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Survey 17

GEOPHYSICAL RESULTS FROM THE NORTHWEST CONTINENTAL MARGIN OF AUSTRALIA

by

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SUMMARY

During 1972 Compagnie Generale de Geophysique under contract to the Bureau of Mineral Resources carried out about 10 700 nautical miles of marine geophysical surveying along Australia's northwest margin. The aim of the survey was to investigate the sedimentary and basement structure of the continental slope and marginal plateaus. The area covered in this report includes the northern part of the Wallaby Plateau, the Exmouth Plateau, and Scott Plateau.

The continental slope in this area can be divided into two categories: a steep lower slope and an extensively terraced upper slope. The upper slope includes the Exmouth and Scott Plateaus. It has an estimated crustal thickness not less than 20 km and a sedimentary thickness generally greater than 1 km. The Exmouth Plateau is centrally situated within the area. It has a thick sedimentary cover with magnetic basement estimated to be more than 8 km below sea level. Over the entire area, the major structural and geophysical trends are oriented in two principal directions: northeast and west-northwest. The latter direction is related to fracturing parallel to plate motion from a spreading axis aligned northeast.

INTRODUCTION

Compagnie Generale de Geophysique (C.G.G.) under contract to the Bureau of Mineral Resources conducted a marine geophysical survey of the continental margin of Australia between December 1970 and January 1973. The aim of the survey was to investigate the sedimentary and basement structure around the continental margin by the use of seismic reflection, seismic refraction, magnetic, gravity, and bathymetric techniques (C.G.G., 1974b).

This report covers the survey between latitude 12°S and 24°S and longitude 108°E and 123°E (Fig. 1), and presents a brief description and preliminary interpretation of the data collected.

Equipment

The equipment used is summarized here: a complete list is given in Appendix I. A more detailed report on equipment and performance is given by C.G.G. (1974a).

Primary navigation control was based upon the U.S. Navy TRANSIT satellite navigation system which gave fixes on average at two-hourly intervals. Intermediate ship positions were computed using the ship's gyrocompass coupled with a sonar Doppler system. A Chernikeef electronic log or ship's log was used whenever the sonar Doppler system was inoperative.

Gravity data were obtained from a LaCoste and Romberg marine gravity meter mounted on a stabilized platform. The total magnetic field was measured by a Varian proton precession magnetometer with the sensor towed about 200 m behind the ship.

Gravity, magnetic, and navigational data were sampled at 10-second intervals by a Hewlett Packard model 2116B computer, checked and reformatted, and digitally recorded on half-inch magnetic tape. The computer also provided the ship's dead-reckoned position at 10-minute intervals as well as data for assessment of systems' performance and for geophysical computations.

The seismic energy source was a four-electrode 120 kJ sparker. The seismic signals were recorded by a six-channel hydrostreamer cable 1000 m long and usually a short, single channel Geotech cable, both coupled to S.I.E. PT700 amplifiers and a 14-channel AMPEX FR1300 FM tape recorder. Electrostatic chart recorders were used for monitoring and display purposes. The sparker was also used as an energy source for refracted seismic signals which were detected up to 10 nautical miles away by Aquatronics SM42 sonobuoys.

Operations

For indexing purposes the continental margins work was divided into 'Surveys', each lasting less than 100 days. Parts of Surveys 17 and 18 fall within **this report area.**

The ship, the Lady Christine, entered the area from the south on 5 August 1972 and surveyed lines 17/050 to 17/089. During this time she called at the ports of Broome and Port Hedland. The tie lines 17/090 to 17/094 were surveyed before the ship left the area to dock at Carnarvon on 26 September 1972, there ending Survey 17. She left Carnarvon on the same day and re-entered the area to survey lines 18/004 to 18/014 and then sailed to Darwin for an engine overhaul. After leaving Darwin, the Timor Trough area was surveyed, followed by lines 18/055 to 18/073, which completed traversing in the northwest margin area. The Lady Christine then sailed to Fremantle. A total of 10 000 nautical miles of traverse lines was surveyed in the area (Pl. 1). Operations occupied 77 survey days, of which time 55 days and 4 hours were spent recording. The remaining time was due to port calls, engine and navigational failures, and days when part of the work lay outside the area. During recording, 5½ hours of magnetic data, 24 hours of gravity data, and 10½ hours of seismic data were missed owing to equipment malfunction or routine servicing. Twenty-three refraction sonobuoys were released at various times from the ship. Seventeen gave acceptable results; the others failed owing to collision of the sonobuoys with towed equipment or to early attenuation of radio transmission, apparently by high waves between the sonobuoy and the ship. The sonobuoy results are summarized in Appendix II.

Throughout Survey 17 the short, single channel Geotech cable was under repair. As a substitute procedure, shallow reflection data were specially recorded from one channel of the long cable by using a high pass filter.

Weather conditions during survey time were fair to good; sea swell rarely exceeded 4 m. With the exception of 40 knot winds during the first three days in the area, wind velocities were generally about 10 knots.

Data Quality and Accuracy

The satellite navigational accuracy should be of the order of 10.2 nautical miles after post-survey processing. Over the continental shelf the sonar Doppler was able to operate on bottom-lock and carried this accuracy to the intervening positions, but in deeper water it was operating from back-scattered energy from water below the ship. Since water currents were not measured, the navigational accuracy of intervening positions off the continental shelf is expected therefore to be about ±1 nautical mile.

The main factor affecting the accuracy of the gravity measurements was the short-period accelerations of the ship caused by swell and state of the sea. In rough seas the gravity meter analogue-correcting system was unable to compensate for the rapid motions of the ship, and spurious short-period oscillations were recorded in the gravity data. A criterion was adopted that oscillations of the gravity data should not exceed 6 mGal peak-to-peak within a 10-minute period. Within the survey area 40 hours of gravity data were outside this criterion. During Survey 17 some difficulty was experienced with the gravity meter reading-lamp after day 59. On day 77 the lamp was replaced after a total failure. Thereafter an 8 mGal change in meter zero was noted between the previous check at Port Hedland and the subsequent one at Broome. The jump could have occurred any time between days 59 and 74 of Survey 17, although adjustments to the meter in Broome are believed to have caused the discrepancy.

Noise level on the magnetic records was generally less than 5 gammas peak-to-peak, though there were several short periods of noise up to 10 gammas. Magnetic shore monitors for this area were located at Onslow, Darwin, and Emu Point. There was no magnetic diurnal coverage between survey time 18.501900 (Survey 18, day 50, 1900 hours) and 18.531000.

The magnetic, gravity and bathymetric mistie histograms are illustrated in Figure 2. The mean value and standard deviation for each histogram is also presented. A ratio of mean deviation to standard deviation of about 0.8 would indicate that the distribution was probably normal. For this survey area, values of 0.76, 0.81 and 0.72 were calculated from the magnetic, gravity, and bathymetric histograms respectively. The distribution for magnetic and bathymetric misties are not quite normal.

The probability of obtaining a value outside 3 standard deviations from the mean on a normal distribution is less than 1%. One magnetic anomaly mistie exceeds this number, +85 gamma at the intersection of lines 18/008 and 17/081. This occurs in an area of rapidly varying magnetic intensity where a small error in navigation would produce a large mistie.

One gravity mistie also lies outside three standard deviations from the mean, at the intersection of line 18/069 and 17/062, which is in an area of steep gravity gradient in the vicinity of the continental slope. Small navigational errors would produce a large mistie in this area, also.

Three large positive misties, all associated with rapidly varying water depth, give the bathymetry mistie histogram its bimodal distribution.

These misties occur at the intersections of lines 17/072 and 18/006, 17/092 and 17/079, and 18/066 and 18/055; and are +70, +70, and +80 m respectively. Again small navigational errors can produce large misties in steep gradients.

Single channel monitor records were made from the seismic system as the data were collected. Seismic data quality is fair to good. In areas of good reflection quality, up to 2.5 seconds of recognizable penetration was achieved. However, in areas of steep or rugged surfaces, side reflections and diffractions masked much of the data. In shallow water, reverberation and multiple reflections obscured most events below the first multiple. Six-fold common depth point stacking of the multichannel data recorded on tape should improve resolution and reveal greater penetration.

The data presented in this report are preliminary only. The bathymetric, gravity, and magnetic data were obtained on board ship by manually scaling the analogue records at hourly intervals. These values were stored on punched cards and processed by computer. Contour maps were drawn on a flat-bed plotter using a 'triangular' contouring program as described on each of the contour maps.

3. GEOLOGY AND PREVIOUS GEOPHYSICS

Geology

A simplified map of the regional geology is shown in Figure 3. The brief summary that follows is taken mainly from Forman, Wyborn, Kurlowicz, Passmore, & Mayne (1973).

From south to north the major onshore geological provinces are the Carnarvon Basin, Hamersley Basin, Pilbara Block, Canning Basin, Halls Creek Orogenic Domain, and Kimberley Basin.

That part of the Carnarvon Basin within the area covered by this report is divided into several sub-basins. Offshore, these are the Exmouth, Barrow, Dampier and Beagle Sub-basins. Sediments range from Ordovician to Recent, but nothing older than Permian has been penetrated in offshore drilling. The maximum thickness of sediment is probably as great as 11 000 m.

The Hamersley Basin and Pilbara Block consist of Lower Proterozoic and Precambrian sedimentary, metamorphic, and igneous rocks. These provinces extend offshore and form the basement of a platform known as the Pilbara Shelf, which is bounded to the west by a downwarp, adjacent to the Enderby Fault Zone.

The offshore Canning Basin is bounded to the southwest by the North Turtle Arch and to the north by the Leveque Platform and Leveque Shelf. The Rowley and Bedout Sub-basins are offshore units of the Canning Basin. Onshore sediments range from Ordovician to Cainozoic, but nothing older than Permian has been recognized offshore. The Mesozoic and Permian strata, which cover much of the basin, are flat-lying except in the Fitzroy Trough and within offshore structural units.

Along the onshore northern margin of the Canning basin, the basement rocks are the disrupted Archaean or Lower Proterozoic metasediments of the Halls Creek Orogenic Domain. These rocks and associated Proterozoic granite and mafic and ultramafic intrusives, probably form the basement of the offshore Leveque Platform.

