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PREVIEW REPORT

NORTHERN NEW GUINEA BASIN
AIRBORNE SEISMIC SURVEY 1970

by

P. Jones and P.L. Harrison

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Table 2 has been excluded from the hard copy of 1970/70.

ILLUSTRATIONS

SUMMARY

During the period September to December 1970 the Bureau of Mineral Resources (B.M.R.) will carry out an experimental airborne seismic survey in swamp and other areas of the Northern New Guinea Basin, which are inaccessible to conventional seismic land operations. The survey will be principally a refraction survey, however tests will be carried out using reflection techniques.

A helicopter will be used to place explosives, shooting equipment and geophones connected to sonobuoy transmitters into position on the ground. Seismic signals will be received from the sonobuoy transmitters and recorded on a conventional recording system mounted in an aircraft flying over the seismic field set-up at the time of each shot.

The proposed survey is planned to evaluate the airborne seismic technique and to provide regional information to resolve differing interpretations from aeromagnetic and helicopter gravity surveys over the basin.

Preliminary investigations indicated that the airborne seismic technique is practicable and would be operationally feasible for use in the swamp areas of the Northern New Guinea Basin.

1. INTRODUCTION

The B.M.R. proposes to carry out an experimental airborne seismic survey in the Sepik-Ramu area of the New Guinea Basin between September and December 1970. The survey area is located in the T.P.N.G. Permit to Explore P41 held jointly by the Continental Oil Co. of Australia Ltd. (the operator) and New Guinea Cities Service Inc.

The Sepik-Ramu Plains lie inland roughly east-west along northern New Guinea, between the Central Highlands forming the backbone of the island and the Coastal Ranges. The Central Highlands include the Bismarck, Schrader and Central Ranges as well as high-altitude inter-montane valleys. The term "Coastal Ranges" covers the area north of the Sepik, including the Toricelli-Prince Alexander Mountains and the area east of the Ramu, including the Adelbert Mountains.

The Sepik-Ramu Plains include both the actual swamp-lands and the low hills that rise irregularly from them. They are drained by many highly convolute channels, the larger of which run between levees slightly above the general swamp level. The mean elevation of the swamp is only about 15 metres; at Pagui, 320 kilometres up river from the sea, the elevation of the Sepik River is only 12 metres. Low hills, the remnants of a drowned topography, together with the river levees form the only dry ground in the swamp region and so are the normal sites for villages. At some places, e.g. south of Angoram, large villages have been erected on stilts in the swamp.

Vegetation within the swamp consists largely of sago forest, normally marshy under foot and forming a dense cover broken only by streams. In the more inundated areas tall grasses predominate. The drier areas above the general swamp level are clothed in dense rain forest, although hills lying between the Sepik and Ramu mouths have a cover of Kunai grass.

Rainfall in the district is low, averaging 250 centimetres per annum at Ambunti and 210 centimetres at Angoram. The dry season is between

June and August. Ground mist frequently occurs in the early morning, but usually clears by 9 a.m.

Access within this area is by boat or helicopter only. There are no roads or airstrips, so rivers and minor waterways are the only practicable routes. On the Sepik and the larger tributaries, jet-boats can be used, whilst coastal vessels of about 230 tonne can reach Ambunti. Native traffic, including outboard-powered double canoes, is restricted to the slow-moving waters of the Sepik and the lakes. An outboard-powered barge operating up to Aiome is the only craft on the Ramu River.

Reconnaissance aeromagnetic and helicopter gravity surveys have been carried out over the entire area of interest. However the only seismic survey in the area was restricted to traversing near the Sepik and Keram Rivers. Conventional seismic work in the swampland near the rivers is slow and expensive requiring high effort in moving equipment and supplies and clearing seismic lines for cable-laying.

The airborne seismic survey has been proposed to overcome the limitations of conventional seismic work. It should be able to provide relatively rapid seismic reconnaissance of any area of the swamplands.

Ground to air telemetry is used to transfer the geophone responses to the conventional seismic recording equipment mounted in an aircraft flying overhead at the time of the shot.

Tests of the proposed airborne seismic recording system for the survey in New Guinea made by the B.M.R., using available equipment confirm the suitability of the proposed equipment for the survey. Further a helicopter reconnaissance of the survey area has confirmed the operational practicability of the survey.

2. GEOLOGY *

The area of the proposed Airborne seismic survey falls entirely within the New Guinea Mobile Belt (Dow, Smit, Bain and Ryburn, 1968), a tectonic zone bounded on the south by the Australian Continental Block (Plate 5). It was the site of heavy geosynclinal sedimentation throughout the Tertiary period, accompanied probably by massive contemporaneous transcurrent faulting, leaving the continental block a stable region of shelf sedimentation (Plate 6). Rod (1966) follows Carey (1958) in postulating an earlier (?Mesozoic) phase of activity along these fault lines, during which New Guinea moved from a position parallel to the Queensland coast to its present site.

Thompson (1965) following Osborne (1956) has described this zone of thick Tertiary sediments as the Northern New Guinea Basin (Plate 7). He suggests that the principal axis of deposition lies offshore, but the abrupt near-shore bathymetry, including a plunge to 1800 metres 26 kilometres off Wewak (Krause, 1965, Plate 1, incorporated in Plate 4 of this report), does not support this hypothesis. Carey (1965) comments that the ranges north of the Sepik-Ramu zone have a basement core representing "the 'basaltic' ocean floor on which the northern sediments were directly deposited beyond the continental shelf of the time, and which has now been thrust up to form the cores of fault slices". Both of these hypotheses may be tested by the gravity technique, and it is shown (Watts, 1969) that neither is probable. It is also of interest to note that Visser and Hermes (1962, reproduced in Marchant, 1968, Plate 26) show the continental margin diverging from the continental shelf near the West Irian-New Guinea border to include the

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* The airborne seismic survey in the Northern New Guinea Basin will be carried out in the same area as the Sepik River Helicopter Gravity Survey, T.P.N.G. 1968, (Watts, 1969). The summary of the geology is taken from this report.

Bismarck Sea within the continental area. Whilst this of course supports (or rather does not refute) the axial position for the Northern New Guinea Basin suggested by Thompson (op. cit.) it does not agree with gravity data collected on the B.M.R. 1968 helicopter gravity survey (Watts, 1969).

In detail, the stratigraphy is made complex by rapid lithologic variations and considerable faulting (Plate 4). It will be described here in two areas, separated by the Ramu-Markham Fault, a major fault running north-west from near Lae (Plate 8). The zone to the east of this structure may be significantly different from the remainder, and has been termed the Ramu River Basin by Continental Oil Company geologists.

Area to the west of the Ramu-Markham Fault

The swamp-covered Sepik Plains separate the Torricelli-Prince Alexander Mountains from the Central Range to the south. The presence of the swamp prevents any accurate stratigraphic correlation between the two areas, but a synthesis based on the photogeologic interpretation of Marchant (1968) and detailed mapping by Dow et al. (1968) will be attempted.

North of the Sepik River, Marchant has recognised six photo-geologic units, most of which may be diachronous. A thick sedimentary section is present (Table 1), in which the maximum geosynclinal development was reached in the Miocene. This sequence rests on a basement complex exposed in the core of the Torricelli and Prince Alexander Mountains.

The south-western edge of the survey area is crossed by the Lagaip Fault (Plates 4, 8) and according to Dow et al., (1968) this represents the boundary between the stable Australian continental block to the south and the oceanic crust to the north. The tectonic differences were reflected in the region's sedimentation, shelf-type sediments being laid down on the craton whilst geosynclinal deposition was occurring to the north. A detailed summary of the stratigraphy and history is given in Table 2 and Plate 9; however, the correlation with the North Sepik data is tenuous and Watts (1969) assumes responsibility for this attempted correlation.

Basement south of the Sepik consists mainly of the Ambunti Metamorphics, which are largely metasedimentary in nature - slate and schist, etc. - although some complex intrusive bodies, now amphibolite and orthogneiss, are present. The oldest unaltered sedimentary rocks are shelf deposits of Triassic age, the Yuat Shale and Kana Volcanics, which are exposed between the Yuat and Maramuni rivers. The Basement Complex described by Marchant (1968) in the Torricelli Mountains appears to be lithologically similar to the Ambunti Metamorphics but with a higher proportion of acid plutonics.

TABLE 1

Photogeologic unit (Marchant, 1968)	Age (approx.)	Lithology	Thickness (approx.)
VI	Pleistocene	Sand, gravel	?
III-V	Plio-Pleistocene	Sandstone	?
II	Pliocene	Silt, marl, limestone, volcanic agglomerate	2000m +
I	Palaeocene-Miocene	Greywacke, limestone, basalt, spilite, tuff	5000m
Basement complex	?	Amphibolites to phyllites; diorite	

To the south of the Sepik River, sedimentation recommenced in the Jurassic after an orogeny that deformed the Triassic deposits. A thick sequence (over 2400 metres) of basic volcanics was followed in the Upper Jurassic by deposition of shallow marine shales, termed the Maril and Sitipa Shales. These and the lower part of the succeeding Salumei Formation have no counterpart in the North Sepik area.

Full development of the geosyncline was reached in the Cretaceous and Eocene periods when the Salumei Formation, consisting of siltstone, greywacke, and limestone, was laid down. The upper part of this unit is equivalent to the lower part of Marchant's Photo-geologic Unit I, which has a similar lithology.

Uplift and erosion took place during the Oligocene in the South Sepik region, but deposition of Unit I continued apparently without break in the north.

During the Miocene, tuffaceous sediments were deposited over a wide area, being represented by the Pundugum Beds and the upper part of Photogeologic Unit I. At the same time emplacement of the Maramuni Diorite and the April Ultramafics occurred. After this, the only rocks deposited south of the Sepik were Plio-Pleistocene volcanics, but shallow marine sedimentation continued with Units II to V in the Toricelli area.

Immediately west of the Ramu-Markham Fault is a possible equivalent of the April Ultramafics, termed the Marum Basic Belt, an extensive zone of basic (gabbro) and ultrabasic (dunite, pyroxenite, serpentinite) rocks which give rise to a major Bouguer anomaly feature.

Area to the east of the Ramu-Markham Fault

At the south-east of the Northern New Guinea Basin, inland from Madang, a thick sequence of Tertiary rocks lies on a basement of Upper Cretaceous and Lower Tertiary sediments intruded by batholiths, dykes, and sills (Continental, 1968). The so-called Ramu River Basin is fault bounded on the south-west by the Ramu-Markham Fault and may be bounded on the north-east by faulting along the Adelbert Range.

Corbett (1962) described a very thick 5500 metres sequence of Lower Miocene to Pliocene sediments, but the only systematic mapping of this sub-basin has been by Continental Oil Company geologists. The following paragraph is taken from Continental (1968):

"On the eroded basement surface, rest Lower Miocene reefs, shales, sandstones and conglomerates which were folded and faulted in, probably Middle Miocene. Upper Miocene sandstones and mudstones rest unconformably on, mainly Lower Miocene although some Middle Miocene sedimentation did take place. Thick Pliocene sediments begin with basal sandstones and conglomerates and pass upward into mudstones and fine sandstones. The relationship of the Pliocene to Upper Miocene varies; in some areas deposition was continuous and in others there is probably onlap of Pliocene on Upper Miocene. Thick Pleistocene mudstone and sandstone with occasional reef limestones are the youngest fairly consolidated sediments. The total thickness of sediments is not known, but over 4000 metres have been measured on the south flank of the Adelbert Range, the bulk of this being marine".

In that a thick Plio-Pleistocene succession is present, this area seems to have a greater affinity with the North Sepik region than with the geographically closer South Sepik.

