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GEOPHYSICAL RESULTS FROM THE GULF OF PAPUA AND BISMARCK SEA

by

L.A. TILBURY

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CONTENTS

SUMMARY

Continuous reflection seismic, gravity, and magnetic profiles were recorded along 14 500 nautical miles of systematic traverses in the Gulf of Papua and the Bismarck Sea. The traverse grid consisted of north-south lines at 20-nautical-miles spacing in the Bismarck Sea and east-west lines at 10-nautical-miles spacing in the Gulf of Papua. Regional reconnaissance lines were surveyed around southeast Papua.

Results were generally good although the standard deviations of the misties seemed high. The standard deviations for bathymetry, gravity, and magnetics were 37.8m, 5.6 mGal, and 48.9 nT, respectively.

Strong magnetic lineations with northwest, northeast, and easterly trends were recorded in the Bismarck Sea and correlate with seamount chains and basement ridges. The major east-west anomaly band correlates with the Bismarck Sea seismicity lineament and an almost continuous seamount chain/ basement ridge extending across the Bismarck Sea from New Ireland to the New Guinea coast near Wewak. Gravity anomalies indicate a depth to mantle of about 20 km in the eastern portion of the Bismarck Sea. The crust thickens to over 40 km along the New Guinea coast and to about 25 km along the West Melanesian Arc. Sediments up to 2 km thick have accumulated behind basement ridges around the peripheries of the Bismarck Sea.

A very rough basement topography, with little overlying sediment, is characteristic of the Woodlark Basin. Intense east-west magnetic lineations correlate with seamounts and basement ridges. The easterly extension of the offshore Cape Vogel sedimentary basin between the Trobriand and D'Entrecasteaux Islands has been outlined. Within the basin a major unconformity (?Mid-Miocene) is present between gently folded sediments and the overlying flat-bedded sediments.

Seismic and gravity results defined the southwest extent of the Papuan Basin. The Aure Trough, the depositional axis of the basin, extends southeast to 10°S and is marked by a Bouguer anomaly low. The region is magnetically quiet. A major erosional unconformity, probably Mid-Miocene, is apparent throughout the Gulf region.

1. INTRODUCTION

Between September and December 1970, the Bureau of Mineral Resources (BMR) carried out a gravity, magnetic, and seismic survey in the Gulf of Papua and the Bismarck Sea. The survey was the fourth major marine survey conducted by BMR and was contracted by Compagnie Generale de Geophysique (CGG). The objectives of the survey were to investigate the extent of offshore sedimentary basins, the sedimentary structures, and the tectonics of the area.

Operations

The survey lasted for 69 operational days during which 14 496 n miles were traversed. The area surveyed is outlined in Figure 1. The M.V. Hamme, a converted North Sea trawler, was used as the survey vessel. Personnel on board included 16 CGG technicians and geophysicists, 2 to 3 BMR representatives, 7 ships' officers, and 7 crew.

Two preliminary cruises, from Sydney to Port Moresby and offshore from the Fly River delta, were used for testing the newly installed equipment. These cruises were followed by the five cruises of Survey 05 which were sailed between 4 September 1970 and 7 December 1970. Details of the cruises, the areas surveyed, and the mileages covered are shown in Table 1.

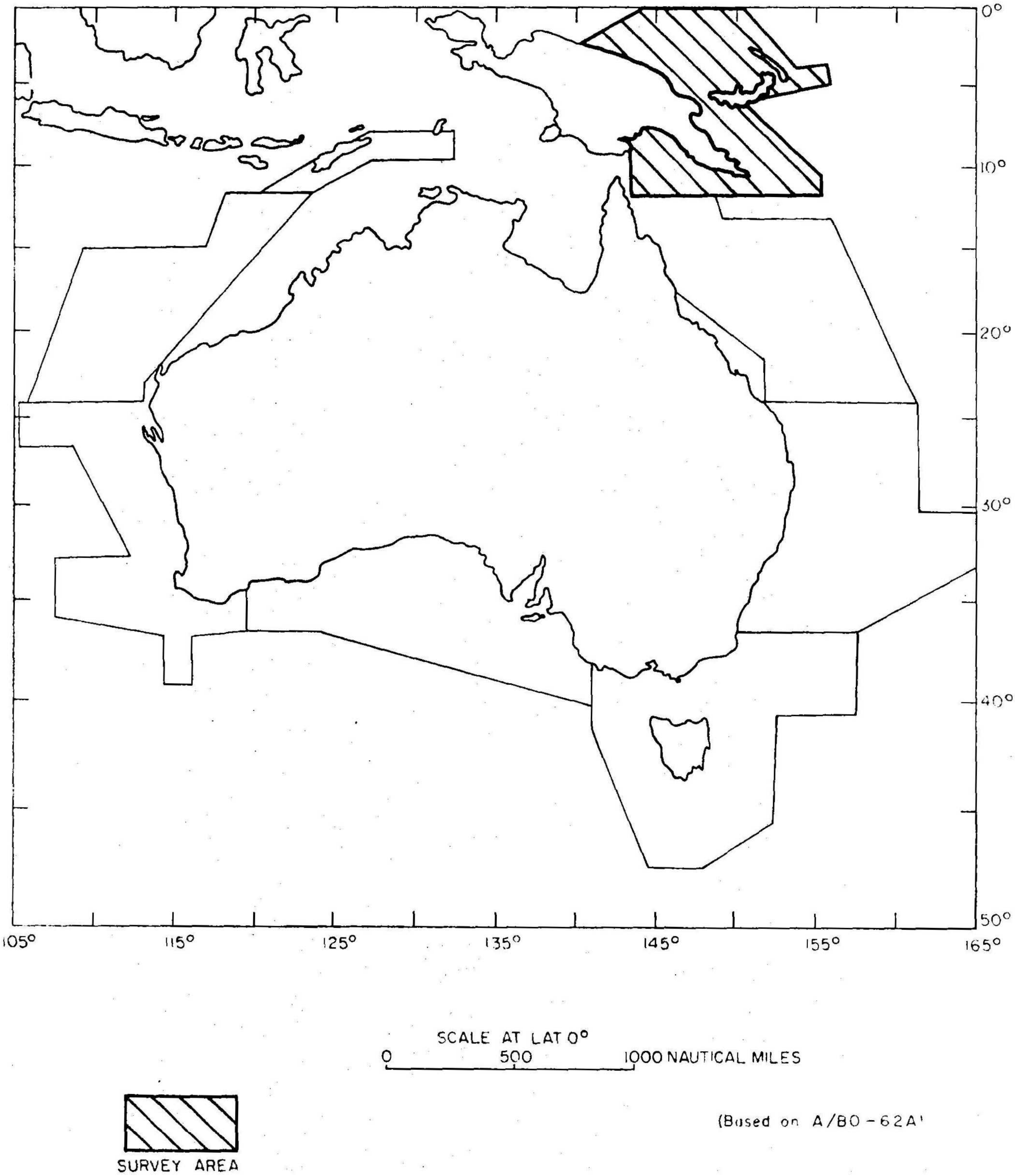
The traverse network in the Bismarck Sea consisted of north-south lines at 20 n miles spacing. Additional lines gave 10 n miles spacing along the southern margin of the Bismarck Sea. Most lines around southeast Papua were of a regional nature, except for an approximate 20 n miles spaced network of north-south lines in the Woodlark Basin. East-west lines at 10 n miles spacing constituted the traverse network in the Gulf of Papua. The Track Chart is shown in Plate 1.

Several extra lines from later surveys completed the traversing in the south of the Gulf of Papua. These included some 38 hours surveying from Survey 10 (lines 10/004 to 10/008) and 100 hours from Survey 14 (lines 14/018 to 14/031). These lines add about an extra 1000 n miles and are incorporated in Plates 1 to 5. Equipment changes in these later surveys included new amplifier banks and better graphic recorders in the form of EPC recorders for the seismic system. Further details of these surveys can be found in the report on the Coral Sea area (Mutter, 1974).

TABLE 1. CRUISE STATISTICS OF SURVEY 05.

	START	AREA SURVEYED	LINES SURVEYED	DAYS	MILES SURVEYED
CRUISE 1	Port Moresby	Central Bismarck Sea	05/001-05/032	10.8	2131
CRUISE 2	Lae	Western Bismarck Sea	05/033-05/085	15.9	3277
CRUISE 3	Madang	Eastern Bismarck Sea	05/086-05/135	16.1	3459
CRUISE 4	Rabaul	Southeast Papua	05/136-05/188	12.1	2600
CRUISE 5	Port Moresby	Gulf of Papua	05/189-05/230	14.1	3028
			Total	69	14 495

FIG. 1



LOCALITY MAP

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Equipment

The 1970 survey was the first BMR survey to include on-line computers for data acquisition and digital seismic stacking. These systems were designed to collect, process, and store large quantities of survey data.

The primary navigation system was an ITT satellite Doppler system using a Digital Corporation PDP-8 computer. Position fixes were obtained at approximately two hourly intervals. A Marquardt sonar Doppler, Chernikeeff electromagnetic log, and ship's pressure log were used in conjunction with a Hewlett Packard 2116B computer to provide independent dead-reckoning systems. Omega-VLF radio navigation was also run as an independent system but the results were not used as it was easier, much faster, and more accurate to obtain position fixes from the satellite/sonar Doppler system.

Gravity data were obtained using LaCoste & Romberg marine gravity meter No. S24 mounted on a gyro-stablized platform. Linear corrections for ship's accelerations and meter beam movement were applied using analog computers within the meter and a milligal value recorded directly. Total magnetic field readings were obtained from a Varian proton procession magnetometer with the sensor towed about 180 m behind the ship.

All gravity, magnetic, and navigational data were sampled at 10-second intervals by a Hewlett Packard HP2116B computer, checked, reformatted, and recorded on magnetic tape. All data were also recorded in analogue form on multi-channel strip chart recorders for back-up and display purposes. Every 10 minutes the computer read the magnetic tape and printed the last block of sampled information on a teletype. The data acquisition computer computed the ship's dead-reckoned position and diagnostics on the reliability of the recorded data and these also were printed out on the teletype every ten minutes. This printout was used for navigation, assessment of systems performance, and preliminary geophysical computations.

Seismic reflection information was obtained using a 120 kJ sparker energy source, a multi-channel analogue amplifier bank and two hydrophone cables; a single-channel cable with a high-frequency response for near-surface reflections and a six-channel cable for deep reflections. This information was recorded on EG & G graphic recorders for on-line monitoring and display purposes; and on a 14-channel FM magnetic tape recorder for permanent storage.

The shot interval of the sparker was controlled so that the six-channel cable gave a 6-fold CDP configuration with common depth points at 25 m intervals. On-line processing of this six-channel data using a second HP2116B computer produced a stacked CDP seismic record.

Aquatronics SM44 or Spartan SSQ41 sonobuoys were used to record refracted seismic signals from the sparker energy source out to a distance of a few miles.

Further information on the equipment can be found in CGG(1974). It is proposed to give detailed descriptions of the equipment and systems in a later report.

Data Presentation

The data presented in this report are preliminary. The bathymetric, gravity, and magnetic data were obtained on board ship by manual scaling of the analogue records at hourly intervals. After conversion to digital form, the data were processed by computer and contour maps prepared on a flat-bed plotter using a 'triangular' contouring program, as shown in Plates 2, 3, and 4.

The single-channel seismic monitor records have been inspected at a fairly superficial level and regional information has been extracted. Plate 5 which shows the sediment distribution and structure has been prepared from this inspection.

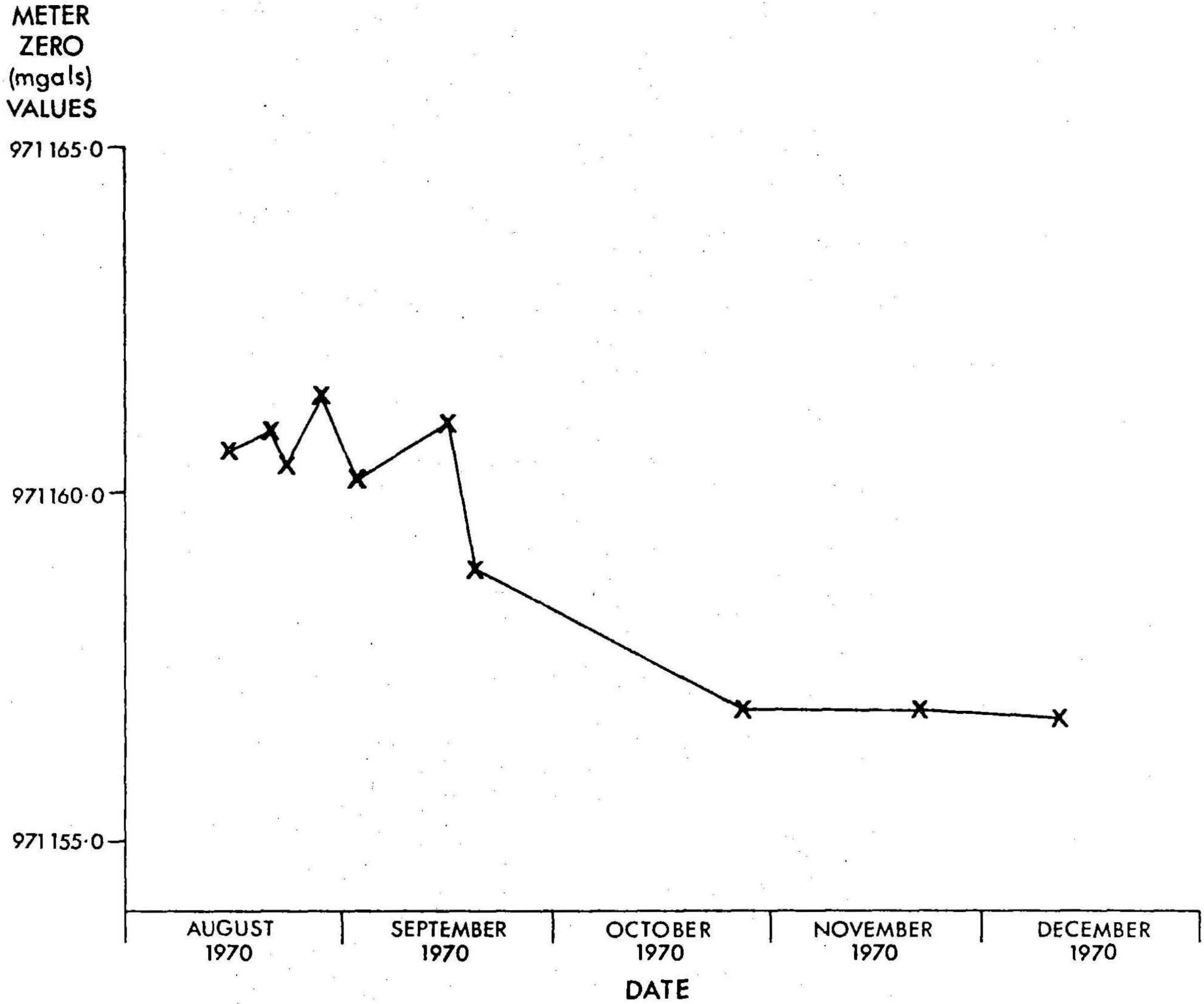
2. DATA QUALITY

About 10% of the area surveyed is on the continental shelf while practically all the rest is in areas with water depths of 1 to 2 km. In the deep-water areas the sonar Doppler and ship's logs are current-dependent and thus navigational accuracy is likely to be about 1 n mile because of uncertainties in measuring the deep-water currents. However, post-processing of the satellite fixes should remove the effect of currents to some extent and the navigational accuracy could be improved to about 0.3 n mile.

Gravity

Gravity data accuracy was influenced by two major factors; weather conditions which affected the short-period accelerations being applied to the meter, and ship's velocity errors which caused resultant errors in the Eotvos correction.

FIG. 2



PLOT OF METER ZERO SHOWING DRIFT

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During rough seas at the start of the survey fluctuations in the gravity meter cross-coupling with periods of 2 to 10 minutes and amplitudes to 30 mGal showed a marked correlation with the final recorded gravity. It was established that AX and AX2 circuit constants in the meter were suspect so these were disconnected at the end of cruise 1. The AX and AX2 terms are measures of the horizontal accelerations (cross) coupled into the gravity reading when the beam is off zero (See CGG, op. cit., fig. 6 for details). At the beginning of cruise 4 a reduced AX based on the average of values from other Geophysical Associates Inc. meters was added to the cross coupling correction. Despite this it was found that the meter gave unsatisfactory results in sea states above about Force 5 to 6 on the Beaufort Scale. A total of 85 hours of gravity data were considered unusable owing to the poor performance of the meter in rough weather. This was mainly in the Gulf of Papua and includes all the gravity data on lines 05/001 to 05/006 together with 35 hours of data from cruise 5. Noise levels on the final gravity trace were generally less than 2 mGal for the remainder of the survey. Weather conditions in the Bismarck Sea were mostly calm.

Velocity errors from the final processed navigation generally should be less than 0.5 knot which could give a maximum error in the Eotvos correction of 3 mGal.

