COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 130
(REPORT PNG 4)

A Photogeological Assessment of the Petroleum Geology of the Northern New Guinea Basin, North of the Sepik River, Territory of New Guinea

BY

S. MARCHANT

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Bureau of Mineral Resources, Geology and Geophysics, Canberra
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DEPARTMENT OF NATIONAL DEVELOPMENT

MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

SECRETARY: R. W. BOSWELL, O.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DIRECTOR: N. H. FISHER

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FOREWORD

This Report presents the results of a photogeological study of the part of the New Guinea Sedimentary Basin that lies north of the Sepik River. It follows and completes a compilation that the late G.A.V. Stanley had been working on at the time of his death. Stanley was one of the pioneers of New Guinea geology, as well as being an explorer, geographer, and anthropologist. He spent nearly all his working life in geological mapping in New Guinea and Papua and before the Second World War he worked for several years in the Aitape district of New Guinea. After he joined the Bureau of Mineral Resources he commenced this compilation of the geology of the northern Sepik District but unfortunately when he died in 1965 he had not advanced very far with his review of the geology.

Mr Marchant took over the project and devoted a considerable amount of time to a photogeological study of the area, supported by a limited amount of field work. No two photogeologists will produce exactly the same interpretation of the geology of an area. Others who have studied parts of the area covered by Mr Marchant have produced interpretations which, although in general agreement, differ considerably in detail from his, and in particular have been less inclined to interpret as faults many of the linear topographic features.

The judgments in this Report on the petroleum prospects of the area and of the exploration necessary to test them are Mr Marchant's own. They are not necessarily supported by the Bureau of Mineral Resources or by other Bureau geologists who have worked in the area. Nevertheless a great deal of painstaking work has gone into the preparation of the Report and maps and the reader will find much useful information in them and much to stimulate further study and discussion.



(N.H. FISHER)
Director.

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SUMMARY

A photogeological assessment of the petroleum geology of that part of the Northern New Guinea Basin lying north of the Sepik River has been made in continuation of the work started by the late G.A.V. Stanley in the Bureau of Mineral Resources. The study is confined to upland areas north of the Sepik Plains and was aided by much surface information kindly made available by Oil Search Limited and originally obtained by many geologists of the Australasian Petroleum Company Pty Ltd.

The sequence in the area consists of Tertiary sediments resting on basement. Early classifications of the stratigraphic sequence by Raggatt (1928), and Nason-Jones (1930) were superseded by the more detailed work of APC geologists. On the photographic evidence six broad stratigraphic units above the basement complex can be distinguished. These are correlated reasonably with the detailed formations erected by the APC geologists. It has been necessary to validate these formations with the Stratigraphic Nomenclature Committee and full definitions, extracted from APC reports, are given in an Appendix. The photogeological units and the APC classification are also correlated broadly with the sequence in Indonesian territory as established by Visser and Hermes (1962).

The structure of the area is discussed and except in the south-western corner of the area near the Border Mountains it is maintained that the principal feature is high-angled thrusting running somewhat north of west, interrupted by cross faulting which could be tensional under east-west rotational stress or dextral and sinistral transcurrent under compressional stress in a direction about 30° east of north. This applies throughout the area except in a central zone roughly along longitude $142^{\circ}30'$E where the strike is about north-south. If it is thought that simple shear cannot explain the situation, this may have come about because a coherent block to the west moved more quickly northwards than a similar block to the east, thus causing a twist locally so that the general structural pattern of the whole area has taken on the appearance of a large 'Z'. Near the Border Mountains, probably separated from the main area by north-west faults along the Bapi valley, an entirely different tectonic regime exists with flat-lying sediments resting on the basement complex.

The region developed as a eugeosyncline probably in very early Tertiary time or conceivably in the late Cretaceous. There was much volcanic activity before the Miocene followed by almost continuous heavy marine sedimentation which filled the trough by the late Pliocene or early Pleistocene. The coastal area of the Oenake Mountains and Serra Hills had throughout been more positive with thin sedimentation and a tendency for the development of shoal limestone. Most of the Bewani-Torricelli-Prince Alexander Mountains-chain was probably formed after the end of the Pliocene and the uplift along the mountain front on the north has been dramatic.

The tectonic position of New Guinea has previously been considered as part of the mobile belts fringing the Pacific on the west and south-west, or as part of a major equatorial shearzone. It seems however on the evidence of vulcanicity, seismicity, structural pattern and relation with the ocean floor to the north that the trapezoidal central area of New Guinea is distinct from areas on the east and west, that it is certainly not a present day mobile belt in the same stage of development as the Banda and New Britain areas and that there is reason to doubt whether it has ever been subjected to massive east-west rotational stress as postulated by Carey.

The petroleum prospects of the mountain ranges, of the coastal ranges, and of the coastal plains are negligible, chiefly because of a quite unsuitable structural pattern. South of the mountains, on the slopes to the Sepik Plains and in the plains themselves, prospects are not so poor, though much of this region seems to be a simple homocline with only a few narrow faulted and disrupted folds. The Bongos-Namblo fold is the most attractive and warrants a test without further work. If the results of a well there were not encouraging it would not be worthwhile exploring the region further at the present time.

INTRODUCTION

For about three years before he died in October, 1965 G.A.V. Stanley worked at the Bureau of Mineral Resources compiling the geology of the Sepik District of northern New Guinea. He assembled much information and prepared topographical maps on a scale of 1:63,360 covering the region north of the Sepik River from the mouth of that river to the West Irian border, as well as studying stratigraphical problems. However he had not progressed far towards a geological interpretation, having completed only part of the area along the border south of Vanimo and in the Bewani Mountains.

In order not to waste the information collected by Stanley I was assigned the task of compiling a report on the area from those data. Without previous knowledge of the geology of New Guinea it was not envisaged that my results could be so comprehensive or authoritative as those which Stanley with long experience would have produced, nor have I attempted a reconciliation of all available information. A proper review of the palaeontology and stratigraphy would certainly improve the accuracy and quality of this presentation, but would have taken too long.

Of the material collected by Stanley only a few major reports by geologists of the Australasian Petroleum Company Pty Ltd have been taken into account; otherwise this enquiry would have become too detailed. At the start a difficulty arose because Stanley's interpretation of the tectonics was different from that adopted by other APC geologists. However a check of the air photographs of a critical locality in the Bewani Mountains showed that Stanley's interpretation was the less likely.

The work which is here described is basically a photogeological study, helped by available surface information. After a preliminary study of most of the photographs I had the opportunity of two months field work in the Romei area, south-west of Aitape, with geologists of Continental Oil Company of Australia Ltd, and I also did some field work in the Wewak area. This enabled me to make a photogeological interpretation with greater confidence than would otherwise have been the case.

PREVIOUS WORK AND ACKNOWLEDGEMENTS

Although solely responsible for the interpretation, opinions and conclusions expressed in this report, I could not have reached them without the help of many past and present workers. The geologists of Oil Search Limited, Island Exploration Company Pty Ltd and Australasian Petroleum Company Pty Ltd, whose reports, maps and general information have been made available by Oil Search Limited, discovered the basic geological facts of the area when they worked there for the ten years or so before World War II. The chief contributors were S.W. Carey, A.K.M. Edwards, J.N. Montgomery, N. Osborne and G.A.V. Stanley. They were, in fact, preceded by German geologists before, and by British Petroleum (at that time Anglo-Persian Oil Company) geologists (e.g. J. Nason-Jones) after, World War I, but I do not intend to trace the history of geological investigation further back than the APC surveys of 1930-1940 because the earlier work was incorporated in the compilation reports of Osborne (1942) and Montgomery (1943). It may be assumed that all general reference to the work and maps of APC geologists is contained in these reports and that further simple mention of Osborne and Montgomery also refers to these reports.

Those who are familiar with the unpublished compilation reports of Osborne and Montgomery will realize that my own interpretation does not seriously disagree with theirs. The differences are largely matters of detail and can, I think, be easily explained. The APC geologists were up against the difficulty of all work in tropical rain forests, that of deciding the structural trends without any chance of viewing the general topography. For some areas they had aerial photographs which were available about 1940 after their

field work had been done. The delineation of topography and recognition of dip-slopes on their photogeological maps were meticulously accurate, but faulting was mostly disregarded. Although the geologists clearly recognized in the field that much faulting occurred, in later compilations they did not use the photo-interpretation to determine the extent and direction of fault lines. In consequence they were liable to join up two localities of faulting observed on the surface which, according to the photos, lie on different faults. Thus in places where the photos clearly show two faults the APC geologists show only one with a somewhat different trend and in places crossing the topography in an impossible fashion.

Further in some critical places in the Romei area where disturbances and steep dips occur in stream sections there is no record of them on the extant APC maps. This does not mean that the outcrops were totally disregarded, but suggests that the evidence provided by such disturbed zones was not thought to be important. It is now difficult to know whether there is the same omission in other places where a presumed photo-fault crosses a surveyed stream without any record of disturbed surface dips on the maps.

Probably this merely represents two different approaches to the geology of the area. The APC geologists were exploring for oil, to find drillable structures, and hence were inclined to discount the effects of faulting where antiforms were detected, whereas on the photographic evidence I discount the anticline in favour of the fault.

After APC gave up concessions in the Sepik district at the end of World War II no one did geological work in the area until recently. Continental Oil Company of Australia Ltd and Australian Aquitaine Petroleum Pty Ltd took out concessions in 1964 over the area dealt with in this report and their geologists have been working in various places since early 1965. Continental Oil Company kindly invited me to join their field party in the Aitape area in March and April 1966 and I take this opportunity of gratefully acknowledging the benefit which this experience of the area has had on my whole study. Apart from a most useful introduction to New Guinea geology discussions with A. Kugler, leader of the field party who had just completed a year's field work south of the Torricelli Mountains, were exceedingly helpful and have played a large part in formulating my ideas on many geological aspects.

The Division of Land Research, Commonwealth Scientific and Industrial Research Organization, has carried out two surveys over the eastern two-thirds of the area. The first in 1959 was east of longitude 143°E over the land north of the Sepik River. Some rock samples were collected at scattered localities and the available descriptions (Baker 1960; CSIRO 1961) of some of these have been very useful. In 1966 the second survey covered the area between longitudes 142°E and 143°E, and between the Sepik and the coast. I am grateful to B. Ruxton and H.A. Haantjens for discussing their results with me and allowing me to use the information. I am further indebted to B. Ruxton for reading early drafts of this report and making suggestions which have led to useful additions and alterations; without his advice the chapter on tectonics would not have been written.

I have also had discussions with R. Heilammer and F.H. van Oyen of Australian Aquitaine on the geology of the area and am grateful to them for certain matters mentioned below.

I am grateful to N.H. Fisher, M.A. Condon, R.P.B. Pitt and other colleagues in the Bureau of Mineral Resources for reading and commenting on the draft of this report.

Finally I acknowledge the insight into, and understanding of, New Guinea geology provided by Visser and Hermes in their account of the 'Geological results of the exploration for oil in Netherlands New Guinea' (1962) to which repeated reference is made below. That compilation of course summarizes the work of many geologists of the Nederlandsche Nieuw Guinee Petroleum Mij.

