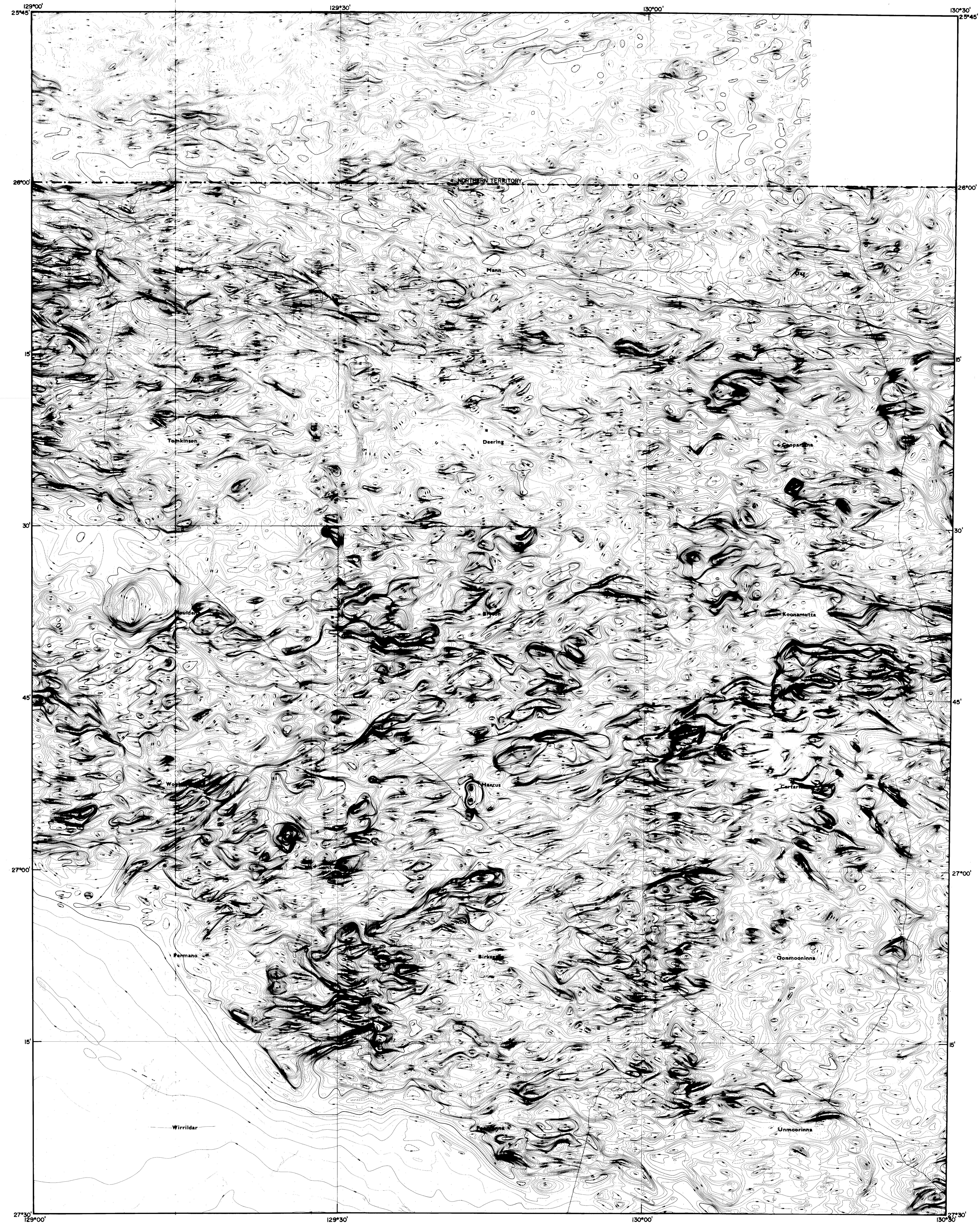
Fig.7

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

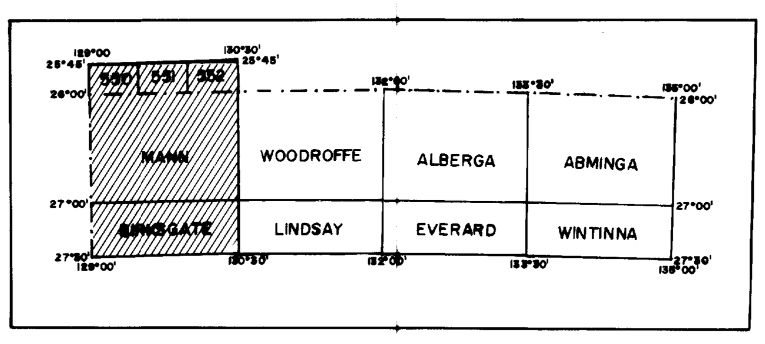
MUSGRAVE BLOCK

AEROMAGNETIC CONTOURS WITH INTERPRETED MAJOR FEATURES.

	COMPILED R.Smith	DRN N.D.G.	SCALE 1:1 000 000	PLAN NUMBER 78–797
DIRECTOR GENERAL		CKD	DATE 16·10·78	



INDEX TO ADJOINING SHEETS



Contour Interval 50nT

SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

LEGEND

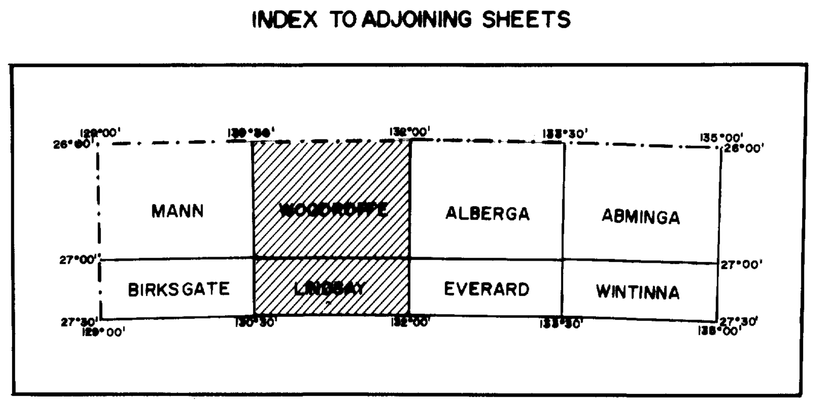
MAGNETIC CONTOURS (values in gammas) 300

FLIGHT LINES .... - - - - - -

Fig.8

DEPARTMENT OF MINES AND ENERGY– SOUTH AUSTRAI.IA				
MUSGRAVE BLOCK AEROMAGNETIC MAP OF TOTAL INTENSITY. MANN, BIRKSGATE (Part of) & 550, 551, 552.				
	COMPILED: R.SMITH.	DRN: D.O.	SCALE: 1:250000	PLAN NUMBER 78-397
DIRECTOR GENERAL		CKD:	DATE: 12·5·78	