Gravity ties made between the ship and gravity base stations of the Australian Isogal Network (Barlow, 1970; Mather et al., 1971) allowed determination of the drift of the shipboard meter. The meter zero was found to have a negative drift and experienced some small tares or rapid changes in meter zero value (Garnett, (in prep)). The drift of the meter during this survey is displayed in Figure 2 using the gravity tie data from Appendix 1. The negative tare of 4 mGal apparent during September will be discussed in the section of the mistie data.

Magnetics

Magnetic readings were influenced by two major factors: daily magnetic variations which superimpose spurious anomalies on the normal field, and interference during the magnetometer sampling giving incorrect readings.

The daily magnetic variation is composed of the quiet day variation (Sq), of amplitude 20 to 50 nT depending on latitude, and the disturbance daily variation (Sd), with short periods and amplitudes up to 10 nT (on average days) which are due to solar activity. If these variations are not removed from the shipboard readings long wavelength anomalies of about 200 n miles will be introduced into the magnetic results by the Sq variation while the Sd variation will give short wavelength anomalies which will affect determinations of depth to magnetic basement. Correction for the diurnal variations has been discussed by Royer et al. (1971) in relation to high sensitivity aeromagnetic data.

A shore station was established at Port Moresby to monitor the diurnal variations in the magnetic field and in the VLF - Omega transmissions. Magnetic records were of poor quality as the magnetic trace had noise levels up to 10 nT and was subject to erratic jumps of several nanoteslas. The poor performance of the shore magnetometer was due to heating of the sensor head during the day.

Magnetic results on this survey were degraded by the interference of sparker emission and radio transmission. Radio interference persisted for up to 30 minutes at a time and was caused by the magnetometer cable and winch being run on deck. This interference was eliminated by running the cable between decks and relocating the winch in a Faraday cage at the stern of the ship. Sparker interference remained throughout this survey. In later surveys this was removed by synchronizing the magnetometer polarization cycle with the shot instant.

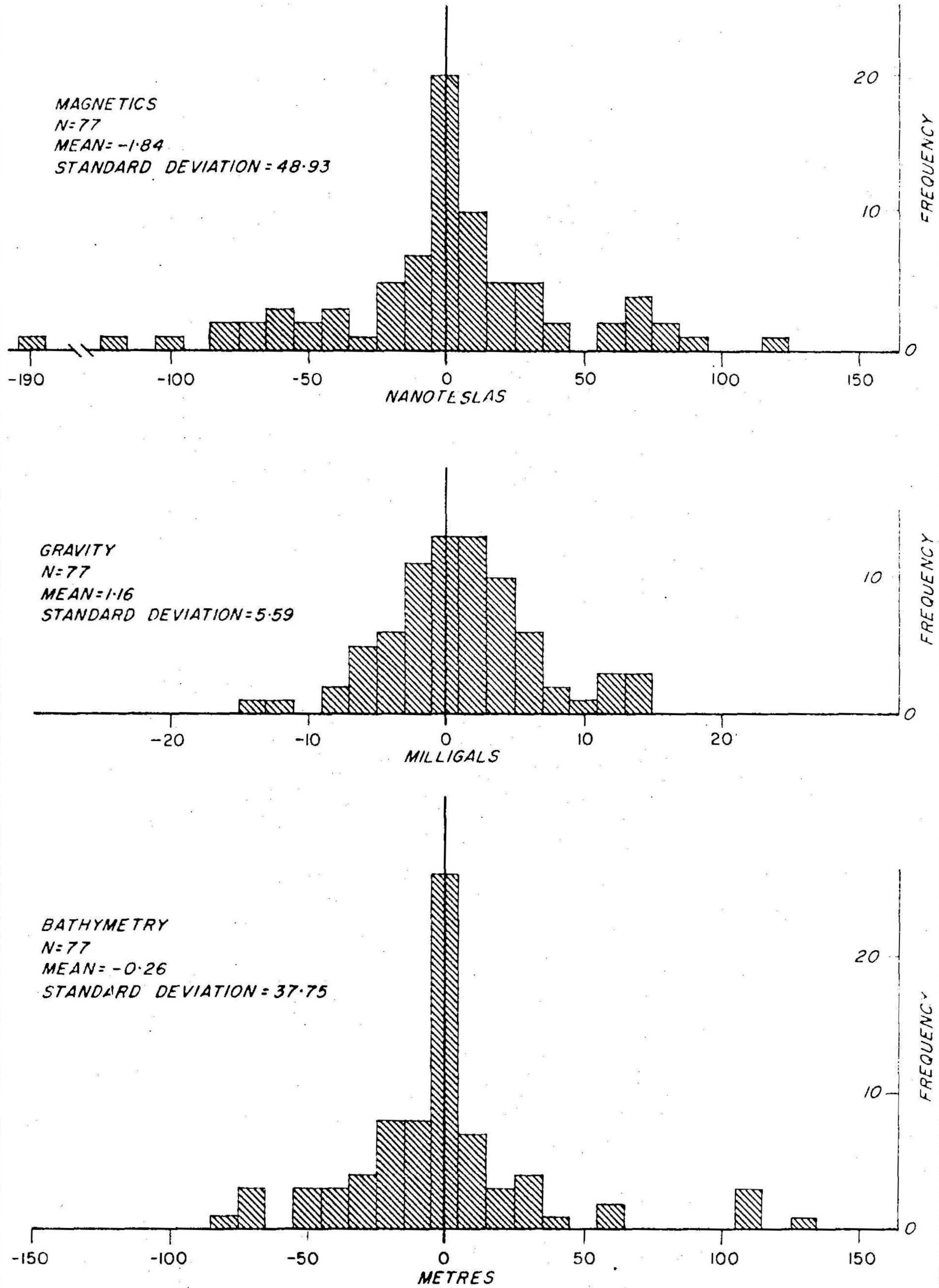
Apart from these periods of interference the magnetic trace usually had noise levels less than 5 nT peak-to-peak.

Seismic

The seismic results were generally good. Most problems with the seismic system were associated with the facsimile recorders. These recorders, using chemically treated wet paper occasionally gave poor results. The slow speed used sometimes caused erratic advance and sometimes drying of the paper. Poor adjustment of the recorder threshold controls sometimes weakened, or lost altogether, weak reflections deep down in the section. However, post-processing of selected lines has shown the data recorded on magnetic tape to be good and when displayed an variable area cross-section plotters has given a better presentation of the seismic results.

As expected, the records in shallow water are of poor quality owing to interference from multiple reflections and ringing. CDP stacking of the six-fold data should improve resolution and penetration in these areas.

FIG. 3



MAGNETIC, GRAVITY & BATHYMETRIC MISTIES

The on-line CDP stack gave marginal improvement of results at the start of the survey. With operating experience an improved result was expected. However a hardware fault, namely a faulty track on the storage disc, and several software problems put the system out of action for the remainder of the survey.

Noise levels on the 6 seismic traces were usually of the order of 20 microvolts at a ship speed of 10 knots. During rough weather in the Gulf of Papua some noisy records were obtained and noise levels over 100 microvolts were measured.

Misties:

Overall estimates of the accuracies of the bathymetry, gravity, and magnetic data can be obtained from the misties or differences between readings at intersection points. Histograms of the misties are shown in Figure 3. The mistie values were determined by subtracting the earlier value of the parameter from the later value at each intersection point.

The mean and standard deviation of each parameter (Fig. 3) was calculated using 77 of the available 82 samples. The five rejected samples had bathymetric misties greater than 150 m and were considered to be unusually bad tie points; four were in the Huon Gulf over steep sea-bed slopes and the other off southeast Papua where the intersection was on a turn, and consequently the intersection time difficult to determine. The standard deviation of the bathymetry misties improved from 93 m for the original 82 samples, to 38 m for the accepted 77 samples. Gravity and magnetic misties at these poor tie points were also omitted from the statistical analyses.

Should the errors be random as one would expect, the mean should be statistically insignificantly different from zero. If the true mean of each population is zero than the probabilities of obtaining the observed means are 95%, 7%, and 74% for bathymetry, gravity, and magnetics (Table 2).

TABLE 2. STATISTICAL ASSESSMENT OF MISTIES.

MEAN	STD DEVIATION	STD ERROR OF MEAN	MEAN STD ERROR	% PROBABILITY if true mean zero
Bathymetry -0.26 m	37.75	4.30	-0.06	95.22
Gravity 1.16 mGal	5.59	0.64	1.81	7.02
Magnetics -1.84nT	48.93	5.58	-0.33	74.14

From these figures it appears that the bathymetry and magnetic misties are randomly distributed. Any conclusion on the gravity misties must be made with reservation. The rapid drop in the gravity meter zero (Figure 2 & Appendix 1) between Madang and Rabaul is the probable cause for the high observed mean for the gravity misties. As the meter zero at the commencement of each cruise is used throughout the cruise for on-board computations, some 29 misties are too positive by about 2 mGal. This results in a positive shift of about 0.8 mGal in the gravity mean. Without this shift the gravity mean would become acceptable and the misties could be considered as randomly distributed.

A significant correlation was found between gravity and bathymetry misties. The correlation co-efficient and slope were -0.34 and -0.0506 mGal/m. Inaccurate positioning of intersections over a sloping seabed could explain this as the Bouguer correction for differences in water depth is -0.05 mGal/m. However removal of the systematic error gives only a slight improvement from 5.59 to 5.25 mGal in the standard deviation of the gravity misties.

The standard deviations of the misties are larger than one would expect. Bathymetry and magnetic standard deviations are possibly related to the rapid variation in these parameters throughout the survey area. However, it is difficult to explain the gravity standard deviation in the same way as most intersections were in areas of small variation.

3. GEOLOGY AND GEOPHYSICS

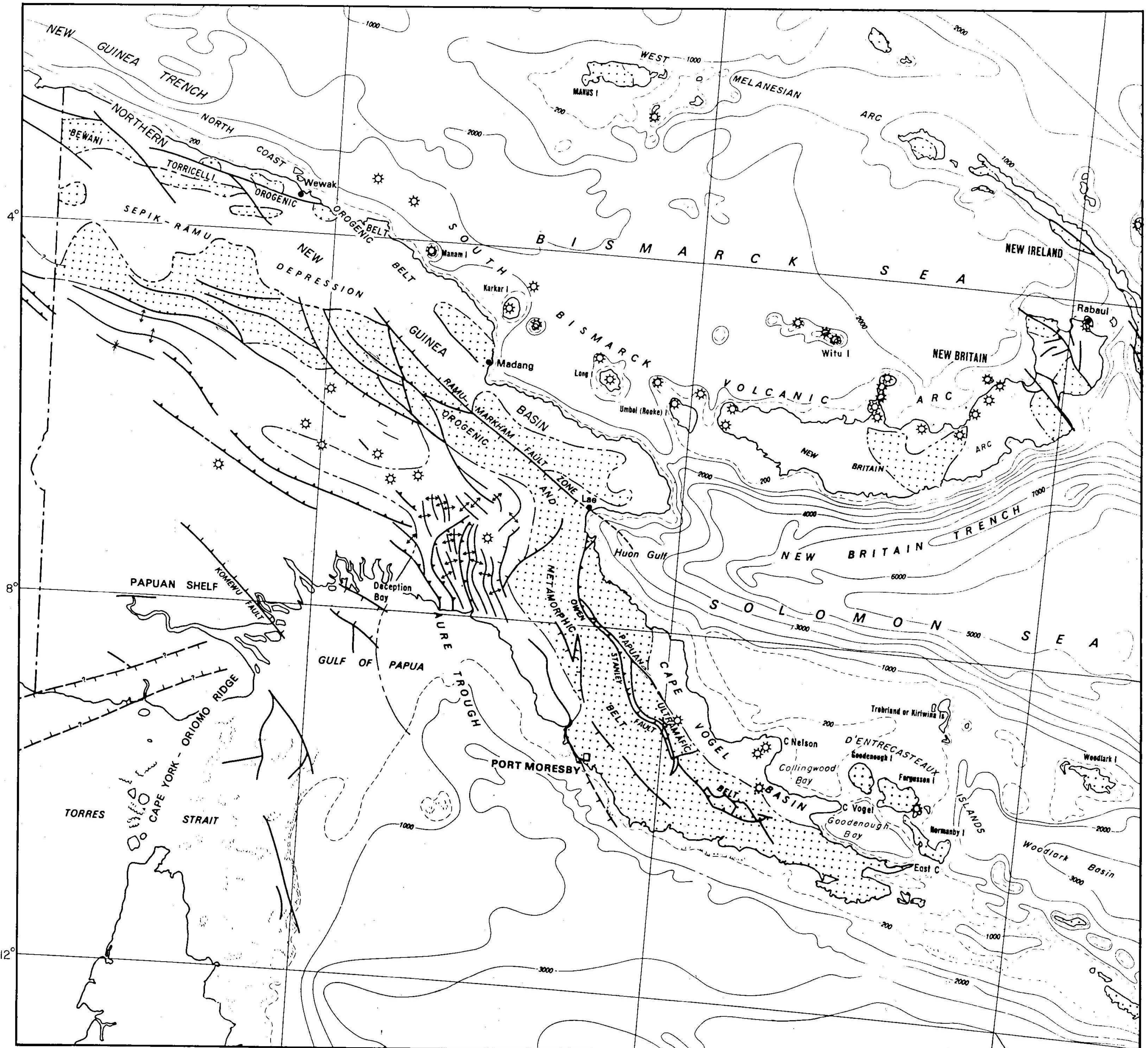
The geology of New Guinea has been discussed wholly or in part by many authors including Visser & Hermes (1962), Thompson (1965, 1967) and Davies & Smith (1971). In the preview report for the 1970 marine survey Willcox (1973) has summarized the geology and previous geophysics of the survey area. The following description of the geology and geophysics relies largely on that report.

Geology:

The New Guinea region can be divided into six structural units after Denham (1969) and (Thompson and Fisher, 1965); these are shown in Figure 4 and are:

(i) Stable Papuan Shelf
(ii) Aure Trough

FIGURE 4



STRUCTURAL MAP OF PAPUA NEW GUINEA

100 0 100 200km

(Compiled from the Tectonic Map of Australia and New Guinea, Geological Society of Australia, 1971)

LEGEND

- Geological and Tectonic boundary
- Anticline
- Syncline
- Fault, type unknown
- High angle fault, normal or reverse, ticks denote downthrown block
- Thrust fault, teeth point to upper plate
- Strike slip fault
- Active and recently active volcanoes
- Bathymetric contours in metres (200, 1000)
- Mainly volcanic and metamorphic rocks

(iii) Orogenic and Metamorphic Belt
(iv) North Coast Orogenic Belt and the New Britain Arc
(v) Papuan Ultramafic Belt
(vi) West Melanesian Arc

The Stable Papuan Shelf is a Mesozoic-Quaternary platform extending from continental Australia. Granitic basement which crops out on the Cape York/Oriomo Ridge dips gently to the north beneath Miocene and Upper Jurassic/Cretaceous sediments. These sediments extend eastwards to the Aure Trough where the Miocene sediments thicken rapidly. The Aure Trough, containing up to 10 km of Cainozoic and several kilometres of Mesozoic sediments occupies the area between the stable shelf and the 'spinal ranges' of New Guinea. The stable shelf, the Aure Trough, and the narrow shelf to the northeast of the Gulf form the Papuan Basin.

The Orogenic and Metamorphic Belt forms the 'spine' of the island. It consists of mid-Tertiary volcanic and metamorphic rocks with a core of Jurassic/Cretaceous and probably older metasediments.

The coastal ranges of New Guinea and the ranges of New Britain lie within a region of active mountain building termed the North Coast Orogenic Belt and New Britain Arc. Sediments throughout this region lie on Tertiary volcanic 'basement' and are generally folded into antiform structures. Faulting is predominant over folding, with faults trending northwest usually subparallel to the New Guinea coast. Between the highlands and the coast, an area of Miocene-Pliocene sedimentation forms the Northern New Guinea Basin. An active volcanic chain, the South Bismarck Volcanic Arc, forms the offshore islands of New Guinea and the northern portion of New Britain.

The Papuan Ultramafic Belt is a narrow discontinuous band of ultramafic intrusions consisting of Jurassic/Cretaceous gabbro and peridotite. This ultramafic belt separates the metamorphic belt (iii) from the volcanics of northeast Papua. The ultramafic sequence thins to the southeast. Thompson & Fisher (1965) attribute the ultramafic belt to an upthrust wedge of oceanic floor and subjacent mantle over the acidic Owen Stanley metamorphics.

The West Melanesian Arc extends from New Ireland, through Manus Island, with a possible projection onto the New Guinea coast near the Irian Jaya/Papuan New Guinea border (Denham, 1969). A shallow, well defined trench about 200 km north of the islands is associated with the arc. Generally, the islands of the West Melanesian Arc consist of a complex pile of volcanics and limestones of Upper Tertiary and Quaternary age, overlying acidic basement rocks.

Sedimentary Basins

In the New Guinea region are three major sedimentary basins, namely the Northern New Guinea Basin, the Cape Vogel Basin, and the Papuan Basin.

The Northern New Guinea Basin lies between the Highlands and the New Guinea coast and extends from the Huon Peninsula northwestwards to Irian Jaya. Several sub-basins have been recognized, the Bewani-Torricelli Basin (Aitape Trough) north of the Bewani-Torricelli Orogenic Belt, the Wewak Trough, the Sepik-Ramu depression, and several other small localized areas of thick sedimentation which have been outlined by aeromagnetic surveying. The southern boundary of the basin appears to be in faulted contact with the Highlands area, (orogenic and metamorphic belt), especially, for example, along the Ramu-Markham Fault (Figure 4).

