COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 138

North Bowen Basin gravity survey, Queensland 1963

BY

F. DARBY

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Bureau of Mineral Resources, Geology and Geophysics, Canberra
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DEPARTMENT OF NATIONAL DEVELOPMENT

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

SECRETARY: R. W. BOSWELL, O.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DIRECTOR: N. H. FISHER

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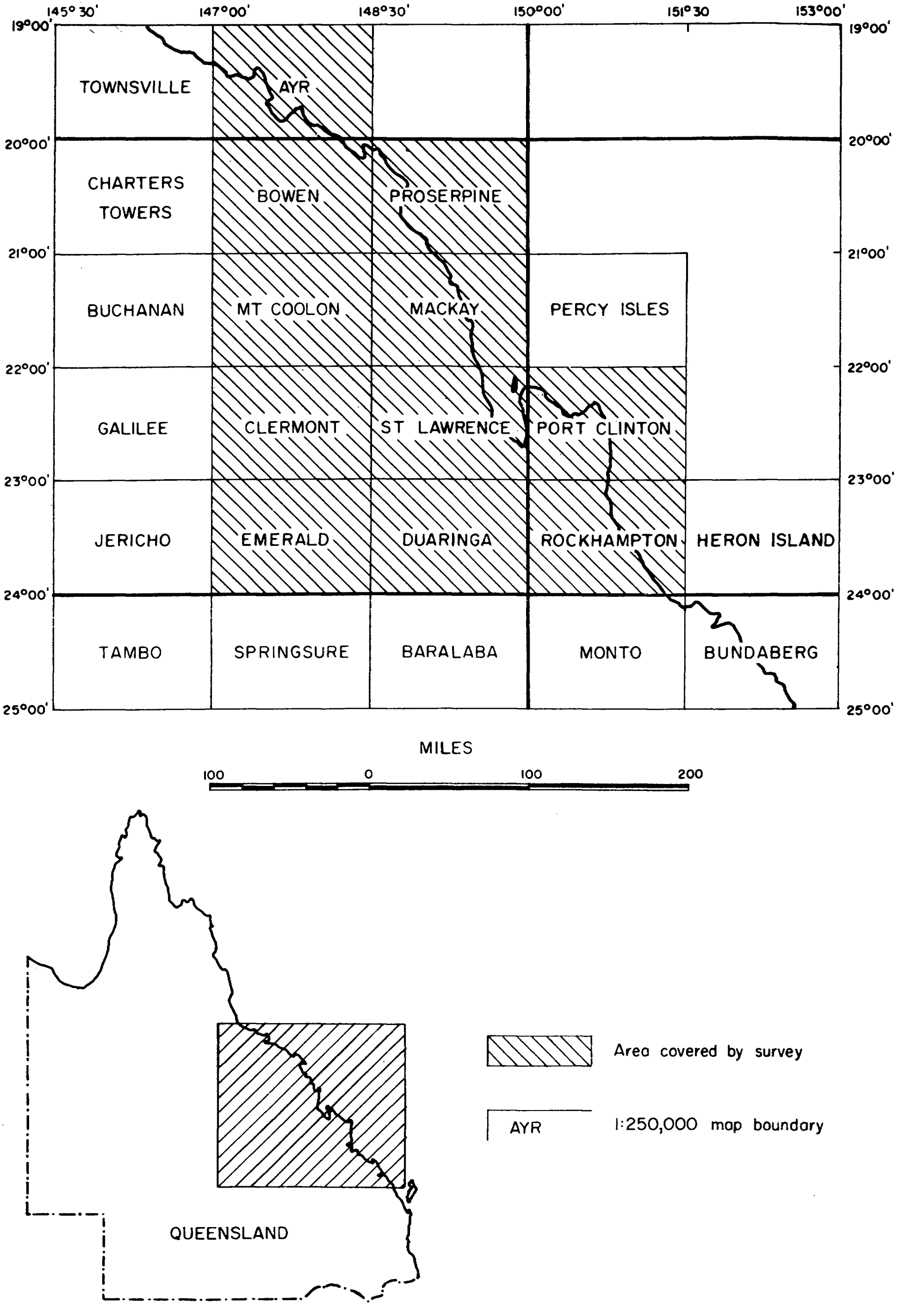

Fig. 1 Locality map and key to 1:250,000 map areas

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SUMMARY

This Report presents the results of the 1963 helicopter gravity survey done in the eastern part of Central Queensland by Velocity Surveys Ltd under contract to the Bureau of Mineral Resources, Geology & Geophysics. The survey was planned as a reconnaissance survey to explore the broad structures of the north Bowen Basin and its relation with the surrounding areas.

The Bouguer anomalies show a fairly good correlation with the known regional geology. On the basis of these anomalies the area is divided into four major gravity units: the Drummond Gravity Shelf, the Anakie Regional Gravity High, the Bowen Regional Gravity Low, and the Coastal Gravity Complex.

The Bouguer anomaly features of the Drummond Gravity Shelf correspond to broad regional features within the Drummond Basin.

The Anakie Regional Gravity High corresponds to the Anakie Structural High. This structural high is shown to extend at shallow depth beyond its outcrop limits both to the south, where it continues as a basement ridge, and to the east, where it forms the shallow basement to the Bulgonunna Volcanic Block.

The Bowen Regional Gravity Low is correlated with the Bulgonunna Volcanic Block and the Bowen Basin. The thickest sequences of the Bulgonunna Volcanics are indicated by Bouguer anomaly 'lows'. Bouguer anomaly features related to sedimentary structure in the north Bowen Basin are obscured by the Suttor and Poitrel Gravity Lows in the Mount Coolon and Clermont 1:250,000 map areas. These 'lows' (in particular their northern closure) could indicate the presence of a pre-Carboniferous granite. In this northern area the sedimentary features are the source of residual Bouguer anomaly features. In the south of the area the Bowen Basin structures (e.g. the Comet Platform and the Mimosa Syncline) are the source of semi-regional Bouguer anomaly features.

Separating the Bowen Basin from the coastal area is a zone of low Bouguer anomaly gradients, which could correspond to a hinge zone between the area of central uplift of the Tasman Geosyncline and the Bowen Basin. This hinge zone is probably a fundamental tectonic element in the evolution of the Tasman Geosyncline.

The Coastal Gravity Complex is related to this central uplift, into which large ultrabasic masses were emplaced prior to uplift and large granitic batholiths were emplaced during uplift.

A sedimentary trough containing Cretaceous and Tertiary sediments extends from Prosperpine offshore to Broad Sound, but whether or not this is a continuous feature cannot be decided on the data available.

1. INTRODUCTION

The 1963 helicopter gravity survey in Queensland was carried out under contract to the Bureau of Mineral Resources, Geology & Geophysics (BMR) by Velocity Surveys Ltd of Canada. This Report describes the gravity results obtained in the eastern part of the surveyed area, which covered approximately 51,000 square miles of Central Queensland over the following 1:250,000 map areas: AYR, BOWEN, MOUNT COOLON, CLERMONT, EMERALD, PROSERPINE, MACKAY, ST LAWRENCE, DUARINGA, PORT CLINTON and ROCKHAMPTON (Fig. 1).

The survey was conducted by transporting the gravity meters and barometers by helicopter, using the cell method of flying (Hastie & Walker, 1962).

An accurately levelled network of traverses, surveyed by Department of the Interior field parties prior to the gravity survey, gave good control for barometric heighting throughout the area. Gravity readings were taken along these levelled traverses by two BMR field parties, and thus good gravity control was also obtained throughout the area. Gravity ties were made to previous surveys within the area so that all work of sufficiently high quality might be incorporated in the final Bouguer anomaly maps. Results of previous surveys were recomputed where necessary. Results incorporated in the final Bouguer anomaly maps include those from the Comet-Rolleston survey (Oldham, 1958), the Blair Athol Coalfield survey (Neumann, 1965), the underwater gravity survey of the Great Barrier Reef (Goodspeed & Williams, 1959 ; Dooley & Goodspeed, 1959), and the Cooroorah Anticline survey (Associated Freney Oil Fields N.L., 1961). The areas covered in those surveys are shown in Plate 4.

The survey was planned as a reconnaissance survey with the object of exploring the broader structural elements of the region, with special emphasis on the following:

(a) To outline parts of the Drummond, Bowen, and Yarrol Basins.

(b) To establish the likely presence or otherwise of thick sediments offshore from the Queensland coast.

(c) To establish the regional gravity pattern over a portion of the Tasman Geosyncline.

(d) To define the offshore limits of the Styx Basin.

(e) To establish the relation between the Yarrol, Bowen, and Styx Basins.

The extent to which the survey was successful in attaining these objectives will be discussed in this Report, together with other structural problems raised as a result of the survey.

Details of the staff employed, vehicles and equipment used, and survey statistics are given in an appendix.

2. GEOLOGY

The main references used in this brief summary of the geology are 'The Geology of Queensland' (Hill & Denmead, 1960), the Tectonic Map of Australia, and several BMR Records describing recent field mapping (Jensen, 1963; Jensen, Gregory & Forbes, 1963; Malone, Corbett & Jensen, 1961; Malone, Jensen, Gregory, & Forbes, 1962; Malone et al., 1963; Veevers, Mollan, Olgers, & Kirkegaard, 1964; Veevers, Randal, Mollan, & Paten, 1961). The geology and structural elements of the area are shown in Plates 1 and 2, and the known stratigraphic sequence is shown in Table 1.

The Tasman Geosyncline extends from North Queensland south along the eastern margin of Australia. The geosyncline was active during Palaeozoic time, although its western margin in South Australia could have been active during the Proterozoic.

During Palaeozoic time the focus of activity of the Geosyncline moved progressively north and east across the survey area. Considerable activity during Permian time was located about the Bowen Basin, where extremely thick Permian rocks were laid down. In Mesozoic time the tectonic acivity lessended and presumably took place off the east coast of Australia.

The complex geological structure of the Tasman Geosyncline in the area surveyed has been subdivided into a series of basins (Drummond, Bowen, Styx, and Yarrol Basins), which are separated by structural 'highs' (Anakie Structural High, Gogango Structural High, Urannah Complex, and South Coast Structural High).

Drummond Basin

The Drummond Basin extends in a north-westerly direction for 250 miles from west of Springsure in the south to south of Charters Towers in the north. The Basin is 40-50 miles wide and its sediments crop out in SPRINGSURE, JERICHO, EMERALD, GALILEE, CLERMONT, BUCHANAN, MOUNT COOLON, CHARTERS TOWERS, and BOWEN. (In this Report, capitalised names refer to 1:250,000 map areas). The Basin contains about 16,000 feet of rhyolite, trachyte, tuff, quartz-sandstone, shale, and greywacke of Middle Dovonian to Lower Carboniferous age.

The major trend within the Basin is north-west, but in the extreme south there is a north-easterly trend. The sediments are folded into a series of relatively simple structures, some of which are of a regional nature. Major faulting is not common and most of the faults are normal, confined to the tighter folds, and appear to be either crestal or transverse faults.

Bowen Basin

The Bowen Basin, a Permian-Triassic basin, is the most extensive structure within the survey area and covers parts of BOWEN, MOUNT COOLON, MACKAY, CLERMONT, ST LAWRENCE, EMERALD, and DUARINGA.

The sediments of the Bowen Basin succession are subdivided into the Upper Bowen Coal Measures, the Middle Bowen Beds, and the Lower Bowen Volcanics (Malone, Corbett, & Jensen, 1961).

The Lower Bowen Volcanics (Table 1) consist of intermediate to basic flows, tuffs, and agglomerates with interbedded sediments, and minor acid flows. The unit is a thick wedge of volcanics cropping out on the eastern side of the Bowen Basin and thinning out towards the south-west. The Lower Bowen Volcanics were deposited in a partly terrestrial, partly marine environment; rare plant remains occur throughout the unit and marine fossils occur near the top.

The Middle Bowen Beds are a fossiliferous marine and non-marine sequence overlying the Middle Palaeozoic Bulgonunna Volcanics and the Permian Lower Bowen Volcanics. The lithologies of the sediments in the Middle Bowen Beds vary greatly and three distinct units have been recognised, each with a distinct fauna. In the area around Collinsville the Collinsville Coal Measures are regarded as a formation in the Middle Bowen Beds (Malone, Jensen, Gregory & Forbes, 1962).

The Upper Bowen Coal Measures consist of sediments, probably of freshwater origin, with an abundant and varied fossil flora. There is a varied lithology within this unit, sandstone being the dominant rock type in outcrop.

The Bowen Basin itself is composed of several subsidiary structural elements, including the Gogango Structural High, the Strathmuir Syncline, the Folded Zone, the Comet Platform, the Western Shelf, and the Mimosa Syncline (Plates 1, 2).

The Gogango Structural High. At one time considered to be a 'high' of older rocks separating the Yarrol and Bowen Basins, the Gogango Structural High consists dominantly of Permian rocks. It is within this region in DUARINGA that the Bowen Basin sequence overlaps the Yarrol Basin sequence. The Gogango Structural High embraces three structural features, the most northerly of which is a broad south-plunging anticline of Lower Bowen Volcanics, which is intruded by the Urannah Complex and Tertiary volcanic plugs. This structure is the Connors Range Arch and forms the southern end of the Eungella Strip (Hill & Denmead, 1960). The two other structural elements within the Gogango Structural High are the Leura Area and the Gogango Range Area. The former is located at the southern end of the Connors Range Arch and consists of tightly folded Middle Bowen Beds with Lower Bowen Volcanics in the core of a complex dome, which bifurcates into two anticlines at its southern end. The Gogango Range Area is characterised by sheared sediments, steep and overturned dips, overfolding, faulting, and possibly thrust faulting. The area is occupied mainly by Middle Bowen Beds with Lower Bowen and Rookwood Volcanics occupying the cores of complex anticlines.

TABLE 1

STRATIGRAPHIC SEQUENCE IN THE BOWEN BASIN AND SURROUNDING AREA

Age	Formation	Maximum thickness (ft)	Main rock type	Distribution
TERTIARY	Suttor Formation	200-400	Sandstone with some conglomerate	NW, central, and south MOUNT COOLON. Isolated areas of BOWEN. Isolated areas in NE CLERMONT.
	Basalt	0-600		East part of EMERALD. Third of CLERMONT. Remnants in east part of MOUNT COOLON. Isolated areas of BOWEN. West and SW of MACKAY. SW and SE DUARINGA.
	Exevale Formation	400	Sandstone with some conglomerate	Redcliffe Tableland in MOUNT COOLON.
	Acid volcanics	0-700		Peak Range in CLERMONT (the Peak Range Volcanics). Small isolated areas in BOWEN and MACKAY. West of Connor Range and near Craiglee H.S. in ST LAWRENCE.
	Unnamed (sediments (	265	Mudstone to conglomerate	Small isolated outcrops in MACKAY.

Age	Formation	Maximum thickness (ft)	Main rock type	Distribution
TERTIARY (Contd)	(	1600	Rhyolite and sandstone	Mainland and islands in PROSERPINE.
	Unnamed sediments (	1000 (usually 200-400)	Shale to sandstone	Mackenzie - Dawson Trough in DUARINGA.
	(	50	Sandstone to breccia	North end of Blackdown Tableland in DUARINGA.
CRETACEOUS	Styx Coal Measures	3000	Coal, shale, sandstone	Basin south of Broad Sound in ST LAWRENCE.
	Lower Cretaceous sediments	-	Conglomerate	Redbank H.S. in DUARINGA.
TRIASSIC	Teviot Formation	500	Sandstone and siltstone	Redcliffe Tableland, Carborough and Kerlong Ranges in MOUNT COOLON.
	Carborough Sandstone	Up to 1500	Sandstone	Isolated outcrops east of Isaacs River in CLERMONT. The Carborough, Kerlong, and Burton Ranges in MOUNT COOLON. Redcliffe Tableland in MOUNT COOLON and BOWEN.
	Clematis Sandstone	Up to 500	Sandstone	Blackdown Tableland and Dawson, Shotover, and Expedition Ranges in south DUARINGA.
	Rewan Formation	1500	Shale and sandstone	West, north, and east of Blackdown Tableland in south DUARINGA.
PERMIAN	Upper Bowen Coal Measures	10,500	Sandstone, conglomerate, shale, and coal	East part of EMERALD. East part of CLERMONT under Isaacs River. Throughout east half of MOUNT COOLON except NE corner. Triangular area in centre of Bowen Basin in BOWEN. Three small areas in the SW part of MACKAY, west part of DUARINGA, and SW part of ST LAWRENCE

Age	Formation	Maximum thickness (ft)	Main rock type	Distribution
PERMIAN (Contd)	Burngrove Member (1000 ft above base of Upper Bowen Coal Measures)	300	Siltstone	Thin belt extending north from west of Blackwater to NW DUARINGA.
	Blair Athol Coal Measures	800	Sandstone, shale, and coal	Around Blair Athol in CLERMONT.
	Middle Bowen Beds (divided into units A,B,C)	4500-8000	Greywacke and sandstone	Stockton-Hillalong area in MOUNT COOLON.
		8000	Metasediments	Annandale area in SE MOUNT COOLON.
		2000	Sandstone	West edge of Bowen Basin extending south across middle of MOUNT COOLON.
	Middle Bowen Beds	800	Sandstone and sub-greywacke	Homevale, Mount Flora, and Funnel Creek areas of MACKAY. Broad belt on west and north margin and narrow belt on east flank of Bowen Basin in BOWEN.
		1000		West region of Bowen Basin on SW corner of ST LAWRENCE and three areas in DUARINGA.
		3000		Folded Zone of Bowen Basin. Several anticlines from Dingo NNW to Isaacs River in DUARINGA and ST LAWRENCE. Around Bundarra Granodiorite in NW corner of ST LAWRENCE.
		4000		Connors Range area of Bowen Basin in NNW-trending belt in ST LAWRENCE.
		5000-10,000		Eastern region of Bowen Basin in east DUARINGA and ST LAWRENCE.

Age	Formation	Maximum thickness (ft)	Main rock type	Distribution
PERMIAN (Contd)	Middle Bowen Beds	-		Undifferentiated Middle Bowen Beds in east part of EMERALD.
		Up to 2000		Three areas (Rugby, Cherwell Range, and Peak Down) in CLERMONT.
	Collinsville Coal Measures (containing Glendoo Sandstone Member) above Unit A in Middle Bowen Beds	750	Sandstone, conglomerate, and shale	Collinsville area in BOWEN. Found in Rugby bore in CLERMONT.
	Undifferentiated Freshwater Beds	10,000	Shale and sandstone san	South of PROSERPINE.
	Calen Coal Measures (top unit of undifferentiated Freshwater Beds)	1000	Sandstone with minor coal	Small areas in north MACKAY.
	Carmila Beds	7000 2000	Conglomerate and shale	SW of MACKAY. Coastal strip in St LAWRENCE.
	Lower Bowen Beds	10,000-20,000	Mainly intermediate flows	NE corner of MOUNT COOLON. East flank of Bowen Basin in BOWEN. Each side of Urannah Complex in MACKAY. Two areas to the north and south of Calen in PROSERPINE. Eastern Ranges in ST LAWRENCE. Isolated domes in DUARINGA.
	Colinlea Formation	4500	Conglomerate and grit	South from Anakie in EMERALD.
	Rookwood Volcanics	-	Spilitic lavas	Several areas in NE DUARINGA.
CARBONIFEROUS to LOWER PERMIAN	Dinner Creek Beds	4000	Conglomerate and mudstone	10 miles east of Rookwood H.S. in east DUARINGA.

Age	Formation	Maximum thickness (ft)	Main rock type	Distribution
CARBON-IFEROUS	Middle Carboniferous beds	2000	Siltstone, greywacke, etc.	East and west flanks of Craiglee Anticline in ST LAWRENCE.
	Lower to Middle Carboniferous beds	-	Limestone and greywacke	SE of Redbank H.S. in DUARINGA and east of Broad Sound in ST LAW-RENCE.
	Lower Carboniferous beds	-	Limestone and mudstone	East and west flanks of Craiglee Anticline in ST LAWRENCE.
DEVONIAN to CARBON-IFEROUS	Campwyn Beds	24,000	Volcanic flows and sediments	NW-trending coastal belt in MACKAY and PROS-ERPINE.
	Drummond Beds (Ducabrook Formation Raymond Sandstone Mount Hall Conglomerate Telemon Formation Silver Hills Volcanics)	15-20,000	Sandstone, siltstone etc.	West parts of EMERALD, CLERMONT, MOUNT COOLON, and BOWEN south.
	Bulgonunna Volcanics	Possibly 15,000	Rhyolite and sediments	Between Bowen Basin sediments and Anakie Metamorphics in a strip running N-S in BOWEN, MOUNT COOLON, and CLERMONT.
	Devonian to Carbon-iferous volcanics	-	Spilite, etc.	From Redbank H.S. to Armagh H.S. in DUAR-INGA.
	Douglas Creek/ Theresa Creek Beds	-	Sediments and volcanics	Douglas and Theresa Creek areas in CLER-MONT.
	Undiffer-entiated volcanics	-	Mainly tuffs	Three small areas in BOWEN (south of Hidden Valley, SW of Hidden Valley, and south of Sellheim River).

