DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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BMR GRAVITY SURVEYS, GIPPSLAND BASIN, VICTORIA 1948-61

by

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FOREWARD

This report was written by the late Dr F.J.G. Neumann about 1966. Some of Dr Neumann's usages, as in particular the contouring at 1 mgal intervals with the density of gravity data available, are not normal BMR practice.

SUMMARY

Since 1948 the Bureau of Mineral Resources, Geology & Geophysics (BMR) has made gravity surveys in the Gippsland Basin area, southeastern Victoria. The purpose of this work was to investigate the relation between gravity variation and geological structure.

In this Report survey results are presented in the form of gravity anomaly contour maps, depicting 'measured' Bouguer anomaly as well as 'regional' and 'residual' anomaly.

'Residual' anomaly contour trends are closely related to faulting in sediments of Palaeozoic, Mesozoic, and Tertiary age, associated with warping and draping structure. The pattern in the 'regional' gravity anomaly contour map obviously reflects the larger form of the basement rock underlying the younger sediments.

Orogenic axes known in Palaeozoic rock outcrops north of the Gippsland Basin can be traced as 'residual' anomaly trends into the area of Mesozoic and Tertiary sedimentation in southern Gippsland.

1. INTRODUCTION

The Gippsland Basin probably ranks foremost in Australia as the area most intensely investigated by gravity surveys. This is understandable, if one considers the immense commercial value attributed to the huge coal deposits contained in the Latrobe Valley Coalfield of central Gippsland. In this area Tertiary brown coal seams with a total maximum thickness exceeding 1500 ft occur under relatively thin overburden beds.

The State Electricity Commission of Victoria, which was instituted in 1917, extracted during the year 1965 the amount of 18.2 million tons of raw brown coal from three open-cut workings, located at Yallourn, Yallourn North, and Morwell. Power generation from Latrobe Valley coal will exceed 2000 megawatts by 1970.

In the year 1965 more than five million tons of brown coal was converted in factories located near Yallourn and Morwell into 1 880 000 tons of briquettes having a calorific value similar to that of black coal.

In the gasification plant near Morwell, raw brown coal and briquettes have been converted for many years into household gas for use in the Melbourne area. During 1965, 600 000 tons of raw brown coal was won from the 'Latrobe Seam', which contains hard brown coal, the fuel quality of which improves north of the Latrobe River.

From 1954 onwards, BMR gravity surveys have assisted in locating the 'Latrobe Seam' on the northern wing of the Latrobe Valley. The seam has been followed over a distance of approximately eight miles, and coal reserves have been proved by drilling to exceed 150 million tons.

Oil was discovered in the Gippsland Basin during 1924 at Lakes Entrance near the eastern end of the sedimentary basin. At this locality crude oil occurs in glauconitic sandstone of early Tertiary age at an average depth of 1200 feet in an area covering approximately eight square miles. This field was abandoned as uncommercial during 1946.

By the end of February 1965, the first bore drilled in Australian offshore waters struck a flow of natural gas approximately 20 miles east-northeast of Seaspray in eastern Gippsland. This bore, the Esso Gippsland Shelf No. 1, was subsidized by the Commonwealth Government. A second bore subsequently drilled approximately 2½ miles from the discovery well produced natural gas and condensate.

Early in 1966 and in June 1966 more natural gas and crude oil were discovered by sinking an offshore bore on a separate structure approximately 28 miles southeast of Lakes Entrance.

Commencing in 1948, BMR carried out gravitymeter, airborne magnetic, and seismic surveys in the Gippsland Basin. Some borehole logging was also performed during this period.

The area investigated by BMR gravity work is shown in Plate 1. It extends from latitude 37°45'S to 38°45'S and from longitude 146°E to 148°E, covering approximately 6000 square miles.

During the 1948-49 period a semi-regional gravity survey, initiated by private enterprise, was carried out by the Robert H. Ray Company of Houston (Texas). This survey includes that portion of the Gippsland Basin east of a line which runs north from Giffard through Stradbroke, Longford, Sale, Stratford, and Munro. The pattern established in the Bouguer anomaly contours by the private work has been used to supplement the gravity maps issued by BMR.

A total of approximately 9400 gravity stations have been established in Gippsland during the course of the various surveys of the 1948-1961 period. If evenly distributed, these stations would provide in this area an average station density of 1.6 observations to every square mile. This coverage rate is well above the average station density achieved by BMR gravity surveys over any other geological basin in Australia.

Depending on the specific aims of any particular survey, the spacing of the gravity stations in Gippsland varies from 165 and 330 feet to half a mile or even wider intervals. Small areas over critical portions of particular coal targets have been examined in detail by stations spaced out on a rectangular grid of traverses. In the less intensely surveyed portions of the Gippsland Basin the network of roads available has been used as gravity traverses.

Gravity data established by BMR up to 1959 have been published in the form of Bouguer anomaly contour plans of one mile to one inch scale together with the lines of total magnetic intensity.

2. PHYSIOGRAPHY AND DRAINAGE

Physiographic features of the Gippsland area have been described by Hills (1964) and by Thomas & Baragwanath (1949-51). The following major divisions can be distinguished:

Gippsland Plains

Eastern Section: East Gippsland Plains, Latrobe Valley.

Western Section: Lowlands including Koo-Wee-Rup Swamp, Western Port Bay, and Moe Sunkland.

Eastern Highlands of Victoria

South Gippsland Hills, also named 'Strzelecki Ranges'

Wilsons Promontory

Gippsland Plains

Eastern section. Between longitudes 145°E and 148°30'E the Gippsland Plains extend from Port Phillip Sunkland near Melbourne as far east as Orbost, a distance of approximately 190 miles. The eastern section of these plains, or more precisely the area east of Yallourn, includes a tectonic valley, the Latrobe Valley. It lies between the Eastern Highlands to the north and the South Gippsland Hills to the south. This valley is drained by the Latrobe River and its tributaries, which include the Morwell River, Traralgon River, and Flynns Creek flowing from the south, and three major rivers from the north, viz. the Tyers, Thomson, and Macalister Rivers.

Near their eastern end the Gippsland Plains are submerged beneath the sea and the lower portion of the Gippsland drainage system has been truncated. Subsequently estuaries, bays, and several large lakes - the Gippsland Lakes - have been formed; they include Lake Wellington, Lake Victoria, and Lake King.

The eastern seaward edge of the Gippsland Plains is formed by an elongated sand ridge, the Ninety Mile Beach.

Western section. Thomas & Baragwanath (loc. cit.) have adapted the Haunted Hill Fault immediately west of Yallourn as providing the natural boundary between the western and eastern portions of the Gippsland Plains.

The continuity of the western section of the Gippsland valley is interrupted by northeast-running faults, which produce a pattern of alternating higher-standing blocks and sunken areas. For instance, Port Phillip Sunkland is bounded on the east by the Mornington Block which, in turn, terminates the Koo-Wee-Rup Swamp and Western Port Bay.

Farther east the Warragul Block with an average elevation of approximately 500 ft provides the watershed between Western Port Bay and the drainage eastwards through the Latrobe Valley. East of the Warragul Block lies the Moe Sunkland, a small basin area terminated in the east by the Haunted Hill Block.

Eastern Highlands of Victoria

Typical topographic features of the Eastern Highlands of Victoria include the Sandstone Belt and the Cave Country. In the area of the Sandstone Belt between Briagolong in the south and Mansfield in the north, plateaus and table mountains occur with elevations in the range from 3000 to 5000 ft. In the area of limestone outcrops between Buchan and Murrendai, caves and sinkholes as a result of particular forms of weathering are known.

The recent topography of the Eastern Highlands was shaped during the course of a general uplift, the Kosciusko Uplift, which occurred during Early Pliocene time. The land surface was subsequently eroded and deeply dissected by river action. In certain localized areas the ancient peneplain remained over outcrops of rocks resistant to erosional forces. For instance, north of Yallourn the Mount Baw Baw Plateau forms the surface of a huge intrusion of granite.

Relatively small marginal sections of the Eastern Highlands were traversed during the course of gravity surveys referred to in this Report. They include small portions of the Highlands which extend into the MOE, ROSEDALE, and GLENMAGGIE 1:63 360 Sheet areas. However, other gravity surveys made by BMR extend over large portions of the Eastern Highlands.

South Gippsland Hills (or Strzelecki Ranges)

The hilly country south of the Gippsland Plains comprises two main physiographic features: the South Gippsland Hills and Wilsons Promontory (Hills, loc. cit.).

In the South Gippsland Hills two major fault blocks occur, the Narracan Lobe to the west and the Balook Lobe to the east (Thomas, 1958).

These blocks are terminated by fault-lines trending east and north-east.

Between the two blocks, which in the higher altitude ranges are dissected by erosion, there lies an area of relatively low relief, also controlled by northeast-trending faults. The southern portion of the low country is formed into a broad valley, through which the Tarwin River flows southwest into Andersons Inlet. In the northern portion of the depressed area the Morwell River runs north-northeast into the Latrobe River.

Topographic contours show that the shape of the Narracan Lobe is similar to that of a flat-topped plateau with maximum altitudes just above 900 ft. In contrast, the Balook Lobe is a much larger feature with the maximum elevation exceeding 2400 ft at a point north of Balook township.

Detailed studies of dip angles measured on Jurassic outcrops suggest that the inner structure of the Balook Lobe is one of a large dome, open to the southwest (Edwards, 1942).

East of the Balook Lobe the average elevation of the land surface gradually decreases into the low topography, which prevails over the eastern coastal plain.

Tectonic boundaries in the form of faults, which are indicated in the topography of the high ranges of the South Gippsland Hills, become less significant as the elevation decreases.

Southeast of Rosedale a stretch of timbered hills extends eastward south of the Latrobe River into the area near Lake Wellington. The topography of this particular area suggests an eastward extension of a major fault which forms the boundary of the South Gippsland Hills over a considerable distance and causes a distinct gravity anomaly referred to below.

Wilsons Promontory

An outstanding topographic feature is Wilsons Promontory, approximately 20 miles south of the south Gippsland Hills. The Promontory and groups of islands east and west of it form erosional remnants of a huge mass of granite. The altitude rises to 2475 ft at Mount Latrobe at the southern end of Wilsons Promontory. The lower portion of the granite has been shaped into steep slopes between 300 and 900 ft altitude.

3. GEOLOGY

General

The onshore portion of the Gippsland Basin is relatively small, considering the dimensions of the major sedimentary basins on the Australian mainland. The geological boundaries of the Gippsland Basin are shown in Plate 1, which is based on the geological map of Victoria, issued in 1963 by the Geological Survey of Victoria.

The Gippsland Basin occupies the coastal region of southeastern Victoria. It contains Tertiary and younger sediments in its eastern and central portions, bordered in the west by Mesozoic sediments and in the north by Palaeozoic rocks.

The geology of the Gippsland area has been described by many authors. Thomas & Baragwanath (loc. cit.) and Herman (1952) have dealt with the stratigraphy and structure of the commercially important brown coal deposits. Thomas, assisted by the officers of the Geological Survey of Victoria, has investigated the Palaeozoic geology in the Eastern Highlands of Victoria (Thomas, 1939 and 1958).

More recently, Gloe (1960) has used the latest drilling data obtained by the Victorian State Electricity Commission to define the geological structure of the Latrobe Valley Coalfield. The age classification of Tertiary rocks in the Gippsland region has been reviewed from time to time by Singleton (1941), Crespin (1943, 1952, and 1953), Carter (1958/1959) and others.

The lithology and structure of the Jurassic rocks in Gippsland has been studied by Edwards (1942), Medwell (1954) and Philip (1958).

Potential oil structure and possible source rocks of petroleum within the sedimentary sequence of the Gippsland Basin have been discussed by Boutakoff (1951, 1954-55), Webb (1961), Sprigg (1961), Rudd (1963), Trumpy & Tissot (1963), Baker (1963) and Hopkins (1965).

Tectonic history of Gippsland and the Eastern Highlands

As a tectonic feature the Gippsland Basin is orthogonal to the orogenic axes evident from Palaeozoic rock outcrops in the area of the huge Tasman Geosyncline, which runs mainly parallel to the eastern seaboard. Consequently the structural setting in the formations contained in the Gippsland Basin can be described as being framed by the strike direction of two intersecting tectonic systems. The deformation in the Palaeozoic rocks was mainly in the form of submeridional folds, faults, and thrusts, accompanied by the effusion of lava and the emplacement of granite. In contrast, the Mesozoic and Tertiary sequence of beds is mainly faulted and only gently folded, and major flows of basalt lava were discharged during Tertiary time.

In the Eastern Highlands of Victoria there is a mobile tectonic belt evident in the Palaeozoic rocks, composed of a number of anticlinoria and synclinoria (Thomas, loc. cit.). This zone is terminated in the east by the Sandstone Belt earlier referred to between Mansfield and Briagolong, where gently folded Carbo-Devonian terrestrial sandstones and acid volcanics lie unconformably upon steeply folded and faulted beds of Lower Devonian, Silurian, and Ordovician age. In localized areas Cambrian greenstone crops out along thrusts.

In the area southeast of the Eildon Reservoir, proceeding east, the following orogenic axes have been recognized: (1) Mount Easton Anticlinorium; (2) Walhalla Syncline; (3) Phosphate Hill Anticlinorium; (4) Macalister Syncline; (5) Mansfield-Barley Thrust; (6) Dookie-Tatong-Howqua-Jamieson-Wellington Anticlinorium.

Farther east, the Avon-Wonnangatta Syncline, the Pretty Hill Tectonic Ridge, and the Tabberabbera Syncline are broader features in the structural setting of Palaeozoic rock outcrops.

Near the northern boundary of the Mesozoic Gippsland Basin, the predominant strike direction of the Palaeozoic axes mentioned is north. Farther north in the Eastern Highlands, these axes swing more to the northwest. In southern Victoria, for example in Palaeozoic outcrops on Mornington Peninsula and Waratah Bay in Southern Gippsland, the direction of the Palaeozoic trend lines northeast.

Three periods of folding occurred during Palaeozoic time, namely:

(1) Tabberabberan Orogeny, of early Upper Devonian age.

(2) Bowning Orogeny, of Upper Silurian to Lower Devonian age.

(3) Benambran Orogeny, of Upper Ordovician to Lower Silurian age.

The Tabberabberan Orogeny was a major tectonic event. It created the north- and northwest-trending orogenic axes mentioned; it also caused metamorphism and granite emplacement.

Victoria in early Mesozoic time has been visualized as a highland elongated eastwards and flanked on the south by a subsiding trough. The Gippsland Basin formed a portion of this trough, which continues westward as a major feature into the Bass Basin, Port Phillip Sunkland, Otway Basin, and Mount Gambier Sunkland in western Victoria and South Australia.

During Jurassic times a sequence of continental sediments exceeding 8000 feet in thickness was deposited in the Gippsland area, overlain by Cretaceous and Tertiary sediments. Cretaceous beds of appreciable thickness were only recently intersected in bores sunk off the Gippsland coast.

Movements commenced during the Jurassic period and continued throughout Tertiary time. Thick seams of brown coal accumulated in the Latrobe Valley over an area of continuous subsidence. Later, the sea transgressed from the southeast.

Tectonic activity caused Tertiary beds to be warped into gentle anticlines terminated by faults and into monoclines over faulted basement rocks. In localized areas Tertiary coal measures were warped into domes. Tectonic movements also formed parts of the margin of the Latrobe Valley, where Tertiary beds were bent into steeply dipping to vertical monoclinal flexures extending into deeply sunken elongated troughs.

In Victoria the formation of the coal measures was preceeded by early Tertiary volcanicity, which spread beyond the geological boundaries of the Gippsland Basin.