The Browse Basin lies entirely offshore from the Kimberley Basin and contains Ordovician(?) to Recent sediments. It is bounded to the north by the Londonderry Arch and the Ashmore-Sahul Block; to the east by the sea floor outcrop of Proterozoic sediments and volcanics of the Kimberley Basin; and to the south by the Canning Basin. Structural units within the Browse Basin include the Browse Shelf, Leveque Platform, and Leveque Shelf.

Previous Geophysics

Very few geophysical surveys have been conducted over the northwest continental slope, though many marine seismic surveys and a few gravity and magnetic surveys have been conducted over the adjacent shelf. Until 1968 the quality of seismic data from these surveys was fair to poor, with penetration rarely deeper than basal Cretaceous. Since then, work by B.O.C. and Ocean Ventures Pty Ltd has been of good quality, due to improvements in seismic technique and energy sources.

In 1968 BMR marine survey over the northwest shelf (Whitworth, 1969), was conducted partly to evaluate use of the BMR seismic reflection system in this area. Up to 2 km of sediment was penetrated. Well correlations indicate that the oldest reflectors visible on the seismic sections are Palaeozoic.

Four major seismic reflectors have been distinguished in the BMR and B.O.C. results on the continental shelf. These are thought to represent unconformities between Plio-Quaternary and lower Miocene; middle and lower Miocene; upper Eocene and lower Oligocene; and lower Senonian and upper Turonian.

In 1971 a regional bathymetric map, prepared by Falvey & Stewart (Falvey, 1972), defined all the major features covered by the present BMR survey.

During 1972 the Deep Sea Drilling Project (DSDP), leg 27, drilled hole 263 in the Cuvier Abyssal Plain and hole 260 in the Gascoyne Abyssal Plain (Heirtzler, Veevers, et al., 1973). Two reflection seismic profiles parallel to the coast were recorded by DSDP during Leg 27, one passing through site 260, the other through site 263 (Heirtzler, Veevers, et. al., 1974).

Subsidized geophysical and drilling operations in the area are listed in Appendix IV.

BATHYMETRY

A water depth map is presented in Plate 2. The major topographic feature of the area is a very wide, terraced upper continental slope of which the Exmouth and Scott Plateaus are a part. This area is separated from the abyssal depths by a lower continental slope which has an average gradient of about $2\frac{1}{2}^{\circ}$.

The continental shelf is about 300 km wide in the north of the survey area and narrows to less than 15 km near North West Cape. The shelf break deviates very little from the 200 m isobath except around numerous small terraces in the northern half of the area, which may be considered as either deep shelf or part of the upper slope. The identification of the shelf break is uncertain in these areas. South of Exmouth Plateau the shelf break is marked by a small but clear change in bottom gradient. The present survey lies mostly outside the 200 m isobath.

The distinction between the lower and upper slope is valid for the whole area except north of Scott Plateau. The upper slope is bounded by the shelf break and a line of distinct increase in gradient at about the 2000 m isobath. South of Exmouth Plateau the upper slope is up to 120 km wide, with its border approximately parallel to the shelf break. Sea-bed gradients within the upper slope are less than $\frac{1}{2}^{\circ}$ except along the sides of minor erosional canyons or along the steps adjoining slope terraces. Most of the upper slope is typified by very smooth topography and low relief.

The lower continental slope is considerably steeper, with gradients as high as 14°. Its outer limits are not clearly defined by any distinct topographic discontinuity but are marked by a zone of transition between slope and abyssal areas.

Erosion of the lower slope has been widespread and gives rise to rugged topography with many canyons. The southern margin of the Exmouth Plateau is notable: its adjoining slope is one of the most consistently steep within the area, and is so linear that it may be related to faulting. Other steep slopes are all related to either deep oceanic ridges or erosional features.

Exmouth Plateau lies 500 km west of Port Hedland and is the largest marginal plateau along Australia's western coast. It is elongated northeast and covers an area of at least 280 000 km^2. The plateau has an overall slope to the west and its shallowest point lies on a central rise at 840 m below sea-level. Topographic features generally strike northeast except along the southern margin, where a small west-trending ridge marks the edge of the plateau. The northern part of the plateau consists of a number of smaller sub-plateaus with an average surface depth of 2000 m. These are surrounded and cut off from the main plateau surface by submarine valleys up to 3000 m deep.

Scott Plateau lies immediately west of Scott Reef and extends seawards for 200 km. Its north-south extent is at least 150 km, but the northern margin was not clearly defined by this survey. The plateau slopes downwards to the southeast from a depth of 1900 m close to its northern and western edges. The western quarter of the plateau is rugged; the remainder is gently undulating, with little relief.

No definite continental rise can be identified in the survey area; but there is a transition zone between continental slope and abyssal plain. This zone varies throughout the area. South of North West Cape there are erosional valleys and levees around the perimeter of the abyssal plain, up to 50 km wide but less than 5 km along the base of the escarpment south of Exmouth Plateau. A number of basement hills and sediment ponds extend westwards to the limit of the survey area. Along the northern margin of the plateau, survey lines mostly parallel the slope and a transition zone is difficult to identify but appears to be narrow and very irregular. At the base of the slope west of Scott Plateau is an abyssal area of gently undulating sediment-covered hills.

Only one survey line crosses the Wallaby Plateau. It shows the plateau reaching to within 2160 m of the surface with an eroded, low relief surface. A terrace is evident at 4000 m on the northern slope of the plateau.

The Cuvier Abyssal Plain lies southwest of Exmouth Plateau at a depth of 5000 m. This is shallower than any other abyssal plain off the west coast. A ridge 1500 m high and 100 km long trends north-northeast across the plain. A similar ridge farther west may be a northern extension of the Wallaby Plateau and possibly forms the western boundary of the Cuvier Abyssal Plain.

The Argo Abyssal Plain lies north of Exmouth Plateau at a depth of 55060 m. No ridges similar to those found on the Cuvier Abyssal Plain have been found here.

4. GRAVITY AND MAGNETIC RESULTS

Gravity Results

Preliminary reduction of observed hourly gravity data is described in Appendix III. The Bouguer anomaly map is presented in Plate 3. Its main feature is a broad regional gravity low over Exmouth Plateau, superimposed on a regional gravity gradient associated with crustal thinning.

The continental shelf-break has little gravity expression and probably does not constitute a major geological discontinuity. Bouguer Anomaly values ranging from -20 mGal to +70 mGal were recorded over the continental shelf. The highest values are associated with the Rankin Platform. The lowest Bouguer anomaly values of -20 mGal are adjacent to, and to the east of, the Rankin Platform and are probably related to thick Cretaceous and Tertiary sediments within the Dampier Sub-basin. Elsewhere on the shelf, Bouguer anomaly values from the Continental Margins Survey vary between +10 mGal and +40 mGal. Previous surveys confined to the shelf showed a slightly greater range.

Over the upper continental slope Bouguer anomaly values range from 0 to +100 mGal. South of North West Cape the gravity pattern is smooth, with values between +10 and +40 mGal, with a gentle regional gradient to the west; the highest values in this region occur immediately west of North West Cape. An area of near-zero Bouguer values over the northern Exmouth Sub-basin is probably related to sediment thickening. This area is flanked to the northeast by high gravity values which are associated with the southern part of the Rankin Platform. A west-trending low northeast of the Rankin Platform is sub-parallel to an adjacent flexure in the shelf break. Gravity values between Scott and Exmouth Plateaus are comparatively high for the upper slope region; however, the larger terraces in this area are associated with local gravity lows superimposed on a regional gradient which rises to the northwest. North of Scott Plateau the gravity gradient is broad and irregular with no abrupt increases to indicate an upper/lower slope division.

The Bouguer anomaly pattern over the lower continental slope is characterized by a 1.0 to 2.0 mGal/km regional gradient which represents thinning of the crust around the continent. Anomaly values range from +50 mGal to 280 mGal and exceed this value only west of Scott Plateau. The gradient is steepest along the southern margin of Exmouth Plateau and to the west of the upper continental slope terraces north of Exmouth Plateau. The gradient is fairly smooth to the southwest of North West Cape and along the southern margin of the Exmouth Plateau, but between latitude 14°S and 17°S it is disrupted by a number of small disturbances.

The gravity field over Exmouth Plateau can be subdivided into areas of differing gravity pattern. The eastern Plateau has a northeast-trending, 20 mGal gravity low about 300 km long and 70 km wide, associated with the downwarped eastern half of Exmouth Plateau. To the southwest of this feature is a westerly trending gravity low. The western half of the Plateau is characterized by a westward gravity rise having a gradient up to 0.7 mGal/km on which are superimposed small amplitude, broad, north-trending gravity highs. The northern part of the plateau has a northwards gradient of 0.4 to 0.5 mGal/km. Along latitude 18°S a gravity step separates the relatively low anomaly values to the south from the higher northern values. At the northwestern corner of the plateau is a +120 to +140 mGal gravity platform whose northern limit was not covered by the survey. This is a distinctive subdivision of the plateau in terms of the Bouguer gravity pattern.

The Bouguer gravity expression of the Scott Plateau is similar to that of the northwest part of Exmouth Plateau, with a gravity platform between the +120 and +130 mGal contours.

The gravity pattern associated with the transition zone between the slope and the Argo and Cuvier Abyssal Plains is a continuation of the regional gradient observed over the lower continental slope. The area west of Exmouth Plateau has a gravity expression which shows no particular trends; the anomaly values range between +170 and +210 mGal. North of this, however, the regional gradient swings eastward and the gravity pattern over the transition zone shows a broad gravity platform at +230 mGal.

The Cuvier Abyssal Plain has an associated gravity platform at +210 mGal with a gradient around its eastern perimeter. No particular gravity trends can be recognized there. The ridges on the western margin and central portion of the plain are characterized by relative Bouguer gravity lows down to +160 mGal.

Only the southeastern perimeter of the Argo Abyssal Plain was surveyed and this shows a similar pattern to the eastern perimeter of the Cuvier Abyssal Plain. Anomaly values, however, are much higher and range up to +280 mGal.

Estimates of crustal thickness have been made in the area by assuming local isostatic equilibrium and a crustal model composed of water (density 1.03 g/cm^3), crust (2.85 g/cm^3), and mantle (3.30 g/cm^3), and a standard continental crust 33 km thick. Estimates of crustal thickness using this model may be excessive since no low density upper layer (i.e. sedimentary cover) has been assumed.

