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1966-72

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1966/72

TIMOR SEA / JOSEPH BONAPARTE GULF MARINE GRAVITY AND SEISMIC "SPARK ARRAY" SURVEY, NORTH-WEST AUSTRALIA 1965

by

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SUMMARY

The Bureau of Mineral Resources has again extended its geophysical programme in the search for oil to the continental shelf areas of Australia by carrying out a combined gravity and seismic survey in the Timor Sea/Joseph Bonaparte Gulf area of north-west Australia.

The survey investigated the capabilities of the surface marine gravity meter for reconnaissance gravity work at sea, and the penetration and quality of seismic reflections obtainable using a spark discharge source consisting of an array of electrodes. The possibility of operating the two methods simultaneously was also investigated.

The gravity data were mostly recorded under very good sea and weather conditions, and consequently the quality of the results obtained is near the maximum obtainable with the equipment. A preliminary examination indicates that the accuracy before distribution of errors is about 3 mgal. The seismic reflection sections recorded were much better than expected, with good-quality reflections being recorded to 1.6 sec. The gravity meter and seismic equipment were operated simultaneously at boat speeds of 8 to 9 miles per hour.

The seismic results have shown that a large Permian and Mesozoic sedimentary basin exists in the Joseph Bonaparte Gulf and extends to the north and north-west into the Timor Sea. It is an offshore extension of the Bonaparte Gulf Basin, and contains at least 10,000 feet of post-Permian sediments. Although the trends of the gravity anomalies agree with the general shape of the basin as defined by the seismic results, a large positive anomaly occupies the central deep part of the basin and does not seem to be related to basement relief.

1. INTRODUCTION

In recent years the search for oil in Australia has been extended to the continental shelf, and in line with this trend, the Bureau of Mineral Resources considered it desirable to extend its surface geophysical reconnaissance programme to offshore areas. As an initial experiment, a combined surface marine gravity and seismic sparker survey was conceived. Both of these methods are relatively new as exploration techniques, and are still being developed. They required testing to see whether each was suitable for the type of reconnaissance work envisaged, and whether they could be operated simultaneously.

The area selected for the survey was the Timor Sea/Joseph Bonaparte Gulf area in north-west Australia (Plate 1), covering the probable seaward extension of the Bonaparte Gulf Basin. On land this Basin is known to contain up to 15,000 feet of marine Palaeozoic sediments, and appears to be plunging to the north-north-west beneath the Joseph Bonaparte Gulf. The survey was aimed at revealing the major tectonic features of the shelf and in particular to outline the margins of the Bonaparte Gulf Basin.

The gravity equipment used was designed and built by LaCoste Romberg Inc. and is operated under licence by Geophysical Associates Pty Ltd. The measurement of the gravity field on board a moving vessel is complicated by the disturbing accelerations introduced by the motion of the vessel; these accelerations have to be eliminated or reduced, or else a correction must be applied. The accuracy obtainable with a surface marine gravity meter is therefore much less than with an ordinary land meter. Under good sea conditions an accuracy of about 3 mgal has been claimed. An underwater gravity meter was also used during the survey to provide accurate base stations to which the surface data could be adjusted.

The seismic equpment used for the survey was manufactured by Edgerton, Germeshausen, and Grier, Inc. (E.G.G.) and is owned by the Bureau. It is a spark discharge system which uses an array of electrodes firing simultaneously to produce the initial seismic pulse. By using a high capacitance, lower voltage (3600 volts), and an array of electrodes a lower frequency content and more energy output have been obtained than in earlier spark discharge systems. Measurements made by E.G.G. on the output pulse show that the dominant frequency of the pulse is around 120 cycles per sec. The equipment was operated by Geophysical Associates, which also supplied the cable and detector array for receiving the seismic signals.

The survey was carried out under contract to the Bureau by Geophysical Associates Inc. This company hired a local ship in Brisbane, the M.V. Moorah. The gravity and seismic equipment was installed in a special instrument room built in the hold of the ship, with the gravity meter mounted as near as possible to a point at which it would experience least motional acceleration.

A "Toran" radio location network was used to record the position of the ship. This system is designed and operated by the French company, Compagnie Generale de Geophysique (CGG). It is a phase comparison system which sets up a grid of hyperbolic lanes, the position being determined by intersection of two hyperbolas. It was set up primarily for an aeromagnetic survey conducted by CGG for Arco Ltd.

The survey commenced from Darwin in mid-July and concluded on 8th October, 1965. The weather was generally good throughout, and only two days were lost because of rough seas. Five separate cruises were made and a total of 3600 line miles was completed. The area covered and the traverses are shown in Plates 1, 2, and 3.

2. GEOLOGY

The north-western part of Australia in the vicinity of the Timor Sea has remained relatively stable since Precambrian times, and can be considered as being part of the Australian Precambrian Shield. In this area the continental shelf extends 200 to 300 miles from the coast and is probably an extension of this stable Precambrian Shield. It is bordered in the north-west by the deep Timor Trough (Plate 1) which has water depths ranging up to 10,000 feet. The Timor Trough separates the Australian continental block from the vastly different, young orogen of Timor and adjacent islands.