Tectonics

There is little doubt that the structure of the New Guinea Mobile Belt is dominated by faulting, but opinions differ widely as to its nature. Dow et al. (1968) have considerable evidence in favour of a complex system of faults, many of a transcurrent nature. Marchant, on the other hand, in an interpretation which he warns may be subjective, maintains that high-angled thrusting, trending 300° to 310°, is the principal structural feature. This would require a tectonic regime of quite different character from that suggested by Dow's hypotheses.

Both authors infer the presence of a major fault - the Sepik Fault - near the southern margin of the Sepik Plains. On the basis of a straight contact between the high-grade Ambunti Metamorphics and the unaltered Salumei Formation, Dow et al. propose a fault downthrown to the south by many thousand metres (Plates 8, 11).

Marchant, on the other hand, postulates a fault upthrown to the south, (Plate 11) running along the southern side of the Sepik Plains. The main evidence in this case is the "improbability of completely disposing of 4600+ metres of Mio-Pliocene sediments by simple thinning and overlap on to the basement in a distance of 30 ~~km~~ kilometres between their southerly outcrops in the Bongos and Yellow River areas and the appearance of basement near Ambunti".

Other geologists (e.g. Krause, 1965) have shown major faults running along the Sepik River itself, but offer no substantial support for their hypotheses.

Dow et al. also postulate north-west extensions of major faults mapped in the Highlands (Plate 8).

On a preliminary analysis of the available gravity data, none of the faults mentioned have a major effect on the Bouguer anomaly pattern. However, the Ramu-Markham Fault has an appreciable expression caused by the contrast between ultrabasic rocks of the Marum Basic Belt and Tertiary sediments of the Ramu River Basin. It is probably one of the most important faults in New Guinea but is geologically poorly known, since its topographic expression as a valley has resulted in its being covered with alluvium. Two theories on its extent exist: Rod (1966, Fig. 3) shows it turning west near Annanberg to join a supposed Sepik Fault, whilst Dow et al. (1968) show it continuing in a north-west direction to the Bismarck Sea (Plate 8).

3. PREVIOUS GEOPHYSICAL INVESTIGATIONS

A large area of the Sepik-Ramu Plains is covered by Recent sediments. Extrapolation from outcrops at the margins of the Plains indicates that under the Recent cover a thick sequence of Lower Miocene to Pliocene sediments lies on a basement of Upper Cretaceous and Lower Tertiary sediments. However the total thickness of these sediments throughout the area is unknown.

Regional geophysical surveys carried out to determine the thickness of sediments and structure in the Northern New Guinea Basin were a helicopter gravity survey by the B.M.R. (Watts, 1969), and aeromagnetic surveys by Australian Aquitaine (Aquitaine 1967), and Continental Oil Co. (Continental, 1969). A reconnaissance seismic survey mainly in the vicinity of the Sepik and Keram rivers was conducted by Continental in 1969.

Gravity

The B.M.R. helicopter gravity survey in 1968 (Watts, 1969) covered a much larger area (Plate 10) than will be covered in the airborne seismic survey. The six principal Bouguer anomalies that were revealed in the area of interest, are:

(A)	Adelbert Gravity High	(Plate 10, Feature A)
(B)	Ramu Gravity Low	(Plate 10, Feature B)
(C)	Potter Gravity Low	(Plate 10, Feature C)
(D)	Marum Gravity High	(Plate 10, Feature D)
(E)	New Guinea Coastal Gradient	(Plate 10, Feature E)
(F)	Madang Gravity Low	(Plate 10, Feature F)

The following is a brief description of each of these features.

A The Adelbert Gravity High is a residual high of 10-15 mgal amplitude. It correlates with the basement high mapped by Continental geologists (Continental 1968) to the northwest of Madang.

B The Ramu Gravity Low has close areal correspondence to the Tertiary Ramu River Basin. It has an amplitude of 70-90 mgal and a half-width of 48 kilometres with its axis trending north-west, parallel to that of the basin for nearly 160 kilometres. A steep gradient to the south-west separates the Ramu Gravity Low from the Marum Gravity High and marks the extension of the Ramu-Markham fault. Residual Bouguer anomaly profiles suggest that a fault may also bound the basin on the north-east, separating it from the Adelbert Range.

C The Potter Gravity Low is a north-south trending low of about 25 mgal amplitude. This low may represent an off-shoot or extension of the main Ramu River Basin.

D The Marum Gravity High, although of -90 mgal amplitude, is a relative Bouguer anomaly high. It corresponds closely to the gabbroic phase of the Marum Basic Belt but not to the ultrabasic part of the mapped outcrop.

E The New Guinea Coastal Gradient is the dominant feature of the Bouguer anomaly map, Bouguer anomaly values varying from about -80 mgal in the Central Highlands to +130 mgal on Kairiru Island, near Wewak. This gradient is almost certainly caused by thinning of the continental crust towards the continental shelf, with the denser oceanic crust coming closer to the surface. This fact as well as evidence from marine gravity data (U.S.S. Shoup) and refraction seismic data (B.M.R., 1969), suggests that the Bismarck Sea is underlain throughout by typical oceanic crust. This contradicts the idea of Visser and Hermes (1962) that the Bismarck Sea is an extension of the continental area. At the same time it casts doubt on the suggestion of Thompson (1965) that the major part of the Northern New Guinea Basin lies offshore.

F The Madang Gravity Low. Near Madang the Bouguer anomaly values decrease rapidly to -140 mgal at the top of the continental slope. Surface marine data show this feature to be a closed roughly circular relative Bouguer anomaly low of about 30 mgal amplitude and 12-13 kilometres half-width. The maximum depth appears to be 7 kilometres i.e. well above the Moho. In a paper delivered at the APEA conference in March 1969 J. Harrison of the Continental Oil Co. described a small Pliocene basin, containing at least 4800 metres of sediments, north of the Finisterres. It seems highly likely that the Madang Gravity Low represents the marine extension of this basin.

Aeromagnetic

Sepik Aeromagnetic Survey (Australian Aquitaine, 1967)

This survey was restricted to the area north from the Sepik River to the coast and to the west of Wewak. Magnetic basement depth contours derived from magnetic and geological information are indicated on Plate 12.

Interpretation of the magnetic results from the area between the Central Highlands and the Coastal Ranges indicated a basin in which the depth of sediments is considered to exceed 6100 metres. The northern flank of the basin is marked by what appear to be foothills of the Coastal Range. These seem to be surface anticlines.

Another basin was outlined, north of the Coastal Ranges in the Arnold River area, with more than 3000 metres of sediments. Aeromagnetic evidence suggests that the basin extends off-shore, but this is not supported by gravity evidence (Watts, 1969).

Madang P41 Aeromagnetic Survey (Continental, 1969)

The Ramu River Sub-basin was outlined. The magnetic basement depth contour map (Plate 13) indicates a major character change east-west across a line along the north-south lower reaches of the Ramu River. East of the Ramu River the basin trends north-west. It has a maximum depth of 4000 metres and is disturbed by predominantly north-south faulting.

West of the Ramu River, the magnetic basement depth estimates vary from 460 metres to 3700 metres. A number of north-west trending structural features are evident in this area.

Comparison of Gravity and Magnetic Results

The structure of the Northern New Guinea Basin appears different from the gravity and magnetic viewpoints. The major axis of the basin indicated from the gravity and the aeromagnetic work is shown on Plate 10.

Although in fair agreement, particularly in the south-east, the interpretations differ somewhat in the central part of the basin between the Sepik and the Ramu Rivers.

The major differences are as follows:

1. The magnetic results indicate a thick sedimentary section, with magnetic basement depth up to ~~4 kilometres~~ 4000 metres, which is however not coincident with the main gravity feature which indicates a sedimentary section of ~~4.3-5.5 kilometres~~ 4300 5500 metres.
2. The gravity results indicate the Potter Gravity Low which may represent a northern off-shoot of the deep Ramu River Basin. The magnetic results do not confirm this suggestion. Conversely, in the tidal inlet swamp area to the west of the mouth of the Sepik River, magnetic basement is indicated at 1.5-2.0 kilometres whereas the gravity results do not indicate a thick sedimentary section.
3. The gravity results suggest that the Ramu-Markham fault zone trends north-west, whereas the aeromagnetic results give no indication of an extension of the fault zone into the basin.

Seismic

Two seismic surveys have been carried out in the Northern New Guinea Basin. The Maprik Seismic and Gravity Survey (Aquitaine, 1969) was limited to several traverses near the Sepik River between Ambunti and Maprik. The only seismic work in the Sepik Plains area, the Madang Seismic Survey, was completed in 1969 (Continental 1970).

Madang Seismic Survey (Continental, 1970)

The seismic traverses were located on structures inferred from Continental's 1968 aeromagnetic survey (Continental, 1969) and the B.M.R. 1968 helicopter gravity survey (Watts, 1969).

The traverse locations indicated on Plate 1, were:

1. Josephstaal area

Lines 1 and 2 were shot near Josephstaal in the foothills of the Adelbert Range to investigate a large anticline mapped from surface geology.

2. Sepik River area

Lines 4 and 9 were shot parallel to and close to the Sepik River between Angoram and New Bien. The coverage included 24 kilometres of 6-fold C.D.P. on land and 140 kilometres single coverage shot in the Sepik River.

Line 9, shot to investigate a postulated magnetic basement ridge was the only profile allowing direct correlation with surface geology and Marienberg well no. 1 was near to the line. The results indicated 1800 metres of Tertiary sediments above basement. This was confirmed by refraction work which indicated a good velocity contrast between sediments and basement i.e. 1.8-2.1 kilometres/second and 5.2 kilometres/second, indicating that the refraction method could prove to be the most useful tool to delineate basement in the area.

3. Keram River area

Lines 5, 6, 10 and 11, mainly 6-fold C.D.P., were shot to investigate a number of possible north-west trending structural highs interpreted from the aeromagnetic results.

The seismic reflection results, which were of fair to poor quality, did not delineate structural highs in the plains area. The Josephstaal anticline was however confirmed at depth.

Limitations of Conventional Seismic Operations

The Madang Seismic Survey was confined mainly to the Sepik and Keram River area where the crew and equipment were transported by boat. The crew was airlifted at great expense to Josephstaal to survey the surface anticline. The traverses surveyed cover a very small part of the Northern New Guinea Basin. The area in the centre of the basin between the Ramu and Sepik Rivers is seismically unknown.

The Ramu River is not navigable from the sea thus all seismic equipment would have to be airlifted by helicopter into the area together with supplies and camping equipment. There are no landing-strips in the swamplands of the Sepik and Ramu Plains. Boats and helicopters would be required for transport during traversing.

If rivers close to a survey are ~~are~~ navigable, seismic traversing is not too difficult and costs may be moderate. However, at some distance from a navigable river the difficulties and cost of walking-in of a seismic crew and equipment are prohibitive mainly because of the time and effort required.

In swamp-covered areas the problems facing conventional seismic work are the difficulty of movement and in cutting seismic lines for cable-laying. These areas may be dry for short periods but because of the wet it is often necessary to build bridges over the swamps to allow for movement of personnel and equipment. In many areas there is insufficient timber available for this purpose and the cost of importing it is prohibitive.

The north-west trending magnetic-basement highs (Plate 13) investigated seismically by Continental are elongated features and could equally well have been profiled at any point on their major axis. However the locations of the seismic traverses were determined by the geography of the survey area.

Furthermore, recommendations have been made by Continental Oil Co. for follow-up work on these "structural leads" by a "floating seismic survey" on the lakes and rivers between the Sepik and Keram Rivers.

In view of these limitations, the proposed airborne seismic survey method could be a relatively cheap regional reconnaissance survey technique for seismic investigation of the Sepik-Ramu Plains area. The method may also be developed in the future to provide detailed seismic profiling of structures in areas inaccessible to conventional seismic surveys.