Under these assumptions the calculated crustal thickness is greater than 30 km over the continental shelf and eastern half of the Exmouth Plateau. Elsewhere on the continental margin, east of the lower continental slope, the depth to the base of the crust is about 25 to 30 km. This gradually thins down the continental slope to thicknesses of about 10 to 15 km in the abyssal areas.

Magnetic Results

Preliminary reduction of observed hourly magnetic data is described briefly in Appendix III. The main feature of the magnetic map as presented in Plate 4 is a broad area of low magnetic relief over the major part of the Exmouth Plateau and an east-west zone of very intense anomalies which lies to the north of this.

On the continental shelf magnetic values vary between +100 and -100 gamma except along the eastern end of line 17/068 near Port Hedland, where a +1250 gamma anomaly was recorded. This anomaly is probably related to shallow basement near the western edge of the Pilbara Shelf. The marine survey in 1968 showed strong disturbance of the magnetic field in the same vicinity (Whitworth, 1969).

South of North West Cape the magnetic field over the upper continental slope is characterized by broad anomalies with values in the range 0 to -400 gamma. Immediately west of North West Cape is a magnetic dipole anomaly of -600 and +500 gamma which may indicate the presence of an igneous basement high or intrusion. The upper continental slope from North West Cape to Scott Plateau has magnetic anomalies which range from +350 to -250 gamma. Near Scott Plateau and over the adjacent terraces, the upper slope anomalies are more intense, probably as a result of susceptibility changes within a shallower magnetic basement.

The magnetic field over the lower continental slope as defined by this survey has no consistent character. South of Exmouth Plateau much of the lower slope is covered by a large dipole. The southern and western margins of the plateau are associated for the upper 75% of the slope with a long wavelength magnetic pattern and the lower 25% by a short wavelength pattern which is aligned north-south. Also north of Exmouth Plateau east of 114°E longitude the magnetic field over the lower slope has short wavelength disturbances but the north-south trends are not apparent.

The southern Exmouth Plateau has an associated broad magnetic pattern which deviates very little from the range -150 to -200 gamma. Estimates of depth to magnetic basement were made for this area. They are greater than 8 km below sea level over the central plateau. Results over the northern half of the Plateau, however, show a number of large magnetic dipoles which coincide with the dissected plateau surface in this region. The more westerly of these anomalies appear to have a distinctly shorter wavelength than those to the east, and correspond to a basement change which will subsequently be shown to exist on the seismic records.

The Scott Plateau has associated magnetic anomalies in the range -350 to +200 gamma. A probable dipole of +50 and -350 gamma on the eastern margin of the plateau may indicate the presence of basic volcanics within the sediments or susceptibility changes within basement rocks. The more detailed magnetic field of the western part of the plateau coincident with rugged water bottom suggests that a near surface basement high may form the western margin of the plateau. This is supported by the seismic results.

The abyssal regions in the survey area have an anomaly pattern of north-south elongation with values ranging between +300 and -300 gammas. The ridges to the west of and on the Cuvier Abyssal Plain have associated +150 gamma magnetic highs. The anomaly of largest amplitude recorded over the abyssal regions is at the base of the slope south of Exmouth Plateau; it may be due to intrusives leaking along fractures parallel to the slope. High magnetic values are recorded over adjacent lines; however, no elongation in the anomaly pattern is apparent on the contour map because of the line orientation in this area.

SEISMIC RESULTS

Three seismic section sketches are presented in Figure 4; their locations are marked on the track-map (Plate 1). A map of minimum sediment thickness (Figure 5) was calculated by assuming a sediment velocity of 2000 m/s.

Seismic penetration achieved 3 km but was usually less because of multiple reflections, insufficient energy return from below strong reflectors, or scattering of the signals by rugged or steep sea bottom. Some of the deepest penetration was recorded over the Exmouth Plateau and over the horst blocks along its northern margin.

Very little detail can be seen on the seismic sections over the continental shelf because of the masking effect of multiple reflections and bottom reverberations. However there is a suggestion of faulting to the south of North West Cape and broad folding in the sediments to the east of Exmouth Plateau.

The upper continental slope has a deep sedimentary section. South of North West Cape there is a very widespread unconformity above which the sediments are prograded and thicken downslope. Strata below it are folded and block-faulted. Because of the steep, rugged seabed, very little can be seen of the sedimentary structure of the lower continental slope. However, reflections from sediments up to 1 km deep are recognizable on the seismic sections from the lower slope south of North West Cape.

Figure 4a illustrates the section recorded along line 17/068 over Exmouth Plateau beginning in the east near Port Hedland. Because multiple reflections obscure true events over the continental shelf, it is difficult to see any continuity of particular horizons from the shelf to the plateau. The main structural features shown are a sedimentary basin in the eastern part of Exmouth Plateau and an anticline in the central portion - actually an elongate dome with its axis aligned approximately north-south. The strong unconformity in the west is of wide but unknown extent, since it cannot be traced beneath multiple reflections associated with the shallower areas of the plateau. The section illustrates the sediment ponding features of the slope abyssal plain transition zone mentioned earlier.

Figure 4b is from line 17/079 along the northern margin of the plateau. One prominent unconformity has been marked on this section. Below it the strata are faulted and very broadly folded and contain several unconformities. A number of horst-like features are clearly evident; they are characteristic of northern Exmouth Plateau. The faults that have produced the easternmost blocks are probably parallel to the shelf break, that is, they have a northeasterly trend. The northwest part of the plateau, although topographically connected with Exmouth Plateau, consists of flat-lying sediments resting on a shallow acoustic basement. In this area the basement gives rise to numerous diffractions and coincides with a shorter wavelength magnetic pattern.

Figure 4c is taken from line 18/059 across Scott Plateau. A slope terrace 500 m deep is present in the east. Sediments underlying the terrace are flat-lying, although there is seismic evidence for what may be igneous stocks or diapiric intrusions. A large monoclinal flexure, probably associated with faulting, separates Scott Plateau from the slope terrace. The deepest sediments beneath the plateau lie in a north-trending elongated basin along the eastern margin. The far western part of the plateau has a rugged surface and a shallow basement, probably igneous.

The abyssal plains are covered by up to 1.2 km of sediment overlying an irregular acoustic basement which is probably oceanic basalt. The Cuvier Abyssal Plain has both a thicker sediment accumulation and a far less rugged basement than the Argo Abyssal Plain. The sediments of the Cuvier Plain can be subdivided into an overlying well-stratified layer and a lower acoustically transparent section which thickens towards the continental slope.

Results from 23 seismic refraction probes recorded in the area are listed in Appendix III: they have not yet been interpreted.

INTERPRETATIONS AND CONCLUSIONS

The continental shelf of the northwest margin is particularly wide and has very smooth topography. The seismic sections give a hint of broadly folded structures. Magnetic anomalies are broad and indicate a deep sedimentary section, except in the Pilbara Shelf area, which is marked by a strongly disturbed magnetic field. Bouguer gravity lows are associated with the Dampier and Exmouth Sub-basins and a +70 mGal gravity high is associated with the Rankin Platform.

With the exception of Exmouth Plateau, sediment is thinner on the upper continental slope than on the shelf. The coincidence of a large magnetic dipole and a Bouguer anomaly high immediately west of North West Cape indicates a large basic intrusion or basement uplift. Low-amplitude magnetic disturbances, possibly dipolar, that were recorded in the vicinity of Scott Plateau may be due to basic igneous rocks.

The lower continental slope is eroded and has an average gradient of about $2\frac{1}{2}^{\circ}$. Evidence for a sedimentary sequence thicker than 1 km on this part of the continental slope was found only south of North West Cape. Gravity and magnetic trends are continuous across the boundary between the upper and lower slopes. The rising regional Bouguer anomaly gradient over the entire slope is due to thinning of the crust in a seaward direction.

Exmouth Plateau south of latitude 18°S is a distinct geophysical province. Topographic features generally strike northeast and are parallel to the geophysical trends. The most prominent feature of the stratigraphic sequence is a widespread unconformity beneath which the rocks are block-faulted and folded. Gravity trends can be related to structure in this unconformity as well as to folding above it. North of latitude 18°S the plateau consists of a number of horst blocks which form irregular plateaus with an average surface depth of 2000 m. An unconformity within the sediments of the northern area separates flat-laying eroded strata from a gently folded sequence below. The horst blocks correspond to magnetic highs, evidently indicating that the faulting has displaced magnetic basement. The northwest corner of the plateau has an associated short-wavelength magnetic anomaly pattern and a distinctive seismic basement. This basement region belongs to a geological province which differs from the rest of the survey area.

Scott Plateau is fault-controlled on its eastern margin and lined by basement ridges along its western margin. Sedimentary thickness reaches 1.2 km.

North-trending magnetic anomalies and topographic ridges in abyssal areas suggest that the crust there is oceanic and has probably spread in an easterly direction.

In the entire area there are two major structural directions. Northeast orientation is shown by:

- the continental shelf break,
- the continental slope strike, both north and south of Exmouth Plateau,
- the topographic and Bouguer anomaly features of that plateau,
- faulting associated with the Rankin Platform,
- faulting associated with the horst blocks on the north of the Exmouth Plateau.

West to northwest alignment is shown by:

- the southern escarpment of Exmouth Plateau,
- a Bouguer anomaly feature along the southern border of that plateau,
- a major flexure in the bathymetry and Bouguer anomaly contours near latitude 19°S,
- the northern limit of the quiet magnetic zone associated with the southern part of the Exmouth Plateau.

The northeast structural direction may parallel a postulated axis of Early Cretaceous rifting. The northwest direction could relate to fracturing parallel to the subsequent plate motion.

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APPENDIX I

EQUIPMENT ON BOARD M/V LADY CHRISTINE, 1972

SEISMIC

Amplifiers: SIE PT 700

Recorders: four E.P.C. 4100

6 channel hydrophone streamer: C.G.G. manufacture.

Single channel streamer: GEOTECH.

Tape recorder: 14 channel AMPEX F.M.

Energy Source: Single electrode pair teledyne sparker; 120 Kilojoules.

GRAVITY AND MAGNETIC

Gravity meter: LaCoste and Romberg stabilized platform air-sea gravity meter (serial no. S-24).

Magnetometer: Varian proton precession.

DATA ACQUISITION SYSTEM

Computer: HP2116B, 16K word memory core.