Age	Formation	Maximum thickness (ft)	Main rock type	Distribution
DEVONIAN	Mount Wyatt Beds	1000	Sandstone	About Sellheim River and east of Rutherfords Tableland in BOWEN.
	Ukalunda Beds	4000+	Mainly sediments and some low-grade metamorphics	SW of BOWEN.
SILURIAN-DEVONIAN			Limestone sequence	Near Armagh H.S. and SE corner of DUARINGA.
PRE-DEVONIAN	Anakie Metamorphics	-	Schists, etc.	North from Anakie for 200 miles across EMERALD, CLERMONT, and MOUNT COOLON.
	Metamorphics	-	Schists, etc.	Several areas SE, east, and north of Marlborough in ST LAWRENCE.

The Strathmuir Syncline. The Strathmuir Syncline is to the east of the Gogango Structural High in ST LAWRENCE and is a NW-trending structure occupied by Middle Bowen Beds. The structure of the eastern flank of the Syncline is complex in comparison with the western flank and may be the result of thrusting from the east of the Marlborough Block.

The Folded Zone. The Folded Zone is an elongate straight-sided zone in which there are areas of very tight sub-isoclinal folds. There are up to 40,000 feet of sediments in some parts of this zone, which has previously been referred to as the Dawson Tectonic Zone (Robertson, 1961).

The Comet Platform. The Comet Platform is a north-trending feature that has been traced about 35 miles to the north and south of Comet. On the Comet Platform the structures are low-amplitude, short-wavelength folds with sinuous axial trends. The occurrence of the gentle folds of the Comet Platform as opposed to the tight folds of the Folded Zone to the east is probably due to the presence of shallower and rigid basement under the Comet Platform. To the west of the Comet Platform there is another zone of thicker sediments which is referred to as the Denison Trough (Hill & Denmead, 1960) and in which there is a known thickness of 13,000 feet of Permian sediments.

The Western Shelf. The Western Shelf is a zone of transgressive overlap of marine Middle Bowen Beds on to a fairly regular surface of the Bulgonunna Volcanic Block. Within the shelf area the beds dip east at angles of five degrees or less, and the folding on the eastern margin of the shelf takes the form of a complex series of domes and basins. It is possible that a fault zone defines the eastern margin of the Western Shelf as the sediments thicken rapidly into the Folded Zone.

The Mimosa Syncline. The Mimosa Syncline consists of Triassic sediments and occurs in the south of DUARINGA. Structures in the Rewan Formation conform to those in the underlying Upper Bowen Coal Measures in that there is gently folding west of the synclinal axis and tight folding north-east of the axis.

The orogeny affecting the Bowen Basin sequence probably took place in Triassic time though some intrusions may be associated with the volcanic phase which produced the Lower Bowen Volcanics. Folding becomes progressively gentler and intrusions less common westwards from one structural zone to the next and is probably due to basement shallowing to the west, possibly in steps.

Between the Folded Zone to the west and the Gogango Range and Leura Areas to the east is a narrow strip which has been named the Mackenzie-Dawson Trough. This trough is occupied by Tertiary sediments, possibly more than 1000 feet thick. The thickness of the sediments, which is much greater than is common for Tertiary sediments in the area, and the straightness of the trough, suggest that it is fault-controlled.

The Styx Basin

The Styx Basin, in ST LAWRENCE, is an elongated basin plunging shallowly to the north. It contains east-dipping Lower Cretaceous sediments (at least 1300 feet thick) unconformably overlying more steeply dipping Middle Bowen Beds. The eastern boundary is probably a high-angle reverse fault. The Cretaceous sediments are folded and faulted just west of the line of this presumed fault and are absent east of it.

The Yarrol Basin

The Yarrol Basin, in DUARINGA and ROCKHAMPTON, is a long narrow basin with 10,000 feet of sediments almost continuously marine from at least the upper Middle Devonian to the end of the Permian. This sequence includes a considerable thickness of intermediate volcanics and limestones. The boundary with the South Coast Structural High is an overthrust from the east and serpentinites are known along it. Major intrusions of granite and diorite occur throughout the Basin, e.g. the Mount Morgan Granite is an offshoot of a main batholith.

In the north-west of the Basin is the Craiglee Anticline, which is a sinuous, intruded anticline containing Devonian-Carboniferous volcanics, Carboniferous sediments, Dinner Creek Beds, and Rookwood Volcanics. The structures on the western flank are more complex than on the eastern flank with some overturning of sediments in places.

The Anakie Inlier

Separating the Permian Bowen Basin and the Carboniferous Drummond Basin is a sequence of folded metamorphic rocks, the Anakie Metamorphics, which have been termed the Anakie Structural High (Hill & Denmead, 1960) and the Anakie Inlier (Veevers et al., 1961). It will be shown in Chapter 5 that the Anakie Metamorphics continue at depth below the Permian rocks of the Bowen Basin. This leads to the conclusion that the Anakie Inlier is only the exposed portion of a much larger Anakie Structural High. In this report 'Anakie Inlier' will be used in this restricted sense.

Rocks of the Anakie Inlier crop out in EMERALD, CLERMONT, MOUNT COOLON, and BOWEN. The Anakie Inlier consists of the Anakie Metamorphics, which are folded and sheared quartz and mica schists and intrusions of granite (e.g. the Retreat Granite in EMERALD) and which are all pre-Devonian in age. The Inlier is overlain unconformably by the Drummond Beds and also in the east it is overlain unconformably by an estimated 16,000 feet of Upper Devonian to Lower Carboniferous Bulgonunna Volcanic rocks. Webb, Cooper and Richards (1963) give a Middle Devonian age for the Retreat Granite (based on K-Ar dating).

The structures within the Anakie Inlier are at variance with the trend of the Inlier. This suggests that the Inlier is not directly related to the folding of the Anakie Metamorphics, but rather was gently superimposed on the already folded unit. It is probably a relic of the high-standing stable area between the sinking Drummond Basin to the west and the lows of deposition of the Bulgonunna Volcanic Block to the east.

The Bulgonunna Volcanic Block

Rocks of the Bulgonunna Volcanic Block crop out in BOWEN, MOUNT COOLON, and CLERMONT. They are probably of Upper Devonian to Upper Carboniferous age and have an estimated thickness of 16,000 feet. Together with intrusives (e.g. a Carboniferous granite in south BOWEN) these mainly acidic volcanics form the shallow east-dipping basement to the western shelf of the Bowen Basin.

The Urannah Complex

As stated previously the Connors Range Arch forms the southern end of the Eungella Strip. The northern portion of the Strip is composed of the Urannah Complex, which is a diorite-granite-granodiorite mass and which occurs in AYR, MACKAY, MOUNT COOLON, BOWEN, PROSERPINE, and ST LAWRENCE. The Complex forms the eastern margin of the Bowen Basin. It is partly contemporaneous with and partly intrusive into the Lower Bowen Volcanics.

Recent geological studies show that much of the Urannah Complex and part of what was mapped as Lower Bowen Volcanics are pre-Permian, unconformably underlying the Lower Bowen Volcanics; some of the intrusives in the Urannah Complex are contemporaneous with the Lower Bowen Volcanics and some are younger (Malone, E.J., pers. comm.). K-Ar dating gives a Lower Permian age for the granites of the Urannah Complex (Webb, Cooper, & Richards, 1963).

East of the Urannah Complex

In the coastal areas of MACKAY and PROSERPINE there is a Devonian-Carboniferous block, which consists of a south-plunging anticline. It is faulted against a Permian block to the west and is on the upthrown side of the fault.

To the east of this block in MACKAY, aeromagnetic work (Ampol Exploration (Qld) Pty Ltd, 1963) has shown the basement to be at a greater depth, whilst in PROSERPINE the western fault of a graben has been identified. This graben could continue into MACKAY, into the area of deeper basement.

To the south of Proserpine, a Tertiary graben (termed the Proserpine Graben) has been delineated by aeromagnetic and seismic surveys (Ampol Exploration (Qld) Pty Ltd, 1964a). This could be the northward continuation of the graben that has been postulated off the coast in MACKAY.

The South Coast Structural High

The coastal regions of ST LAWRENCE, PORT CLINTON, and ROCKHAMPTON constitute the South Coast Structural High. This structure consists of low-grade Lower Palaeozoic metasediments and granites. The northern portion of this structural 'high' is termed the Marlborough Block and here the metasediments have associated ultrabasic intrusions.

Stratigraphic wells

There have been two deep wells drilled within the area, namely H.B.R. Wreck Island No. 1 and A.F.O. Cooroorah No. 1. A number of shallow bores have been drilled in the area but are not considered in this Report.

Wreck Island No. 1 was drilled in 1959 for Humber Barrier Reef Oils Pty Ltd (1960). An underwater gravity survey in 1958 (Goodspeed & Williams, 1959) indicated an increase in gravity seaward. The survey indicated that Wreck Island lies on the eastern side of a local gravity 'high', suggesting that the islands of the Capricorn Group lie along the crest of a structural uplift. There is one other bore in the vicinity of Wreck Island, at Heron Island. This reached a depth of 732 feet and encountered reef and reef-derived sediments to 506 feet and land-derived sediments below that depth. The stratigraphic sequence encountered in Wreck Island No. 1 is given in Table 2.

TABLE 2

STRATIGRAPHIC SEQUENCE IN WRECK ISLAND No. 1 WELL

Formation	Depth, feet	Lithology
Recent	0 - 398	Calcareous reef sediments
Pleistocene	398 - 530	Fine-grained quartz sandstone
Upper Pliocene	530 - 735	Foraminiferal limestone
Lower Pliocene	735 - 945	Calcarenite
Upper and middle Miocene	945 - 1110	Calcarenite
Lower Miocene	1110 - 1795	Calcareous siltstone and sandstone
Basement	1795 - 1891	Volcanic breccia

The occurrence of volcanic breccia at shallow depth confirms the structural uplift indicated by the gravity survey. It appears that the sediments may be thicker to the south-west and north-east of the Capricorn Islands.

The sediments indicate that the Great Barrier Reef is the site of a marine Tertiary basin and that these sediments thicken away from the east coast of Queensland (Humber Barrier Reef Oils Pty Ltd, 1960).

Cooroorah No. 1 was drilled in 1959-1960 for Associated Freney Oil Fields N.L. (1960), after the completion of gravity and seismic surveys, on the Big Churchyard Culmination of the Cooroorah Anticline. The stratigraphic units penetrated by this well are presented in Table 3.

The age of these units is in doubt, but it is known that the Crocker Formation is Upper Permian, and from spore examination it appears that the Permian extends down to 1882 feet (Associated Freney Oil Fields N.L., 1961).

The sequence found in the well differed greatly from that postulated from the seismic results (Morton & Moss, 1961), which suggested a possible basement depth of 10,000 feet. However, it is not really clear whether the well did in fact penetrate the sedimentary basement, although the andesite was considered to be economic basement.

TABLE 3

STRATIGRAPHIC SEQUENCE IN COOROORAH No. 1 WELL

Formation	Depth, feet	Lithology
Crocker Formation	0 - 140	Mainly sandstone
Maria Formation	140 - 1215	Sandstone and siltstone
Upper Siltstone	1215 - 1638	Mainly silt

TABLE 3 (Continued)

Formation	Depth, feet	Lithology
Sandstone	1638 - 2640	Sandstone
Lower Siltstone	2640 - 3010	Interbedded sandstone and siltstone
Andesitic tuff	3010 - 3090	Intermediate volcanic tuff
Breccia	3090 - 3190	
Andesite	3190 - 3380	
'Basement'	3380 - 3523	Type of rock doubtful, but probably igneous below 3470 ft

3. PREVIOUS GEOPHYSICAL SURVEYS

Aeromagnetic surveys (Plate 3)

BMR flew regional aeromagnetic traverses across parts of the Great Artesian Basin in 1956 and 1958 (Jewell, 1960). Only one traverse, from Tennant Creek to Mackay, crossed the present survey area. The part of the profile over the Tasman Geosyncline is very disturbed and indicates that the magnetic basement is close to the surface.

An aeromagnetic survey was made for Exoil N.L. in 1962 over a portion of the Great Artesian Basin and Drummond Basin (Exoil N.L., 1962a). The most significant feature of the magnetic basement deduced from this survey is a deep trough (16,000 feet deep at its maximum) centred about the boundary of BUCHANAN and GALILEE and trending north-west. This trough is thought to underlie the western edge of the Drummond Basin and to have a western margin consisting of a series of step faults.

In 1962 a subsidised reconnaissance aeromagnetic survey over a part of the Great Barrier Reef was made for the Australian Oil and Gas Corporation Ltd (1962). No areas of deep sediments were located although several regions were detected where up to 6000 feet of sediments might exist.

In 1963 an aeromagnetic survey was made for Ampol Exploration (Qld) Pty Ltd (1963) in the Mackay area. Here there is a pronounced north-west trend throughout the area. The anomalies in the south and north-east portions of the area are due to a largely crystalline intrusive basement. Elsewhere anomalies are elongated and probably result from volcanic rocks which have continuity along the strike. It is thought that Devonian-Carboniferous volcanics account for most of the elongated anomalies.

Three major fault systems are indicated. The most prominent fault system has a north-west trend and forms the graben east of Proserpine. The aeromagnetic interpretation of this graben is based on seismic depth control (Ampol Exploration (Qld) Pty Ltd, 1964a). A second fault system trends slightly west of north and seems to be more prevalent in the southern part of the area. This suggests that the fault system extends into the area from the Styx and Yarrol Basins farther to the south. The third system of faults trends north-east and seems to be responsible for most of the cross-structures in the Proserpine Graben.

The maximum depth to magnetic 'basement' in the graben to the south of Proserpine is 7100 feet. South of this there is a high area before the graben again plunges south to a maximum depth of about 4000 feet. A narrow trough in the south-west corner of the aeromagnetic survey area may be the northward extension of the Styx Basin.

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BMR made an aeromagnetic survey over the Bowen Basin between 1961 and 1963 (Wells & Milsom, 1966). The interpretation of the results of this survey shows that there is only limited correlation between the aeromagnetic anomalies and the known geology of the Bowen Basin. The magnetic basement is correlated with rocks of unknown age, which are below the prospective basement. The aeromagnetic results can be correlated with Lower Bowen Volcanics only where these rocks crop out. The results therefore cannot be used for delineating structures within the Bowen Basin itself. The results also suggest that the Lower Bowen Volcanics do not extend for any great distance beneath the Middle Bowen Beds.

Gravity surveys (Plate 4)

A considerable number of gravity surveys had already been made in the survey area. Regional traverses had been made along roads, but good overall coverage of the area was not available prior to this survey.

The initial gravity work in this area was completed by Shell (Queensland) Development Pty Ltd (1952) which surveyed a traverse in the south of the area, from Rockhampton to Jericho. The main part of the Shell survey was south of the present survey area.

In 1951-52 the University of Sydney made gravity observations at 10-mile intervals along some of the roads within the survey area (Marshall & Narain, 1954). Readings along the traverse from Rockhampton to Longreach indicate that the Gogango Structural High and the Anakie Inlier give rise to high residual Bouguer anomaly features.

In 1956, BMR made a semi-detailed gravity survey in the Comet-Rolleston area (Oldham, 1958). A new position for the axis of the Comet Platform was obtained and sediments were thought to thicken to the south.

In 1958, BMR made a regional underwater gravity survey of the Great Barrier Reef. The preliminary results of this survey are presented in two reports (Goodspeed & Williams, 1959; Dooley & Goodspeed, 1959) and a more detailed analysis of the results to the north of the present survey area was prepared subsequently (Dooley, 1965).

In 1958 a regional gravity survey was made over the Bowen Basin by Associated Freney Oil Fields N.L. (Starkey, 1959). In several areas a relatively shallow depth to basement was suggested by the Bouguer anomaly features (e.g. the Comet Platform and another basement ridge in the Clermont-Capella area). Other 'highs' were associated with outcropping Lower Bowen Volcanics and undifferentiated Permian metamorphics.

In 1959 a semi-detailed gravity survey was made over the Cooroorah Anticline for Associated Freney Oil Fields N.L. (1961). It was found that there was a Bouguer anomaly 'high' associated with the Big Churchyard Culmination of the Cooroorah Anticline but the axis of this 'high' was displaced approximately one and one-quarter miles north-west from the mapped anticline. A seismic survey (Morton & Moss, 1961) showed that the structure at depth is closely conformable with the surface and so it appears from this displacement of the Bouguer anomaly and geological axes that the Bouguer anomaly 'high' is due to some deep-seated density variation. No Bouguer anomaly feature was associated with the Redrock Culmination.

A detailed gravity survey by BMR in 1959 over the Blair Athol Coalfield (Neumann, 1965) indicated a 'low' of about 3 milligals associated with the main coal basin. Distinctive Bouguer anomaly 'highs' in the east and south-east margin of the coal deposit indicate raised areas of basement rocks, and strong Bouguer anomaly gradients suggest a rapid thinning of the coal measures on the north-west margin of the coalfield.

BMR also made regional gravity surveys between pendulum stations in 1956, 1959, and 1960.

Seismic surveys (Plate 3)

In 1950, BMR conducted a short refraction survey over the Comet Platform (Smith, 1951), which suggested that the basement was at a comparatively shallow depth (about 2200 feet).

In 1959, BMR carried out a detailed seismic survey over the Cooroorah Anticline, near Comet (Morton & Moss, 1961). This survey showed that the geologically mapped Big Churchyard Culmination persists at depth and that a second culmination (the Mount Stuart Culmination) occurs to the south along the axis of the Cooroorah Anticline. A high-velocity refractor at a depth of 2200 feet on the west flank of the Big Churchyard Culmination was considered to correlate with the refractor recorded near Comet in 1950 and was in this instance interpreted as a probable limestone band. The sedimentary rocks were considered to extend to a depth of at least 6000 feet and probably to 10,000 feet but there was no evidence to show that the basement is not considerably deeper than 10,000 feet. The Redrock Culmination as defined by surface geology does not appear to persist at depth. Subsequent to this survey Associated Freney Oil Fields N.L. drilled Cooroorah No. 1 well on the Big Churchyard Culmination and the sedimentary section as postulated from the seismic results differed considerably from that found in the well (Table 3).

In 1960, BMR made a reconnaissance seismic survey in the Bowen Basin (Robertson, 1961). This survey was a series of traverses from Emerald to Duaringa. The survey confirmed the existence of the Comet Platform with sediment-filled troughs on either side of it. The depth of the reflections on the Comet Platform was greater for the 1960 survey than for the 1950 survey but the actual thickness of sediments in this area was not determined precisely. In the Folded Zone of the Bowen Basin (previously called the Dawson Tectonic Zone) reflections from strongly folded rocks were obtained from depths of up to 20,000 feet. South-west of Duaringa it was shown that there is about 3000 feet of relatively undisturbed sediments, which are probably Tertiary.

From 1961 until 1963 subsidised reflection and refraction seismic work was done for Exoil N.L. (Exoil N.L., 1962b & 1963) in TANGORIN, BUCHANAN, and GALILEE. The results suggest that the Mesozoic beds of the Great Artesian Basin are flat-lying and that they thin out to the east. Deeper reflections suggest the presence of a sedimentary trough that trends north-west and plunges to the north-west. These deep reflections were obtained on the northern flank of an apparent depression detected by an aeromagnetic survey (Exoil N.L., 1962a).