About 4 km of Upper Cretaceous/Paleogene mafic volcanics and limestone appear to be the earliest sequence of rocks in the basin. Overlying this sequence are several kilometres of a mid to upper Miocene turbidite sequence followed by an increasingly paralic sequence terminating with non-marine conglomerate and coal beds (upper Miocene to Pleistocene). Maximum sediment thickness in the basin is about 10 km.

The Cape Vogel Basin is primarily a Miocene to Pliocene basin occupying a 50 km wide coastal strip along the northern edge of the Papuan Peninsula. Offshore extensions of the basin have been outlined by geophysical surveys and show the basin to extend to the Trobriand Islands and to underlie Goodenough Bay. Miocene and Pliocene sequences of sandstone, conglomerate, and marl about 4 km thick overlies a volcanic/volcaniclastic basement.

The Papuan Basin is a composite basin covering about 200 000 km^2 in central Papua and the Gulf of Papua. It contains a thick Tertiary sequence of marine and paralic sediments unconformably overlying an Upper Jurassic/Cretaceous sequence. Between the Lower Cretaceous and the Miocene a major depositional break occurred over most of the basin except in the eastern portion of the basin where Eocene sediments were deposited. This period was one of widespread emergence and eastward tilting about the stable shelf. Development of the Aure Trough in the lower Miocene accelerated the easterly tilting of the shelf areas and provided an environment for limestone deposition. The Aure Trough contains about 10 km of primarily Miocene to Pliocene marine clastics, limestone, and pyroclastics overlying several kilometres of Upper Jurassic/Cretaceous basalt and low-grade metamorphics and Eocene limestone and marine clastics.

Previous geophysics

There have been many regional onshore surveys around the peripheries of the Bismarck Sea but few offshore surveys. Major gravity surveys have been undertaken in the Sepik River valley (Watts, 1969) on the Solomon and Bismarck Islands (Laudon, 1968), and on New Britain and New Ireland (Harrison, in prep.). Aeromagnetic surveying has been carried out in the Sepik River valley (Australian Aquitaine Petroleum Pty Ltd, 1967) and northwest of Madang in the Ramu River area (Continental Oil Co of Australia Ltd, 1968).

Basement contours from the Ramu survey west of Madang indicate a north-west trending basin with depths to 4 km, disturbed by predominantly north-south faults. This depression parallels the Ramu Gravity Low (Watts, op. cit) but is slightly offset to the southwest. Near the coast about 200 km west of Wewak the Bewani-Torricelli basin is delineated by the magnetic basement contours. Basement dips north-north-east at about 150 m/km and attains a depth of 3 km at the coast. This may continue deepening to the north to form a possible offshore sedimentary basin but it can only have a maximum of 15 to 20 km offshore extent before it is truncated by the continental slope.

An offshore basin 15 km northeast of Wewak is indicated by aeromagnetic data and a poorly defined gravity low. Another gravity low of 20-30 mGal closure northeast of Madang possibly indicates an area of thick Pleistocene sediments. A strong regional gradient of up to 3 mGal/km towards the north-east extends across the Ramu River area and the Bismarck Sea.

The Solomon and Bismarck Islands are characterized by large positive free-air and Bouguer anomalies with extremely steep gradients. Bouguer anomalies are related to the near-surface geological features, the highs being an expression of basement ridges and Quaternary volcanics, and the lows an expression of Tertiary sedimentary basins (Laudon, op. cit).

The BMR conducted crustal studies in the Rabaul area during 1967 and 1969 (Brooks, 1971 and Finlayson et. al., 1972). This seismic refraction work indicated higher than normal crustal velocities over most of the area and crustal thicknesses of 32 km under the east end of New Britain and of 20 km under the Bismarck Sea.

Marine traverses have been run by the U.S.S. Shoup (Krause, 1965), H.M.S. Dampier, (Rose et. al., 1968), the Japanese vessel Umitaka-Maru, and the Hawaiian Institute of Geophysics vessel Mahi. Ships' tracks and type of data collected for these and other oceanographic surveys in the area can be found on maps of oceanographic traverses in the Australian region compiled by Riesz & Moss (1971).

Gravity determinations made aboard the U.S.S. Shoup were not accompanied by echo-sounding, and in their general navigation was unreliable.

Rose et al. (1968) have produced gravity and magnetic contour maps of the Solomon Islands region using data gathered primarily by the ships Dampier and Baird. They found that gravity anomalies in the region southeast of New Britain and between Bougainville and New Guinea appear excessively positive by more than 100 mGal. This is attributed to the geoidal bulge detected over the Solomon Islands region and/or the anomalously high mantle density found in the Bismarck Sea region by satellite perturbation studies (Schwiderski, 1967). Magnetic anomalies are generally less than 200 nT in amplitude and are in the form of elongate bipoles striking perpendicular to the observed structural trends on land. Using depth estimations and computed susceptibility contrasts they proposed a three-layered crust and suggested that magnetic anomalies are associated with intrusive basalts or andesites.

Regional surveys in the Southeast Papuan region included the eastern Papua aeromagnetic survey by BMR (1971), the eastern Papua helicopter gravity survey (Milsom, 1971) and several marine seismic surveys carried out by Amoco Australian Exploration Co. (1972a, 1972b, 1973a).

The aeromagnetic survey which was flown mainly over the eastern Papuan continental shelf outlined a major east-trending sedimentary trough extending from Cape Nelson to the Trobriand Islands. The sedimentary trough is divided into two basins by a basement ridge at 1500 m depth formed by a northward extension of the shallow basement of the D'Entrecasteaux Islands. The eastern basin is the larger and deeper of the two, with basement depths reaching 3000 m southwest of the Trobriand Islands. The western basin has depths to 2500 m north of Cape Nelson.

Another smaller sedimentary basin outlined in the offshore area between Cape Vogel and East Cape has basement depths to 1500 m. It is completely encircled by shallow or exposed basement along the Papuan Peninsula, the D'Entrecasteaux Islands, and beneath the narrow dividing straits. These basins are the offshore sub-basins of the Cape Vogel Basin (Figure 4).

The marine seismic surveys by Amoco confirmed the aeromagnetic interpretation and showed the sedimentary trough to be about 60 km wide and containing a maximum of 4500 m of sediments. Two anticlinal trends parallel the northern and southern margins of the trough. Two wells were drilled, the first Goodenough No. 1 (Amoco, 1973 (b)) was drilled on a structural anomaly associated with one of the anticlinal trends, and the second Nubiam No. 1 (Amoco, 1973 (c)) on an area of supposed reefal development associated with a shallow basement plateau located in the northeast of the sedimentary trough. Goodenough No. 1 is located about 32 km north of Goodenough Island and Nubiam No. 1 is 63 km northeast of the Goodenough well and about 35 km southwest of the Trobriand Islands. Both wells penetrated thick Pliocene and Miocene sequences and bottomed in volcanics and volcaniclastics. Miocene clastics in Nubiam No. 1 were finer-grained than in Goodenough No. 1, suggesting a greater distance from their source, that is from the west or southwest. The presence of mid-Miocene tuffs in Nubiam No. 1 suggests a greater proximity to contemporaneous volcanic centres than Goodenough No. 1 (Amoco, 1973 (c)).

The eastern Papua gravity survey outlined an elongate Bouguer anomaly high of 160 mGal over the Papuan Ultramafic Belt which Milsom (op. cit) has modelled as a thrust sheet of some 20 km thick dipping gently (about 30°) to the north-east. Of this 20 km, about 8 km belongs to ultramafic and the remainder to feldspathic suites.

A gravity low of 20 mGal was found between the Trobriand and D'Entrecasteaux Islands. The large amplitude of the anomaly and the steep gradients on its edges implied the presence of a deep basin infilled with low-density sediments. Milsom explained the origin of this by extensional movements related to the opening of the Woodlark Basin. Using bathymetric and earthquake epicentre data, Milsom (1970) postulated that the Woodlark Basin was an area of minor sea-floor spreading.

In the north of the Gulf of Papua several seismic surveys have been carried out by Phillips Australian Oil Co (1968 (a), 1968 (b), and 1969) and by Tenneco Australia Inc (1967). Numerous scattered seismic and gravity surveys have been carried out on the adjacent land. Several aeromagnetic surveys have been flown in the area including one extensive survey over the Papuan Basin and Ultramafic Belt, (BMR, 1969). Phillips (1967-1968 various well completion reports) and Tenneco (1969) have drilled several wells on reef structures within the Gulf of Papua.

On the basis of their reconnaissance seismic survey, Phillips (1968(a)) have subdivided the offshore Papuan Basin into six structural zones as shown in Figure 5.

Zone 1: Western stable shelf with relatively thin Tertiary section dipping eastwards. Structurally undisturbed. Miocene reef development is suggested on the basinward edge.

Zone 1A: A Miocene limestone shelf area in Deception Bay. Eocene block uplift and Miocene reef development were interpreted.

Zone 2: West slope of the basin in which the Tertiary section dips more steeply, and rapidly thickens, towards the east. Tertiary/Miocene unconformity is evident and the Mesozoic section is locally folded and faulted.

Zone 3: An undeformed belt occupying the western part of the mobile Tertiary basin. Sediments dip steeply to the east. Local faulted structures are recognized in the older rocks on the eastern edge of this zone. Gentle folding is present in strata tentatively identified as upper Miocene and Pliocene.

Zone 4: Seaward extension of the Aure Trough, a complex fold belt characterized by gentle synclines separated by tight anticlines. Crests of the anticlines tend to be thrust-faulted, and diapirs have developed in the anticlinal cores as a result of flow of incompetent mudstones. Regional dip is to the west.

Zone 5: A mobile eastern shelf and slope province where there is good evidence of thrust-faulting associated with the eastern shelf of the Aure Trough.

Seismic results from the reconnaissance surveys gave a maximum depth of 7500 m to the Mesozoic horizon about 55 km south-east of Deception Bay (Zone 2).

The BMR aeromagnetic survey (BMR, 1969) outlined the offshore Papuan Basin and showed it to be almost symmetrical with maximum depths of 7500 - 9000 m at the head of the Gulf (Zone 2). South and west the basement rises sharply by 50m/km to reach a depth of 4200 m along latitude 9°S and the western flank of the Gulf. Northwards the basement rises rapidly to 5400 m near the coast and then deepens again further north.

REGIONAL GEOLOGY AND OFFSHORE STRUCTURAL ZONES IN THE GULF OF PAPUA

(After Phillips Australian Oil Co.)

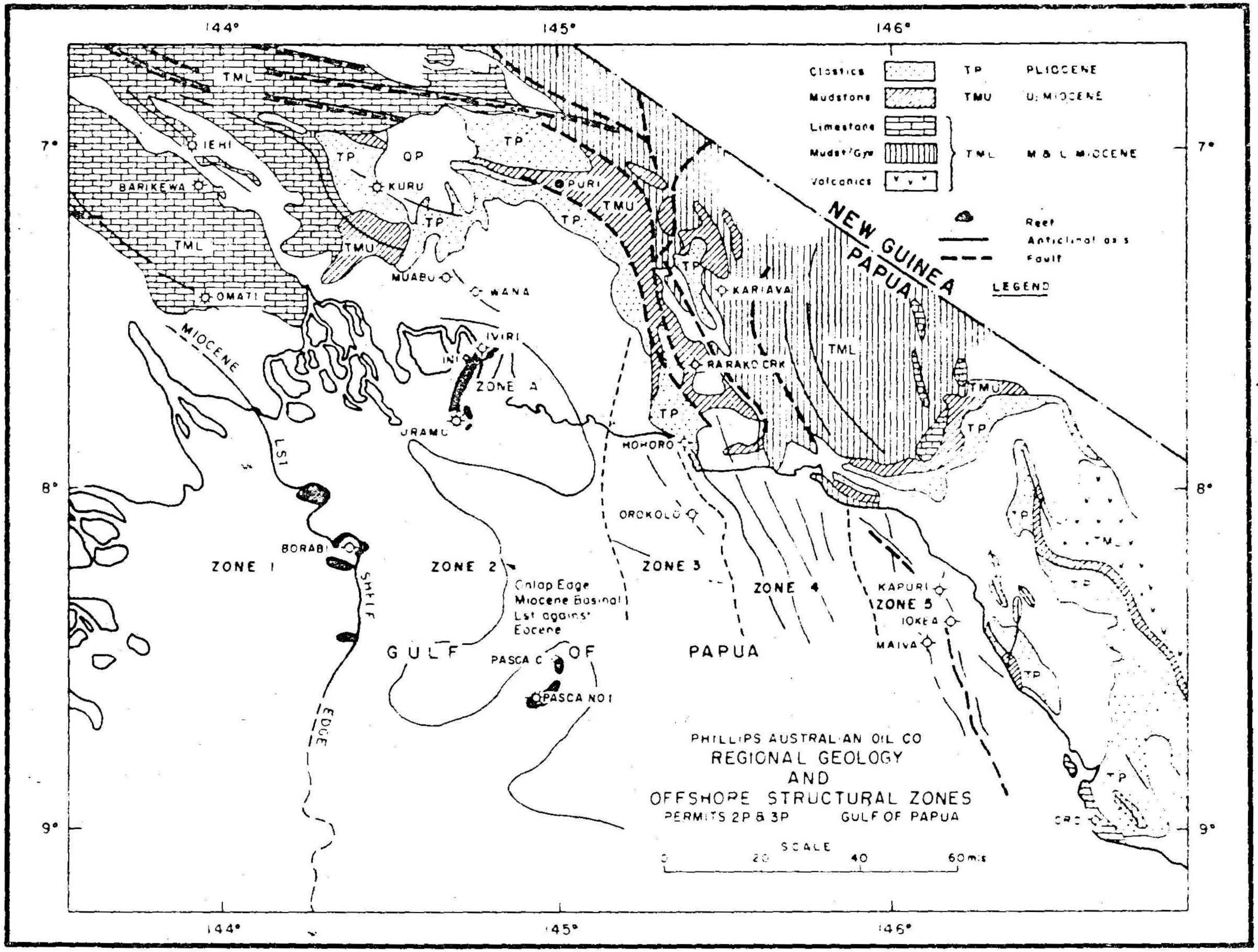


Fig 5

To the east, magnetic anomalies due to the complex tectonic structures and intermediate volcanics obscure the basement anomalies and prevent any realistic depth determinations. It is of interest to note that in both seismic Zones 2 and 3 the sediments dip and thicken towards the east and thus the maximum sediment thickness must be in excess of 7500 m and must occur in Zone 4, the seaward extension of the Aure Trough.

Several deductions were made about the anomalies over the Papuan Peninsula from this aeromagnetic survey:

(a) The Owen Stanley Metamorphics produce low-intensity magnetic anomalies which decrease in amplitude to the southwest.

(b) Anomalies of 20 nT closure and northwesterly and westerly trends are associated with the Ultramafic belt. The anomaly pattern is consistent with a northeast dip for the ultramafics.

(c) Tertiary sediments and volcanics northeast of the Ultramafic belt are about 1700 m thick.

(d) Profiles across the Huon Gulf indicate a northeast-dipping basement to 3 km with only thin sedimentary cover.

4. BATHYMETRY RESULTS

The water depth contours are displayed in Plate 2.

1) Bismarck Sea

The Bismarck Sea forms an enclosed marginal basin and is divided into two sub-basins by the Willaumez-Manus Rise which trends northwest from Willaumez Peninsula to Manus Island. The sea is bounded on the north and west by the West Melanesian Arc and on the south by the islands of New Guinea and New Britain.

The New Guinea continental margin consists of a very narrow shelf generally less than 15 km wide and a slope which drops abruptly from the 200 to 2000 m isobath into the western basin of the Bismarck Sea. The slope dips sharply at some 6^{o} in the west and gradually lessens to about 1 to 2^{o} east of Madang. Between New Britain and Wewak the slope has been modified by the volcanic island chain of the South Bismarck Volcanic Arc.

The <u>western basin</u> is an elongate feature about 600 km from east to west and 100 km from north to south lying at depths of 1800 to 2200 m. It trends parallel to the New Guinea coast and extends from the western end of New Britain to longitude 143° where it dips sharply westwards to 3600 m into the eastern end of the New Guinea Trench. Seismic and echo-sounding profiles show that the floor of the basin is relatively smooth and has little relief. Isolated seamount peaks are present throughout the western basin and a major seamount chain trends east from the vicinity of Wewak. The northern margin is formed by a gentle rise with gradients of only 1° compared to the steep southern margin adjacent to New Guinea. A smooth-floored region lying at 1800 m in the eastern portion of the basin has been defined as a platform by Crook (1969).

The <u>Willaumez-Manus Rise</u> which divides the Bismarck Sea into two Basins lies chiefly between the 1000 and 1800 m isobaths and is up to 100 km wide. It has gently sloping flanks of less than 1° into both the eastern and western basins except where several islands and reefs locally produce steep slopes.