LIMITS OF AREA STUDIED AND RELIABILITY OF COVERAGE

It was intended to cover all the mainland north of the Sepik River, i.e. the north-western half of the Northern New Guinea Basin, but maps south of latitude 4°S have not been prepared because there is so little outcrop in the flood plain of the Sepik River and indeed so little geological knowledge of any outcrops that occur. This is tantamount to limiting the photogeological study to the areas north of the Sepik plain from longitude 144° 30' E westward to the West Irian border. Photographs cover the whole of this region except in the south-western corner which is discussed later.

Topographical maps prepared from aerial photographs were available for nearly all the area. East of longitude 143°E compilation maps on a scale of 1:40,000 had been prepared by the Division of National Mapping. West of that longitude most of the region was covered by a series of APC maps on the same scale. From these, standard sheets on 1:100,000 scale have been prepared. There is however one important gap in this map coverage, from the coast between Aitape (J17)* and Matapau (M25) south to about latitude 3°30'S. Stanley's 1:63,360 sheets covered this area and he had presumably compiled them from various sources such as military maps. His compilation and some other topography available from compilation sheets of APC have been used to fill this gap.

Thus there are three degrees of topographical reliability over the area:

(1) The Maprik (4447), Kai (4446), Wewak (4547), Tring (4546) and Marienberg (4646) sheets. Prepared by DNM from aerial photographs with good ground control. Accurate in themselves and regionally.

(2) The Vanimo (4050), Kilimeri (4049), Bewani (4048), Serra Hills (4149), Moari (4148), Kalingum (4147), Aitape (4248 - western two-thirds), Lumi (4247 - except the north-eastern quadrant), Nigre (4246), Dreikikir (4347 - southern one-third), and Masalaga (4346) sheets. Prepared by APC from aerial photographs probably without proper ground control. Probably locally, but not regionally, accurate. Approximately the western halves of the Vanimo, Kilimeri and Bewani sheets have been taken from the Border (Special) Sheet 1 of DNM. In these parts the regional accuracy is higher than elsewhere.

(3) The Aitape (4248 - eastern third), Lumi (4247 - north-eastern quadrant), Suain (4348) and Dreikikir (4347 - northern two-thirds) sheets. Compiled from various published and unpublished sources and adjusted as well as possible. Distorted locally and regionally.

Distortions occur along longitude 143°E where (1) and (2) above meet and differ, because the 143°E meridian of DNM does not coincide with that of APC, and also over the whole area of (3); but the inaccuracies are not thought to be serious.

Geological reliability is affected by cloud, insufficient overlap of photographs or even just bad prints, which impede or prevent interpretation in places, but generally not excessively so. Where this is important it will be mentioned in the text. Surface knowledge in support of the photogeology is generally good to reasonable everywhere west of longitude 143°15'E except in areas of basement rocks. It is almost all provided by the surveys of APC which were thorough and detailed along the mountain front from the West Irian border to the Raihu River (KLM15,16), but less complete in the Oenake Mountains (E1,2) and Kohari Hills (FG1) south of Vanimo (DE4), and in the Serra Hills (H10). South of the Bewani Mountains (K1-11) there was little work except in the Unumbu River (K4,5); surface information starts at the Sand River (MNO9) and is then plentiful as far east as longitude 143°15'E. Much detailed geology is known from the area between Matapau (M25)

* For ready reference each map square (5' x 5') is lettered latitudinally and numbered longitudinally.

and Maprik (P25). Thus topographical Area (2) is mostly covered by good surface information except around Vanimo and the Serra Hills and south of the Bewani Mountains. Area (3) was not surveyed extensively and much information seems to be available no longer but some preserved by Stanley has been useful. East of longitude 143°15'E in the area south of Wewak (O32) and eastwards to the coast from Terebu (P34) to Kaup (R36) there is very little surface information. APC geologists never worked in this area except for some isolated traverses in the drainage area of the Hawain River (NO29,30). Papp (1929) in 1920 seems to have been the only geologist to traverse the country south-east of Wewak extensively and even his observations were scanty. A few scattered observations were made by CSIRO workers in 1960 and by myself in 1966.

Geologically the region can be graded as follows:

(1) The mountain front from the West Irian border to the Raihu River, and again around Matapau and in the mountains south-west, south and south-east; the Sepik slopes from the Sand River eastward to longitude 143°15'E. Plentiful traverses often in great detail.

(2) Oenake Mountains and Kohari Hills, south of Vanimo; the Serra Hills. More scattered and less detailed traverses.

(3) The mountain front east of the Raihu River to the Dandrawad River (L22); the Aitape area. Some information not well described.

(4) Most of the area east of longitude 143°15'E and all that south of the Bewani Mountains west of the Sand River. Very few surface observations; one or two traverses.

The three south-western sheets (Border (4047), Green (4046) and Yellow (4146)) have not been considered above because of the absence of reliable information. Only a strip along the West Irian border has been photographed so that one cannot make topographical maps or photo-interpretation for the greater part of the area. The maps have been made up for the sake of completeness with what information there is and geological aspects of this area will be discussed separately from the rest of the region.

STRATIGRAPHY

Previous Classifications

Only two previous publications deal reasonably fully with the stratigraphy of the Northern New Guinea Basin in the Sepik District. First Raggatt (1928) published 'A geological reconnaissance of part of the Aitape District, Mandated Teritory of New Guinea'. In this he classified the succession provisionally as follows:

Recent and Pleistocene	Coastal Deposits
	Matapau Coralline Limestone
	Mau River Conglomerate and Muds
----------Unconformity----------	
Late Tertiary (probably Pliocene)	Aitape Beds
	Mendam Beds
----------Disconformity---------	
Tertiary (probably Miocene)	Yalingi River and Ulau Beds
	Aiterap Beds
	Bliri River Beds
----------Unconformity---------	
Pre-Miocene (possibly Mesozoic)	Older altered sediments
Pre-Cretaceous	Schists, gneisses

Raggatt defined none of these divisions and subsequent work by APC geologists proved that this sequence bears no resemblance to the one which they established much more carefully, except for the Bliri River Beds. No further reference to Raggatt's classification is necessary.

Secondly Nason-Jones (1930) on the basis of work carried out in 1928 and 1929 set up the following classification:

Pleistocene	Yalingi Series and Upper Vanimo Group
Mio-Pliocene	Finsch Coast Series
Upper Middle (sic) Miocene	Upper Aitape Group
Upper Eocene - Lower Miocene	Lower Aitape Group
Basement Complex	

Because he defined none of these divisions APC geologists could not recognize them everywhere easily and, worse still, one geologist began to use them in a different sense from another. They therefore discarded Nason-Jones' terms and reclassified the sequence with different names in different areas. This classification was based on palaeontology and correlated with the familiar letter classification of van der Vlerk and Umbgrove in what was then Netherlands Indies (Tertiary Stages 'a', 'b', 'c', 'd', 'e', 'f', 'g', 'h').

The photogeological interpretation supports the classification of Osborne and Montgomery, but because the method is less precise than surface mapping the smaller divisions cannot be detected everywhere. On the photographic evidence only six broad divisions of the sedimentary section above the basement complex are justifiable. To go further than this would probably obscure, rather than clarify, the general geology. These photogeological units are numbered I to VI and the Roman numerals I-V on Plate 22 show their correlations with the divisions erected by APC geologists in different areas. The Pleistocene (Unit VI) is not included on the chart. However the sequences established by surface mapping in different areas have not been correlated one with another in all respects and the photogeological units can of course be recognized as the definite equivalents of the surface divisions in a few places only. APC geologists correlated the sequence on the Bewani mountain front tentatively with that in the Barida-Neni area, while the correlation between the sequence in either of these areas and that south of the mountain divide was based purely on palaeontology because the areas of outcrop are quite separate. Photogeological units III-V are exactly correlated with the succession in the Bewani mountain front; units II and III with the succession in the Keang River valley; units III and IV with the succession in the area south and south-west of Lumi. Otherwise the correspondence between photogeological and surface units is not so precise, but complete discrepancy between them is admitted only in the area between Nuku and the Keang River, where I interpret the succession above Unit III differently, and on the southern slopes of the mountains east of Maprik.

All these matters will be discussed later under the headings of the six photogeological units, where it is hoped they will be adequately explained. However in order to make the discussion intelligible it is necessary to use the stratigraphical names erected by the APC geologists. Few of these have been published but fortunately Osborne and Montgomery defined nearly all their formations clearly. For the reader's convenience a formal definition of each formation is given in Appendix 1 to this report. The Stratigraphic Nomenclature Sub-Committee of the Commonwealth Territories Division, Geological Society of Australia, has accepted these definitions and validated the nomenclature which, except for four formations (Bliri River Beds, Bewani Formation, Nopan River Beds and Neumayer Beds), is that used by APC geologists. The four changes of name have been necessitated because of priority or inadequacy of the terms used by them.

As mentioned earlier a completely satisfactory reconciliation of the stratigraphy and an adequate review of the palaeontology of the rocks is outside the scope of this report. No doubt detailed surface work will find plenty of local errors in the maps. Yet in general terms the photogeology will probably be found to agree reasonably with the detailed stratigraphy of APC geologists. In Indonesian territory Visser and Hermes have already simplified the stratigraphy into a few broad units and a rough correlation with these is possible because both they and APC geologists correlated their classifications with that of Zwierzycki (1921, 1927). The result is that Visser and Hermes' stratigraphy and interpretation are clearly recognizable in Australian territory. There can be little doubt that when the geological knowledge of Australian territory reaches the same standard as that west of the border the geology of the whole region between the mouths of the Memberamo and Sepik Rivers and north of those rivers will be found to be very similar indeed.

Plate 22 is a correlation chart of the stratigraphy of northern New Guinea, reconciling as far as possible all the important attempts to classify the sequence. To avoid confusion however an explanation is needed. The divisions of age, time-stratigraphic units and Tertiary Stages 'a' to 'h' are copied from Visser and Hermes as is the correlation of formations in Indonesian territory because it is sensible to try to relate the stratigraphy of Australian territory to that clear standard. As stated above this can be done by way of Zwierzycki's classification. There is however a confusing situation regarding Tertiary Stage 'g' because Visser and Hermes and APC geologists may not have been regarding this in the same way. Visser and Hermes relied on divisions based on modern work on pelagic foraminifera which apparently did not tie in precisely with the divisions made by van der Vlerk and Umbgrove on large benthonic foraminifera. Thus Visser and Hermes do not maintain Stage 'g' separately from Stage 'h', presumably because they found in their area that benthonic foraminifera were inadequate. Their division between Miocene and Pliocene is put tentatively at the top of Stage 'f' or between T34 and T35, which means that Stage 'g' presumably corresponds at least to T35, T41 and T42 and was regarded by them, in so far as it was regarded at all, as basal Pliocene. On the other hand APC geologists correlated their stratigraphy only by the larger benthonic foraminifera, following van der Vlerk and Umbgrove, and, as many others do and have done, regarded this as uppermost Miocene. Moreover Visser and Hermes gave the range of their Memberamo B Formation as T34, T35 and T41 which straddles their tentative division between Miocene and Pliocene. Thus in spite of the correlation from both sides with Zwierzycki's Globigerina Marls the Stage 'g' beds of APC geologists (Puwani Formation, Barida Beds and Songaien Formation) may not exactly correspond to the Memberamo B Formation, as is shown on the chart.

Because palaeontological controversy is none of my business I refer to Tertiary Stage 'g' as Mio-Pliocene in the rest of this report.