During 1962 and 1963 a subsidised seismic reconnaissance survey was conducted for Associated Freney Oil Fields N.L. in CLERMONT, ST LAWRENCE, and MOUNT COOLON (Associated Freney Oil Fields N.L., 1963). The survey, on the north-west flank of the Bowen Basin, indicated a few structures, all of which had limited areal extent. The basement was at shallow depth beneath the area and reached a maximum of 7000 feet in the east of the area.

In 1963 a subsidised seismic refraction and reflection survey was conducted for Ampol Exploration (Qld) Pty Ltd (1964a) to the south of Proserpine. The survey was conducted to investigate the presence of the graben that was indicated by aeromagnetic results. The results of the seismic survey indicated an asymmetrical syncline trending north-west to the south of Proserpine. The syncline is characterised by a moderately dipping southern flank and a sharply dipping and faulted northern flank. A refraction profile indicates that the 'basement marker horizon' has a maximum depth of about 7000 feet. It appears that there is a regional thickening of the sediments to the south-east.

In 1964 a marine seismic survey was carried out for Ampol Exploration (Qld) Pty Ltd (1964b) in the offshore region near Mackay. This survey established the presence of a sedimentary trough. Presumed Tertiary sediments similar to those at Proserpine and Cape Hillsborough appear to occupy part of this trough.

A summary of the previous geophysical work and stratigraphic bores in the survey area is given in Table 4.

TABLE 4

SUMMARY OF PREVIOUS GEOPHYSICAL WORK AND STRATIGRAPHIC DRILLING

Year of survey	Type of survey	Area	Reference
1940-1951	Regional gravity traverses	Queensland	Shell, 1952
1950	Refraction seismic	Comet Platform	Smith, 1951
1951-1952	Regional gravity traverses	Queensland	Marshall & Narain, 1954
1956	Semi-detailed gravity	Comet-Rolleston	Oldham, 1958
1956-1960	Regional gravity traverses between pendulum stations	Queensland	Unpublished BMR surveys
1956-1958	Aeromagnetic	Great Artesian Basin	Jewell, 1960
1958	Regional gravity	Bowen Basin	Starkey, L.J., 1959
1958	Underwater gravity	Great Barrier Reef	Goodspeed & Williams, 1959; Dooley & Goodspeed, 1959; Dooley, 1963
1959	Semi-detailed gravity	Cooroorah Anticline	Associated Freney Oil Fields N.L., 1961
1959	Detailed gravity	Blair Athol Coalfield	Neumann, 1965
1959	Detailed seismic	Cooroorah Anticline	Morton & Moss, 1961
1959	Stratigraphic well	Wreck Island	Humber Barrier Reef Oils Pty Ltd, 1960
1959-1960	Stratigraphic well	Cooroorah Anticline	Associated Freney Oil Fields N.L., 1960
1960	Reconnaissance seismic	Emerald-Duaringa	Robertson, 1961
1961-1963	Aeromagnetic	Bowen Basin	Wells & Milsom, 1966
1961-1963	Reflection and refraction seismic	Great Artesian and Drummond Basins	Exoil N.L., 1962b and 1963
1962	Aeromagnetic	Great Barrier Reef	Australian Oil and Gas Corporation Ltd, 1962
1962	Aeromagnetic	Great Artesian and Drummond Basins	Exoil N.L., 1962a

Year of survey	Type of survey	Area	Reference
1962-1963	Reconnaissance seismic	Bowen Basin	Associated Freney Oil Fields N.L., 1963
1963	Reflection and refraction seismic	Proserpine	Ampol Exploration (Qld) Pty Ltd, 1964a
1963	Aeromagnetic	Mackay	Ampol Exploration (Qld) Pty Ltd, 1963
1964	Marine seismic	Mackay	Ampol Exploration (Qld) Pty Ltd, 1964b

4. BOUGUER ANOMALY FEATURES

The Bouguer anomaly features are shown in Plate 5 on a scale of 40 miles to one inch. The principal Bouguer anomaly features have been numbered and the key to them is given in Table 5, which contains a brief description of each Bouguer anomaly feature as well as proposed names for the features.

In previous BMR literature Bouguer anomaly features have been named from analogous topographic and geological terms, viz. gravity ridge, gravity trough, gravity depression, gravity shelf, etc. This terminology may lead to some confusion as any term could lead to differing conceptions of the anomaly by different people. To overcome this ambiguity it is thought advisable to include for interpretative purposes an abbreviated description of Bouguer anomaly features. The system proposed (L.M. Hastie pers. comm.) gives essential characteristics of individual Bouguer anomaly features such as amplitude, trend, and size. For example (+5, NNW, 4, 34, -32) indicates, in order, the amplitude of the feature in milligals in relation to its general background, the trend of the feature, the ratio of the length to the width of the feature, the length of the feature in miles, and the degree of curvature of the feature. The first four terms are self-explanatory but the fifth needs some explanation; it is the distance in miles across, and not round, the arc of the feature and the sign preceeding this figure indicates whether the feature has its convex side to the right (+) or to the left (-) of the trend direction. For an unclosed feature the trend is in the direction of the nose of the feature and the description is followed by a U.

This system does not cover all desired situations in that it does not specify a major feature consisting of several distinct minor features. In the table which follows, advantage will be taken of the code where possible. The system does not supplant the use of terms such as ridge, trough, etc. but rather adds precision to their use.

The area is immediately divisible into four major tectonic zones on the basis of the Bouguer anomalies and structural geology. These zones have been named as follows:

(a) The Drummond Gravity Shelf, which corresponds closely to the Drummond Basin.

(b) The Anakie Regional Gravity High, which is directly related to the Anakie Structural High.

(c) The Bowen Regional Gravity Low, which is related to the Bulgonunna Block and the Bowen Basin.

(d) The Coastal Gravity Complex, which embraces a geologically complex area of structural 'highs' and local basins of deposition.

TABLE 5

GRAVITY ANOMALY FEATURES

No.	Name	Description	1:250,000 map area
(a)	Drummond Gravity Shelf		
1	Beresford Gravity Ridge	Prominent NNW-trending gravity ridge (feature D13 of Gibb, 1969)	EMERALD, GALILEE
2	Withersfield Gravity Lows	Series of NNW-trending elongated gravity 'lows'	BUCHANAN, EMERALD
(b)	Anakie Regional Gravity High		
3	Clermont Gravity Highs	Series of NNW-trending irregular gravity 'highs'	MOUNT COOLON, EMERALD
4	Retreat Gravity Low	Local gravity 'low' (-10, NNW, 2, 26)	EMERALD
5	Karin Gravity Low	Local, intense gravity 'low' (-25, E, 2, 20)	CLERMONT
(c)	Bowen Regional Gravity Low		
6	Glendon Gravity Low	Extensive gravity 'low' (-15, NNW, 2, 35)	BOWEN
7	Bulgonunna Gravity Lows	Series of north-trending gravity 'lows'	MOUNT COOLON, CLERMONT
8	Wyena Gravity High	Irregular gravity 'high' (+10, N, 4, 55)	MOUNT COOLON, CLERMONT
9	Waterford Gravity Spur	East-trending gravity spur (+10, E, 3, 36, U)	CLERMONT
10	Suttor Gravity Low	Extensive NW-trending gravity 'low' (-15, NW, 3, 70)	MOUNT COOLON
11	Poitrel Gravity Low	NNW-trending gravity 'low' (-15, NNW, 2, 40)	CLERMONT
12	Mount Roper Gravity Low	NE-trending irregular gravity 'low' (-10, NNE, 4, 40, +30)	CLERMONT
13	Denison Gravity Low	Gravity 'low' centred on Emerald (-10, NNW, 4, 48)	EMERALD
14	Comet Gravity Platform	North-trending elongated gravity 'high' (+10, N, 3, 60)	EMERALD, DUARINGA
15	Bluff Gravity Depression	Very extensive north-trending gravity 'low' (-15, N, 2, 70)	DUARINGA

No.	Name	Description	1:250,000 map area
16	Collinsville Gravity Low	Local gravity embayment (-10, N, 2, 20, U)	BOWEN
17	Redcliffe Gravity Low	Local gravity embayment (-10, NNW, 2, 20, U)	MOUNT COOLON
18	Mackenzie-Dawson Gravity Low	Local NNW-trending gravity low (-20, NNW, 3, 30)	ST LAWRENCE, DUARINGA
19	Duaringa Gravity Highs	Two local NNW-trending gravity 'highs'	DUARINGA
20	Boolburra Gravity Lows	Two local gravity 'lows'	DUARINGA
(d)	Coastal Gravity Complex		
21	Eungella Gravity Ridge	Prominent NNW-trending ridge of very high gravity anomalies	AYR, MACKAY
22	Connors Range Gravity Platform	Zone of prominent gravity 'highs'	MACKAY, ST LAWRENCE
23	Urannah Gravity Lows	Two prominent, extensive gravity 'lows'	BOWEN, MACKAY
24	Seaforth Gravity Spurs	Two gravity 'spurs' practically enclosing feature 26	PROSERPINE, MACKAY
25	Proserpine Gravity Trough	Local gravity 'low' (-20, NW, 3, 25)	PROSERPINE
26	St Helens Gravity Low	Local WNW-trending gravity 'low' (-5, WNW, 1, 18)	PROSERPINE
27	Douglas Gravity Low	Intense gravity 'low' (-20, N, 2, 25)	MACKAY
28	Styx Gravity Low	NNW-trending gravity 'low' (-15, NNW, 4, 40, 35)	ST LAWRENCE, MACKAY
29	Strathmuir Gravity Low	North-trending gravity 'low' (-10, N, 3, 30)	ST LAWRENCE, DUARINGA
30	Sarina Gravity High	Gravity 'high' to the north-east of feature 22 (+10, -, 1, 30)	MACKAY
31	Port Clinton Gravity Lows	Zone of low gravity values with four significant closures	PORT CLINTON

No.	Name	Description	1:250,000 map area
32	Marlborough Gravity Ridge	Zone of high positive anomalies	ST LAWRENCE, ROCKHAMPTON
33	Westwood Gravity High	Zone of high gravity anomalies	ROCKHAMPTON
34	Gogango Gravity High	NNW-trending zone of relatively high gravity values	DUARINGA
35	Grantleigh Gravity Low	Local NW-trending gravity 'low'	ROCKHAMPTON
36	Bajool Gravity Low	Intense gravity 'low' which extends south into MONTO	ROCKHAMPTON
37	Gladstone Gravity Plateau	Zone of high gravity values	ROCKHAMPTON
38	-	Offshore zone of high gravity anomalies	PROSERPINE
39	Long Island Gravity High	Zone of high gravity values	MACKAY, PORT CLINTON

5. DISCUSSION OF GRAVITY RESULTS

Plate 5 was contoured by a mechanical method using linear interpolation between the gravity stations and some smoothing of the isogals. Preliminary contours had been drawn by a semi-interpretative method using trend directions and not having large changes of gravity gradient. Where gravity control is good and gradients are relatively steep the two methods give similar results but in other cases the results differ slightly. These differences will be discussed when they are considered important. The contours were initially drawn on individual 1:250,000 map areas and then reduced to a scale of 40 miles to 1 inch (Plate 5).

The results of the survey will be discussed in this chapter and a semi-detailed interpretation of some of the more interesting anomalies will be carried out.

As stated in the previous chapter, the area is divisible into four zones corresponding to major geological structural units. These zones have a common north-north-west trend. Each zone embraces several more local Bouguer anomaly features, many of which are themselves of regional significance. Many of these features can be directly correlated with known geological features. The zones will be discussed in turn.

The Drummond Gravity Shelf

This Bouguer anomaly zone is situated in the south-west corner of the survey area. The main part of the zone lies in CHARTERS TOWERS, BUCHANAN, and GALILEE (Gibb, 1969). It corresponds to the Drummond Basin and is a zone of predominantly positive Bouguer anomalies in contrast to the large Bouguer anomaly depression that coincides with the Great Artesian Basin. The sediments of the Drummond Basin are of

Devonian-Carboniferous age and are denser than the Permian and Mesozoic sequence found in the Great Artesian Basin. The Bouguer anomaly features associated with the Drummond Basin are of similar magnitude to those associated with the Anakie Inlier. This does not suggest a sequence of some 16,000 feet of sediments as suggested by Veevers et al. (1964), and so it is inferred that there is little density contrast between the sediments of the Drummond Basin and the metasediments of the Anakie Inlier.

Some density variation is evidenced by the Beresford Gravity Ridge and the Withersfield Gravity Lows (features 1 and 2). Feature 1 extends through GALILEE and EMERALD (feature B9 of Gibb, 1969) and reflects high-standing basement of possibly Precambrian age. In EMERALD, feature 1 is related to the Pebbly Creek Anticline (Veevers et al., 1964).

Feature 2 is a series of Bouguer anomaly 'lows' which are situated between feature 1 and the Anakie Regional Gravity High and corresponds to a regional synclinal zone of the Drummond Basin sediments (e.g. the Withersfield Syncline). The inference from these features is that the Drummond Beds are thickest next to the Anakie Inlier and the junction of the two could possibly be fault controlled.

This zone therefore takes the form of a Bouguer anomaly shelf between the generally low Bouguer anomaly values of the Great Artesian Basin and the Anakie Regional Gravity High. The Bouguer anomaly features within this zone are related to regional anticlinoria and synclinoria within the Drummond Basin.

The Anakie Regional Gravity High

The Anakie Regional Gravity High can be directly correlated with the Anakie Structural High. This regional gravity 'high' is essentially a series of NNW-trending positive Bouguer anomaly features (feature 3).

The Anakie Regional Gravity High extends into the area covered by Bowen Basin sediments to the south and east of the Anakie Inlier outcrop area. The southerly extension confirms previous aeromagnetic results (Wells & Milsom, 1966), which indicate that the Anakie Inlier is of greater extent than that indicated by surface mapping. The easterly extensions of the Anakie Regional Gravity High indicate that the Anakie Structural High is at shallow depth below parts of the Western Shelf zone of the Bowen Basin. Features 8 and 9 are the most important of these easterly extensions, and they will be discussed in the section on the Bowen Regional Gravity Low.

Two Bouguer anomaly 'lows' occur in this zone of high Bouguer anomalies, namely, the Retreat Gravity Low (feature 4) and the Karin Gravity Low (feature 5). These are discussed in turn.

The Retreat Gravity Low. This 'low' (feature 4) is located over an area in which a large mass of granite, the Retreat Granite, crops out. It is postulated that the 'low' is directly related to the granite mass. The geology suggests that the granite contact with the Anakie Metamorphics is steep and non-gradational.

The Bouguer anomaly gradients bordering this anomaly do not suggest that the granite is steep-sided. Also the amplitude of the feature (-11 mgals) indicates that the lower-density rock (i.e. the granite) does not continue downwards to any great depth. A detailed interpretation of the anomaly is not attempted owing to the lack of areal gravity coverage and lack of density information. However, an assumed density contrast of 0.10 g/cm^3 between the granite and the country rock would indicate that the Retreat Granite is about 10,000 feet thick (the thickness is inversely proportional to the assumed density difference) with its maximum thickness closer to its western margin.

This 'low' has an extension in an easterly direction indicating that the granite cropping out at Capella is possibly connected to the Retreat Granite at depth.

The Karin Gravity Low. Feature 5 is located over the eastern margin of the Anakie Inlier, to the south-east of Clermont. In this region the Anakie Metamorphics are covered by a veneer of recent deposits. However, the 'low' suggests that a granite could be very close to the surface.

Feature 5 is much more intense than feature 4, which means (assuming the density contrast between the postulated granite and the Anakie Metamorphics is the same in both cases) that the postulated Karin granite has steeper sides and a greater downwards continuation than the Retreat Granite.

The Bouguer anomaly feature is elongated in an east-west direction with two minimum closures. For purposes of interpretation, only the western closure was considered. This closure is circular in form and could be produced by a vertical cylinder of granite. Skeels (1963) demonstrates an empirical technique for determining the maximum depth to the top of a vertical cylinder by using the amplitude, the half-maximum and three-quarter-maximum widths of the anomaly, and the observed density contrast. Using the charts presented by Skeels, maximum depths to the top and bottom of the cylinder are 15,000 feet and 75,000 feet.

The Bowen Regional Gravity Low

The Bowen Regional Gravity Low is a strip of predominantly negative Bouguer anomalies about 60 miles wide occurring between the Anakie Regional Gravity High and the Coastal Gravity Complex. This regional gravity feature corresponds to the Bulgonunna Volcanic Block and parts of the Bowen Basin. The regional gravity 'low' has been subdivided into several distinct smaller features, which will be discussed in turn. These features correlate extremely well with the known subsurface structure except for the Suttor Gravity Low (feature 10), which cuts across several structural boundaries.

The Bulgonunna Volcanic Block. The Bulgonunna Volcanic Block is an estimated 16,000 feet of acidic lavas with some granitic intrusions, which forms the shallow east-dipping basement to the Western Shelf of the Bowen Basin.

The Glendon and Bulgonunna Gravity Lows (features 6 and 7) are associated with the Bulgonunna Volcanic Block and these could be due either to an increased thickness of the volcanics or to granitic intrusions whose roots penetrate the underlying Anakie Metamorphics.

The Glendon Gravity Low (feature 6) occurs on the south-west corner of BOWEN just north of the Anakie Inlier. In this area the Bulgonunna Volcanic Block is intruded by a Carboniferous granite. The Bouguer anomaly feature is correlated with the development of the granite at depth.

The Bulgonunna Gravity Lows (feature 7) are a series of small Bouguer anomaly 'lows' which suggest an increase in thickness of the volcanic pile. These areas may represent the centres of igneous activity in Devonian-Carboniferous times (Plate 13).

The western edge of the Bowen Basin. The positive Bouguer anomaly features associated with the Anakie Regional Gravity High extend for some distance to the east of the outcrop area of the Anakie Metamorphics indicating that there is a gentle shelving of the Anakie Metamorphics beneath the Bulgonunna Volcanic Block. The Wyena Gravity High, the Waterford Gravity Spur, and the Comet Gravity Platform (features 8, 9, and 14) suggest that the Anakie Metamorphics, or their equivalents, are in structurally high positions in the areas covered by these Bouguer anomaly features. Feature 14 corresponds to the Comet Platform and will be discussed below.

The Wyena Gravity High is an irregular Bouguer anomaly 'high' in MOUNT COOLON and CLERMONT and straddles the boundary between the Bulgonunna Volcanic Block and the Western Shelf of the Bowen Basin. This is interpreted as being a high-standing block of Anakie Metamorphics. In the depression between this postulated ridge and the Anakie Inlier it is likely that the thickest section of the Bulgonunna Volcanic Block is developed, as this depression, if real, probably acted as a topographic trap for the lavas.

The Waterford Gravity Spur (feature 9) is related to a spur of Anakie Metamorphics extending across the Bulgonunna Volcanic Block into the Western Shelf area. That this feature is due to a highstanding basement block is evidenced by outcropping metamorphics at Fletchers Awl, which is on the north-pointing extension of feature 9.

The Comet Platform area. The Comet Platform is a north-trending basement ridge in EMERALD and DUARINGA, consisting of Devonian-Carboniferous rocks, possibly over Anakie Metamorphics, and flanked on either side by sedimentary troughs. A seismic survey conducted between Emerald and Duaringa (Robertson, 1961) attempted to determine the thickness of Permian sediments overlying the pre-Permian basement. The Bouguer anomaly profile approximating to this seismic line correlates well with the suggested subsurface structure (Plate 12).

From Plate 5 it can be seen that the Comet Gravity Platform (feature 14) trends north for about 70 miles and culminates about 30 miles north-east of Emerald. There is a NW-trending extension of the Comet Gravity Platform, which forms the northern margin of the Denison Gravity Low (feature 13). This could mean that early Permian sedimentation in the Denison Trough took place independently of sedimentation in the northern part of the Bowen Basin. To the east of the Comet Gravity Platform there is the more extensive Bluff Gravity Depression (feature 15), which corresponds to a locus of Permian-Triassic sedimentation (the Mimosa Syncline).

The Mount Roper Gravity Low (feature 12) may correspond to a thickening of the Permian succession to the north of the Comet Platform, but as R.G. Mollan (pers. comm.) points out, 'the Mount Roper Gravity Low appears to correspond to the Shell Creek Anticline. Norwich Park Scout No. 1 (Geological Survey of Queensland, 1963) was drilled on this anticline, and ?Devonian-Carboniferous volcanics were found at 488 feet. The Mount Roper Gravity Low is probably not caused by a thinning of Permian section north off the Comet Platform but may possibly be due to a pile of acid volcanics'.