<u>The eastern basin</u> is a triangular-shaped feature slightly deeper than its western counterpart. It is about 200 km across the base of the triangle and extends about 400 km northwest to its apex near Manus Island. The depth of the basin ranges from 2000 m along the edge of the Willaumez-Manus Rise to about 2600 m along the New Ireland margin, the sea floor dipping towards the northeast. Gradients of the basin margin along the north coast of New Britain and south of the West Melanesian Arc average 3° and are much steeper than the gentle 1° slopes of the southwestern boundary formed by the Willaumez-Manus rise. Several east-trending seamount ridges and graben features occur over the Willaumez-Manus Rise and in the eastern basin.

The <u>West Melanesian Arc</u> is an arcuate ridge containing New Ireland and Manus Island. Its limits are delineated by the 1400m isobath although it is shallower than 1000 m in most places. The average gradient of the northern slope of the Arc and the southern slope near the western basin is about 1°. The southern slope steepens eastwards to over 2° in the eastern basin. North of the West Melanesian Arc parts of the West Melanesian Trench were traversed and depths to 4000 m encountered.

ii) <u>Southeast Papua and the Solomon Sea</u>

Most survey lines in this area were for regional reconnaissance purposes, and although they provide profile information, they should be integrated with other bathymetric soundings before any contours are drawn.

Two openings exist between the Bismarck and Solomon Seas. An opening of some 35 km width between New Britain and New Ireland is the St Georges Channel. This is a steep-sided trough with a relatively flat floor at about 2000 m depth and which dips southwards into the New Britain Trench (Brooks et al., 1971). The Vitiaz Strait, some 50 km wide between New Guinea and New Britain, forms the second opening into the Solomon Sea. It is between 1000 and 1600 m deep and the sea-bed dips southwards into the western end of the New Britain Trench.

Lines 05/129 to 05/134 were surveyed through the St Georges Channel and then eastwards across the area north of Bougainville Island. A deep basin southeast of New Ireland reaches some 4200 m. The seabed then shallows to 1000 m across the Bougainville Island ridge and then deepens to 3400 m into a trough to the east of the island.

The Huon Gulf is formed by a steep-sided canyon, the floor of which dips sharply at about 3^{o} into the New Britain Trench. Locally the canyon sides attain slopes greater than 6^{o}. Depths to 3400 m were encountered in the southeast region. The Ramu-Markham Fault Zone passes through the canyon and was probably the original cause of the structure, but the current of the Lae River has probably further eroded the canyon.

Survey line 05/161, the only line across the New Britain Trench, recorded a maximum depth of 6400 m. The trench is asymmetric, the maximum depth lying close to its northern margin near New Britain. This margin dips at about 4^{o} to 5000 m where it forms a terrace of some 20 km width before continuing into the bottom of the trench with the same dip. The southern margin also dips at 4^{o} from 2000 to 5000 m, but the gradient then decreases to about 1^{o} for a distance of 60 km into the trench bottom.

Bathymetric provinces in the southeast Papuan region include the Papuan continental shelf, Woodlark Ridge, Woodlark Basin, and the Pocklington Ridge (Krause, 1967).

The Papuan continental shelf is a large triangular area with its base on the Papuan coast and its apex at the Trobriand Islands. It has a maximum width of 160 km and is generally shallower than 200 m. Between the coast and the D'Entrecasteaux Islands are two small basins. The southern basin underlying Goodenough Bay is 1200 m deep and the other beneath Collingwood Bay is 600 m deep.

The northern boundary of the Woodlark Basin is formed by the Woodlark Ridge. This ridge, which encloses Woodlark Island, extends eastwards from the shelf with its northern slope being an extension of the continental slope. Depths along the ridge range between 200 and 1000 m.

The Woodlark Basin lies to the east of the D'Entrecasteaux Islands and varies in depth from 1000 to 3200 m with depths increasing to the east. Slopes on the edge of the basin are generally less than 3^{o} except along parts of the Pocklington Ridge where reef development has resulted in abrupt drops in elevation of several kilometres at dips of up to 10^{o}. The Woodlark Basin is bounded on the south by the Pocklington Ridge, which contains the Louisaide Archipelago and is a southeasterly extension of Papua. It consists of numerous reef and island chains and lies mostly above the 200-m isobath. South of the Ridge, the slope drops abruptly at a dip of 6^{o} into the Coral Sea basin.

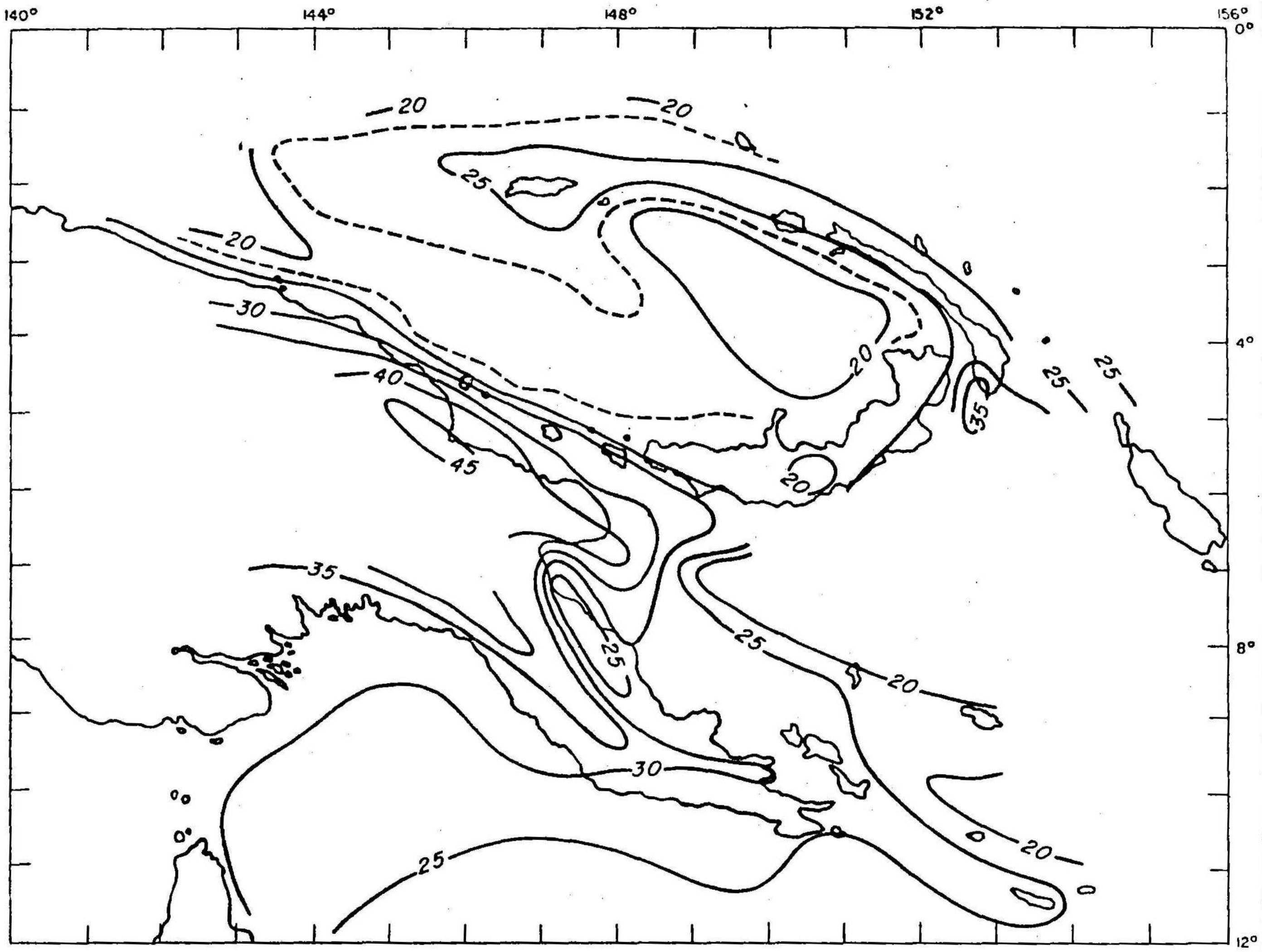
iii) Gulf of Papua

In the Gulf of Papua the five major bathymetric features are the Papuan continental shelf, the Eastern Plateau, the Pandora Basin and Moresby Trough, the Portlock Trough, and the Papuan Plateau. (Winterer, 1970; Mutter, 1972).

The Papuan continental shelf consists of two distinct shelf regions. On the northwestern flank of the gulf the shelf is up to 160 km wide and the adjoining continental slope has a gradient of about 1^{o}. However, the shelf along the south-east Papuan coast is very narrow, generally less than 20 km wide and the slope is twice as steep as the northwestern slope.

The Eastern Plateau, some 17 000 km^{2} in area, is a triangular-shaped feature with its northern apex at the Eastern Fields Reefs. It lies between 1000 and 1600 m depth and its smooth surface dips southwards with a gentle slope of 1 in 2000 (0.03^{o}). At about the 1600-m level, the gradient steepens to over 1^{o} and the sea-floor dips south and southeast into the Coral Sea Basin. The plateau is a true marginal plateau, being almost wholly detached from the continental slope by two marginal troughs, the Portlock Trough to the west and the Moresby Trough to the northeast. The Portlock Trough lying between 1600 and 2800 m dips southwards and extends beyond the survey area, and the Moresby Trough between 1800 and 2400 m deep trends southeast to enter the Coral Sea Basin.

FIG. 6



0 200 400 600 KILOMETRES

SCALE 1:10 000 000 AT EQUATOR

——20—— DEPTH TO MANTLE
- - -22·5- - - (KILOMETRES)

DEPTHS TO MANTLE INFERRED FROM GRAVITY

A southwest extension of the head of the Moresby Trough forms the Pandora Basin, which is a smooth-floored basin lying at a depth of 1600 m. Towards the south a saddle point at 1500 m is formed between this basin and the head of the Portlock Trough.

The Papuan Plateau, intermediate in depth between the continental shelf and the Coral Sea Basin, is situated south of the Papuan peninsula. It forms a flat-surfaced terrace at about 2200 m depth. To the west it is separated from the Eastern Plateau by the Moresby Canyon at about longitude 147°30'E. This canyon, although not apparent on the contour map owing to the aliasing affect of the hourly sample interval, is clearly shown as a steep-walled canyon of 450 m relief on seismic profiles from lines 14/019 and 14/024.

5. GRAVITY RESULTS

Bouguer anomaly values shown contoured in Plate 3 were computed using the method outlined in Appendix 2.

Bouguer anomaly contours show a close correlation with the bathymetry contours over most of the area except the Aure Trough region even though the Bouguer correction is designed to remove the effects of submarine topography. Calculations of various Bouguer corrections using densities between 2.0 and 3.0 g/cm^3 (see Appendix 2) did not remove this correlation and thus indicates that the Bouguer anomaly reflects a density contrast other than the water sea-bed interface. Therefore the Bouguer anomaly contours probably reflect the variations in the depth of the crust-mantle interface, the pattern of which may bear a close resemblance to the topographical pattern. Superimposed upon the gravity effect of variations in the crustal thickness will be smaller gravity anomalies due to variations in sedimentary thickness and local geological structures.

A map showing the approximate depths to the crust-mantle interface is shown in Figure 6. This has been compiled assuming that the Bouguer anomaly is due to a 0.45 g/cm^3 density contrast at the base of the crust. The model also assumes a standard crust of 33 km and that the area is in isostatic equilibrium. The map is intended to show the variations of depth to mantle with little reliance being placed on the absolute figures. In areas of thick sedimentation the depths will be overestimated.

i) Bismarck Sea

Two Bouguer anomaly platforms overlie the eastern and western basins of the Bismarck Sea. These are separated by a regional gravity trough over the Willaumez-Manus Rise.

Surrounding these platforms are strong regional gravity gradients. Free-air gravity values, not presented in this report, are an almost constant value of 50 mGal over most of the area and indicate that the Bismarck Sea region is nearly in isostatic equilibrium. The region requires about 1 km adjustment in the crustal section to obtain equilibrium.

Along the New Guinea continental margin is a strong regional gradient of over 3 mGal/km. Values in the west range from +20 to +150 mGal and reflect oceanward crustal thinning from about 30 km to 20 km. Near Madang the gradient is intensified by the Ramu Gravity Low (see Chapter 3) and values range from -160 to +130 mGal. This low, although caused partly by the thick sediments of the Northern New Guinea Basin, is very intense and is mainly due to a thicker-than-normal crust of about 40 km.

The significance of many of the small anomalies along the continental margin is not recognized until this map (Plate 3) is compared with one containing the land Bouguer anomalies (see Willcox (1973), pl. 7).

Several small gravity lows about 200 km west of Wewak may correlate with the Bewani-Torricelli sub-basin indicated by previous geophysical work. These lows of 30 and 10 mGal amplitude overlie the continental slope between water depths of 100 and 3000 m and may be caused by sediment wedges on the slope.

Northeast of Wewak the 20 to 40 mGal contours outline the offshore limits of a sedimentary sub-basin that had previously been interpreted from an aeromagnetic survey (see Chapter 3). A calculation of the basement depth below this anomaly of 20 mGal, using a basement/sediment density contrast of 0.2 g/cm^3 gives a figure of about 3 km which is consistent with the magnetic basement depth.

Near Madang, superimposed on the regional gravity gradient is a gravity minimum of -160 mGal which forms a small gravity low 20 mGal below its surroundings. This low is associated with a sedimentary sub-basin which probably contains several kilometres of recent sediments.

Overlying the western basin is a regional gravity platform with values averaging +150 mGal. It forms an elongate northwest-trending platform about 600 km long and 75 km wide. Towards the western end the Bouguer anomaly values increase to +190 mGal indicating thinning of the crust by several kilometres (Fig. 6).

The gravity trough over the Willaumez-Manus Rise has a minimum of +110 mGal with values generally 20 to 30 mGal lower than the western platform. These differences in values are attributed to a slight thickening of the crust along the rise. However, a trend of free-air values about 10 mGal higher than the surroundings indicates that the rise is partly supported by the strength of the crust.

The gravity platform over the eastern basin is a triangular-shaped feature with values ranging from +150 to +180 mGal and averaging about +170 mGal. This average is slightly higher than that of the western platform and indicates that the crust is a few kilometres thinner than that in the western region. Crustal thicknesses in this region are the thinnest in the Bismarck Sea and are about 20 km.

Surrounding the two platforms on the north and east is a gravity trough of +120 to +70 mGal, which overlies the West Melanesian Arc. Crustal thickness is about 25 km. The Bouguer anomaly gradient is steepest to the south of New Ireland where it is about 2 mGal/km. The lines that run northwards into the West Melanesian Trench recorded gravity values of +170 m Gal which indicate the crust has thinned to about 20 km in this region.

ii) Southeast Papua and Solomon Se:

The gravity data along the few regional lines in this region present a very complex picture. A knowledge of land gravity data from southeast Papua and offshore islands will be used to provide a more complete explanation of the observed marine gravity features.

South of the St Georges Channel is a regional gravity low of -50 mGal with a steep gradient of 3 mGal/km on the New Britain side. A faulted margin along the western boundary and over 1 km of sediment in the channel have accentuated both the regional gradient and gravity low, but are insufficient to account for all of the anomaly. Thickening of the crust under the Gazelle Peninsula probably results in crustal thicknesses of 30-35 km in this region. South of New Ireland a 0 mGal contour in an area devoid of sediments (Plate 5) supports the interpretation of continental crustal thicknesses in this region.

Traverses near Bougainville outlined a pronounced gravity ridge with an amplitude of +190 mGal and steep gradients of 3 mGal/km on both sides. This gravity ridge overlies the bathymetric ridge. Laudon (1968) has correlated the Bouguer anomaly highs on the Solomon Islands with basement ridges and Quaternary volcanics. However, the amplitude of the gravity ridge is too high to be explained solely by a high-density basement ridge. Rough calculations indicate that basement relief could cause about half of the +190 mGal anomaly and the remainder is most probably associated with crustal thinning below the topographic ridge. If this is the case the crustal thickness is about 25 km for the Bougainville region, which is consistent with that of the New Ireland region.

An intense negative anomaly of -130 mGal occurs over the Huon Gulf/Vitiaz Strait area. This gravity low lies on the same thick crustal trend as that near Madang. Recent tectonism forming the young mountain ranges in the Northern New Guinea Basin has caused this thick crustal trend. An extremely steep gradient of 5 mGal/km lies between this intense low and a +90 mGal high in the west of the Huon Gulf. This high is the offshore extension of the elongate Bouguer anomaly of +160 mGal which occurs over the Papuan Ultramafic Belt. The high forms a closure approximately overlying the southern margin of the gulf and indicates that the Papuan Ultramafic Belt terminates along the southern continental slope and is possibly terminated by an offshore extension of the Ramu-Markham Fault.

A Bouguer anomaly of +190 mGal was recorded on line 05/161 across the New Britain Trench and indicates that the depth to the base of the crust is about 17 km. The thinnest crust along this line is located in the central portion of the Solomon Sea about 30 km south of the bathmetric trench.

In southeast Papua the Bouguer anomaly contours show the same broad pattern as the topography and can be interpreted as arising from a decrease in crustal thickness from 25 km under the Papua Peninsula and the Pocklington Rise to less than 20 km in the Woodlark Basin.