4. PRE-SURVEY INVESTIGATIONS

Operations

A helicopter reconnaissance tour of proposed survey locations in the Northern New Guinea Basin was made by two B.M.R. geophysicists directly concerned with geophysical investigations in the area and with the airborne seismic method. They concluded that the proposed airborne seismic method could be used advantageously in most locations visited.

The swamp vegetation is basically of three types: the very wet, often extensive grasslands, the sago palm swamp with small and large clearings, and the relatively dry kunai grass patches on ridges rising from the swamp plains.

The grasslands offer the most suitable working areas. A helicopter fitted with floats can land there easily, deposit explosives in the water or on the ground at shot-points and place sonobuoys and geophones (or hydrophones) along a straight line for both refraction and reflection profiling.

In the sago swamp, it will be necessary for the helicopter to land in the large clearings or hover above smaller clearings whilst sonobuoys, detectors, and explosives are lowered into position. The Bell GB31 helicopter used for the reconnaissance was somewhat underpowered, however the helicopter recommended for the survey will be a Bell Jet-ranger which the pilot on the reconnaissance was confident had the necessary performance.

Clearings in the sago swamp, and kunai patches where they occur, are irregularly distributed, so that in these two areas the detector positions probably will have to deviate from a straight line. For refraction work, depth and dip will be determined by reverse shooting and applying time-term analysis.

Normal seismic geophones, marsh geophones, or hydrophones will be used, dependent on the terrain.

The aircraft to be used on the survey will be the B.M.R. DC3, VH-MIN and a chartered Jetranger helicopter. Originally it was recommended that a Piaggio aircraft should be chartered for the survey. This aircraft is smaller than the DC3 and could have used airstrips closer to the survey traverse locations. For the major part of the survey operations both the helicopter and a Piaggio aircraft could have been centred on the same base (at Angoram). Use of the DC3 limits operations of this aircraft to larger airstrips, at Madang and possibly Wewak thereby presenting an operational communications problem.

One Jetranger was chosen in preference to two Bell GB31s. The latter each have only 136 kilograms carrying capacity whereas the Jetranger has 450 kilograms. The Jetranger is much faster, cruising at 145 kilometres/hour, compared to 80 kilometres/hour for the GB31. Furthermore it has a greater hovering ability.

Navigating and surveying will be done using aerial photographs. The shotpoints and detector stations will be located and identified on the photos. Shotpoint positions may be 400 metres out relative to true latitude and longitude, however shotpoint to geophone distances scaled from aerial photos are considered accurate to about 6 metres. This accuracy is considered sufficient for the purpose of the reconnaissance survey. To check positioning the DC3 will photograph the field set-up after coloured plastic strips have been placed at the shotpoints and recording stations.

The almost uniform level of the swamplands (the elevation of the Sepik river is only 12 metres 320 kilometres upriver from the sea) means that accurate levels are not required in the swamp. If kunai patches on ridges are used elevation differences may be estimated or measured using microbarometers as on helicopter gravity surveys.

Procedures for the field operations have been planned. Although it may be necessary to modify these procedures in the field they will be essentially as follows:

(1) The helicopter will load geophones, detonators, sonobuoys, shooter and navigator on board.

(2) It will proceed to the traverse area.

(3) The shooter and navigator will lay out sonobuoys and geophones, the navigator will also identify geophone locations on aerial photographs.

(4) The shooter with detonators will be deposited at the shot point, which will be identified by the navigator and pricked on the photograph.

(5) The helicopter with navigator will return to base to pick up explosives, the loading being done with help from base personnel.

(6) The loaded helicopter with navigator will return to the shot point.

(7) On arrival of the helicopter at the shot-point, the observer at the base will be advised and the recording aeroplane will take off.

(8) The explosives will be unloaded and placed in position.

(9) The helicopter with shooter and navigator will retire to a safe position.

(10) The aeroplane will arrive overhead.

(11) The shot will be detonated, and recorded in the plane.

(12) The plane will then return to base.

(13a) The helicopter will take the shooter and navigator to recover sonobuoys and geophones.

(13b) Alternatively it will transport the shooter to new shot point.

(14) If (13a) operations will be repeated from (3).

If (13b) the helicopter will return to base to pick up more explosives and operations will be repeated from (6).

Safety will be of paramount importance in a survey of this type. All D.C.A. safety regulations for aircraft flying in New Guinea will be strictly observed. Safety precautions concerning the use of explosives on seismic parties will be observed as usual. In addition, where it is necessary to leave the seismic shooter at the shotpoint while the helicopter returns to base for more explosives, the shooter will be equipped with a radio, flare pistol and rubber dingy and lifejacket if these are necessary.

The airborne seismic operations will be simpler in many respects than conventional land seismic operations. It is specifically envisaged for reconnaissance, not detailed work. A very small staff (7) is envisaged compared with the normal large staff together with approx. 300 native labourers for conventional operations in the area. No special camps will be set up, since the airborne operations will be based on populated areas with accommodation and other facilities. No drilling of shot holes will be done; surface shots will be used, however charges will be placed in water wherever possible. Surveying of shot hole and detector locations will be limited to identification of the locations on aerial photographs. The need for man-handling equipment, laborious line-cutting and the limitations of connecting detectors, by cable to the recording equipment on the ground will be obviated by using the airborne method. The field set-up is not limited by fixed distances between detector positions on detector cables as in conventional operations thus detectors may be placed in any position and at any distance apart dependent on local conditions.

The airborne seismic method is envisaged basically for reconnaissance seismic refraction work and not for seismic reflection profiling. It would be impracticable to use large detector and shot-hole arrays or C.D.P. methods, to improve the quality of reflection events, therefore reflection profiling will be attempted only with simple field techniques.

Equipment

A list of the equipment to be used for the airborne survey is given in Appendix 1 and a block diagram of the recording equipment is shown (Plate 14).

A series of equipment tests was made between June 1969 and April 1970. They included operational tests of individual components of the system as well as of the integrated system. A detailed account of these tests is given by Jones and Moss, 1970. A summary of the tests is given below:

Ground Tests   Initial tests were made with sonobuoys and receivers on the ground. The quality and range of signal reception, and the channel separation of several receivers connected to the same receiving antenna were tested and found to be satisfactory.

Ground to Air Tests   These tests were carried out using B.M.R.'s DC3 VH-MIN. The optimum height for seismic signal reception was found to be 1200 metres. The seismic signal was received satisfactorily up to 32 kilometres from the sonobuoy location. Time breaks, transmitted using f.m., V.H.F. radio were recorded at distances up to 40 kilometres.

Several off-end shots were fired into a line of four geophone groups each connected to sonobuoys. Recordings were made in VH-MIN which flew overhead at the time of each shot.

Comparison Tests   These tests were made using both the airborne recording system and a conventional recording system on the ground with cable connected geophones alongside geophones connected to sonobuoys. No aircraft was available at the time thus the airborne seismic recording equipment was placed on a hill 800 metres from the sonobuoys. Comparable results were obtained from the two recording systems.

Limitations of Tests   The scope of the tests was limited by lack of equipment, the requirement to modify equipment and aircraft availability. Sonobuoys operating on only four different frequencies were available whereas the proposed fully operational system will use ten sonobuoy channels.

Modifications to the equipment were necessary before and during the test series. In particular the only available sonobuoys were of a marine type, requiring changes to their frequency response and sensitivity. The sonobuoys to be used on the survey are a type specially designed for land seismic work.

VH-MIN was unavailable after the initial ground to air tests and it was not practical to use another aircraft for this purpose.

<u>Conclusions on Equipment Tests</u> Despite the limitations on testing with equipment available at the time, it was concluded that the airborne seismic recording method is practicable.

5. OBJECTIVES AND PROGRAMME

The major purpose of the experimental airborne seismic survey will be to establish a practical method for application to reconnaissance or detailed seismic exploration of swamp, jungle and other areas which are inaccessible for conventional seismic operations, but are otherwise of interest in the search for petroleum in New Guinea and elsewhere.

A further objective of the survey will be to provide information, by seismic methods, on the thickness of and structure within the Northern New Guinea Basin, in a number of areas where there is a lack of geological information. It should also assist in resolving problems which have arisen out of the interpretation of aeromagnetic and gravity reconnaissance survey data previously obtained in the basin.

To achieve these objectives, seismic refraction/reflection traverses will be located in the following areas, (Plate 1):

1. Madang Gravity Low. Equipment and supplies for the survey will be shipped to Madang. Tests of the equipment and operational systems will be carried out in the coastal swamp region north of Madang, over the Madang Gravity Low. All transport, equipment and personnel will be based in Madang for these systems tests. Information on the thickness of sediments on the gravity low will be obtained from the seismic results.

2. Sepik River Area Near Angoram. It is proposed to shoot a refraction probe along a line (Line 4) shot by conventional land seismic techniques in the swamps near the Sepik River. A direct comparison between the results of the airborne seismic and conventional work will be obtained. For this work the helicopter, and line personnel will be based closeby at Angoram, whilst VH-MIN with the recording equipment and observing personnel will be based at Madang. It will be possible to establish an operationally satisfactory, communications system between the two operational teams when the helicopter is operating only a short distance from its base.

3. <u>Potter Gravity Low</u>. A regional traverse will be shot in the swamps over the gravity low and continued to the south-west to determine if the Ramu-Markham Fault Zone, as indicated by the gravity interpretation does, in fact, extend to the north-west.

4. <u>Ramu-Sogeram River Area</u>. A traverse will be shot to confirm the thickness of the sedimentary section. It is proposed that the traverse will be extended to the south-west to obtain seismic information on the nature of the Ramu-Markham Fault Zone in this area.

5. <u>West of the Mouth of the Sepik River</u>. A short probe will be shot in the tidal inlet swamp area to the west of the mouth of the Sepik River to determine the thickness of sediments in this area.

Although unlikely, a further probe may be located in the following area if time permits.

6. <u>Bongos Area</u>. A surface anticline in this area could be investigated using the airborne seismic method. The area is very rugged thus conventional seismic work is difficult because of access problems and problems of geophone emplacement due to restrictions imposed by the fixed lengths of geophone cables.

The principal seismic method to be used will be the seismic refraction method. Traverses will be kept as straight as possible, dependent on the local conditions, to facilitate the interpretation of refraction results. However, if necessary, the detectors may be randomly distributed. A number of shots from different locations would be recorded with the position of the detectors unchanged. The results of recording in this manner would be analysed using a method of time-term analysis (Wilmore and Bancroft, 1960).

The proposed airborne seismic method to be used in this survey is not considered suitable for detailed continuous reflection profiling. Excessive effort would be required to lay shot and detector patterns for single, and multiple-coverage C.D.P. work. However, some reflection work will be carried out on the refraction traverses principally to test whether a simple reflection technique can yield useful results in the swamplands of the Sepik-Ramu Plains.

The survey is expected to be of approximately 12 weeks duration. Although the detailed programme cannot be determined until preliminary results are obtained, the tentative timetable will be as follows:

1. Madang Gravity Low: 1 week.
2. Sepik River area near Angoram: 1 week.
3. Potter Gravity Low: 4 weeks.
4. Ramu-Sogeram River Area: 4 weeks.
5. West of the mouth of the Sepik River: 1 week.
6. Bongos Area: 1 week.