The Mackenzie-Dawson Zone. The Mackenzie-Dawson Zone (Malone et al., 1963) is a long narrow strip between the Folded Zone of the Bowen Basin and the Gogango Range and Leura Areas. The zone is thought to be occupied by Tertiary sediments, possibly more than 1000 feet thick (Malone et al., 1963). Robertson (1961) suggests that there could be up to 3000 feet of Tertiary sediments just to the south-west of Duaringa. Recent seismic results from west and north-west of Duaringa indicate up to 3500 feet of Tertiary sediments (Mount Morgan Ltd, pers. comm.).

The Bouguer anomaly pattern does not indicate such a simple picture for this zone. There is no well defined Bouguer anomaly 'low' over the whole zone as would be expected if the zone was a long, fault-controlled structure; it could be that Bouguer anomaly 'highs' to the east obscure the gravity pattern in this area, but this is considered unlikely. There is, however, the well defined Mackenzie-Dawson Gravity Low (feature 18) in DUARINGA and ST LAWRENCE, which could indicate the thickest section of Tertiary sediments in this zone. The shape of the Bouguer anomaly feature indicates that the associated structure is fault-controlled. The Bouguer anomaly gradient on the eastern side of feature 18 trends NNW for about 100 miles and indicates that a major fault separates the Folded Zone from the Gongango Range Area.

The Bouguer anomaly features indicate that the Tertiary sediments vary greatly in thickness in the area of the Bowen Basin. Features 18 and 20 correlate with the two main areas of deposition; the Boolburra Gravity Lows (feature 20) correspond to the trough indicated by seismic work (Robertson, 1961). These areas of maximum sedimentation are offset from the geologically mapped Mackenzie-Dawson Zone, but as there is a blanket of Tertiary sediments over much of this area it is suggested that the Bouguer anomaly features represent the loci of sedimentation more precisely.

Feature 18 could be related to a sedimentary trough containing up to 5000 feet of sediments (Plate 10), which is in excess of the thickness of Tertiary sediments suggested by Robertson (1961) and Malone et al. (1963) in other parts of the zone. It is postulated that feature 18 is related to a steep-sided trough occupied by both Mesozoic (?Triassic) and Tertiary sediments. This structure could be a remnant of Triassic rocks similar to the Mimosa Syncline but at a lower structural level.

The eastern margin of the Bowen Basin. Immediately west of the Coastal Gravity Complex there is a NNW-trending zone in which the Bouguer anomaly gradients are very gentle. This zone is related to the eastern part of the Folded Zone of the Bowen Basin. The Bouguer anomaly pattern is complicated because there are four distinct features that occur in this zone; these are the Collinsville Gravity Low, the Redcliffe Gravity Low, the Mackenzie-Dawson Gravity Low and the Duaringa Gravity Highs (features 16, 17, 18, and 19).

The Collinsville Gravity Low (feature 16) is a residual Bouguer anomaly 'low', in BOWEN, which corresponds to the northern boundary of the Bowen Basin and indicates a southerly thickening of the Permian sediments (Plate 7).

The Redcliffe Gravity Low (feature 17) is also a residual Bouguer anomaly 'low' in MOUNT COOLON, and corresponds to the Redcliffe Syncline in which Triassic rocks are developed. Both features 16 and 17 become obscured to the south by the Suttor Gravity Low.

Feature 19 consists of two positive culminations, in DUARINGA, which are related to the Folded Zone. This feature corresponds to areas within the Folded Zone in which the Middle Bowen Beds crop out and are intensely folded. The Bouguer anomaly culminations, therefore, could be due either to a relatively high basement beneath these outcropping Middle Bowen Beds or to sediments that have a local higher density owing to the highly compressed nature of the rocks.

This whole zone of gentle Bouguer anomaly gradients indicates a probable eastern margin of the Bowen Basin. The zone is intermediate between the Bowen Regional Gravity Low and the Coastal Gravity Complex and is probably related to a regional rise in basement towards the structurally complex coastal area. Part of the Bouguer anomaly gradient could also be caused by a lateral increase in rock density towards the more disturbed sediments in the east. The postulated rise in the basement could correspond to a hinge line of the Bowen Basin along the western edge of the zone of central uplift of the Tasman Geosyncline.

To the north of the survey area, the Palmerville Fault, a 'fundamental' element of the Tasman Geosyncline, has been mapped over a distance of 600 miles (de Keyser, 1963), until it disappears at Townsville. It is thought that the postulated hinge line is also a 'fundamental' element but its relation to the Palmerville Fault is not known at present.

The northern part of the Bowen Basin. The Bouguer anomaly pattern in MOUNT COOLON and north CLERMONT is dominated by the Suttor and Poitrel Gravity Lows (features 10 and 11), which have a north-west trend in the north and a northerly trend in the south.

The Poitrel Gravity Low (feature 11) straddles the Folded Zone and the Western Shelf parts of the Bowen Basin and appears to be separate from the Suttor Gravity Low (feature 10), which crosses three structural zones - namely the Folded Zone, the Western Shelf, and the Bulgonunna Volcanic Block. In addition, feature 10 appears to have two significant closures, which possibly suggests that its source may be composite in form.

The origin of these Bouguer anomaly features is not readily understood but two possible theories are proposed:

1. Feature 11 is wholly within the area covered by the Upper Bowen Coal Measures, and the boundary between these beds and the Middle Bowen Beds coincides with the gradient on the western side of the feature. It is possible that feature 11 corresponds to an area of regional subsidence in this central position of the Bowen Basin. However, the geology (Malone et al., 1961) and the seismic results (Associated Freney Oil Fields N.L., 1963) do not support such an interpretation. The seismic results indicate a general increase in the sedimentary thickness towards the east across feature 11, and the sediments reach a maximum thickness of about 7000 feet over the eastern side of the Bouguer anomaly feature. The deepest reflections, however, were from a horizon above the base of the Middle Bowen Beds and so it is possible that sediments below this horizon show a great increase in thickness.

   If the Poitrel Gravity Low has a sedimentary origin it must be due to a sequence of pre-Middle Permian beds underlying this central part of the Bowen Basin.

2. A second interpretation of the Poitrel Gravity Low is that it reflects a low-density plutonic intrusion at depth. A small syenite intrusion is exposed in north-east CLEARMONT and it is possible that this intrusion is more greatly developed at depth. However, it is unusual for large batholiths to occur in areas of subsidence as they are usually associated with areas of central uplift. It is possible that the Poitrel Gravity Low is correlated with a low-density plutonic mass that was intruded into the basement of the Bowen Basin prior to the commencement of the deposition of the Bowen Basin sediments.

The Suttor Gravity Low (feature 10) can also be interpreted in these two different ways, i.e. as a pre-Middle Permian sedimentary trough or as a granitic batholith. If it reflects a sedimentary trough the sediments would probably have to pre-date the Bulgonunna Volcanic Block. This is not considered likely as these sediments would have been involved in the orogeny that produced the Anakie Metamorphics and they probably would not result in such a well defined Bouguer anomaly feature.

A common cleavage direction in the Anakie Metamorphics is approximately north-west (Veevers et al., 1961), which corresponds to the trend direction of the Suttor Gravity Low. Granites intruded at the same time as cleavage formation would tend to have a north-west trend. A possible explanation of the 'low' is that it is produced by a major granitic batholith intruded into the Bowen Basin basement at the time of the orogeny that produced the north-west cleavage in the Anakie Metamorphics. This area may then represent the axis of central uplift of a pre-Carboniferous orogeny.

Aeromagnetic results available over this area aid in the qualitative interpretation of these Bouguer anomaly features. Over feature 11 and the southern closure of feature 10 the aeromagnetic pattern is very regular and similar in nature to the pattern over sedimentary areas farther south in the Bowen Basin. This suggests that these gravity features are sedimentary in origin, even though the gravity axis is displaced from the sedimentary axis. This offsetting of the axes could be caused by the regional Bouguer anomaly gradient on the eastern side of the anomaly (which has been correlated with a hinge line of the Bowen Basin), which would have the effect of displacing the Bouguer anomaly axis to the west.

Over the north-western closure of the Suttor Gravity Low there is an irregular aeromagnetic pattern that could possibly originate from an igneous body. Thus from the gravity and aeromagnetic results it is inferred that this closure within the 'low' is related to a granitic intrusion.

It is concluded that Bouguer anomaly features 10 and 11 are possibly produced by pre-Middle Permian structures of a composite nature. The north-western closure of feature 10 is possibly related to a granitic intrusion, and feature 11 and the southern part of feature 10 could have a sedimentary origin. These are only tentative suggestions as to the origin of these gravity features. Combined seismic reflection and refraction traverses across the features are an obvious next step for their further investigation.

The Coastal Gravity Complex

The Bouguer anomaly pattern within this zone is very irregular owing to the structural complexity of the area, which results in a complicated distribution of a great variety of rock types. The rocks found within this area can be very broadly divided into three groups: (1) plutonic, (2) Palaeozoic sediments and lavas, and (3) Upper Mesozoic and Tertiary sediments. The Bouguer anomaly features related to these different rock types will be considered in turn.

(1) Bouguer anomaly features related to plutonic masses

Within the coastal zone there are several plutonic masses which are the source of Bouguer anomaly features: (a) the Urannah Complex (relates to features 21 and 23); (b) the postulated Port Clinton granite (based on feature 31) and the postulated Bajool granite (based on feature 36); and (c) the Marlborough Block ultrabasic intrusions (related to features 32 and 33).

(a) The Urannah Complex. The exposed Urannah Complex is a diorite-granite-granodiorite mass, which occurs in AYR, BOWEN, PROSERPINE, MACKAY, MOUNT COOLON, and ST LAWRENCE. In south BOWEN, however, basic rock types are found which intrude the acidic complex.

It is postulated that the Eungella Gravity Ridge and the Urannah Gravity Lows (features 21 and 23) are related to the Urannah Complex. The Eungella Gravity Ridge extends for about 160 miles in a NNW direction and is paralleled to the east by the Urannah Gravity Lows as far north as the northern edge of BOWEN. For much of their length the Urannah Gravity Lows occur over the granitic Urannah Complex and can be directly correlated with this granite. The Eungella Gravity Ridge occupies a position along the western margin of the Urannah Complex, sometimes over the exposed granite and sometimes over the Lower Bowen Volcanics. This Bouguer anomaly feature therefore does not correlate with a unique geological element.

The Urannah Gravity Lows (feature 23) are not a continuous feature, as Bouguer anomaly 'highs' from the Eungella Gravity Ridge extend into them. On the border of PROSERPINE and MACKAY the 'low' is split by one of these 'highs'. The 'low' in MACKAY has an easterly extension beyond the mapped outcrop of the granite, indicating that the granite possibly extends, at shallow depth, beneath the Lower Bowen Volcanics and the Campwyn Beds, which crop out in this area.

To the south any correlation between the Bouguer anomaly features and the granitic Urannah Complex is even more obscure. In this region the Urannah Complex outcrop becomes very narrow and cuts across many Bouguer anomaly features. It is postulated that the granite complex is not well developed in this region and occurs only at shallow depth.

It has been stated previously that the Eungella Gravity Ridge does not correlate with the known surface geology and in order to explain the Gravity Ridge it is postulated that there may be a basic plutonic mass associated with the western margin of the Urannah Complex. As the Lower Bowen Volcanics and the Urannah Complex are considered to be, in part, contemporaneous (Malone et al., 1962) it is quite possible that there is a basic plutonic mass associated with these extrusives. The Eungella Gravity Ridge is thought to be the Bouguer anomaly expression of this basic pluton.

That the contact between the basic and acidic masses is not simple is shown by the irregular nature of the boundary between Bouguer anomaly features 21 and 23. The Bouguer anomaly gradient across this contact is usually steep, indicating that the contact is probably nearly vertical. This indicates that the junction between the basic and acidic masses is possibly an intrusive one.

It is concluded that the Urannah Complex is a multiple intrusion with granitic rocks on the east and basic rocks on the west. It is possible that the basic intrusion is more greatly developed in the north, in north BOWEN and AYR, where the Eungella Gravity Ridge has a larger areal extent. In this region the feature occurs over widespread granite outcrops (Christian et al., 1953), indicating that the basic intrusion occurs at shallow depth. Another possibility is that the granite has a different, more basic, composition in this northern part of its outcrop.

(b) The Port Clinton Granite and the postulated Bajool granite. To the east of the high Bouguer anomaly values associated with the Marlborough Gravity Ridge and the Westwood Gravity High (features 32 and 33) lies the Gladstone Gravity Plateau (feature 37). This is a zone of relatively low Bouguer anomalies. In this 'plateau', which correlates with the South Coast Structural High, the general Bouguer anomaly is about +10 to +15 mgals. The main variations from this Bouguer anomaly 'plateau' are a series of negative Bouguer anomalies, namely the Port Clinton Gravity Lows and the Bajool Gravity Low (features 31 and 36).

The geology of this Structural High is not known in detail, but essentially it is a heterogeneous marine assemblage of Lower Palaeozoic metamorphic rocks of very low grade. The assemblage is intruded by Permian granites.

The obvious interpretation of the Bouguer anomaly features in this zone is that the general background reflects the structural position of the metasediments and the Bouguer anomaly 'lows' reflect the granitic intrusions.

The Port Clinton Gravity Lows (feature 31) form a composite Bouguer anomaly feature in PORT CLINTON consisting of four significant closures. The north-west closure of feature 31 is associated with a granitic outcrop, and the Bouguer anomaly feature is almost certainly related to this granite. It is inferred that the other closures of this Bouguer anomaly feature are also associated with granitic masses at depth. The north-west closure of feature 31 is the most intense of the Bouguer anomaly features but this is probably due to the granite being adjacent to the high-density ultrabasic rocks of the Marlborough Block.

It is thought that these Bouguer anomaly features could be associated with one large batholith with the closures occurring either over granite cupolas or over the deep-seated roots of the granite. The significant inference gained from these Bouguer anomaly features is that in PORT CLINTON there is probably a large mass of granite which has a greatly varying thickness of cover rock. The south-west margin of the inferred granite would appear to be indented by a 'nose' of dense rocks, which are probably related to the Marlborough Dlock. Thus the plan of the inferred batholith is crescent-shaped within the survey area but its likely seaward extension is not known.

The Bajool Gravity Low (feature 36) is also thought to be associated with granitic rocks, probably at shallow depth. Although no granite is exposed in the immediate vicinity of the Bouguer anomaly feature there is evidence of granitic rocks in the area (e.g. granites crop out in MONTO and the Mount Morgan Granite crops out in ROCKHAMPTON). The southern part of the Bajool Gravity Low appears to be widening out so as to embrace the granites in MONTO* and there is a 'nose' of this 'low' in the vicinity of Mount Morgan. These facts indicate the presence of a large batholith, only small parts of which are exposed.

(c) The Marlborough Block ultrabasic intrusions. The Marlborough Gravity Ridge, the Westwood Gravity High, and the Gogango Gravity High (features 32, 33, and 34) are associated with three structural zones - the Marlborough Block, the Gogango Range Area, and the Yarrol Basin.

The Marlborough Gravity Ridge (feature 32) is definitely related to the Marlborough Block, which is a structurally high area consisting of metasediments with associated ultrabasic intrusions. The areal extent of feature 32 indicates that the ultrabasic rocks could have a greater development at depth than is exhibited at the surface.

To the south, feature 32 widens out to link with features 33 and 34, which encompass the Gogango Range Area and the Yarrol Basin. This could possibly mean that the ultrabasic rocks are developed at depth. The association of covered ultrabasic rocks with the Westwood Gravity High (feature 33) is probably true, as the magnitude of the anomaly here is of the same order as that of feature 32. The Bouguer anomaly gradient between features 32 and 31, which reflects a known contact between granite and ultrabasic rocks, and the gradient between features 33 and 36 are similar, which suggests that there may be an ultrabasic/granite contact between features 33 and 36 also. The relief and gradients of features 33 and 36 obscure any features that may be associated with the sediments of the Yarrol Basin**.

The Gogango Gravity High (feature 34) is possibly related to the structurally high position of the Gogango Range Area and not to the presence of ultrabasic rocks at depth. This will be discussed in the next section.

(2) Anomalies related to Palaeozoic sediments

As will be discussed below in section (3), the St Helens Gravity Low (feature 26) can be contoured to make it continuous with the Proserpine Gravity Trough (feature 25). This method of contouring results in the Seaforth Gravity Spurs (feature 24) being a long, narrow 'high' along the coastal region of PROSERPINE and MACKAY. In this coastal region there is a Devonian-Carboniferous block, which consists of a south-plunging anticline faulted against a Permian block to the west. The Seaforth Gravity Spurs (feature 24) are directly related to this structurally high block of Palaeozoic sediments. Similarly the Sarina Gravity High (feature 30) is related to a high basement block; the southern 'nose' of the Bouguer anomaly feature corresponds to the Devonian-Carboniferous anticline.

(a) The Connors River Area and the Connors Range Arch. The Connors Range Gravity Platform (feature 22) is a very extensive region of high Bouguer anomaly values. The Bouguer anomaly feature occurs over two structural zones - the Connors River Area

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* Recent gravity mapping shows that feature 36 does in fact extend southwards in MONTO over outcropping granite (Lonsdale, 1965).

** The BMR 1964 helicopter gravity survey (Lonsdale, 1965) has shown that features 33 and 36 extend south into MONTO and no features associated with the Yarrol Basin have been observed.

and the Connors Range Arch. The Connors River Area consists of poorly exposed Middle Bowen Beds dipping WSW away from the Lower Bowen Volcanics. They form the southerly extension of the eastern flank of the Bowen Basin. The Connors Range Arch is a south-plunging anticline composed of Lower Bowen Volcanics intruded by the Urannah Complex.

The Urannah Complex in this area is only a narrow strip with a number of isolated outcrops. It is inferred that in the region of gravity feature 22 the Urannah Complex does not extend to any great depth.

The general 'high' in this area is thought to be due to Lower Bowen Volcanics being in a structurally high position. To the south, feature 22 noses out between the Mackenzie-Dawson Gravity Low and the Strathmuir Gravity Low (features 18 and 29). This corresponds to the nosing-out of the Connors Range Arch and indicates that the Bouguer anomaly feature can be related to the structural zone. It is probable that the Middle Bowen Beds that crop out in the Connors River Area are relatively thin.

Included within feature 22 is a five-milligal Bouguer anomaly 'low', which could be due to a thickening of the Permian sediments in this area. This 'low' is bounded by the +15 contour near the centre of ST LAWRENCE.

(b) Strathmuir Syncline. The Strathmuir Gravity Low (feature 29) is correlated with the Strathmuir Syncline. This synclinal feature is a NW-trending structure occupied by Middle Bowen Beds in ST LAWRENCE and DUARINGA. To the south the structure loses its identity amid tightly folded and sheared sediments in DUARINGA. The Strathmuir Syncline may be the southern extension of the syncline occupied by the Carmila Beds (Malone et al., 1963), but the relation between the two structures is obscured by the overlying Styx Basin sequence and the sea. The Strathmuir Syncline is a structurally low area between the Connors Range Arch in the west and the Marlborough Block in the east.

The Strathmuir Gravity Low does not appear to be connected to the Styx Gravity Low (feature 28) although this is indefinite owing to insufficient control (Feature 28 is discussed in the section on Mesozoic and Tertiary sediments).

The structurally low position of the Strathmuir Syncline is illustrated by the absence of outcrops of Lower Bowen Volcanics in the region. Feature 29 is related to the sequence of Middle Bowen Beds overlying the Lower Bowen Volcanics. Plate 11 shows a possible section across the synclinal area in which it is assumed that the eastern margin of the Strathmuir Syncline is in the nature of a thrust fault.

The Strathmuir Gravity Low (feature 29) extends south of the Strathmuir Syncline into the Gogango Range Area and the Leura Area. This indicates that the structurally low area extends farther south than is shown by the boundaries of the Strathmuir Syncline in Plate 2. This is possible as the geological maps (Malone et al., 1963) show Middle Bowen Beds extending into this area.

Feature 29 is therefore interpreted as occurring in a region in which the Lower Bowen Volcanics are in a structurally low position.

(c) The Gogango Range Area. The Gogango Range Area is characterised by sheared sediments with complex folding and faulting. The older sediments, Silurian-Devonian* and Lower Permian, are predominant in the cores of some of these structures (Olgers et al., 1964).