INDEX TO ADJOINING SHEETS



Contour Interval 50nT

SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

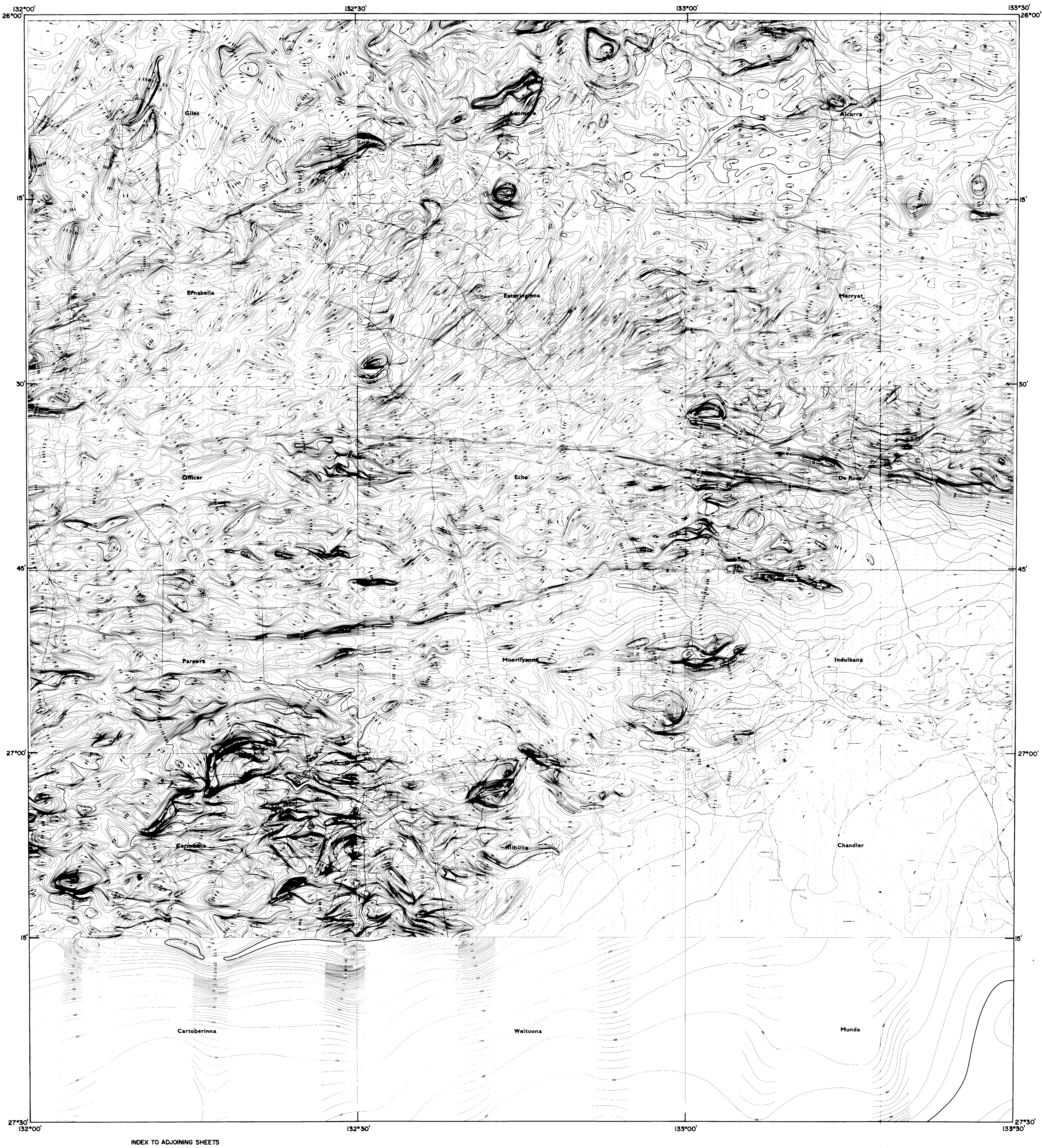
LEGEND

MAGNETIC CONTOURS (values in gammas) 300

FLIGHT LINES .... - - - - - -

Fig.9

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA				
MUSGRAVE BLOCK				
AEROMAGNETIC MAP OF TOTAL INTENSITY.				
WOODROFFE & LINDSAY. (Part of)				
	COMPILED: R.SMITH.	DRN: D.O.	SCALE: 1:250000	PLAN NUMBER 78-398
DIRECTOR GENERAL		CKD:	DATE: 24·4·78	



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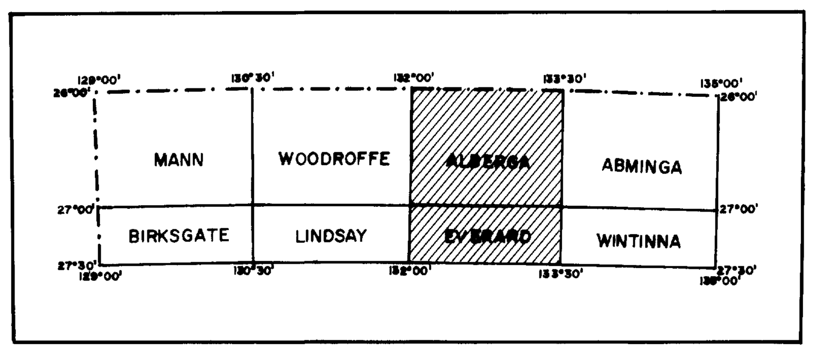