A general uplift in eastern Victoria, the Kosciusko Uplift, occurred during the Pleistocene period.

Stratigraphy

The sequence of Gippsland Basin sediments is tabulated in Table 1, which summarizes the stratigraphic terminology used in this report.

The oldest Palaeozoic rocks are slate, sandstone, shale, and greenstone of Cambrian to Silurian age. This complex is frequently intruded by granite, deformed and metamorphosed (Mount Kosciusko Metamorphics).

Middle Devonian rocks consist of shale, sandstone and reef limestone (Wentworth Group, Buchan Cave Limestone), underlain by lava flows of rhyodacite (Snowy River Volcanics).

The Carbo-Devonian redbeds (Mansfield Beds) comprise massive sandstone, coarse conglomerate, grit, micaceous shale, and mudstone, underlain by porphyry and effusive basic rocks (Cerberean Volcanics).

Permian deposits do not crop out in Gippsland, but the Duck Bay No. 1 bore north of Lake Victoria penetrated a sequence of Permian rocks composed of sediments and volcanics, 949 ft thick.

Triassic sediments are absent in the Gippsland area, but the thick sequence of Jurassic sediments is composed of lacustrine beds including cross-bedded feldspathic sandstones ('arkoses') interbedded with conglomerates and minor coal seams.

Cretaceous sediments are not known from outcrop, but marine fossils of Lower Cretaceous age (Strzelecki Group) have been identified in a core recovered from the bottom of the Hollands Landing bore, located immediately east of Lake Wellington (Webb, 1961). Approximately 25 miles from Seaspray in southeastern Gippsland, a sequence of Upper Cretaceous sandstone, siltstone, shale, and thin coal bands was intersected in the Gippsland Shelf No. 1 bore (Esso Expl., 1965). Lithologically these beds are distinctly different from the Strzelecki Group intersected in onshore bores. The formation water salinities are very high, suggesting marine deposition.

Early Tertiary rocks in Gippsland include the mainly volcanic Narracan Group composed of some pre-volcanic coal, clay, sand, and conglomerate overlain by tuff and basalt up to several hundred feet thick (Older Basalt of Victoria).

The Latrobe Valley Coal Measures of Middle Eocene age comprise more than 2000 ft of brown coal beds, including coal seams with a total thickness exceeding 1500 ft. The coal occurs in three groups named 'Yallourn', 'Morwell' and 'Yinnar' (Gloe, 1960). The youngest seams of the Yallourn Group contain more than 70 percent moisture and have a net wet calorific value of about 2500 Btu per lb. Older and drier seams, named 'Latrobe', 'Traralgon' and 'Coolun Goolun' have a moisture content of approximately 50 percent and a calorific value of just over 5000 Btu's per lb.

Marine transgression in eastern Gippsland followed the coal formation period during Upper Eocene and Oligocene time. The Colquhoun Gravel and glauconitic sandstone containing crude oils (Lakes Entrance Formation) were deposited during this period. During Miocene time a major transgression caused the deposition of the Gippsland Limestone Formation, composed of bryozoal marl and limestone, which is overlain by the fossiliferous marl and limestone of the Tambo River Formation. Pliocene and post-Pliocene beds in the Gippsland area included friable sandstone and sandy marl of the Jemmy Point Formation and the continental Haunted Hill Gravels.

Recent deposition in Gippsland occurs in the form of thin beds of alluvium; some peat beds are found on river flats and river terraces.

Bores drilled within the limits of the Gippsland Basin in search of coal and oil have not completely penetrated the sequence of Tertiary-Mesozoic deposition at its maximum thickness. The deepest bore, the Wellington Park No. 1, was sunk during 1961-62 in the area south of Lake Wellington to a total depth of 12 000 feet, ending in Jurassic rocks. The numerous bores drilled since 1955 have considerably widened the knowledge of stratigraphic and lithological data. These bores are listed in chronological order in Table 2.

TABLE 1

STRATIGRAPHIC SEQUENCE - GIPPSLAND BASIN, VICTORIA

AGE	FORMATION OR GROUP	LITHOLOGY	FACIES
QUATERNARY	-	Alluvials	Continental
TERTIARY			
Post or upper Pliocene	Haunted Hill Gravel	Gravel, sand, sandy clay	Continental
Lower Pliocene	Jemmy Pt. Fm. (KALIMNAN)	Friable sandstone, sandy marl (fossiliferous)	Marine
Upper Miocene	Tambo River Fm. (MITCHELLIAN, HELTENHAMIAN)	Marl and limestone (fossiliferous)	Marine
	Gippsland Limestone Fm. (BALCOMBIAN; sub-stages: BAIRNSDALIAN, BATESFORDIAN, LONGFORDIAN)	Bryozoal marl and limestone	Marine
	MAJOR TRANSGRESSION		
Oligocene	Lakes Entrance Fm. (JANJUKIAN)	Glauconitic sandstone (oil reservoir)	Marine
Upper Eocene	Colquhoun Gravel	Sand, clay, pebbles (fossiliferous)	Marine
	TRANSGRESSION		
Middle Eocene	Latrobe Valley Coal Measures	Thick brown coal seams, sand, clay	Continental
Lower Eocene	Narracan Group	Thorpdale Volcanics Basalt, tuff, sand, clay Childers Fm. conglomerate, clay, pre-volcanic coal	Continental
	EROSIONAL UNCONFORMITY		
Upper Cretaceous		Sandstone, siltstone, shale thin coal bands	(intersected in offshore bores) Marine?
Lower Cretaceous	OTWAY (STRZELECKI) Group	Mudstone, soft sandstone, subgreywacke	Marine and Continental
Jurassic	including (TYERS GROUP)	Feldspathic sandstone ('arkoses') Siltstone, mudstone, carbonaceous shale, calcareous concretions, some coal seams, conglomerate.	Continental
	EROSIONAL UNCONFORMITY		
Lower Permian	-	Sandstone, glacial deposits, volcanics	Continental (intersected in bores)
	UNCONFORMITY		
Carbo-Devonian	Mansfield Fm.	Massive sandstone, siltstone, conglomerate (redbeds)	Continental
Upper Devonian	Merimbula Fm. Iguana Ck Fm. Cerberean Volcanics		

TABLE 1 (continued)

AGE	FORMATION OR GROUP	LITHOLOGY	FACIES
	UNCONFORMITY		
	TABBERABBERAN OROGENY		
Middle Devonian	Wentworth Gp. Buchan Gp	Siltstone, Buchan Cave Limestone, tuffaceous sediments	Marine
Lower Devonian	Snowy River volcanics Walhalla Beds	Rhyodacite, greywacke, shale, conglomerate.	Continental
	BOWNING OROGENY		
Upper to Middle Silurian	Boola Beds Cowombat Group Wombat Creek Group	Mudstone, Shale	
	BENAMBRAN OROGENY		
Ordovician	Mt Kosciusko Metamorphics	Graptolite-bearing sediments, metamorphics	Marine
Cambrian	-	Greenstone	-

Note:

For the compilation of the stratigraphic sequence and stratigraphic terminology, various sources have been used, including: Singleton, 1941; Crespin, 1943, 1952 and 1953; Carter, 1958/59; Thomas, 1939 and 1958; Boutakoff, 1951 and 1954/55.

TABLE 2

BORES DRILLED SINCE 1955 - GIPPSLAND BASIN, VICTORIA

NAME and POSITION	COMPANY	YEAR (when completed)	TOTAL DEPTH (Feet)
	A. Bores drilled onshore		
DARRIMAN NO. 1 lat. 38°26'43" long. 147°00'30"	Frome Lakes Pty Ltd	1955	4730
ROSEDALE NO. 1 lat. 38°8' - long. 146°47' -	Aust. Paper Manufacturers Ltd	1960	5836
WELLINGTON PARK NO. 1 lat. 38°08'25" long. 147°22'10"	Woodside-Atlantic Refining Company	1962	12001 (Jurassic)
EAST LAKE TYERS NO. 1 lat. 37°51' - long. 148°08'-	"	1962	1541
EAST NOWA NO. 1 lat. 37°48' - long. 148°10' -	"	1962	1196
NORTH SEASPRAY NO. 1 lat. 38°17'38" long. 147°12'13"	"	1962	5000 (small gas production)
SOUTH-WEST BAIRNSDALE NO. 1 lat. 37°52'06" long. 147°21'58"	"	1963	3919 (granite)
MERRIMAN NO. 1 lat. 38°20'52" long. 147°10'43"	"	1963	6005
CARRS CREEK NO. 1 lat. 38°17'32" long. 147°15'55"	"	1963	5507
BELLBIRD NO. 1 lat. 38°12'54" long. 147°00'46"	"	1963	2500
DUCK BAY NO. 1 lat. 37°50'45" long. 147°39'36"	"	1964	4238 (Ordovician shale)
SEASPRAY NO. 1 lat. 38°19'39" long. 147°09'43"	"	1964	5556
SOUTH LONGFORD NO. 1 lat. 38°11'54" long. 147°05'16"	"	1964	2450

NAME and POSITION	COMPANY	YEAR (when completed)	TOTAL DEPTH (Feet)
NORTH SEASPRAY NO. 2 lat. 38°17'58" long. 147°12'25"	Woodside- Planet Oil	1965	5358
LAKE REEVE NO. 1 lat. 38°19'52" long. 147°13'25"	"	1965	6635
WOODSIDE SOUTH NO. 1 lat. 38°34'25" long. 146°54'30"	Woodside	1965	5816
GOLDEN BEACH WEST NO. 1 lat. 38°14'55" long. 147°21'23"	Woodside-B.O.C. Continental Oil of Aust. Planet Oil, A.O.G.	1965	7512
SUNDAY ISLAND NO. 1 lat. 38°42'19" long. 146°40'11"	"	1966	6000
ST MARGARET ISLAND NO. 1 lat. 38°38'16" long. 146°50'05"	"	1966	4664
TARWIN MEADOWS NO. 1 lat. 38°43'26.5 long. 145°51'36"	Alliance Group	1965	3945
DUTSON DOWNS NO. 1 lat. 38°12'00" long. 147°21'45"	Woodside, B.O.C. Continental Oil of Aust. Planet Oil, A.O.G.	1966	6110
LAKES ENTRANCE NO. 1 lat. 37°52'00" long. 147°59'55"	Woodside	1966	1386 (oil shows)
	B. Bores drilled offshore		
ESSO GIPPSLAND SHELF NO. 1 lat. 38°16'41" long. 147°42'45"	Esso-B.H.P.	1965	8701 (Gas discovery bore)
ESSO GIPPSLAND SHELF NO. 2 lat. 38°17'58" long. 147°40'26"	"	1965	4015 (Gas bore)
ESSO GIPPSLAND SHELF NO. 3 lat. 38°21'43" long. 147°58'33"	"	1965	9540
ESSO GIPPSLAND SHELF NO. 4 lat. 38°14'03" long. 148°13'33"	"	1966	8485 (Gas and oil discovery bore)
ESSO GIPPSLAND SHELF NO. 5 lat. 38°15'59" long. 148°10'45"	"	1966	(Gas and oil discovery bore)

TABLE 3

BMR GRAVITY SURVEYS, 1948-61, GIPPSLAND BASIN, VICTORIA

PERIOD	NUMBER OF STATIONS	METER	OBSERVER	TOPOGRAPHICAL WORK	AREA SURVEYED / MAP REFERENCE
1948 January and February	189	Western No. 29	L.W. Williams	BMR	MORWELL ANTICLINE detailed survey G 39-1 G 39 - 14
1949	112	"	L.W. Williams S. Waterlander K. Holywell	BMR	MORWELL area J 55/B2 - 50 G 39-11 (Pt I and II)
1950	240	"	S. Waterlander K.M. Kennedy	BMR	YALLOURN, MORWELL and TRARALGON area J 55/B2 - 39
1951 January	98	"	F.J.G. Neumann	National Mapping Division	ROSEDALE AND GORMANDALE area
May	242	"	"	"	ROSEDALE, COWARR, GLENGARRIE area
June	94	"	"	"	ROSEDALE, WILLUNG, LONGFORD, STRADBROKE area
August to October	414	"	"	"	E. YARRAM, STRADBROKE, GIFFARD, DARRIMAN, WOODSIDE area No. 732 Rosedale 733 Sale 736 Carrajung 737 Stradbroke 727 Glenmaggie
1951/52 December to January	47	"	"	BMR	MOE-BASIN area G 39 - 28
1952 January	90	Worden No. 61	"	S.E.C.	HAZELWOOD detailed survey G. 39-20
February	181	"	"	S.E.C.	LOY YANG detailed survey of local dome G. 39-16
March	47	"	"	BMR	HOLEY PLAINS COOLUN GOOLUN area G 39-68 G 39-64
April	11	Western No. 29	"	BMR	WILLUNG area
	32	"	"	National Mapping Division	GIFFARD area No. 737 Stradbroke
August	201	Western No. 29	F.J.G. Neumann	Dept Interior	ROSEDALE, SALE, and MAFFRA area

PERIOD	NUMBER OF STATIONS	METER	OBSERVER	TOPOGRAPHICAL WORK	AREA SURVEYED MAP REFERENCE
October to November	226	"	"	"	MAFFRA, HEYFIELD, TINAMBA, GLENMAGGIE and SEATON areas. No. 733 Sale " 728 Stratford " 727 Glenmaggie
1953 January to March	900	Atlas N. F21	"	S.E.C.	MELTON PARK, Parish of Loy Yang detailed survey G 39 - 32
February	268	Western No. 29	"	Dept Interior	MAFFRA, BAIRNSDALE, BRUTHEN No. 737 Stradbroke No. 729 Bairnsdale
May to June	186	Heiland No. 53	"	"	W. YARRAM SOUTH GIPPSLAND HILLS No. 739 Alberton " 738 Foster " 735 Mirboo North " 731 Moe
1954 January to March	560	"	"	S.E.C.	TANJIL COALFIELD detailed survey G 39 - 39
March	198	"	"	S.E.C.	ANDERSONS CREEK and YALLOURN NORTH area J 55/B2 - 31 G 39 - 40
August	71	Worden No. 169	'	S.E.C.	YALLOURN NORTH EXTENSION G 39 - 41
September	98	"	"	S.E.C.	MARYVALE and BOOLA BOOLA Parishes J 55/B2 - 50
1955 January to March and June	750	Heiland No. 53 Worden No. 61	" R. Kent	S.E.C.	FERNBANK detailed survey, Parish of Loy Yang G39 - 44
February	22	Heiland No. 53	F.J.G. Neumann	S.E.C.	YALLOURN NORTH EXTENSION area: gravity readings on bore locations G 39 - 67
March to August and October to November	450	Worden No. 61 and Worden No. 169	S. Waterlander	C.A. Herron on behalf of Woodside (Lakes Entrance) Oil Company	CORNER INLET area, including SNAKE, SUNDAY, and ST MARGARETS ISLAND G 93 - 45 Alberton G 93 - 46 Foster
October	81	Worden No. 169	S. Gunson	Victorian Dept of Crown Lands and Surveys	FOSTER regional survey No. 731 Moe " 735 Mirboo North " 738 Foster
1956 January	210	Atlas No. F21	F.J.G. Neumann	S.E.C.	RINTOULS CREEK area, Parishes of Boola Boola and Toongabbie South. TYERS area, gravity readings on bore locations G 39 - 54 G 39 - 55

PERIOD	NUMBER OF STATIONS	METER	OBSERVER	TOPOGRAPHICAL WORK	AREA SURVEYED MAP REFERENCE
January to February	290	"	F.J.G. Neumann and S. Waterlander	S.E.C.	NARRACAN, HAUNTED HILL area. J 55/B2 - 49
August	17	Worden No. 196	L.W. Williams	Victorian Dept of Crown Lands and surveys	FOSTER area semi-detailed survey G 93 - 46 Foster
1957 January to February	410	Worden No. 61	J. Van Son	S.E.C.	TOONGABBIE and SEATON area G 93 - 55
1958 January	106 133	Worden No. 61 "	R. Vanderworst "	S.E.C. "	SOUTH TYERS G39 - 67 HOLEY PLAINS and COOLUN GOOLUN G 39 - 68 - 1
May	70	"	K.B. Lodwick	S.E.C.	BENNETTS CREEK and TRARALGON SOUTH area G 93 - 56
1959 January	111	Worden No. 140	B.C. Barlow	S.E.C.	TRARALGON SOUTH area G 39 - 71
1960 January	63	Worden No. 61	G.F. Lonsdale	S.E.C.	LONGFORD area G 39 - 68 - 1
January	150	"	"	S.E.C.	BILLY'S CREEK - MIDDLE CREEK area G 93 - 93
December	100	Worden No. 140	"	S.E.C.	HAZELWOOD DOME detailed survey G 93 - 92
1960 - 61 December and January	208	"	"	S.E.C.	GORMANDALE area J 55/B2 - 17

Reference : BMR, 1965, CATALOGUE OF PUBLICATIONS

MAGNETIC AND GRAVITY MAPS, VICTORIA (Gippsland Area)
Geophysical maps of 1 mile to 1 inch scale:

1. No. 727 GLENMAGGIE
2. " 728 STRATFORD
3. " 729 BAIRNSDALE
4. " 730 HARTLAND
5. " 731 MOE
6. " 732 ROSEDALE
7. " 733 SALE
8. " 734 STOCKYARD
9. " 735 MIRBOO NORTH
10. " 736 CARRAUNG
11. " 737 STRADBROKE
12. " 738 FOSTER and part of YANAKIE
13. " 739 ALBERTON and part of CLIFFY

4. GEOPHYSICAL WORK

The various gravity surveys conducted by BMR in Gippsland during the 1948-61 perio are tabulated in chronological order in Table 3. Also listed are reference numbers of the relevant gravity maps.