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* Recent fossil evidence suggests that these rocks could be Permian (F. Olgers, pers. comm.).

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As previously stated the Gogango Gravity High (feature 34) is associated with the Gogango Range Area. The 'high' is definitely related to a high basement region (Plate 12), as Devonian rocks crop out at one locality. Associated with this Bouguer anomaly 'high' is the Grantleigh Gravity Low (feature 35), which could be related to either Tertiary sediments or a granitic intrusion (see below in section (3)).

(d) The Yarrol Basin. The Yarrol Basin is a long narrow basin with 10,000 feet of sediments, mostly marine, from upper Middle Devonian to the end of the Permian. The sequence contains a considerable thickness of intermediate volcanics and limestones. It was expected that the Yarrol Basin would show up as a relative Bouguer anomaly 'high'. However, any features associated with the Yarrol Basin are obscured by the magnitude and gradients of the Westwood Gravity High and the Bajool Gravity Low (features 33 and 36) and it is not possible to establish any relation between the Yarrol and Bowen Basins.

Serpentinites are known in the Yarrol Basin but only along its thrust-faulted eastern margin. It is postulated that these are only minor offshoots of a large ultrabasic plutonic mass, which occurs beneath the central and western parts of the Basin.

Granites are also known throughout the Yarrol Basin, e.g. the Mount Morgan Granite, and it is probable that these granites form a continuous batholith at depth, as postulated in the discussion of the Bajool Gravity Low (feature 36).

(e) Herbert Creek Block and Long Island Area. The Herbert Creek Block consists of Lower Bowen Volcanics and forms the north-east flank of the Strathmuir Syncline.

The Long Island Area is a block of steeply dipping Carboniferous sediments, sheared and intruded in places. The structures in the area are not known owing to insufficient geological mapping and also to a blanket of Cainozoic sediments, which obscure the Carboniferous rocks.

The Long Island Gravity High (feature 39) corresponds to these areas, especially the Long Island Area. This Bouguer anomaly feature may be connected to the Sarina Gravity High (feature 30), which is related to the Devonian-Carboniferous anticline in MACKAY, but additional gravity control is needed before definite conclusions can be drawn. If they are connected it would indicate that the Upper Mesozoic-Tertiary trough (discussed below in section (3)), postulated to extend from Broad Sound to Proserpine, is not continuous. This in turn would indicate that the Cretaceous Styx Basin is separated from the Tertiary trough by a basement ridge. On the other hand if features 39 and 30 are not connected (as shown in Plate 5) it would indicate that the Cretaceous and Tertiary troughs are connected through a breach in the ridge of Carboniferous rocks.

(3) Anomalies related to Upper Mesozoic and Tertiary sediments

The main area of Upper Mesozoic and Tertiary sedimentation is postulated to be a narrow trough extending offshore from Proserpine to Broad Sound (gravity features 25, 26, 27, and 28).

The Proserpine Gravity Trough (feature 25) is a well defined Bouguer anomaly 'low'; it is related to the Proserpine Graben, which has been delineated by aeromagnetic and seismic surveys (Ampol Exploration (Qld) Pty Ltd, 1963 & 1964a). The seismic results indicated an asymmetrical syncline, trending north-west, which is characterised by a moderately dipping south flank and a steeply dipping and faulted north flank. The depth to the seismic 'basement marker' bed is approximately 7000 feet in the centre of the syncline.

The geological cross-section (Plate 8) is based on the seismic results. Several densities were assumed for the different layers indicated by the seismic survey, and the theoretical Bouguer anomalies were computed for these different density distributions.

The mass distribution to give a theoretical anomaly that best fits the observed gravity anomaly is shown in Plate 8. From this interpretation it is established that the bulk density contrast between the sediments occupying the graben and the basement rock is about 0.30-0.40 g/cm^3. This seems to be realistic for the density contrast if the sediments are Tertiary shales, with some volcanics, and the basement is either Permian volcanics or Upper Devonian-Lower Carboniferous Campwyn Beds.

From the interpretation presented above it is obvious that in this case there is excellent correlation between the gravity and the seismic results, i.e. the northern flank of the graben is more steeply dipping than the southern flank and may in fact be fault-controlled. A more detailed gravity survey would probably allow a relatively exact interpretation of the northern flank of the graben to be made.

The gravity results over this locus of Tertiary sedimentation suggest that other pockets of Tertiary sediments in offshore locations could be the source of gravity 'lows'.

Cropping out on Cape Hillsborough, to the north of Mackay, are at least 1600 feet of Tertiary sediments and acid volcanics, which are faulted against the Campwyn Beds to the west (Jensen, 1963). Aeromagnetic results (Ampol Exploration (Qld) Pty Ltd, 1963) indicate that there could be up to 4000 feet of sediments in this area. The St Helens Gravity Low (feature 26) is shown in Plate 5 to be centred on Cape Hillsborough. The contours in Plate 5 have been drawn by mechanical means and show feature 26 to be isolated from feature 25. This is not the only way of contouring the values in this region, as preliminary contouring showed features 26 and 25 to be continuous. The St Helens Gravity Low is based on only one gravity station, which is situated on the Tertiary outcrop on Cape Hillsborough, and so it is not possible to obtain the true areal extent of this anomaly until more gravity stations are established in St Helens Bay. Recent marine seismic results (Ampol Exploration (Qld) Pty Ltd, 1964b) indicate that there is a continuous sedimentary trough extending from Proserpine into the offshore vicinity of Mackay. It therefore seems probable that features 26 and 25 could be continuous.

It appears that the Tertiary sequence thins to the south-east from its maximum of 7000 feet at Proserpine.

To the south-east of the St Helens Gravity Low (feature 26) is the Douglas Gravity Low (feature 27), but it is not possible to determine, with the data available, whether these features are continuous. The preliminary contouring indicated that feature 27 was connected to feature 26 to the north and to feature 28 to the south with only minor saddles between them. In Plate 5 the saddles are more strongly emphasised. It is not possible to ascertain which of these two alternatives is correct owing to the lack of gravity coverage.

In this offshore region both volcanics and granites occur and so the 'low' could be either sedimentary or plutonic in origin. The aeromagnetic results (Ampol Exploration (Qld) Pty Ltd, 1963) indicate a poorly-defined thickening of the sedimentary sequence in this area. If the Douglas Gravity Low (feature 27) is of sedimentary origin it could represent sediments roughly 7000 feet thick.

The Styx Gravity Low (feature 28) is situated south-west of the Douglas Gravity Low (feature 27) in MACKAY and ST LAWRENCE. The Styx Gravity Low appears to be related to both the Carmila Block and the Styx Basin. In MACKAY the Carmila Beds (Lower Permian) are folded into a SSE-plunging syncline. In ST LAWRENCE the southern end of the Carmila Block is obscured by the sediments of the Styx Basin.

The interpretation of feature 28 is very tentative as there are very few gravity data to control its eastern development, over Broad Sound. It is possible that the shape of the feature would be greatly changed if more data were available.

The Carmila Beds are between 2000 and 7000 feet thick (Jensen et al., 1963) and the Styx Coal Measures could be up to 3000 feet thick (Malone et al., 1963). Feature 28 can be interpreted as being due to this total thickness of relatively light sediments in the synclinal area.

A few stations were read on the Styx Basin outcrop. These stations appear to be about five milligals lower than the values on either side of the Basin. This can be interpreted as meaning that there are about 2000 feet of Cretaceous sediments in the Basin, if these sediments are about 0.2 g/cm^3 lighter than the surrounding rocks. The faulted nature of the eastern margin of the Styx Basin is not indicated by the gravity results; this is to be expected from the large station spacing.

It therefore appears that feature 28 can be related wholly to the Cretaceous sediments of the Styx Basin or to the combined effect of the Styx Basin and the synclinal Carmila Block.

The Proserpine Gravity Trough, the St Helens Gravity Low, the Douglas Gravity Low, and the Styx Gravity Low (features 25, 26, 27, and 28) form a region of low Bouguer anomalies extending from Proserpine to Broad Sound. However, the paucity of gravity data in critical regions does not make it possible to determine whether these features are in fact continuous. The origin of the Douglas Gravity Low (feature 27) is important in any conclusions postulated about this region. If this feature has a sedimentary origin it is probable that there is a trough of Cretaceous and Tertiary sediments extending from Proserpine to Broad Sound. This trough would have its maximum development at Proserpine with the section thinning to the south-east as far as Mackay and then thickening towards the Styx Basin.

Another possible locus of Tertiary sedimentation could be related to the Grantleigh Gravity Low (feature 35) in ROCKHAMPTON. This 'low' occurs over an area where the Lower Permian rocks of the Gogango Range are overlain by Tertiary and Cainozoic sediments. These sediments could be over 2000 feet thick if they are responsible for the whole of the Bouguer anomaly relief. In the south the Bouguer anomaly feature is more intense and its source is not so clear. The increase in intensity could be due to the large density contrast between the Tertiary sediments and the ultrabasic rocks that are postulated as being at shallow depth in this area. This intense part of the Bouguer anomaly feature could also be related to a granitic intrusion at depth. The 1964 helicopter gravity survey may help to elucidate this problem.*

(4) Summary of Coastal Gravity Complex

The main features of the Coastal Gravity Complex are two NNW-trending regions of plutonic activity, the Urannah Complex in the north and the Marlborough 'Complex' in the south. Both of these belts are characterised by an ultrabasic mass on the western side and a granitic mass on the eastern side. These areas are separated by an area in which plutonic development is slight and which is an area of high basement, the Connors Range Arch. Superimposed on these structural elements is a narrow trough, fault-controlled in many places, in which sediments of Middle Permian (if the Strathmuir Syncline is included in this trough) to Tertiary age have been preserved. The sediments are youngest in the northern part of this trough, the Proserpine Graben.

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* The 1964 helicopter gravity survey results show that the Grantleigh Gravity Low is not very extensive in MONTO and could possibly be related to a structural 'low' between the Gogango Range Area and the postulated southern extension of the Marlborough Block (Lonsdale, 1965).

6. DISCUSSION OF BOUGUER ANOMALY PROFILES

A number of Bouguer anomaly profiles crossing important structural elements in the survey area have been examined in some detail. Their location is shown in Plate 5. They are:

1. Profile AB across the Glendon Gravity Low, the Collinsville Gravity Low, and the Eungella Gravity Ridge.

2. Profile CD across the Proserpine Gravity Trough.

3. Profile EF across the Beresford Gravity Ridge, the Retreat Gravity Low, the Karin Gravity Low, the Mount Roper Gravity Low, the Connors Range Gravity Platform, the Styx Gravity Low, and the Long Island Gravity High.

4. Profile GH across the Mackenzie-Dawson Gravity Low.

5. Profile IJ across the Connors Range Arch, the Strathmuir Syncline, and the Marlborough Block.

6. Profile EK across the Beresford Gravity Ridge, the Clermont Gravity Highs, the Denison Gravity Low, the Comet Gravity Platform, the Bluff Gravity Depression, the Duaringa Gravity Highs, the Boolburra Gravity Lows, the Gogango Gravity High, the Westwood Gravity High, the Bajool Gravity Low, and the Gladstone Gravity Plateau.

Profile AB (Plate 7)

Profile AB is located in BOWEN and crosses the northern end of the Bowen Basin. The geological section is based on BMR geological mapping (Malone et al., 1962) and shows the relation between the Bulgonunna Volcanic Block, the Bowen Basin, and the Urannah Complex. In general the Bouguer anomaly pattern can be directly related to the known geology.

In the west the Bulgonunna Volcanics are intruded by a Carboniferous granite, which is the source of the Glendon Gravity Low (feature 6).

The relative Bouguer anomaly 'high' to the east of the Glendon Gravity Low is a southerly-trending 'nose' of the Eungella Gravity Ridge and is related to the Lower Bowen Volcanics, which crop out on the western side of the Bowen Basin. The Lower Bowen Volcanics are found only on the western edge of the Bowen Basin, in this northern area, and the Bouguer anomaly nose corresponds very well to the wedge of basic lavas.

The Collinsville Gravity Low in the centre of the profile can be correlated with an increase in the thickness of the Middle Bowen Beds. The density contrast between the Middle Bowen Beds and the surrounding rocks (either basic volcanics or basic intrusions) is probably quite large. If the contrast is as great as 0.6 g/cm^3 (which seems not unreasonable) then there would be about 2000 feet of sediments in this part of the Bowen Basin. This agrees with the known geological section.

The Eungella Gravity Ridge on the east of the profile is not related to any known geological structure, but it is postulated that it is caused by a large basic intrusion at shallow depth. Small outcrops of basic rocks in this area indicate that there could be a larger subsurface basic mass, which could possibly have been the source of the Lower Bowen Volcanics. The Bouguer anomaly gradients bounding this 'high' are relatively large (4 mgal/mile) and so indicate that the basic plutonic mass has steep sides, which is characteristic of a faulted or intrusive contact.

Profile CD (Plate 8)

Gravity readings were made at approximately one-mile intervals along a seismic reflection and refraction traverse that crosses the Proserpine Trough near the township of Proserpine. The resulting Bouguer anomaly profile is shown in Plate 8, which also gives a simplified geological cross-section based on the seismic results (Ampol Exploration (Qld) Pty Ltd, 1964a).

A faulted northern flank of the Proserpine Trough is clearly indicated. If an unfaulted northern margin is assumed the observed and computed Bouguer anomalies do not reasonably coincide.

The age relations of the rocks in this sedimentary trough are not fully known. Bodies 1 and 3 are thought to be Tertiary, but the ages of bodies 2 and 4, which occur below the first major reflection, are not known. It is possible they could be Tertiary acidic lavas or perhaps even Cretaceous sediments.

This profile was also discussed in the previous chapter.

Profile EF (Plate 9)

Profile EF crosses EMERALD, CLERMONT, and ST LAWRENCE. The main features of this profile have been discussed in the previous chapter and will be only briefly summarised here. There is good correlation between the Bouguer anomaly features and geology on the eastern and western ends of the traverse where the Drummond Basin, the Anakie Inlier, the Carmila Block, and the Styx Basin are found. The Bowen Basin sediments cannot be clearly correlated with any Bouguer anomaly feature; the Mount Roper Gravity Low (feature 12) occurs over the general region of the Bowen Basin but the axis of this 'low' does not correspond to the axis of sedimentation. However, this 'low' is still thought to be sedimentary in origin, but the true axis of the feature is obscured by a large regional gravity gradient along the eastern margin of the Bowen Basin (see discussion of profile EK).

Good qualitative correlation can be seen between the aeromagnetic profile and the geology. There is an irregular magnetic pattern over the Anakie Inlier, the Bulgonunna Block, and the Western Shelf of the Bowen Basin, which indicates a magnetic source close to the surface. Over the area of the thickest sedimentary sequence there is a broad magnetic 'high', which has a deep-seated origin. The irregular pattern over the Connors Range Arch probably correlates with the Lower Bowen Volcanics that crop out in these areas.

Profile GH (Plate 10)

Profile GH is in DUARINGA and ST LAWRENCE and crosses the Mackenzie-Dawson Zone, which is thought to be a fault-controlled Tertiary trough (Malone et al., 1963). Little is known of the thickness of these sediments although Malone et al. suggest a general thickness of over 1000 feet, and Robertson (1961) suggests they are possibly over 3000 feet thick in the Duaringa area.

The Mackenzie-Dawson Gravity Low has an amplitude of over -20 milligals, which suggests that there is a relatively large thickness of light sediments in this zone. There is no geological control over this Bouguer anomaly feature and so an infinite number of models could be constructed to give a computed Bouguer anomaly that would fit the observed Bouguer residual anomaly. The residual Bouguer anomaly was obtained graphically by removing a regional Bouguer anomaly gradient of one milligal per one and two-thirds miles, which is the gradient related to the postulated hinge line along the eastern margin of the Bowen Basin.

One simple model was constructed (Plate 10) and Bouguer anomalies were computed using different densities for the 'fill' sediments and leaving the basement density constant at 2.60 g/cm^3). Owing to lack of control there is no way of telling which of these possibilities is nearest to the correct solution. However, it can be concluded that in this part of the Mackenzie-Dawson Zone there is probably a fault-controlled sedimentary trough in which there is a thickness of between 2000 and 5000 feet of sediments, which could be from Triassic to Tertiary in age.

Profile IJ (Plate 11)

Profile IJ in ST LAWRENCE crosses the Connors Range Arch, the Strathmuir Syncline, and the Marlborough Block. The geological contacts at the surface are based on BMR mapping (Malone et al., 1963). The densities indicated on the cross-section are those on which the computer Bouguer anomaly profile is based.

The fit between the observed and computed Bouguer anomalies is considered good enough to indicate that the subsurface structure shown in Plate 11 could approximate to the true structure.

Malone et al. (1963) suggest that the eastern limb of the Strathmuir Syncline is a thrust fault. This suggestion is supported by the Bouguer anomaly results owing to the fact that the Bouguer anomaly gradient associated with the Marlborough Block/Strathmuir Syncline junction occurs over the Marlborough Block, and so indicates an easterly dipping contact, i.e. a thrust fault.

It is concluded that there is a reasonably good correlation between the gravity results and the known geology. There is also a good qualitative correlation between the aeromagnetic results and the geology: the Marlborough Block gives rise to intense anomalies. The anomalies associated with the Strathmuir Syncline indicate a relatively deeper source.

Profile EK (Plate 12)

Profile EK crosses EMERALD, DUARINGA, and ROCKHAMPTON and illustrates the Bouguer anomalies associated with the Drummond Basin, the Anakie Inlier, the Bowen Basin, and the Yarrol Basin.

Drummond Basin. It was concluded in the previous chapter that there appeared to be little density contrast between the Drummond Basin sediments and the Anakie Metamorphics. The Beresford Gravity Ridge, which is associated with the Pebbly Creek Anticline, contines on into GALILEE, where it attains a maximum value greater than the Bouguer anomalies associated with the Anakie Inlier (R.A. Gibb, pers. comm.). It is unlikely that this Bouguer anomaly ridge is related to rocks that pre-date the Anakie Metamorphics. Therefore the major features within the Anakie Regional Gravity High and the Drummond Gravity Shelf may reflect the configuration of a pre-Anakie Metamorphic basement.

Anakie Inlier. The Anakie Inlier is the source of the Clermont Gravity Highs, on which is superimposed the Retreat Gravity Low that is correlated with the Retreat Granite. The aeromagnetic anomalies over the Anakie Inlier suggest a magnetic source close to the surface.

Bowen Basin. The Bouguer anomaly profile over the Denison Trough, the Comet Platform, and the Mimosa Syncline shows good qualitative correlation to the seismic profile (Robertson, 1961). Using the seismic interpretation as depth control, a Bouguer anomaly profile can be computed across this part of the Bowen Basin (Robertson used the gravity data available at that time to help to construct his section). Assuming a density contrast of 0.2 g/cm^3 between the Bowen Basin sediments and the underlying

Anakie Metamorphics, good correlation is obtained between the computed and observed Bouguer anomalies over the Denison Trough and the Mimosa Syncline. However, over the Comet Platform the computed Bouguer anomaly is about six milligals less than the maximum observed anomaly. Three possible explanations will be given for this:

1. The Comet Platform could be at a shallower depth than indicated on the profile.
2. If the Comet Platform had been a zone of uplift in pre-Permian time, a thick section of the Anakie Metamorphics could have eroded away leaving a possible Precambrian basement close to the base of the Permian. This Precambrian basement could then be the source of part of the Bouguer anomaly feature over the Comet Platform.
3. There could be a lateral change in density contrast across the Comet Platform. It is possible that a denser and more resistant basement rock could underlie or form the core of the Comet Platform.

The eastern part of the Bouguer anomaly feature over the Bowen Basin is dominated by a regional Bouguer anomaly gradient, which increases eastwards by about 35 milligals in about 50 miles. This gradient is found along all of the eastern margin of this northern part of the Bowen Basin and is possibly caused by a deep-seated density contrast, which possibly forms the hinge line between the Bowen Basin and the axis of central uplift of the Tasman Geosyncline. The structure that produces the Bouguer anomaly gradient could be either a fault or a monocline in a ?Precambrian basement. The aeromagnetic results show a regional gradient over this zone, and a deep-seated source is postulated for this feature.