The regional structural units of the land area were described by Traves (1955) and they reveal two rather striking trends (Plate 1). The Fitzroy Trough and King Leopold Mobile Zone, the south-western margin of the Bonaparte Gulf Basin and the north-east coast of the Kimberley Block, and the Pine Creek Mobile Zone, all have parallel trends in a north-west to south-east direction. In addition, one of two major systems of joints in the Kimberley Block and strike faulting along the south-western margin of the Bonaparte Gulf Basin parallel this trend. The second major trend, in a north-east to south-west direction, is exhibited by the Halls Creek Mobile Zone, the eastern margin of the Bonaparte Gulf Basin, the dominant fault system of the Bonaparte Gulf Basin along its eastern margin, the west coast of the Kimberley Block, and a second system of joints in the Kimberley Block. These two trends are primary lineaments in the Precambrian rocks. South of Darwin, in the zone where the Halls Creek and Pine Creek Mobile Zones intersect, the trend of faulting, etc. is in a more northerly direction, and this may represent an important trend in the north-eastern part of the area.

In the course of a study undertaken by the Scripps Institute, van Andel, Curray and Veevers (1961) have made the following comments on the sea-bed topography and geology of the continental shelf. "The shelf area studied is limited in the north-east and south-west by shallow rises extending from the mainland to the shelf edge and with a mean depth of approximately 40 fathoms. The rises, in particular the north-eastern one, are crowned by an extensive system of reefs and banks rising to 18 or even locally 10 fathoms. A similar rise extends along the shelf edge with a crest depth of from 40-45 fathoms. This shelf edge rise is essentially free of reefs and banks. Together with the Australian nearshore shoals, the rises enclose a central deep basin on the shelf with a mean depth of 65-70 fathoms. The inclination towards the central depression of some Pleistocene and post-Pleistocene terrace on the slope of banks suggests that downwarping of the depression is a recent process. If the pattern of rises and central depression is structurally controlled, its similarity in size and shape to Precambrian and Palaeozoic basins on the adjacent continent suggests a rejuvenation of very ancient structural patterns".

Van Andel and Veevers (pers. comm.) have recognised trends in the sea-floor topography in similar directions to the Precambrian tectonic trends of the adjacent continent discussed above (Plate 1). Thus the Leveque Rise, West Londonderry Rise, and the northern part of the East Londonderry Rise parallel the north-west trend; the Sahul Rise and the southern part of the Malita Shelf Valley follow the north-east trend, while the northern part of the Malita Shelf Valley and the sea valley between Bathurst Island and Van Diemen Rise follow the north trend. The repetition of these trends on the continental shelf may signify that the structural units and tectonics of the continent have extensions onto the shelf, and that in particular the rises may correspond to areas or zones of relatively shallow Precambrian rocks, whereas the central depressed area, the Bonaparte Depression, may represent the seaward extension of the Bonaparte Gulf Basin. Fairbridge (1953) has pointed out the correspondence, along the Western Australian coast, between basins on land and depressions on the shelf, separated by high blocks and their seaward extensions, the rises.

TABLE 1

STRATIGRAPHIC COLUMN, BONAPARTE GULF BASIN AND ADJACENT AREAS

Age	Stratigraphic unit	Description	Thickness
TERTIARY	White Mountain Formn	Siltstone, chert, marl	370'
		? ? ? ?	
MESOZOIC	Mullaman Group	Clay & sandstone (lateritic cap)	100' to 1000'
		Disconformity	
Permo-Triassic	Port Keats Group	Sandstone, shale, limestone with coal	≃ 2000'
		Unknown	
	Keep Inlet Beds	Sandstone with conglomerate	?
		Unknown	
UPPER PALAEOZOIC (Weaber Group) (Low.Carb to Low.Permian) (7000'+)	Border Creek Sandstone	Sandstone with conglomerate	1000'+
	Point Spring Sandstone	Sandstone with some limestone	600'
	Tanmurra Formation	Sandstone, calcarenite, limestone, oolite	1000'
	Milligans Beds	Dark shale with interbedded sandstone and siltstone	5000'+
		Unconformity	
MIDDLE PALAEOZOIC (C-D Group) (Up.Dev. to Low.Carb) (8000')	Septimus Limestone	Limestone and calcareous sandstone	400'
	Enga Sandstone	Sandstone	≃ 800'
	Burt Range Formation	Shale, siltstone, sandstone, limestone	2000' to 4000'
	Cockatoo Sandstone	Sandstone, cross-bedded	4000'
		Faulted - Probable Unconformity	
LOWER PALAEOZOIC (Carlton Group) (U.Mid.Camb. to Lower Ord.) (4000'+)	Pander Greensand	Greensand and sandstone	500'+
	Clark Sandstone	Glauconitic sandstone	600'+
	Pretlove Sandstone	Sandstone	400'+
	Skewthorpe Formation	Limestone, shale, sandstone	600'+
	Hart Spring Sandstone	Sandstone, limestone, shale	500'+
		Probably Disconformity	
		Possibility of Middle Cambrian sedimentation	
Lower Cambrian	Antrim Plateau Volcanics	Basalt, agglomerate, tuff	Up to 3300'
		Unconformity	
UPPER PROTEROZOIC (8000'+)	Mt. House Beds and Victoria River Group	Sandstone, shale, limestone with some dolomite	2000' to 3000'+
		Possibility of Walsh Tillite	
		Unconformity	
	Warton Beds	Sandstone, shale (with dolomite)	4000'+
		Possibility of volcanics (Mornington Volcanics)	
		Unconformity	
	King Leopold Formn	Sandstone and quartzite	1500'+
		Unconformity	
LOWER PROTEROZOIC	Lamboo Complex	Intrusives into and granitised Halls Creek Metamorphics - granite, gneiss, granodiorite.	-
	Halls Creek Complex	Metamorphosed sediments - sandstone, quartzite, slate, phyllite, schist, and volcanics	-