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APPENDIX 1

LIST OF EQUIPMENT

VH-MIN DC3 AIRCRAFT (Plate 14)

Magnetic Recorder	:	AMPEX F.R. 1300 - 14 Channel
F.M. Receivers	:	R-316B/ARR-26 (10)
Oscillograph Camera	:	S.I.E. VRO-6D
Seismic Amplifiers	:	T.I. 8000
Photographic Camera	:	f24 - for Aerial Photography
Radio Receivers	:	Pye FM 10D - for T.B. transmission
		Traeger TM3 - for communication with base
Power Inverters	:	28V - 115V, 50 Hz Sorensen
		28V - 115V, 400 Hz Rotary Inverter (2)
		28V - 12V D.C. B.M.R. model

BELL JETRANGER HELICOPTER

Radio Receivers	:	Pye FM 10D - for T.B. transmission
		Traeger TM3 - for communication
Shot-Box	:	Electro-tech. BC8-A (2)

GROUND

Sonobuoys	:	Aquatronics SM 42-4 (33)
Geophones	:	Mark Products Marsh Type M-10, 10 Hz (60)
		Hall-Sears, HS-J, 14 Hz (120)
Hydrophones	:	Aquatronics (35)

ADDITIONAL EQUIPMENT

Gravimeter	:	Master Worden No. 548
Microbarometers	:	Mechanism Type M1991/A (2)
Wet and dry bulb hygrometer	:	Mason's type
Base Radio Transceivers	:	Traeger TM3 for communication (2)

APPENDIX 2

ADDITIONAL GEOPHYSICAL PROJECTS

Gravity

Watts, 1969, carried out a helicopter gravity survey in the Sepik-Ramu area of New Guinea. The density of observations was an average of one per 15 square miles. During the airborne seismic survey, it is proposed to increase the density of observations in the seismic traverse locations by taking gravity readings at as many shot point and geophone stations as possible.

The readings will be made by the seismic party personnel using the helicopter, which is attached to the party, for transport. The basic loop procedure of normal helicopter gravity surveys will be used.

Deep Crustal Seismic

The proposed seismic traverse locations lie in a zone ringed by LAE, GOROKA, WABAG and MANAM ISLAND, the locations of observatory seismic outstations (Plate 15). During the course of the airborne seismic survey additional temporary observatory seismic outstations will be located at MADANG and WEWAK.

A cooperative attempt will be made by the observatory and seismic groups to obtain deep crustal information from the largest refraction seismic shots in each traverse area in the Northern New Guinea Basin. The maximum explosive charges for the "sedimentary basin" seismic work, which may be of the order of 1000 kilograms, may be sufficient. However special shots involving larger charges could be detonated at each of the traverse locations if preliminary results indicate that this would be worthwhile.

This work will require a minimum amount of additional effort and may yield valuable crustal information in the area. In particular, it may assist in delineating the extension of the Ramu-Markham fault and may provide information on the extent of this faulting in the deeper parts of the crust.

Proposed B.M.R. Traverses	(red)
Continental Oil Co. Traverses, 1969	(blue)
Australian Aquitaine Traverses, 1969	(black)
Continental Oil Co. Lease Boundary	(green)

Preliminary Bouguer Anomalies Sepik-Ramu area computed using a rock density of $2{\cdot}67\ g/cm^3$. Marine data from U.S.S. Shoup, 1963-1964, reduced to Bouguer anomalies using bathymetry from Krause (1965)

