COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1965/64

GRAVITY SURVEYS OF PORT PHILLIP BAY AND ADJACENT AREAS, VICTORIA 1957-1958

by

S. GUNSON and L.W. WILLIAMS

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SUMMARY

The Bureau of Mineral Resources made an underwater gravity survey of Port Phillip Bay in 1957 and a gravity survey of Mornington Peninsula in 1958. The combined results of these surveys show that the area is structurally more complex than was previously supposed. The main feature to be outlined by the Bouguer anomaly contours is a down-thrust block in the south-western part of the Bay. It is bounded on the north, east, and west by faults, but its southern limit was not determined. Further surveys are recommended to the south and west of Port Phillip Bay.

1. INTRODUCTION

The gravity surveys described in this Record were made by the Bureau of Mineral Resources as regional surveys. The field work was divided into two parts: an underwater gravity survey of Port Phillip Bay, and a gravity survey of Mornington Peninsula. In addition to the results of these surveys, information gathered during previous surveys of adjoining areas has been used in the compilation of the gravity anomaly contour map.

The underwater survey commenced on 18th June 1957 and was completed on 16th December 1957. A remote-controlled gravity meter, model UW-2R, manufactured by North American Geophysical Co. was used from a boat (auxiliary ketch 'Commissioner'), which was chartered for the duration of the survey. The crew of the boat consisted of one or two geophysicists and a field assistant to operate the gravity meter equipment, and a master, engineer, and one seaman to handle the boat.

The survey of the Mornington Peninsula was made between 19th February and 17th March 1958 by one geophysicist, who used a Worden gravity meter and a vehicle-mounted elevation meter, model 204, manufactured by Western Geophysical Co.

This Record supersedes the preliminary report on the survey by Gunson, Williams, and Dooley (1959).

2. GEOLOGY AND DESCRIPTION OF THE AREA

Mornington Peninsula

Physiography. Mornington Peninsula is the name given to the projection of land that separates Port Phillip Bay and Western Port Bay. It is roughly rectangular and is about thirty miles long and ten miles wide. From its most westerly part, a point of land, which is covered mainly by low sand dunes, extends to the north-west to form Point Nepean. The Peninsula consists of low hills along its length and some low land on the eastern side.

Geology. Hills (1946) describes the high land of the Peninsula as a horst bounded on the west by the Selwyn Fault and on the east by the Tyabb Fault. Plate 1 shows the geological structure of the area.

Port Phillip Bay

Physiography. Port Phillip Bay is an irregularly shaped, almost land-locked body of water. The foreshore is generally low-lying except for the Mornington Peninsula and the Bellarine Peninsula.

Port Phillip Heads, which stand on either side of the opening to the sea, comprise Point Nepean on the east and Point Lonsdale on the west. The entrance to the Bay is two miles wide and has a very irregular bottom, which gives rise to tidal rips and eddies.

Most of the Bay has water depths in the range five to thirteen fathoms, but there are large banks of mud and sand with only a few feet of water over them, in the southwestern part of the Bay.

The change of water level in response to tides is about two feet at Williamstown and between four and five feet at Port Phillip Heads.

Geology. Plate 1 shows the geological structure of the areas surrounding Port Phillip Bay.

Hills (1946, p.160) describes the Bay as part of the Port Phillip Sunkland, which is bounded on the west by the Lovely Banks Monocline and the Rowsley Fault, and on the east by the Selwyn Fault, which is considered to be a 'shatter belt' of many small faults, rather than a single fault plane.

The majority of the area surrounding the Bay is covered by Recent, Pleistocene, and Tertiary sediments, and large areas of Newer and Older Basalts. Granite is known in the You Yangs, at Arthurs Seat, and north-east from Dandenong. Outcrops of Silurian and Ordovician sediments occur on the Mornington Peninsula.

3. EQUIPMENT

The equipment used on the Mornington Peninsula survey was a Worden gravity meter No. 260 and a Western elevation meter No. 204.

Both these instruments are well known and will not be described here. The remainder of this section will be devoted to a description of the marine gravity meter and its associated equipment.