The Bonaparte Gulf Basin is an area of Palaeozoic sediments covering about 8000 square miles adjacent to the Joseph Bonaparte Gulf. It is bounded on land by the Precambrian rocks of the Kimberley Block and the Halls Creek Mobile Zone, and probably has a seaward extension (Plate 1). The stratigraphy of the Basin is a record of repeated marine invasion followed by uplift and denudation. During the Palaeozoic era there were three such invasions, during which considerable sedimentation took place with a possible total thickness of the order of 15,000 feet. There has probably been further wide-spread transgressions during Mesozoic and Tertiary times, but only isolated remnants of these sediments remain. The stratigraphy is summarised in Table 1, which is based on reports or summaries by Traves (1955), Drummond (1963), Jones (Reynolds et al., 1963) and Veevers (Veevers, Roberts, Kaulback and Jones, 1964).

Three oil exploration bores have been drilled in the Bonaparte Gulf Basin. Spirit Hill No. 1 (Westralian, 1963), which was drilled to 3003 feet in the south-eastern part of the Basin, encountered 800 feet of shale of the Weaber Group (see Table 1) overlying a sequence of dolomite, limestone, and sandstone of the Carboniferous-Devonian group. Slight oil traces were found in the shale, suggesting that it may be a potential source rock for petroleum. Bonaparte No. 1 (Alliance, 1964) was drilled in the north-western part of the Basin to a total depth of 10,530 feet. It penetrated 7480 feet of the Weaber Group, including 5850 feet of the lower shale unit (Milligans Beds) and 3050 feet of Carboniferous-Devonian sandstone, siltstone, and shale. Bonaparte No. 2 (Alliance, 1965), five miles south of No. 1, also penetrated a thick section of Milligans Beds, and produced gas at rates up to 1,540,000 cubic feet per day from a thin sandstone within the shale.

3. PREVIOUS GEOPHYSICAL WORK

Aeromagnetic surveys have been made in the Timor Sea/Joseph Bonaparte Gulf area by the Bureau of Mineral Resources (Quilty, 1966), Woodside (Lakes Entrance) Oil Co. Ltd (Woodside, 1964), and Associated Australian Oilfields, N.L. (A.A.O., 1963). An extensive survey was made by Arco Ltd concurrently with the marine gravity and seismic survey, covering most of the continental shelf area of the Timor Sea. The interpretation of the results of the three earlier surveys shows an extensive sedimentary basin occupying the central part of the area, with thicknesses of 30,000 feet of sediments within the Bonaparte Depression. The eastern margin trends northerly to Bathurst Island, where it swings sharply eastwards for about 40 miles before resuming a northerly trend. The western margin probably trends in a north-west direction from Cambridge Gulf at about 25 miles from the coast.

A number of regional and detailed gravity surveys have been made along the eastern and southern coastal areas of Joseph Bonaparte Gulf, by the Bureau of Mineral Resources and the various leaseholders (Bigg-Wither, 1963). The Bureau has also made an underwater gravity survey along the coastal waters between Darwin and Wyndham (Williams & Waterlander, 1959). The Bouguer anomaly contours shown over the land areas in Plate 2 are compiled from those surveys. The trend of these contours along the eastern coastline of the Gulf is in general conformity with the geological trends, but in the south there is no obvious relation to the geology. One anomalous feature is the large positive anomaly at the mouth of Queens Channel.

A surface marine gravity traverse was run from Darwin to Timor by the Institute of Geophysics of the University of California (Helfer, Caputo, Michele & Harrison, 1962). On their profile the main feature of relevance to the present survey is a steep gradient of about 2 mgal per mile decreasing to the west about 50 miles west of Darwin; this is probably associated with the eastern margin of the Bonaparte Gulf Basin.

A number of seismic reflection and refraction surveys have been made on land in the Port Keats and Keep River areas. A compilation and review of these surveys up to 1962 has been made by Bigg-Wither (1963). The quality of the reflection results obtained in these surveys is generally poor, and in all the most recent reflection work, high multiplicity values for both geophones and shot-points have been used.

Associated Australian Oilfields (1962) conducted a marine seismic survey in 1961 along the eastern coast of Joseph Bonaparte Gulf, off the Port Keats area. In 1964, Australian Aquitaine (1964 a,b) made two marine surveys to the north and south of this survey, and tying to it. The reflection quality was generally good to the north of latitude 14°20'; there were several fair reflection horizons, one of which is possibly continuously correlatable throughout this part of the area. This horizon shows a regional dip to the west and reaches a depth of about 10,000 feet on the latitude of Darwin at about 129°E. South of latitude 14°20', in the Queens Channel area, this zone of fair reflection quality has apparently been eroded. The remaining cross-section exhibits only poor-quality reflections, although they are reliable enough to suggest a thickness of about 7000 to 9000 feet of sediments. Thus, it appears that most of the 10,000 feet of sediments in the northern part of the area is younger than the sediments in the Queens Channel area.

4. OBJECTIVES OF THE SURVEY

As the instruments and techniques used in this survey are relatively new to petroleum exploration, particularly in Australia, and there are conflicting reports on their performance and accuracy, a prime objective of the survey was to investigate their present suitability and future potential for use as reconnaissance geophysical tools in the search for petroleum. Assuming their application would be at least partially successful, there were underlying geological objectives on which it was hoped the geophysical information might throw light. Thus, the objectives of the survey may be classified in two groups: geophysical and geological.