Photogeological Units

Basement Complex

This can generally be recognized without difficulty by the very rugged relief and at least in Area (1) of geological reliability there is enough surface information not only to feel reasonably certain about the basement rocks themselves and the position of the boundary with the sediments, but even to make suggestions on the nature of the boundary.

Throughout the Bewani and Torricelli Mountains east to Mt Wesaguhimi (N27) and in the coastal hills behind But (M27) and Dagua (M28) probably most of the highest and more rugged country is formed by acid to basic plutonics. There may be areas of metamorphic or ultrabasic rocks at the edges of the igneous masses, because Osborne

mentions schist pebbles in the Puwani or Me River (H-K2-4) and also states that his lower Bliri Group is 'always underlain by basaltic lava flows; and dense dark green-black igneous rocks which may be either volcanic or plutonic separate the undoubted volcanic rocks from undoubted coarse-grained diorite.. in the Bliri and Me (Puwani) Rivers and a little less clearly in the Upper Maiu River (IJ4)'. The basaltic lava flows are probably best considered as basal Bliri and the green- black igneous rocks probably represent a zone of metamorphics or ultrabasics. Raggatt (1928) mentioned altered sediments, gneissic rocks and schists in the Mt Somero area (M14) between the Mau-Yalingi drainage and that of the Gweinif River (M14), but Ruxton of CSIRO collected diorite and granodiorite in this area in 1966 and gabbro in the hills west of Keraitem (M13). Australian Aquitaine geologists found various occurrences of 'green rocks' below the sediments in the general area of the Bliri drainage around longitude 142°E. They also found, when working up Nenabu Creek (L11,12), that the first basement range consisted of metamorphics. Ruxton also found a 300-m zone of light green epidosite about 10 km long between sediments and plutonic basement along the mountain front east of the Nigia River (LM16-18).

There are patches of sediments within the basement areas, perhaps as in-faulted blocks and as uplifted outliers. APC geologists record Eocene limestones near the summit of Mt Sulen (M15). Haantjens of CSIRO found limestone on the mountain tops south-west of the Atob River (N24,25). In the hills west of Keraitem and in the mountains at the head of the Piore River (JK9-11), even as far as the West Irian border south of the Bewani and Pulan (HJ2) Rivers, there are other areas which are strangely devoid of character when compared with the steep interfluves and deep gorges of typical basement outcrop. All could be sedimentary areas but none is convincingly recognizable as such on the photographs. Figures 1 and 2 are photographs of Mt Mudul (O24) and west Keraitem areas respectively as examples of these indefinite localities. Inadequate photographs are only partly to blame for the difficulty of interpreting these areas. It is well known that the Wewak earthquake of 1935 caused tremendous damage and changes at the surface (Oil Search Limited, 1935) and certainly some of these obscure areas are ones that suffered especially badly then or at the time of other earthquakes. Simonett (1967) has discussed the distribution of landslides in connexion with the 1935 earthquake and a more careful study of the photographs from this point of view than I have made would probably be of much interest. In most places I have not tried to distinguish on the maps these areas of possible or probable sediments from basement.

Thus plutonic rocks seem to predominate throughout the Bewani and Torricelli Mountains. However in the hills west of Keraitem, in the area of Mt Somero and in the narrow basement ridge between Mene Creek (K11,12) and the Bliri River (I-M12,13) north of the main basement outcrop they may not occur extensively or may even be absent. One colour tone for all these basement areas is used on the maps.

East of longitude 143°E descriptions of the basement sound different. Garnet-mica schists occur in the headwaters of the Kamen River (O27); altered volcanics and gneiss have been found near the watershed of the Screw River (O25) north of Maprik. North of Yangoru (P28) on the slope of Mt Turu (P29) garnet gneiss and hornblende schist are recorded from an area which can be distinguished with difficulty on the photographs from sediments. On Mt Turu itself CSIRO workers (1961) collected zoisite amphibolite but APC geologists also mention diorite in this area. Dr Fisher tells me that much of the basement in this general area is phyllite. Farther east near Tring (R35) hornblende sanidine trachyte, diabase and hypersthene gabbro were identified in CSIRO samples. Papp (1929) who traversed this area and the Hansemann Coast (QR35,36) mentions 'gabbro, diorite, andesite, basalt, melaphyre, rhyolite and... their tuffs, agglomerates, and breccias', but without further elaboration. The Australian Aquitaine geologists tell me that the coastal hills at Terebu (P34) consist of 'green rocks' similar to normal basement metamorphics; CSIRO workers collected a sample of basalt at the eastern end.

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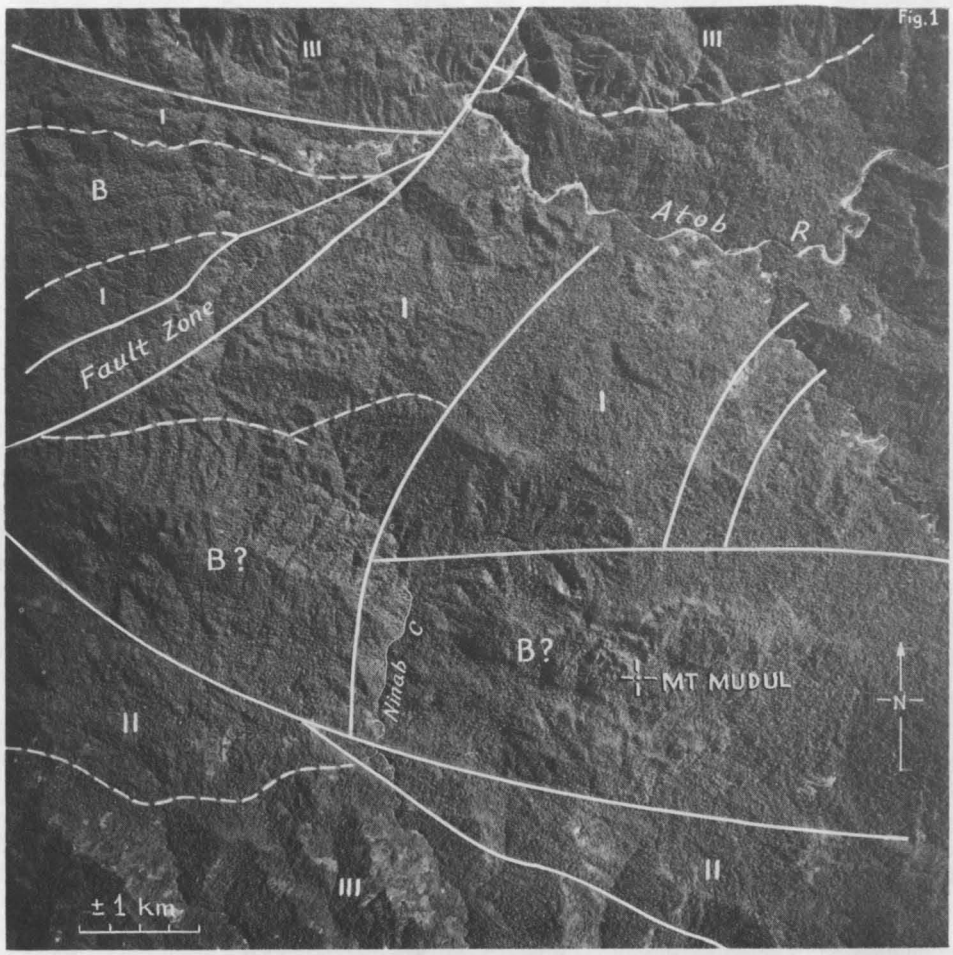

Fig. 1 Mt Mudul area, south and south-west of Mabam and Atob Rivers (Vertical air-photograph CAJ 93-5085. BUT Run 3; Photogeological Sheet 4347).
The hill mass south-west of Atob River is very indefinite. Much of the crestal area and the headwaters of Ninab Creek seem rugged enough to be basement, but CSIRO workers reported limestone in these hills. The slope of the hills towards the Atob River is entirely nondescript and may be mostly composed of Unit I, though in the Atob River itself APC geologists recorded basement rocks. The steep southern limb of the Mabam Syncline just appears along the northern edge of the photograph, and on the southern edge Unit III forms reasonably prominent dip-slopes, dipping away from the intervening basement-Unit I outcrop.
Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

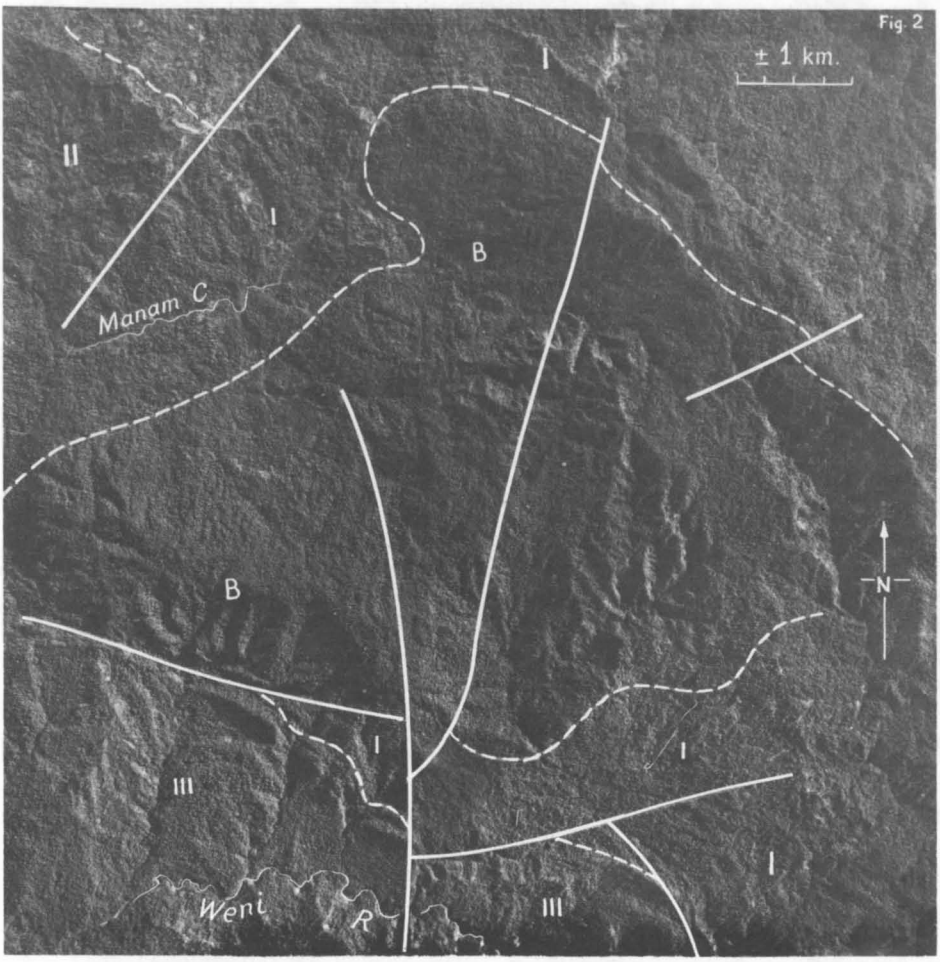

Fig. 2. **Area between Keraitem, Twaitei and Manam Creek (Vertical** air-photograph CAJ 195-5018. SENO Run 3A; Photogeological Sheet 4147).
Apparently basement crops out over the central part of the photograph where much of the topography is sufficiently rugged to suggest this, but on the south-eastern side of the Manam valley and in the south-eastern corner of the photograph the topography is without character, as well as in places within the central hills. The distinction between basement and sediments is very indefinite within this central area. In contrast Unit III is very clearly seen in the south-western corner, forming steep prominent dip-slopes, and the entirely nondescript topography of outcrops of Unit I is seen in the northern and north-eastern parts of the photograph.
Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

It is not certain in this area of the Torricelli and Prince Alexander Mountains east of longitude 143°E whether all reports are of basement in situ or, if they are, whether these are anything more than small outcrops in the streams. Probably the basement outcrops which I show in the general district north of Maprik are too extensive but equally probably in this area basement is near the surface.