Projection: Lambert conformal conic

LOCALITY PLAN FOR PROPOSED NORTHERN NEW GUINEA BASIN SURVEY

SCALE

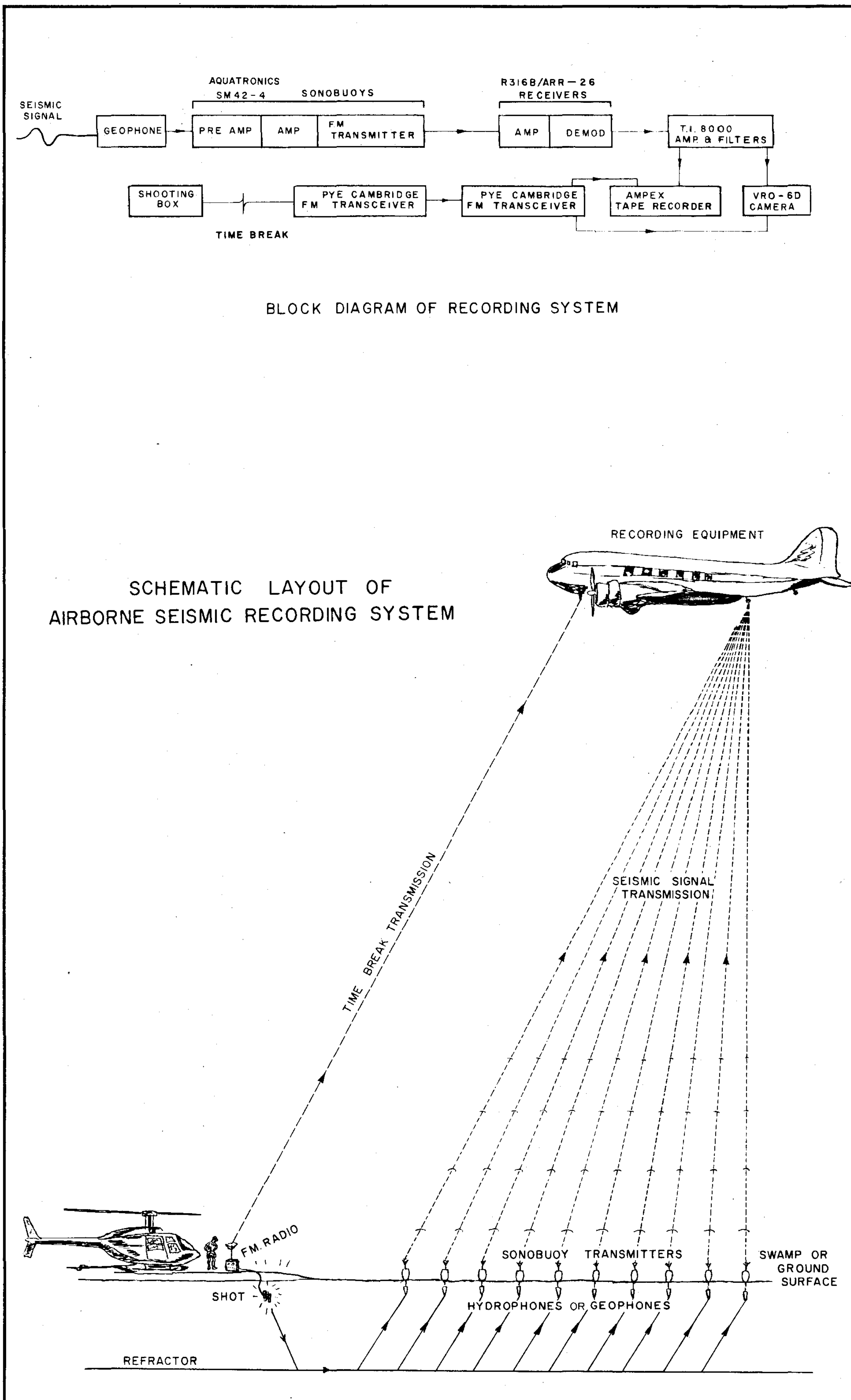
10 0 10 20 30 40 50 MILES

10 0 20 40 60 80 KILOMETRES

Contour interval 10 milligals

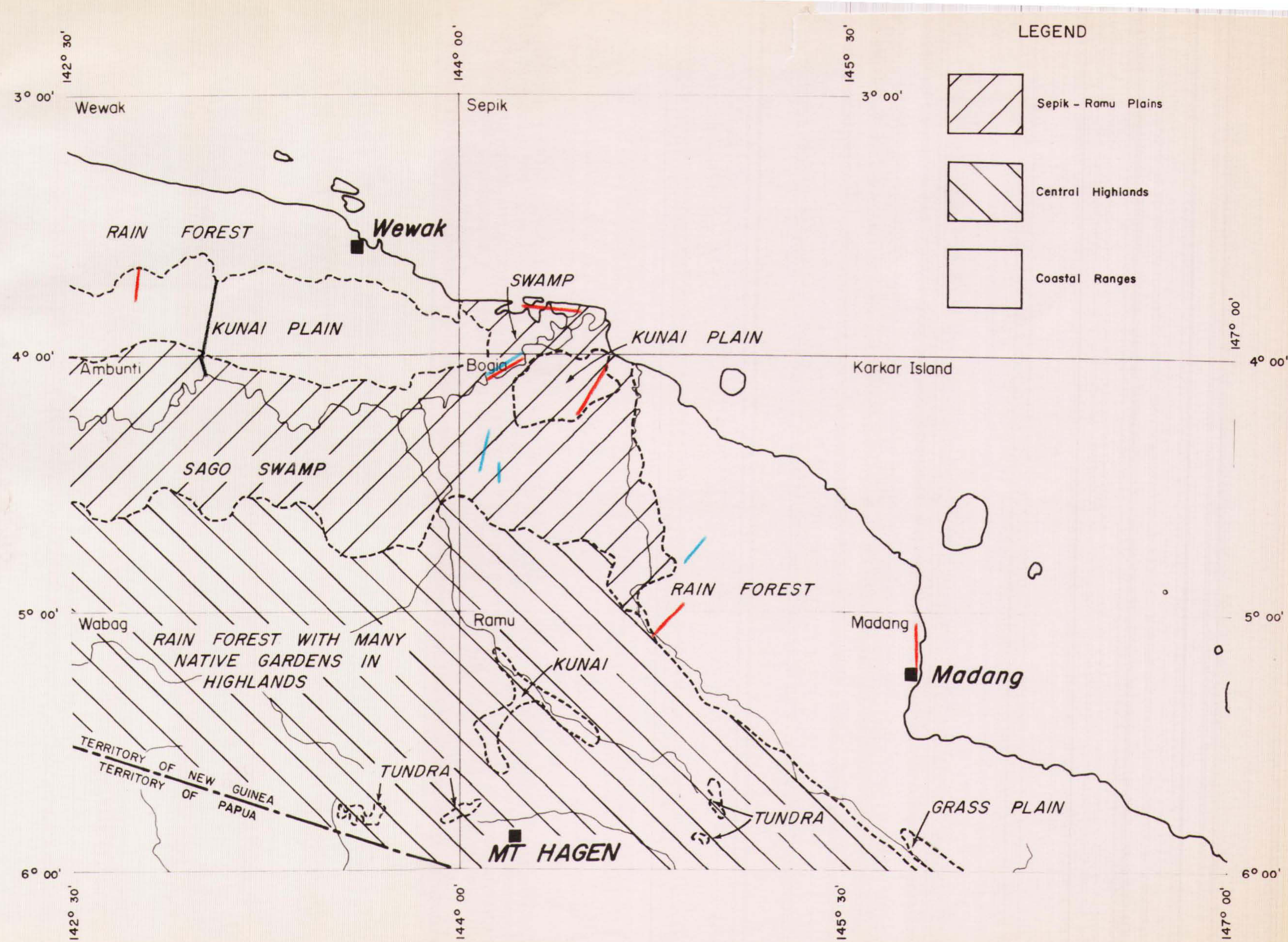
PNG/B2-26-3

PLATE 2



G85/3-132-2A

PLATE 3



Proposed B.M.R. Traverses

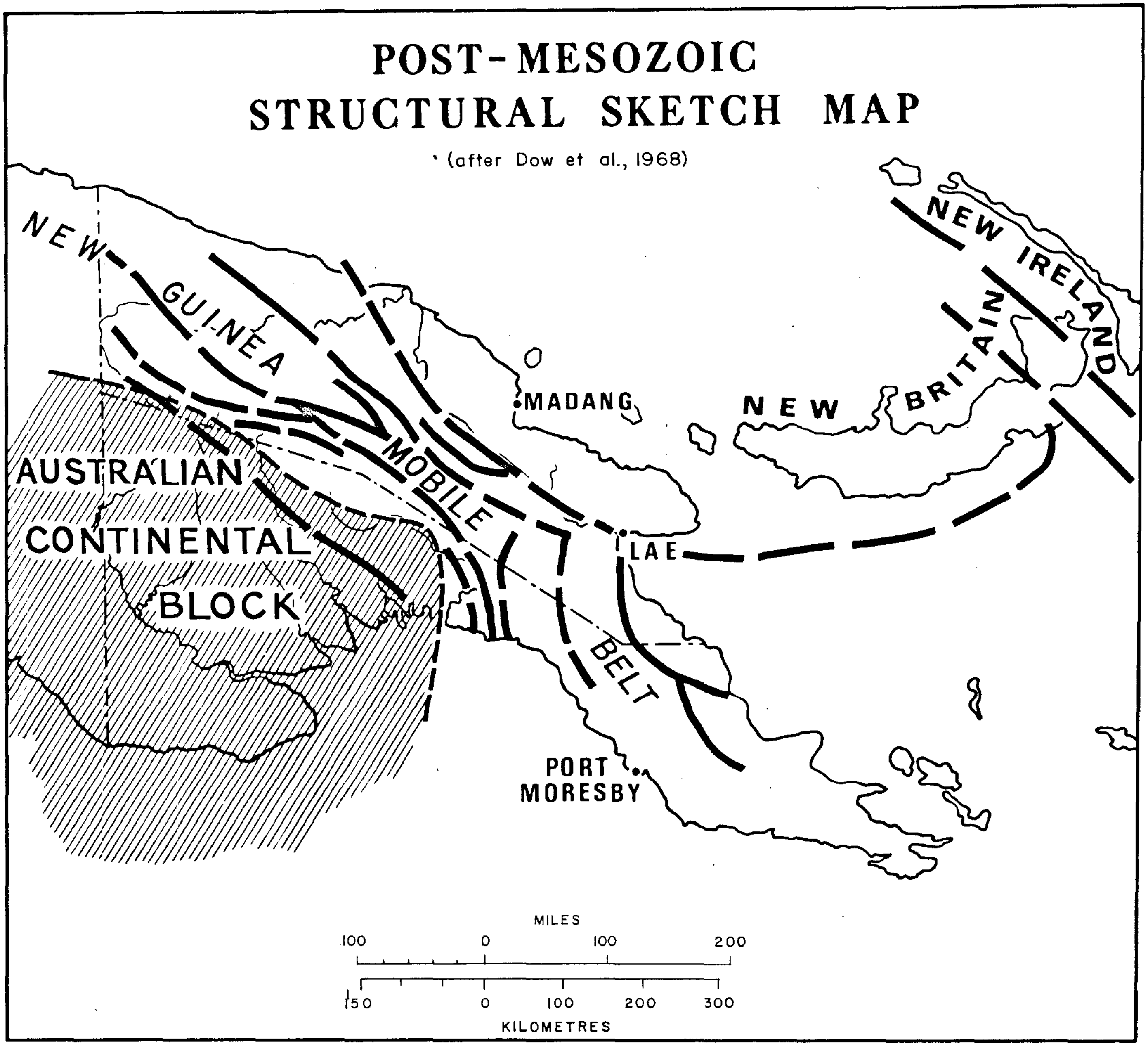
Continental Oil Co. Traverses, 1969

Australian Aquitaine Traverses, 1969

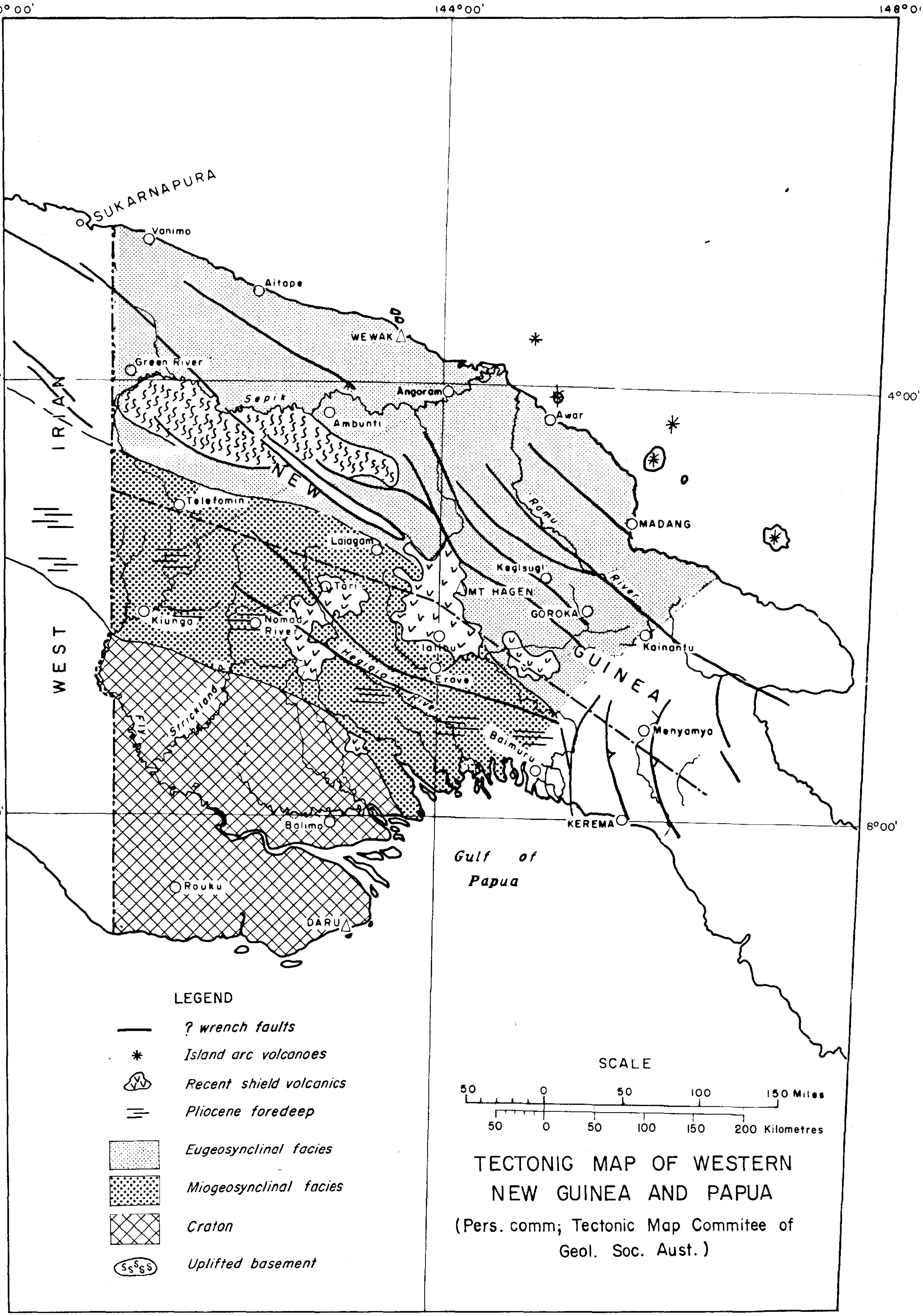
VEGETATION TYPES

PNG/B2-21-2A


PLATE 4
Proposed B.M.R. Traverses
Continental Oil Co. Traverses, 1969
Australian Aquitaine Traverses, 1969
SOURCE DIAGRAM
A : Photogeology after S. Marchant Nov. 1965 - Dec 1966
B : Detailed reconnaisance geology, after D.B. Dow, D.E. Mackenzie and R.J. Ryburn 1968
C : Outline geology after Continental Oil Company of Australia 1968
CAINOZOIC
QUATERNARY
RECENT
Qa
PLEISTOCENE
Photogeological Unit VI
Hagen Volcanics
TERTIARY
PLIOCENE
Photogeological Units III, IV & V
Tp
MIOCENE
Photogeological Units I & II
Tm
LOWER MIOCENE
Maramuni Diorite
Tmp
April Ultramafics
Tma
Marum Basic Belt
ultrabasic phase
Tmm
LOWER MIOCENE (TERTIARY g STAGE)
Yangi Beds
Tmy
Tibinini Limestone Member
Tmt
Pundugum Formation
Tms
MESOZOIC
CRETACEOUS
CRETACEOUS TO EOCENE
Salumei Formation
Tls
UPPER CRETACEOUS
Kumbruf Volcanics
Kuk
MIDDLE JURASSIC TO PALAEOCENE
Lagaip Beds
J-kp
JURASSIC
JURASSIC ?
Chambri Diorite
Jc
Ambunti Metamorphics
Jbt
UPPER
Sitipa Shale
Maril Shale
Jus
Jum
MIDDLE
Mongum Volcanics
Jmm
M
TRIASSIC
UPPER
Kana Volcanics
Ruk
MIDDLE
Yuat Formation
Rmy
Undifferentiated plutonics
Bathymetric contours after D.C. Krause (1965), contour interval 183 metres (100 fathoms)
Residual Tsogals (10 milligal interval)
GEOLOGY OF THE
SEPIK-RAMU AREA
TERRITORY OF NEW GUINEA
MILES
KILOMETRES
Projection: Lambert Conformal Conic
Base Map: World Aeronautical Charts nos 2974, 2987, 2988, 2973
PNG/B2-19-1
Sepik River
RAMU RIVER
LAGAIP FAULT ZONE
APRIL FAULT ZONE
KARAWARI FAULT ZONE
MARAMUNI
JIMI FAULT
RAMU MARKHAM FAULT ZONE
SIMBAI FAULT
BUNDI FAULT
RAMU RIVER FAULT ZONE


POST-MESOZOIC
STRUCTURAL SKETCH MAP
(after Dow et al., 1968)
NEW GUINEA MOBILE BELT
AUSTRALIAN CONTINENTAL BLOCK
MADANG
NEW BRITAIN
NEW IRELAND
LAE
PORT MORESBY
MILES
100 0 100 200
150 0 100 200 300
KILOMETRES

PNG/B2-17-1A


140° 00'
144° 00'
148° 0
4° 00'
8° 00'
SUKARNAPURA
Vanimo
Aitape
WEWAK
Green River
Angoram
Sepik
Ambunti
Awar
NEW
GUINEA
WEST IRIAN
Telefomin
MADANG
Ramu River
Laiagam
Kegisugl
Tari
MT HAGEN
GOROKA
Kiunga
Nomad River
Ialibu
Kainantu
Erave
Hegigio River
Strickland
Fly
Baimuru
Menyamya
Balimo
KEREMA
Gulf of Papua
Rouku
DARU
LEGEND
? wrench faults
Island arc volcanoes
Recent shield volcanics
Pliocene foredeep
Eugeosynclinal facies
Miogeosynclinal facies
Craton
Uplifted basement
SCALE
50 0 50 100 150 Miles
50 0 50 100 150 200 Kilometres
TECTONIC MAP OF WESTERN
NEW GUINEA AND PAPUA
(Pers. comm; Tectonic Map Commitee of
Geol. Soc. Aust.)