Geophysical objectives

(1a) Investigate the performance and reliability of the surface marine gravity meter and the accuracy attainable with it under various conditions of speed, weather, etc.

(1b) Investigate the quality of reflection data and the depth penetration obtainable with the "spark array" seismic equipment.

(1c) Determine whether the two techniques can be operated simultaneously and at a boat speed at which the cost per mile is substantially lower than for normal independent seismic and gravity operations.

(1d) Outline the zones of good and poor reflection quality so that future seismic surveys may be planned to the best advantage.

(1e) If possible, make a gravity tie to Timor, in order to give some absolute control on the north-western side of the survey area and establish a gravity link between Australia and Timor.

Geological objectives

(2a) Investigate the extension of the mainland structural units onto the continental shelf and ascertain whether the two main Precambrian tectonic trends are maintained, viz. north-west to south-east and north-east to south-west.

(2b) In particular, investigate the seaward extension of the Bonaparte Gulf Basin with particular reference to:

(i) Whether the Basin extends to the edge of the continental shelf.

(ii) The location of the western margin.

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(iii) The extension of the eastern margin to the north past Bathurst Island.

(iv) The general form of the basin, including the possibility of a shelf zone along the eastern side.

(v) The thickness of sediments within the Basin, including the relative thicknesses of Mesozoic, Palaeozoic, and Proterozoic sediments.

(vi) Major basement and/or sedimentary structure within the Basin.

(2c) Investigate the likelihood of any other prospective sedimentary basins on the continental shelf.

(2d) Investigate the basement structure beneath the shoals along the edge of the continental shelf in the northern part of the area.

(2e) Make a preliminary investigation of the relation between the continental shelf, the Timor Trough, and the island of Timor.

5. PROGRAMME

The general programme for the survey remained much as was planned before the commencement, but the order in which items were carried out and many details were modified to fit in better with the day-to-day circumstances. The chief controlling factor in the daily planning was the operational difficulty associated with maintaining a known position for the ship. This arose because (1) the nearest calibrated point in the "Toran" network at the start of the survey was at Cape Scott, which was over 100 miles from Darwin; (2) it was found impossible to use the "Toran" radio-positioning equipment during the night, thus necessitating that the ship be anchored at a fixed known position from between 5 p.m. and 6 p.m. until between 8 a.m. and 9 a.m.; (3) the lane identification facility of the "Toran" euipment was not operational.

The original plan was to spend the first week making initial trials and tests along latitude 12°18'S, between Darwin and Flat Top Bank (longitude 129°15'E). These were to consist of:

(a) Combined gravity and seismic work at varying boat speeds to establish the best location for a calibrated gravity range and give a preliminary idea of the quality of seismic results at various boat speeds.

(b) Establishment of a calibrated range with the underwater gravity meter across the steepest part of the gravity gradient to the west of Darwin.

(c) Surveying the calibrated line with the marine surface meter at the recommended speed, and repeating at other speeds.

(d) If necessary, making further comparisons of the seismic results obtained at various speeds.

The ship arrived in Darwin, and it and the gravity and seismic equipment were ready for operation about one week before the "Toran" radio location equipment was available. A trial run was therefore made approximately along latitude 12°18'S without any positioning system. This immediately demonstrated that it was possible to obtain good seismic results at boat speeds up to 7 or 8 knots, which was a satisfactory speed for the gravity work, and consequently removed any need for extensive tests at varying boat speeds prior to commencement of the reconnaissance programme. The run also confirmed that there is a substantial gravity gradient along this line, which was therefore satisfactory for the calibrated gravity range.

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To commence the survey proper, a run had to be made down to the "Toran" buoy at Cape Scott in order to pick up the "Toran" lane count. From here a start was made on the reconnaissance programme. The establishment of the calibrated gravity range of underwater stations and the traversing along it with the surface meter were left until later in the survey, so that they would fit in conveniently with the reconnaissance programme. A limited amount of testing of the quality of the seismic results at various boat speeds was done along traverse P10 during the first main cruise.

As discussed above, the most prominent structural trends were considered likely to be in north-east, north-west, and north directions, and for this reason the reconnaissance lines were run in an east-west direction. A latitude spacing of 9 minutes was used, which represented a distance of 10.3 miles. This spacing was considered to represent the minimum coverage that would permit reasonable contouring at 5-mgal intervals. This interval is the target set for the Bureau reconnaissance surveys on land, which usually employ a 7 x 7 mile grid of stations. A number of tie lines also were run. Altogether, 3600 miles of traversing were done, as shown in Plates 2 and 3.

6. RESULTS AND DISCUSSION

Gravity

The sea state during the survey was generally very good, with seas varying from smooth to slight. Only two days were lost owing to bad weather. On a further three days there was a long swell which caused long-period accelerations of the surface gravity meter with a consequent deterioration in the quality of the recorded data on these days. During the remainder of the survey the disturbing accelerations due to the motion of the ship were relatively small, and the gravity measurements made with the surface meter should be quite reliable within the limits of the method.