1948

Gravity field surveys commenced early in 1948 south of Morwell township in the parish of Hazelwood. Using a Humble-Truman and later a Western type gravity meter, approximately 200 readings were made over a section of the Morwell Anticline, known from drilling. As a result of this work, a major gravity anomaly was outlined. Obviously this gravity variation was related to the structure in the coal beds (Thyer & Williams, 1948).

1949-50

During 1949-50, semi-regional gravity-meter readings were extended from Morwell township northwards and eastwards into the wider area of the Latrobe Valley and into the foothills along the northern slopes of the South Gippsland Hills.

The Princes Highway and the network of country roads were used as gravity traverses with stations spaced out at approximate half-mile intervals. A more complete gravity coverage of the Morwell Anticline and of the Yallourn-Morwell-Traralgon area generally was obtained as a result of the extended work (Neumann, 1951).

1951

During 1951, semi-regional gravity-meter readings were made over still larger portions of the Latrobe Valley, using Rosedale as a base and having gravity traverses set out along country roads.

During this stage of the field operations the Division of National Mapping supplied a topographic surveying party under the supervision of G.R.L. Rimmington. This party during the 1951-52 period conducted the marking, levelling, positioning, and description of a total of 1892 gravity stations spaced at half-mile intervals in the area outlined by Welshpool, Port Albert, Woodside, Stradbroke, Rosedale, Cowwar, Traralgon, and Boolarra.

Early during 1951 a relatively large gravity anomaly, including a steep gravity gradient, was located for the first time in the area between Rosedale and Gormandale. As work extended east later in the year, it was recognized that this anomaly was consistent over several miles and that it extended into the area where a fault, the Rosedale Fault, had been established by drilling as a displacement in the coal beds south of Longford (Thomas & Baragwanath, loc. cit.).

<u>1952</u>

A semi-detailed gravity survey including 36 readings at approximate half-mile spacing was conducted, mainly during January 1952, over the eastern portion of the Moe Sunkland west of the Haunted Hill Block. Ties to the earlier work were made on traverses across the hills. During this survey a university vacation student employed by BMR assisted in carrying out the topographic work involved. The results of the survey indicated a separate weak gravity 'low' west of the Haunted Hill Block.

During the same year, relatively detailed gravity investigations were made to assist in solving geological problems related to small areas. These surveys were conducted over a portion of the Morwell Anticline and in a localized area in the Parish of Loy Yang southeast of Traralgon.

The Morwell Anticline survey was made as an attempt to investigate in more detail possible variations in the thickness of the overburden above the coal beds, caused for instance, by fire destroying portions of the coal and leaving crater-like features filled with clay. The field work included 90 gravity stations set out on rectangular traverses 660 feet apart with single stations spaced at 330 feet.

The purpose of the detailed Loy Yang survey was to provide gravity data to investigate a suspected thinning in the coal beds. During the course of the work 181 gravity observations were made using a rectangular grid of traverses 330 feet apart. A distinct residual gravity anomaly was outlined under the suspected dome.

A bore (998 Ly) drilled into the centre of the residual gravity anomaly confirmed the existence of a small sharp dome (Gloe, loc. cit.) under the area surveyed.

The topographic work involved in the detailed gravity surveys mentioned was carried out by the State Electricity Commission's Brown Coal Investigation Branch. Technical data relating to the mapping of gravity results are referred to in Appendix B.

In 1952 the first reconnaissance gravity traverse was made across the Coolun Goolun Coalfield south of Longford (Herman, 1952), including 47 gravity stations set out at half-mile intervals (Neumann, 1960). Later during the same year semi-regional observations were extended into the area east and northeast of Rosedale towards Sale, Maffra, Tinamba, Glenmaggie, and Seaton.

From the middle of 1952, topographic survey requirements were met by the Commonwealth Department of the Interior. Field parties of this Department prepared a total of approximately 1200 gravity station positions in the area around Heyfield, Maffra, Briagolong, Bairnsdale, Stockyard, and Bruthen. They also laid out gravity traverses across the South Gippsland Hills along the Midland Highway and between Won Wron and Traralgon South.

As the field work progressed in the Gippsland area, more efficient instruments became available. During February 1952 a portable meter of the Worden type was used for the first time, and later an Atlas meter of a similar design was put to field use.

Atlas and Worden gravity meters are equipped with a system of temperature-compensated quartz springs to measure gravity variations with a high degree of accuracy. Heiland and Western type instruments contain thermostatically controlled metal-spring movements.

For convenience, technical data relating to the construction and performance of the gravity meters used are collated in Appendix A.

<u>1953</u>

In the Melton Park area, parish of Loy Yang, a detailed gravity survey, including the reading of 900 stations, was made early in 1953. The area investigated extends east of Flynns Creek valley. It was covered by a rectangular grid of traverses, one mile by four miles in size, with traverses and single stations spaced at 330-foot intervals.

The result of the survey showed the Melton Park area as relatively 'low' on the gravity anomaly level. The axis of a major gravity 'low' was determined, extending northeastwards from Flynns Creek valley with the anomaly widening in this direction.

To the southeast of this 'low', steep gravity gradients were measured on a distinct northeast trend, earlier described as the anomaly related to the Rosedale Fault.

To the west of the Melton Park gravity 'low', readings were found to rise moderately on the eastern side of a gravity 'high', located in the Fernbank area and more closely investigated during the course of the 1955 detailed survey.

Later in 1953, semi-regional gravity readings were extended on the northern wing of the Gippsland Basin into the area northeast of Maffra towards Briagolong, Bairnsdale, and Sarsfield.

Gravity observations were also made from May to June 1953 on traverses across the South Gippsland Hills by occupying the station sites earlier prepared by the Dept of the Interior's topographic party.

<u>1954</u>

During 1954, gravity field operations were shifted to the area along the northern wing of the Latrobe Valley by extending detailed and semi-detailed work from the Tanjil Coalfield west of the Haunted Hill Block into the parishes of Tanjil-East, Maryvale, and Boola Boola.

The critical area of the Tanjil Coalfield was investigated by observing 560 gravity stations on a rectangular grid of traverses, with the traverses spaced at 165 and 330 feet.

The results of the detailed work disclosed numerous irregular anomaly features, suggesting local interference with the coal beds by basaltic intrusions; such intrusions had been intersected in bores prior to the gravity survey. The Tanjil Coalfield project was discarded in the following year as uneconomic.

The geophysical problem posed in the area east of the Haunted Hill Block is related to a major structure in the coal measures, known as the Yallourn Monocline. Tectonics involved can be briefly described as a combination of a monoclinal flexure in the coal beds caused by faulting in the underlying basement rocks. The origin of the Yallourn Monocline has been explained as a result of vertical displacements in the beds, accompanied by horizontal compression and minor thrusting (Gloe, loc. cit.).

Early gravity traversing across the Yallourn Monocline disclosed a rapid gravity variation occurring on a narrow zone approximately 800 feet wide. It could be suggested that this steep gravity gradient was caused by the presence of steeply tilted coal measures dipping southeast upon faulted basement rocks. This empirically established relation between the gravity anomaly and subsurface geology was found to be consistent over a distance of several miles.

The commercial importance of the Yallourn Monocline lies in the fact that an older and dryer seam, the Latrobe Seam, occurs on this structure in a relatively high tectonic position, so that the coal of better fuel value can be extracted by open-cut mining. As much of the flat-lying portions of the Latrobe Seam has been eroded, the steeply dipping parts of the coal deposit have been preserved as a narrow strip of coal, concealed beneath younger beds. Course variations along strike are frequent so that the subcropping coal is easily missed by drilling.

The Latrobe Seam has been worked in the Yallourn North opencut area since 1889. At this locality the coal was considered to form an isolated block with limited reserves rapidly depleted by the ever-increasing demand. Exploration drilling initiated prior to the geophysical work failed to locate appreciable coal reserves further away from the Yallourn North open-cut workings.

Field operations involving a more precise investigation of the gravity anomaly caused by the Yallourn Monocline commenced during March 1954. At this time exploration bores sunk in the hilly area east of Andersons Creek (Plate 7) had intersected a relatively small deposit of coal, rapidly narrowing eastwards. The area of the drilling east of Andersons Creek was investigated by 198 gravity stations laid out on a rectangular grid of traverses at 200-foot spacing. The readings taken on the detailed surveyed area were tied by single traverses to the coal deposit working in the Yallourn North open-cut area and also to the Palaeozoic rocks exposed farther north in the East Gippsland Highlands.

The combined results of the various surveys mentioned indicated a narrow zone of closely spaced Bouguer anomaly contours comprising the zero to +5 mGal interval. It was noticed that this zone extended from the Yallourn North open-cut area through the area of the exploration drilling east of Andersons Creek and farther east over a distance of approximately two miles. The zone of narrow contour spacing, indicative of a relatively rapid gravity variation, was tentatively interpreted as being related to the existance of an elongated geological structure at depth, occurring over the same area.

Using the gravity information available at this stage of the investigation, the sinking of a coal bore some distance away from the Andersons Creek area was suggested. Consequently the State Electricity Commission drilled bore No. 969 approximately one and a half miles east of Andersons Creek Valley (see Plate 7), and intersected 59 ft of hard coal of the desired quality. The result of the drilling immediately confirmed the value of a gravity anomaly contour plan in locating the position of the Yallourn Monocline under cover beds, and, for that matter - the position of the Latrobe Seam.

During the following months of August and September 1954, the gravity coverage in the parishes of Tanjil East, Maryvale, and Boola Boola and also in the prospective coal area west of Tyers River was extended by using passable roads as gravity traverses. The objective of this work was to investigate a possible extension of the Yallourn Monocline and to determine the position of the tilted coal measures in relation to the deeper sunken areas around the A.P.M. paper pulp mill at Maryvale.

As an important result of this work it was recognized that the critical zone of maximum gravity variation, referred to above, was still noticeable in the gravity anomaly contours northeast of the successful coal bore No. 969. In fact the zone of steep gradients extended into the hilly country west of Tyers River 400 feet above sea level. As the gravity anomaly remained essentially unchanged, it was concluded that the corresponding geological structure would also exist as a feature similar to the Yallourn Monocline in the Tyers River area. This concept was later confirmed as correct by sinking coal bores into the critical gravity anomaly.

<u>1955</u>

From January to March 1955 a detailed gravity survey, comprising 750 stations, was commenced in the parish of Loy Yang, Fernbank area, southeast of Traralgon. The work was completed during June in the same year. Earlier reconnaissance work in the area had indicated the presence of a closed gravity 'high' between the Traralgon River in the west and Flynns Creek in the east. To further investigate the eastern part of this anomaly, stations were placed on a rectangular grid of traverses with the individual lines 330 ft apart.

Geologically the coal structure in the Loy Yang area was not immediately recognized from the limited number of bores sunk during the early stage of coal exploration. Several writers (Hills, loc. cit.; Thomas & Baragwanath, loc. cit.) assumed that the Rosedale Fault continued to strike due west and extended westward into the area south of Traralgon.

The commercial importance of the Loy Yang structure has become known by drilling, which intersected over 700 feet of continuous coal interbedded only with streaks of clay. Most of this coal occurs on the north side of a large dome, causing a correspondingly large gravity anomaly with maximum Bouguer values measured on a sharp ridge, elongated east-west. Local variations in the bedding of the coal measures include the reversal in the dip over the crest of a small dome, earlier referred to as a residual gravity feature delineated by the 1952 detailed survey results.

As a result of the 1955 Fernbank detailed survey the eastern side of the large Loy Yang Dome and the eastern portion of the crest of this structure were precisely determined as a distinct gravity anomaly.

During January 1955, drilling for coal on the Yallourn Monocline was stepped up by extending the exploration eastwards into the area near Tyers River. Plate 7 shows the position of the bores No. 1017, 1023, 1032, and 1042 sunk into the critical zone outlined by gravity surveys.

As before, this method of guiding coal bores by gravity data was entirely successful (Neumann, 1957). The bores mentioned intersected hard coal of the desired quality in large thicknesses, ranging from 125 to 194 feet. That the coal deposit extends far enough to permit practical mining was easily proved by drilling follow-up bores west and east of the discovery bores.

As it was considered desirable to use the numerous precisely levelled bore sites in the area west of Tyers River as gravity stations, readings were made on 22 of these sites during February 1955. The information gained in this way was used to supplement the gravity anomaly picture obtained the year before in the same area using only roads and bush tracks as traverses.

At the request of the Woodside (Lakes Entrance) Oil Company, N.L., a semi-detailed gravity survey was carried out during 1955 in southern Gippsland, including a number of islands east of Corner Inlet; 450 gravity stations were occupied during the course of this survey in the area south of the railway between Toora and Alberton. Observations were also made at half-mile spacing along the tidal channels between the islands south of the mainland including Snake Island, Sunday Island, and St Margaret Island.

Motor boats were used for transport.

The results of this work showed the area investigated as being of mainly low gravity intensity but with a rapid rise westwards towards the Wilsons Promontory area, indicating shallower basement near the western end of Snake Island. A closed residual gravity 'high' was located on the southern side of St Margaret Island.

The area of the 1955 Corner Inlet survey was tied by a traverse running northeast to a localized gravity anomaly, delineated about four miles south of Woodside township by earlier work.

During October 1955 a regional survey comprising 81 stations was conducted in the South Gippsland Hills, in an area which extends from a line through Thorpdale, Korumburra, Inverloch, and Cape Liptrap east to longitude 146°30. One traverse with stations spaced at 3-mile intervals was run southeast to include portions of Wilsons Promontory. The topographic work involved in this survey was arranged by the Victorian Department of Lands and Survey.