Contour Interval 50nT

SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

LEGEND

MAGNETIC CONTOURS (values in gammas) 300

FLIGHT LINES .... - - - - - - -

Fig.10

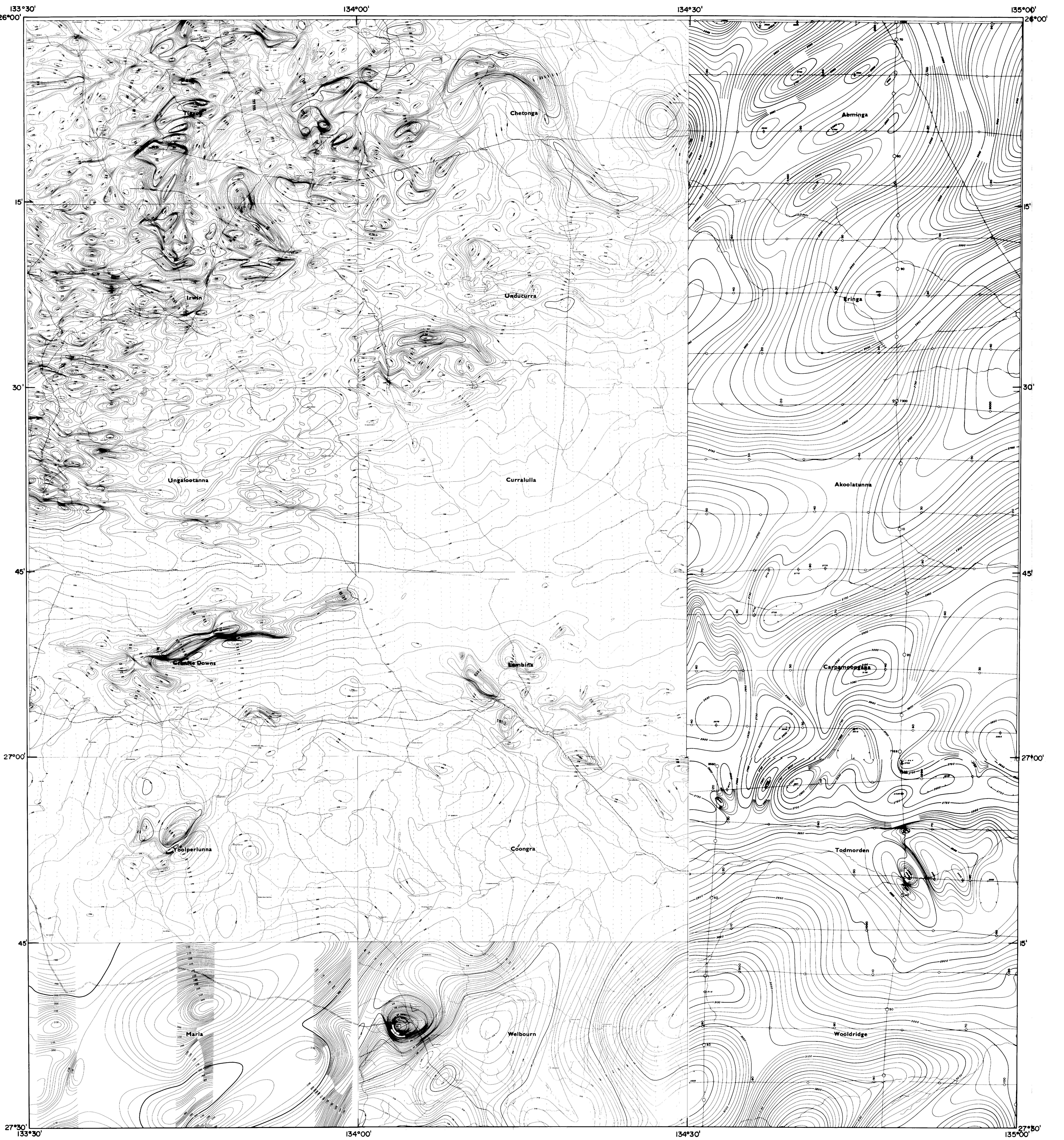
DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

MUSGRAVE BLOCK

AEROMAGNETIC MAP OF TOTAL INTENSITY.

ALBERGA & EVERARD.(Part of)

	COMPILED: R.SMITH.	DRN: D.O.	SCALE: 1:250000	PLAN NUMBER 78-396
DIRECTOR GENERAL		CKD:	DATE: 12·5·78	



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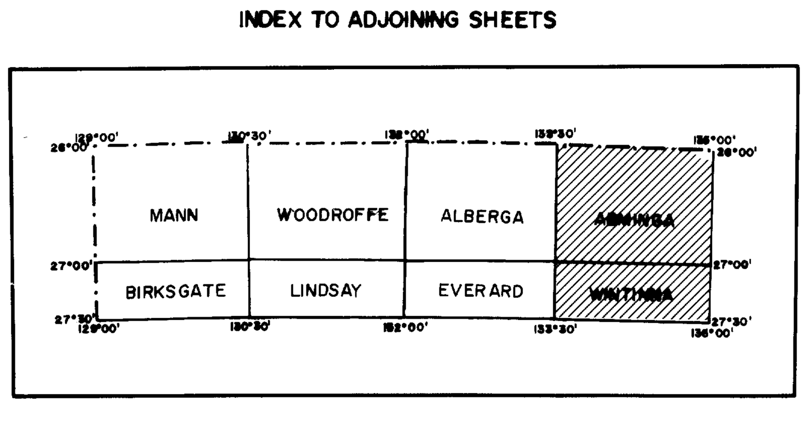


Contour Interval 50nT

SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

LEGEND

MAGNETIC CONTOURS (values in gammas) 300

FLIGHT LINES .... - - - - - -

Fig.11

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA				
MUSGRAVE BLOCK AEROMAGNETIC MAP OF TOTAL INTENSITY. ABMINGA & WINTINNA. (Part of)				
	COMPILED: R.SMITH.	DRN: D.O.	SCALE: 1:250000	PLAN NUMBER 78-395
DIRECTOR GENERAL		CKD:	DATE: 11·5·78	