A complete assessment of the accuracy of the results obtained with the surface marine gravity meter has not yet been made. There are two possible ways of making this assessment: the surface meter effectively gives an independent reading of gravity at each point, and hence values obtained at line intersections may be compared to obtain an idea of the likely magnitude of errors inherent in the system of surface readings; in addition, about 60 accurate gravity stations were established with the underwater gravity meter, and the surface readings may be compared with this base network. A preliminary comparison of the values on 29 line intersections during the first two cruises showed that the maximum difference was 6.4 mgal and the standard deviation of the differences was 2.9 mgal. It is expected that the results of the remainder of the survey will show similar figures for the probable magnitude of the differences. Accuracies of this order should enable contouring to be done reliably at 5-mgal intervals.

A preliminary Bouguer anomaly map, contoured at 10-mgal intervals, is shown in Plate 2. The various corrections to make this reduction were computed only approximately; the Eotvos corrections in particular may be in error by 1 or 2 mgals, as only rough plots of the traverses were used to calculate the speed of the boat. However, the major features shown by the contour pattern should be reliable.

The most striking feature is the large positive anomaly, here named the Wickham Regional Gravity High, which occupies the central part of the area. This is a development of the positive anomaly previously known to exist at the mouth of Queens Channel. It is an elongate feature reaching a maximum of +60 mgal and extending from the coast west of Queens Channel in a northerly direction for at least 120 miles. It is flanked by a minimum of -30 mgal to the east and one of -20 mgal to the west. The eastern minimum strikes approximately north, but the western one strikes north-west.

The results of the seismic work, to be discussed in the next section, have definitely shown that a large sedimentary basin exists in the central part of the area, the deepest part approximately coinciding with the positive Bouguer anomaly feature. The positive anomaly therefore is not caused by a basement "high". It is probably related to an intrabasement density change. However, the trends of the minima flanking the positive anomaly do correlate very well with the basin margins.

Seismic

The trials made at varying boat speeds demonstrated clearly that the noise recorded by the hydrophone array increases greatly with increased boat speed. It is believed that this is largely caused by the increase in propeller revs, as it is noticeable that the noise increases immediately the revs are increased and before the boat has picked up speed. A second, rather surprising, phenomenon was observed during these speed trials. At the slowest speeds, the reflection section became full of water reverberations which were so bad that the strong reflections observed at higher speeds were completely obscured by the multiples. Two possible explanations of this phenomenon are advanced. At the slower speed, the "spark array" rides much deeper in the water and this may cause a filering effect with a resonance within the frequency band used, which was 20 to 80 c/s; or it may be that at the slower speed the surface of the water is much less disturbed and becomes a better reflecting interface. With regard to the latter explanation, however, the magnitude of the disturbance (3 to 4 feet) is much less than the wavelengths used (50-250 feet), and would not be expected to have much effect.

Fortunately, at a boat speed of about 8 to 9mile/h, corresponding to engine speed of 1300 to 1350 rev/min, the water reverberations were not noticeable and the noise was still at a tolerable level. This speed was satisfactory for the operation of the surface marine gravity meter and also meant that a good line-mile coverage could be obtained. Most of the sections recorded on the first cruise appear to be of generally better quality than those redorded on later cruises. This is partly due to the earlier ones being recorded at 1300 rev/min engine speed, whereas this was later increased to 1350 rev/min.

The filter pass-bands available in the instruments are 20-80 c/s, 80-200 c/s, 200-800 c/s, 800-2000 c/s, 2000-8000 c/s, and 8000-20,000 c/s or combinations of these. Some experimenting was done with filtering, mainly using pass-bands of 20-80 c/s, 80-200 c/s, and 20-200 c/s. Inclusion of the lower frequencies definitely improves the quality of the reflections, but there is little difference between the 20-80 c/s and the 20-200 c/s settings. The former settings were used, however, because inclusion of the higher frequencies allows the direct arrivals to come in strongly, and these interfere with the reflection and refraction arrivals from the sea-bottom. These direct arrivals have a dominant frequency around 160 c/s, so if more flexible filter units had been available, a pass band of 20-150 c/s would probably have been used. As the signals are being recorded unfiltered on magnetic tape, further experimenting with filters will be possible later.

The quality of the seismic reflection sections recorded with the "spark array" equipment varied from poor to very good, but in general exceeded expectations held prior to the survey. Traverse 17 is displayed in Plate 4 as a typical example of the quality of the reflection sections obtained during the survey. In general, it can be said that the quality is quite good along the margins of the basin, but only poor in the central deep part of the basin. This is demonstrated in Plate 4, where the reflection quality is good between positions 830 and 1100, but then deteriorates to the west (or left of section) as the main horizons get deeper. This undoubtedly is mainly a function of the energy output of the "spark array" relative to the random noise level, in particular the boat noise. The eastern part of the section shown in Plate 4 is believed to be over shallow granitic basement, and hence no reflections have been recorded. In the central part of the basin a new suite of reflections appears, but these are usually of much poorer quality than those recorded around the margins.

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Along the eastern margin, three main reflections are recorded, and these will be referred to as the M, P_1, and P_2 horizons. The P_1 horizon is the strongest and most wide-spread of these, and it can probably be followed continuously throughout the basin, except where it becomes obscured by noise as it gets deeper. This generally occurs when it has reached about 1.2 to 1.6 seconds. At position 1000 on line 17 (Plate 4), the P_1 horizon occurs at 0.75 seconds. It is possible to follow this reflection through to the area of the Port Keast survey conducted by A.A.O. in 1962 (A.A.O., 1962), and via this survey, it can be tied to an old bore drilled for coal at Port Keats. The reflection can be correlated with the top part of the Permian strata penetrated in this bore at about 800 feet and probably about 200 feet below the conformable transition from Permian to Triassic which has been recognised in the bores. A contour map has been drawn on this horizon, omitting minor variations, and is displayed in Plate 3. This map shows that a large post-Permian basin exists in the Joseph Bonaparte Gulf and extends north and north-west into the Timor Sea. Although the greatest time this horizon has been traced to is about 1.6 sec, it seems most likely that it deepens to at least 2.0 sec in the central part of the basin. The basin therefore contains at least 10,000 feet of Mesozoic and Tertiary sediments. Along the eastern side of the basin the reflection becomes confused with the arrivals associated with the sea-bottom at reflection times greater than 0.4 sec, but it can almost certainly be extrapolated to the Permian sediments along the coast, as was possible at Port Keats. The trends of the contours along this margin agree well with the basin margins as mapped on land. On the western side the trends and depths indicate that the margin is close to the shore line and striking north-west.