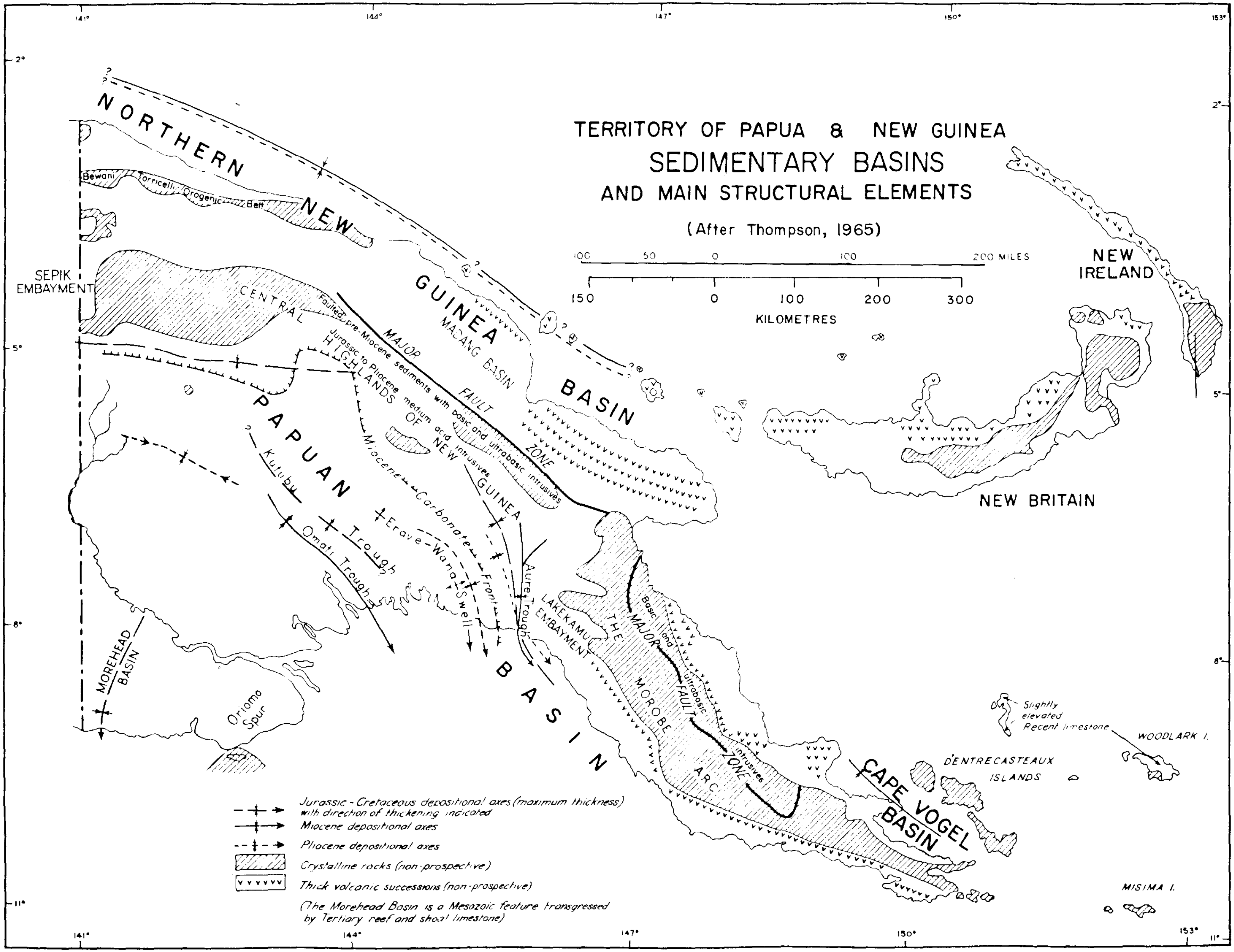
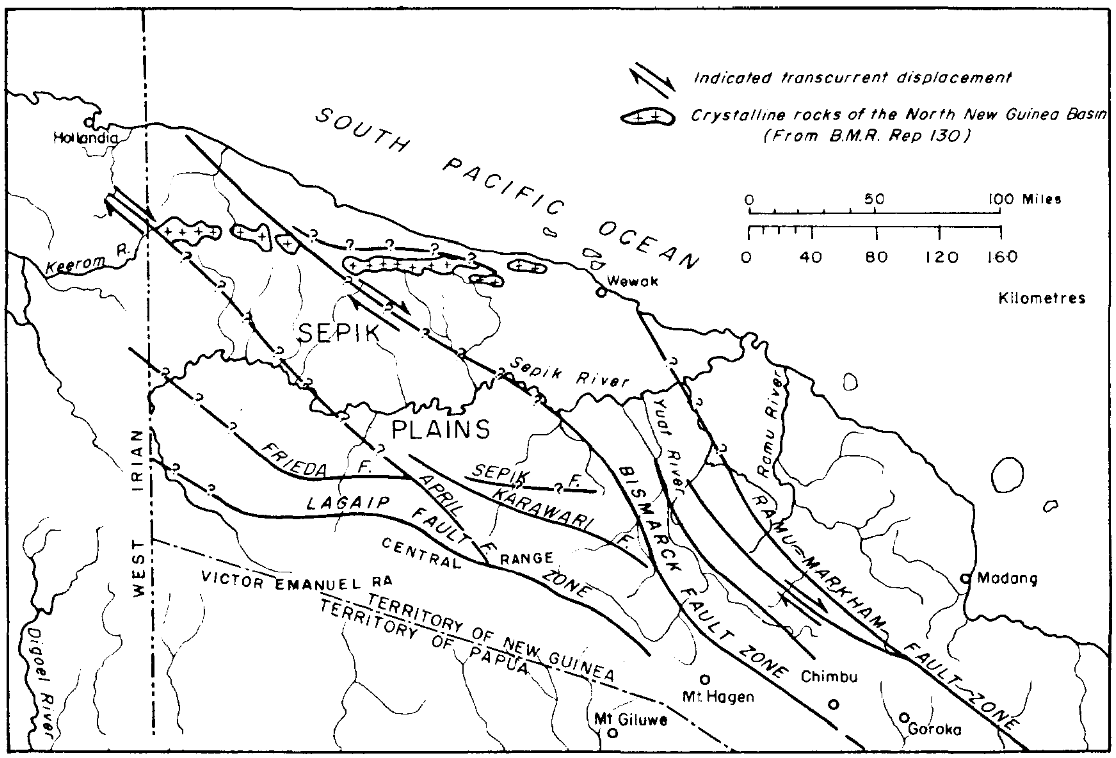


PLATE 7

PNG/B2-24-2A

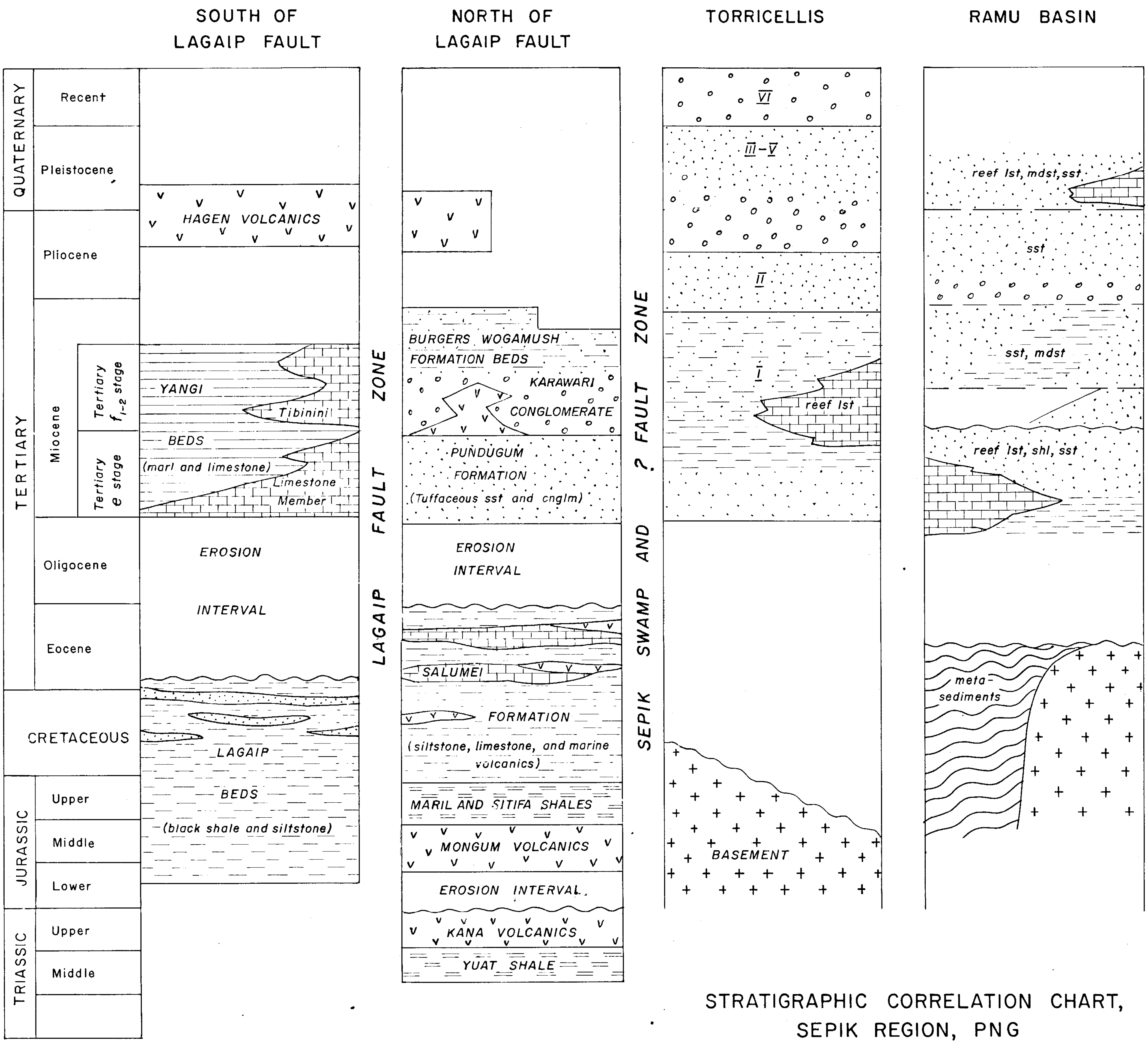
PLATE 8



MAJOR FAULTS - SEPIK REGION

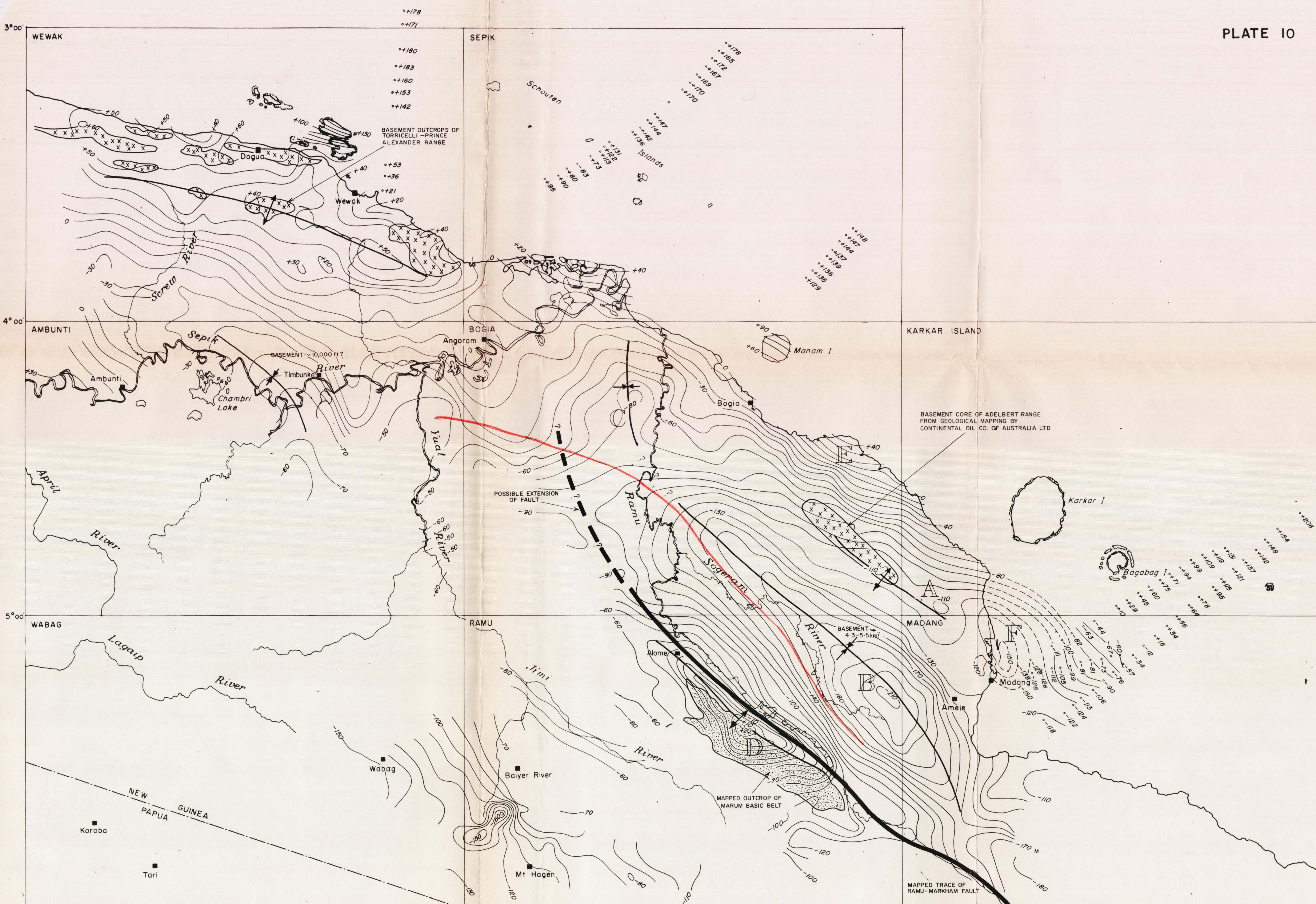
PNG/B2-16-1A

Showing postulated trends across the Sepik Plains
(modified from Dow et al.,1968)