ZONE BOUNDARIES DISCRETE ANOMALIES

SHALLOW / DEEP — BOUNDARY OF SHALLOW BASEMENT

DISLOCATION, POSSIBLE FAULT

POSITIVE LINEAR ANOMALY

NEGATIVE LINEAR ANOMALY

ELONGATE SOURCE

SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 KILOMETRES

Contour Interval 100nT

Fig.12

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

MANN – BIRKSGATE

AEROMAGNETIC CONTOURS WITH INTERPRETATION

COMPILED R.Smith	DRN T.G.	SCALE 1:250 000	PLAN NUMBER 78-798
DIRECTOR GENERAL	CKD	DATE 17-10-78	

ZONE BOUNDARIES DISCRETE ANOMALIES

SHALLOW / DEEP — BOUNDARY OF SHALLOW BASEMENT

DISLOCATION, POSSIBLE FAULT

POSITIVE LINEAR ANOMALY

NEGATIVE LINEAR ANOMALY

ELONGATE SOURCE

SCALE 1:250000

KILOMETRES 5 0 5 10 15 20 KILOMETRES

Contour Interval 100nT

Fig.13

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

WOODROFFE & LINDSAY

AEROMAGNETIC CONTOURS WITH INTERPRETATION

	COMPILED R.SMITH	DRN M.B.	SCALE 1:250 000	PLAN NUMBER
DIRECTOR GENERAL		CKD	DATE 12·10·78	78-784

WOODROFFE THRUST ZONE

ELONGATE SOURCE

POSITIVE LINEAR ANOMALY

NEGATIVE LINEAR ANOMALY

A ZONE BOUNDARIES DISCRETE ANOMALIES

SHALLOW / DEEP BOUNDARY OF SHALLOW BASEMENT

DISLOCATION, POSSIBLE FAULT

SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

Contour Interval 100 nT

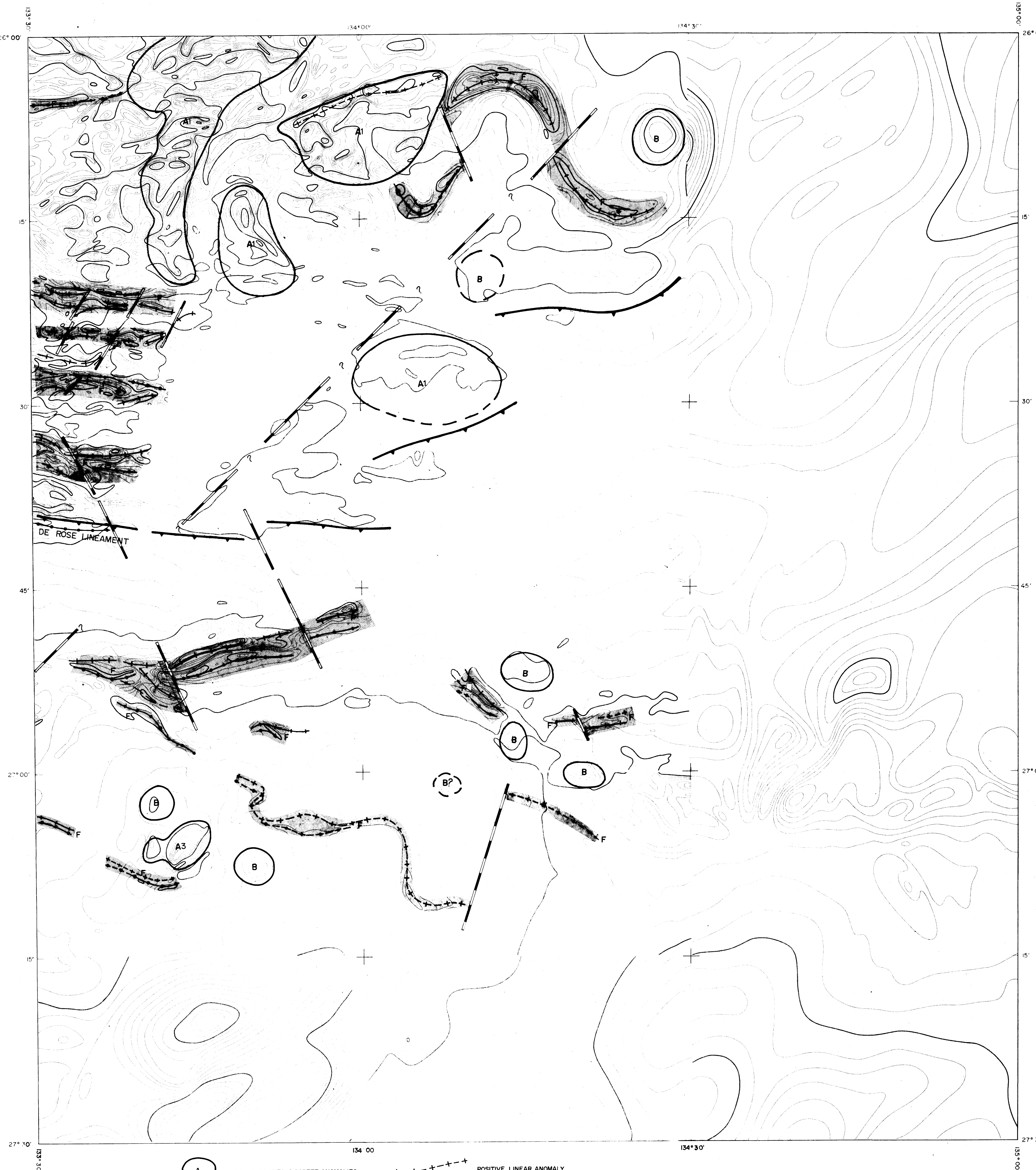
Fig 14

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

ALBERGA – EVERARD

AEROMAGNETIC CONTOURS WITH INTERPRETATION

	COMPILED R. SMITH	DRN K. S. J.	SCALE 1:250 000	PLAN NUMBER 78-814
DIRECTOR GENERAL		CKD	DATE 26 · 10 · 78	



ZONE BOUNDARIES DISCRETE ANOMALIES

SHALLOW / DEEP BOUNDARY OF SHALLOW BASEMENT

DISLOCATION, POSSIBLE FAULT

POSITIVE LINEAR ANOMALY

NEGATIVE LINEAR ANOMALY

ELONGATE SOURCE

SCALE 1:250000

KILOMETRES 5 0 5 10 15 20 KILOMETRES

Contour Interval 100nT

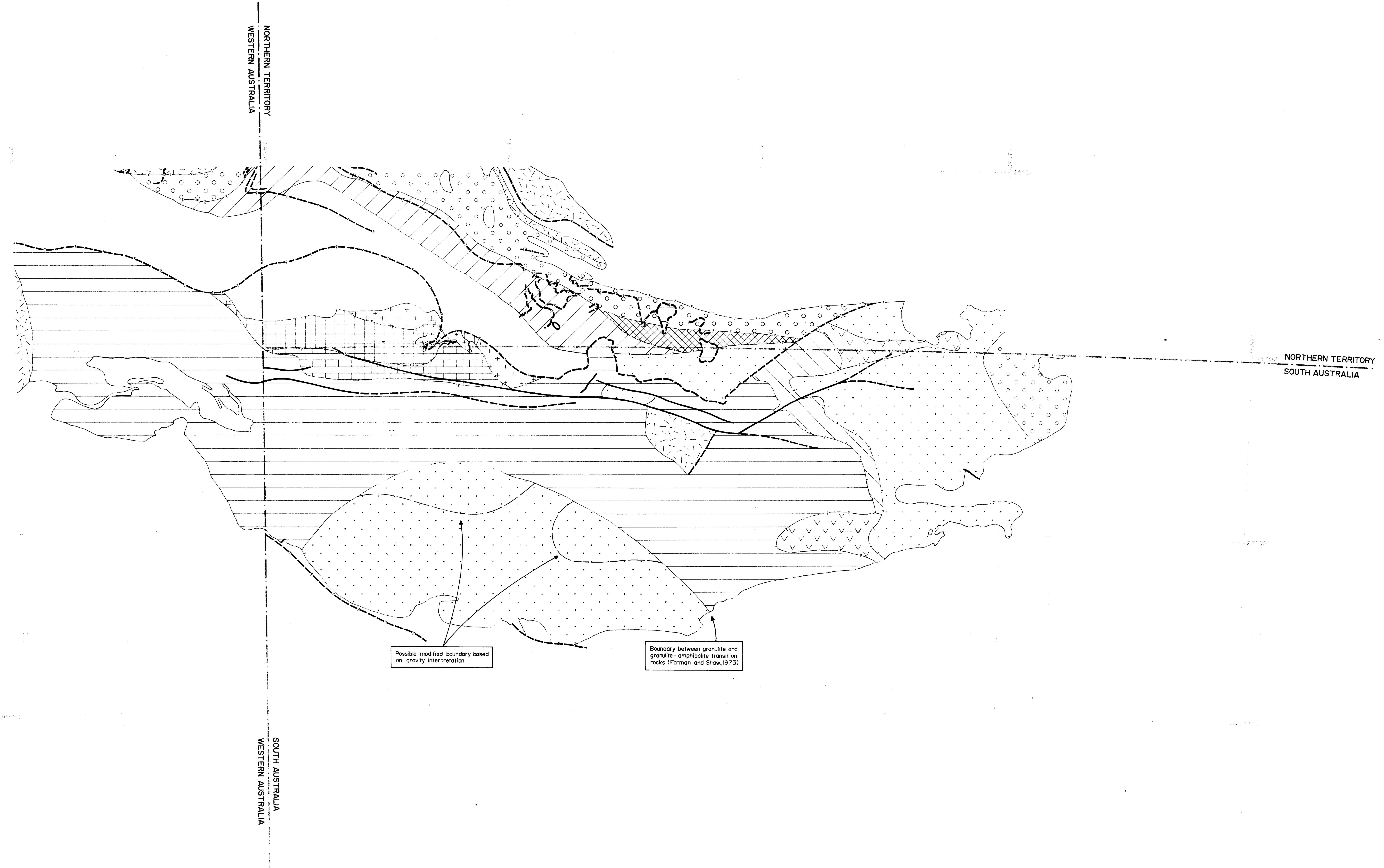
Fig.15

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

ABMINGA & WINTINNA (Part of)