The P_2 horizon is recorded as a distinctive horizon in the southern part of the area at 0.2 sec, or about 1000 ft, below the P_1 horizon. However, in the north it tends to merge into the strong band of reflected energy which follows the P_1 horizon, and to lose its distinctive character (Plate 4). It is conformable with the P_1 horizon, and by correlation with the section in the Port Keats coal bore, it is also a Permian horizon. Very little useful information has been obtained below this horizon, although the onshore geology suggests that there is almost certainly a considerable thickness of Permian and other Palaeozoic sediments below the P_1 horizon.

The M horizon is at a time of 0.57 sec on line 17 at position 1000. It is not conformable with the P_1 horizon, there being a considerable thickening between the two towards the centre of the basin. However, it is difficult to distinguish an unconformity. A slight unconformity may be indicated on line 17 (Plate 4) at position 935 and again at position 1020. In each case these are just above the P_1 horizon, and may mean that there is only a thin section of the Permian-Triassic system above the P_1 horizon and that above the unconformity the strata are of Mesozoic age. The M horizon is at present taken to represent the Mesozoic sediments younger than Triassic. The M horizon appears to overlap the P_1 horizon along the eastern margin in the north, but in the south the M horizon has been eroded from above the Permian horizons.

On the eastern side of the basin a large anticlinal structure was crossed by lines 9 and 10 about 40 miles west of Cape Scott. In appears that this structure is on a hinge line where the strata begin to plunge more steeply into the basin. Farther south there is evidence of faulting on this same trend. Along the south-western side of the basin, lines 4 to 9 and 63 have shown that there is a line of folding and faulting which trends north-west, parallel to the western margin and about 40 miles from the coast. Elsewhere in the basin, particularly in the deeper parts, very little structure was revealed by the seismic work, except for a few minor disturbances which appear as if they may be caused by intrusive material.

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7. CONCLUSIONS

From a preliminary assessment of the gravity and seismic results of this survey, the following conclusions have been reached:

(1) Under sea conditions as good as those during most of the survey, the surface marine gravity data can maintain an accuracy of 3 milligals, and contouring at 5-milligal intervals should be reliable.

(2) The seismic "spark array" equipment can give good reflection results and a penetration of about 1.5 sec, or 7000 to 8000 feet.

(3) The two methods can be run concurrently at a boat speed through the water of 8 to 9 mile/h.

(4) The Bonaparte Gulf Basin extends offshore into the Joseph Bonaparte Gulf and Timor Sea and contains at least 10,000 feet of Mesozoic and possibly Tertiary sediments, most of which are new section. The survey has not defined the northern and north-western margins.

(5) There is some folding and faulting around the margins of the Basin, but a lack of it in the central deep area.

(6) The trends of the gravity anomalies around the basin margins agree with the shape of the basin as defined by the seismic results, but a large positive anomaly that occupies the central part of the basin does not seem to have any direct relation to basement relief.