The evidence suggests that plutonic rocks are less common in the Prince Alexander Mountains east to the Hansemann Coast than they are in the Bewani and Torricelli Mountains; indeed north of Maprik and at Mt Turu the topography of probable basement outcrop generally seems more subdued than that of the Bewani-Torricelli plutonics. In the Tring area however it becomes difficult to decide which is basement, partly because recent coral limestone masks much of the underlying geology and produces a nondescript topography. Consequently on the maps of this area the distribution of basement sediments and coral limestone is uncertain.

There is so little knowledge of the surface geology east of Yangoru that only two areas, apparently wholly of metamorphic rocks, can reasonably be recognized, viz. at the head of Kamen River and on the slopes of Mt Turu north-east of Yangoru. An area inland from Boiken (N30) and Karawop (M-N30) is also shown as metamorphic on the strength of the outcrop at Karawop Point. I distinguish the rest of the basement areas in the Prince Alexander Mountains from those in the Bewani-Torricelli Mountains by a different colour tone on the maps because they are probably much less plutonic.

Generally the northern side of the basement outcrops seems to be faulted. Along the mountain front the surface evidence for this is confirmed by the photographs where in many places there is a bewildering pattern of lineaments. There are probably few undisturbed contacts of sediments on basement throughout this zone. Osborne is not really specific on this matter, though he states that Bliri sediments 'seem to overlie coarse-grained diorite' in the Bliri section and that in the Puwani River 'basal conglomerates ... overlie dense dark greenish volcanic or plutonic rocks which in turn give way to coarse-grained diorite'.

On the other hand there are many places south of the divide, on the slope of the mountains towards the Sepik, where basement topography grades into the subdued topography of the sediments. These seem to be sedimentary contacts, but CSIRO and Australian Aquitaine workers have found that in some places my boundary is wrongly placed by about a kilometre and even misinterpreted. Perhaps this is because a zone of non-plutonic basement intervenes between plutonics and sediments, thus explaining the gradual change in topographical effect and enabling a fairly wide choice of position for the contact. In this connexion Osborne stated that 'the upper Bliri is seen to overlap the lower Bliri to rest directly on the basement on the southern side of the Mountain Zone in the Torricelli-Bewani Saddle'. Moreover Kugler has told me that in traverses up this slope to the north of Keraitem northerly dips were noted to the limit of the survey which, though it did not reach basement, cannot have stopped far short of it. That information makes the interpretation on the southern slope of the basement outcrop locally doubtful.

The following five areas of possible or known basement are mentioned separately:

Oenake Mountains - Mt Bougainville (D1)

APC geologists reported diorite boulders 'in the Mossu River (E1,2) associated with a boulder conglomerate and volcanics which might mark the basal Bliri'. Australian Aquitaine geologists found basement debris in streams flowing north off Mt Bougainville and this seems to be more significant than the APC report because the area of provenance for the material is much more limited. However both reports could refer to material derived from conglomerates and on the photographs there is no evidence for basement on Mt Bougainville of which the summit area seems to be taken up by limestone ridges of Unit I. If there is an outcrop of basement here it is probably small.

Serra Hills south of Leitere (F8)

APC geologists found schists, serpentine and diorite in several creeks south of Leitere. The photographs do not help in deciding the extent of these outcrops or their relation with overlying sediments.

Karawop (N30) area - eastern end of But-Dagua Hills

Montgomery says: 'At Karawop, about 17 miles west-north-west of Wewak, Mena Series rocks resting unconformably upon rocks, apparently identical with those of the Mebu Series of the Madang District, were observed by P. Hossfeld ...' Not knowing the Madang geology I cannot comment on this and indeed am puzzled by the outcrop. At Karawop Point there were thin-bedded indurated olive-green silicified sandstones and hard brown and bright green tuffs. About 8 km south-south-east, i.e. 4 km from Boiken on the Wewak road, there are pillow lavas. Between these localities fine sandstone and brownish-weathering marls or clay shales crop out. The latter could be what Hossfeld correlated with the Mena Series, the other outcrops being of the Mebu Series.

On the other hand the Australian Aquitaine geologists consider that these rocks at Karawop Point are 'green rocks' like those known in the basement elsewhere on the mainland and suggest a sequence showing increasing alteration from this occurrence through the outcrops at Matapau to the Terebu outcrops.

In any case the outcrop at Karawop represents economic basement from the point of view of oil exploration and the area is shown as metamorphic on the maps.

Wulima Creek (Q28)

Five and a half kilometres west-south-west of Yangoru, in the core of an anticline which was not named by Montgomery but which we may call the Wulima Anticline (Q28), APC geologists recorded an outcrop of basement, as they did also about 15 km east-south-east of there in the Hambili River (P-T29,30). Neither of these is identifiable on the photographs but I show the first outcrop on the map because it alone can be located reasonably accurately.

Diorite Inlier - Weni River (NOP12,13)

APC geologists reported this outcrop which occurs high in the Nopan River Beds. There are no signs of it on the photographs nor is there faulting at the locality. It is shown on the map but should be re-examined before it is accepted as a simple inlier.

To sum up, we must admit to great ignorance of the basement rocks and their relations throughout the area. The mode of occurrence of the plutonic rocks is not known; the ages of the igneous and metamorphic rocks are also unknown; the relations of the plutonic and metamorphic rocks are unknown and the relation of both to overlying rocks is mostly uncertain. Probably the plutonic rocks intrude the metamorphic but I do not believe that this has yet been conclusively demonstrated.

Unit I

Nearly everywhere west of a line from Dagua to Yangoru the outcrops of basement are in contact with a zone of sediments which form an undistinguished topography (see Figure 3). It is impossible to subdivide this on the photographic evidence and generally impossible to detect structural features. In places there are indistinct and unconvincing dip-slopes or isolated crags and ridges. Some of these ridges are of limestone (see Figure 4), e.g. in the Mene and Bliri Rivers and the More-Make Hills (K11,12), but without more knowledge of the surface geology it would be dangerous to identify them all.

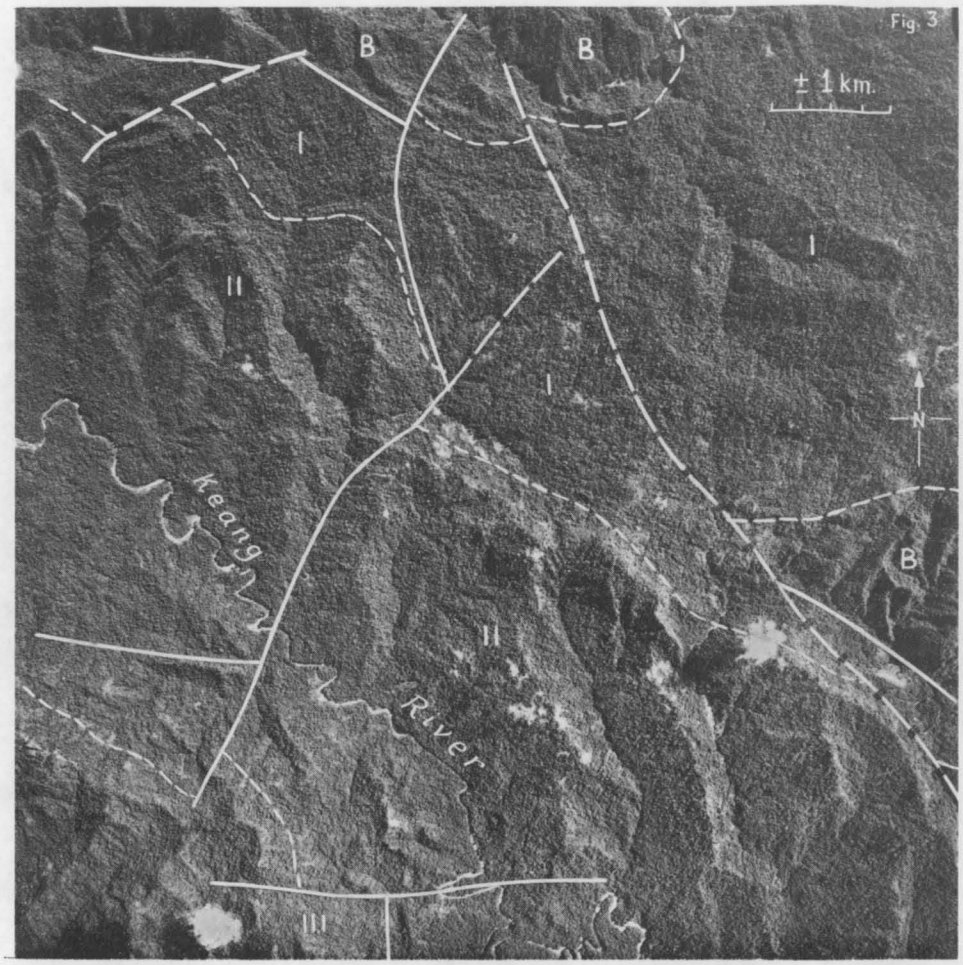

Fig. 3. Upper Keang River valley west of Dato (Vertical air-photograph CAJ 194-5057, SUAIN Run 4; Photogeological Sheet 4347).
The characterless outcrop of Unit I rocks can be seen clearly separating the rugged basement on the northern edge of the photograph from Unit II (here = Molang Creek Beds) with its prominent chevron dip-slopes along the north-eastern side of the Keang River valley. The basement outcrop north of Dato is displayed prominently mid-way down the eastern side of the photograph. Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