Bouguer anomaly lows on the Papuan continental shelf are associated with the offshore Cape Vogel sedimentary basin outlined by previous geophysical work. Northwest of Cape Nelson a relative low of 20 mGal overlies the western sub-basin. This low, some 30 mGal below its surrounds, can be attributed to a 2.5-km-deep sedimentary basin if a sediment/basement density contrast of 0.3 g/cm^3 is assumed. This supports Milsom's (1971) interpretation that the offshore Cape Vogel basin has been infilled with relatively low-density sediments.

Near the Trobriand Islands another relative low of 50 mGal is associated with the eastern boundary of the eastern sedimentary sub-basin. Seismic results in this region indicate about 2 km of sediments. Southwest of the Trobriands the depocentre of the eastern sub-basin and possibly the offshore Cape Vogel Basin gives rise to the gravity minimum of 20 mGal found by the Eastern Papua gravity survey (Milsom, 1971).

Bouguer anomaly highs of 80-90 mGal with some 10-20 mGal relief are associated with basement ridges extending offshore from the three major capes along the northern Papuan coast. A small high in the centre of Goodenough Bay correlates with an area of basement outcrop.

A regional gravity gradient of over 3 mGal/km culminating in a Bouguer anomaly high of 220 mGal is associated with the northern margin of the Woodlark Ridge. Land gravity values from Woodlark Island shows a 200 mGal contour in the northwest and a 140-mGal contour in the southwest of the island and together with gravity readings taken on reefs indicate that the data on line 05/163 are representative of the gravity field over the Woodlark Ridge. This gravity high correlates with a volcanic basement ridge which trends northwest beneath the Trobriands and possibly Woodlark Island. The ridge is probably composed of a relatively high-density volcanic material (?ultramafic) as this is necessary to account for the high amplitude of the Bouguer anomaly.

Over the southern margin of the Woodlark Ridge a gravity trough is formed by values between about +140 to +50 mGal. The gravity minimum lies some 30 km south of the topographic ridge and may be caused by a combination of the gravity effect of the sedimentary basin on the southern flank of the ridge and the thickening of the crust below the ridge.

The Woodlark Basin has an associated regional gravity high with Bouguer anomaly values of +140 to +180 mGal that increase towards the east. Corresponding crustal thickness is about 20 km. On the south of the regional high a gravity gradient of 2 mGal/km delimits the northern margin of the Pocklington Ridge. A gravity trough with Bouguer anomaly values generally about +100 mGal overlies this ridge. The minimum observed value in the trough is +60 mGal.

iii) Gulf of Papua

Bouguer anomalies in the Gulf area increase southwards with values which range from -20 mGal along the coast to +150 mGal on the edge of the Coral Sea basin. Corresponding inferred mantle depths decrease from 33 km along the coast to about 20 km in the Coral Sea basin.

On the Papuan continental shelf two gravity lows correlate with areas of thick sedimentation within the offshore Papuan Basin. At the head of the Gulf a gravity low of-20 mGal overlies a region where over 8 km of sedimentary section has been found by previous aeromagnetic and seismic surveys. Southwards away from the low a positive gravity gradient reflects the thinning of sediments from 8 km to 4 km along latitude 9°S (see Chapter 3). Using the difference in sediment thickness of 4 km, the change in Bouguer anomaly values of 40 to 60 mGal can be explained if an average density contrast of about 0.3 g/cm^3 is assumed for the basin sediments.

A Bouguer anomaly ridge of +60 to +80 mGal in the centre of the Gulf trends east along latitude 9°S over both the continental shelf and slope. This high is possibly caused by a basement arch between the sedimentary sub-basin on the north and the Pandora Basin in the south and may form the southern boundary of the major portion of the basin.

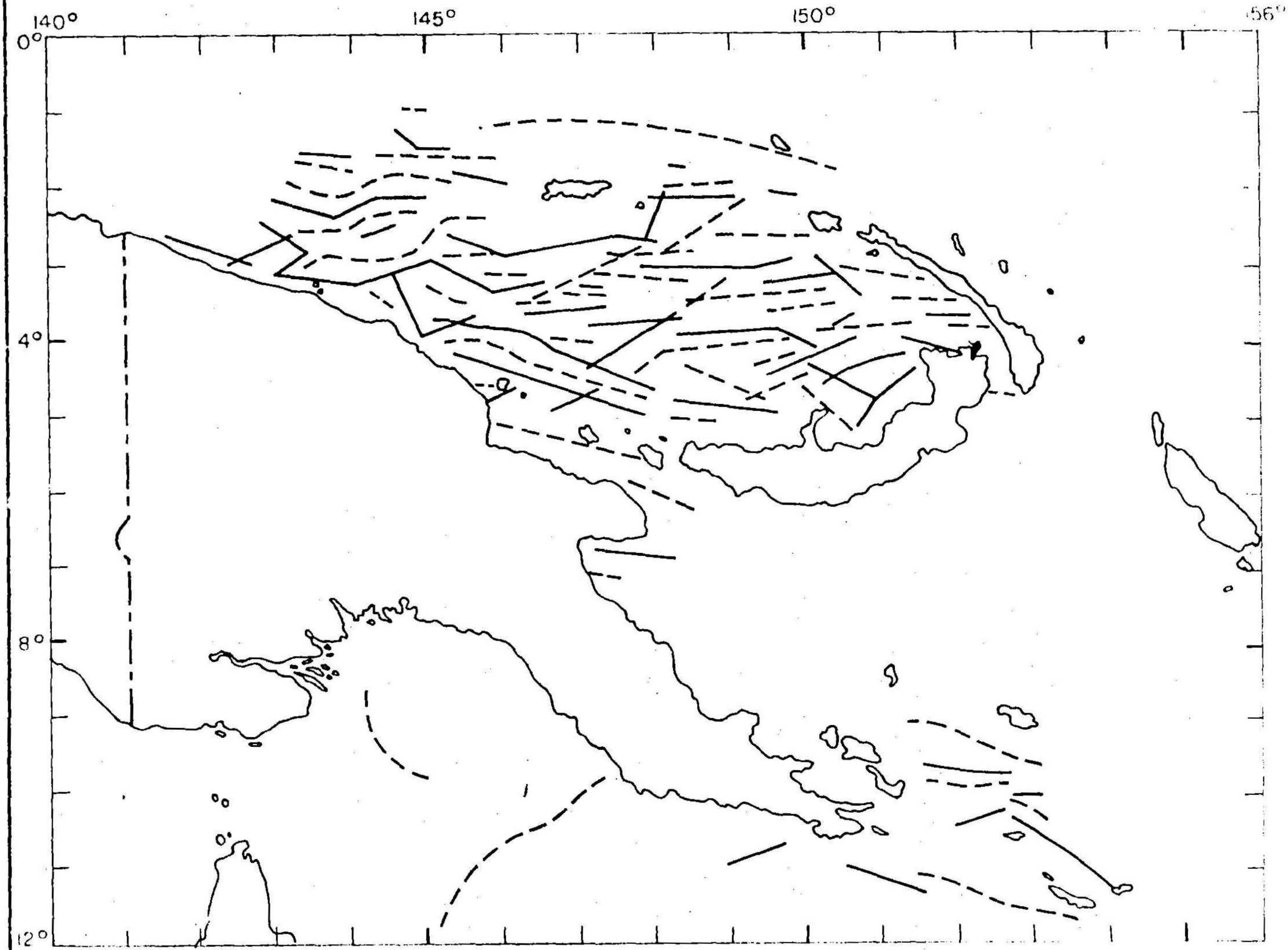
Along the southeast continental margin an elongate gravity low of -10 mGal correlates with the seaward extension of the Aure Trough. This trough, which is the depositional axis of the Papuan Basin, trends southeast to latitude 10°S (Mutter, 1972).

The Bouguer anomaly contour pattern shows little correlation with bathymetric features off the continental shelf except for the Pandora Basin which has an associated gravity low. The average gravity gradient over the deep water area is 0.5 mGal/km towards the south and southeast. Numerous small anomalies modify this regional gravity gradient and most likely reflect varying sediment thickness.

The low over the Pandora Basin attains values of +40 mGal with relief of 20-30 mGal below the surrounding field and indicates an area of thick sedimentation. Seismic results show a typical sedimentary basin with a maximum of 2 km of sediments overlying a smooth ?metamorphic 'basement'.

The Moresby Trough has an associated gravity gradient of 1 mGal/km towards the southwest and values that range from +10 to +80 mGal. This gradient reflects the thinning of the sedimentary sequence away from the axis of the Aure Trough which lies along the northeast margin of the bathymetric trough. Seismic results indicated over 2 km of sediments on the northeast flank of the trough. No basement horizon was visible on the seismic records in the region.

FIG. 7



0 200 400 600 KILOMETRES

SCALE 1:10 000 000 AT EQUATOR

POSITIVE
NEGATIVE

MAGNETIC TRENDS

The Eastern Plateau is characterised by a gravity terrace with a gentle southerly gradient. Bouguer anomaly values are generally between +80 and +100 mGal. Small lows of 10 mGal relief are associated with areas of localized thick sediments. To the west a north-trending gravity ridge separates the gravity low over the Pandora Basin from a low of similar amplitude over the continental shelf. An easterly extension of the gravity terrace cuts across the Moresby Trough at about latitude 10°30'S. This gravity terrace separates the southwesterly regional gradient in the north from the chiefly southeasterly regional gradient in the south. This may mark the transition zone between anomalies produced primarily by thick sedimentary sequences in the north from those produced by the crust/mantle interface in the south.

The Papuan Plateau is associated with a vague gravity terrace with values ranging between +90 and +110 mGal. A small low of 10-20 mGal relief through the centre of the plateau probably reflects an area of thick sedimentation.

6. MAGNETIC RESULTS

Magnetic anomalies depicted in Plate 4 have been computed using the method outlined in Appendix 2.

i) Bismarck Sea

High-amplitude short-wavelength magnetic anomalies are characteristic of the Bismarck Sea area. Observed amplitudes ranged between ± 1500 nT, but a range of only +850 to -1200 nT is apparent on the contour map (Plate 4) owing to the aliasing effect of the hourly sampling interval. Strong lineations are evident with trends in east, northeast, and northwest directions (Figure 7). Willcox (1971) has correlated the major east-west anomaly pattern with seamount lineations formed along a zone of shallow seismicity. This zone of seismicity at about 3°S defines a left-lateral strike-slip fault (Johnson & Molnar, 1972).

Along the New Guinea continental margin only one of the sedimentary sub-basins has an associated magnetic low. Off Madang the basin outlined by gravity results has an associated negative anomaly of -250 nT. West of Wewak, a positive magnetic trend of +150 to +200 nT along the continental slope with an associated negative of -50 to -100 nT on the shelf probably indicates either a basement ridge along the slope or a shallowing of the basement from the coast towards the continental margin. A horizontal basement which steps downwards at the shelf edge would, by induced magnetization, lead to a positive trend along the continental slope. However, this trend would only have a weak low of about -10 nT associated with it and therefore to account for the -50 to -100 nT low on the shelf the basement must deepen towards the coast. Seismic results indicate that the basement crops out at about 1 km on the continental slope and this together with magnetic interpretation in the Bewani-Torricelli sub-basin (Chapter 3) which gave magnetic basement depths of 3 km near the coast supports the interpretation of basement shallowing towards the continental margin.

A series of positive and negative magnetic trends parallel to the New Guinea and New Britain coast correlate with volcanic basement ridges of the South Bismarck Volcanic Arc.

In the western basin of the Bismarck Sea the magnetic lineations are less distinct, and anomalies lower in amplitude compared to those in the eastern basin. Anomalies in the western basin generally range from +400 to -300 nT except for a-600 to +650 nT anomaly associated with the seamount chain trending east from near Wewak. These lower amplitudes may indicate thick sedimentary sequences especially in the southern part of the western basin. Basement ridges and seamount peaks are not as common in this basin as in the east and this probably contributes to the decrease in amplitude of the anomalies.

High-amplitude anomalies from -1200 to +850 nT form strong east-trending lineations over the eastern basin and Willaumez-Manus Rise. The more intense anomalies are over the Willaumez-Manus Rise and correlate well with basement ridges and seamount chains as seen on the seismic sections. Farther east the correlation is present but is more vague. The amplitudes of the anomalies are too great to be explained solely by induced magnetization and thus most are due to remanent magnetization. Areas of comparatively quiet magnetic field near New Britain correlate with thick sedimentary sections.

The zone of seismicity across the Bismarck Sea (Denham, 1973) vaguely correlates with the intense negative anomaly zone between latitudes 3° and 4°S. At about longitude 148° the east-trending anomaly pattern and seamount ridge show a dextral offset to the north by some 40 km. This offset is of the same magnitude and direction as a step in the seismicity zone at longitude $148^{\circ}30'$ and may be caused by a right-lateral strike-slip fault which strikes to the north.

Connelly (1973) has modelled a magnetic profile across the eastern basin at about longitude 150°E. He found that most of the Bismarck Sea can be modelled as a reversely magnetized body except for a central block which is normally magnetized and correlates with the seismicity lineament. He concluded that this portion is the product of recent earth movements (the last 0.7 m.y.).

Along the West Melanesian Arc magnetic anomalies are of lower amplitude and longer wavelength than in the Bismarck Sea, indicating a greater depth to magnetic basement and/or a relatively non-magnetic basement. Values generally range between ±200 nT with broad anomalies of ±50 nT associated with the areas of thick sedimentation on the northern margin of the Arc. Farther north, anomalies become increasingly negative and attain values of -300 nT along the southern margin of the West Melanesian Trench.

ii) Southeast Papua and Solomon Sea

The magnetic anomaly field is quieter in this region than in the Bismarck Sea and contains anomalies characteristic of oceanic areas.

Anomalies south of New Ireland and near Bougainville Island are similar to those along the West Melanesian Arc and form a natural extension of these anomalies to the south. In the St Georges Channel a negative anomaly of -400 nT and a gentle gradient of 10 nT/km is associated with the western side of the channel and is consistent with the gravity results which suggest a faulted margin. A positive anomaly of +100 nT some 200-300 nT above its surroundings is related to the Bougainville basement ridge.

In the Huon Gulf/Vitiaz Strait region, magnetic anomalies are of small amplitude and broad wavelength with values generally between ±100 nT. High-frequency anomalies to +200 nT off the southeast tip of the Huon Peninsula indicate an area of shallow basement. The relatively non-magnetic character of this basement shows that it is probably related to the lavas and older sediments of the Northern New Guinea Basin.

A broad magnetic high about 120 km wide overlies the New Britain Trench and Solomon Sea. Values increase from -150 nT near New Britain, to +150 nT in the central Solomon Sea, and then decrease to +50 nT along the southern margin.

Along the survey line near the Papuan coast, the same magnetic pattern as in the Woodlark Basin is observed. Data from the 1969 BMR aeromagnetic survey shows that this magnetic pattern continues over the D'Entrecasteaux Islands and the shelf area southwest of the Trobriand Islands. The lines along the coast recorded a fairly undisturbed magnetic field indicative of the thick sedimentary section of the Cape Vogel Basin and the relatively non-magnetic ?metamorphic basement. Lows to -100 nT correlate with the areas of thick sedimentation. Anomalies intensified to +250 nT near Cape Vogel, Cape Nelson, and East Cape where the metamorphic and/or volcanic basement crop out.

Magnetic anomalies in the region off the continental shelf trend roughly west-northwest and correlate with basement ridges. Line 05/163 across the Woodlark Ridge outlined a positive anomaly of +300 nT on the northern margin and a negative anomaly of -400 nT at the southeast tip of the Trobriand Islands. These two anomalies are the magnetic expression of the shallow basement ridge beneath the topographic ridge. Farther south, a negative anomaly of -400 nT is superimposed on the basinal area defined by the seismic results (Plate 5). This negative anomaly and a relative high of -150 nT to the north are possibly the magnetic expression of the basement beneath the basin, but as this basement was not visible on the seismic records the exact nature of the basement topography remains unknown.

A strong dipole feature, from +500 to -300 nT, trends eastwards along the centre of the Woodlark Basin and roughly correlates with seamount peaks in the west and basement outcrops in the east.

Most of the Pocklington Ridge has a corresponding positive anomaly of 100-200 nT, which originates from the shallower magnetic basement depths along this ridge compared to those in the flanking basins. Anomalies are not intense as the basement is metamorphic in origin. Local magnetic highs to +350 nT are associated with basement highs underlying the numerous reefs in the area. South of the ridge, on the edge of the Coral Sea basin, negative anomalies of -150 nT were recorded.

iii) Gulf of Papua

A smooth magnetic anomaly field with low-amplitude long-wavelength anomalies between ± 50 nT is characteristic of the Gulf area. This type of field is to be expected, as the thick sedimentation results in a large depth to magnetic basement. On the Eastern Fields reef structures, small local positive anomalies up to 150 nT are associated with exposed or shallow basement. The low amplitude of these anomalies reflects a relatively non-magnetic basement probably of granitic or low-grade metamorphic composition. A local dipole of +300 nT and -50 nT in the western region is probably caused by an igneous intrusion.