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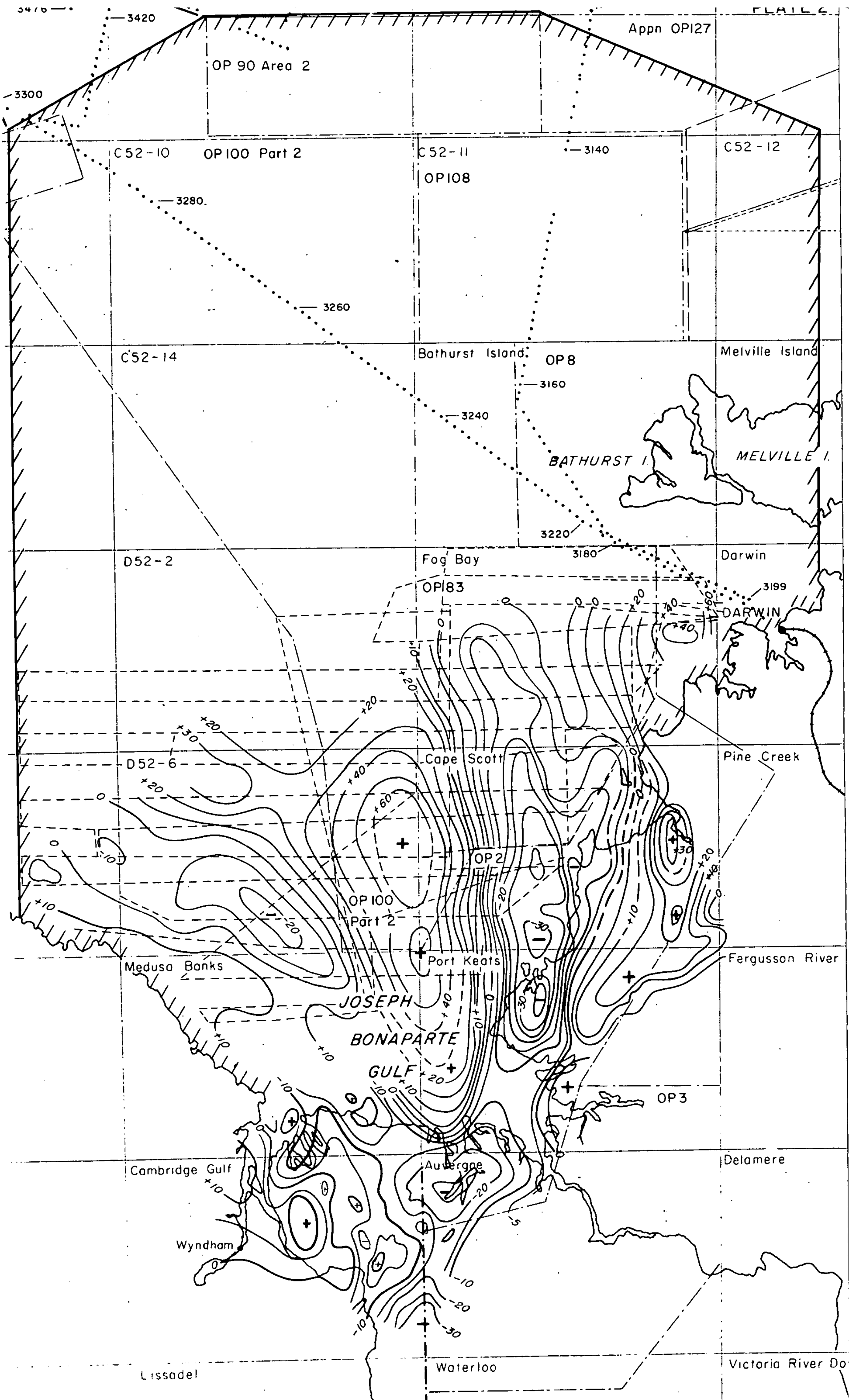
PLATE 1


TIMOR
SUMBA I.
AXIS OF TIMOR TROUGH
AXIS OF MALITA SHELF VALLEY
SAHUL RISE
BONAPARTE DEPRESSION
VAN DIEMEN RISE
AXIS OF SEA VALLEY
TIMOR SEA
WEST LONDONDERRY RISE
EAST LONDONDERRY RISE
POSSIBLE MARGIN OF BONAPARTE GULF BASIN
POSSIBLE MARGIN OF BONAPARTE GULF BASIN
BROWSE DEPRESSION
LEVEQUE RISE
KIMBERLEY BLOCK
KIMBERLEY BASIN
JOSEPH BONAPARTE GULF
BONAPARTE GULF BASIN
BONAPARTE No.1
SPIRIT HILL No.1
HALLS CREEK MOBILE ZONE
ORD BASIN
VICTORIA RIVER BASIN
STURT BLOCK
DALY RIVER BASIN
PINE CREEK GEOSYNCLINE
KING LEOPOLD MOBILE ZONE
FITZROY TROUGH
CANNING BASIN
DAMPIER FAULT
Melville Island
Bathurst Island
Cobourg Peninsula
Van Diemen Gulf
Beagle Gulf
DARWIN
Scattered mesas of M/Pzl
Flat-lying Mesozoic sediments
Daly Waters
Victoria River Downs
Larrimah
Derby
Broome
Ashmore Reef
Scott Reef
Port Keats
Cape Scott
Flat Top Bank
Fog Bay
Londonderry
Wyndham
Montague Sound
Camden Sound
Prince Regent
Pender
Mt Anderson
Noonkanbah
Fitzroy Crossing
Lansdowne
Mt Elizabeth
Charnley
Limbunya
White Mountain
Birrindudu
Gordon Downs
Halls Creek
Auvergne
Cambridge Gulf
Medusa Banks
Holothuria Reefs
120° 00'
123° 00'
126° 00'
129° 00'
132° 00'
8° 00'
11° 00'
14° 00'
17° 00'
JOSEPH BONAPARTE GULF - TIMOR SEA
1:2,534,400
REGIONAL GEOLOGY
(BASED ON BMR TECTONIC MAP OF AUSTRALIA & VANANDEL & VEEVERS)
BOUNDARY OF 1965 MARINE GRAVITY AND "SPARK ARRAY" SURVEY
D51/B3-1
BASED ON D51-B0-2