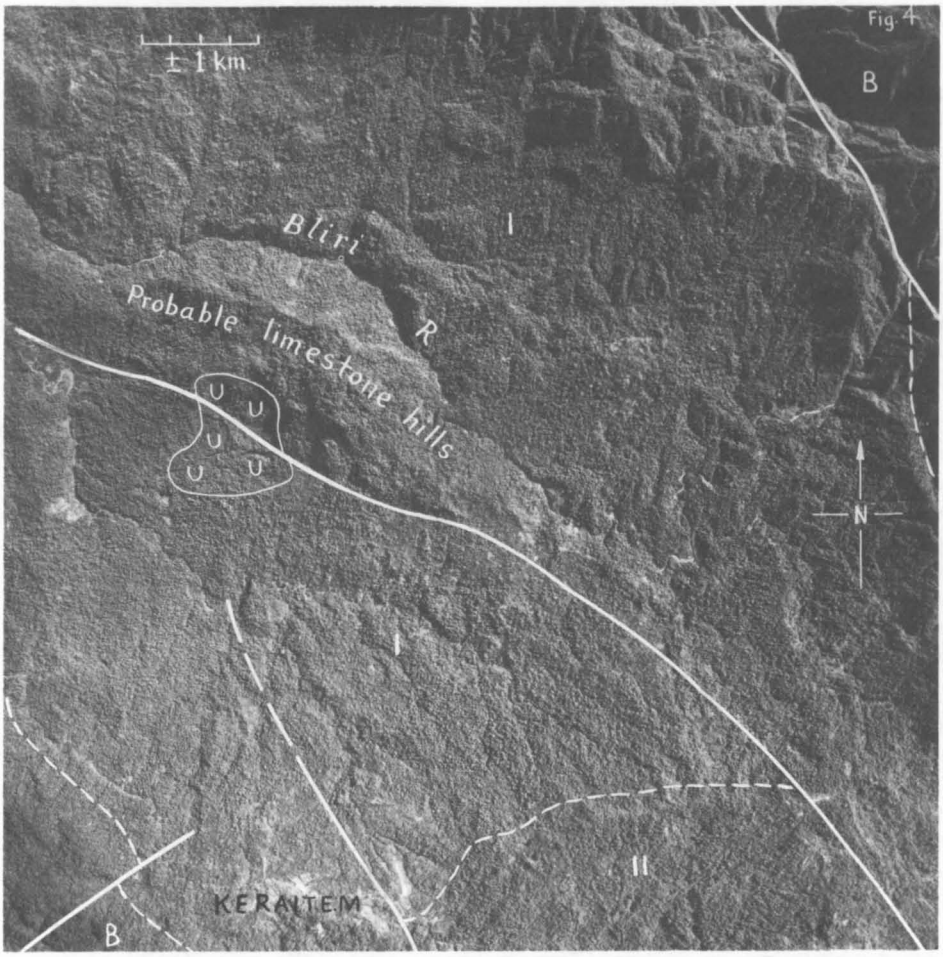

Fig. 4. Upper Bliri River valley north of Keraitem (Vertical air-photograph CAJ 194-5009. SENO Run 3; Photogeological Sheets 4147 and 4247).
This photograph is of the area north-east of Figure 2, and shows the nondescript outcrop of Unit I covering the headwaters of the Bliri River. The surface from Keraitem northwards to the middle of the picture is quite characterless and is thought to have been affected by surface slumping as the result of earthquakes. The ridges south of the Bliri River, probably with an old landslip scar on their southern side, are assumed to be made of limestone.
Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

The topography in many places is so confused and irregular that one has a wide choice for possible faulting. In some places, e.g. the Bliri basin north of Keraitem (Figure 4) and in the headwater areas of the Senu (M7) and Gedik (M-O7,8) Rivers, the topography of this unit becomes entirely nondescript. The tributary valleys are poorly defined and appear choked; the interfluves subdued. Such areas may have been badly disturbed by earthquakes.

No doubt this unit broadly represents the Auwewa and Makats Formations of Indonesian territory. Visser and Hermes describe the Auwewa Formation as being predominantly volcanic (basalt, spilite, volcanic breccias and tuff) in the lower part, with calcareous intercalations near the top, and predominantly of calcilutite in the upper part. The Makats Formation is predominantly of greywacke-type sandstone with some marl, siltstone, claystone and lenses of coralline calcarenite throughout. Mutatis mutandis these descriptions are like the more detailed ones of the Bliri River Beds given by APC geologists who however do not emphasize greywackes and do not clearly describe flysch, which seems characteristic of the Makats Formation. This is understandable because the APC geologists worked in the area before Kuenen's work on turbidites was published, the Dutch afterwards: but perhaps greywacke and flysch are less well developed eastwards from the West Irian border.

Visser and Hermes are precise about the age of the Auwewa and Makats Formations. The Auwewa Formation is from Upper Cretaceous to early Miocene (i.e. M23 to T26 or thereabouts) and the Makats is later Miocene (i.e. T27 to T33 or thereabouts), with a hiatus assumed between the two but not established clearly. In other words these two formations occupy the whole of the Tertiary Stages 'a', 'b', 'c', 'd', 'e' and nearly all Stage 'f'. But Visser and Hermes had only one identification of M23 age and few of T21-22 (Tertiary Stages 'c' and 'd') and say of the type section of the Auwewa Formation: 'Below the lowest fossil occurrences there are some 2000 m of unfossiliferous volcanics, the basal part of which may be older than T2', having already said that the fossils in the upper part of the type section give a minimum age of T23-26 (= Tertiary Stage 'e').

APC geologists referred their Upper Bliri beds to Tertiary Stage 'f', i.e. essentially equalling the Makats Formation, and apparently found it unconformable on their Lower Bliri beds, since they quote several occurrences of overlap by the Upper Bliri. Osborne says that 'Lower Bliri rocks or their equivalent are not known anywhere south of the Mountain Zone short of the central mountain range' and, as quoted above, that 'the Upper Bliri is seen to overlap the Lower Bliri to rest directly on basement'. (I should however doubt whether the first statement would be substantiated by further work along the southern slopes of the mountains where knowledge is poor, especially to the west). Their Lower Bliri beds were Tertiary Stage 'e'. They never identified rocks of Tertiary Stages 'c' and 'd' but recorded scattered occurrences of Tertiary Stages 'a' and 'b' (Eocene), usually as remnants among the basement outcrop in the mountains. This suggests widespread uplift throughout the Oligocene and they quote the occurrence of Eocene pebbles in the Bliri conglomerates as evidence for it.

It is not easy to account for a major break in Oligocene time, when considering the geological history of the area. Visser and Hermes thought that vulcanicity and sedimentation continued from late Cretaceous to mid-Miocene. The thoroughness of, and extensive knowledge shown by, their account encourage one to believe in the accuracy of their work and so I prefer to think that they are right in this respect. The discrepancy between the findings of the Dutch and APC geologists could be explained by local uplifts and by sheer bad luck. The APC geologists may simply not have found, or not sampled, outcrops of Tertiary Stages 'c' and 'd', which could be scarce in the disturbed country in which they worked. They would also have had less chance of finding suitably fossiliferous sediments if Tertiary Stages 'c' and 'd' are largely volcanic, as suggested by Visser and Hermes. The evidence of Eocene pebbles in Bliri conglomerates may not be so reliable as it sounds. Some of the conglomerates in the unit are not basal conglomerates, indicating a proper

break in sedimentation. They are typical rubble beds which would now be regarded as the product of submarine sliding, formed very rapidly and perhaps as the result of a single seismic catastrophe. The occurrence of the Eocene pebbles and the nature of the conglomerates should be critically re-examined before that evidence can be accepted without reservation, though naturally some of the conglomerates may be associated with local uplifts, even if most of the area was submerged or depressed during the Oligocene.

As has been said, Unit I appears to be in fault-contact with basement along the mountain front from the West Irian border to the Dagua-Wonginara (N28) area but in the mountains and on the southern slopes there are probably many places where a sedimentary contact occurs. On the photographs there is no indication of a break within Unit I, representing the division into Auwewa (lower Bliri) and Makats (upper Bliri) Formations. Such a break has not been firmly established by surface evidence in Indonesian territory, though it seems more probable east of the border.

It is difficult to separate Units I and II on the photos and to identify the boundary between them. An undisturbed contact may not occur on the mountain front west of the Raihu River and Unit II has not yet been found east of that river. Osborne says that 'the contact of the Barida Formation (= Unit II) with the underlying Bliri Group is always obscure, chiefly because the transition is so gradual and partly because both units are seldom exposed in one section'.

On the southern slopes of the mountains the boundary seems clearer in a few places. In the Dato (N20) area and along the northern side of the upper reaches of the Keang valley (NOP19,20) the characterless topography of Unit I is overlain by an area of good chevron dip-slopes (Figure 3). These are formed by the Molang Creek (= Songaien) Beds of Montgomery, and Edwards and Millward (1939) who say that the contact with the beds below is probably unconformable. Eastwards there is so much faulting in and around the Songaien Syncline (N21) that it is difficult to identify Unit II but in the hills north of Maprik a formation with good dip-slopes appears in about the right position to correlate with the beds in the Keang valley. It overlies, and is separated from basement by, a zone of typical Unit I topography (Figure 5). (Poor photographic coverage north-east of the Humal River adds some doubt to interpretation thereabouts). West from the Keang to Keraitem there is no convincing boundary between Units I and II; in fact, Montgomery stopped his Songaien Formation north of the Makafim (Q17) area or roughly at the valley of the Wagasu River (N-R16,17). It may be wrong to continue Unit II west of the Keang but, if so, there is either some striking facies change in that direction or a marked unconformity. However near Keraitem and west of Manam Creek for about 35 km a unit which forms recognizable ridges overlies Unit I and this may represent Unit II. Thus I continue Unit II from the Keang to the Gedik Rivers, although this does not agree with APC identifications based on palaeontology.

North of Maprik, in the Prince Alexander Mountains, Unit I apparently surrounds the basement outcrop, partly having much the same characterless topographical expression as elsewhere but partly giving rise to a finely dissected topography (Figure 5). East and west of the Mt Turu ridge a similar finely dissected topography probably represents the Unit.

Because of tectonic disturbance it is impossible not only to subdivide Unit I on the photographs but also to distinguish small outcrops of basement or other units which may occur in places. An outcrop of basement certainly occurs in the Bliri River below the junction of Norkorne Creek (L12) and others in Tambau Creek (N21) and in the upper reaches of the Amu River (NOP22-24). Moreover a great variety of rocks probably crops out in the fault zones and areas of much tectonic disturbance shown on the maps. In these, basement rocks of many types and upper and lower Bliri rocks may well crop out in a most confused manner.

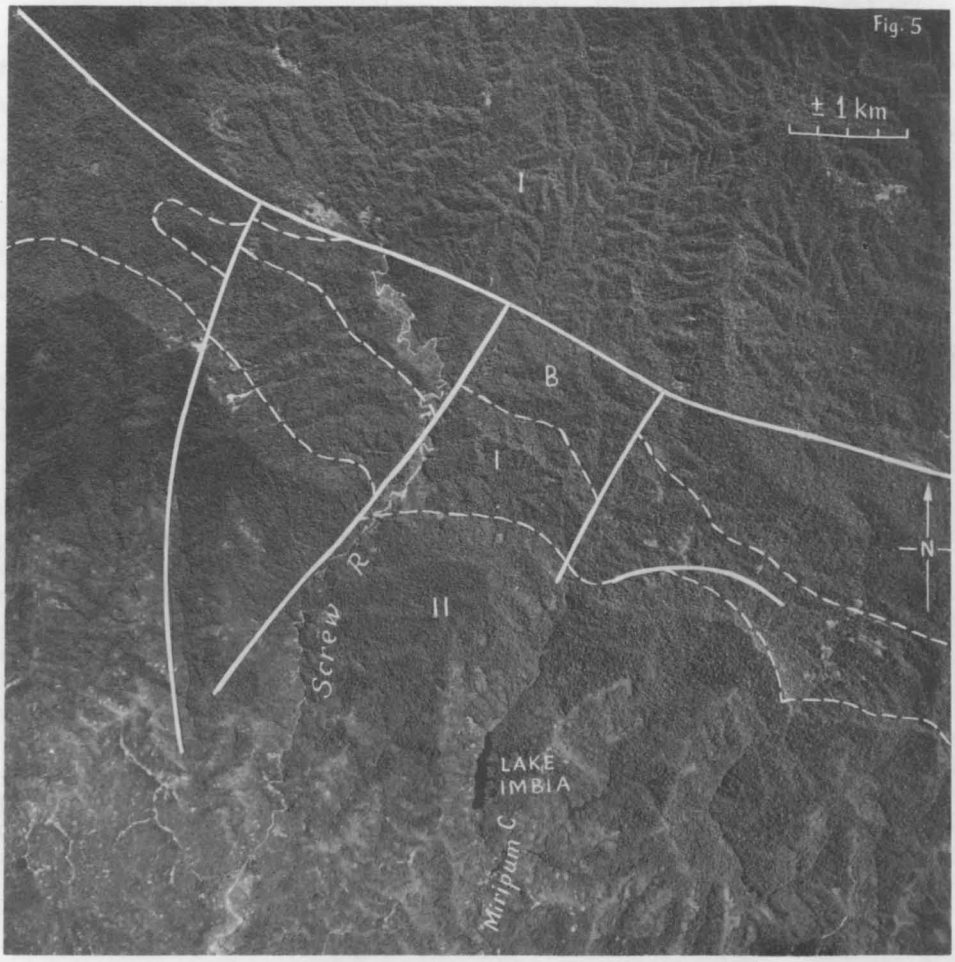

Fig. 5. Screw River valley north of Maprik (Vertical air-photograph CAJ 94-5018. MAPRIK Run 1; Photogeological Sheet 4447).