The gravity meter

This is a normal land meter that has been modified so that the position of the beam and the tilt of the meter can be detected electrically, as well as optically. The external controls (clamp, reset, and reading dial) can be operated electrically through a motor panel that is fitted on top of the meter and enclosed with it in a watertight bell. The bell is mounted in gimbal rings that are attached to a rigid circular base; its attitude is controlled by two electric motors, which respond to signals that originate from the level detectors on the meter. All the control and power supply circuits enter the bell from a neoprene-covered cable through a watertight connector. The other end of this cable is attached to the control unit on the boat.

The control unit

This consists of four units, all mounted in one rack. The units and their functions are as follows:

The power supply. This unit distributes the electric power for all the measuring and controlling circuits. It operates from a 115-volt, 60-c/s supply when the meter is operating, but has a 'standby' supply for periods when the meter is temporarily not in use, e.g. overnight. The 'standby' supply is a 12-volt battery and vibrator, which supply power only to the gravity meter heaters. There is provision for this supply to operate the clamp circuit in an emergency, for example, when failure of the 115-volt supply occurs while the meter is unclamped.

The level amplifier units. These are a set of two amplifiers which amplify the error signals received from the level detectors on the gravity meter and apply the output to the levelling motors.

Gravity/depth amplifier. This is an amplifier which either amplifies the signals that show the position of the beam of the gravity meter, or amplifies the signal from the depth-measuring device. It can perform only one of these functions at a time. The amplified signals are applied to indicators on the operating console.

The operating console. This is the panel from which all the operating of the meter is done. It has controls for all functions of the meter and is equipped with indicators and meters to show whether the gravity meter is level, clamped or unclamped, set on the null point, and at its correct temperature. The cycling of the heating circuits can be checked by observing the changes of heater current.

The console is equipped with a reading dial of the same type as that on the gravity meter. The dial on the console controls that on the meter through a selsyn motor system.

The depth-measuring device has a null indicator and a reading dial that is read in the same way as the gravity dial.

Power Generator

The power requirements for all this equipment, when used on a boat, are supplied by a 1500-watt, 115-volt, 60-c/s supply generator that is driven by a petrol engine.

Hoist and power unit

The bell with the gravity meter sealed inside is lowered from the boat to the sea bottom on the end of a stranded steel wire cable, the other end of which is attached to a hydraulic winch. A two-cylinder petrol engine drives the hydraulic pump, which supplies oil under pressure to the winch. The cable from the winch is led through a shock-absorbing system, over a jib, and is then attached to the bell. There is a mechanical arrangement to prevent the bell hitting the side of the boat during lowering and raising.

The boat

The boat used in this survey was the auxiliary ketch 'Commissioner', chartered with a crew of three. It was a single-screw vessel, having a length of 85 ft, a beam of 18 ft, a draught of $8\frac{1}{2}$ ft, and a maximum speed (for surveying duties) of eight knots. It had accommodation for six people. A boat of this size is not essential and in fact, on Port Phillip Bay, a boat drawing less water would have been desirable. The requirements of space for the gravity equipment are: a clean deck space of 10 ft x 4 ft for the hoisting winch, a sheltered and well ventilated space for the generator and hydraulic pump, and a sheltered space (from which the winch can be seen) for the control unit.

On the 'Commissioner', the winch was mounted over the forward hold, the generator and pump were fixed in the hold below the winch, and the control unit was installed in the wheelhouse.

Surveying equipment

The boat was equipped with two magnetic compasses, one in the wheelhouse for steering and the other on the after deck as a 'standard' compass. These compasses were used only to bring the boat to an approximate position where a reading was required. The actual position of the reading was found and plotted using a horizontal sextant and a station pointer. The horizontal sextant was used to measure the two included angles subtended at the boat by three known landmarks. These angles were then set between the three arms of the station pointer, the station pointer placed on a chart so that the arms passed through the positions of the known landmarks, and the position of the boat plotted at the intersection of the arms. The horizontal sextant had a micrometer dial that could be read to one minute of arc; the verniers on the station pointer also read to one minute of arc.

4. DELAYS

A considerable amount of survey time was lost during the course of the underwater gravity survey for various reasons.