AEROMAGNETIC CONTOURS WITH INTERPRETATION

	COMPILED R.SMITH.	DRN D.O.	SCALE 1:250000	PLAN NUMBER 78-369.
DIRECTOR GENERAL		CKD	DATE 1·5·78	



LEGEND

INCREASING METAMORPHIC GRADE

GREEN SCHIST

- Quartz – albite – epidote – actinolite – chlorite ± microline
- Quartz – feldspar – epidote – actinolite – chlorite – biotite

AMPHIBOLITE

- Quartz – muscovite – andalusite (or viridine) ± biotite, garnet, cordierite
- Quartz – muscovite – kyanite ± garnet, biotite, staurolite
- Undifferentiated; includes plagioclase – hornblende – biotite ± quartz, K-feldspar, epidote, and sillimanite – quartz – K-feldspar – garnet – biotite
- Garnet – biotite – hornblende – plagioclase ± quartz, K-feldspar; reaction rims of hypersthene and clinopyroxene – spinel between olivine and plagioclase in intrusive mafic igneous rocks
- Clinopyroxene – hornblende – plagioclase ± scapolite, sphene
- Clinopyroxene – garnet – biotite – amphibole – plagioclase ± quartz, K-feldspar, rutile, apatite; reaction rims of clinopyroxene and garnet between hypersthene and plagioclase in intrusive mafic igneous rocks

GRANULITE

- Orthopyroxene – clinopyroxene – hornblende biotite – plagioclase ± quartz, K-feldspar, garnet
- Orthopyroxene – clinopyroxene – plagioclase ± quartz, K-feldspar, biotite
- Clinopyroxene – garnet – plagioclase (relict orthopyroxene) ± quartz, K-feldspar

Fault or Thrust

SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

Fig.16

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA				
MUSGRAVE BLOCK **REGIONAL METAMORPHISM AND STRUCTURE, CENTRAL AUSTRALIA** (After Forman and Shaw, 1973)				
	COMPILED: R. Smith	DRN: T. G.	SCALE: 1 000 000	PLAN NUMBER
DIRECTOR GENERAL		CKD:	DATE: 9 · 5 · 78	78 384

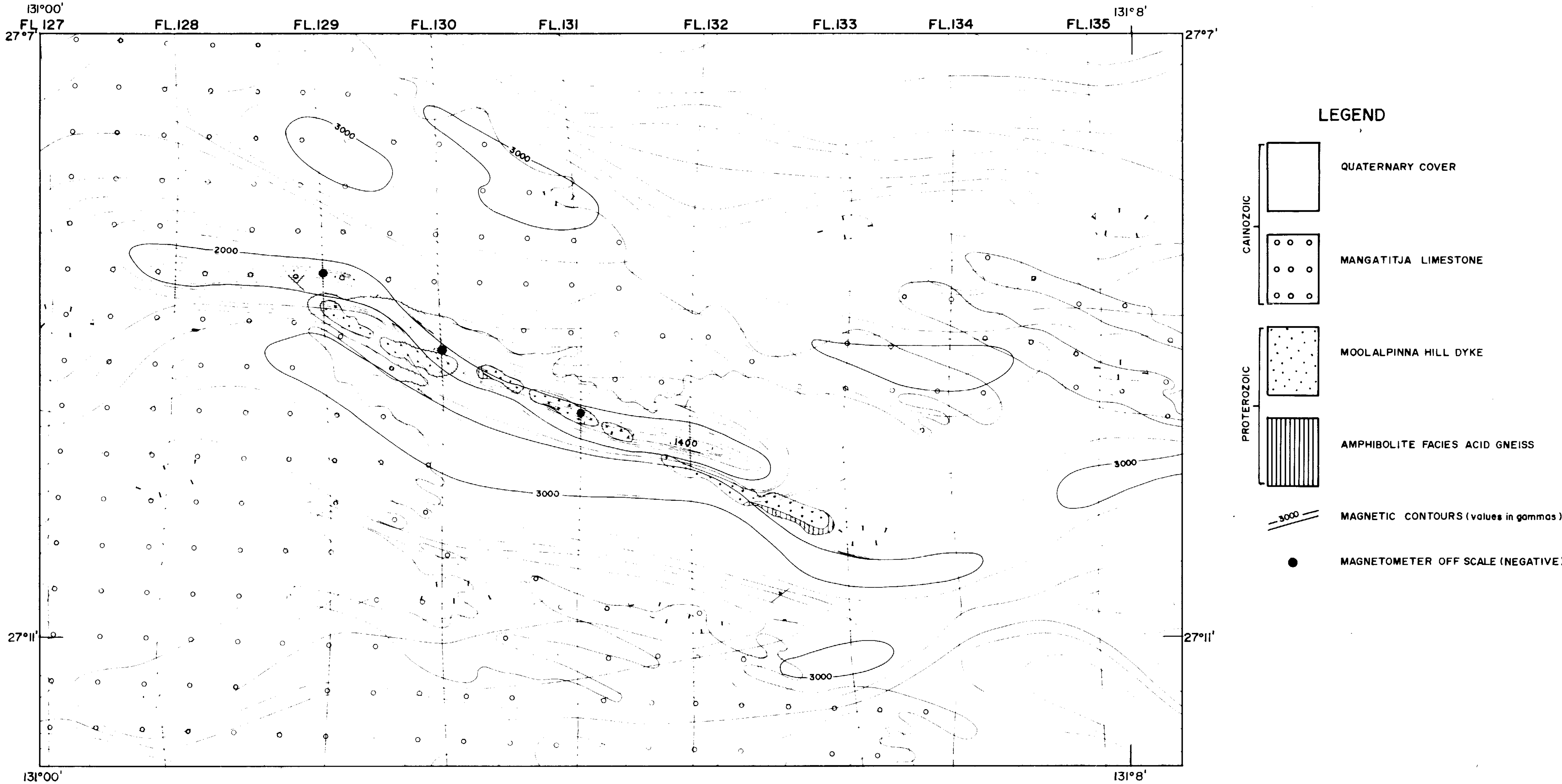


Fig.18

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE 1:50 000
COMPILED R. SMITH	MUSGRAVE BLOCK MOOLALPINNA HILL DYKE (PART OF LINDSAY 1:250000) GEOLOGY (AFTER MAJOR 1976) AND MAGNETIC CONTOURS (REVISED)	DATE 8·6·78
DRN D.O. CKD		PLAN NUMBER 78-444