The removal of this 'regional' Bouguer anomaly gradient isolates three 'residual' Bouguer anomaly features: two 'highs' and one 'low'. The western 'high', the Duaringa Gravity Highs (feature 19) is related to a rise in pre-Permian basement beneath an area of the Folded Zone where the Middle Bowen Beds are exposed.

The 'low', the Boolburra Gravity Lows (feature 20), is related to Tertiary sediments in the Mackenzie-Dawson Zone. The residual anomaly indicates about 3000 feet of Tertiary sediments (0.3 g/cm^3 density contrast between the Tertiary and Permian sediments), which agrees with the thickness determined by the seismic reflection method (Robertson, 1961).

The eastern 'residual high', the Gogango Gravity High (feature 34) is related to a rise in pre-Permian basement beneath the Gogango Range Area, which is a structurally high zone in which the Lower Permian and Carboniferous sediments occupy the cores of many anticlines (Olgers et al., 1964).

Yarrol Basin. Any Bouguer anomaly features associated with the sediments of the Yarrol Basin are obscured by the Westwood Gravity High and the Bajool Gravity Low (features 33 and 36), which are correlated with plutonic rocks. The Westwood Gravity High is thought to be related to ultrabasic rocks, intruded during the initial stages of the geosyncline. The Bajool Gravity Low is interpreted as correlating with a granitic batholith which was intruded during the uplift of this coastal region. The nature of the Bouguer anomaly feature suggests that the postulated granite continues to considerable depth.

7. GENERAL STRUCTURAL CONSIDERATIONS

In the development of a geosyncline the initial magmatic stage is the outpouring of basic lavas or the intrusion of ultrabasic magmas or both (Beloussov, 1962), the ultrabasic magmas probably being the differentiate of the basic lava. These magmas are intruded into the zone that will eventually become the zone of central uplift. During a later stage this central part of the geosyncline is uplifted with much folding and faulting of the sediments, accompanied by the intrusion of large masses of granitic magma. During this orogenesis marginal troughs are formed, which are basins in which the sediments may or may not be folded. Batholiths within geosynclinal belts are usually associated with the zone of central uplift and are rarely found in the lower flanks of the central uplift and even less in the areas of subsidence.

The gravity results discussed in the previous chapter indicate that the area under consideration is in general accordance with this type of geological history. During Carboniferous-Lower Permian times the part of the Tasman Geosyncline covered by the Coastal Gravity Complex was in a structurally low position and large masses of ultra-basics were intruded (the intrusions are postulated to be related to the Urannah Complex and the Marlborough Block) together with the outpouring of large amounts of basic lavas. During the uplift of the central zone of the geosyncline large granite batholiths were emplaced. These granites intruded the same zones as the ultrabasics and form two igneous complexes (one in the north of the area and one in the south) where the granites and ultrabasics are found in intimate association. At the time of the central uplift a marginal trough was formed in which sedimentation continued until at least the Triassic (this corresponds to the Bowen Basin). The structurally high block between the two igneous provinces of the coastal region probably acted as a relatively stable block throughout the orogeny.

The eastern margin of the Bowen Regional Gravity Low is characterised by a zone of relatively low Bouguer anomaly gradients, with gravity increasing towards the east. In this zone the Bouguer anomaly contours are rather erratic and possibly represent residual anomalies related to variations in thickness of the Permian-Triassic sequence (e.g. the Redcliffe Syncline and the Mackenzie-Dawson Zone). The regional Bouguer anomaly gradient over this zone is interpreted as a rise in the basement towards the east, and can be related to the flanks of the central uplift. In this area there are isolated intrusions which are typical of this structural position. The rise in basement possibly represents the hinge zone between the zone of central uplift and the marginal trough and could be in the form of a monocline, possibly with associated faulting. It is suggested that the tectonic activity within the hinge zone was fundamental in the evolution of the Tasman Geosyncline in the survey area.

In the area of central uplift, thrust faulting has been observed in many places, e.g. on the eastern side of both the Strathmuir Syncline and the Styx Basin. Steep Bouguer anomaly gradients are associated with these faults, although the gradient to the east of the Styx Basin may be associated with a fault in the basement and not with the one exposed at the surface. To the south of the Strathmuir Syncline this gradient trends to the west between the Strathmuir Syncline and the Gogango Range Area. This suggests that the Strathmuir Syncline and the Gogango Range Area are separated by a cross-fault which brings the Gogango Range Area into a structurally high position. The western side of the Gogango Range Area is also bounded by a steep Bouguer anomaly gradient, which is probably related to a fault separating the folded zone from the Gogango Range Area. This Bouguer anomaly gradient continues for about 100 miles in a north-north-west direction and forms the eastern boundary of the Mackenzie-Dawson Zone, thus suggesting that this boundary is fault-controlled.

The Bouguer anomaly pattern over this part of the Tasman Geosyncline indicates therefore that the coastal zone is an area of central uplift characterised by ultrabasic and granitic intrusions with much faulting of the sediments. This zone is separated from the marginal trough (the Bowen Basin) by a hinge zone, which may be in the form of a monocline or a fault in the basement.

8. CONCLUSIONS AND RECOMMENDATIONS

The major findings of the survey are summarised below.

The Anakie Structural High extends at shallow depth both southward and eastward of its outcrop area. To the south it apparently continues as a basement ridge and to the east as a shallow basement to the Bulgonunna Volcanic Block. The Anakie Metamorphics also appear to exist in structurally high positions in three other localities as is shown by the Wyena Gravity High, the Waterford Gravity Spur, and the Comet Gravity Platform.

Bouguer anomaly features associated with sedimentary features in the Bowen Basin are rather irregular in outline when compared with anomalies related to plutonic masses. Gravity features associated with sedimentary features in the northern part of the Bowen Basin are obscured by the Suttor Gravity Low, which may be associated with a pre-Carboniferous granite. There is a good quantitative correlation between the gravity results and the Denison Trough, the Comet Platform, and the Mimosa Syncline.

The Mackenzie-Dawson Zone does not appear to be as simple as Malone et al. (1963) postulated, but it possibly has one main zone of sedimentation, illustrated by the Mackenzie-Dawson Gravity Low, in which Triassic sediments could be present.

The Bowen Basin is interpreted as a marginal trough separated from the zone of central uplift of the Tasman Geosyncline (indicated by the Coastal Gravity Complex) by a hinge zone, which could be in the form of a monocline or a fault in the basement.

The zone of central uplift in the survey area is characterised by large ultrabasic masses (indicated by the Eungella Gravity Ridge, the Marlborough Gravity Ridge, and the Westwood Gravity High), which appear to be flanked on their eastern side by granite batholiths (indicated by the Urannah Gravity Lows, the Port Clinton Gravity Lows, and the Bajool Gravity Low).

Features associated with the Yarrol Basin are obscured by the Westwood Gravity High and the Bajool Gravity Low, which are interpreted as being associated with the plutonic masses just mentioned.

The Gogango Range Area is in a structurally high position and is probably bounded by faults on its north and west sides.

There is a sedimentary trough extending from Proserpine offshore to Broad Sound. Owing to lack of data it is not possible to predict whether this trough is continuous over its entire length.

On the basis of the problems raised by the gravity interpretation the following geophysical investigations are recommended:

1. A detailed gravity traverse across both closures of the Suttor Gravity Low (feature 10) and one across the Poitrel Gravity Low (feature 11) to determine the degree of similarity between the features and the likelihood of the features having similar sources.
2. A detailed gravity traverse across the Styx Gravity Low (feature 28) to clarify the gravity profile across the Styx Basin and the Carmila Block and their structural relations.
3. A few gravity stations between the Styx and Strathmuir Gravity Lows (features 28 and 29) to determine whether these features are continuous.
4. Offshore seismic work to determine whether the Douglas Gravity Low (feature 27) is related to Cretaceous-Tertiary sedimentary development.
5. Seismic refraction and reflection work to investigate the structure of the eastern hinge zone of the Bowen Basin.
6. Seismic refraction and reflection work to determine the sedimentary thickness within the area of the Mackenzie-Dawson Gravity Low (feature 18).

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APPENDIX

SURVEY DETAILS

The field operations were carried out by a private geophysical contractor, Velocity Surveys Ltd of Canada. The method of operation used by the contractor was identical with procedures adopted by BMR on previous helicopter gravity surveys. All traversing was done by the cell method described by Hastie and Walker (1962). The general operational procedures used on helicopter parties are described by Vale (1962).

Set out below are some details concerning the party organisation:

Staff

Velocity Surveys Ltd

Party Leader	- D. Robertson
Chief Meter Reader	- K. Schulte
Meter Reader	- J. Koekabakker
Draftsman	- A. Potter
Computers	- J. Almekinders, P. Smith

Helicopter Staff of 2 pilots and 2 engineers.
Casual staff comprised 1 cook and 1 field-hand.

BMR

R.A. Gibb

Equipment

2 x Canadian (Sharpe) Gravity Meters
4 x Wallace and Tiernan Microbarometers
1 x Paulin Microbarograph
1 x Taylor Hygrograph-Thermograph
10 x Taylor Sling Psychrometers

Helicopters

2 x Bell 47D-1, VH-UTK and VH-UTL

Vehicles

1 x Ford 3-ton 4 x 4 truck
1 x International 4 x 2 utility
2 x Landrovers 4 x 4

Statistics

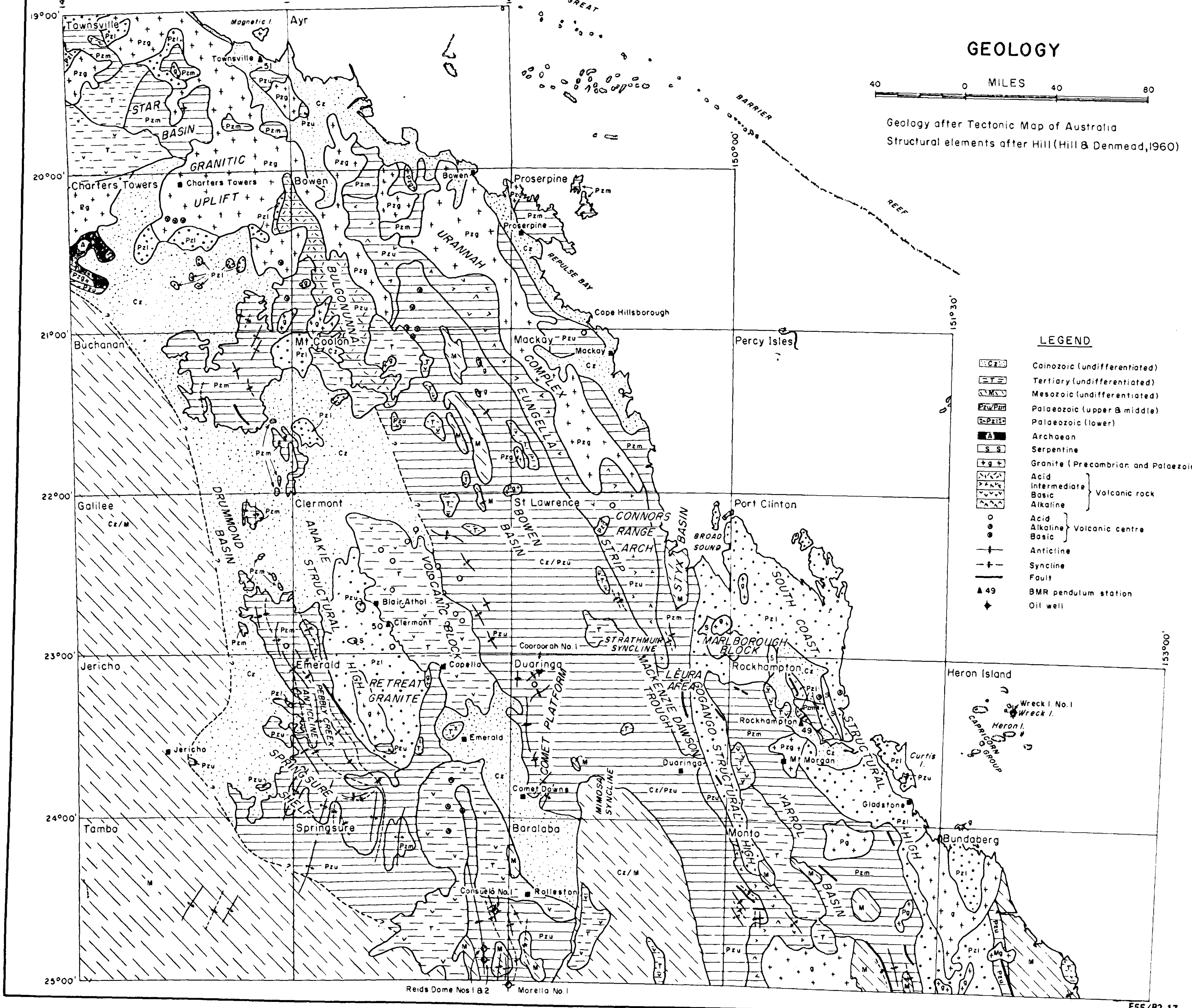
New readings	1393
Grid stations	1060
Control stations	545
Total new stations	1605
Loops (normal)	143
Loops (follow-up)	7
Area covered	43,000 sq. miles
Helicopter hours	377½
Total helicopter days	119

Statistics (cont)

Days lost:	
(i) helicopter unserviceable	43
(ii) not required	7
(iii) bad weather	4
(iv) other	2
Days available	63
Helicopter unserviceability	36.1%
Loops per day	2.4
New readings per hour	3.7
Grid readings per hour	2.8