MARINE GRAVITY & SEISMIC SPARKARRAY SURVEY

PRELIMINARY BOUGUER ANOMALIES

MILES

40 30 20 10 0 40 80

– – – – – TRAVERSE

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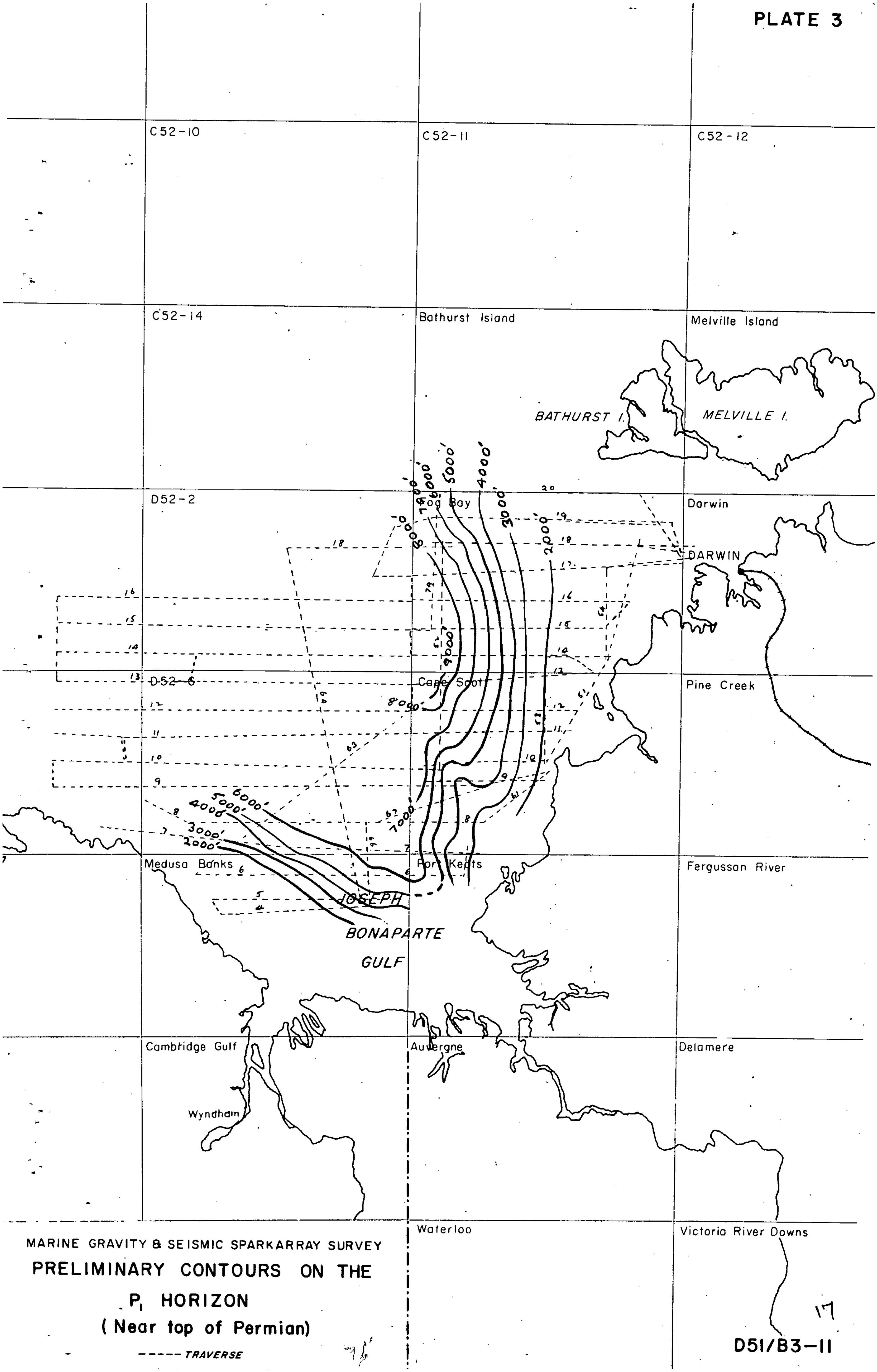
D51/B3-10

PLATE 3



MARINE GRAVITY & SEISMIC SPARKARRAY SURVEY

PRELIMINARY CONTOURS ON THE

P_1 HORIZON

(Near top of Permian)

----- TRAVERSE

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D51/B3-11

Bureau of Mineral Resources
Geology and Geophysics
TIMOR SEA - JOSEPH BONAPARTE GULF AREA
NORTH - WEST AUSTRALIA

MARINE SEISMIC "SPARKARRAY" SECTION

TRAVERSE P-17C, P-17B

SHIP: M.V. Moorath — DATE: 11·8·65, 10·8·65

EQUIPMENT

Energy Source:	E.G.G. 14,000 Watt-sec System
Transducers:	E.G.G. "Sparkarray," Model 267-Two
Receiving System:	Chesapeake "Towflex," Model 12
Hydrophones:	Chesapeake Model PC-100
Recorder:	E.G.G. Model 254

RECORDING INFORMATION

Source Power:	14 K.W.S.
Firing Rate:	5 seconds
Hydrophone Array:	6 at 30 ft
Source - Receiver Distance:	1100 feet
Source Depth:	8-10 feet.
Receiver Depth:	12-18 feet
Gain (i) Receiver Amp:	-10 db
Gain (ii) Recorder Amp:	x1-100
Filter:	20-80
Print Mode:	Negative
Paper Speed:	9.8 inches per hour
Boat Speed (i) Engine Revs:	1350 r.p.m
Boat Speed (ii) Approx. Speed:	8 miles per hour

DIRECTION ⊢— E

HORIZONTAL SCALE 1" = .82 mile

REMARKS

P-17C
0710-1250
Paper Speed 12.3 inches per hour
Boat Speed 8.4 miles per hour
Hor. Scale 1" = .71 mile
0706 Gain x1,080
0725 Gain x1,090
0930 Gain x1,200
0940 Gain x1,100
1257 12 K.W.S. 2.5 sec/sweep
400 msec timing

P-17B
Paper Speed 12.6 inches per hour
Boat Speed 8.4 miles per hour
Hor. Scale 1" = .67 mile

BASED ON G85/3-46)

Recorded by: Geophysical Associates Pty. Ltd.

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