The southern part of the photograph is composed of large dip-slopes taken to represent the eastward extension of Unit II. A narrow faulted ridge of basement rocks forming a rather smooth topography crops out roughly across the middle of the photograph. Between it and Unit II is a zone of rather characterless topography attributed to Unit I. The distinction between basement and Unit I at the western end of the basement ridge is not at all clear. In the north Unit I probably crops out widely but is more closely dissected in a dendritic manner. This character also appears, presumably in equivalent strata, in the area of Mt Turu, about 30 km east of Lake Imbia.

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The thickness of Unit I cannot be estimated from the photographs. Visser and Hermes say that their Auwewa Formation is at least 4000 m thick, without the base being clearly determined, and that the Makats Formation is perhaps more than 1850 m thick. Osborne said that the Bliri River Beds were at least 4600 m thick. It may be impossible to establish the thickness conclusively because a complete and undisturbed section may nowhere be exposed but undoubtedly it must be considerable.

Unit I forms a big outcrop in the Oenake Mountains and Ijapo (EF1) Hills, and several small ones at and west of Aitape. The boundaries are hard to decide on the photographs and broadly those of the APC geologists have been used.

Finally Kairiru Island (M31) is presumably made up of Unit I. It has been described as a volcanic island (CSIRO, 1961), probably because of a statement by Glaessner (1950) that it is the westernmost volcano of the New Britian volcanic arc, and CSIRO workers (Baker, 1960) collected two samples of basalt from the southern slopes though they also sampled sediments on the western side. The Australian Aquitaine geologists told me that they found rocks of Bliri type on the island and so it is reasonable to show it as such on the maps, especially as dip-slopes seem to occur and the summit lake is certainly not a crater lake. Young (1963) interpreted the aeromagnetic lines run by the Bureau of Mineral Resources in 1961 from Kairiru Island southward under the idea, then prevalent, that the island was an extinct volcano but emphasized the shallowness of magnetic basement under the island. In fact this is very much the same condition as found in the Oenake Mountains south of Vanimo and certainly shows that magnetic basement is near the surface. This probably means that the island is the eastern end of the coastal mountain chain which consists of the Cyclops Mountains, the Oenake Mountains and Serra Hills, with remnants at Aitape and Matapau, and is also an antiform.

Incidentially it would be extraordinary if the island were either an extinct or an early Tertiary volcano. The modern volcanoes of the Bismarck Island arc occur only as far west as the Schouten Islands ($3^{o}30'S$, $144^{o}30'E$), about 100 km to the east, where they are trending north-west into the Pacific; and Kairiru has none of the typical form of the extinct or dormant volcanoes on the north coast of New Britain. Westwards there is no known centre for the extrusives which occur so plentifully in Unit I and it is hardly likely that Kairiru is the only centre which has been preserved.

Unit II

This unit is not easy to recognize on the photos. On the northern side of the mountains it corresponds to the Barida and Puwani Formations of APC geologists. Along the mountain front I have copied the distribution given on the APC maps, modifying it where the evidence for photographic lineaments demands. However, following the APC work, Unit II evidently occurs in the Barida-Nengian-Wapa'alu (JK13-16) Hills, though its distribution to the east in the Raihu and Nigia valleys is most doubtful. It is more obvious in the Ainbai (J2)-Puwani Anticline because of the distinctive karst topography; similar karst topography between the Puwani River and Kulanap Creek (J2,3) is perhaps caused by the same formation and is shown as such indefinitely on the map. I have shown the small outcrops south of Vanimo and in the Serra Hills as Unit II after the APC maps, although there is no evidence on the photos to distinguish them from Unit I or from the Pliocene.

Between the Boap (H-J5,6) and Bilia (H-J6,7) Creeks, on the plains in front of the mountains, there is a substantial hill which APC geologists showed as Quaternary. However the hill seems too high to be composed of the most recent sediments and has the rather smooth nondescript appearance of other areas which one can attribute confidently to the Barida or Bliri River Beds. Hence I show it as Unit II, though it could easily be Unit I.

On the southern side of the mountains the photogeological problems are rather worse than for Unit I which at least can be recognized as a broad division characterized by nondescript topography. Above Unit I in places there is an easily recognized division which forms good dip-slopes (Figure 3). In the northern part of the Keang valley this certainly equals Edwards and Millward's (1939) Molang Creek Beds. However, this outcrop is seen for only about 20 km on the northern side of the Keang valley, from Molang Creek (N20) north-westwards. To the west there is a topographical zone above Unit I with large dip-slopes rather poorly developed, as far as Lumi (N13) and Keraitem, narrowing because of unconformable overlap of Unit III from west of the Keraitem Hills to the Gedik River. It may be wrong to assign this zone to Unit II, especially because APC geologists did not recognize the Molang Creek Beds west of the Wagasu River, but clearly it occurs between Units I and III and from its position I assume it to be rightly correlated. There may be facies change westward from the Keang River.

It is also difficult to trace the Unit east of the Keang River. APC geologists correlated the Molang Creek Beds with the Songaien Formation and so it is reasonable to carry the outcrop into the Nanu valley (N-Q21-23) and around the Songaien Syncline. In the headwaters of the Humal River (O23), Misa Creek (O23) and the Ninab River (P24,25) the photographic coverage is poor and inferred distribution of the Unit may be astray. However in the hills north of Maprik, on either side of the Screw River and Lake Imbia (P25), a formation appears with massive dip-slopes resembling the topography of the Keang valley. This outcrop was identified on APC maps as Pliocene (above Tertiary Stage 'g') but Montgomery gives no detailed description of the section. If it is younger than Stage 'g' it is wrong to place it in Unit II, unless of course the photogeological unit represents a diachronic rock unit.

On the other hand if the outcrop is not Unit II it seems that the difficulties are increased eastward. From about longitude 143°E all aspects of the geology became more speculative than they are to the west, partly because the photographs are less help in identifying formations and detecting structural features and partly because the surface geology is less well known, so that the distinction between Miocene and Pliocene becomes decidedly doubtful. Indeed Montgomery did not attempt to differentiate Miocene from Pliocene in the Anumb-Kulaim-Hawain (M-O26-30) drainage basin, north of the Prince Alexander Mountains. What information there is from this area and from the whole area south of Wewak suggests that foraminiferal marls of Tertiary Stage 'g' crop out extensively. But the palaeontological evidence is derived only from a few samples which I collected from the Hawain River, along the Wewak road to Passam (Q32), in the Minjim River (P-S30, 31) and in creeks near Sassoia (Q30) (see Appendix 2), and some scattered samples collected by CSIRO workers (Belford, 1962). If the outcrop in the hills north of Maprik, and thence to the area north-east of Yangoru, is identified as Tertiary Stage 'h', as the APC geologists did, one has to introduce a violent unconformity for a distance of only 25 km. Moreover the topography of the hills north of Maprik resembles that of the hills east and north of the Anumb-Kamen valley, as well as that north of the Kamen River near Mendamen (O28), where rocks of Tertiary Stage 'g' (Unit II) probably crop out.

In consequence I disagree with the APC interpretation and think that the southern flank of the Prince Alexander Mountains, from the Maprik area to east of Yangoru, is formed of Stage 'g', not 'h', rocks, and that such rocks also crop out in the core of the Wulima Anticline. This certainly simplifies the geology of the area. I have shown most of the valley between the Prince Alexander Mountains and the eastern end of the Torricellis and the Dagua Hills as Unit II, though here the Pliocene (Unit III) at the eastern end of the Mabam Syncline (N24) is stopped quite arbitrarily and Pliocene may occur much farther south-eastwards in the faulted synclinal area running towards Mt Turu.

Unit II is broadly Tertiary Stage 'g'. In the appropriate localities it certainly represents the outcrops of the Puwani Formation, Barida Beds and Molang Creek Beds, all of which

were correlated by APC geologists on the basis of palaeontology. They correlated the Barida Beds with Zwierzycki's (1921, 1927) Globigerina Marls which Visser and Hermes in turn correlated with their Memberamo B division. In its type locality the Memberamo B is more than 900 m thick and consists of blue-grey to yellow marl with subordinate silt and sandy siltstone and local intercalations of light-coloured well-bedded marly limestone with abundant pelagic foraminifera. The Barida Beds in Tomoflu Creek (K12,13) on the Barida structure are said to be about 100 m thick, (though, having briefly seen part of the exposure, I doubt the reliability of any measurements there) and to consist 'largely of hard white globigerina marls... brown sandy tuffaceous limestones or calcareous, tuffaceous sandstones, some volcanic agglomerate and at least one 10 to 20-foot lava flow'. The section in the Fieni Creek (J9) consists of marl and mudstone with harder calcareous bands and at the top sandstone with hard calcareous bands; it passes gradually down into Bliri rocks, the whole being about 1250 m thick. The Puwani Formation in the river of that name is only partly exposed and consists almost wholly of hard massive algal, coralline limestone. The description of the Barida Beds at Barida (J13) by APC geologists is not similar to that of the Memberamo B by Visser and Hermes; it is most remarkable that the section has a lava flow which seems to be the only occurrence of vulcanism known above the base of Tertiary Stage 'g' in this part of New Guinea. In short the outcrop on the Barida ridge may not be a proper formation because the structure is so disturbed tectonically that it would be difficult to be sure of a reasonably complete and undisturbed section anywhere. The whole core of the structure could be a mélange of pre-Stage 'h' rocks including some of the Bliri volcanics. Moreover in most places over the crest of the Barida Hills it is difficult to get a clear view of the outcropping rocks because of a thick travertine deposit.

On the southern side of the mountains the Molang Creek section is approximately 200 m thick, consisting of massive hard argillaceous sandstone, hard silty, pebbly mudstone, coarse ferruginous sand, and conglomerate. This resembles Visser and Hermes' description of Memberamo B except that there is no limestone.

This identification of Unit II is unsatisfactory, chiefly because on the south side of the mountains it differs from the interpretation of APC geologists who knew most about the geology. On the other hand without more research I can find no clear descriptions in their reports of critical areas in the Lumi, Keraitem, and Maprik districts. Full descriptions may not in fact be available in the Bureau and the accounts in compilation reports which I have studied seem incomplete and incoherent. The photogeological interpretation at least has the merit of greatly simplifying the geology.