Instrument breakdowns

The only serious trouble with the equipment was the continual breaking of the mainspring suspension loops of the gravity meter. Very little effective work was done during the first three months because of this trouble. The cause was eventually found to be an auxiliary engine mounted on the deck. This engine set up vibrations of the same frequency as the natural frequency of the mainspring system, and the loops failed apparently by fatigue. The trouble was overcome by shock-mounting the hoist and replacing the engine by one that ran at a different speed.

Unfavourable weather

Two types of unfavourable weather were encountered, both of which caused delays.

Rough conditions. In rough conditions it was not advisable to put the bell down because of risk of damage to the gravity meter. When the boat was rolling or pitching heavily, there was the danger that the bell would hit the bottom with sufficient force to damage the meter. There was also the danger that the anchor might drag while the bell was on the bottom and cause the bell also to drag.

Bad visibility. On calm days when conditions were otherwise perfect for operating, there was sometimes fog. This prevented the use of the sextant, and the location of the boat could not be determined. No work was possible until the fog disappeared.

On this survey, about 25% of the time for which the equipment was working satisfactorily was lost owing to unfavourable weather.

Installation and removal of equipment

Although it cannot be strictly regarded as a delay, it is of interest to note the time taken for the installation of the equipment on the boat, and its removal at the end of the survey. One week was required for the initial installation of the equipment on the boat. Later, approximately six days were spent in installing different anchor winch gear. Three days were required to remove the equipment from the boat.

5. FIELD WORK AND REDUCTION OF RESULTS

Mornington Peninsula

A network of 117 stations was laid out along roads and railway lines, the stations being at approximately two-mile intervals.

The gravity values were carried from points of known value and are based on a value of 979,979.0 milligals at the National Gravity Base at Footscray.

Victorian Railway levels were available for the gravity stations that were located at railway stations; these levels were also used as controls for the elevation meter survey along roads. The levels were adjusted to make them relative to mean sea level.

Standard methods were used to calculate free-air and Bouguer anomalies for each station. A density of 2.67 g/cm^3 was used in the reduction.

Port Phillip Bay

It was found that a sufficiently good check could be kept on the drift of the underwater gravity meter by measuring at a base station only at the beginning and end of a day's work. As it was desirable to moor the boat to a jetty at night, and in order to save the necessity of travelling long distances back to one base station, base stations were established at six jetties situated conveniently round the Bay.

The first reading on any day was at a base station at a jetty. The boat then proceeded to the position of the next sea-station and dropped anchor. After the boat had taken up a steady riding position under the influence of wind and tide, the bell was lowered to the bottom and sufficient slack cable was run out to ensure that the bell would not be affected by the motion of the boat. The operator at the console then turned on the level motors, waited until the instrument was level, then unclamped the gravity meter, and took a gravity reading. The meter was then clamped, a depth reading taken, and the bell brought back to the surface. Another depth reading was then taken to check zero drift and the bell was lifted again into its travelling position.

While the boat was still at anchor, its position was determined with the horizontal sextant and station pointer.

The total time the boat was at a station was generally between 20 and 25 minutes.

After completion of a day's readings along a traverse the boat proceeded to the most convenient base station for the final reading of the day.

A total of 115 stations, generally at two-mile intervals, were established during the survey.

In the reduction of the results, the first thing to be determined was the drift of the meter. To do this, the two base readings were corrected for the difference between mean sea level and sea level at the times of observation, and the remaining drift was assumed to be linear over the period between readings. On this linear drift was superimposed the theoretical gravity effect of the sun and moon. The resulting drift curve was used to correct the observations at the other stations.

For the free-air anomaly, the observed value was reduced to mean sea level in free air (0.09406 mgal/foot) and a correction made for the effect of the water. This correction is twice the gravity effect of an infinite layer of water of density 1.03 g/cm^3 and thickness equal to the measured depth. Calculation showed that the error introduced by using the actual depth of water above a gravity station, instead of depth below mean sea level, was insignificant because of the small rise and fall of tide in Port Phillip Bay.