Interface: SERCEL

A/D Converter: HP2301B.

Tape Recorder: HP7970A, 32 channel, 556 bpi

Teletype: ASR 35

NAVIGATION

Satellite receiver: I.T.T.

Computer: Digital PDP 8/1

Gyrocompass: Anschutz.

Sonar Doppler: Marquardt

Electronic log: Chernikeeff

Pressure log: Hartmann and Braun

V.L.F. receivers: Tracor (used in range-range mode).

OTHER EQUIPMENT

Fathometers: One ELAC, one ATLAS-EDIG, one EDO WESTERN

One DIGITRACK, Raytheon bathymetric system

Anemometers: Alcyon

Analogue recorders: Westronics and Linax

D/A converts: SERCEL and H.P. 580 A.

APPENDIX II

Refraction Probes

(a) Survey 17.

START TIME (Day - hours)	STOP TIME (Day - Hours)	NO. OF S'BUOYS	DIRECT WAVE	WATER DEPTH (metres)	VELOCITIES (m/s)
36. 0622	36. 0758	1	NONE	277	NONE
41. 0949	41. 1108	2	NONE	1110	NONE
54. 0217	54. 0374	1	GOOD	1440	1800
					3490
56. 0143	56. 0250	2	GOOD	1430	1945
					3280
59. 0722	59. 0852	1	NONE	2670	NONE
59. 2244	60. 0013	1	GOOD	2490	1600
					3700
65. 2335	66. 0103	1	POOR	2680	2660
75. 1403	75. 1530	1	POOR	1962	2000
					2840
76. 1648		1	NONE	2345	BUOY FAILURE
80. 1240	80. 1410	1	POOR	1880	2100
					3100
					3350
					3700
80. 2337	81. 0050	1	POOR	1903	2100
					2500
82. 0510		2	POOR		1800
					2400
					3050
					3400
					4100
83. 1130		2	NONE	500	BUOY FAILURE

(b) Survey 18

START TIME (Day - hours)	STOP TIME (Day - Hours)	NO. OF S'BUOYS	DIRECT WAVE	WATER DEPTH (metres)	VELOCITIES (m/s)
07. 0547	07. 0710	1	NONE	1900	
10. 1025	10. 1150	1	NONE	3100	
37. 1143	37. 1310	1	NONE	3300	3825
					5200
39. 0549	39. 0710	1	GOOD	2140	2667
41. 0416	41. 0540	1	NONE	2625	2870
					3875
45. 0218	45. 0427	1	NONE	1875	3584
					4638
					6856

APPENDIX III

GRAVITY AND MAGNETIC DATA REDUCTION OF HOURLY VALUES

A. GRAVITY DATA REDUCTION

Ties to the stations of the Australian Isogal Network provided estimates of the drift characteristics of the gravity meter.

Free Air Anomaly

Latitude corrections and Eotvos corrections were applied to the observed gravity values to produce the free air anomaly. The gravity field of the International Reference Spheroid was used to derive the latitude effect:

$$GL = 978.049\ (1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi)$$

where ϕ is the latitude.

The Eotvos correction was calculated using the following expression:

$$GE = 7.5\ (\cos \phi) Ve,$$

where ϕ is the latitude and Ve is the eastward component of ship's speed in knots. Tidal Corrections have been omitted.

Bouguer Anomaly

The Bouguer correction was calculated by subtracting the gravity effect of the sea-bed substituting the water layer with the same density as sediments on the sea floor. The equation used is:

$$g - 2\rho\ Gd,$$

where G is the gravitational constant, ρ is the density difference between sea floor sediments and the ocean, assumed to be 1.2 g/cm^3, and d is the depth of sea water.

The correction is computed from the gravity effect of an infinite slab and thus is not valid in areas where water depths change rapidly. However, an approximate correction for sea bottom topography is better than none at all. Thus the discussion of the gravity field presented in this report is based on the Bouguer anomaly contour data. Terms such as gravity gradient and gravity intensity infer Bouguer anomaly gradient and Bouguer anomaly intensity.

B. MAGNETIC DATA REDUCTION

The observed total field magnetic data were corrected for the diurnal effect computed from shore station readings and for the magnetic field of the International Geomagnetic Reference Field (IGRF) as follows (C.G.G., 1974b)

$$\text{Anomaly} = \text{Observed} - \text{IGRF} - \text{diurnal}$$

Appendix IV (a) Offshore Drilling Operations

NAME	LAT.	LONG.	DEPTH ft. below S.L.	COMPANY	YEAR COMPLETED	BMR SUBSIDY NO.
LONG ISLAND	21°37'	114°41'	7061	WAPET	1966	66/4261
ONSLOW NO. 1.	21°45'	114°52'	9835	WAPET	1966	66/4218
MUIRON NO. 1.	21°39'	114°21'	5857	WAPET	1967	67/4259
PEAK NO. 1.	21°36'	114°30'	7026	WAPET	1967	67/4260
OBSERVATION	21°44'	114°32'	7510	WAPET	1967	67/4275
ASHMORE REEF NO.1	12°10'	123°05'	12843	BOC	1968	67/4264
HOPE ISLAND NO.1	22°09'	114°28'	4680	WAPET	1968	68/2003
LEGENDRE NO.1	19°40'	116°43'	11303	BOC	1968	68/2016
DAMPIER NO.1	19°52'	116°00'	13588	BOC	1969	68/2062
PETREL NO.1	12°49'	126°28'	130671	ARCO	1969	69/2001
MADELEINE NO. 1	19°38'	116°21'	14526	BOC	1969	69/2006
ANCHOR NO.1	21°32'	114°42'	10002	BOC	1969	69/2019
PENDOCK I.D. NO.1	23°17'	114°20'	8129	GENOA OIL	1969	69/2020
LACEPEDE NO.1A	17°05'	121°26'	7500	BOC	1970	70/426
LIVEQUE NO. 1	15°45'	122°00'	2951	BOC	1970	70/670
ENDERBY NO. 1	20°09'	116°24'	7051	BOC	1970	70/737
LEGENDRE NO.2	19°37'	116°47	11871	BOC	1970	70/769
LYNHER NO. 1	15°56'	121°04'	8940	BOC	1970	70/948
SCOTT REEF NO.1.	14°04'	121°49'	15520	BOC	1971	71/82
BEDOUT NO. 1	18°14'	119°23'	10082	BOC	1971	71/435
RANKIN NO.1	19°47'	115°44'	13486	BOC	1971	71/495
DE GREY NO.1	19°29'	117°95'	6850	BOC	1971	71/616
ANGEL NO.1	19°30'	116°35'	11190	BOC	1972	71/617

Abbreviations:

WAPET: West Australia Petroleum Pty Ltd

BOC: Burmah Oil Company (Australia)

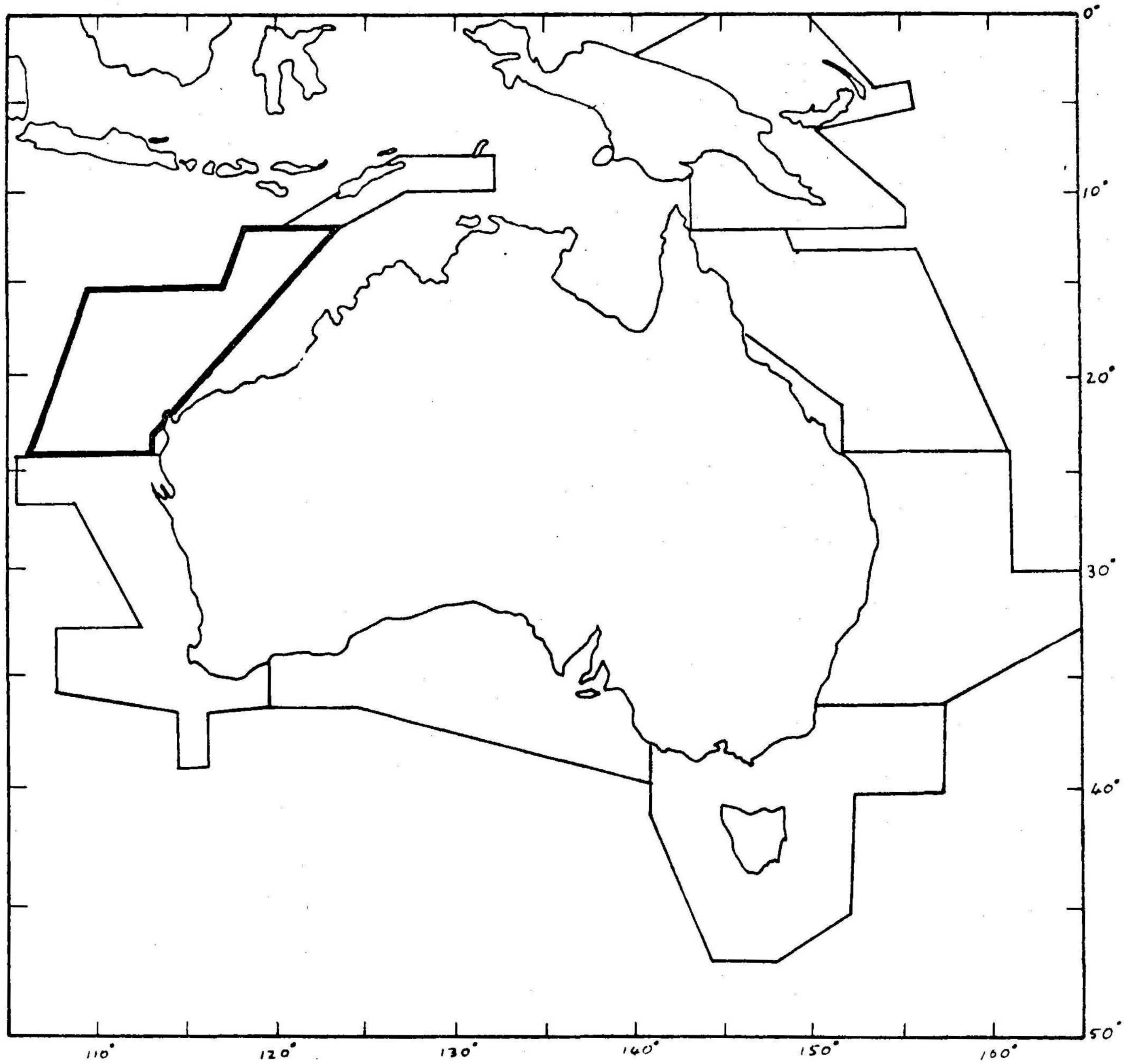
APPENDIX IV (b) Offshore Geophysical Survey