Ties were also made to the more detailed gravity work in Gippsland east of the regional survey. The results of the 1955 investigation have been integrated with the contours shown in Plates 2 and 3.

1956

At the beginning of 1956 gravity work on the northwestern margin of the Latrobe Valley was extended into the hilly area between Rintouls Creek and Eaglehawk Creek, in the parishes of Boola Boola and Toongabbie South. As an important result of this work, it was recognized that the critical zone of steep gravity gradients lost its significance in the area east of Rintouls Creek. Consequently, in the absence of typical gravity indications, no useful guidance could be derived from gravity readings in relation to a possible extension of the Yallourn Monocline or to the presence of the Latrobe Seam in a vertical or tilted position. In actual fact subsequent drilling in the area east of Rintouls Creek showed that the Yallourn Monocline loses its steepness and that the Latrobe Seam is thinning out in this direction (Gloe, 1960). Residual gravity reductions, referred to in Section 7 of this Report, can be used to further explain the structural setting in the area between Rintouls Creek and Eaglehawk Creek (Plate 7).

As the exploration drilling was stepped up, additional gravity observations were made on bores located in the area east of Tyers River, and during January 1956, numerous bore sites in the area west and east of Tyers township were used as gravity stations.

The drilling in this area revealed the existence of an elongated deposit of the Latrobe Seam, occurring on the bulge convex to the southeast in the pattern of the gravity anomaly contours. This coal had been preserved from erosion, and subcrops under younger beds at 380 feet above S.L. (Gloe, 1960).

During January and February 1956 a more detailed gravity survey was carried out at the request of the State Electricity Commission near the western end of the Latrobe Valley, in the parish of Narracan. The main objective of this work was to investigate a possible southwestward extension of the Yallourn Monocline. 290 gravity stations were occupied during the course of this survey, spread out over the timbered hills south of the Princes Highway and north of Wilderness Creek.

A distinct gravity 'high' was located in the western portion of the area surveyed, and was interpreted as an indication of high basement rocks. Steeper gravity gradients on the eastern side of the 'high' were interpreted as the expression of steeper dip angles in the sediments on a monoclinal structure, which gradually disappeared southwestwards.

During August 1956, a localized area south of Foster, near the northwestern beach of Corner Inlet, was investigated by 17 gravity stations, spaced at one-third of a mile intervals. The purpose of this work was to obtain more complete gravity coverage over an area of high total magnetic intensity located by airborne magnetic surveying (Quilty, 1965). As a result of the gravity investigation a 'high' anomaly was partly delineated. It extends into the inundated area and can be assumed to be centred in the northwestern portion of Corner Inlet.

<u>1957</u>

Early in 1957 a semi-detailed gravity survey was conducted in the area west and north of the Traralgon-Maffra railway between Toongabbie and Seaton, in the parishes of Toongabbie North and Glenmaggie. The objective of this work was to investigate by gravity readings the structural relation between Palaeozoic and younger rocks in the area. 410 stations were observed during the course of the field work, placed at approximate quarter-mile intervals and covering the low-lying country as well as Palaeozoic outcrops in the foothills of the Eastern Highlands.

A distinct strip of steep gravity gradients was located between Rintouls Creek and Eaglehawk Creek north of Glengarry, expressed by the narrow spacing of the +5 to +10 milligal Bouguer anomaly contours. Obviously this trend in the pattern of the gravity map was a new feature distinctly different from the gravity expression of the Yallourn Monocline farther southwest of Rintouls Creek, referred to above.

1958

During January 1958 an area of about eight square miles south of Tyers township was investigated by 106 gravity stations on both sides of the Latrobe River. The readings were tied to the gravity stations of the earlier surveys in the adjoining areas. The result of the field work disclosed a number of irregular features in the anomaly contours.

Also during the same year additional gravity work was performed in the area of the Coolun Goolun Coalfield on the Baragwanath Anticline southeast of Rosedale. 133 gravity stations were occupied every 1/4 mile along roads and tracks with additional traverses along lines cut through thickly overgrown bush country. The results of this survey confirmed that a number of localized closed anomaly features are superimposed on the generally high gravity anomaly in the area of the Baragwanath Anticline (Thomas & Baragwanath, loc. cit.), which is terminated to the north by the prominent anomaly trend caused by the Rosedale Fault, mentioned earlier.

During 1958 an experimental seismic survey was carried out by BMR on three traverses set out in the area east and southeast of Morwell and south of Traralgon on the southern limb of the Latrobe Valley (Lodwick & Moss, 1959). After the completion of the seismic survey 70 gravity readings were taken along the seismic lines and at new stations along roads. The purpose of the work was to investigate by combined seismic and gravity methods the local structure in the coal measures and to provide information on the depth to, and the lithology of, the basement rocks underlying the coal measures. The results of the survey point to the existence of a number of small structures with indications of possible faulting in the basement layer.

1959

Early in 1959, semi-detailed gravity readings were taken in the area near Traralgon South; 111 stations were occupied on bush tracks, at bore sites, and between earlier stations on roads, to give an average separation of a quarter mile.

In the area of the survey tectonic movements have created a somewhat complex setting in the coal measures. For instance older coal beds were folded around the western end of the large Loy Yang Dome, earlier mentioned. Immediately south of the dome, the coal measures were warped into a narrow syncline, expressed on the gravity contour plan as a sharp 'low'. Farther south of this syncline faulting in the basement rocks, including exposures of basalt, is known from the Shingle Creek area.

As a result of the 1959 survey, low gravity readings were confirmed southwest of Shingle Creek in the area of the Traralgon River valley. This low anomaly is trending south into the region of the South Gippsland Hills. It might indicate the occurrance of cross-faulting parallel to the course of the Traralgon River which is almost at right angles to the northeastern boundary of the South Gippsland fault block. East of the Traralgon River the prominent gravity anomaly, related to the Rosedale Fault mentioned earlier, extends as a uniform feature over a great distance, and is described as the 'Flynns Creek/Lake Wellington Trend' in Section 7.

1960-61

During January 1960 a portion of the Baragwanath anticlinal structure was subjected to detailed gravity investigations in the area south of Longford in eastern Gippsland; 63 gravity readings were taken about a quarter of a mile apart along fire-breaks in a pine plantation. The purpose of the survey was to obtain more complete gravity coverage on secondary movements relative to the Rosedale Fault.

The result of the work indicated localized cross-faulting superimposed on the major fault structure (Lonsdale, 1963).

Also in January 1960, more complete gravity coverage was obtained in the area southeast of the Morwell Anticline between Billys Creek and Middle Creek south of Yinnar. A domed structure, the 'Hazelwood Dome' northeast of Yinnar township, was further investigated during December 1960.

In the Middle Creek/Billys Creek area 150 gravity stations were observed at about quarter-mile spacing on secondary roads and bush tracks, ties being made to previous surveys in the adjoining area.

To further analyse the gravity information obtained during the course of the survey residual gravity reductions were used. The method of residual gravity computation is described in more detail in Section 5 of this Report.

The purpose of the Hazelwood detailed survey, referred to above, was to examine more closely the gravity expression of a domal structure in the coal measures, indicated by drilling to be a closed anticlinal feature (Gloe, 1960). North-south traverses were laid out to intersect the suggested axial trend of the Hazelwood Dome. Station intervals were 300 feet on traverses at about half-mile spacing. The gravity results suggested that the Hazelwood structure was most likely formed by a more superficial warping in the sediments rather than by faulting in the basement rock underlying the coal measures.

During the period from December 1960 to January 1961, a semi-detailed gravity survey was conducted in the hilly area southwest of Rosedale and north of Gormandale. The purpose was to obtain more complete gravity coverage on a deposit of hard brown coal occurring on a structure south of the Rosedale Fault on the southern wing of the Latrobe Valley Coalfield. 208 new gravity observations were made at quarter-mile intervals along fire breaks, bush tracks, and the few available roads. Ties were performed to stations established near the area on previous surveys.

The results of the 1960-61 Gormandale survey confirmed the large gravity variations related to the Rosedale Fault, mentioned earlier. South-east of this fault high gravity readings indicate the possible extension of higher-standing basement rocks in the form of a fault block, for which the name 'Gormandale Block' was suggested.

Gradient characteristics determined over the area of the Gormandale survey support the concept of tilting. The major block, which is terminated on the northwest by the Rosedale Fault, can be suggested as tilting down to the southeast. (Neumann & Lonsdale, 1973).

5. EQUIPMENT, FIELD PROCEDURE, AND REDUCTIONS

Equipment and Field Procedure

For the purpose of obtaining sufficiently accurate gravity readings, the Humble-Truman gravity meter was found to be inadequate after a short period of field use early in 1948. Later, the Western type gravity meter (No. 29) was exclusively available for taking gravity observations during the first four-year period of gravity field work in the Gippsland area. From 1953 onwards the Heiland No. 53 meter of similar construction was also used. More modern instruments became available during the later stages of the field operations.

Both Western and Heiland gravity meters are relatively heavy, and require vehicle transport. These instruments are equipped with metal-spring movements, which necessitate a constant temperature for sufficiently reliable performance. For this particular purpose a thermostat-controlled heating device is provided, powered by batteries. For detailed technical data the reader is referred to Appendix A.

Holden sedan and Land-Rover vehicles were mainly used for transport. They were equipped with a shock-absorbing cradle to protect the gravity meter from mechanical jolting when travelling on rough sections of roads. At the site of a gravity station marked by a survey peg, the tripod was lowered to the ground through holes in the floor, so that readings could be taken inside the vehicle. In order to minimize the unpredictable element from the time-drift behavior of the metal-spring type gravity meters, each station of the semi-regional traverses was read twice during the first years of the Gippsland field operations.

Since 1953, gravity observations were obtained by using Worden and Atlas meters. These light-weight instruments are portable, and contain temperature-compensated movements composed of a system of quartz springs. Quartz-type gravity meters used in Gippsland showed a permanent drift of a few scale divisions per day, on which the daily drift curve, affected mainly by temperature variations, was superimposed.

For each station the gravity-meter readings were corrected for instrument drift, using repeat readings taken every hour at a base station or previously read auxiliary base station for drift control. Drift curves were plotted for each day after the end of the field work.

The permanent upward drift in the readings caused the behaviour of quartz-type meters to become more erratic near the end of their useful life. When the continuous drift made the meter move out of reading range, the instrument had to be sent to the manufacturer for range adjustment. But the drift behaviour of quartz-type instruments is superior to that of metal-spring gravity meters: Atlas and Worden give lesser irregularities in the readings and more moderate characteristics of the daily drift curves; unpredictable 'jumps' very seldom occur in the readings.

In a modern gravity meter the spring system is sealed inside a partly evacuated oscillation chamber. The maintenance of this vacuum is essential for the protection of the movement against outside temperature changes and for correct damping. Leakages in the oscillation chamber caused this vacuum to become insufficient after several months of field use. It was then noticed that the drift curve became to a certain extent a function of the outside temperature. For this reason Atlas and Worden meters were evacuated at the BMR's Geophysical Laboratories, Footscray, every time they were taken for longer periods of field use.

Reduction

Calibration factor. Drift-corrected readings, expressed in scale divisions, were converted into milligals by using the appropriate scale factor. Experience shows that calibration factors tend to vary slightly with time. It is also important to examine from time to time, if possible, the linearity of the calibration factor over the full reading range of the meter.

Since 1951 the gravity meters used in the Gippsland area were calibrated by check readings taken at the main gate of Brenock Park, Ferntree Gully, and at BMR's pendulum station (P.S.39) at Kallista (Victoria).

During the 1950-51 period a network of 59 gravity base stations was established throughout Australia, using 'Cambridge' pendulums (Dooley et al., 1961). During the course of this work the gravity interval between the National Gravity Base Station (P.S.1 in Melbourne) and P.S.39 in Kallista was determined. By using a set of gravity meters the gravity interval between Brenock Park station and P.S.39 in Kallista was then measured as 55.60 mGal. This is a provisionally adopted value subject to possible slight adjustments.

During July 1961, the provisional Ferntree Gully/Kallista calibration range was replaced by the Melbourne Calibration Range using two separate gravity reference stations, located in Upper Ferntree Gully and near Ferny Creek. The gravity interval between the two stations is 53.04 $\pm$ 0.01 mGal.

This new calibration range is now recommended for the convenience of gravity meter operations (Barlow, 1965).

Calibration factors used with field instruments are listed together with the relevant technical data in Appendix A.

Gravity reference datum. Gravity meter readings give relative observed gravity values to be converted into absolute data by tying the readings taken in any particular area to the nearest BMR pendulum base station available.

In the absence of a gravity base station during the initial period of the fieldwork in Gippsland, the gravity readings were referred to an arbitrary datum. With the completion of the pendulum base station network referred to above, a common gravity datum became available, to which individual gravity meter surveys could be reduced.

In Gippsland a pendulum station was established at Yarram as P.S.2 (long. 146°40.5', lat. 38°33.9'). Its value was revised in 1962, giving an observed gravity value of 980,022.4 mGal.

During 1964-65 the Australian National Gravity Network was considerably improved by a number of regional gravity meter surveys, referred to as the 'Isogal Project'. This network provides gravity base stations at intervals of about 150 miles throughout most of Australia. In the Gippsland area the pendulum station P.S.2 at Yarram and a secondary Isogal station established at the Bairnsdale aerodrome were included in the Isogal Project. It can be expected that further slight adjustments to the absolute observed gravity data available as this stage will be made from the results of the Isogal survey.

To refer the relative gravity values measured during th 1948-61 Gippsland surveys to the datum of the Australian National Gravity Network, an average amount of 5.00 mGal has to be subtracted from the relative values. This amount has been provisionally determined by the reoccupation of numerous earlier stations during the course of BMR's 1961 Regional Gravity Survey in Gippsland. This survey was accurately tied to the pendulum station at Yarram.

Bouguer reduction. The results of gravity surveys are usually shown in the form of a Bouguer anomaly contour plan. Experience shows that Bouguer gravity anomalies are most suitable for the purpose of geological interpretation. Bouguer anomaly values result after corrections are made to observed gravity values for latitude and for the gravity attraction of the layer of material between the station site and sea level. For Bouguer reductions the spot height measured at the station site is used and an average rock density for the layer beneath the surface is adopted.

For the calculation of Bouguer anomaly values an average rock density of 1.9 g/cm^3 has been used as it was considered to be representative of the surface layer composed of loose sediments in the area of low topography. A higher density of possibly 2.5 g/cm^3 would be more applicable in the areas of Jurassic outcrops, and densities of 2.6 to 2.8 g/cm^3 would be representative of the area of Palaeozoic outcrops.

In low-lying country the variation in the Bouguer gravity anomaly that results from the adoption of different densities is almost negligible. In areas of high topography the Bouguer reductions made with higher densities lead to considerably lower anomaly values.

Owing to the incorrect density used in the Bouguer reductions in the area of the South Gippsland Hills the maximum shown in the Bouguer anomaly is too high. Using a rock density of 2.5 g/cm^3 instead of the adopted value of 1.9 g/cm^3 could cause the maximum of 36 mGal shown in Plate 2 in the Balook area to be approximately 12 mGal lower.

However, any error which might occur in the Bouguer anomaly values owing to an incorrect assumption of rock densities would not greatly affect the anomaly trend expressed in the contours.

Terrain corrections. In the hilly portions of the survey area, terrain corrections were used in order to adjust the observed gravity values for the negative effect on the gravity attraction resulting from larger terrain undulations. In this context it must be explained that conventional Bouguer reductions are based on the approximation that the topography consists of an infinite horizontal plain. For this reason Bouguer reductions are correctly applicable only in the case of relatively level traverses.