The Bouguer anomaly was calculated by allowing for the difference in gravitational effect between a layer of sea water (1.03 g/cm^3) and a layer of rock (2.67 g/cm^3) of thickness equal to the measured depth of water.

6. INTERPRETATION

The results of the survey are presented in the form of a Bouguer anomaly contour map (Plate 2).

A striking feature of the map is the area of negative Bouguer anomaly in the south-western part of the Bay. It is bounded on three sides by gravity gradients that are interpreted as faults. The fault on the western side of this area strikes N30°E along the edge of the Bellarine Peninsula. It corresponds to the Bellarine Fault (David, 1950, p.570), but its direction is a little more northerly and it does not persist across the Bay to join the Beaumaris Monocline. The southern limit of the fault is not shown by the gravity survey, but to the north it finishes abruptly against another fault that strikes N50°W. This second fault marks the northern boundary of the area of negative anomaly. This fault possibly extends to the northwest but the gravity information over its probable course is rather sparse. To the south-east, the fault can be traced to the eastern shores of the Bay at Schnapper Point. Here it meets the fault on the eastern side of the gravity 'low'. This fault strikes

N30°E and is evidently the well-known Selwyn Fault (David, 1950, p.570). The gravity indications of the fault do not extend to the north as far as the fault is usually mapped; its extension to the south is uncertain, but additional gravity surveying in the Cape Schank area would probably resolve it.

The three faults just described enclose three sides of an area of negative gravity anomaly. This is evidently a down-faulted block. The gravity survey did not disclose the southern end of the block, which is outside Port Phillip Bay, but the anomaly seems as though it is becoming less negative seaward from Point Nepean.

The gravity map shows an area of positive gravity anomaly over the Mornington Peninsula. It is considered that these high values arise from the presence of Older Basalt, which is exposed in places, notably in the south, but it may exist under a Tertiary cover in other places. The Peninsula is bounded on the west by the Selwyn Fault. Its eastern boundary is not defined precisely by the gravity results, but there seems to be some effect from the Tyabb Fault.

A closed gravity 'high' occurs four miles north-east of Portarlington on the western side of Port Phillip Bay at the entrance to Corio Bay. It is considered to be due to the presence of underlying basalt, which is probably the Older Basalt, but this cannot be decided on the gravity evidence alone.

Further west and on the southern side of Corio Bay there is a gravity gradient suggestive of a fault that strikes N70°W for a distance of about seven miles; on the west, the gradient veers to the north and becomes less steep, and on the east, it merges into the gradient associated with the Bellarine Fault. This gradient does not correspond to any known geological fault and is indeed at variance with the Barrabool and Curlewis Faults, which generally follow the southern shore of Corio Bay (Hills, 1946, p.161). A further and perhaps more striking departure of the gravity evidence from the geological is that the former suggests a fault down-thrown on the south side while the latter would make the fault down-thrown to the north.

? could it be southern edge of basalt.

The only remaining features to be described are the two gravity trends, one in the north centre of Port Phillip Bay and the other in the north east, which join in the centre of the Bay. These two seem to represent the old courses of the Yarra River and the Dandenong Creek (Hills, 1946, p.220). As mentioned earlier, the Beaumaris Monocline cannot, on the gravity evidence, be considered an extension of the Bellarine Fault, but is apparently the south-eastern flank of a dome or nosing feature that plunges to the southwest between the old courses of the Yarra River and the Dandenong Creek.

7. CONCLUSIONS

The use of the underwater gravity meter was established as an exploration instrument.

The results of the present survey point to the following conclusions:

1. The Selwyn Fault, as detected by gravity, coincides with the geological postulate except that the gravity results suggest a slight curtailment of its extension to the north.

2. The Bellarine Fault is shown to have a more northerly strike and not to continue across the Bay to join the Beaumaris Monocline, as previously supposed.

3. A new fault has been detected in the centre of the Bay. This fault marks the northern end of a down-faulted block in the south of the Bay. The fault extends across the Bay from Schnapper Point in the east and is well marked until it reaches the Bellarine Fault. The effect is then modified by other features but it almost certainly extends past the north-western shores of the Bay.

4. A downthrust block has been outlined in the south-western part of the Bay. Its southern limit is not known but it is bounded on the east, west, and north by the faults described in 1, 2, and 3.