NAME	TYPE	OPERATOR	CONTRACTOR	YEAR	BMR SUBSIDY NO.
XMOUTH GULF	M/S	WAPET	SEISMOGRAPH SERVICE	1961	62/1563
BARROW ISLAND	M/S	WAPET	G.S.I.	1962	63/1536
Rowley Shoals, Scott Reef and Sahul Bank	A/M	MID EASTERN OIL and WOODSIDE	AERO SERVICE	1963	63/1709
NORTHWESTERN SHELF	M/S	BOC	WESTERN GEOPHYSICAL	1964	64/4529
OFFSHORE CANNING	A/M	WAPET	ADASTRA HUNTING	1965	65/4614
MONTEBELLO - MERMAID SHOAL	M/S	BOC	WESTERN GEOPHYSICAL	1965	65/11015
WEST CARNARVON	M/S	CANADIAN SUPERIOR	G.S.I.	1966	66/11089
RANKIN TROUBADOUR	M/S	BOC	WESTERN GEOPHYSICAL	1966	66/11104
OFFSHORE ONSLOW	A/M	WAPET	ADASTRA HUNTING	1967	67/4628
CAPE RANGE	GRAV	WAPET	-		67/4828
ASHMORE REEF	M/S	BOC	WESTERN GEOPHYSICAL	1967	67/11144
LONG ISLAND	M/S	WAPET	WESTERN GEOPHYSICAL	1967	67/11153
WEST GNARRALOO	M/S	CANADIAN SUPERIOR	G.S.I.	1967	67/11158
MUIRON	M/S	WAPET	G.S.I.	1967	67/11167
SCOTT CARTIER	M/S	BOC	WESTERN GEOPHYSICAL	1967	67/11173
WEST BATHURST	M/S	CANADIAN SUPERIOR	NAMCO GEOPHYSICAL	1967	67/11183
WALLAL	M/S	WAPET	G.S.I.	1967	67/11208
OFFSHORE CANNING-SERINGAPATEN	M/S	BOC	WESTERN GEOPHYSICAL	1968	68/3027
HELBY	M/S	WAPET	WESTERN GEOPHYSICAL	1968	68/3045
LEGENDRY - MARIE	M/S	BOC	WESTERN GEOPHYSICAL	1969	69/3005
BEDOUT	M/S	WAPET	G.S.I.	1969	69/3013
FRASER	M.S	WAPET	G.S.I.	1969	69/3015
WALLAL	A/M	WAPET	HUNTING	1969	69/3037
ADELE SCOTT	M/S	BOC	WESTERN GEOPHYSICAL	1969	69/3038
CANNING	M/S	WAPET	G.S.I.	1970	70/158
TRYAL EVANS	M/S	BOC	WESTERN GEOPHYSICAL	1970	70/245
TRIMOUILLE - DILLON	M/S	BOC	WESTERN GEOPHYSICAL	1970	70/976
SCOTT REEF	M/S	BOC	WESTERN GEOPHYSICAL	1971	71/481
RANKIN TREND	M/S	BOC	WESTERN GEOPHYSICAL	1971	71/538
ASHMORE - SAHUL	M/S	BOC	WESTERN GEOPHYSICAL	1971	71/667
MONTE BELLO - TURTLE	M/S	BOC	WESTERN GEOPHYSICAL	1972	72/509
BROWSE BASIN	M/S	BOC	G.S.I.	1972	72/1017
NORTH REEF	M/S	BOC	G.S.I.	1972	72/1017

Code: M/S : marine seismic survey
A/M : aeromagnetic survey
GRAV: gravity survey

Abbreviations: WAPET : West Australian Petroleum Pty. Ltd.
BOC : Burmah Oil Company (Australia)
GSI : Geophysical Services International

FIGURE 1



GEOPHYSICAL RESULTS FROM NORTH WESTERN MARGIN

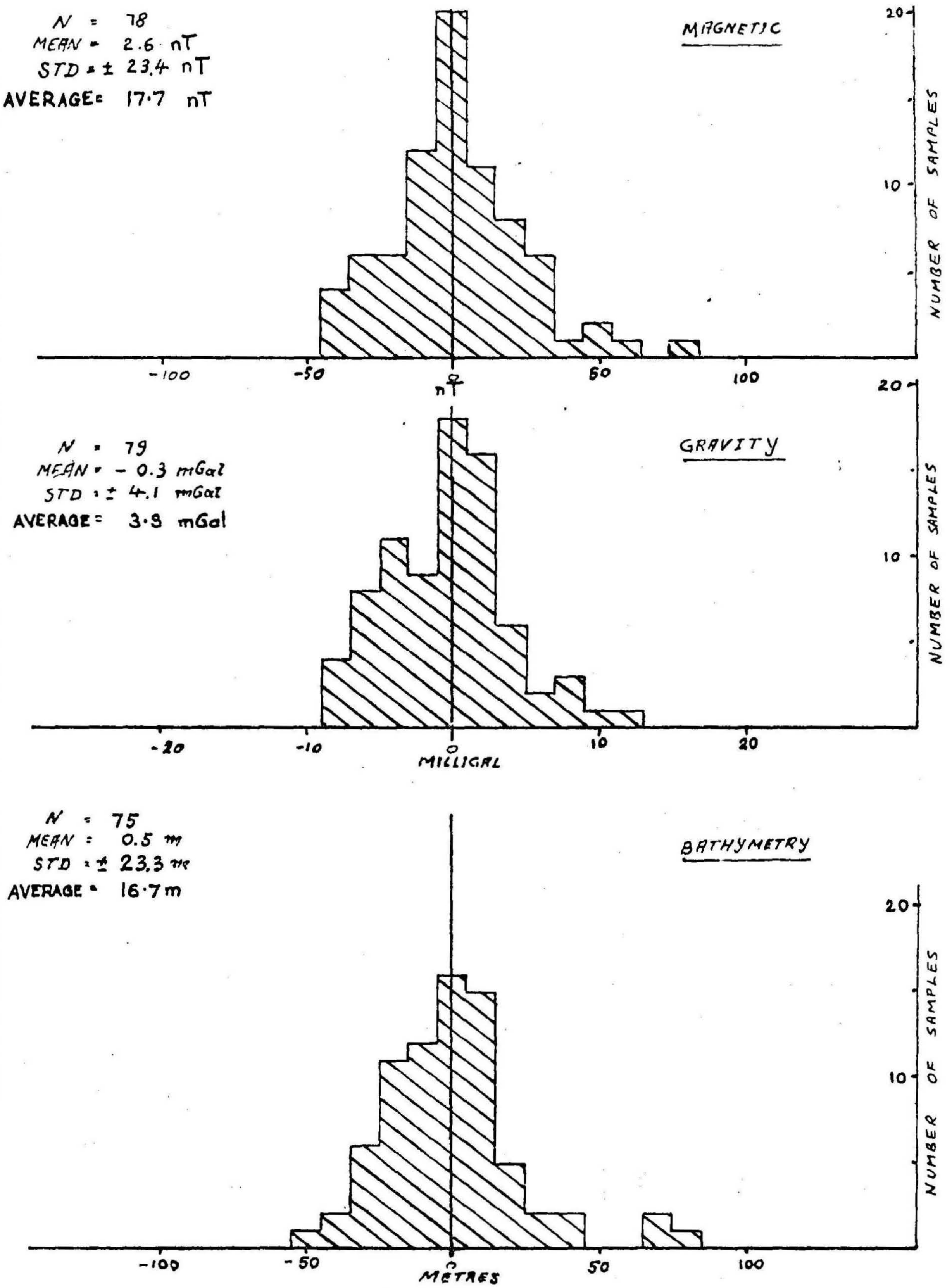
LOCALITY MAP

(Based on A/B0-62A)