7. SEISMIC RESULTS

A map showing the sediment distribution and structure of the Papua New Guinea region is presented in Plate 5. Sedimentary thicknesses have been determined from the seismic records assuming a sediment velocity of 2000 m/s. This velocity is appropriate for unconsolidated sediments but in regions of thick sedimentation velocities up to 3000 m/s may be closer to reality and hence thicknesses can be greater than those depicted on the map. Thicknesses were only determined to the limit of penetration: a maximum of 2 seconds of reflection time.

i) Bismarck Sea

Most of the Bismarck Sea region is covered by a veneer of sediments. Around the peripheries thick accumulations of sediment have formed behind basement ridges and in general have accumulated on the southern side. Sediment thicknesses greater than 2 km were found in these areas.

Along the New Guinea continental margin thick sediments have accumulated in the west of and near to Wewak, and east of Madang between Karkar and Umboi Islands.

Between Wewak and the Papua New Guinea/Irian Jaya border the shelf sediments are 500 to 1000 m thick. Sediments are flat-lying and the basal unit (basement) crops out on the continental slope at 600 m water depth. In most areas a thin drape of sediments has formed over the slope. On line 05/074 on the shelf in the extreme west of the survey area, a rugged water bottom is associated with a region of shallow basement. Sediments up to 1 km thick have accumulated at the base of the slope and presumably cause the gravity lows over the continental slope.

The Wewak sedimentary sub-basin extends onto the continental shelf where it contains over 1 km of flat-lying well stratified sediments. The eastern margin of the basin is steep and is formed by a fault of about 1000 m throw which separates the basin sediments from an area of shallow basement to the south. This fault is probably the offshore extension of the northwest-trending fault south of Wewak (Fig. 4). The western margin is formed by a series of northeast-trending basement ridges offshore from Wewak. Off the shelf the expression of the sub-basin is probably a sediment pocket which has formed behind a basement ridge and contains over 1 km of sediments. The east-trending seamount chain near Wewak probably indicates an offshore extension of the Bewani-Torricelli Orogenic Belt.

Two deep sedimentary troughs have formed on the southern side of two basement ridges in the area between Karkar and Umboi Island. Line 05/026 provides the best seismic definition over the ridges and troughs and is used to describe the structure of the region. Sediments which are about 1 km thick near the New Guinea coast dip gently northwards and attain a thickness of over 2.5 km in the southern trough. This trough is bounded on the north by a basement ridge which is part of the South Bismarck Volcanic Arc (Fig. 4). In the trough the sediments form a three-layer sequence. An unconformity at 500 m below sea-bed separates an upper layer of well stratified sediments from an acoustically transparent to poorly stratified layer. About 1000 m below sea-bed is another band of well stratified sediments 400 m thick. Near Madang, only the upper two sequences are visible on the seismic sections and on line 05/038 600 m of well stratified sediments overlie the acoustically transparent layer. No basement surface or stratified sediments were visible below the transparent sequence and thus the transparent layer possibly thickens westward. This supports the gravity evidence of several kilometres of sediments in this region.

The northern ridge lies parallel to and some 70 km north of the South Bismarck Volcanic Arc. South of this ridge about 2 km of well stratified sediments have accumulated. The sedimentary sequences are similar to those in the southern trough but the unconformity, if present, is only 100 m below sea-bed, the acoustically transparent layer only 100 m thick, and thus the upper two layers are much thinner. Several faults of about 100 m throw disturb the otherwise flat-lying sediments.

The basement surface underlying the western basin appears on the seismic records as a strong reflector near the sea-bed. This smooth reflector is most likely oceanic basement. To the south this basement is truncated by the outer South Bismarck Volcanic Arc and farther west by the New Guinea continental margin. Northwards it is continuous across the West Melanesian Arc west of Manus Island. Sediments which overlie this surface are between 100 and 200 m thick and occupy a broad zone some 100 km wide in the north of the region. These sediments thicken gradually southwards and attain a thickness of about 1 km at the base of the New Guinea continental slope.

On the western end of the survey area the seismic results indicate a possible subduction zone extending some 250 km westwards across the survey area from lines 05/057 to 05/068. The basement surface and sediments dip southwards into the eastern end of the New Guinea Trench. Relatively undisturbed conformable sediments thicken from about 200 m near the basement ridge about 100 km north of Wewak to 800 - 900 m at the base of the continental slope. This form of sedimentation indicates that there has been no significant contribution of sediments from the continental margin or New Guinea mainland and thus the sedimentary section over the western basin is most likely to be pelagic in origin. Between lines 05/057 and 05/059, the originally south-dipping sediments have been uplifted by volcanism associated with the South Bismarck Volcanic Arc and now dip towards the north.

The absence of volcanism along the New Guinea mainland indicates that the subduction zone is relatively recent as the underthrusting plate has not reached a depth sufficient to induce volcanism. An alternative interpretation of this western region is that the sediments may have been deposited by turbidite currents from the New Guinea margin and then regionally tilted by faulting along the continental margin.

Seamount chains and basement ridges produce a rugged basement topography in the eastern basin and the Willaumez-Manus Rise and together with graben features give an overall east-west structural grain to this region. A major zone of seamount chains and basement ridges extends eastwards across the Bismarck Sea at about latitude $3^{o}30'$S. This zone of basement ridges has presumably been formed by ?basaltic volcanics intruded along the fault zone across the Bismarck Sea. Oceanic basement similar to that beneath the western basin is found in the eastern basin and Willaumez-Manus Rise. It is truncated on the north by the steep, possibly faulted, margin of the West Melanesian Arc. The southern boundary may be the South Bismarck Volcanic Arc but because there are no strong lineations of the Arc in this region the boundary is indistinct.

A graben about 20 km wide lies parallel to and south of New Ireland. It extends the complete length of the island and is possibly the northwest extension of the graben forming the St Georges Channel. Other grabens and faults in this region parallel the main graben.

Sediments over the eastern basin and Willaumez-Manu Rise are between 100 m and 250 m thick except for large accumulations of sediments near the New Britain continental margin. These thick sequences of sediment have accumulated behind basement ridges and form two sedimentary basins which are structurally similar to the sediment troughs in the Karkar/Umboi Island region. One basin to the east of Willaumez Peninsula contains about 1.5 km of flat-lying and well stratified sediments. These sediments drape against the basement highs which form the boundaries. The other basin west of Willaumez Penisula contains about 1 km of flat-lying sediments. In this basin the well stratified sediments are restricted to the bottom part of the sequence and are overlain by acoustically transparent to poorly stratified sediments. This sedimentary sequence is similar to that of the two lower layers found in the sedimentary troughs some 150 km to the west. The unconformity present in the western troughs is not apparent in the basins of the eastern region.

Major sedimentary basins have developed on the northern margin of the West Melanesian Arc. Sediment thicknesses are generally about 1 km with local maxima to 1.5 km in basement depressions. North of Manus Island a prominent horizon about 500 m below sea-bed marks the top of a zone of well stratified sediments. Overlying this horizon is a 400-500 m band of acoustically transparent sediments and 100-200 m of stratified sediments which lie immediately beneath the sea-bed. These relatively undisturbed sediments dip gently north and form slump features at the base of the steepest part of the slope. On line 05/045 the prominent horizon deepens northwards down the slope from 200 m to 400 m below sea-bed. As mentioned earlier an oceanic basement is characteristic of the western basin of the Bismarck Sea. This basement is continuous across the West Melanesian Arc west of Manus Island. About 50 km northwest of Manus Island a transition zone some 10 km wide separates the oceanic basement of the Bismarck Sea from the 'arc-type' basement of the West Melanesian Arc.

Between Manus Island and New Hanover three east-trending basement ridges enclose two deep sedimentary basins. On line 05/102 which crosses the area from south to north, the southernmost basement ridge underlies the bathymetric rise which, at a water depth of 750 m, forms part of the West Melanesian Arc. On the northern slope of this rise the other two basement ridges lie close to the sea-bed at depths of 1200 m and 1800 m. The more southerly, shallower basin contains up to 1.5 km of undisturbed, well stratified sediments which dip towards the north. The deeper basin contains about 1 km of folded or slumped sediments. Eastwards the two basins merge into one containing about 1.5 km of sediments except on a sediment-covered ridge where a thickness of 2 km was measured. The southernmost basement ridge extends eastwards but deepens to about 1500 m. North of New Hanover sediments dip northeast and pinch out against a southwest-dipping basement surface. Farther to the northeast the basement surface becomes rugged and has little overlying sediments.

ii) Southeast Papua and Solomon Sea

The smooth floor of the St Georges Channel is formed by flat-lying, well stratified sediments which abut against faulted margins. The south end of the channel is formed by a graben which contains 1200 m of sediments. The nature of the northern margins of the channel is uncertain as traverses are parallel to the coast. Shallow and exposed basement was found on the bathymetric ridge south of New Ireland.

On the flanks of the ridge of Bougainville Island are two sedimentary basins. The western basin contains relatively undisturbed sediments about 1 km thick which dip down-slope. In the eastern basin sediments up to 1.5 km thick are gently folded and have a regional tilt to the west instead of a normal down-slope dip to the east. A broad anticline some 3 km across lies along the eastern boundary of the basin. Disruption of the sediments to the east of the anticline is probably caused by a fault zone, which may have uplifted or formed the anticline and produced the regional tilt to the west of the basin sediments.

Shallow basement with up to 600 m of overlying sediment is characteristic of the Huon Gulf-Vitiaz Strait region. Westwards along the northern flank of the Gulf sediments thicken from near zero at the tip of Huon Peninsula to about 1 km near Lae. Southwards along the coast and eastwards to the major change in slope, flat-lying sediments about 600 m thick overlie a rugged basement. Farther east in the deeper portions of the Gulf the basement lies close to the sea-bed.

The New Britain Trench contains about 1300 m of sedimentary section in the bottom of the trench. Sediments are mainly flat-lying and disturbed by several small faults. Basement is exposed on the northern margin of the trench and only a small infill of sediments has accumulated in depressions. Immediately north of the trench, on the northern slope, is a major basement high of some 1 km relief. The southern margin of the trench appears to be a series of fault blocks, downthrown to the north, which have about 1 km displacement at the sea-bed between blocks. The basement surface of each block dips southwards and has provided a depression behind the basement crest where up to 2 km of sediments has accumulated. Reflectors within these sedimentary sections are well stratified and indicate that sediments are most probably turbidites from the Papuan continental margin. A transition zone between basement types occurs in the region of the 5000 m isobath and separates the continental basement beneath the southern blocks from the oceanic basement under the northern block and the trench.

Along the survey line near the Papuan coast basement ridges between the three capes and the D'Entrecasteaux Islands divide the offshore Cape Vogel Basin into several smaller sub-basins. In Goodenough Bay a sedimentary basin contains up to 1.2 km of well stratified sediments overlying a rugged basement. A basement high in the centre of the basin is probably a southwest extension of the shallow basement below Fergusson Island and causes the associated gravity high. In Collingwood Bay sediments are about 1 km thick. These sediments dip northwards away from the graben shown in Plate 5. Little is known of the northern margin owing to the loss of several hours of seismic date near Cape Nelson. On the north side of Cape Nelson a rugged basement dips sharply towards the north beneath the major part of the offshore Cape Vogel Basin. Multiples and ringing due to the shallow water conceal the basin structure on the seismic sections. A basement ridge visible on line 05/011 across the north Papuan continental margin possibly forms the northern boundary of the basin. North of this ridge steeply-dipping sediments up to 1.5 km thick have built outwards and extended the continental shelf to the north by some 10 km.

The Woodlark Ridge is formed by a flat-topped basement ridge about 60 km in width. The basement surface is relatively smooth and is overlain by 400 m of flat-lying sediments. No change in basement character is apparent on the seismic section across the ridge although major changes are necessary to explain the large gravity and magnetic highs near the northern margin.

South of the Trobriand Islands is a major sedimentary basin with sediment thicknesses of at least 1700 m. Only the eastern end of the basin was surveyed, with the major portion of the basin defined by the aeromagnetic survey of eastern Papua (BMR, 1971). A major unconformity between

500 and 1000 m below the sea-bed is present throughout the basin. It is formed between gently folded sediments and the overlying flat-bedded sediments. This unconformity is probably the Mesozoic/mid-Miocene unconformity found in the Cape Vogel Basin (Thompson, 1965).

The Woodlark Basin has sediments up to 500 m thick formed in pockets within the rough basement topography. Faults and basement ridges have predominantly east trends.

Along the Pocklington Ridge basement ridges correlate with the major zones of reef development. On line 05/007 across the Ridge, two sedimentary basins have formed between the basement ridges, and contain up to 1.5 km of flat-lying sediment.

iii) Gulf of Papua

Sediment distribution in the Gulf area is difficult to determine as basement is rarely visible on the seismic sections. Off the shelf an erosional unconformity probably the Mesozoic/mid-Miocene unconformity has been used as 'basement' for preparation of the sediment thickness map.

On the Papuan continental shelf the seismic information is obscured by multiples. In places seismic penetration up to 1600 m confirmed the previous geophysical results that sediments dip and thicken eastwards towards the Aure Trough. Near the west ends of the survey lines at about longitude 144°15', the Miocene Limestone shelf edge outlined by Phillips (Fig. 5) appears on the sections as a steeply-dipping strong reflector. This shelf edge can be traced south to latitude 9°20', that is to line 05/207 the southernmost survey line on the shelf. A southeast-trending anticline lies under the eastern continental shelf near to the shelf break and may have formed a dam behind which the shelf sediments accumulated. Several anticlinal trends associated with the Aure Trough have been traced southwards across the continental slope to about latitude 9°S by Mutter (1972).

In the Eastern Plateau region 500 m of flat-lying, well stratified sediments overlie a smooth 'basement' surface which is an erosional unconformity and possibly represents the top of the Mesozoic (?Lower Cretaceous). The period between the Lower Cretaceous and Miocene was one of widespread emergence and erosion and consequently a major depositional break occurred over most of the Papuan Basin.

The 'basement' crops out near the Eastern Fields reefs. Sediments thicken rapidly to about 1 km along the eastern edge of the plateau and to 1.5 km into the Pandora

Basin in the west. Southwards sediments thicken from 500 m to about 1 km. Sediments up to 1.5 km thick have accumulated in pockets in the 'basement' surface. Several strong reflectors originate at or near the 'basement' surface.

The Pandora Basin is a typical sedimentary basin formed in a depression in the 'basement' surface. It is some 150 km by 60 km in extent and is elongate in a northeasterly direction. Sediment thicknesses vary from 400 m on the west, to a maximum of about 2000 m in the centre of the basin and to 1000 m on the east. The southern boundary is formed by a basement high which reaches almost to the sea-bed. Northwards away from this high the sediments gradually thicken into the basin. Sediments are flat-lying throughout the basin and well stratified reflectors appear to be more predominant on the western side of the basin. On the eastern side the reflectors become more jumbled and poorly stratified. Line 14/028 across the south end of the basin shows a sharp west-dipping contact between these two sedimentary types. The well stratified reflectors on the west possibly represent fluvial sediments, and the jumbled and poorly stratified reflectors on the east probably represent shallow marine sediments, reefs, and reef detritus.

A prominent horizon about 1 km below sea-bed is present throughout the Moresby Trough. This horizon probably originates from near the seismic 'basement' as it overlies the 'basement' near the Eastern Fields reef. At the head of the trough the flat-lying prominent horizon is overlain by a 600 m sequence of jumbled reflectors which in turn is overlain by 400 m of well stratified reflectors. To the east the prominent horizon is overlain by much thicker sediments. In the middle zone of the trough around lines 05/211 and 05/213, this prominent horizon is 600 m below sea-bed in the centre of the trough and deepens to the east to about 1.5 km at the base of the continental slope. Towards the west the sediment thickness is generally about 800 m but it reaches more than 1 km in pockets along the eastern boundary of the Eastern Plateau.

This thickening of the sediments to the east is consistent with the gravity results which show a negative gravity gradient to the northeast.

The Moresby Canyon is a recent feature cut into flat-lying sediments which have infilled a trough in the 'basement' surface. This trough is some 30 km wide and about 1 km deep. The form of the trough and its proximity to the canyon probably indicate that it also was formed by erosion. Sediments are about 1 km thick between the Eastern Plateau and Moresby Canyon. They thicken to over 2000 m beneath the canyon and then thin to about 800 m east of the canyon. Several strong reflectors occur near the basement surface.

Seismic 'basement' lies at about 800 m below sea-bed over most of the Papuan Plateau region. Poorly defined reflections within the 'basement' indicate it is probably sedimentary or metamorphic in character. Sediments in the Papuan Plateau region and neighbouring continental slope are flat-lying with down-slope dips and are relatively undisturbed. They thin from about 2 km on the Papuan slope to 1 km along the northern margin of the plateau and then thin further to 500 m along the southern edge.

Seismic sections over the western margin of the Portlock Trough show 'basement' about 400 m below sea-bed. The 'basement' deepens to about 1 km under the trough. On the eastern margin the trough appears to be fault-bounded. Line 05/228 shows sediments thinning from 1.5 km in the south to 0 km at latitude 10°50' where a basement outcrop forms the southern boundary at the Pandora Basin.