5. The presence of a mass of basalt beneath the Bay, between the Bellarine Peninsula and Werribee River, is indicated.

6. The Beaumaris Monocline exists as the south-eastern flank of an anticline that pitches south-west.

7. The presence on Mornington Peninsula of basalt under a Tertiary sedimentary cover is indicated by the positive anomalies on the Peninsula.

8. The Tyabb Fault is only weakly indicated and it is believed therefore to have only a small throw.

9. The old courses of the Yarra River and Dandenong Creek over what is now Port Phillip Bay can be determined from the gravity map.

10. The gravity anomalies in the western part of Corio Bay do not support the present geological postulates as regards faulting in the area.

8. RECOMMENDATIONS

It is recommended that additional gravity surveying be done in the following areas:

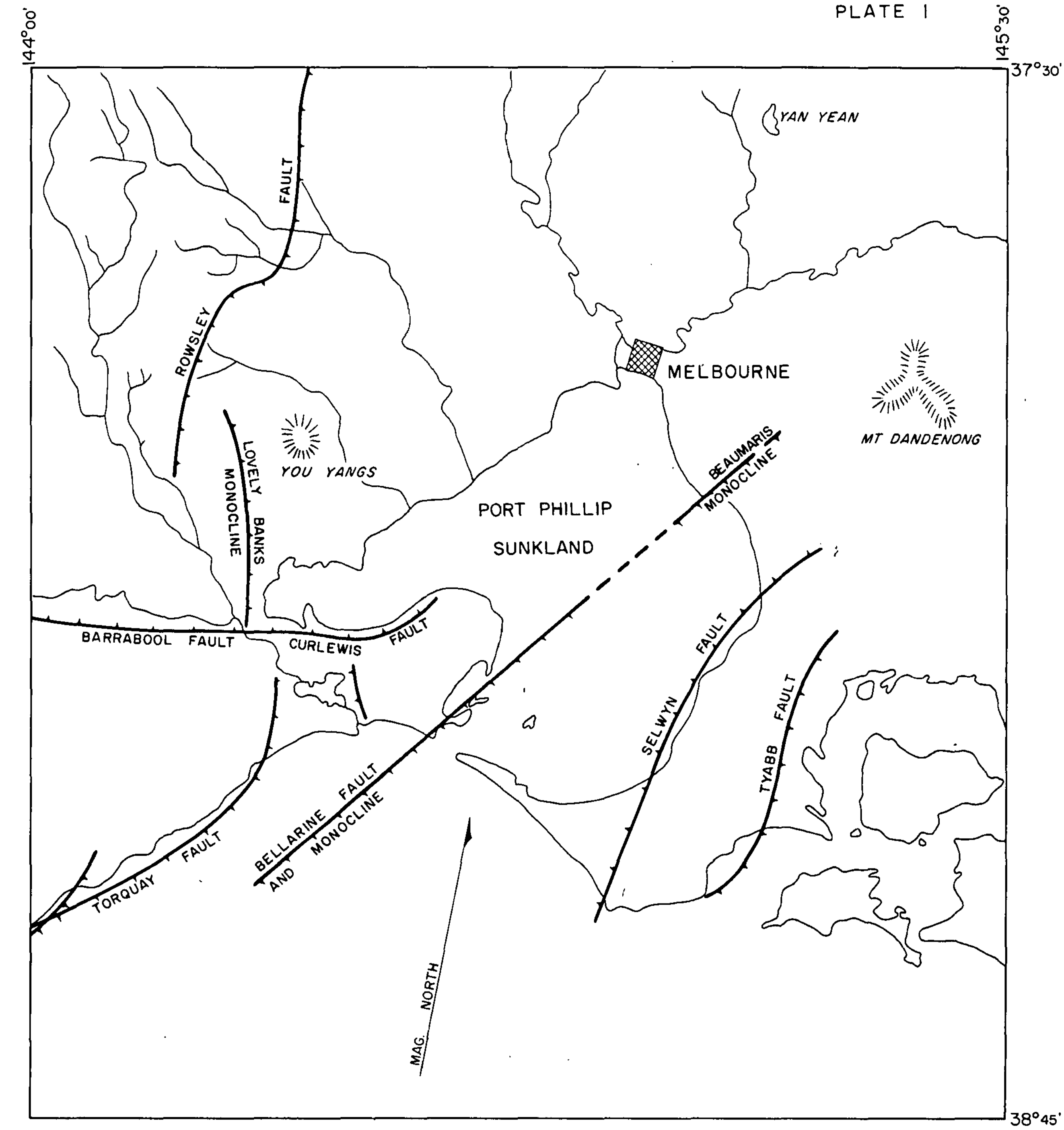
(a) Cape Schank.