Record No. 1975/101

A/B8-77A

FIGURE 2



HISTOGRAM OF

MAGNETIC, GRAVITY & BATHYMETRIC MISTIES

Record No. 1975/101 WA/B8-51A

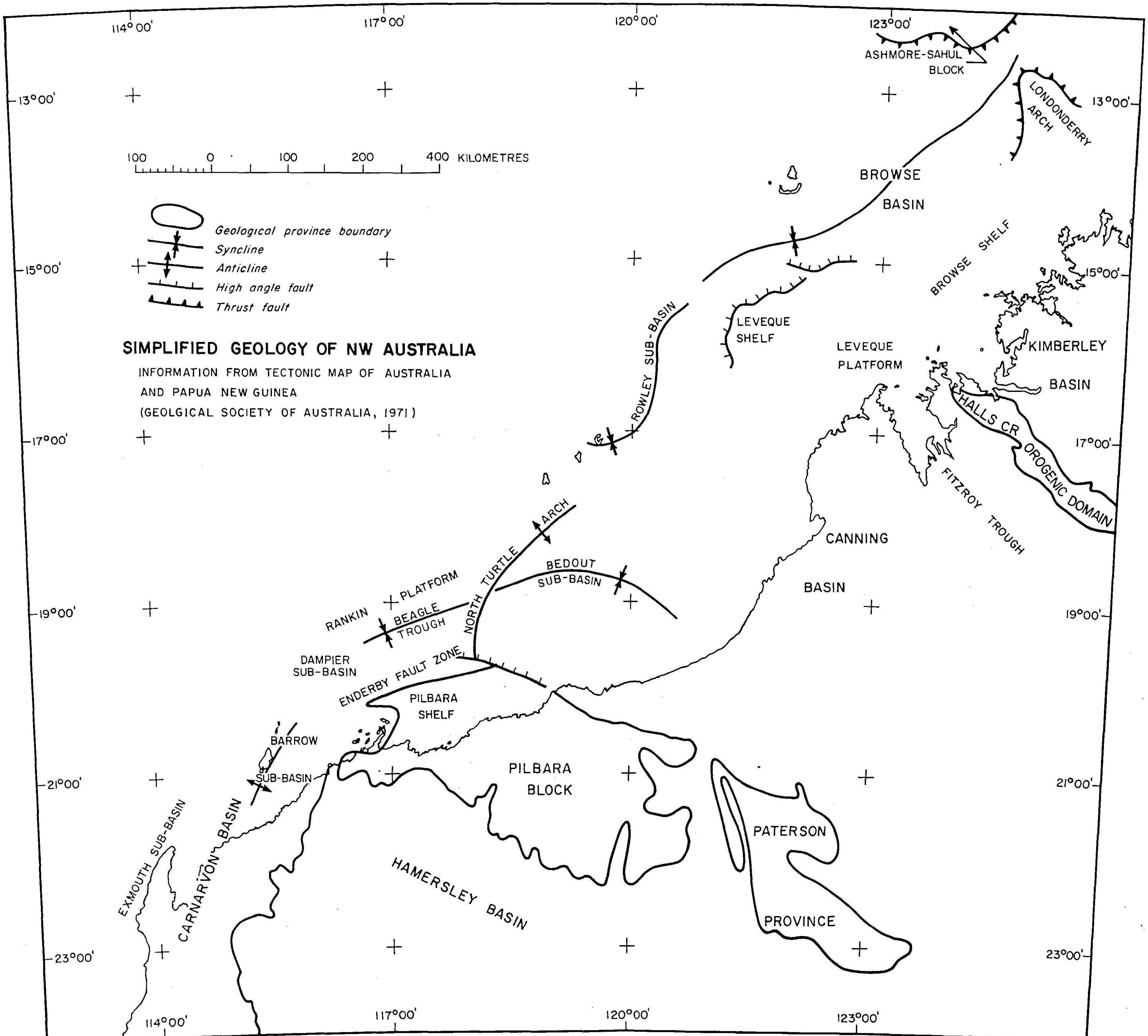
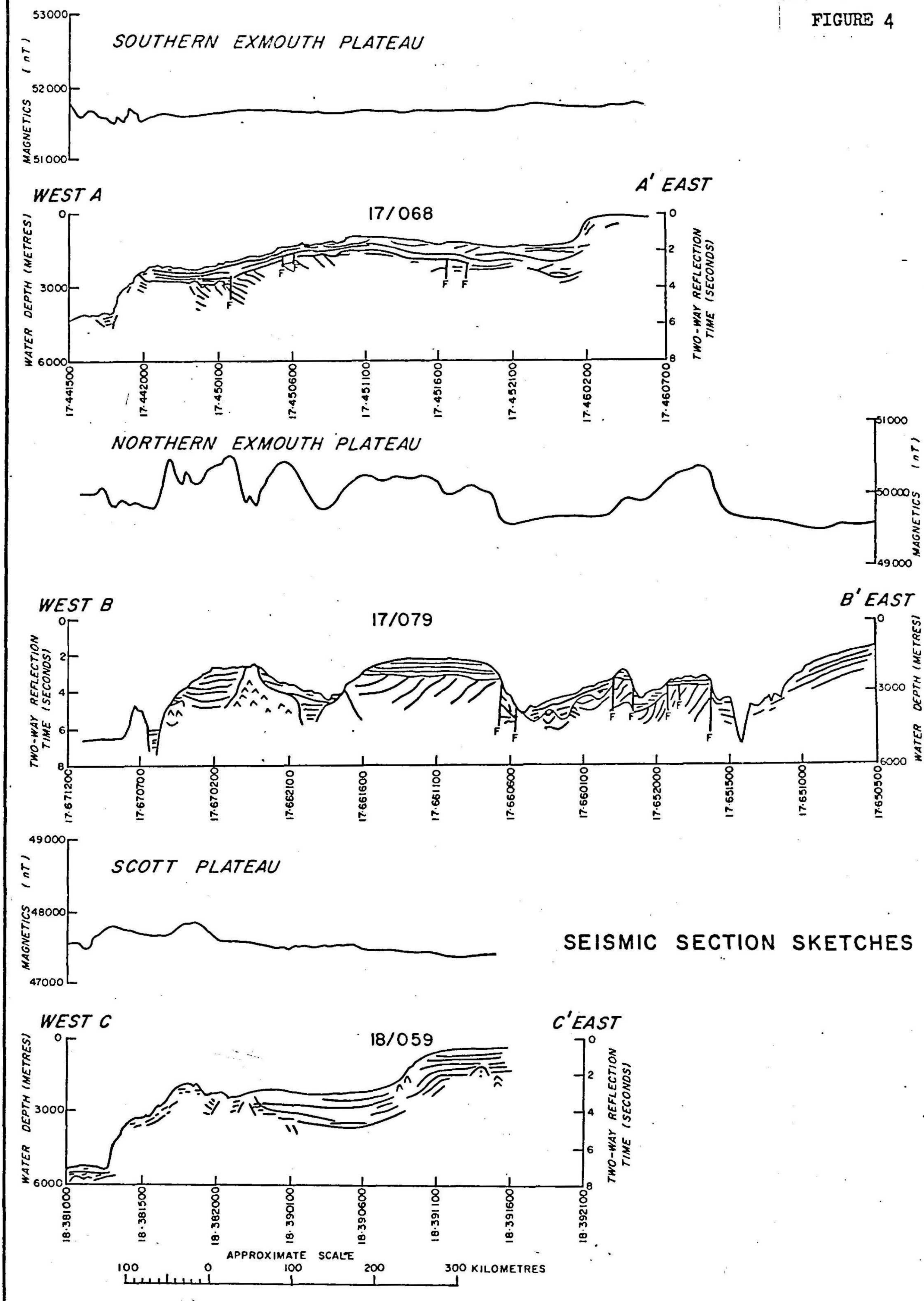

114° 00'
117° 00'
120° 00'
123° 00'
13° 00'
15° 00'
17° 00'
19° 00'
21° 00'
23° 00'
100 0 100 200 400 KILOMETRES
Geological province boundary
Syncline
Anticline
High angle fault
Thrust fault
SIMPLIFIED GEOLOGY OF NW AUSTRALIA
INFORMATION FROM TECTONIC MAP OF AUSTRALIA
AND PAPUA NEW GUINEA
(GEOLGICAL SOCIETY OF AUSTRALIA, 1971)
ASHMORE-SAHUL
BLOCK
LONDONDERRY
ARCH
BROWSE
BASIN
BROWSE SHELF
LEVEQUE
SHELF
LEVEQUE
PLATFORM
KIMBERLEY
BASIN
HALLS CR
OROGENIC DOMAIN
FITZROY TROUGH
ROWLEY SUB-BASIN
NORTH TURTLE ARCH
BEDOUT
SUB-BASIN
CANNING
BASIN
RANKIN PLATFORM
BEAGLE
TROUGH
DAMPIER
SUB-BASIN
ENDERBY FAULT ZONE
PILBARA
SHELF
BARROW
SUB-BASIN
PILBARA
BLOCK
PATERSON
PROVINCE
EXMOUTH SUB-BASIN
CARNARVON BASIN
HAMERSLEY BASIN