Unit II probably crops out in the core of the Yukilo Anticline (Q12) forming its usual nondescript topography (Figure 6) but this needs confirming by surface work. The outcrop in Wagir (PQ14) and Klegelu (P14) Creeks is taken from APC maps but it is caused by faulting because there is no anticline here.

Units III, IV and V

There are three important developments of these units which are best discussed separately, as follows:

(1) The Bewani Mountain Front - sections along the Bewani and Pulan Rivers.

(2) The Neni Creek (KL12,13) area - southern flank of the Barida structure.

(3) The southern slopes of the Bewani-Torricelli Mountains - from Gedik River in the west to Korp River (O-R21) in the east.

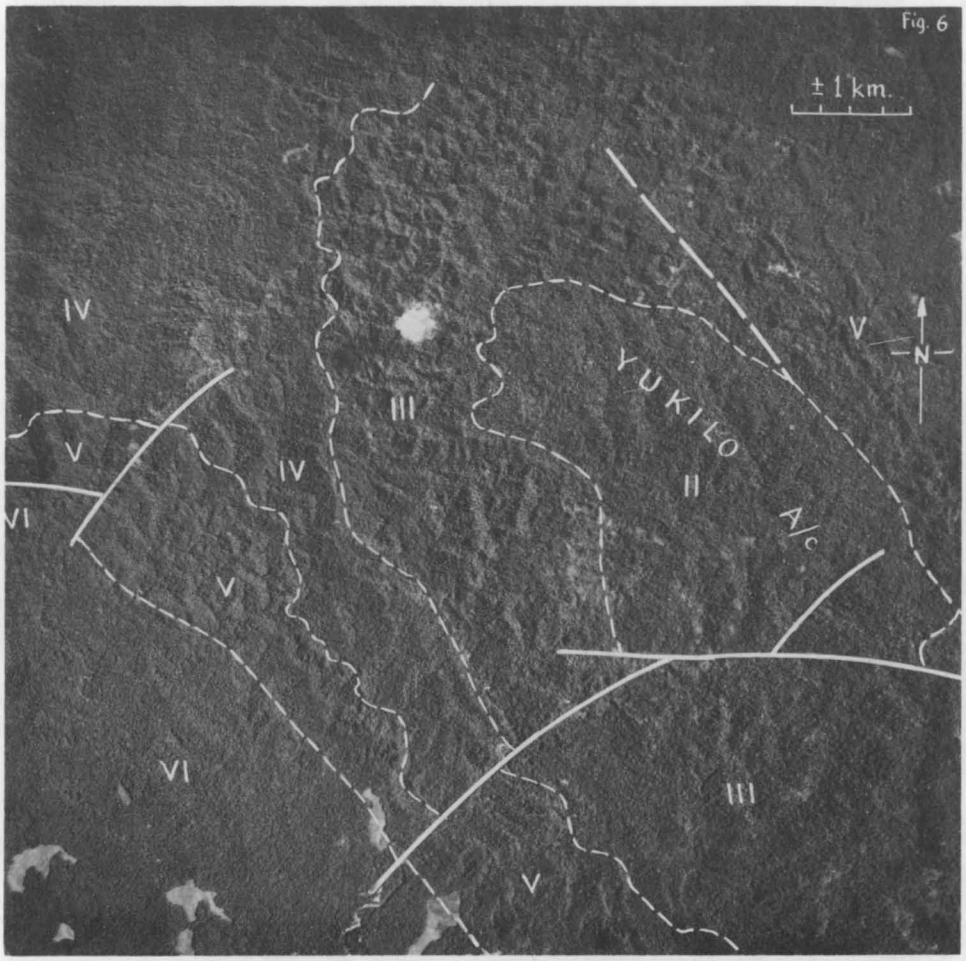

Fig. 6. Yukilo Anticline between Sibi River and Wamala Creek (Vertical air-photograph CAJ 202-5063. AITAPE Run 16; Photogeological Sheet 4146).
East of the centre of this photograph is a large patch of undistinguished topography in the core of the anticline. It is attributed to Unit II, but could indeed equally be formed by Unit I rocks. The very characteristic topography of Unit V with many small dip-slopes and a closely developed drainage is clearly displayed to the north-east and south-west dipping away from the anticlinal axis but probably more steeply so on the north-east where the flank is probably faulted. In spite of the faulting, Unit V is probably unconformable on older rocks in this area, because Unit IV is only satisfactorily identifiable in the western part of the photograph where its characteristic dip-slopes are reasonably well developed.
Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

Bewani Mountain Front

A strip of Pliocene outcrop about 4-5 km wide occurs between the mountains and the plain in the area of the Bewani and Pulan Rivers and runs west-north-west across the West Irian border. Osborne here recognized three divisions in descending order:

Bulimp Formation	1600 m thick =	Unit V
Krisi Formation	1050 m thick =	Unit IV
Bewani Formation ('Smoky Mudstone Group')	2250 + m thick =	Unit III

The base of the Bewani Formation was not seen. These three divisions are clear on the photographs and, as the beds are more or less vertical throughout the section, a rough estimate of total thickness is ± 4500 m which agrees reasonably with APC measurements.

Neni Creek Area

On the southern flank of the Barida structure, north-east of Neni Creek and west of the Pieni River (J-L13), there is an undisturbed and nearly complete Pliocene section. Osborne, compiling work in the area before World War II, divided this section downwards as follows:

Bulimp Formation	350 + m	
Romi Formation	500 m	= 2500+ m
Neni ('Group') Formation	1650 m	

Edwards (1949), who resurveyed the area in 1958, divided the section as follows:

Above Marker	1340 m	
Blue-black Marker Formation	360 m	= 2300 m
Below Marker	600 m	

His thicknesses were made up from different exposures. He states that the lower 1700 m of this section is the Neni Formation and recognized 425 m of typical Romi Formation above this but it is not clear whether he thought that any Bulimp Formation was present.

The photographs also show three divisions (Figures 7 and 8):

Upper =	nondescript topography, but with some poor dip-slopes	= Unit V
Middle =	good formation of chevron dip-slopes	= Unit IV
Lower =	nondescript characterless topography	= Unit III

Unit IV is a good marker between the Bliri and Nengo (J-M14) Rivers; it is also clearly seen on either side of the Yalingi River (J-M14,15), the outcrop ending about 7 km to the east, though there is probably an ill-defined outcrop caused by folding north of Marakabi Creek (LM15,16). West of the Bliri River it can be traced reasonably to the Piore River (JK9-11) and less certainly as far as Muru (I6) and the Boap Creek area.

These units certainly do not correspond to those of Edwards. His Blue-black Marker Formation, with the validity of which I was not impressed from my superficial inspection of the section in Tomoflu Creek, must occur within, and perhaps in the lower part of, Unit IV. The Units are also different from those of Osborne; except that his Neni Formation probably corresponds to Units III and IV.

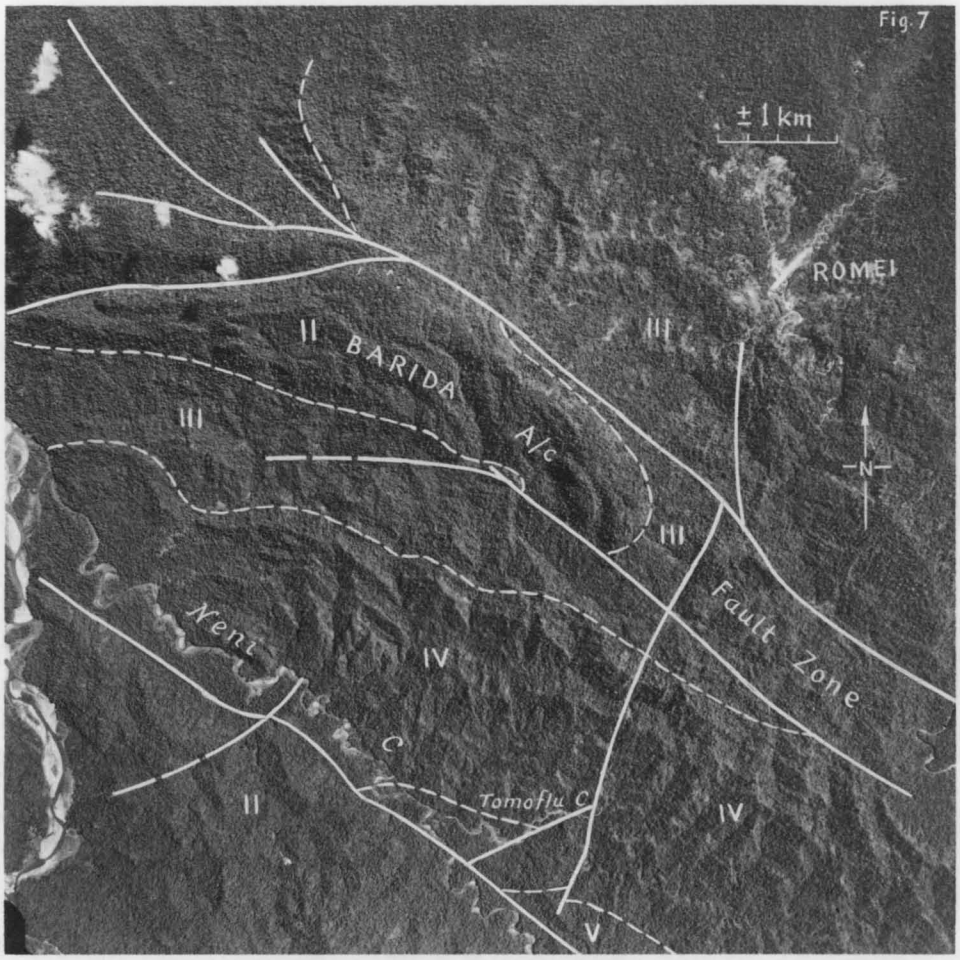

Fig. 7. Barida Anticline south-west of Romei (Vertical air-photograph CAJ 191-5053. AITAPE Run 3; Photogeological Sheets 4148 and 4248).
The core of the anticline is formed of Unit II rocks, probably roughly vertical, and stands out prominently in the centre-west of the photograph. A narrow zone of rather featureless topography partly surrounds this core and on the southern side clearly separates it from the well-displayed chevron dip-slopes of Unit IV which continue as far as Neni Creek.
Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