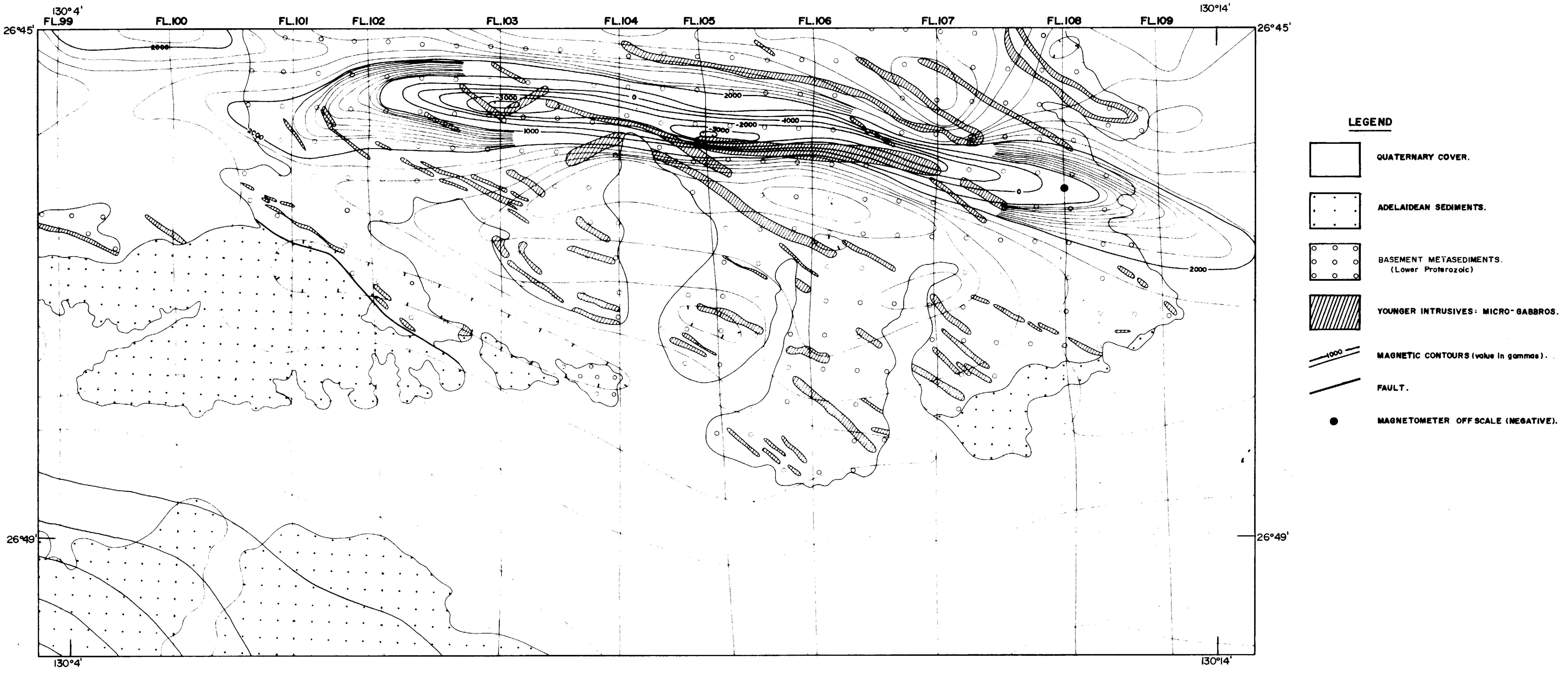
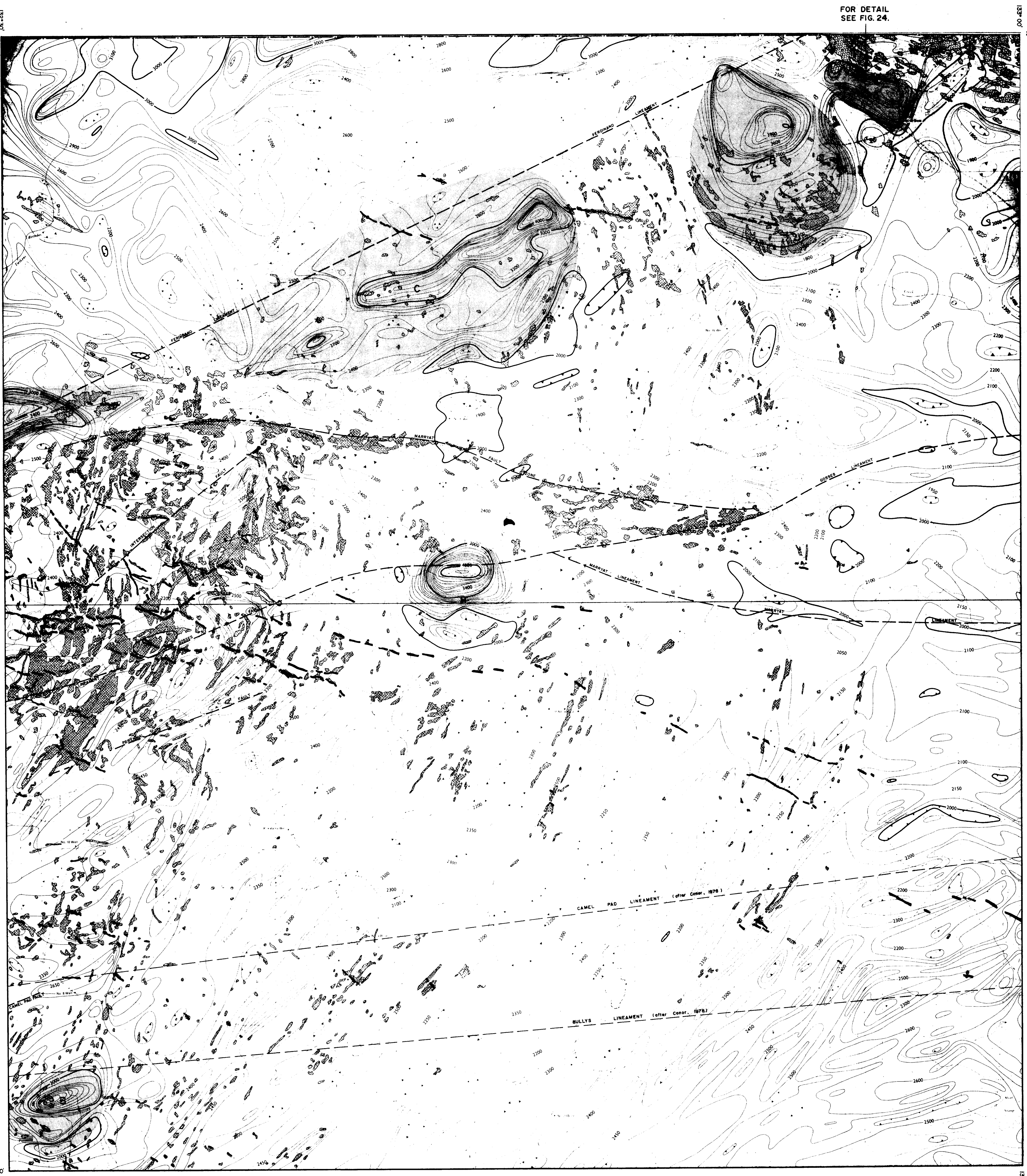


Fig.17

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE 1:50 000
COMPILED R.SMITH.	MUSGRAVE BLOCK OLD WELL DYKE (PART OF INDULKANA 1:63 360) GEOLOGY (AFTER SPRIGG 1955) AND MAGNETIC CONTOURS	DATE 19·6·78
DRN D.O. CKD		PLAN NUMBER 78-472



LEGEND

- Dolerite Dykes.
- Adamellitic granites.
- Magnetic Granite (Interpreted)
- Gneissic Granite
- Gneiss (Musgrave Mann Metamorphics)
- Aeromagnetic Contours (values in gammas)

SCALE 1:100 000

KILOMETRES 2 0 2 4 6 8 10 KILOMETRES

Fig.19

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

MUSGRAVE BLOCK
KENMORE & EATERINGINNA (1:63360 SHEET AREA)
GEOLOGY (After Conor, 1978) AND
REGIONAL AEROMAGNETIC CONTOURS.