STRATIGRAPHIC CORRELATION CHART, SEPIK REGION, PNG

PNG/B2-20-1



(BASED ON PNG/B0-14) (COMBINATION OF PNG/B2-22 and 26-1)

Basement depth estimates derived from application of slab formula to gravity data, density contrast assumed $0{\cdot}4 \pm 0{\cdot}1$ g/cm³

Preliminary Bouguer Anomalies Sepik-Ramu area computed using a rock density of 2·67 g/cm³. Marine data from U.S.S. Shoup, 1963-1964, reduced to Bouguer anomalies using bathymetry from Krause (1965)

Projection: Lambert conformal conic

LEGEND

Axes of gravity Lows

Axes of gravity Highs

Magnetic basement basin axis

A Bouger Anomaly feature

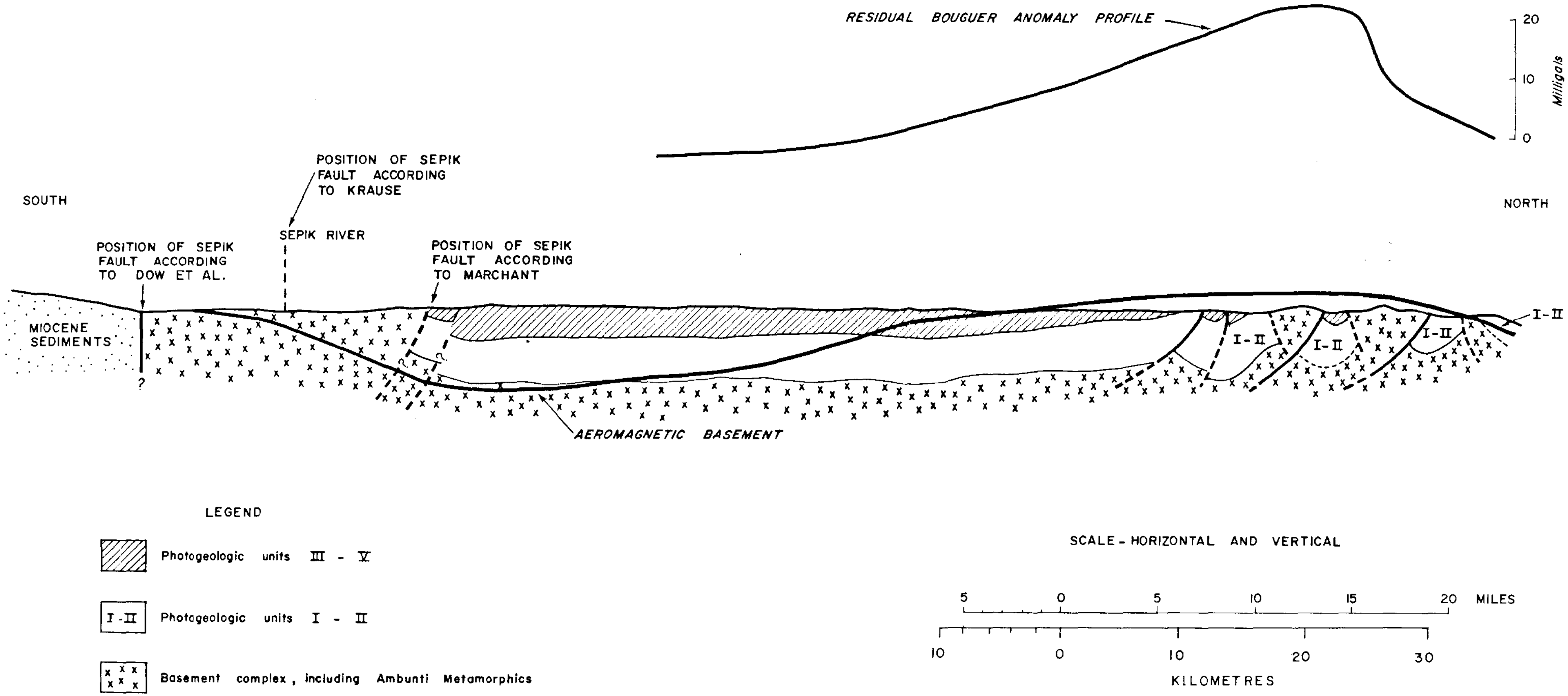
PRELIMINARY BOUGUER ANOMALIES GRAVITY AND MAGNETIC BASIN AXES SEPIK-RAMU AREA

10 0 10 20 30 40 50 KILOMETRES

10 0 10 20 30 40 50 MILES

Contour interval 10 milligals

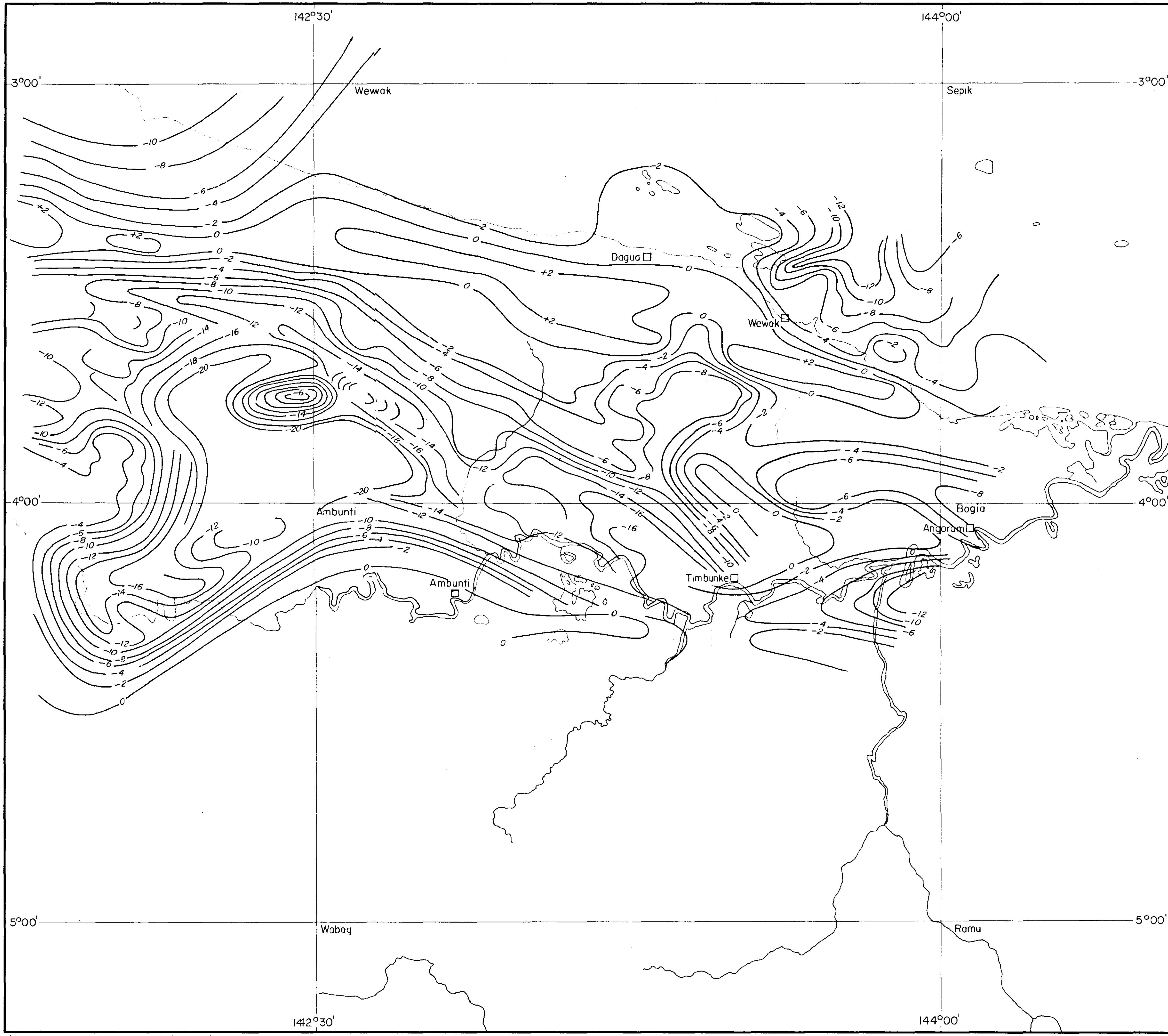
GRAVITY PROFILE AND GEOLOGICAL CROSS-SECTION THROUGH SEPIK AREA



Geology to north of Sepik River after Marchant (1968, pl. 24); to south of Sepik, after Dow et al., (1968)

PLATE II

PLATE 12



MAGNETIC BASEMENT CONTOURS

(AFTER AUSTRALIAN AQUITAINE, 1967)