8. INTERPRETATION AND CONCLUSIONS

1) Bismarck Sea

The Bismarck Sea is an enclosed marginal basin generally about 2000 m deep. It is divided into two sub-basins by a northwest-trending rise between Willaumez Peninsula and Manus Island. Estimations of the depth to the base of the crust made from the gravity data yeild a figure of about 20 to 25 km for the Bismarck Sea region. The eastern sub-basin appears to have the slightly thinner crust at about 20 km.

Intense magnetic anomalies were recorded over most of the Bismarck Sea. The anomalies form strong lineations mainly with an east-west alignment but also with minor northeast and northwest trends. These bands of magnetic anomalies are associated with the seamount chains and basement ridges outlined by the seismic results. Seafloor-spreading type anomalies due to the opening of the marginal basin may exist but, if so, are masked by the intense anomalies arising from the numerous seamounts. Further work on the magnetic profiles may resolve this problem.

The major east-west magnetic anomaly band shows close correlation with a zone of shallow seismicity along latitude 3°30'S and with an almost continuous basement ridge extending from New Ireland to the New Guinea coast near Wewak. The intensity of magnetic anomalies over this basement ridge is much greater than that over the andesitic volcanics of the

South Bismarck Volcanic Arc. This indicates a difference in composition of the basement material and that the basement ridge is most likely composed of basic volcanics, presumably oceanic basalt. Earthquake focal mechanisms indicate left-lateral strike-slip movement along this zone of seismicity (Denham, 1973). Therefore the seamount chain/basement ridge lineament may have formed by the intrusion of basaltic material along the fault zone.

The zone of seismicity continues uninterrupted onto the New Guinea mainland and apparently connects with an extensive zone of recent faulting mapped north of the Torricelli Mountains by Hutchison (1974). Left-lateral strike-slip movement does not disagree with the inconclusive geological information, so it appears that the Torricelli fault zone is an extension of the Bismarck Sea fault zone.

The Torricelli Orogenic Belt is apparently continuous with the Bismarck Sea seamount chain, as well as the fault zone. These features were probably all produced in response to the stress field caused by the interaction of the Australian and Pacific plates. Basement rocks north of the Torricelli fault zone have a strong oceanic affinity when compared to the more 'continental' basement to the south. Together with basic lavas found near Wewak this would be consistent with the seamount chain lineament extending onto the mainland.

Most of the Bismarck Sea basin is covered by a veneer of sediments. However, around the peripheries sedimentary sections up to 2 km thick have accumulated behind basement ridges. These sediments are probably derived from the surrounding islands and have been rapidly deposited since the Early Tertiary, primarily by turbidity currents.

The depositional axis of the Northern New Guinea Basin does not appear to lie offshore as suggested by Thompson (1965), although several small sub-basins and areas of thick sedimentation have been delimited on the continental margin.

The Aitape and Wewak Troughs extend offshore onto the continental shelf where they contain up to 1 km of sediments. The Aitape Trough is bounded seawards by basement which shallows from about 3 km on the coast to outcrop on the continental slope at 700 m water depth. This basement ridge possibly forms part of the Oenake Serra Uplift. The Wewak Trough contains about 1 km of flat-lying conformable sediments on the shelf and a similar amount off the shelf where sediments have ponded behind a basement ridge at about 700 m water depth. The basin is bounded on the southeast by a major fault of at least 1000 m throw, and on the northwest by a series of basement ridges.

The volcanic ridges are associated with the South Bismarck Volcanic Arc in the Karkar/Umboi Island region (Pl. 5). The southern ridge forms the volcanic arc proper and contains numerous volcanic islands and seamounts between New Britain and Manam Island. The other volcanic ridge parallel to and some 70 km north of the main volcanic Arc extends from Karkar to Umboi Islands, and possibly extends into the Witu Islands. This outer ridge has little topographic expression except for small seamounts and shows mainly as a basement high on the seismic sections. The volcanic ridge which forms the Schouten Islands is offset some 40 km to the north from the main volcanic Arc and possibly lies on a northwest extension of the outer volcanic ridge. Strong northwest magnetic trends closely correlate with both the main Volcanic Arc and the outer ridge (Fig. 7). Magnetic anomalies over both ridges have similar amplitudes which indicate that the outer volcanic ridge is composed of andesitic material similar to the South Bismarck Volcanic Arc rather than the basic lavas which form the basement ridges farther north in the Bismarck Sea.

To the south of these volcanic ridges two major sedimentary troughs have developed, containing over 2 km of sediments. Sediments in these troughs are flat-lying, relatively undisturbed, and form three distinct sedimentary sequences. The thickening of the middle sequence to the west and the thinning of the upper two sequences to the north and east indicate a source for the sediments from the south and west, that is possibly the coastal ranges near Madang.

On the northern slope of the West Melanesian Arc thick sediments have accumulated in basins behind the basement ridges. Sediments are generally conformable and dip gently northwards. Slump features have formed at the base of the steepest part of the slope. Magnetic anomalies are much quieter than in the Bismarck Sea, with low-amplitude long-wavelength anomalies reflecting the thick sedimentary sections and relatively non-magnetic basement. Anomalies along the West Melanesian Arc are similar to those over the South Bismarck Volcanic Arc and are in part also associated with andesitic volcanic basement.

The age of the basement underlying the Bismarck Sea is unknown as there is no reliable core information. An approximate age can be deduced using an average rate of sedimentation and the thickness of sediment over the Bismarck Sea region. Results from the Joides Deep Sea Drilling Project (Winterer et al., 1971) at site 62 on the Eauripik-New Guinea Rise (600 km northwest of Manus Island) gave a virtually uninterrupted sequence of upper Oligocene through Quaternary chalks and chalk oozes overlying an intrusive Oligocene basalt basement. The hole penetrated 580 m of sediment and was drilled in a water depth of 2591 m, which is comparable to depths in the Bismarck Sea. Average rate of sedimentation was about 20 m/m.y. This rate is similar to the rates at site 63 (300 km north of Manus Island) while the site was above the carbonate compensation depth, and at site 64 (600 km east of New Ireland). Sediments over most of the Bismarck Sea have an almost constant thickness of 100-200 m. Assuming an average rate of sedimentation of 20 m/m.y. and that there were no major depositional breaks, the base of the sedimentary section would have an age of 5-10 m.y. (upper Miocene). Thus it appears likely that the Bismarck Sea area has a Tertiary oceanic basement possibly of Miocene age.

ii) <u>Southeast Papua and the Solomon Sea</u>

From the seismic and magnetic results, the St Georges Channel appears to be a north-trending graben with a sedimentary fill of at least 1200 m which forms the flat floor. Gravity results indicate that this area has a crust of continental thickness.

The two seismic sections across the ridge north of Bougainville Island show that the topographic ridge is underlain by a central basement ridge, on either side of which is a sedimentary basin. These basins contain over 1 km of sedimentary section with the sediments of the eastern one being faulted and regionally tilted to the west. The strong regional gravity high over the ridge is caused partly by the shallow high-density basement and partly by thinning of the crust from the area south of New Ireland.

An intense gravity low off the Huon Peninsula is the southeast end of a northwest-trending gravity trough which extends past Madang. This trough is associated with the thick crust under the young mountain ranges of the Northern New Guinea Basin. The adjacent gravity high in the Huon Gulf is the northeast edge of the regional gravity ridge associated with the Papuan ultramafic belt. The intense gravity gradient through the Gulf probably indicates that a faulted boundary exists between the ultraaand.the Northern New Guinea Basin sediments and thus the Ramu-Markham fault zone probably extends southeast along the southern continental slope.

The Cape Vogel Basin extends onto the north Papuan continental shelf where it divides into several sub-basins. In Goodenough and Collingwood Bays two small sub-basins contain about 1 km of sediment overlying rugged basement. The major portion of the offshore Cape Vogel Basin is a sedimentary trough which extends from the Papuan coast to the Trobriand Islands. Aeromagnetic and seismic data show this trough to be divided into two sub-basins containing 2500 and 3000 m of sediment. Only the eastern portion of the deeper basin was outlined by the survey. Seismic results showed almost 2 km of sediments in this eastern portion. A major unconformity, probably of mid-Miocene age, separates gently folded sediments from overlying flat-bedded sediments.

The Woodlark Ridge has an associated gravity high which is partly caused by a shallow high-density volcanic ridge and partly by a thin crust. Seismic sections show a flat-topped basement ridge overlain by about 400 m of conformable sediments. Short-wavelength magnetic anomalies were recorded over the steep edges of the basement ridge.

The Woodlark Basin is almost devoid of sediments and has a rugged basement topography typical of oceanic areas. Sediments up to 500 m thick have accumulated in pockets within the rough basement topography. Basement ridges and faults, and their associated magnetic anomalies show a pronounced easterly trend. The magnetic profiles across the basin show no obvious evidence for sea-floor spreading as suggested by Milsom (1970), and Luyendyk et al. (1973). However, the large positive anomaly flanked by negative anomalies which extends across the western Woodlark Basin (Pl. 4) could possibly be the central anomaly (Anomaly 1) which Luyendyk et al. (op. cit.) found in the eastern Woodlark Basin. Further study of the magnetic profiles should resolve this problem.

iii) <u>Gulf of Papua</u>

Throughout the Gulf, the smooth magnetic field indicates a deep, relatively non-magnetic basement. This basement is probably of granitic composition similar to the basement on the western flank of the Gulf. There is a regional gravity gradient across the area, which in the north is associated with the thickening of the sedimentary section into the Aure Trough, and in the south is associated with the crustal thinning from Papua towards the Coral Sea.

At the head of the Gulf lies the offshore Papuan Basin which has associated with it two gravity minima. An elongate gravity low on the northeast flank of the Gulf indicates that the Aure Trough extends southeast along the continental margin to almost latitude 10^{o}S. Seismic results outline several anticlinal trends which are associated with the Trough. Southeast of Deception Bay another gravity low is associated with a depocentre of the offshore Papuan Basin. In this region Phillips (1968a) found 8 km of primarily Tertiary sediments overlying a Mesozoic horizon. An east-trending gravity high at about latitude 9°S possibly arises from an arch in the Mesozoic sediments and/or basement which forms the southern boundary of the major portion of the offshore Papuan Basin. Although the BMR seismic sections are poor on the shelf, and no basement reflection is visible, the Miocene limestone shelf edge outlined by Phillips (op. cit.) can be traced.

The smooth-floored Pandora Basin is 1600 m deep. It contains up to 2 km of flat-lying sediments overlying seismic 'basement'. However, this 'basement' may mark the top of the Mesozoic sediments.

The Eastern Plateau lies between 1000 m and 1600 m water depth and has its shallowest point at its northern apex in the Eastern Fields Reefs. An unconformity surface lies within 500 m of the seabed over most of the Plateau. This major erosional unconformity, close to the basement, is also apparent over most of the Gulf region. It is probably the mid-Miocene unconformity formed during a major depositional break between the Lower Cretaceous and/or Eocene and the middle Miocene. The unconformity surface deepens northeast beneath the Moresby Trough from its outcrop near the Eastern Fields Reefs to 1.5 km below seabed on the eastern margin of the Trough. If this surface continues deepening or remains constant, there would be in excess of 4 km of Tertiary sediment within the Aure Trough in this region.

9. REFERENCES

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Iokea No. 1 Well	" "	68/2013
Kapuri No. 1 Well	" "	68/2038
Maiva No. 1 Well	" "	68/2014
Orokola No. 1 Well	" "	67/4274
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APPENDIX 1

GRAVITY TIES

PORT	DATE	ABSOLUTE WHARF READING AT S.L.	LACOSTE & SCALE	ROMBERG METER MILLIGAL	METER ZERO
Sydney	15/8/70	979690.1	8294.3	8529.50	971160.6
Mackay	21/8/70	978736.5	7367.2	7575.63	971160.9
Cairns	23/8/70	978497.6	7135.5	7337.24	971160.4
Port Moresby	28/8/70	978226.3	6870.8	7064.88	971161.4
Port Moresby	2/9/70	978225.5	6871.2	7065.29	971160.2
Madang	15/9/70	977963.1	6615.4	6802.13	971161.0
Lae	19/9/70	978009.6	6662.6	6850.69	971158.9
Rabaul	27/10/70	978177.1	6827.4	7020.23	971156.9
Port Moresby	21/11/70	978224.0	6873.0	7067.14	971156.9
Port Moresby	11/12/70	978225.5	6874.5	7068.69	971156.8

APPENDIX 2

REDUCTION OF GRAVITY AND MAGNETIC DATA

Gravity

Bouguer anomalies are computed using the formula

$$B.A. = g - g_o + 7.5\ V_E \text{Cos}\ L + 0.0419\ (d-1)H$$

where g = measured value of gravity in milligals
g_o = theoretical gravity computed from the International Gravity Field
V_E = eastward component of speed in knots
L = latitude
d = Bouguer density chosen as 2.2 gm/cm^3
H = water depth.

The term $7.5\ V_E \text{Cos}\ L$ is the first-order approximation for the Eotvos correction.

Magnetics

Magnetic anomalies are computed using the formula

$$M.A. = M - M_o - D$$

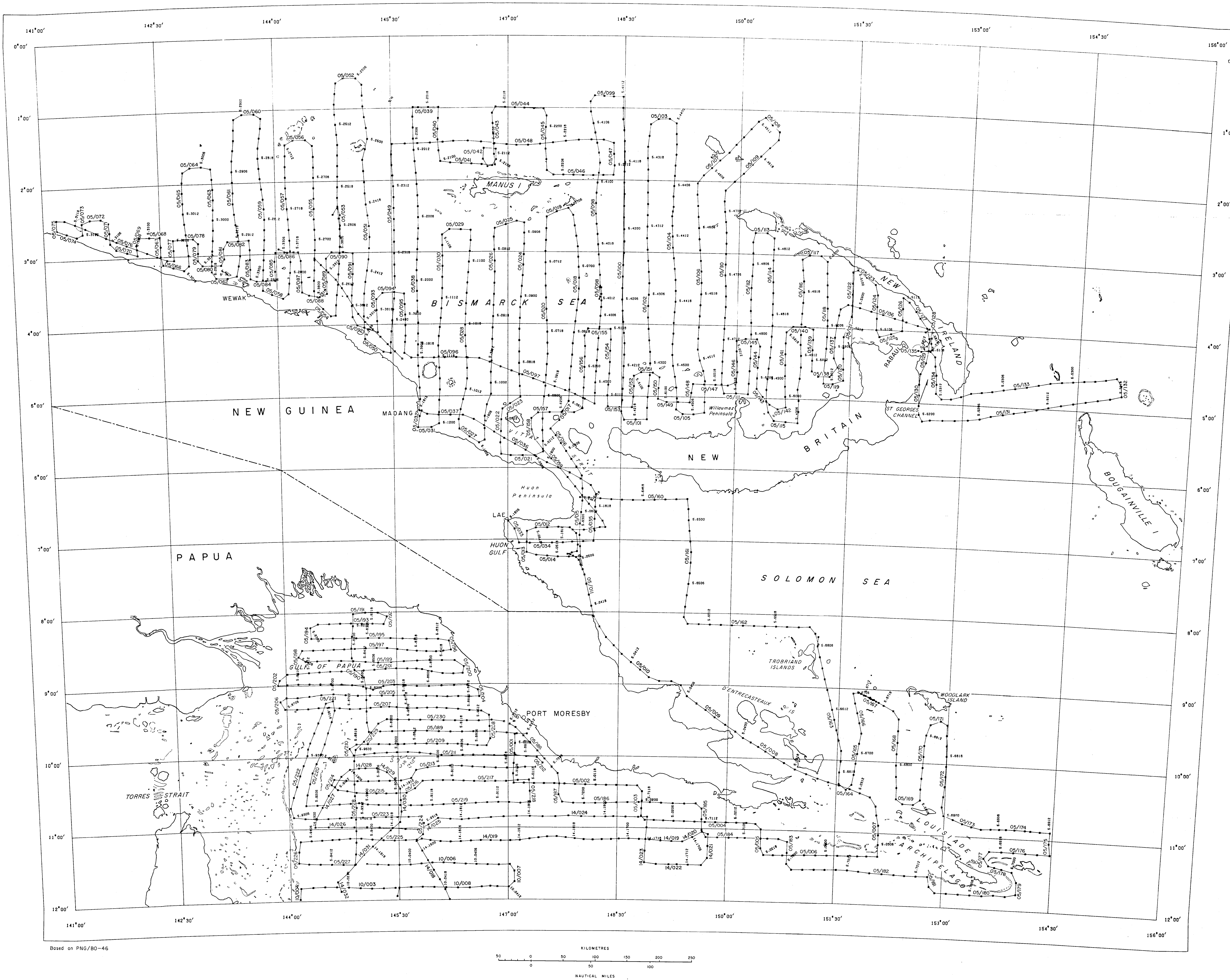
where M = observed reading in gammas
M_o = theoretical value calculated from the International Geomagnetic Reference Field (IGRF)
D = diurnal or departure from a mean level recorded at a shore station.

PLOTTED 73/07/17

AUSTRALIA 1: 2500000

BISMARCK SEA
AND GULF OF PAPUA

PLATE I



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

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.

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.