In order to make full use of the high reading accuracy of modern gravity meters, gravity readings taken in hilly country must be corrected for topographic irregularities. These corrections must be added to the observed gravity values, as a lessening effect on the gravity attraction is caused by topographic variation occurring below as well as above any particular station location. In computing terrain corrections related to the Gippsland survey the method proposed by Hammer (1939) has been used.

In the area of the Haunted Hills the topographic information shown as the Miscellaneous Topographic Maps, Series 90, Herries Oak south, compiled by the Victorian Dept of Crown Lands and Surveys has been used (Appendix B). For larger areas the 1:63 360 scale Military Sheets were used. A maximum terrain correction of approximately 2.0 mGal applies to the very irregular topography of portions of the South Gippsland Hills.

Residual anomaly reduction. Residual gravity reductions are made in order to recognize local anomaly better. Any particular gravity map reflects the superposition of smaller gravity fields due to shallow subsurface density contrasts in geological rock complexes upon regional gravity fields caused by larger and most likely deeper-seated geological structure.

By removing from the 'measured' Bouguer anomaly the 'regional' component, local anomaly features can be delineated more precisely. In computing 'residual' gravity anomalies in this Report the 'arithmetic mean regional' method was used (Griffin, 1949). This method defines the 'regional' anomaly at a chosen station as the average value of gravity, determined by summations on the periphery of a circle centred on the point considered.

By subtracting the 'regional' value thus determined from the gravity value actually measured, the 'residual' gravity anomaly is found. The results of 'residual' gravity reductions depend in any particular area on the radius of the reference circle used. The adoption of a small radius leads to correspondingly small anomaly features.

In computing 'residual' anomalies in the Gippsland Basin area, a radius of 1.5 mile was adopted for the reference circle. For comparison reasons the method of least-squares polynomial fitting to gravity data, as suggested by S.M. Simpson (Simpson, 1954) was also used. A program was developed for fitting an n^{th} order polynomial to the measured Bouguer gravity data by A. Hopkins, university vacation time student employed by BMR.

To test this program the gravity data available from the 1:63 360 CARRAJUNG Sheet were used, with the computing work carried out on the CSIRO's CDC 3600 computer, Canberra. The features disclosed by contouring the residual anomaly values obtained by this method show no essential difference from those determined by the 'arithmetic mean regional' procedure suggested by Griffin.

6. DESCRIPTION OF RESULTS

Bouguer anomalies

Three major divisions are indicated on the Bouguer anomaly contour plan (Plate 2), namely:

(i) A large gravity 'high' in the area of the South Gippsland Hills.

(ii) A major gravity 'low' parallel to and west of the Ninety Mile Beach and a narrow gravity 'trough' extending from the coast westwards into the area near Traralgon.

(iii) A stretch of relatively high Bouguer anomaly along the northern margin of the Latrobe Valley with smaller features superimposed on the large anomaly.

These will now be described in detail.

South Gippsland Gravity High. The high anomaly associated with the South Gippsland Hills area is obviously the most outstanding feature of the Bouguer anomaly map. For convenience the name 'South Gippsland Gravity High' is suggested for it.

The major portion of the anomaly under review is approximately enclosed by the zero-Bouguer anomaly contour. Beyond this line a sharp 'spur' of relatively high anomaly extends farther east into the area near Lake Wellington.

Using the +15-mGal contour as a guide the 'South Gippsland Gravity High' is open to the southwest. This anomaly appears to extend southwest from Waratah Bay beyond the coast into Bass Strait. Separate anomaly features indicated by closing contours in the +25, +30 and +35-mGal range form several culminations on the gravity map.

The highest gravity variation was measured in the southwestern portion of the CARRAJUNG Sheet area. Relatively high readings were obtained farther west on the MIRBOO NORTH Sheet area.

A distinct single anomaly feature is indicated by the closed +25-mGal contour. This gravity 'high' is centred somewhere near the northwestern portion of Corner Inlet. On the inundated area no gravity information is available for accurate contouring. For this reason lines with question marks were used to indicate approximately the suggested pattern in the contours on the eastern side of the anomaly under review. For convenience this feature is referred to in the following text as the 'Corner Inlet Gravity Culmination'.

No direct connexion is noticeable in the pattern of gravity contours between the 'South Gippsland Gravity High' and the relatively high readings obtained on scattered stations occupied on the outcrops of granite in the Wilsons Promontory area.

The uniformity of the outer contours delineating the 'South Gippsland Gravity High' is disturbed by numerous smaller anomalies which cut into the major pattern in the contours in the form of localized bulges.

Areas of low anomaly. A major gravity 'low' is approximately delineated by the -25-mGal contour in the area immediately west of and parallel to the Ninety Mile Beach. This anomaly extends as a rather uniform feature from St Margaret Island northeast to Lake Victoria over a distance of approximately 60 miles. For convenience the name 'Ninety Mile Beach Gravity Low' is suggested.

Within the limits of the Ninety Mile Beach Gravity Low minimum Bouguer values of less than -35-mGal were located near the northeastern corner of the ALBERTON Sheet area.

A relatively narrow gravity 'low' runs from the northern end of the Ninety Mile Beach Gravity Low west and southwest into the area near Traralgon. This anomaly is referred to in the following text as the 'Rosedale Gravity Trough'.

North Gippsland Gravity Terrace. North of the Rosedale Gravity Trough there is a rather uniform and prominent trend expressed in the gravity contours between -5 and -15-mGal; it elongates northeast and east over a great distance. North of this trend the Bouguer anomaly values are generally raised, with distinct localized features superimposed on the larger anomaly. For instance in the area between Yallourn and the Thomson River a strong gravity gradient is indicated by a distinct northeast trend in close-spaced gravity contours.

On the northern margin of the Latrobe Valley eastwards from the area around Seaton, the following separate features can be distinguished (Plate 2):

(a) Gravity 'high' between Seaton and Heyfield.

(b) Gravity 'low' bulging north between Heyfield and Maffra.

(c) Gravity 'high' in the area around Briagolong.

(d) A relatively large gravity 'low' extending north from the Lake Wellington area towards the Mitchell River.

(e) A major platform-like gravity 'high' northwest of Lakes Entrance between Bairnsdale and Lake Tyers. This anomaly is referred to in the following text as the 'Lakes Entrance Gravity High'.

In the area east of longitude 148°00', which is not included in Plate 2, a sharp gravity 'low', trending north, was delineated east of Lake Tyers. This anomaly feature is followed farther east by a continuous rise in the Bouguer anomaly towards Orbost. The anomalies mentioned are shown in detail on the HARTLAND Sheet, no. 730 of the geophysical map of Victoria, issued by BMR.

Regional anomalies

The major anomaly features described above from the Bouguer map also occur in the pattern of the 'regional' anomaly contours (Plate 3). With local irregularities removed, the trends in the regional contour lines are more linear. Several new features become noticeable, and these will be briefly described below under the same headings as before.

South Gippsland Gravity High. The regional anomaly contours disclose a uniform gravity 'high' elongated northeast near the crest of the South Gippsland Gravity High. The high values extend from the southeastern portion of the MIRBOO NORTH Sheet area into the southwestern portion of the CARRAJUNG Sheet area.

Southwest of this maximum anomaly, the regional gravity map shows a sharp gravity 'ridge', associated with the larger anomaly mentioned.

In the area west of the Morwell River and south of Moe a broad gravity 'ridge' is indicated by regional anomaly contours swinging north. This feature is distinctly different from the complex pattern in the Bouguer anomaly contours in the same area.

Areas of low anomaly. The Rosedale Gravity Trough mentioned earlier is outlined by mainly parallel trends in the regional anomaly contours. As a regional feature this anomaly is clearly asymmetrical with steeper gravity gradients on the south and with its axis nearer to the southern margin of the Trough.

Three subdivisions can be distinguished within the regional picture of the Rosedale Gravity Trough. The narrow portion of the anomaly occurs near Traralgon; a middle and somewhat wider section lies west of Rosedale, and a much wider portion is east of Rosedale in the area between Maffra and Sale.

The trend in the regional contours delineating the gravity 'low' is northeast between Traralgon and Rosedale and due east between Rosedale and Lake Wellington.

In the area of the Ninety Mile Beach Gravity Low the regional anomaly contours are distinctly bulging east near Merrimans Creek, Farther north, regional contours enclose a gravity 'low' south of Lake Wellington and immediately west of Lake Reeve.

North Gippsland Gravity Terrace. The pattern in the regional anomaly contours on the northern margin of the Latrobe Valley includes essentially the same features as those shown on the Bouguer anomaly contour plans, but with local irregularities removed.

Residual anomalies

The residual gravity contours (Plate 4) enclose smaller anomaly features, which are grouped together into series of distinct linear trends.

For this reason the pattern in the 'residuals' is distinctly different from that of the regional gravity map, featuring broad and relatively large anomalies.

In the more densely covered sections of the Latrobe Valley the contouring of the residual anomalies can be considered to be fairly accurate. A much denser grid of gravity stations would be required for more accurate delineation in the area of the South Gippsland Hills, where the contouring is sketchy. Owing to the paucity of the gravity data on large portions of the hilly country, the contouring of residual gravity values was attempted only with the intention of showing possible trends in the residuals, but it is felt that the attempt to recognize important trends and individual anomalies was justified even in the area of sparser station coverage.

From an inspection of the residual gravity map (Plate 4) the following major anomaly trends can be recognized:

Yallourn/Thomson River Trend (1). A significant trend, mainly northeast, occurs on the northwestern portion of the residual anomaly map, named the 'Yallourn/Thomson River Trend'. This 'Yallourn/Thomson River Trend' can be first recognized in the area of the Haunted Hill, southwest of Yallourn, where residual gravity contours delineate the eastern edge of a localized gravity 'high'. This high was located during the course of the 1956 Narracan Parish gravity survey (Table 3). From here the trend continues northeast, crossing the Moe-Morwell railway, the Princes Highway, and the Latrobe River. The same trend is parallel to and north of the Latrobe River for about three miles and swings sharply north before it crosses the Tyers River valley on a due east course. Near Tyers township the residual gravity contour lines swing into a broad arc which is convex to the southeast. From here the strike direction of the contours is persistently northeast into the area just south of Thomson River, where the trend ends.

Boolarra-Morwell Trend (2). Sparse gravity data in the southwest of the MIRBOO NORTH Sheet area (Plate 4) indicate the Boolarra-Morwell Trend crossing the Grand Ridge Road on a northeast course. The same northeast trend is expressed in the contours in the area immediately west of and parallel to the Morwell-Boolarra railway. The railway line is crossed near Yinnar, from where residual gravity contours parallel the highway towards Morwell. South and east of Morwell the trend of the lines is more northerly.

The Boolarra-Morwell Trend ends just south of the Latrobe River opposite the point where the Yallourn/Thomson River Trend, referred to above, swings sharply north.

Flynns Creek/Lake Wellington Trend (3). An outstanding feature of the residual gravity map (Plate 4) is the unique trend in the parallel contours, which commences at a point approximately 8 miles south of Traralgon and ends near Lake Wellington, a distance of about 40 miles. The trend direction is northeast in the area east of Traralgon River and then swings due east from a point south of Rosedale. The trend fades away on a northeastern course near the south-western side of Lake Wellington. The gravity anomaly involved is an elongated residual gravity ridge with localized closed anomalies superimposed. To the north this high is accompanied by a low anomaly feature of similar size.

Carrajung Trend (4a). In the Carrajung area of the South Gippsland Hills a residual gravity 'high' was delineated on a northeast axis which swings sharply northwards near the eastern end of the anomaly. North of this 'high' a sharp residual gravity 'low' extends northeast just south of Gormandale.

Dingo Creek Trend (4b). On the northeastern portion of the FOSTER Sheet area a distinct residual anomaly 'high' was delineated, trending parallel to the course of Dingo Creek in the area between the Agnes River and the Grand Ridge Road. The axis of this anomaly appears to be in line with that of the western portion of the Carrajung Trend referred to above.

Foster/Won Wron/Seaspray Trend (5). In southern Gippsland in the area northeast of Foster an important trend can be recognized in the pattern of the residual anomaly contours, expressed by lines parallel to the zero contour. This trend is continuous as a single feature from the area northwest of Corner Inlet to Seaspray near the Ninety Mile Beach. It appears to extend farther east into the sea. The name 'Foster/Won Wron/Seaspray Trend' is suggested for this feature of the residual anomaly map. The course of the trend is mainly northeast and east with local changes occurring in the general strike direction. The trend is distinctly expressed in the area north of Won Wron by a sharp residual gravity 'high', elongated eastnortheast, which is accompanied on the south by a residual gravity 'low' of similar size.

Macalister River Trend (6). In the area of the Glenmaggie Reservoir, residual anomaly contours trend north and north-northwest parallel to the course of the Macalister River. This trend is expressed by a low anomaly feature with two residual anomaly 'ridges' on either side of this 'low'. The Macalister River Trend extends south into the northern portion of the ROSEDALE Sheet area, where it disappears as the contours diverge southwest and southeast.

Sale/Perry River Trend (7). In the area west and east of Sale township a narrow residual gravity 'high' north of the Latrobe River extends easterly over a distance of approximately eight miles. The contours then swing north into a trend parallel to the course of the Perry River, including a group of scattered closed anomalies. The name 'Sale/Perry River Trend' is suggested for the residual anomaly feature as a whole.

Lake King/Bairnsdale Trend (8). In the area around Bairnsdale the residual anomaly contours swing into a large arc convex to the southwest. Farther northwest of Bairnsdale the contours follow a west-southwest course, parallel to the Princes Highway, towards Perry River. Southeast of Bairnsdale the trend in the contours is due east from Lake King towards Lakes Entrance. Consequently the name 'Lake King/Bairnsdale Trend' is proposed for this residual anomaly feature.

Stockyard Hill Trend (9). Near the northwest portion of the STOCKYARD Sheet area, residual anomaly contours enclose two local gravity 'highs' aligned on a northwest trend which extends into the northeastern corner of the SALE Sheet area. The significance of the Stockyard Hill Trend can be seen in the fact that it is in line with the direction of a major fault, suggested from airborne magnetic data to occur in the basement rocks offshore (Plate 1).

Darriman Trend (10). Near the southwest corner of the STRADBROKE Sheet area, residual gravity contours are parallel to the axis of the Darriman structure, on which the Darriman No. 1 bore was drilled during 1955. Two more elongated residual gravity features of a similar size occur in the area northeast and southwest of Yarram township. For this reason a possible extension west and southwest of the 'Darriman Trend' towards Yarram can be suggested.

Snake Island Trend (11). In the area northeast of Corner Inlet the trend in the residual gravity contours is significantly northwest, parallel to the axis of the tidal channel north of Snake Island. The name 'Snake Island Trend' is suggested for the anomaly features involved.

7. INTERPRETATION

Procedure

The initial approach to problems relating to the geological interpretation of gravity anomalies is usually attempted by explaining from known geological data any particular feature disclosed in the pattern of the gravity anomaly contours. For instance, significant trends and very large gravity gradients are interpreted as most probably indicating lines of faulting or steeply dipping monoclines, accepting that the area of higher gravity anomaly represents the upthrown side of the suggested geological feature.

Contours enclosing relatively high gravity features are normally expected to indicate the presence of high-density rock complexes at shallow depth. Areas of low gravity anomaly, on the same principle, are at the first approach expected to express a thickening at depth of low-density rocks such as, for instance, unconsolidated younger sediments.

A more advanced method of interpretation includes cross-section correlation. By using all the information available from various sources, the correlation between gravity, topography, geology and, for instance, seismic data can be illustrated. Cross-sections through critical areas can be chosen for more detailed gravity analysis by using precise mathematical methods to determine the form of any particular geological body causing a gravity anomaly.