	COMPILED R.Smith	DRN T.G.	SCALE 1:100 000	PLAN NUMBER
DIRECTOR GENERAL		CKD	DATE 14·6·78	78-456

LEGEND

- Musgrave – Mann Metamorphics
- Hypersthene – Adamellite
- Anorthosite
- Giles Complex Ultramafic, mafic and related rocks
- Dolerite dykes
- Mylonite and cataclasite
- Fault
- Interpreted geological boundary

SCALE 1:100 000

KILOMETRES 2 0 2 4 6 8 10 KILOMETRES

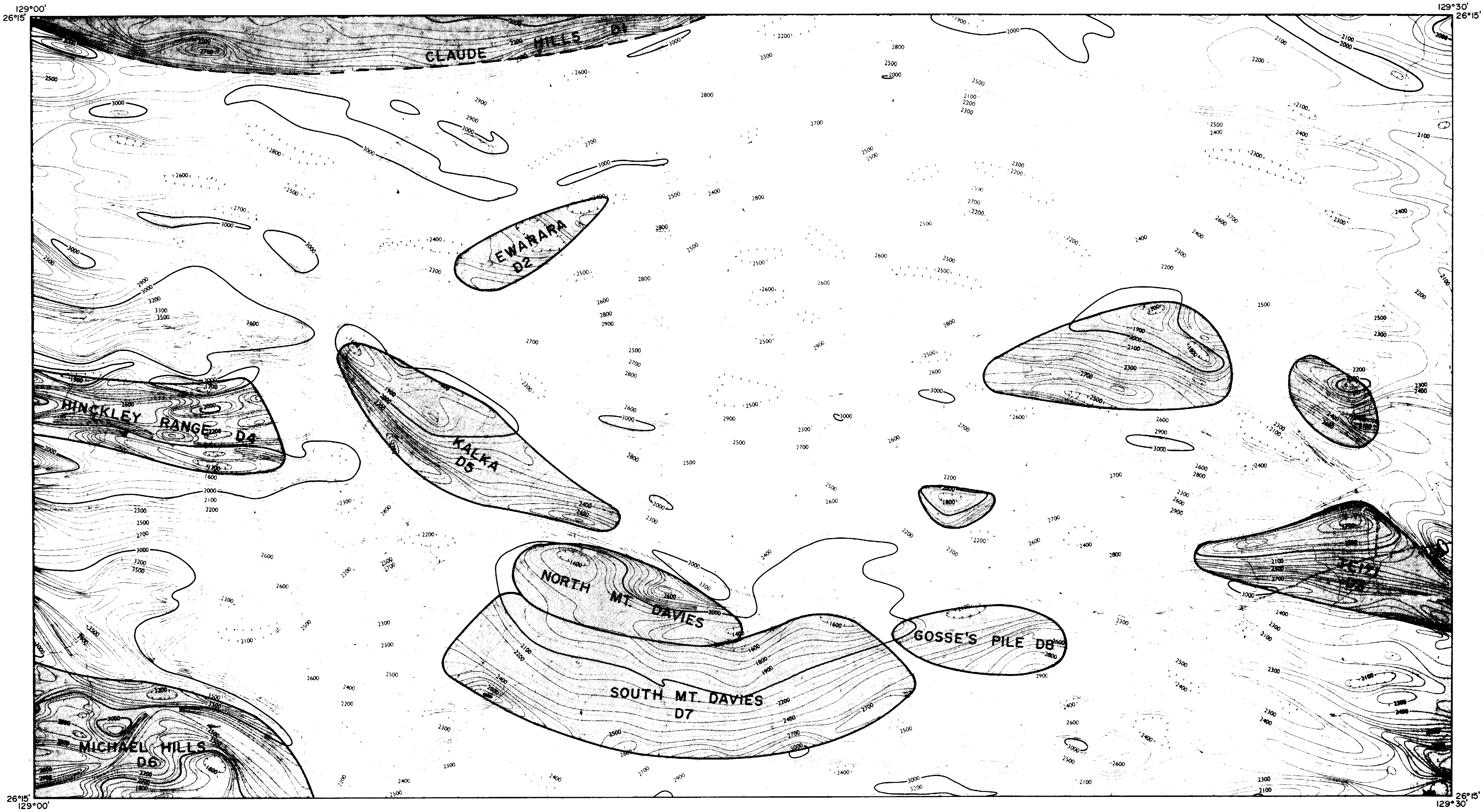
Fig. 20

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

MUSGRAVE BLOCK

DAVIES (1:63,360 Sheet Area) GEOLOGY (After Thomson, 1964)

DIRECTOR GENERAL	COMPILED: R. Smith	DRN: M.G.	SCALE: 1:100,000	PLAN NUMBER
		CKD:	DATE:	78-895



LEGEND

Aeromagnetic Contours (values in gammas)