(b) The hinterland of Port Phillip Bay between Melbourne and Geelong.

(c) South-west and east of Geelong.

9. REFERENCES

DAVID, T.W.E.	1950	THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA, Vol.1. London, Edward Arnold.
GUNSON, S., WILLIAMS, L.W., and DOOLEY, J.C.	1959	Preliminary report on gravity survey of Port Phillip Bay and adjacent areas. Bur. Min. Resour. Aust. Rec. 1959/34.
HILLS, E.S.	1946	THE PHYSIOGRAPHY OF VICTORIA, 2nd Ed. Melbourne, Whitcombe & Tombs.



GEOLOGICAL STRUCTURE OF THE PORT PHILLIP BAY AREA

SCALE

MILES 16 0 16 32 MILES

Geology from Hills (1946, p.161) & David (1950, p.570)

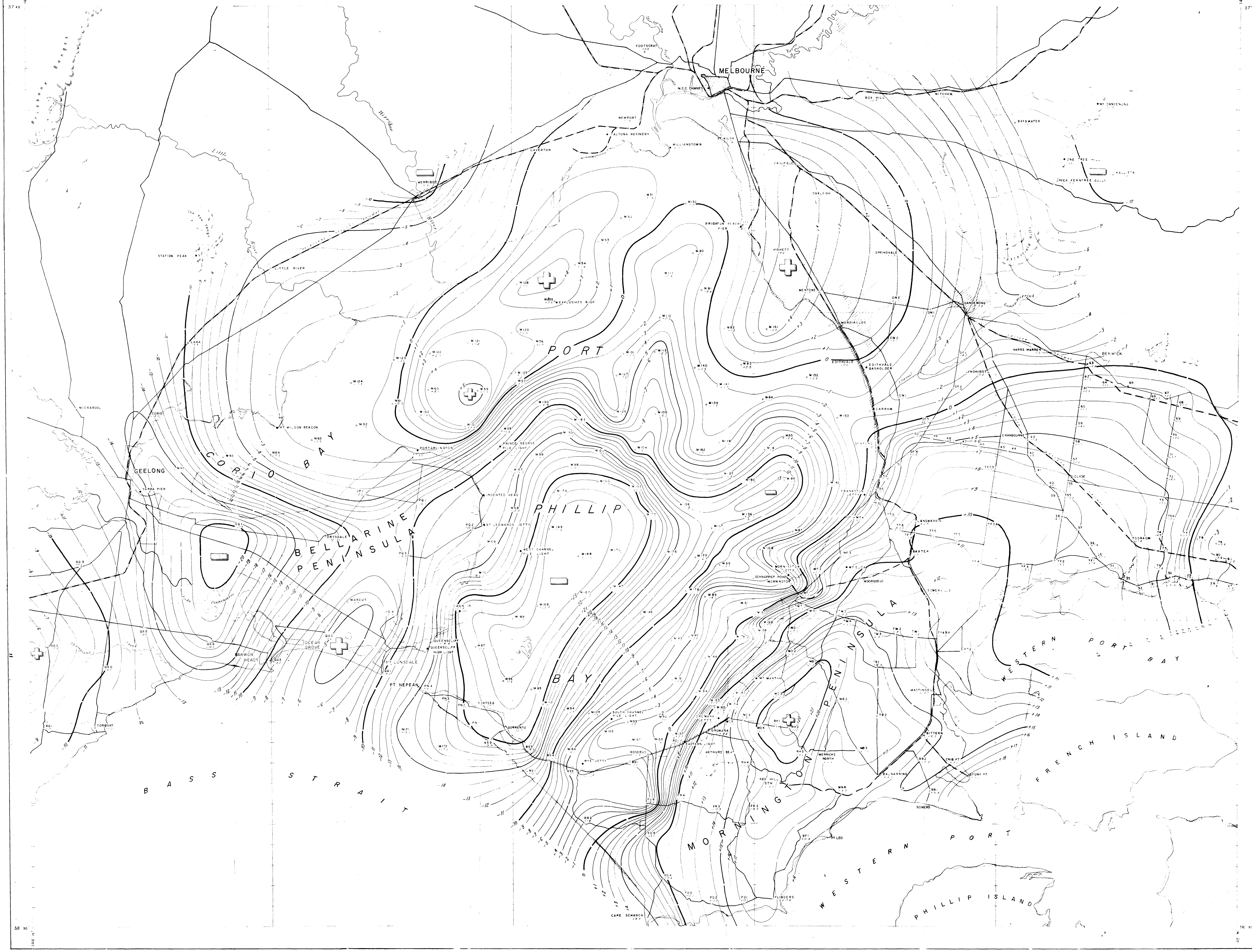
AUSTRALIA 1:126,720

PORT PHILLIP BAY (SPECIAL)

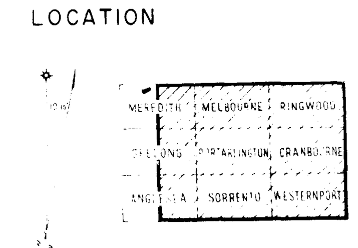
VICTORIA

PLATE 2

J 55/5,9, ZONE 7



LOCATION



REFERENCE TO AUSTRALIAN NATIONAL 1 MILE MAP SERIES

MAP DATA

PROJECTION: TRANSVERSE MERCATOR, AUSTRALIA SERIES

CONTROL: AUSTRALIA 1:63,360 MILITARY MAPS AND B M R SHORAN MEASUREMENTS

DETAIL: BASE GRID, GRATICULE AND POSITION CONTROL STATIONS IN PORT PHILLIP BAY AREA COMPUTED AND COMPILED BY THE GEOPHYSICAL DRAWING OFFICE, B M R