For the purpose of correlating gravity anomaly and tectonics more precisely, 'residual' gravity reductions were used in this Report. This method makes it possible, as explained in Chapter 5, to separate 'residual' anomalies, caused by smaller geological features, from the regional gravity anomalies related to larger and deeper-seated geological structures.

Rock densities

Basically, gravity anomalies are caused by density contrasts between various types of rocks. As a general rule, sediments are less dense than igneous and metamorphosed rocks, which have a more compact texture. Younger sediments are frequently more porous, and thus less dense, than older rocks, which after deposition have become denser by compaction. Limestones are generally known to be denser than sandstones.

In Gippsland rock densities are available from various sources. Bore cores have been submitted for density determinations at the BMR Petroleum Technological Laboratory, Canberra. Some specimens were collected from outcrops and submitted for density testing at the BMR Geophysical Laboratories, Footscray. The 'Nettleton method' (Nettleton, 1940) was used to determine the average density of the uppermost layer in the lowlands from gravity readings and station spot-height data. The State Electricity Commission is currently making routine density tests for technical purposes on the material extracted by mining operations. Relevant density data are listed in Table 4.

In the Gippsland Basin, the lowest density figures are from the Latrobe Valley coals, contained in the younger seams which in situ contain more than 70 per cent moisture (Gloe, 1960). The highest density (2.75 g/cm^3) was found for a specimen of metamorphosed shale of Silurian age. Sandstones are relatively low in density but become generally denser with increasing geological age.

Density data obtained from bore cores are probably more reliable than data from specimens collected from outcrops; outcropping rocks are exposed to the effects of weathering and may have been subjected to alterations of their original physical properties. It is possibly for this reason that the density of specimens of basalt collected from various parts of Gippsland was found to be somewhat lower (2.66 g/cm^3) than that of unweathered basalt (2.9 to 3.0 g/cm^3).

The overall assessment of the density data listed indicates that the sedimentary sequence which infills the Gippsland Basin becomes progressively denser with depth. However, the densities of the Quarternary and Tertiary sediments are mainly a function of the physical properties and not one of age.

In the western part of the Latrobe Valley Coalfield, the analysis, based on rock densities, of the gravity anomalies is relatively simple because of the large density difference between coal measures and the underlying denser rocks, which form the 'commercial basement' composed of Jurassic beds or Tertiary basalt. (Neumann, 1951). Consequently the gravity interpretation can be simplified to the case of two layers having a density difference of 1.0 g/cm^3.

The interpretation of gravity variations on cross-sections correlated with geology and topography in the eastern portion of the Gippsland Basin is complicated by the occurrence of marine Tertiary beds of higher density above the coal measures. These beds are composed of limestone, having an average density of 2.1 g/cm^3. The gravity effect of the cover beds must be removed, in order to obtain sufficiently accurate estimates of the depth to the basement rocks (Neumann, 1960).

In areas of shallow basement rock composed of folded, faulted, and intruded rock complexes of Palaeozoic age, it is virtually impossible to explain gravity variations solely in terms of a two-layer problem by accepting a low-density sedimentary layer overlying a basement composed of a uniform layer of high density.

For this reason a certain part of the gravity variations measured in the Gippsland area must be attributed to density variations because of lithology changes in the basement.

Higher-standing Palaeozoic basement rocks can be expected to occur under a relatively thin cover of younger sediments on the northern margin of the Gippsland Basin. Cores of Palaeozoic formations can also be assumed to be present under Jurassic beds in the higher ranges of the South Gippsland Hills.

Interpretation of Bouguer anomaly features

The value of Bouguer anomaly contour plans in delineating coal structure concealed under the cover of younger beds has been described in Chapter 4.

Bouguer anomaly data obtained from detailed surveys over localized areas north of the Latrobe River during the 1954-56 period were entirely sufficient, for instance, to determine geophysically under critical conditions the presence of the Yallourn Monocline as a distinct gradient feature in the Bouguer anomaly contours, the geophysical indication being consistent over the whole length of the geological structure.

TABLE 4

ROCK DENSITIES - GIPPSLAND BASIN, VICTORIA

ROCK TYPE	AGE/LOCALITY	DENSITY (g/cm^3)	DETERMINED BY
Surface Layer	Quaternary	1.887 1.92	BMR R.H. Ray
Overburden layer composed of sand, clay and gravel	Quaternary	1.86*	S.E.C.
Gippsland Limestone		2.19	BMR
Gippsland Limestone - porous specimen	Miocene	1.74	"
Latrobe Valley coal - in situ	Eocene	1.01*	S.E.C.
Latrobe Valley coal - bulk density after dredging	Eocene	1.11* (=32 cubic ft/ton)	"
Basalt	Eocene	2.66*	BMR
Basalt - vesicular specimen		2.33	"
Arkosic sandstone	Jurassic		
"	Merriman No. 1 bore	2.33*	BMR
"	Seaspray No. 1 bore	2.31*	"
"	Wellington Park No. 1 bore	2.47*	"
"	South Gippsland Hills	2.42	"
"	" " "	2.61	"
Sandstone	Permian	2.50	BMR
"	Duck Bay No. 1 bore "	2.35	"
Reddish Sandstone	Carbo-Devonian, north of Briagolong	2.61	BMR
Shale, metamorphosed	Silurian	2.74	BMR
Greywacke	"	2.75	"
Shale and conglomerate	Ordovician	2.61	BMR
Siltstone and shale	Duck Bay No. 1 bore	2.65	"
Granite	Mt Baw Baw area	2.64	BMR

NOTE: Density figures shown with asterisk (*) are mean values obtained from testing several specimens

The delineation of a major doming structure in the coal beds as a result of the detailed 1955 Fernbank survey, parish of Loy Yang, was successfully performed by using Bouguer gravity reductions. Sunken areas, containing thicker coal measures, e.g. in the area of the Melton Park 1953 survey east of Flynns Creek, were outlined as distinct Bouguer anomaly 'lows'.

As gravity surveys expanded during the years, larger areas were subjected to gravity traversing and major anomalies became available for interpretation. At this stage of the gravity work in Gippsland it was recognized that the larger anomalies interfered to a certain extent with the more localized gravity features. The adverse effect of strong regional gravity variations was naturally more noticeable in areas of steep gravity gradients, which occur near the tectonic margin of the Latrobe Valley and in the area of the South Gippsland Hills.

Consequently it was recognized that more advanced methods of gravity reductions would be required for evaluation of the gravity data.

Interpretation of regional and residual anomalies

In order to facilitate the interpretation, the more important features of the regional and residual gravity anomaly maps (Plate 3 and 4) were combined in Plate 6, superimposed on the pattern of major faults, which is more completely shown in Plate 5. On the combined results of the 'regionals' and 'residuals' the following comments are offered:

Yallourn/Thomson River Trend. The earlier described 'Yallourn/ Thomson River Trend' in the residual anomaly contours is interpreted as the gravity expression of the northwestern tectonic boundary of the Latrobe Valley coal basin. From the area southwest of the Haunted Hill to the Valley of Rintouls Creek, over a distance of approximately 18 miles, the Yallourn/Thomson River Trend is related to the Yallourn Monocline. A major portion of this monocline is shown in Plate 7, which illustrates the geological boundaries in the Tyers area (Philip, 1958) in relation to the pattern in the 'residual' anomaly contours over the same area.

Bodies of hard brown coal contained in the Latrobe Seam have been preserved from erosion mainly on those sections of the monocline where gravity contours indicate variations in the strike direction in the form of arcs convex to the southeast (Gloe, 1960). A major deposit of coal was located by drilling in the area due north of Morwell, where the monocline swings sharply north. Northeast of Rintouls Creek, coal bores intersected the Latrobe Seam, which had split up into smaller seams. In the same area a change is noticeable in thre residual gravity contours. Contour lines delineating a 'low' south of the monocline, might be interpreted as indicating a short extension of the geological feature towards Eaglehawk Creek, where the residual gravity 'low' ends.

A new trend of close-spaced residual contours begins in the area between Rintouls Creek and Eaglehawk Creek. This pattern in the contours most likely indicates a separate geological structure running northeast along the foothills towards Thomson River. It might be caused by faulting in the basement rocks. Drilling in the area south of the Thomson River showed older Tertiary beds dipping at more than 50° to the east under a thin layer of younger sediments (Gloe, 1960). The name 'Toongabbie Fault' is suggested for the tectonic feature indicated by the gravity contour trend.

Boolarra-Morwell Trend. Correlation of geology, topography, drilling data, and residual gravity anomaly explains the Boolarra-Morwell Trend as the expression of the Morwell Fault and monocline. Near Morwell township faulting in the coal measures is associated with anticlinal warping to the west of this fault and synclinal development to the east.

Southwest of Boolarra, the Morwell Fault extends into the Tarwin Fault (Thomas & Baragwanath, loc. cit.), which is evidenced in geological outcrops. A narrow sunken area in the form of a graben occurs east of the Tarwin Fault.

Plate 7 illustrates the northern end of the Boolarra-Morwell Trend showing the residual contours in relation to the Palaeozoic outcrops north of the Latrobe River near Tyers township. Geological mapping in the area of the Tyers River valley indicates the occurrence of mudstone of Silurian age on an anticlinal feature, arranged north-south and flanked by Devonian sandstone (Philip, loc. cit).

Farther north in the Eastern Highlands of Victoria the continuation of an anticlinorium is indicated by the axial line known from Upper Ordovician rocks near Mount Easton (Thomas, 1939).

By combining geophysical and geological data, it is immediately evident that the axis of the residual anomaly feature, described as the 'Boolarra-Morwell Trend' is in line with the orogenic trend in the Palaeozoic sedimentary outcrops north of the Gippsland Basin.

As the residual gravity anomaly reflects mainly on the structural setting in the Tertiary beds, it may reasonably be assumed that the Tertiary movements are rejuvenations of the older orogenic trends.

The sharp turn to the north in the strike direction of the Yallourn Monocline west of Tyers River also appears to be linked with movements in the older rocks. There is no evidence of cross-faulting in the coal beds but the arcuate folding may have been caused by en echelon faulting in the basement (Gloe, loc. cit.).

Flynns Creek/Lake Wellington Trend. The distinct trend in the residual anomaly contours extending from Flynns Creek northeast and east into the area of Lake Wellington is related to the position of the Rosedale Fault and Baragwanath Anticline (Thomas & Baragwanath, loc. cit.). In the area south of Longford in eastern Gippsland, drilling revealed a displacement in the coal measures, downthrown to the north. South of the Rosedale Fault in the area of high anomaly, there is a seam of harder and older coal known to occur in the Coolun Goolun Coalfield (Herman, 1952).

A partly eroded seam of hard brown coal is also known from drilling in the area of the gravity 'high' north of Gormandale (Gloe, personal communications).

To the northwest of the Flynns Creek/Lake Wellington Trend, synclinal warping in the coal measures is known from the Melton Park area west of Flynns Creek as mentioned earlier.

North of Rosedale approximately 4½ miles from the Flynns Creek/ Lake Wellington Trend, the Rosedale No. 1 bore was sunk to a total depth of 5836 ft. This bore intersected the top of Jurassic rocks at 2345 ft after penetrating a sequence of Tertiary sediments containing five seams of coal with a total thickness of 1570 ft.

The analysis of the gravity anomaly prior to the drilling of the Rosedale No. 1 bore had predicted a maximum thickness of Tertiary deposits north of the Rosedale Fault not exceeding 2500 ft. (Neumann, 1960). Gravity analysis suggested a displacement in the Jurassic beds under the Tertiary in the order of 2000 ft.

Consequently from all the data available at this stage the Flynns Creek/Lake Wellington Trend gives gravity expression to a major fault in the Tertiary and also in the underlying basement rocks extending over a distance of 48 miles. This fault forms the tectonic boundary of a fault block tilting down to the south (Neumann, 1960).

Near its easternmost end the strike direction of the Flynns Creek/ Lake Wellington Trend swings distinctly northeast, fading away near the northwestern side of Lake Wellington and south of the course of the Latrobe River.

Rosedale Gravity Trough. The regional gravity map (Plate 3) shows the large low anomaly, earlier referred to as the Rosedale Gravity Trough, as a uniform feature, terminated by distinctly linear trends in the gravity contours extending northeast and east. To the south this low anomaly is bounded over a long distance by the Flynns Creek/Lake Wellington Trend explained above as the gravity expression of a major displacement of Tertiary and older rocks along a large fault, the 'Rosedale Fault'.

Consequently the nearest interpretation would be to visualize the area of low anomaly as indicating a major sunken area in the form of a geological graben, essentially controlled by parallel faulting. Gravity data show that the form of this graben is asymmetrical, and that the deepest depressed portion lies immediately north of the Rosedale Fault. Steeper gradients on parallel gravity contours indicate that faulting may occur on the northern side of the suggested graben. This faulting on the north, if present, might occur in the deeper basement rocks, entirely concealed under the thick sequence of younger sediments.

As the gravity low anomaly deepens eastwards in the area south of Sale the depth to basement of the suggested geological depression most likely also increases in the same direction. Farther east of Sale the Wellington Park No. 1 bore was sunk in an area which forms a possible eastern extension of the graben structure. This bore bottomed in Jurassic rocks at a total depth of 12 000 feet. For this reason a thick sequence of Jurassic sediments could be expected under the entire Rosedale Gravity Trough.

Near its western end in the Moe area, the regional gravity low anomaly under review is terminated by a regional gravity ridge extending north from Boolarra to Moe. This feature of the regional gravity map might indicate a major block of older and denser rocks of Palaeozoic age, occurring at depth under the cover of younger sediments and terminating in the west the thick sediments whose presence has been suggested under the area of lowest gravity values farther east.

In the Yallourn and Morwell area, structural axes in the Tertiary beds, such as the Yallourn Monocline and the Morwell Anticline with the associated residual anomaly trends, are oblique to the axis of the regional gravity low referred to as the Rosedale Gravity Trough. In fact the trend in the coal beds on the Morwell Anticline is obviously related to a prominent axis evidenced in Palaeozoic rock exposures in the Tyers River Valley (Plate 7).

It must therefore be concluded that the sunken graben feature related to the Rosedale Gravity Trough was superimposed as an oblique element on the Palaeozoic axial trends during a first period of tectonic movements. Younger movements during a later tectonic phase then formed the structure in the Tertiary beds as rejuvenated features in line with the Palaeozoic orogenic axes.

South Gippsland Gravity High. The prominent gravity 'high' described in Section 6 from the area of the south Gippsland Hills is clearly related to the geological structure of the Balook Lobe (Edwards, 1942). It has the form of a large elongated dome, composed mainly of Jurassic rocks. These beds dip outwards from the central axis of the doming feature which trends south-westwards through Balook.

Residuals of 'Older Basalt' fringe the Jurassic outcrops on the north-west, north and south-east. It is obvious from the surface exposures that the original horizontal sheet of basalt lava covering the pre-basaltic land surface has been broken up by faulting and was tilted by later movements.

Jurassic rocks decrease in thickness to the south-west of Balook, so that Palaeozoic rocks become exposed near Foster and Toora in southern Gippsland. Palaeozoic beds also crop out at Turton's creek near the central axis of the Balook Dome.

A relatively small fault controlled block of Ordovician rocks has been described from the area east of Boolarra (Thomas and Baragwanath, loc. cit.).

Faulting is intense in the south-west near Foster, where the movements in the Palaeozoic basement rocks continued upwards through the Jurassic rocks, which are also faulted.