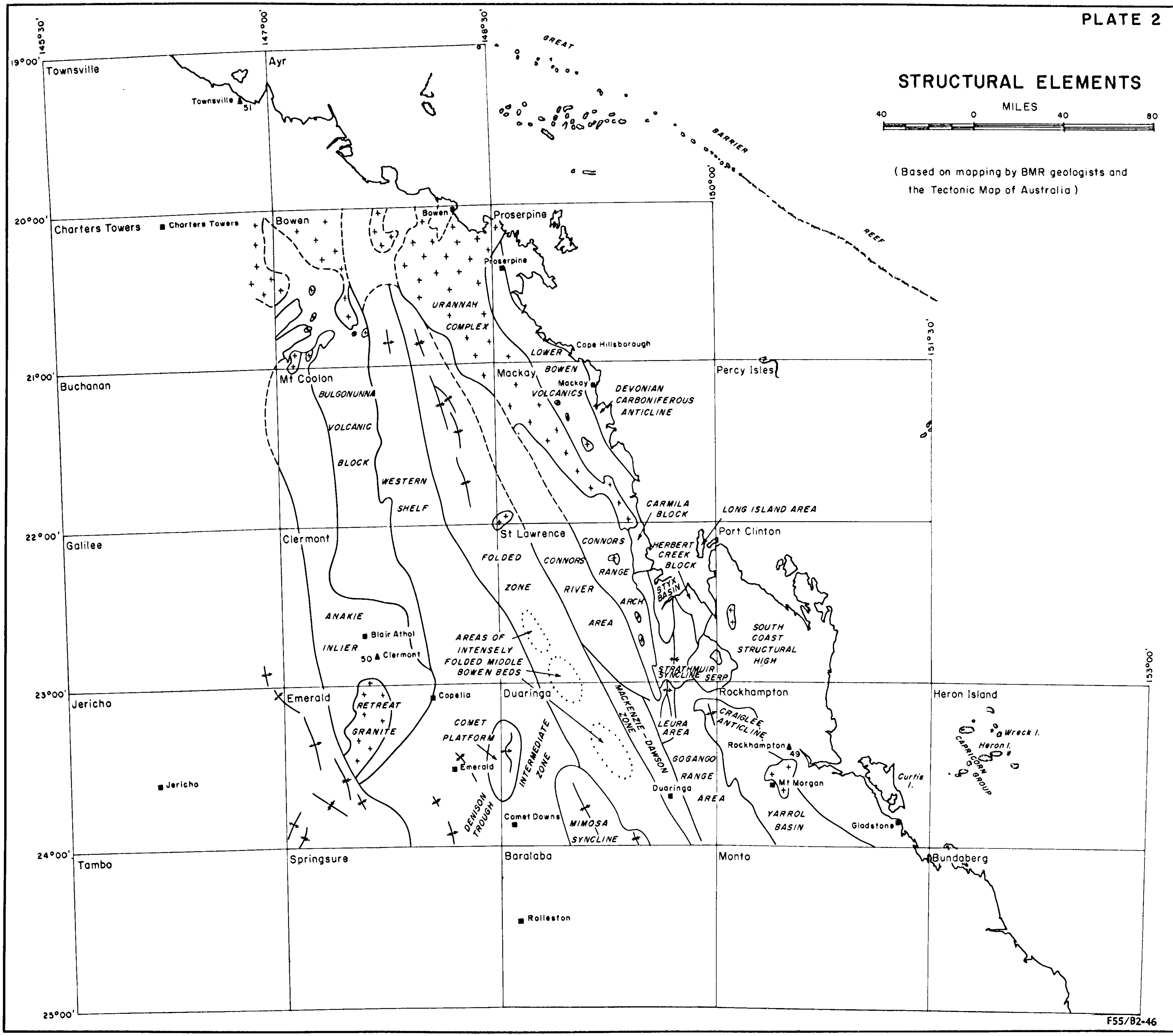
PLATE I

GEOLOGY



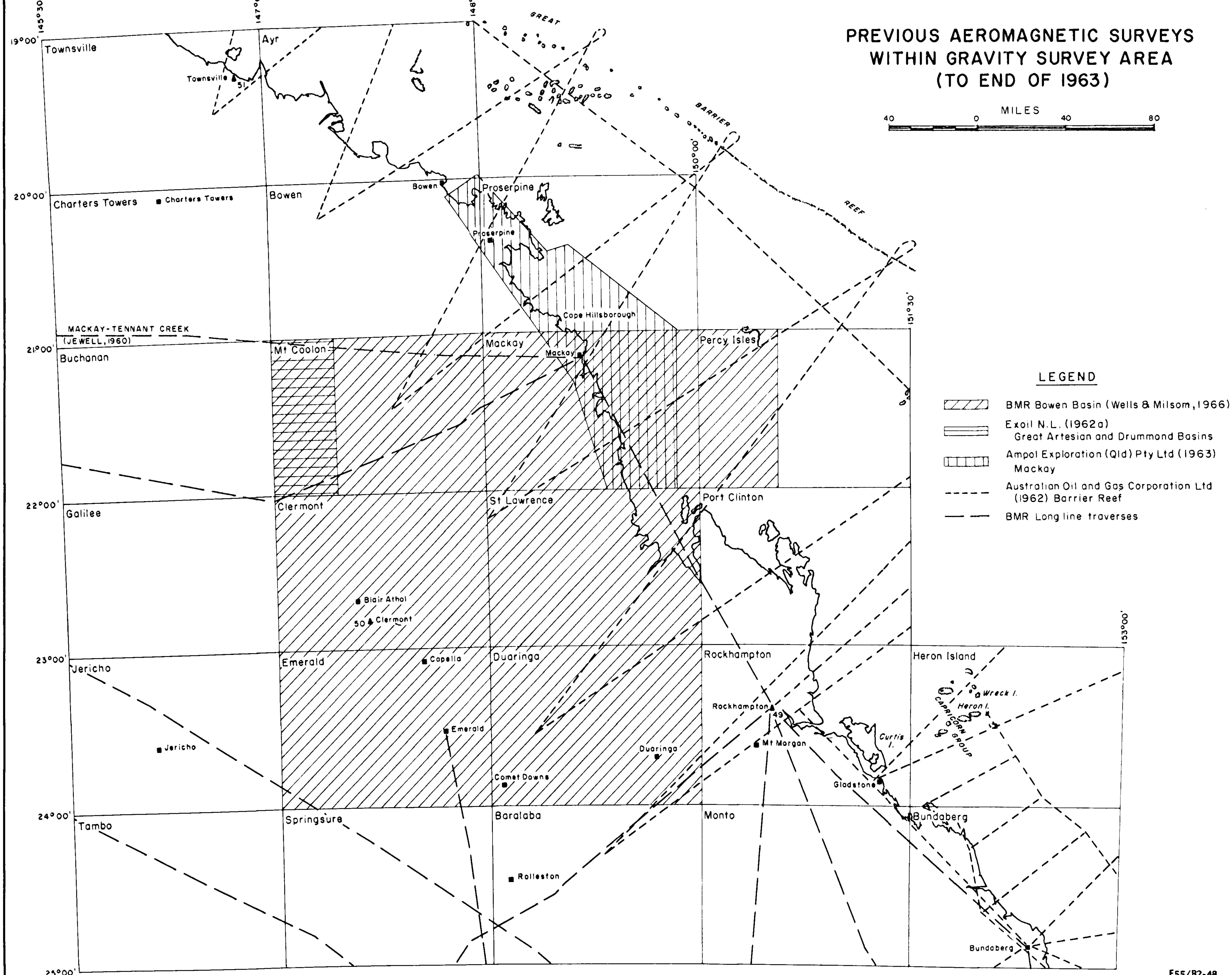
F55/B2-17

PLATE 2



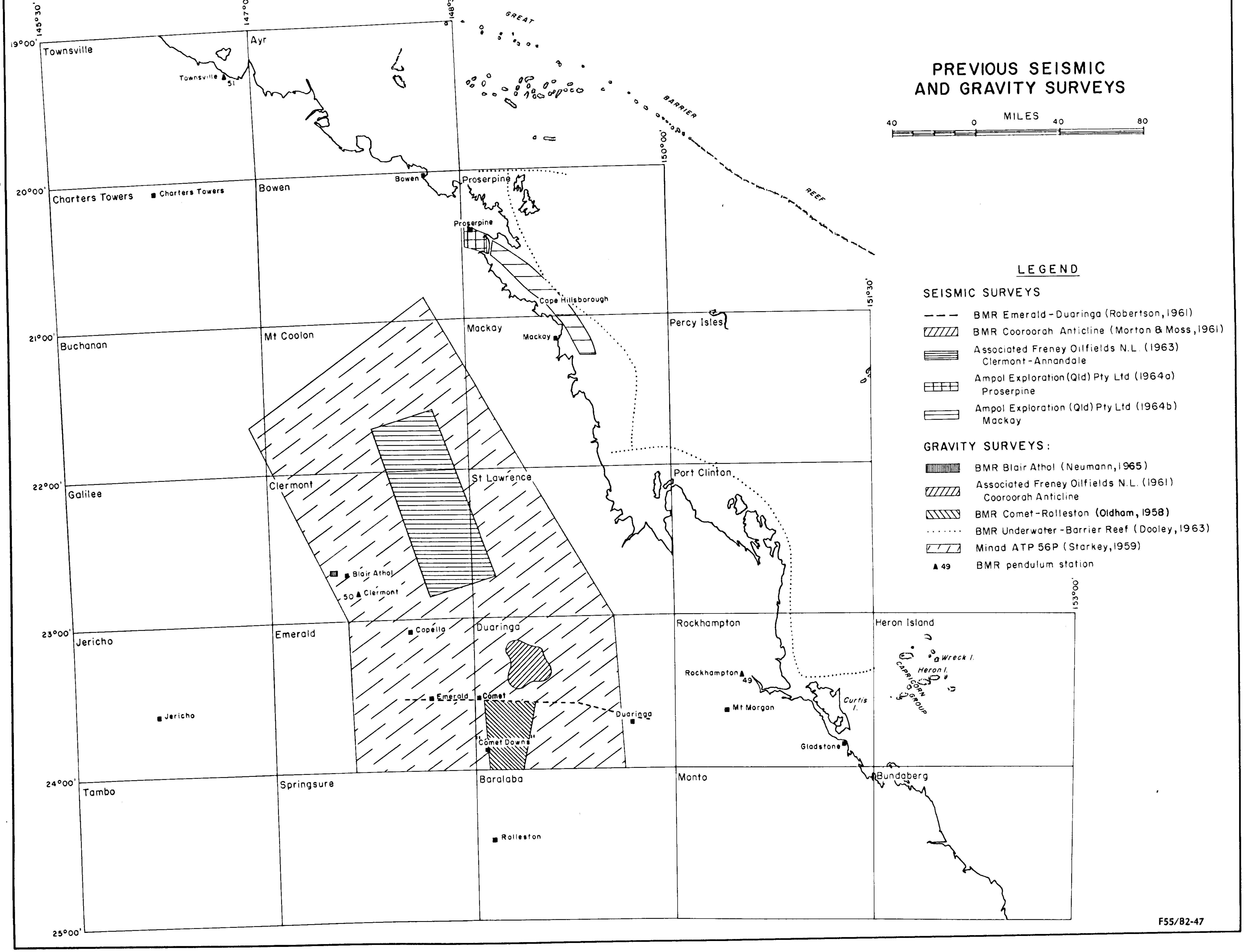
STRUCTURAL ELEMENTS
MILES
40 0 40 80
(Based on mapping by BMR geologists and the Tectonic Map of Australia)
145°30'
147°00'
148°30'
150°00'
151°30'
153°00'
19°00'
20°00'
21°00'
22°00'
23°00'
24°00'
25°00'
Townsville
Ayr
Charters Towers
Bowen
Proserpine
Buchanan
Mt Coolon
Mackay
Percy Isles
Galilee
Clermont
St Lawrence
Port Clinton
Jericho
Emerald
Duaringa
Rockhampton
Heron Island
Tambo
Springsure
Baralaba
Monto
Bundaberg
GREAT BARRIER REEF
URANNAH COMPLEX
LOWER BOWEN VOLCANICS
Cape Hillsborough
DEVONIAN CARBONIFEROUS ANTICLINE
BULGONUNNA VOLCANIC BLOCK
WESTERN SHELF
CARMILA BLOCK
LONG ISLAND AREA
FOLDED ZONE
CONNORS RANGE
CONNORS RIVER AREA
ARCH
HERBERT CREEK BLOCK
STYX BASIN
ANAKIE INLIER
Blair Athol
Clermont
AREAS OF INTENSELY FOLDED MIDDLE BOWEN BEDS
SOUTH COAST STRUCTURAL HIGH
STRATHMUIR SYNCLINE
SERP
Copella
RETREAT GRANITE
COMET PLATFORM
INTERMEDIATE ZONE
MACKENZIE - DAWSON ZONE
LEURA AREA
CRAIGLEE ANTICLINE
Wreck I.
Heron I.
CAPRICORN GROUP
GOGANGO RANGE AREA
Mt Morgan
Curtis I.
DENISON TROUGH
Comet Downs
MIMOSA SYNCLINE
YARROL BASIN
Gladstone
Rolleston
F55/B2-46

PLATE 3



F55/B2-48

PLATE 4



PREVIOUS SEISMIC
AND GRAVITY SURVEYS
MILES
40 0 40 80
145°30'
147°00'
148°30'
150°00'
151°30'
153°00'
19°00'
20°00'
21°00'
22°00'
23°00'
24°00'
25°00'
Townsville
Ayr
Charters Towers
Bowen
Proserpine
Buchanan
Mt Coolon
Mackay
Percy Isles
Galilee
Clermont
St Lawrence
Port Clinton
Jericho
Emerald
Duaringa
Rockhampton
Heron Island
Tambo
Springsure
Baralaba
Monto
Bundaberg
GREAT
BARRIER
REEF
Townsville 51
Cape Hillsborough
Blair Athol
50 Clermont
Capella
Comet
Comet Downs
Rockhampton 49
Mt Morgan
Gladstone
Curtis I.
Wreck I.
Heron I.
CAPRICORN GROUP
Rolleston
LEGEND
SEISMIC SURVEYS
BMR Emerald - Duaringa (Robertson, 1961)
BMR Cooroorah Anticline (Morton & Moss, 1961)
Associated Freney Oilfields N.L. (1963) Clermont - Annandale
Ampol Exploration (Qld) Pty Ltd (1964a) Proserpine
Ampol Exploration (Qld) Pty Ltd (1964b) Mackay
GRAVITY SURVEYS:
BMR Blair Athol (Neumann, 1965)
Associated Freney Oilfields N.L. (1961) Cooroorah Anticline
BMR Comet - Rolleston (Oldham, 1958)
BMR Underwater - Barrier Reef (Dooley, 1963)
Minad ATP 56P (Starkey, 1959)
49 BMR pendulum station
F55/B2-47

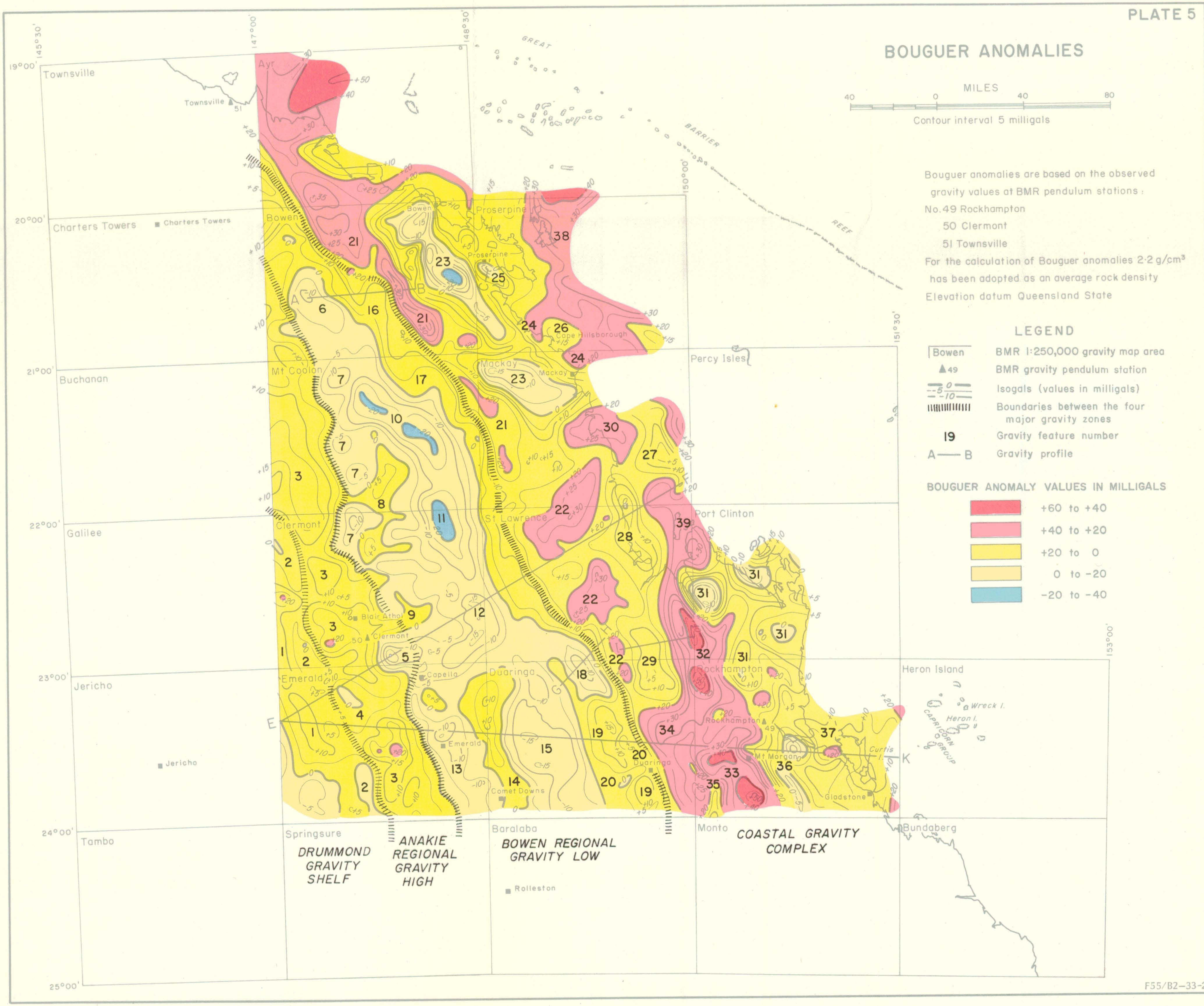
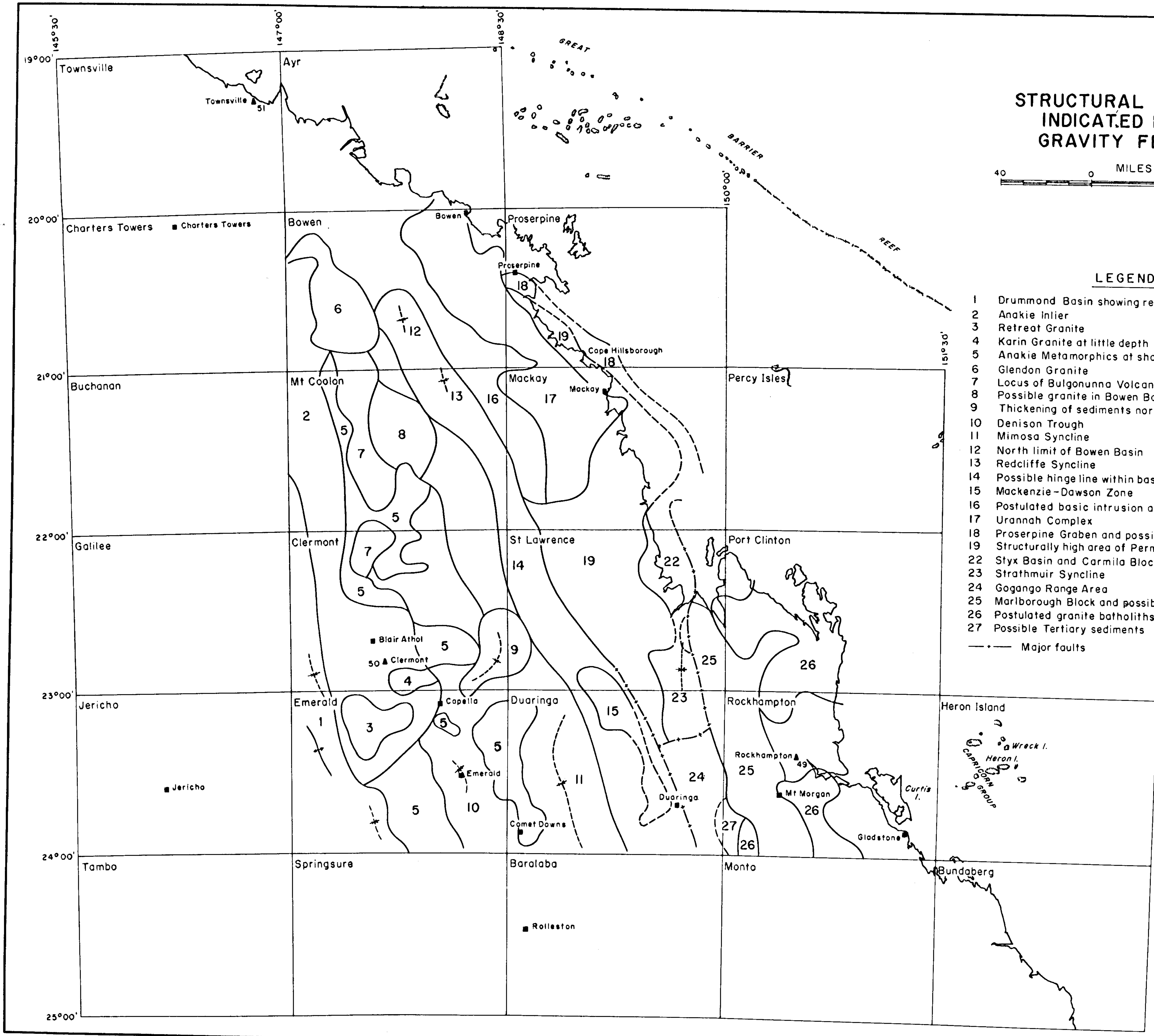


PLATE 5
BOUGUER ANOMALIES
MILES
40 0 40 80
Contour interval 5 milligals
Bouguer anomalies are based on the observed gravity values at BMR pendulum stations:
No. 49 Rockhampton
50 Clermont
51 Townsville
For the calculation of Bouguer anomalies 2·2 g/cm³ has been adopted as an average rock density
Elevation datum Queensland State
LEGEND
Bowen BMR 1:250,000 gravity map area
▲49 BMR gravity pendulum station
Isogals (values in milligals)
Boundaries between the four major gravity zones
19 Gravity feature number
A—B Gravity profile
BOUGUER ANOMALY VALUES IN MILLIGALS
+60 to +40
+40 to +20
+20 to 0
0 to −20
−20 to −40
DRUMMOND GRAVITY SHELF
ANAKIE REGIONAL GRAVITY HIGH
BOWEN REGIONAL GRAVITY LOW
COASTAL GRAVITY COMPLEX
Townsville
Charters Towers
Buchanan
Galilee
Jericho
Tambo
Ayr
Bowen
Proserpine
Mt Coolon
Clermont
Emerald
Springsure
St Lawrence
Mackay
Cape Hillsborough
Percy Isles
Port Clinton
Rockhampton
Duaringa
Baralaba
Monto
Mt Morgan
Gladstone
Curtis I.
Heron Island
Wreck I.
Heron I.
Capricorn Group
Bundaberg
Blair Athol
Capella
Comet Downs
Rolleston
Great Barrier Reef
F55/B2—33—2

PLATE 6

STRUCTURAL ELEMENTS INDICATED BY THE GRAVITY FEATURES



LEGEND

1 Drummond Basin showing regional anticlines and synclines
2 Anakie Inlier
3 Retreat Granite
4 Karin Granite at little depth
5 Anakie Metamorphics at shallow depth
6 Glendon Granite
7 Locus of Bulgonunna Volcanic activity
8 Possible granite in Bowen Basin basement
9 Thickening of sediments north of Comet Platform
10 Denison Trough
11 Mimosa Syncline
12 North limit of Bowen Basin
13 Redcliffe Syncline
14 Possible hinge line within basement
15 Mackenzie-Dawson Zone
16 Postulated basic intrusion at depth
17 Urannah Complex
18 Proserpine Graben and possible offshore extensions
19 Structurally high area of Permian and Carboniferous sediments
22 Styx Basin and Carmila Block
23 Strathmuir Syncline
24 Gogango Range Area
25 Marlborough Block and possible southern extension
26 Postulated granite batholiths
27 Possible Tertiary sediments