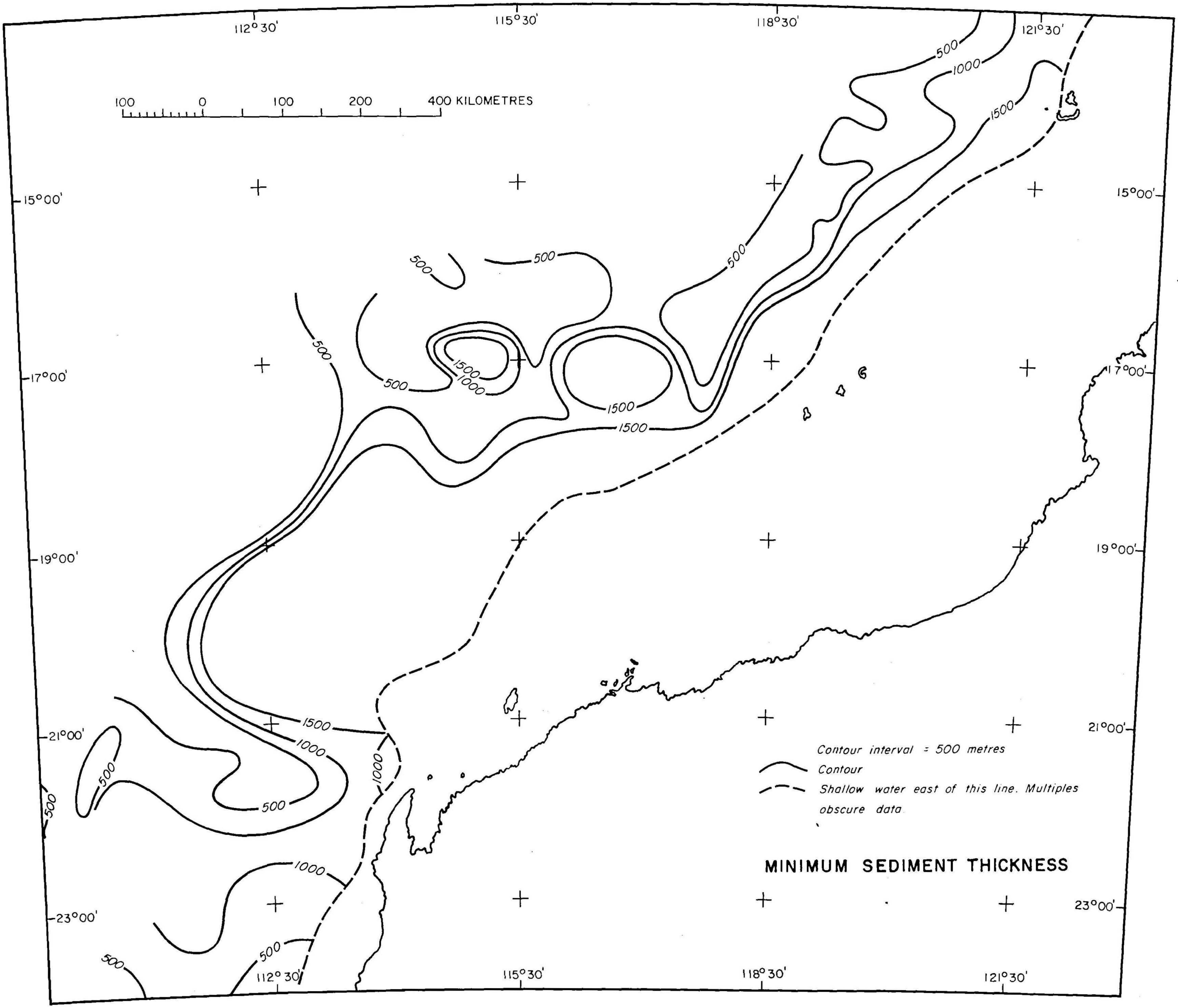
FIGURE 4



SEISMIC SECTION SKETCHES

Record No. 1975/101

WA/B8-93A



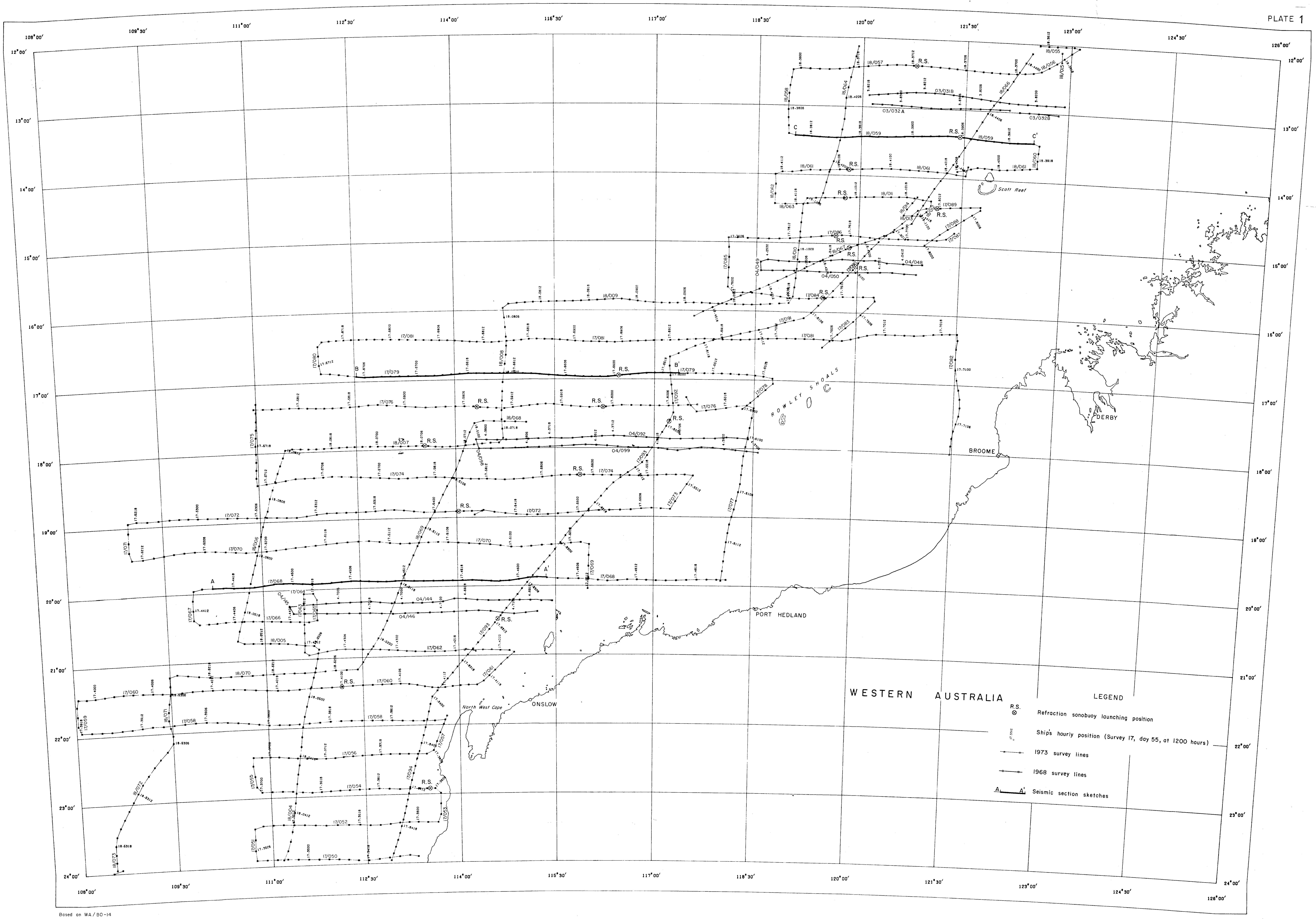
112° 30'
115° 30'
118° 30'
121° 30'
100 0 100 200 400 KILOMETRES
15°00'
17°00'
19°00'
21°00'
23°00'
500
1000
1500
Contour interval = 500 metres
Contour
Shallow water east of this line. Multiples obscure data
MINIMUM SEDIMENT THICKNESS

NORTH WESTERN MARGINS

PLOTTED 73/08/08

AUSTRALIA 1: 2500000

PLATE 1



Based on WA/80-14

AUSTRALIAN NATIONAL SPHEROID
SIMPLE CONICAL PROJECTION
WITH TWO STANDARD PARALLELS
AT 18° 0' AND 36° 0' SOUTH

B.M.R. 1970-73 MARINE SURVEYS

TRACK CHART

NORTH WESTERN MARGINS

AREA 7

WA/B8-34-2

NOTE: The information contained in this map has been obtained by the Department of Minerals and Energy, as part of the policy of the Australian Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus or statement without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

KILOMETRES 50 0 50 100 150 200 250
NAUTICAL MILES 0 50 100

The ship's position is plotted from hourly values based on preliminary data and tied to the satellite navigation fixes. The track line is a linear interpolation between these hourly positions. No adjustments have been applied for misties at traverse intersections.

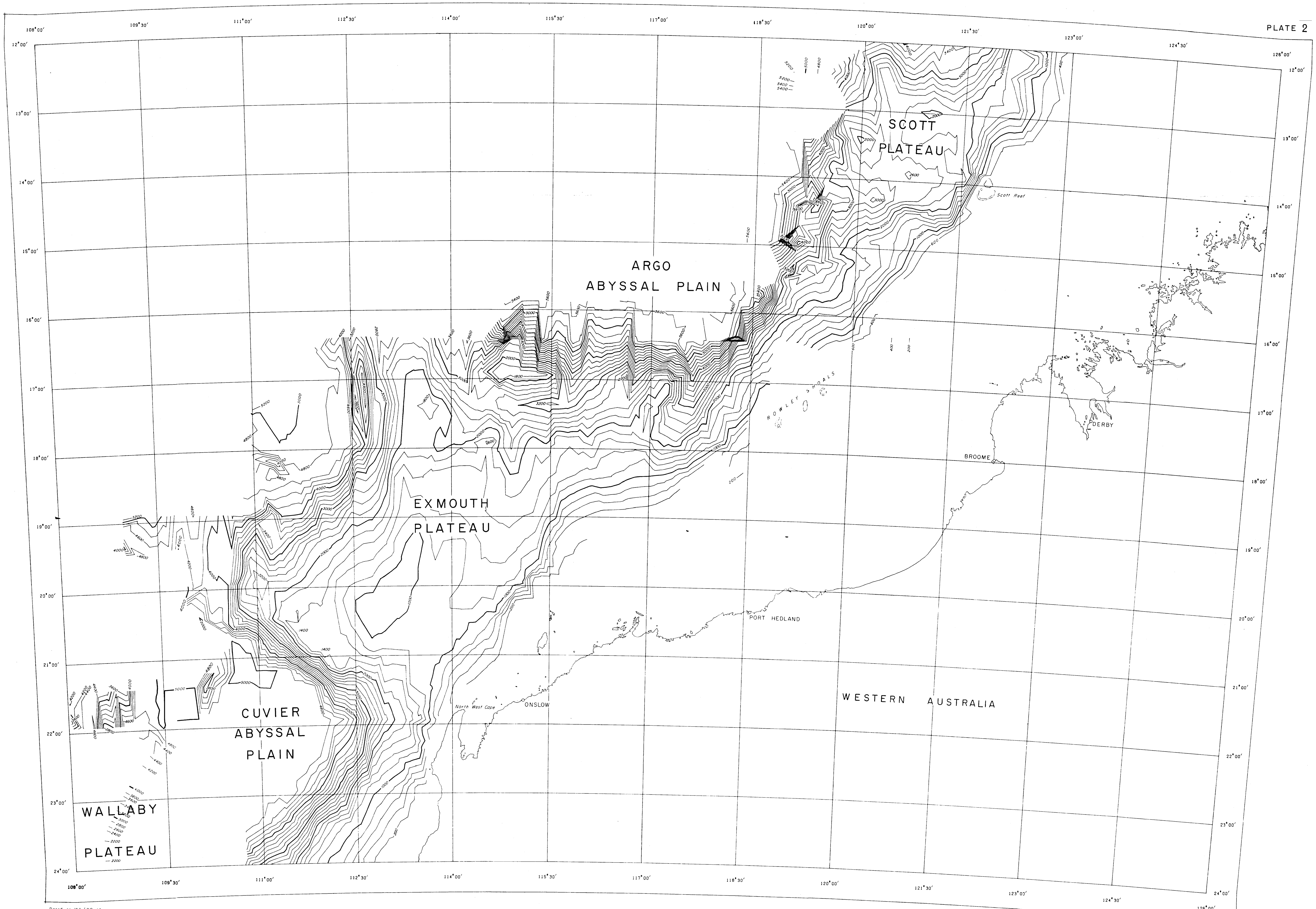
Record No. 1975/101

NORTH WESTERN MARGINS

PLOTTED 73/08/14

AUSTRALIA 1: 2500000

PLATE 2



Based on WA/80-14

AUSTRALIAN NATIONAL SPHEROID
SIMPLE CONICAL PROJECTION
WITH TWO STANDARD PARALLELS
AT 18° 0' AND 36° 0' SOUTH

B.M.R. 1970-73 MARINE SURVEYS

WATER DEPTH (METRES)

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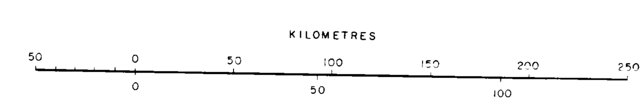


Contour interval 200 metres

Water velocity assumed constant at 1500 m/s

Data used are preliminary, and are based on hourly values extracted on board the survey vessel. No adjustments have been applied for misties at traverse intersections.