Further eastwards on the Balook Dome the thickness of the Mesozoic beds increases and the faulting in the older rocks dies out into monoclinal warping in the younger sediments.

As a topographic feature, the Balook Dome is bounded by scarps. On the north the Carrajung escarpment and on the southeast the Won Wron Monocline form topographic boundaries.

Smaller and lower fault blocks are added as secondary features to the main doming structure of the Balook Lobe. A tilted block of Jurassic rocks, the 'Toora Faultblock', lies between the Won Wron Fault and the Gelliondale-Toora Fault in the area east of Foster.

North-east of Balook, there is a tilted faultblock ending eastwards in the 'Baragwanath Anticline', earlier referred to, which plunges beneath the Tertiary cover beds further east. The Rosedale Fault, a major tectonic feature and pre-dominating gravity anomaly trend, bounds the 'Baragwanath Anticline' on the south, as earlier mentioned.

Apart from the movements which caused the marginal lower lying fault blocks, the western and central portions of the structure of the Balook Dome are clearly created by movements originating in the Palaeozoic basement rocks. This raises the question of whether there is any structural relation noticeable between the Palaeozoic outcrops in the South Gippsland Hills and the major tectonic trends described from the Palaeozoic rock exposures in the Eastern Highlands of Victoria (Thomas, 1958).

The term 'Waratah - Boolarra - Mt Easton Anticlinorium' has been used in the earlier literature (Thomas, 1939), to indicate a possible relationship between the two outcrop areas mentioned.

In this Report the combined 'regional' and 'residual' gravity anomaly data have been used to examine more closely the tectonic position in relation to known orogenic axes and also the inner structure of the Balook Dome.

On Plate 6 the axes of 'residual' anomaly features and closed regional anomalies are superimposed on the pattern of known and suggested fault lines. A major fault trend extends from the area of Waratah Bay northeast towards Foster and Turton's Creek.

Off-set by approximately four miles of the trend mentioned, the central axis of the Balook Dome is identical with that of a regional gravity "high" extending from English Corner through Balook towards Carrajung.

Cores of higher standing Palaeozoic basement rocks of high density can be suggested to extend from the Turton Creek outcrop under a thin cover of Mesozoic beds, where the gravity map indicates maximum regional anomaly values.

In the area northeast of Carrajung the axis of the residual "Carrajung Trend" in the contours swings abruptly north, indicating a possible northward extension of the "Carrajung Trend", across the sunken area near Rosedale into the residual gravity "Macalister River Trend" west of the Glenmaggie Reservoir.

In the critical area southwest of Rosedale, detailed gravity work recently performed along the Rosedale Fault indicates the possibility of cross-faulting approximately perpendicular to the strike direction of the main fault.

It is remarkable that the Won Wron Monocline, which bounds the Balook Dome on the southeast, swings into a large arc convex to the southeast by changing its direction from northeast to north-northeast in the area east of Carrajung. In the same area regional gravity contours swing north and so does the zero anomaly contour line in the area between the Thomson and Macalister Rivers southeast of the Glenmaggie Reservoir area.

If the assumption is essentially correct that the trends expressed in the pattern of the regional and residual gravity anomaly contours reflect the structure in the basement rocks, a structural relation between the main axis of the Palaeozoic Waratah-Balook trend and the Phosphate Hill Anticlinorium of Ordovician outcrops in the Eastern Highlands can be accepted with reasonable reliability.

Ninety Mile Beach Gravity Low. The Ninety Mile Beach Gravity Low indicates an area underlain by thick sediments composed of several thousand feet of marine and continental Tertiary beds overlying Jurassic arkosic sandstone of considerable thickness. The Sunday Island No. 1 bore, drilled in the year 1966 in the southwestern portion of the Ninety Mine Beach Gravity Low, ended in Jurassic beds at a total depth of 6000 ft.

On the north the thick sedimentary deposits are bounded by the Foster/Won Wron/Seaspray Trend in the residual anomaly contours, which gives expression to a major tectonic boundary, the Yarram/Won Wron Monocline.

Near its eastern end the trend bifurcates with a branch turning northeast and recurring near Holey Hill on the southern flank of the Baragwanath Anticline after crossing the course of Merrimans Creek.

This creek turns northeastwards parallel to the axis of the residual gravity high, thereby suggesting tilting movements caused by faulting in this particular area.

The main trend in the residual anomaly contours continues east towards Seaspray, giving expression to the Seaspray Anticline. A small flow of natural gas was obtained from the North Seaspray No. 1 bore drilled on this structure in 1962.

Farther south, the Darriman Trend in the residual anomaly contours correlates with the Darriman Anticline, a fault-bounded block of higher-standing Jurassic rocks under Tertiary beds (Garrett, 1955), confirmed by drilling the Darriman No. 1 bore.

In the southwestern portion of the Ninety Mile Beach Gravity Low, several elongated residual gravity 'highs' were delineated, striking northwest and northeast. For instance near Gelliondale, southwest of Yarram, a residual gravity 'high' was partly investigated during the course of an early gravity survey of the 1928-30 period (Edge & Laby, 1931). Subsequent drilling showed the localized gravity 'high' in the Gelliondale area to be underlain by shallow Jurassic sandstone, intruded by basalt, with a seam of brown coal rapidly thinning on the margin of the high gravity anomaly.

Basaltic intrusions in the form of dykes and vertical plugs could be considered to provide density contrasts sufficiently large to cause localized gravity residuals such as those delineated in the area around Gelliondale.

Airborne magnetic (Quilty, loc. cit) and seismic work (Baker, 1963; Taylor, 1965) carried out offshore in the area south and southeast of the Ninety Mile Beach Gravity Low, indicate high basement rocks east and southeast of Wilsons Promontory (Plate 1). For this reason the thick sediments, suggested from gravity data to occur near the Ninety Mile Beach, are most likely thinning southeastwards.

The gravity anomaly features located beyond the southwestern end of the Ninety Mile Beach Gravity Low are somewhat problematical.

In the area of the Toora Faultblock the normal gravity/geology correlation is reversed, as lower gravity readings were obtained on the upthrown block north of the Toora Fault and higher readings on the south.

A unique feature of the gravity map is the Corner Inlet Gravity Culmination south of Foster. In this area a strong Bouguer anomaly of +25 mGal was partly delineated on the low-lying beach near the northwestern portion of Corner Inlet. The gravity anomaly is obviously related to the strong variation in the total magnetic intensity located by airborne work in the same area.

As there is no surface expression in outcrops, the presence at depth of a magnetic body composed of relatively dense matter must be accepted in order to explain the distinct geophysical indications. It can be suggested that the mass causing the magnetic and gravity anomalies is of volcanic origin.

Lakes Entrance Gravity High. The Lakes Entrance Gravity High is interpreted as the expression of a high-standing terrace of basement rocks which forms a southern extension of a belt of Ordovician rocks and metamorphics exposed in a huge area of the Eastern Highlands farther north of the Gippsland Basin (Plate 1).

Bores drilled for oil in the area of the Lakes Entrance Gravity High intersected a sequence of Tertiary beds, from 1200 to 1400 ft thick, overlying basement rocks.

A small 'low' in the regional gravity anomaly map (Plate 3) north of Bairnsdale, which is superimposed as a smaller feature on the Lakes Entrance Gravity High, is most likely caused by a major mass of granite (density 2.65 g/cm^3) protruding deeply into the complex of denser metamorphic rocks (estimated density 2.8 g/cm^3). Granite is exposed north of the Gippsland Basin near the northern end of the 'low' anomaly mentioned.

The availability of airborne magnetic data facilitates the geological interpretation of the gravity picture near the eastern end of the Gippsland Basin. The cross-sections A-A and B-B (Plates 8 and 9) illustrate the correlation of gravity and magnetic information with the results obtained from drilling, the emphasis being placed on possible faulting.

The residual gravity anomaly map (Plate 4) shows the Lakes Entrance Gravity High terminated on the west and the south by the Lake King/Bairnsdale Trend. Drilling shows that this residual anomaly is most likely the expression of faulting in the basement rocks. Farther southwest near the southwestern end of Lake Victoria, the Stockyard Hill Trend was delineated as a significant anomaly which, from the magnetic data available over the same area, is also interpreted as the expression of faulting in the basement. This interpretation is based on the following facts.

Magnetic depth-to-basement data are considered to be related mainly to metamorphic and granitic rocks of Ordovician-Silurian age. In the Lake King area the Nicholson River Ordovician belt deepens from the margin of the Gippsland Basin to a depth of about 3000 feet below sea level onshore near Lake Victoria (Quilty, loc. cit.)

South of the Lake King/Bairnsdale Trend in the residual gravity anomaly contours the Duck Bay No. 1 bore has been sunk to a total depth of 4238 feet. This well penetrated below a Tertiary sequence of lowermost Cretaceous to uppermost Jurassic sediments, overlying altered olivine basalt, which in turn overlies a Lower Permian non-marine sequence (Evans & Hodgson, 1964). This bore ended in Ordovician slates.

Using the regional and residual gravity data as a guide, the existence of a fault is likely in the area just north of the position of the Duck Bay No. 1 bore. This fault can be suggested to run parallel to the Lake King/Bairnsdale Trend. It would explain the combined results obtained from geophysical work and from drilling (Plate 5).

Depths of 10 000 ft to the magnetic basement rocks are indicated in the Tabberabberan Depression (Plate 1), which strikes south through the eastern end of Lake Wellington (Quilty, loc. cit.). The deepest part of the Gippsland Basin onshore has been shown by magnetic contours to be to the south of Lake Wellington. In this particular area the Wellington Park No. 1 bore was drilled to a total depth of 12 000 feet and ended in Jurassic beds (Plates 8 and 9). Southeast of this bore magnetic data have indicated a depressed area with the -15 000 ft contour closing near the southeast-trending axis of a huge trough, recently tested by drilling.

Bores sunk in search for hydrocarbons on the continental shelf adjoining the onshore portion of the Gippsland Basin during the 1965-66 period (Table 2) intersected Tertiary and Upper Cretaceous deposits, including sandstone members of high porosity developed to considerable thickness (Esso Exploration, 1965; Hetherington, 1966). Reservoir beds intersected in several offshore bores contain natural gas with a high content of liquied hydrocarbons, including crude oil.

The trough magnetically indicated in the offshore area is bounded in the north by a possible fault, suggested from steep dip angles derived from the magnetic depth-to-basement data.

After the completion of the residual gravity compilation and after the contouring of the anomaly feature located in the Stockyard Hill area, it was noticed that the Stockyard Hill Trend was exactly in line with the magnetically established fault. For this reason it is not considered unlikely that both gravity and magnetic indications are related to the same geological feature. The western boundary of the Lake Wellington depression, mentioned above, is defined by a ridge in the magnetic basement rocks that appears to be a continuation of the Pretty Boy Tectonic Ridge, known from Ordovician outcrops west of the Mitchell River. According to the magnetic results this ridge extends south to the northwestern shore of Lake Wellington (Quilty loc. cit.). In the critical area the residual gravity anomaly map shows the Sale/Perry River Trend swinging north with several localized gravity 'highs' aligned parallel to the course of the Perry River. Also in this area the conclusion appears to be justified that both gravity and magnetic data are related to the same geological feature. Plate 1 shows the tectonic boundary of the Lakes Entrance Gravity High in relation to the depression magnetically determined in the offshore area, within the framework of the structural setting in the Palaeozoic outcrops north of the Gippsland Basin. The axis of the offshore trough is in line with that of the Carbo-Devonian deposits known as the Sandstone Belt of the Eastern Highlands.

In the southeastern portion of Plate 1 bathymetric contours are shown to illustrate the possible extension of the geological depression into a large submarine channel occurring in the continental shelf near the south-eastern corner of the Australian mainland.

8. CONCLUSIONS

The gravity survey results over a major portion of the basin have been evaluated by using 'residual' and 'regional' gravity reductions in addition to the 'measured' Bouguer anomalies normally used for geological interpretation.

The method of separating 'residual', that is smaller, gravity anomaly features caused by local structure, from 'regional' gravity variations, related to major geological units, includes the possibility of a gravity data evaluation, which is superior to the use of 'measured' Bouguer anomaly values.

Trends in the residual gravity anomaly contours are more suitable for locating the position of faults and their possible extension into critical areas. Closed gravity anomalies, caused by smaller structure, can be more accurately delineated after the effect of the regional gravity gradient has been removed.

The programming of the computing methods used in any particular area for residual gravity determination is to be adjusted to the expected size of the individual structural feature.

In the area of the Gippsland Basin, the averaging of regional gravity values was carried out - for the purpose of this Report - on the circumference of a circle having a radius of 1.5 miles. The magnitude of this radius was empirically determined as being the most suitable for the elucidation of major faults in the Gippsland Basin. Smaller structure, such as local doming, would require a much smaller radius of the reference circle for residual gravity determination.

The application of residual gravity reductions is more important near the fringes of geological basins, where gravity gradients are steepest.

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APPENDIX A

GRAVITY METERS USED IN GIPPSLAND DURING 1948-61

1. Western gravity meter No. 29

Calibration factor: -0.09 mGal per scale division, metal-spring measuring system, thermostat controlled heating device including 6-volt batteries; weight excluding batteries approximately 30 pounds.

2. Heiland gravity meter No. 53

Calibration factor: +0.0889 mGal/scale division (24 Jan. 1954)

: +0.0874 mGal/scale division (6 Jan. 1955)

Design and weight similar to Western meter.

Performance of metal-spring gravity meter

Western and Heiland meters are relatively heavy, requiring car transport. The behaviour of the metal-spring type instruments was not always satisfactory. Irregular drift rates occurred with the instrument during the initial stages of field use following long periods in store. The instruments were sensitive to mechanical shocks such as those experienced when travelling on rough portions of road. 'Jumps' in the readings occurred at unforeseeable intervals.

Rigid temperature control was obtained by recharging heating batteries daily, in order to minimize drift rates. The performance of the meters improved when constantly protected under a cover of woollen blankets.

3. Atlas gravity meter No. F21

Quartz-spring movement; Calibration factor: 0.1090 mGal/scale division in January, 1953 and 0.1118 mGal/scale division in January, 1956.

4. Worden gravity meter No. 61

Quartz-spring movement; Calibration factor: 0.0756 mGal/scale division in January 1952; 0.08909 mGal/scale division in June 1955, and 0.08898 mGal/scale division in January 1957.

Note:

The instrument was sent to the manufacturers for range adjustment during 1955.

5. Worden gravity meter No. 169

Quartz-spring movement; Calibration factor: 0.10366 mGal/scale division in August 1954; 0.10365 mGal/scale division in August 1956.

6. Worden gravity meter No. 140

Quartz-spring movement; Calibration factor; 0.11126 mGal/scale division in January 1959.

Performance:

Atlas and Worden instruments contain temperature-compensated systems composed of quartz springs. The continuous upward drift in the readings caused these meters to move out of reading range after a period of 20 to 30 months. The continuous drift-rate has been greatly reduced in more recent gravity meters.

The movement of a quartz-spring meter is mounted inside a partly evacuated chamber. It was found necessary to maintain this vacuum for the correct functioning of the instruments during the course of field readings. Atlas and Worden meters were evacuated at BMR's Footscray Geophysical Laboratories every time before longer field trips.

A modern gravity meter is capable of indicating variations in the gravity field of the Earth accurately to one part in one hundred million of the total gravitational force.