PLANIMETRY FROM 1:63,360 MILITARY MAPS
GEOPHYSICAL DATA FROM B M R UNDERWATER AND SURFACE GRAVITY SURVEYS.

RELIABILITY: PLANIMETRIC – ACCURATE
GEOPHYSICAL – REGIONAL TO SEMI-DETAILED GRAVITY

REGIONAL GRAVITY SURVEY (1957)

PORT PHILLIP BAY – MORNINGTON PENINSULA, VIC.

BOUGUER ANOMALIES

SCALE IN MILES

2 0 2 4 6 8

CONTOUR INTERVAL 1 MILLIGAL

LEGEND

TOPOGRAPHY

ROAD

RAILWAY

WATERCOURSE

TOWN

GRAVITY

STATION

FD 5 STATION NUMBER

+11·6 RELATIVE BOUGUER ANOMALY

2078′ ALTITUDE IN FEET

0 5 1 ANOMALY IN MILLIGALS

"HIGH" ANOMALY

"LOW" "

EXPLANATION

RELATIVE BOUGUER ANOMALIES ARE BASED ON THE OBSERVED GRAVITY VALUE OF 979,979·0 MILLIGALS AT B M R No 1 GRAVITY PENDULUM STATION, FOOTSCRAY, VIC.

FOR THE CALCULATION OF BOUGUER ANOMALIES 1·03 g/cm³ HAS BEEN TAKEN AS THE SEA WATER DENSITY AND 2·67 g/cm³ AS THE AVERAGE ROCK DENSITY

ELEVATION DATUM M.S.L. (L.W.M. WILLIAMSTOWN + 1·538′ = M.S.L.)

PLANIMETRIC DETAIL SHOWN ONLY FOR LOCATION OF GEOPHYSICAL DATA.

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS J 55/B2-54

To accompany Records 1965/64