Magnetic Low

D7 Interpreted Giles Complex

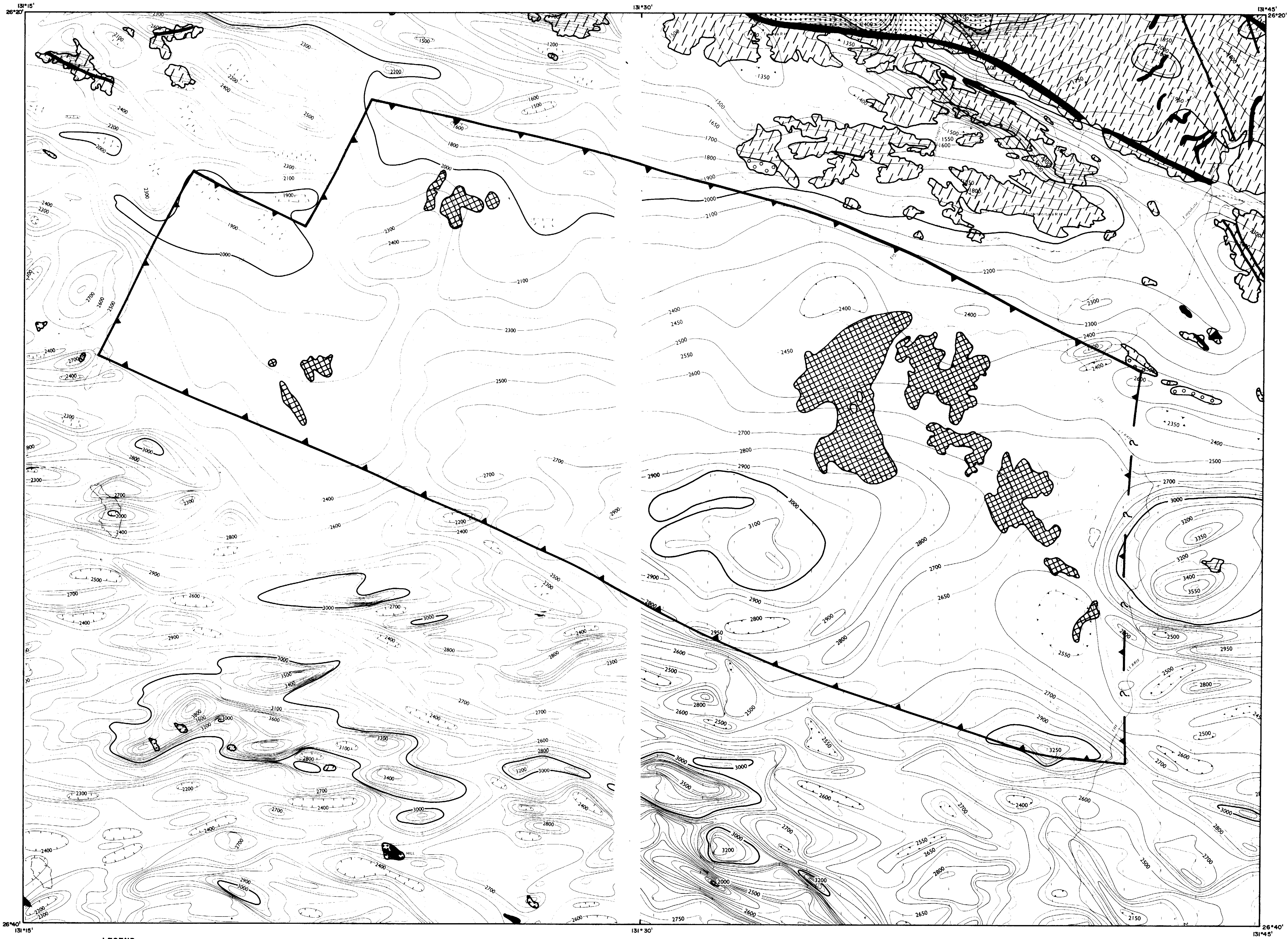
SCALE 1:100 000

KILOMETRES 2 0 2 4 6 8 10 KILOMETRES

Magnetic contours are based on measurements along north-south flight lines spaced approximately 1 mile apart

Fig 21

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA				
MUSGRAVE BLOCK				
DAVIES (1:63,360 Sheet Area) REGIONAL AEROMAGNETIC CONTOURS				
DIRECTOR GENERAL	COMPILED R. Smith	DRN DO.	SCALE 1:100 000	PLAN NUMBER
		CKD	DATE	78-894



LEGEND

LEVENGER ARKOSE.

BASIC DYKE ROCKS.

GRANITOID ROCKS.

MYLONITES and CATACLASITES.

MUSGRAVE-MANN METAMORPHICS.

FAULTS.

MAGNETIC CONTOURS (values in gammas).

INTERPRETED GRABEN BOUNDARY.

SCALE 1:100 000

KILOMETRES 2 0 2 4 6 8 10 KILOMETRES

Contour Interval 50nT

Fig.22

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA				
MUSGRAVE BLOCK **LEVENGER GRABEN** GEOLOGY AFTER MAJOR (1967) AND MAGNETIC CONTOURS				
	COMPILED: B SMITH.	DRN: D.O.	SCALE: 1:100 000	PLAN NUMBER
DIRECTOR GENERAL		CKD	DATE: 16·6·78	78-467.

LEGEND

- Quaternary cover
- Adelaidean Sediments
- Basic Dyke rocks
- Granitoid rocks
- Basement Metamorphics
- Aeromagnetic contours (values in gammas)
- Fault – approximate
- Fault – inferred
- Interpreted Graben Boundary

SCALE 1:100 000

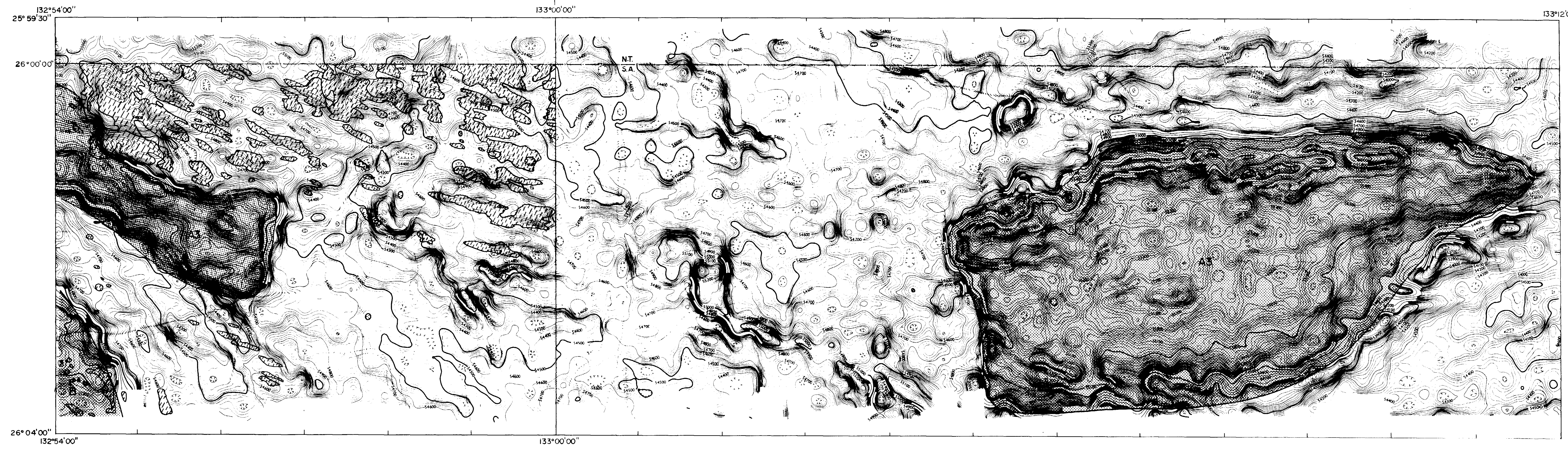
KILOMETRES 2 0 2 4 6 8 10 KILOMETRES

Contour Interval 50 nT

Fig.23

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA				
MUSGRAVE BLOCK **MOORILYANNA GRABEN** GEOLOGY (AFTER SPRIGG,1959) AND MAGNETIC CONTOURS				
	COMPILED R. SMITH	DRN T.G.	SCALE 1:100 000	PLAN NUMBER
DIRECTOR GENERAL		CKD	DATE 7·6·78	78-519

Geology after Conor, 1978 (and interpreted from magnetic data) ⟷ Geology interpreted from magnetic data



LEGEND

Gneissic Granite (mapped)

Magnetic Granite (Interpreted)

54700 Aeromagnetic Contours (values in gammas)

SCALE 1:50 000

METRES 1000 0 1 2 3 4 5 KILOMETRES

Fig.24

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA			
MUSGRAVE BLOCK DETAILED AEROMAGNETIC SURVEY (McPHAR, 1970) WITH GEOLOGY AS SHOWN (PART EATERINGINNA AND ALCURRA 1:100 000 SHEET AREAS)			
COMPILED R. SMITH	DRN D.O.	SCALE 1: 50 000	PLAN NUMBER
DIRECTOR GENERAL	CKD	DATE 17-1-79	78-427