APPENDIX B

TOPOGRAPHIC DATA

MAPS USED

1. Warragul, J 55/10-11, Zone 7; 4-mile scale Series, Australia 1:253 440

2. Stratford. 7/853. 1-mile scale map compiled by the Dept of Lands and Survey, Melbourne 1:63 360

3. Alberton. 1-mile scale map issued by the Dept of Lands and Survey, Melbourne, August 1936; 1:63 360

4. 1 mile Military Maps, Australia Series, Zone 7; 1:63 360

Bairnsdale	7/854	Carrajung	7/871
Moe	7/861	Stradbroke	7/872
Rosedale	7/862	Foster	7/876
Sale	7/863	Alberton	7/877
Stockyard	7/864	Yanakie	7/881
Mirboo North	7/870		

5. Property Maps

½ mile to 1 inch scale sheets, issued by the Dept of Lands and Survey, Melbourne (Vic.) 1:31 680

Tambo	Tinamba
Glenmaggie	Bundalaguah
Wuk Wuk	Wy Yung
Glenaladale	Maffra
Sarsfield	Wa-de-Lock

6. Snake and Sunday Islands

Geological Parish Plan of 1 mile to 1 inch scale, issued by the Geological Survey of Victoria; other maps of the Parish Plans Series consulted, where required.

7. Geological Map of Victoria, 1964

Scale 1:1000 000, issued by the Geological Survey of Victoria

8. Miscellaneous Topographical Maps

Series 90, Herries Oak South Sheets No. 1 to 6

Compiled 1954 by the Victorian Dept. of Crown Lands and Surveys, 400 feet to 1 inch scale; topographic contours shown in 10 feet intervals.

TOPOGRAPHIC SURVEYS

Detailed Surveys of potential structure in the coal measures

Gravity station plans were prepared by the Topographic Drawing Office, Brown Coal Investigation Branch, State Electricity Commission of Victoria, at Morwell and Traralgon. The gravity station plans were drawn on various scales, ranging from 200 ft to 1 inch to 2000 ft to 1 inch. Size and scale of gravity stations plans were chosen to be suitable for the specific aim of the individual gravity survey.

Fieldwork performed by the S.E.C.'s surveying parties involved the following single operations:

1. Selection of station site
2. Marking of gravity station with survey pegs and indicators
3. Fixation of station position on gravity station plan,
4. Levelling of station spot height.

The topographic work conducted by the S.E.C.'s Brown Coal Investigation Branch was supervised by Mr L.C. Heron.

The S.E.C.'s topographic surveys are controlled by triangulation and traversing, based on the First Order Triangulation Station, Mt Hooghly, using the No. 7 Zone transverse Mercator co-ordinates for this point.

The reference datum for the S.E.C.'s levels is the Victoria Railways Datum, which is identical with Low Water Mean - WILLIAMSTOWN and HOBSON BAY.

Mean Sea Level (MSL) is 1.85 ft above Low Water Mean - WILLIAMSTOWN.

Private Survey

In the area of the 1955 Corner Inlet gravity survey a gravity station plan of one-mile to one-inch scale was prepared after field surveys by the Licensed Surveyer, Mr C.A. Heron. This work was carried out on behalf of the lease holding Company, the Woodside (Lakes Entrance) Oil Company, N.L., of Melbourne.

Semi-regional surveys

Gravity station sites occupied for the purpose of semi-regional surveys were spaced out at intervals ranging from half a mile to one mile. Topographic field parties were supplied as follows by:

1. Commonwealth National Mapping Division during the 1951-52 period,

2. Dept of the Interior, Property and Survey Branch during the 1952-53 period.

Topographic field parties selected suitable gravity station sites on highways and passable roads according to the instructions issued by the Geophysical Section of the Bureau of Mineral Resources.

Station positions were marked on the ground by survey pegs. Station numbers were painted on nearby trees, fence poles etc. Station heights were determined by levelling; the position of the stations was shown on topographic maps and station descriptions were prepared for use by the gravity party leader.

Topographic ties were made to permanent survey marks available from various sources, including the Victorian Railways, Country Roads Board, State Rivers & Water Supply Commission, and State Electricity Commission of Victoria.

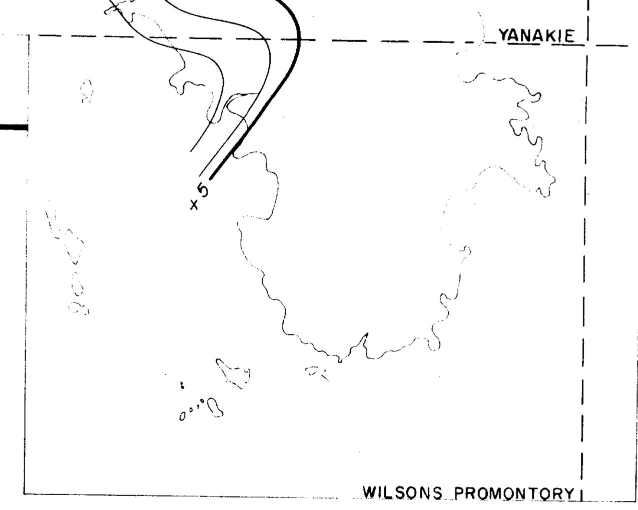
The reference datum for levelling the gravity station heights was identical with the Victorian Railways Datum.

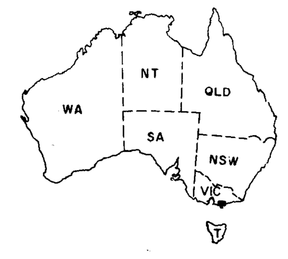
PLATE I

J55/B2-88

PLATE 2

(BASED ON J55/B0-16)





INDEX

MELBOURNE	WARBURTON	BAIRNSDALE
QUEENSCLIFF	WARRAGUL	

Projection: Transverse Mercator, Australia Series, Zone 7

Control and detail after Royal Australian Survey Corps 4-mile strategic series map of the same name.
Gravity data from detailed and semi-detailed surveys

GIPPSLAND, VIC.

BOUGUER ANOMALIES

4 0 4 8 12 MILES 16

10 0 10 20 KILOMETRES 30

Contour interval 1 milligal

TOPOGRAPHY

- Built-up area
- Homestead
- Railway
- MOE — 1" to 1 mile map area
- Principal road
- Minor road
- Track

GRAVITY

- Isogals
- 'High' anomaly
- 'Low' anomaly

Gravity anomaly contours shown are based on relative Bouguer anomaly values referred to an arbitrary datum.
To convert to International values (density = 2·67) subtract from values shown, (9·13+0·01 x h) milligals where 'h' is the station altitude in feet above Sea Level.

For the calculation of Bouguer anomalies 1·9 g/cm^3 has been adopted as an average rock density.

Geophysical field data from BMR and Robert H. Ray Co surveys (1948-1961)

Elevation control by State Electricity Commission of Victoria and Department of the Interior levelling.

Department of National Development
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
Compiled and drawn in Geophysical Branch.

Rec. No. 1974/160

J55/B2-10-1

REGIONAL BOUGUER ANOMALIES

AUSTRALIA 1:253,440

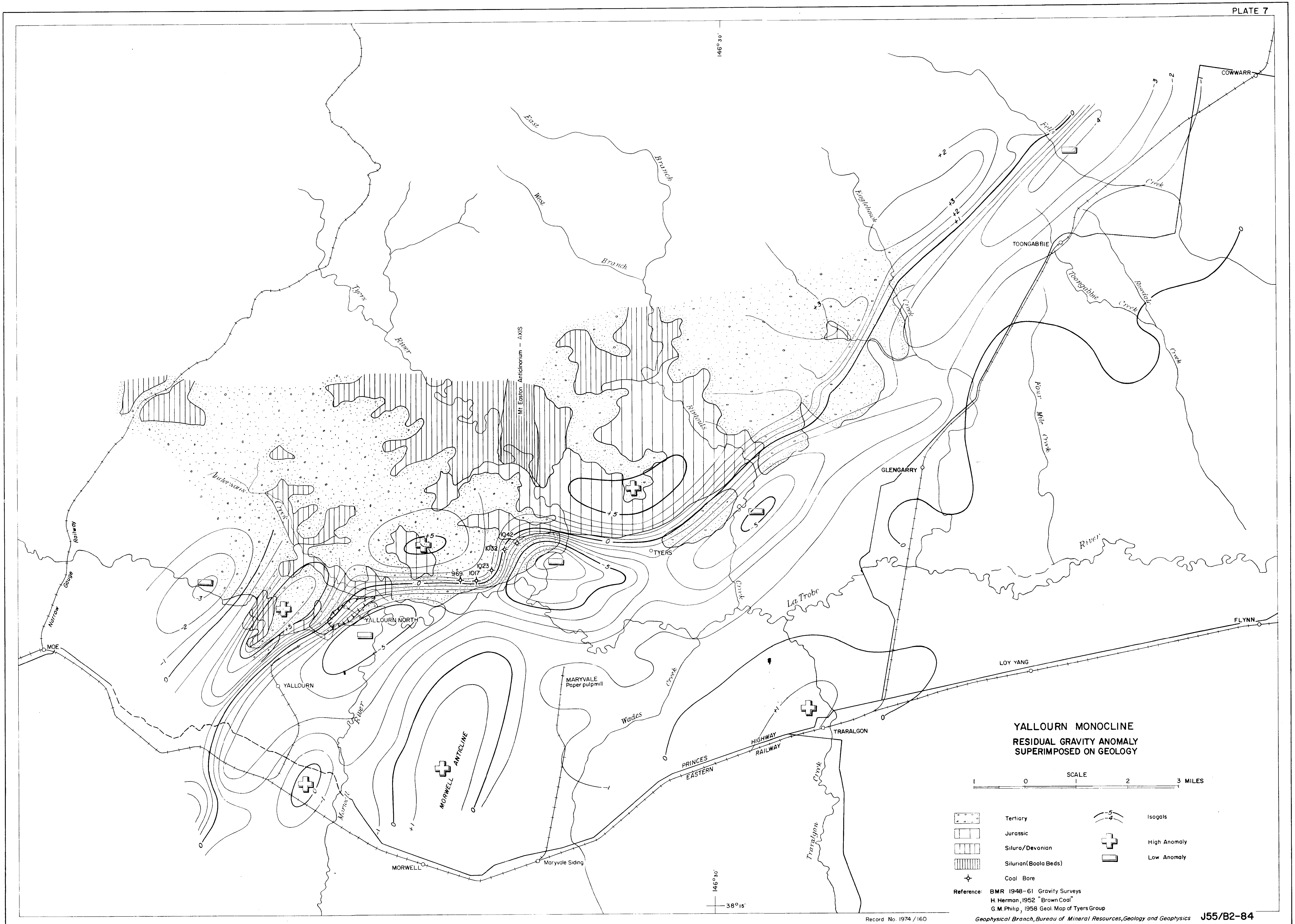
PLATE 4

Record No. 1974/160


BMR GRAVITY SURVEYS – GIPPSLAND BASIN VICTORIA 1948-61
GEOLOGY
LEGEND
Recent
Tertiary
Jurassic
Carbo-Devonian
Lower Devonian
Silurian
Upper/Middle Ordovician
Older and Younger Volcanics
Granite
Bore (TD = Total Depth)
Gas Bore
Fault
MILES 4 3 2 1 0 4 8 12 MILES
BASS STRAIT
CORNER INLET
WARATAH BAY
WILSONS PROMONTORY
SOUTH EAST PEAK 1247 FT
CAPE LIPTRAP
SEAL OR DIRECTION ISLANDS
LAKES ENTRANCE OILFIELD
LAKE KING
LAKE VICTORIA
LAKE WELLINGTON
NINETY MILE BEACH
MITCHELL RIVER FAULT
PRINCES HIGHWAY
WALHALLA SYNCLINE
MOUNT EASTON
GLENMAGGIE RESERVOIR
ROSEDALE FAULT
ROSEDALE MONOCLINE
ROSEDALE TROUGH
YALLOURN MONOCLINE
TARRAGON FAULT
HILL FAULT
HEATH FAULT
KONGWAK FAULT
TARWIN FAULT
FISH CREEK FAULT
DINGO CREEK FAULT
TOORA FAULT
WARATAH FAULT
OLMBURRIM FAULT
BOOLARRA FAULT
BENNETTS CREEK FAULT
YARRAM MONOCLINE
WON WRON MONOCLINE
CARRAJUNG MONOCLINE
GELLIONDALE MONOCLINE
DARRIMAN FAULT
CROSS SECTION A-A'
CROSS SECTION B-B'
CROSS SECTION C-C'
Bairnsdale
Briagalong
Seaton
Walhalla
Maffra
Stratford
Heyfield
Cowwarr
Toongabbie
Glengarry
Sale
Longford
Rosedale
Moe
Yallourn Nth
Warragul
Childers
Strzelecki
Hazelwood
Yinnar
Boolarra
Korumburra
Leongatha
Mirboo North
Gormandale
Carrajung
Balook
Won Wron
Woodside
Yarram
Alberton
Port Albert
Foster
Wonthaggi
Inverloch
ANDERSONS INLET
Seaspray
South-west Bairnsdale No 1 TD 3919 ft (granite)
Duck Bay No 1 TD 4238 ft (Ordovician slate)
Hollands Landing TD 4004 ft (Cretaceous)
Wellington Park No 1 TD 12001 ft (Jurassic)
Rosedale No 1 TD 5836 ft (Jurassic)
Wurruk Wurruk TD 3214 ft
Boola Boola Oil Bore TD 1830 ft
A.P.M. Bore TD 1715 ft
South Longford No 1 TD 2450 ft
Bellbird No 1 TD 2500 ft
Golden Beach West No 1 TD 7512 ft
North Seaspray TD 5000 ft No 1 TD 5368 ft No 2
Carr's Creek No 1 TD 5507 ft
Lake Reeve No 1 TD 6635 ft
Merriman No 1 TD 6005 ft
Darriman No 1 TD 4730 ft
Esso-Gippsland Shelf No 1 TD 8701 ft
Esso-Gippsland Shelf No 2 TD 4015 ft
Esso-Gippsland Shelf No 3 TD 9540 ft
Woodside South No 1 TD 5816 ft
Woodside No 1 TD 6008 ft
Woodside No 2 TD 8862 ft
Woodside No 3 TD 5985 ft
Margaret Island No 1 TD 4664 ft
Sunday Island No 1 TD 6000 ft
Tarwin Meadows No 1 TD 3945 ft
BAIRNSDALE
STOCKYARD
STRADBROKE
CARRAJUNG
ALBERTON
FOSTER
LIPTRAP
YANAKIE
WONTHAGGI
KORUMBURRA
GLENMAGGIE
WALHALLA
STRATFORD
SALE
ROSEDALE
MOE
146° 00'
147° 00'
148° 00'
145° 30'
37° 45'
38° 00'
39° 00'

AUSTRALIA 1:253,440

PLATE 6



Record No. 1974/160

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

J55/B2-84

DIAGRAMMATIC CROSS-SECTION A-A'

BOOLA BOOLA OIL BORE TO LAKES ENTRANCE

GIPPSLAND BASIN, Victoria

HORIZONTAL SCALE 4 3 2 1 0 4 8 12 MILES
VERTICAL SCALES AS SHOWN

Record No. 1974/160

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics J55/B2-91

DIAGRAMMATIC CROSS-SECTION B-B'

ESSO GIPPSLAND SHELF Nº1 TO LAKES ENTRANCE

GIPPSLAND BASIN, Victoria

SCALE

HORIZONTAL 4 3 2 1 0 4 8 12 MILES

VERTICAL SCALES: AS SHOWN

CROSS-SECTION C-C' FROM TYERS COALFIELD TO DARRIMAN Nº I BORE
GIPPSLAND, VICTORIA

CORRELATION OF GRAVITY, GEOLOGY AND TOPOGRAPHY

½ 0 ½ 1 ½ MILES 2

VERTICAL SCALES AS SHOWN

Record No. 1974/160 GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS J55/B2-32