SCALE

10 0 10 20 30 40 MILES

10 0 10 20 30 40 50 KILOMETRES

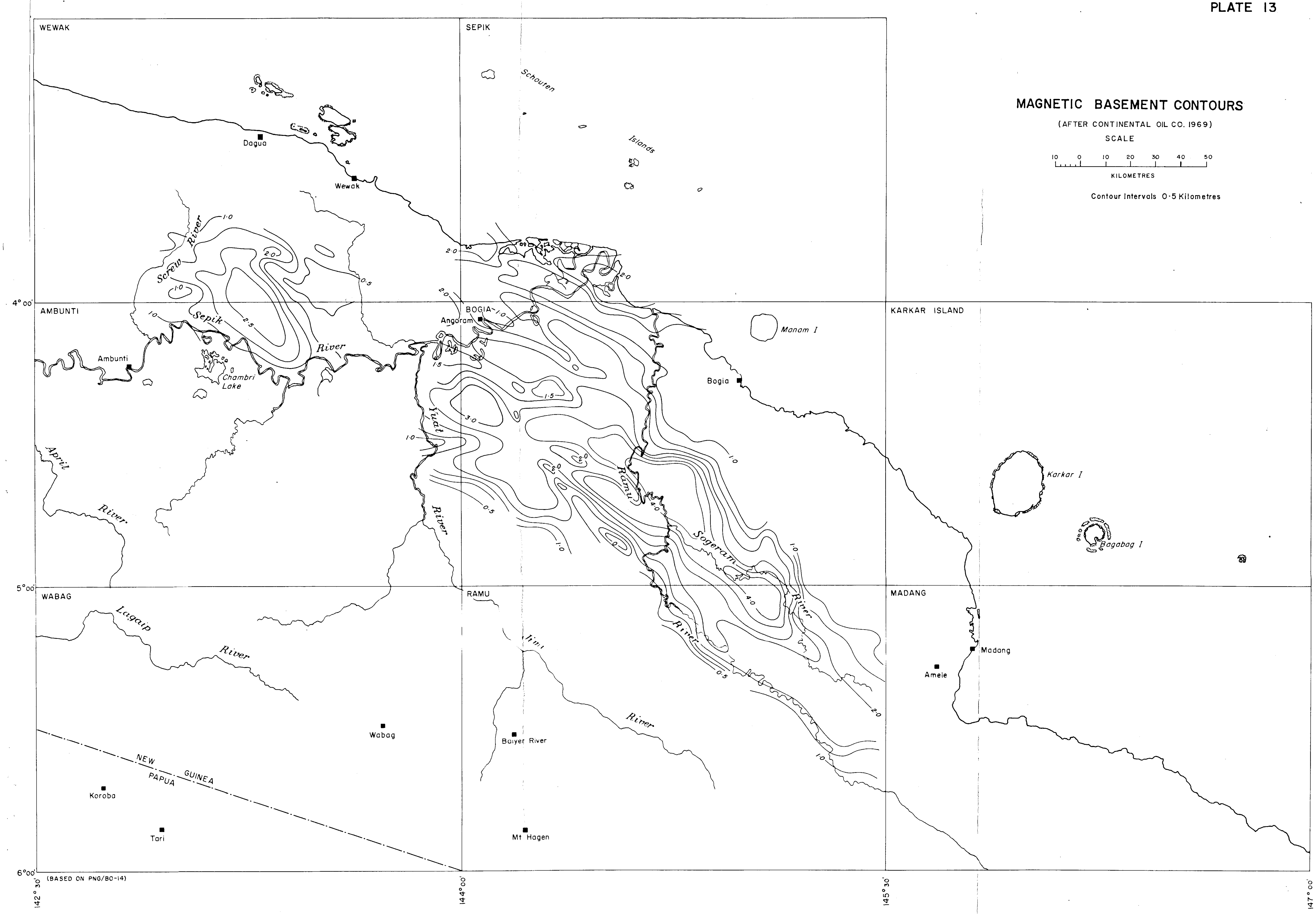
CONTOUR INTERVAL 2000 feet

(2000 feet is equivalent to 610 metres)

PNG/B3-2

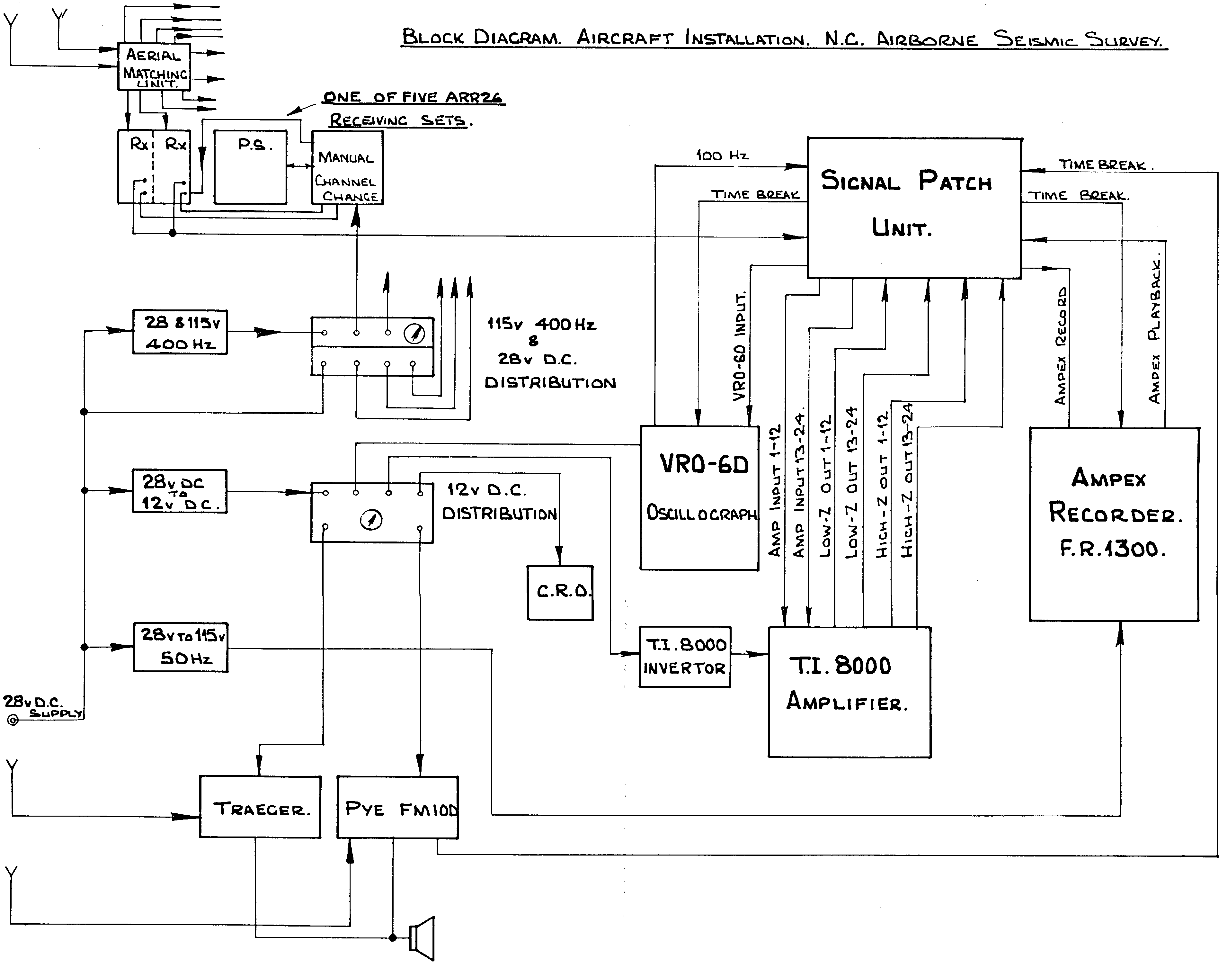
(ENLARGEMENT OF PORTION OF A54/B2-20A)

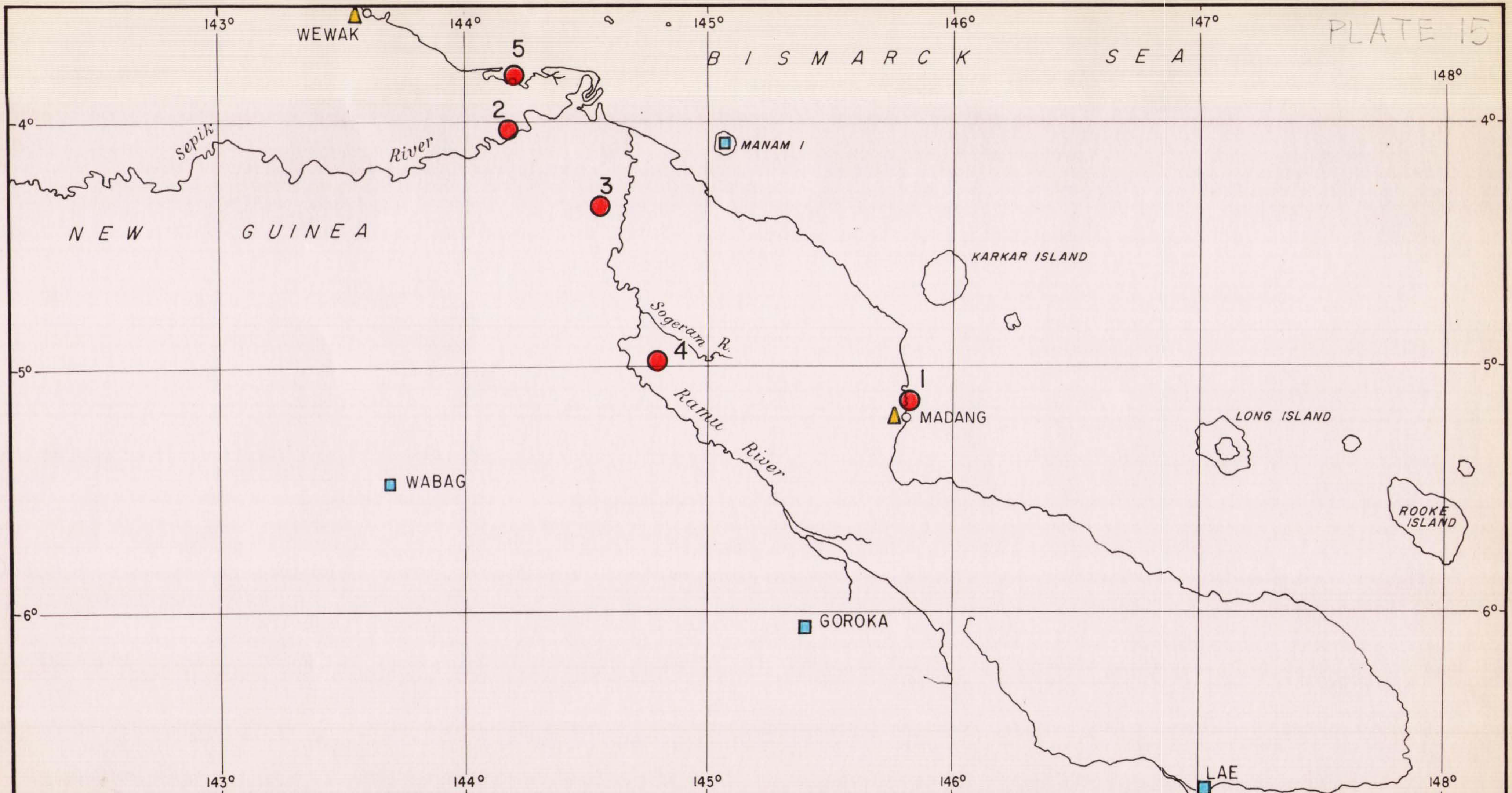
PLATE 13



PNG/B2-32-1

PLATE 14


BLOCK DIAGRAM. AIRCRAFT INSTALLATION. N.C. AIRBORNE SEISMIC SURVEY.
AERIAL MATCHING UNIT.
ONE OF FIVE ARR26 RECEIVING SETS.
Rx
Rx
P.S.
MANUAL CHANNEL CHANGE.
100 Hz
TIME BREAK
SIGNAL PATCH UNIT.
TIME BREAK.
TIME BREAK.
28 & 115v 400 Hz
115v 400 Hz & 28v D.C. DISTRIBUTION
VRO-6D INPUT.
AMPEX RECORD
AMPEX PLAYBACK.
28v DC TO 12v DC.
12v D.C. DISTRIBUTION
VRO-6D OSCILLOGRAPH
AMP INPUT 1-12
AMP INPUT 13-24.
LOW-Z OUT 1-12
LOW-Z OUT 13-24
HIGH-Z OUT 1-12
HIGH-Z OUT 13-24
AMPEX RECORDER. F.R.1300.
C.R.O.
28v TO 115v 50Hz
T.I. 8000 INVERTOR
T.I. 8000 AMPLIFIER.
28v D.C. SUPPLY
TRAEGER.
PYE FM10D



LEGEND

- Observatory seismic outstation (fixed)
- Observatory seismic outstation
- Seismic probe location

LOCATION PLAN

KILOMETRES

50 0 50 100 150

SEISMIC PROBES AND OBSERVATORY SEISMIC OUTSTATIONS

B55/B3 – 2A