Contour lines are drawn by computer using a triangular contouring program. A triangular plate is defined by three adjacent stations whose circumscribing circle contains no other stations. Linear interpolation is then used on the triangular plate. Should any side of an acceptable triangle exceed 40 nautical miles, that plate is not contoured.

NORTH WESTERN MARGINS

AREA 7

WA/88-30-2

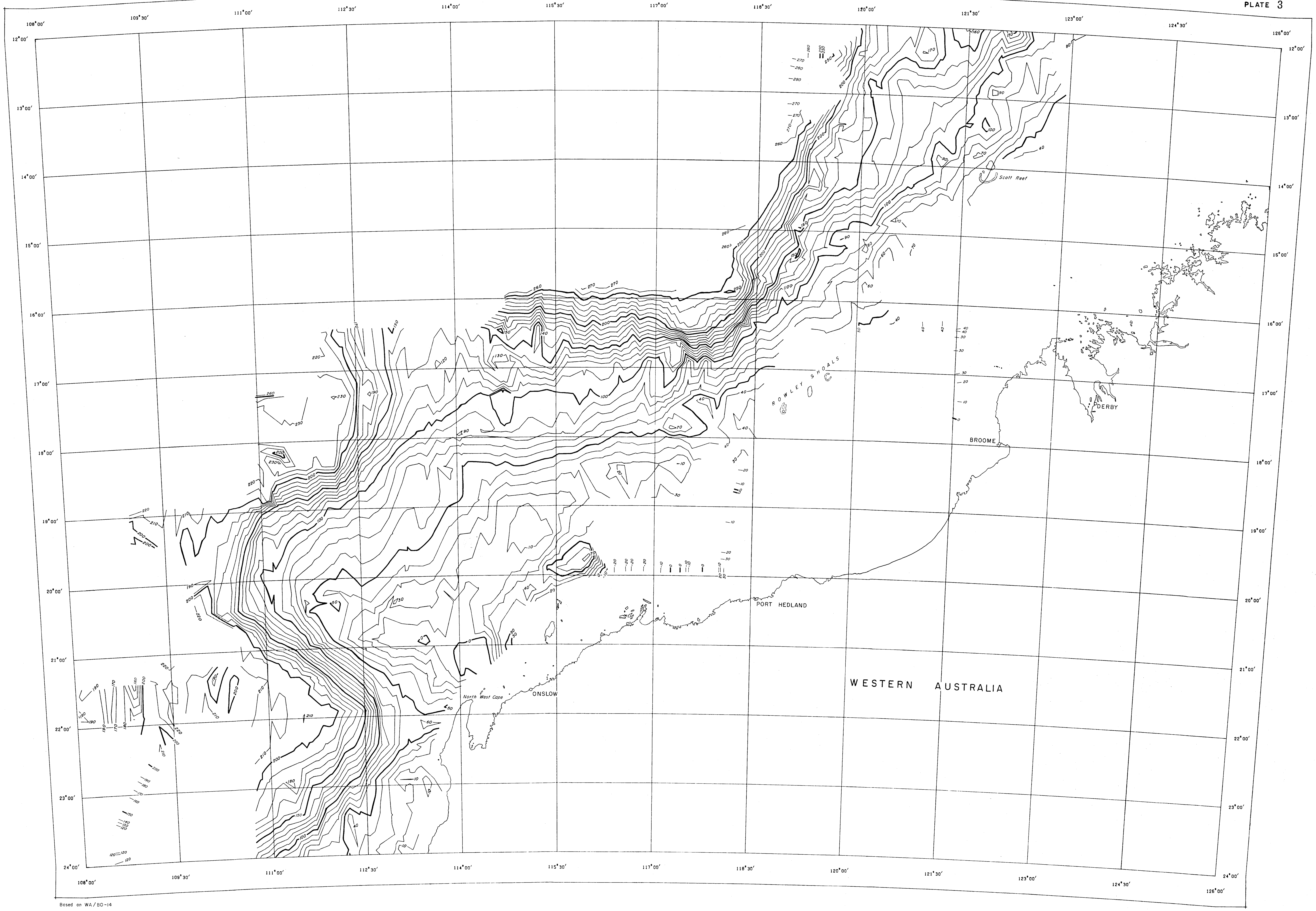
Record No. 1975/101

NORTH WESTERN MARGINS

PLOTTED 73/08/14

AUSTRALIA 1: 2500000

PLATE 3



Based on WA/BO-14

AUSTRALIAN NATIONAL SPHEROID
SIMPLE CONICAL PROJECTION
WITH TWO STANDARD PARALLELS
AT 18° 0' AND 36° 0' SOUTH

B.M.R. 1970-73 MARINE SURVEYS

BOUGUER ANOMALIES

DENSITY = 2.20 GMS/CC

NORTH WESTERN MARGINS

AREA 7

WA/B2-62-1

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KILOMETRES
50 0 50 100 150 200 250
0 50 100
NAUTICAL MILES

Contour interval : 10 milligals

Data used are preliminary, and are based on hourly values extracted on board the survey vessel. No adjustments have been applied for misties at traverse intersections.

Contour lines are drawn by computer using a triangular contouring program. A triangular plate is defined by three adjacent stations whose circumscribing circle contains no other stations. Linear interpolation is then used on the triangular plate. Should any side of an acceptable triangle exceed 40 nautical miles, that plate is not contoured.

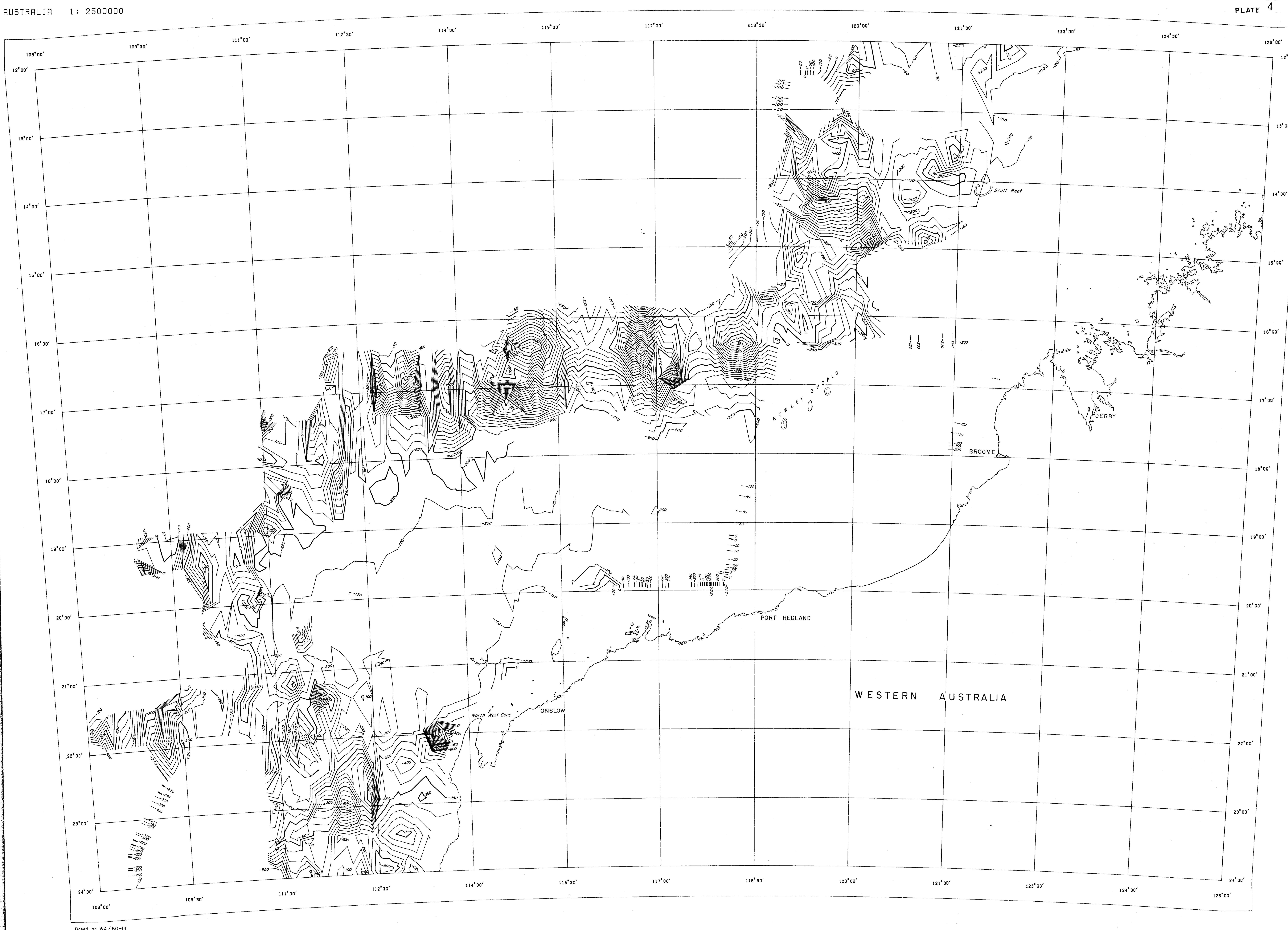
Record No. 1975/101

NORTH WESTERN MARGINS

PLOTTED 73/08/14

AUSTRALIA 1: 2500000

PLATE 4



Based on WA/80-14

AUSTRALIAN NATIONAL SPHEROID
SIMPLE CONICAL PROJECTION
WITH TWO STANDARD PARALLELS
AT 18° 0' AND 36° 0' SOUTH

B.M.R. 1970-73 MARINE SURVEYS

MAGNETIC ANOMALIES

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KILOMETRES
50 0 50 100 150 200 250
0 50 100
NAUTICAL MILES

Magnetic values reduced to the International Geomagnetic Reference Field
Contour interval 50 gammas

Data used are preliminary, and are based on hourly values extracted on board the survey vessel. No adjustments have been applied for misties at traverse intersections.

Contour lines are drawn by computer using a triangular contouring program. A triangular plate is defined by three adjacent stations whose circumscribing circle contains no other stations. Linear interpolation is then used on the triangular plate. Should any side of an acceptable triangle exceed 40 nautical miles, that plate is not contoured.

NORTH WESTERN MARGINS

AREA 7

WA/B1-3-1

Record No. 1975/101