BISMARCK SEA
AND GULF OF PAPUA
AREA 1

RECORD No 1975/115

PNG/B8-72-1

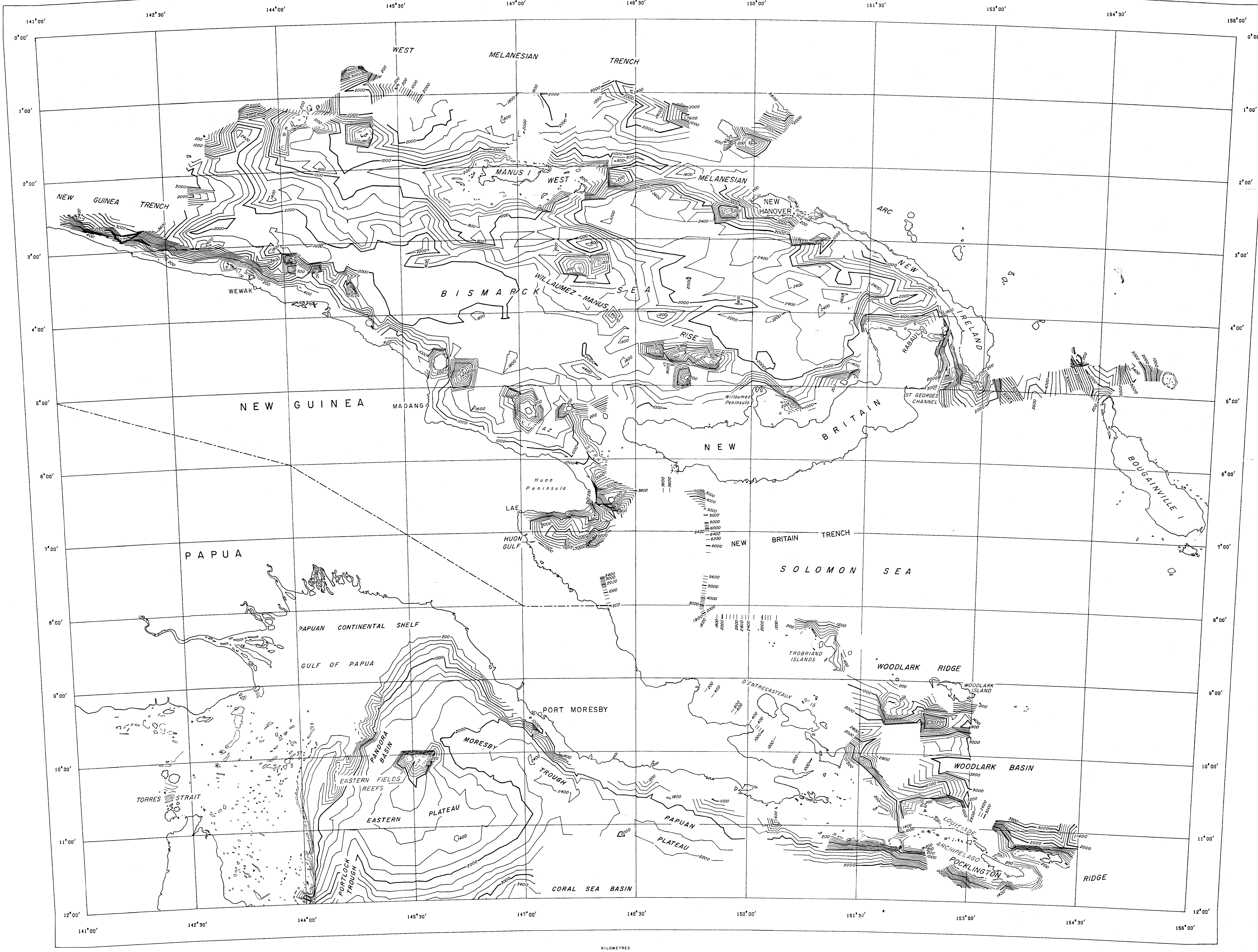
BISMARCK SEA

AND GULF OF PAPUA

PLOTTED 73/07/17

AUSTRALIA 1: 2500000

PLATE 2



Based on PNG/B0-46

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

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)

Contour interval : 200 metres

Water velocity assumed constant at 1500m/s

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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 30 nautical miles, that plate is not contoured.

BISMARCK SEA

AND GULF OF PAPUA

AREA 1

RECORD No 1975/115

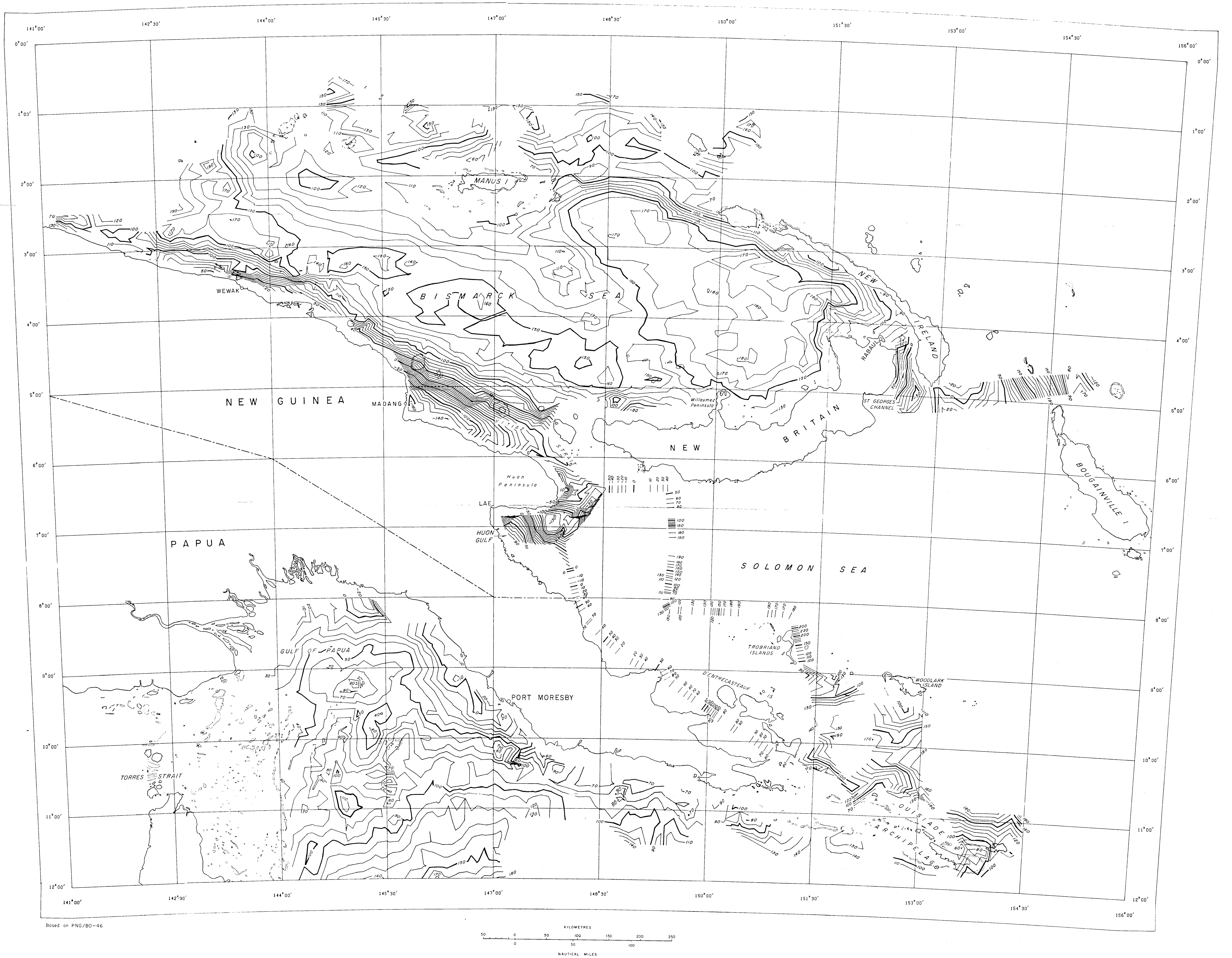
PNG/B8-71-1

PLOTTED 73/07/18

AUSTRALIA 1: 2500000

BISMARCK SEA
AND GULF OF PAPUA

PLATE 3



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

B.M.R. 1970-73 MARINE SURVEYS

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BOUGUER ANOMALIES

Contour interval : 10 milligals

triangular plate. Should any side of an acceptable triangle

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

DENSITY = 2.20 GMS/CC

BISMARCK SEA

AND GULF OF PAPUA

AREA 1

RECORD No 1975/115

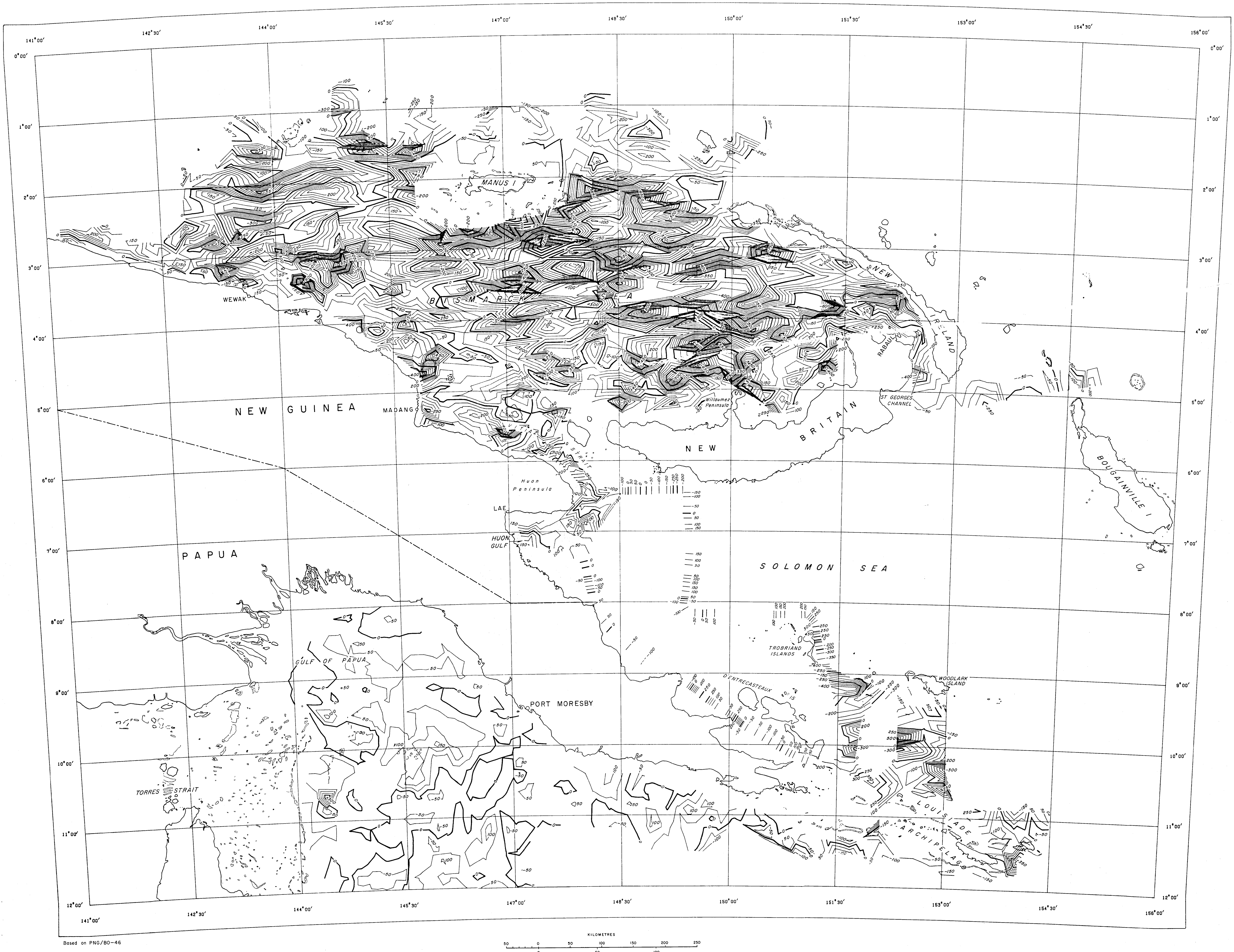
PNG/B2-54-1

PLOTTED 73/07/13

AUSTRALIA 1: 2500000

BISMARCK SEA
AND GULF OF PAPUA

PLATE 4



Based on PNG/BO-46

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

B.M.R. 1970-73 MARINE SURVEYS

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MAGNETIC ANOMALIES

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

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.

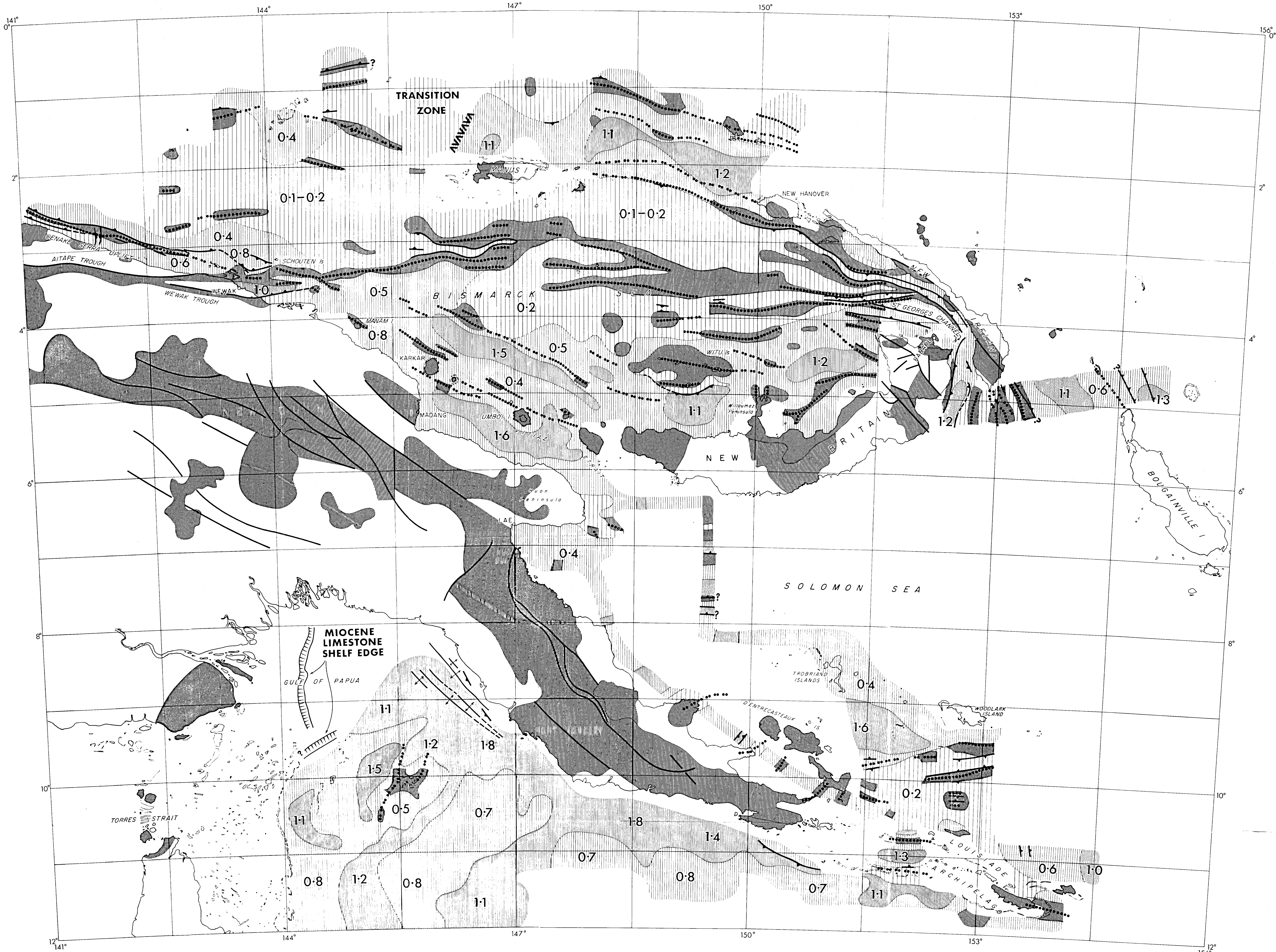
Contour lines are drawn by computer using a triangular contouring program. A triangular plate is defined by three adjacent stations whose circumscribing circle contains no other stations. Linear interpolation is then used on the triangular plate. Should any side of an acceptable triangle exceed 30 nautical miles, that plate is not contoured.

BISMARCK SEA
AND GULF OF PAPUA

AREA 1

RECORD No 1975/115

PNG/BI-II-I



Based on PNG/B0-46

LEGEND

- Basement Ridge (Exposed)
- Basement Ridge (Concealed)
- Fault
- Anticline

KILOMETRES 50 0 50 100 150 200 250

NAUTICAL MILES 0 50 100

SEDIMENT DISTRIBUTION AND STRUCTURE

SEDIMENT THICKNESS

- Basement outcrop (Basement high on land)
- Quaternary Volcanics
- < 300 metres
- 300 – 1000 metres
- > 1000 metres
- **1·4** Average observable thickness (km)

RECORD No 1975/115

PNG/B2-56