—·— Major faults

F55/B2-55

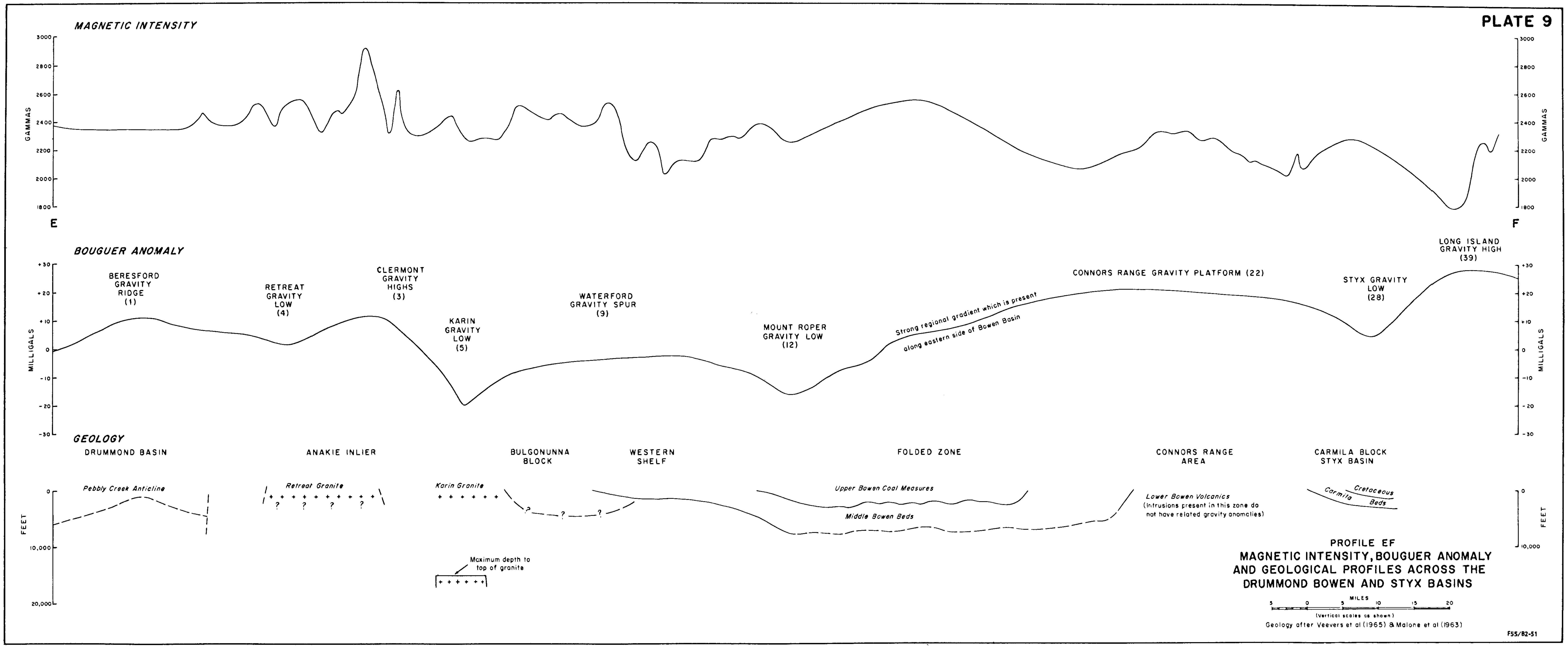
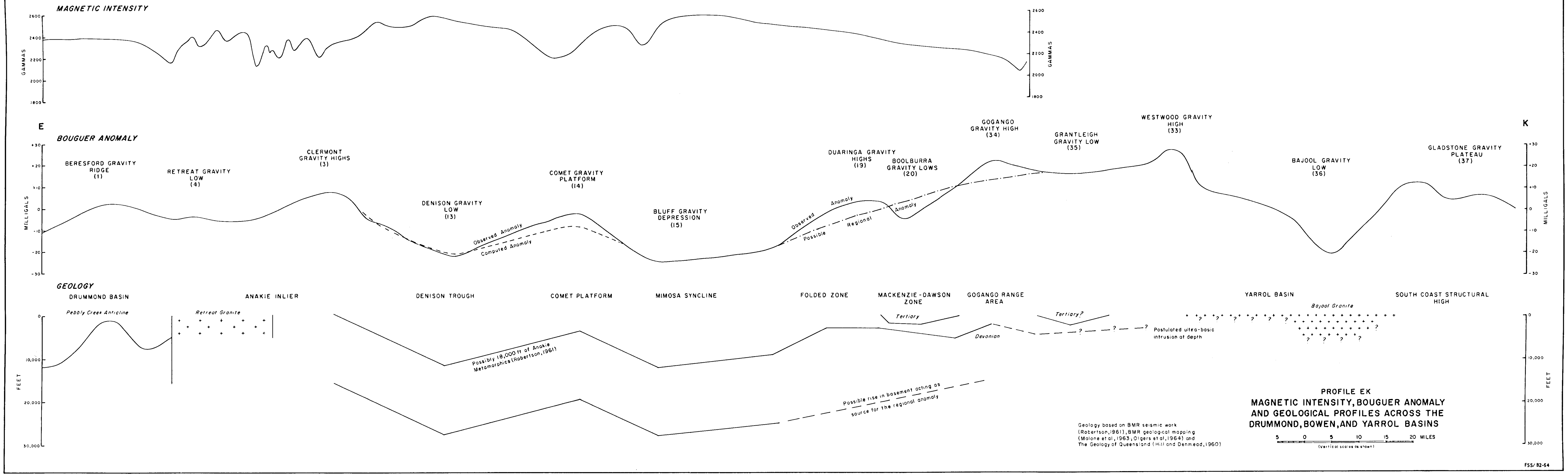


PLATE 9

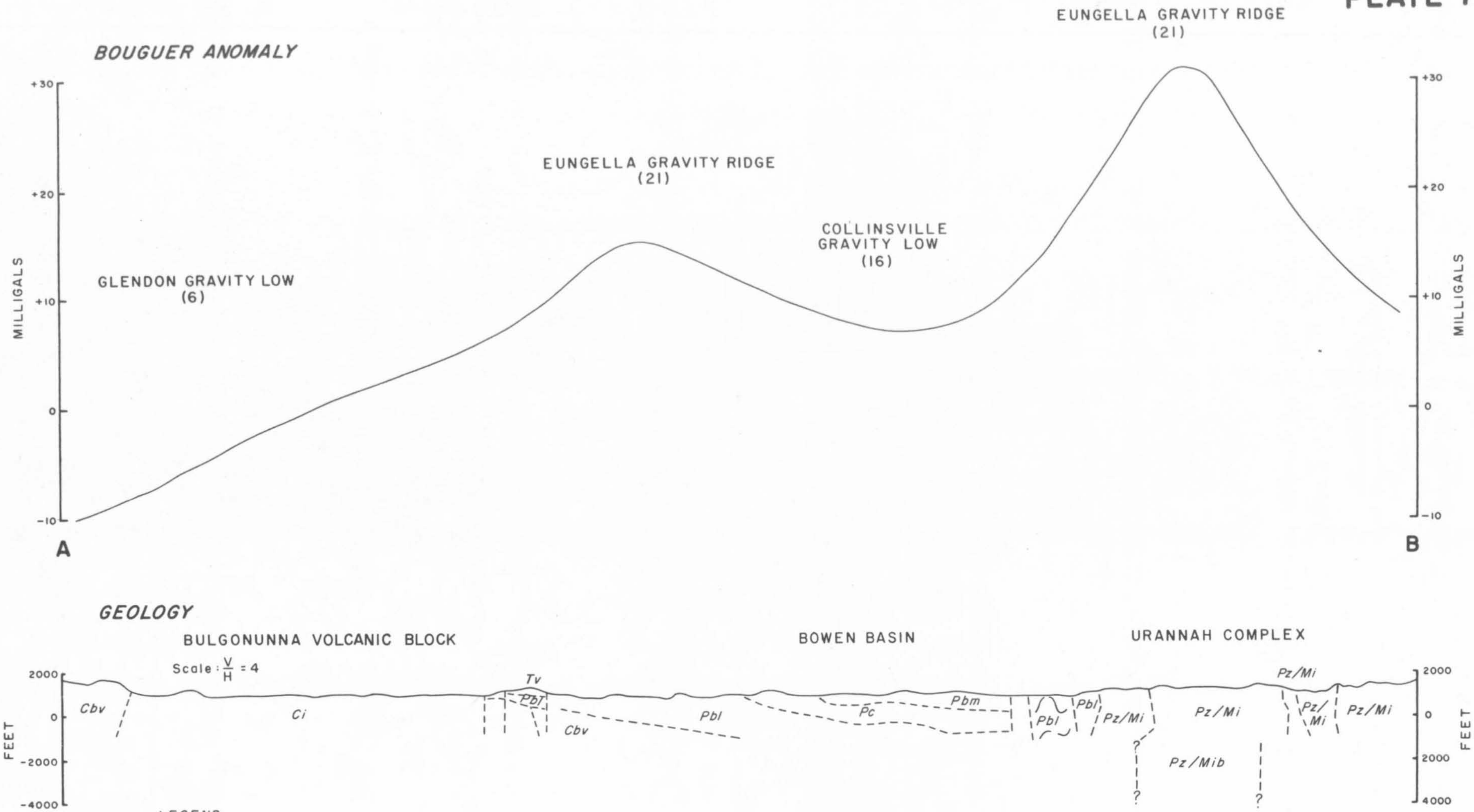
PROFILE EF
MAGNETIC INTENSITY, BOUGUER ANOMALY AND GEOLOGICAL PROFILES ACROSS THE DRUMMOND BOWEN AND STYX BASINS

PLATE 12



PROFILE EK
MAGNETIC INTENSITY, BOUGUER ANOMALY AND GEOLOGICAL PROFILES ACROSS THE DRUMMOND, BOWEN, AND YARROL BASINS

PLATE 7



LEGEND

Tv	Suttor Formation
Pz/Mi	Granite
Pz/Mib	Basic igneous intrusion
Pbm	Middle Bowen Beds
Pbl	Lower Bowen Volcanics
Pc	Collinsville Coal Measures
Ci	Granite
Cbv	Bulgonunna Volcanics
(6)	Gravity feature number

Geology after Malone et al, 1962

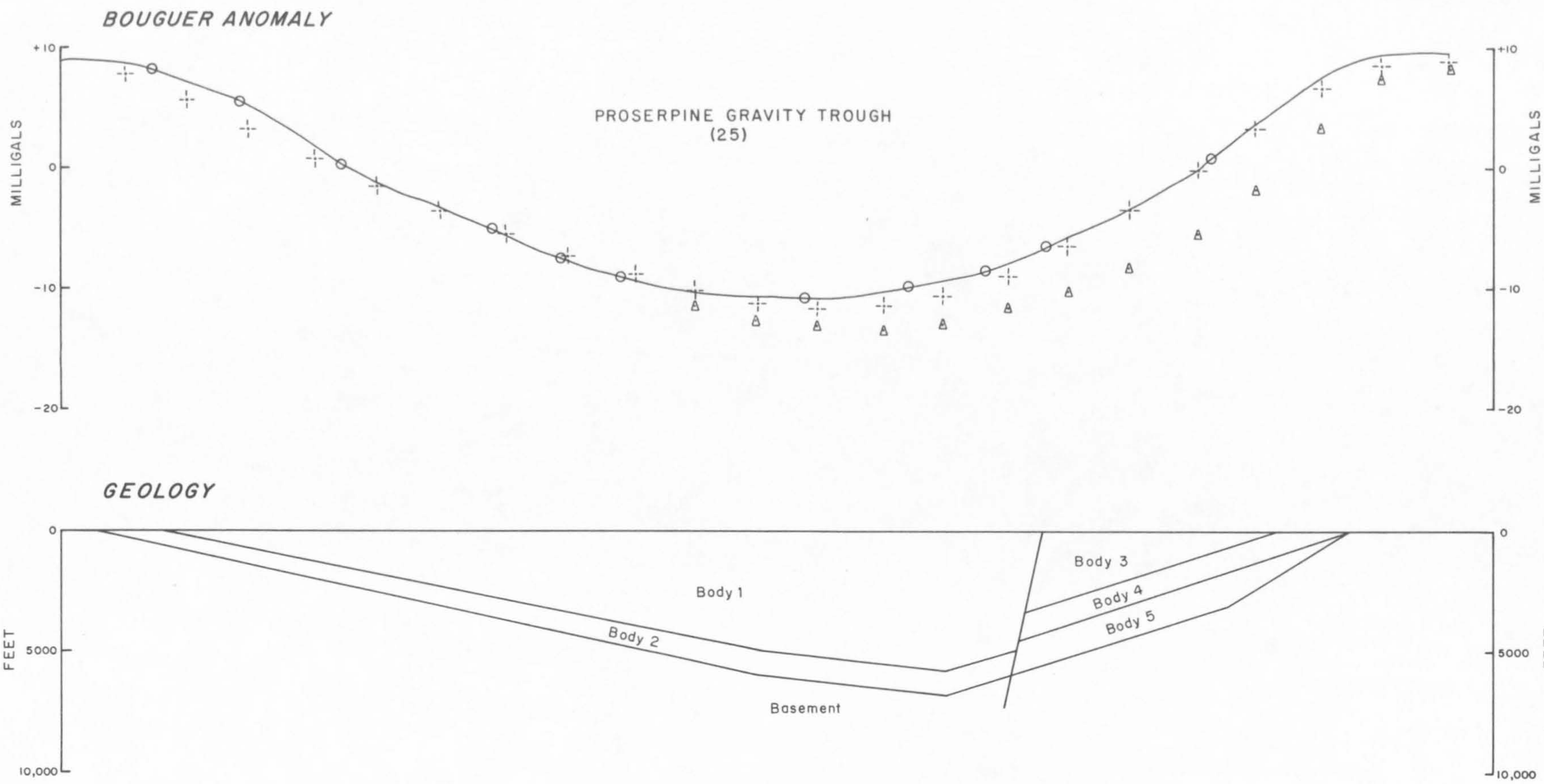
PROFILE AB
GRAVITY AND GEOLOGICAL PROFILES ACROSS THE NORTH BOWEN BASIN AND URANNAH COMPLEX

4 0 MILES 4 8

(Vertical scales as shown)

F55/B2-49

PLATE 8



LEGEND

- ○ Observed gravity values
- -¦- Computed gravity values for the following density distribution:
  - Body 1 2·30 g/cm³
  - Body 2 2·40 "
  - Body 3 2·30 "
  - Body 4 2·40 "
  - Body 5 2·65 "
  - Basement 2·65 "
- Δ Computed gravity values for the following density distribution:
  - Body 1 2·30 g/cm³
  - Body 2 2·30 "
  - Body 3 2·30 "
  - Body 4 2·30 "
  - Body 5 2·30 "
  - Basement 2·65 "

Geology based on seismic work by Ampol Exploration (Qld) Pty Ltd (1964a)

PROFILE CD

GRAVITY AND GEOLOGICAL PROFILES ACROSS THE PROSERPINE GRABEN

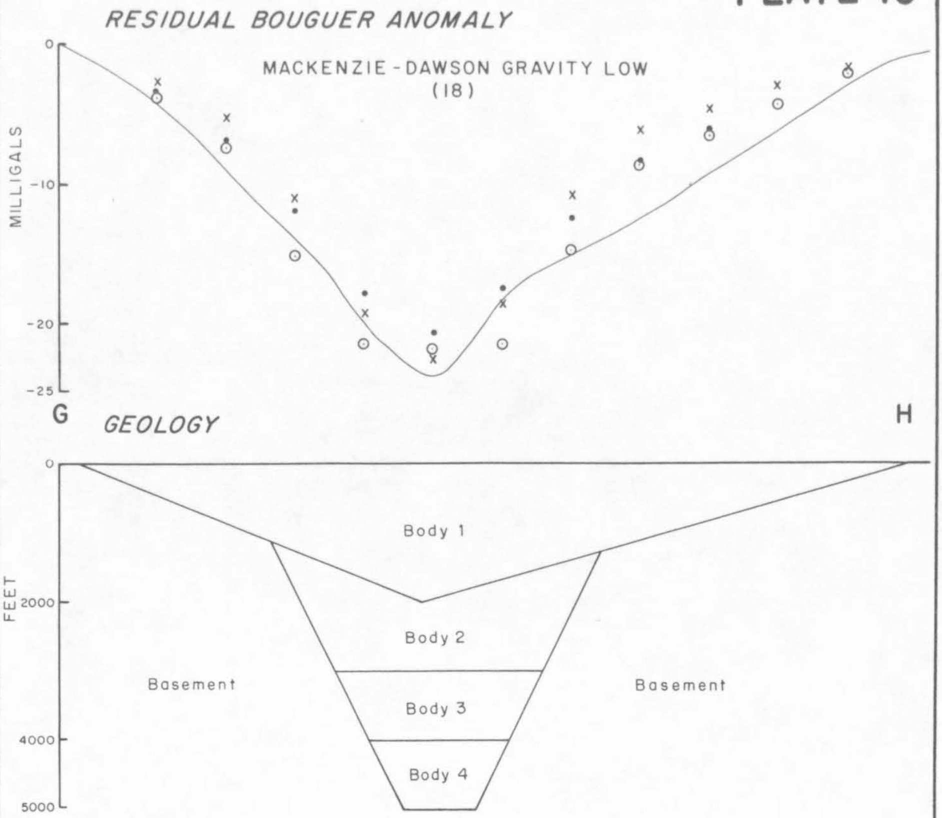
FEET

5000 0 5000 10,000

(Vertical scales as shown)

F55/B2-50

PLATE 10



Case 1 ⊙

Computed residual anomaly using the following density distribution:

Body 1	2·00 g/cm³
Body 2	2·00 "
Body 3	2·60 "
Body 4	2·60 "
Basement	2·60 "

Case 2 x

Computed residual anomaly using the following density distribution:

Body 1	2·20 g/cm³
Body 2	2·20 "
Body 3	2·20 "
Body 4	2·20 "
Basement	2·60 "

Case 3 •

Computed residual anomaly using the following density distribution:

Body 1	2·00 g/cm³
Body 2	2·40 "
Body 3	2·40 "
Body 4	2·40 "
Basement	2·60 "

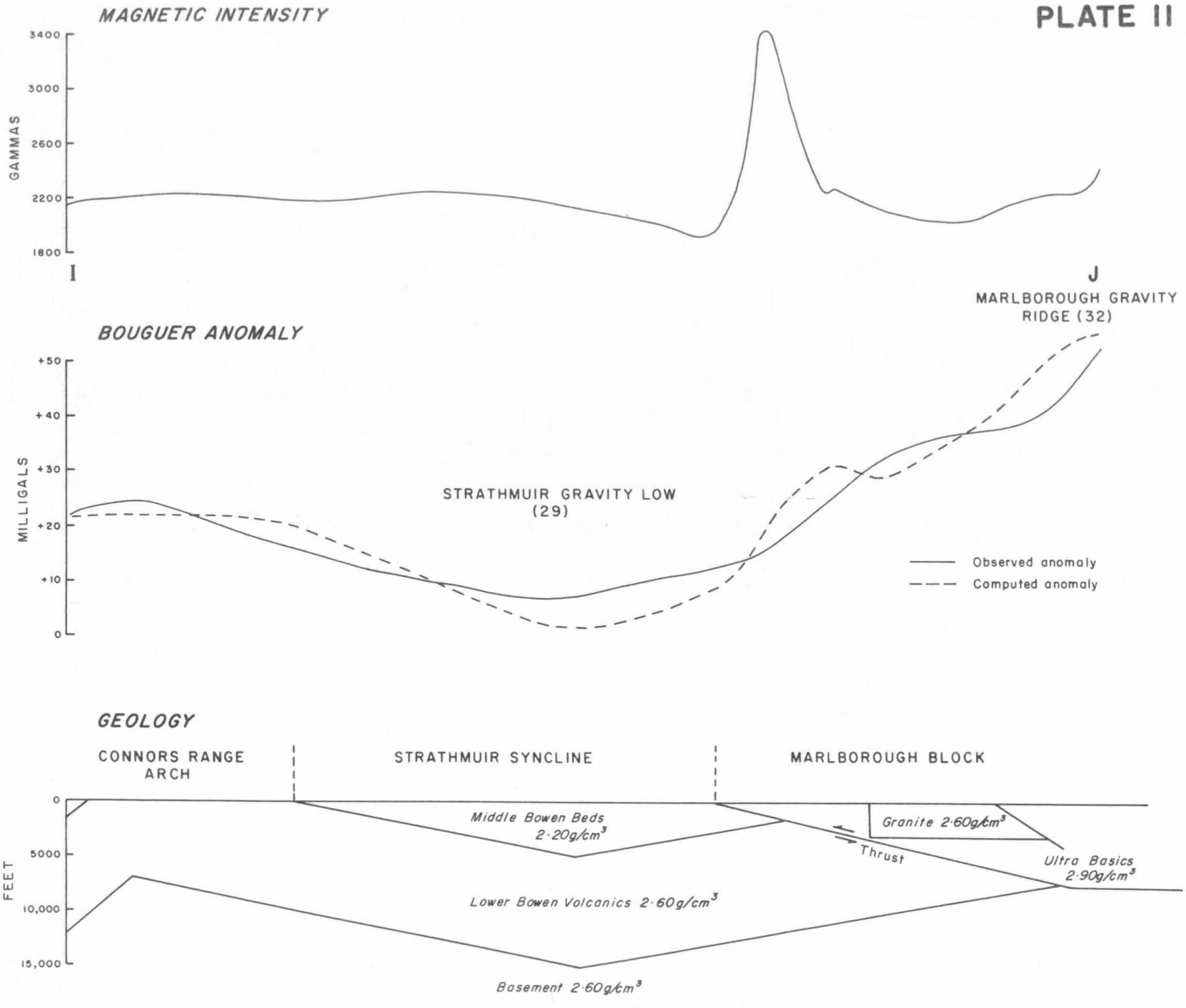
PROFILE GH
GRAVITY AND GEOLOGICAL PROFILES ACROSS THE MACKENZIE-DAWSON ZONE

MILES: 4 0 4 8

(Vertical scales as shown)

F55/B2-52

PLATE II



PROFILE IJ

MAGNETIC INTENSITY, BOUGUER ANOMALY AND GEOLOGICAL PROFILES ACROSS THE STRATHMUIR SYNCLINE AND MARLBOROUGH BLOCK

4 0 4 8 MILES

(Vertical scales as shown)

Geology after Malone et al (1963)

F55/B2-53