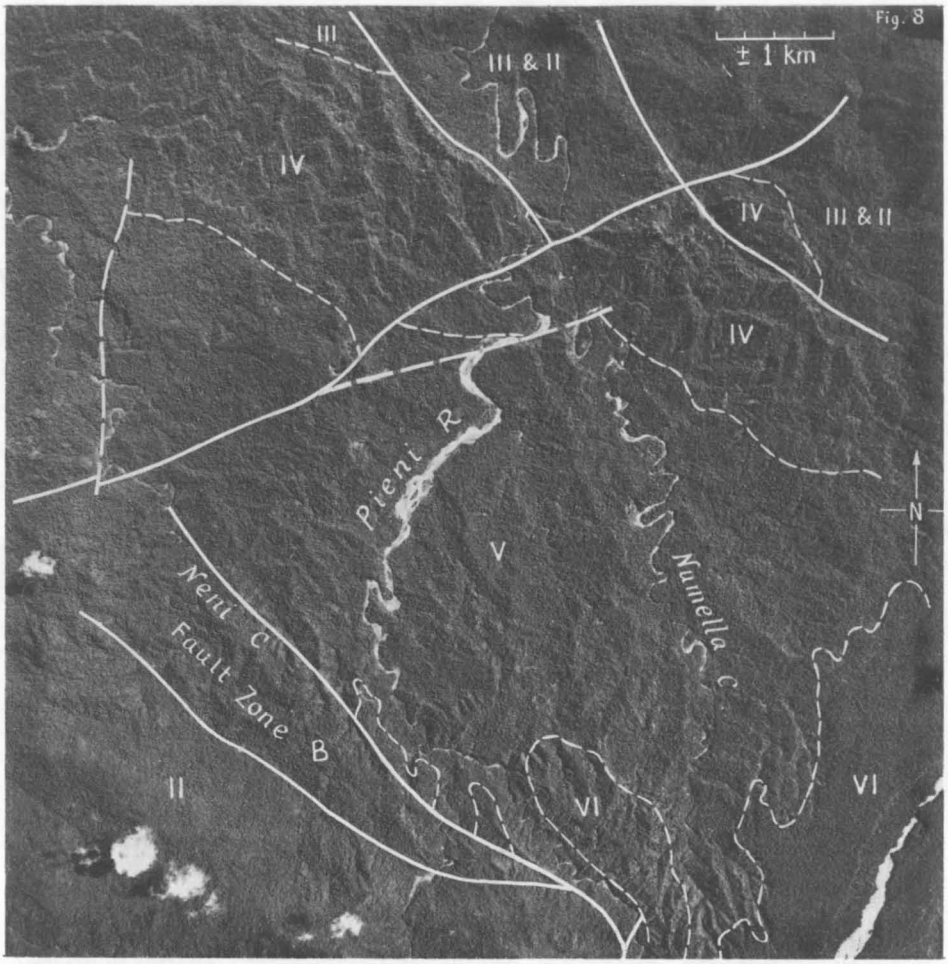

Fig. 8. Pieni River area south of Romei (Vertical air-photograph CAJ 191-5064. SENO Run 1; Photogeological Sheet 4248).

This photograph continues south-south-east from Figure 7 and displays even better the chevron dip-slopes of Unit IV dipping south-west under the much more subdued topography of Unit V. This ends along the line of the Neni Creek, beyond which the area is much confused by faulting. Certainly basement crops out here according to the APC surface evidence but mostly the outcrop consists of Unit II (or Unit I) rocks. The Barida-Nengian Anticline along the north of the photograph is much broken by faulting. In the south-eastern corner the flat terraces of Unit VI are very clear.

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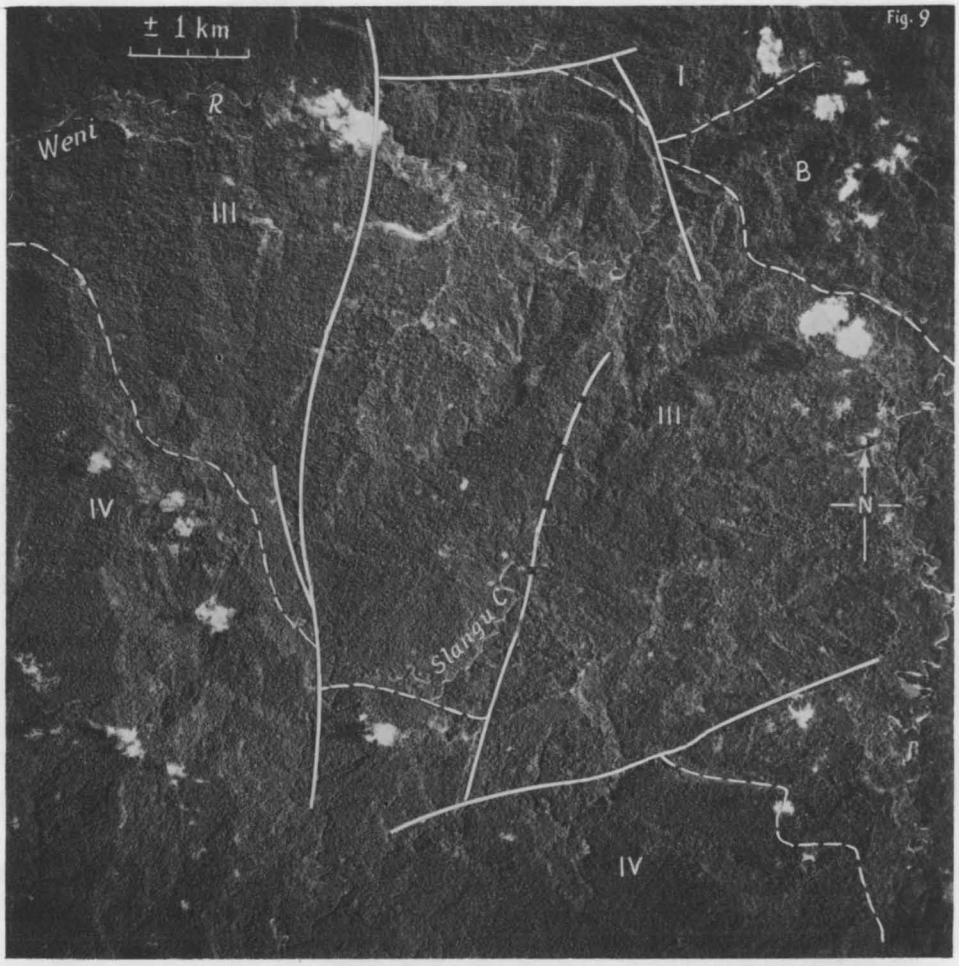

Fig. 9. Kalingum - Twaitei area west-south-west of Lumi (Vertical air-photograph CAJ 202-5068. AITAPE Run 16; Photogeological Sheet 4147).
This photograph overlaps the southern side of Figure 2. The prominent dip-slopes of Unit III, here seen at the edge of the picture, north of the Weni River, are the same as those on the southern edge of Figure 2. The rest of the outcrop of Unit III has rather little character and is overshadowed by the prominent scarp at the base of Unit IV (Nopan River Beds). The massive dip-slopes of this formation are well seen in the south-western third of this photograph.
Air-photograph reproduced by permission of the Director, Division of National Mapping, Department of National Development, Canberra, A.C.T.

A rough estimate of the total thickness of this section is more than 3000 m, perhaps as high as 3700 m. The difference between this and APC figures does not seem important because it is impossible to be certain of measuring a full undisturbed section in this area. Faulting probably occurs in many places at top and bottom, while elsewhere reversed faulting could repeat part of the section.

Southern Slopes

The general Pliocene stratigraphy is perfectly plain on the photographs south-west of Lumi and this area is regarded as representative of the Pliocene between Nuku (Q18) and the Gedik River.

Three photogeological units are again easily identified (Figures 6 and 9):

Unit V Upper: Excellent development of small dip-slopes, giving rise to a very characteristic honey-comb type of land surface.

Unit IV Middle: Excellent development of huge dip-slopes, especially in the lower part but becoming more subdued upward.

Unit III Lower: Somewhat undistinguished topography, but with fair to poor dip-slopes not very uniformly developed.

East of Lumi Unit III appears to be conformable on the beds below but west of Lumi an unconformity develops at this horizon because Unit III comes in contact with basement, apparently without faulting. Similarly between Units III and IV an unconformity probably develops south or south-west of Lumi. Unit IV finally overlaps on to Unit II in the upper reaches of the Weni River (NOP12,13) though the area of overlap is complicated by faulting. Unit V cannot be identified east of the Nopan River (N-S15,16) but to the west appears to be conformable on Unit IV everywhere. Because the outcrop of Unit IV wedges out between the Sand and Gedik Rivers, and Unit V comes very close to, but perhaps never quite lies on, Unit II, another overlap seems probable though again at the Gedik River there is severe faulting. An unconformity below Unit V occurs in the eastern half of the Yukilo Anticline (Q12) although cloud and incomplete photographic coverage hinders interpretation hereabouts.

Comparing this with Montgomery's compilation it is certain that Unit III equals his pre-'Barrier' Formation (pre-Nopan River Beds), i.e. it equals the Nanu, Ipe and Misa Formations in downwards order in the Wam region (approximately $3^{o}35$'S, $142^{o}00$'E). Unit IV equals the Nopan River Beds, the cliff at its base being an excellent marker on the photographs. Unit V is probably a hitherto unrecognized division because Montgomery's description suggests that the 'Sand River Beds', overlying his 'Barrier Beds', are young unconsolidated and flat-lying with strong unconformity on the rocks below, e.g. in Bis Creek near Maurom (Q11). The extent of 'Sand River Beds' on his map however corresponds exactly to that of my photogeological Unit V. The 'Sand River Beds' are much more likely to be the overlying Pleistocene deposits (Photogeological Unit VI) which occur between the Sand and Nopan Rivers. Moreover Photogeological Unit V probably forms only a small outcrop in the Sand River itself because of faulting and overlap by the overlying beds, so that one would not expect that it could represent a formation named after the river.

East of Nuku (Q18) the geology suddenly changes; the prominent marker at the base of the Nopan River Beds vanishes and the topography of the country between Nuku and the valley of the Kamul River (P19) is quite undistinguished.

The easiest interpretation is that a facies change occurs which quickly wipes out the slope-forming sandstones of the Nopan River Beds. However there are massive dip-slopes to the north on either side of the Kamul River from Mesu and Mai (O18) as far east as the Korp River (P21). Although these look as though they are the continuation of slope-forming

beds at the base of Unit III in the area between Yageb (P17) and Aminge (OP18) Creeks, they could also be Nopan River Beds. In the former case there would be a sudden large and local thickening of Unit III-IV near the confluence of the Keang and Kamul Rivers or a new unit not distinguishable from Unit IV would have to be placed between the two. This intercalated unit could not be continued eastwards because the northern flank of the Bongos Anticline (Q20) brings back Unit IV with its obvious dip-slopes. Thus it is so difficult to accept a facies change that I think these massive slopes and escarpments are the continuation of the scarps and slopes of Nopan River Beds (Unit IV) displaced 10-15 km north partly by folding, partly by faulting.

On the other hand there is no convincing lineament here to represent a major fault and only very feeble suggestions of an antiform between Nuku and the Kamul River; also there is no evidence to show that the slopes east of Aminge Creek are of a different formation from those on the west. Yet faulting could occur in the deep gashes which appear in the valleys near Mesu and Wasisi (O17), and in the upper part of Aminge Creek itself. This interpretation is possible and simplifies the whole geology by avoiding the greater difficulty of sudden local increase in thickness of Units III and IV or of an intercalation between the two.

Montgomery in his descriptions avoids this issue and on his map leaves the matter in doubt. The Nopan River Beds are not continued east of Nuku, although a colour distinction, without an inscribed boundary, is shown running generally north-east from Nuku to the Miocene outcrop between the Keang and Korp Rivers. His pre-Nopan River Formation continues to the Yakib (O20) area, virtually on the Keang River, and this brings us to the identity of Edwards and Millward's (1939) Keang River Beds.

The outcrop of these agrees precisely with the outcrop of photogeological Unit III in the Keang River. In the Lumi area the outcrop of Unit III also agrees precisely with that of Montgomery's 'pre-Barrier' section, i.e. Nanu, Ipe and Misa Formations. Therefore the Keang River Beds should equal these three divisions but APC geologists correlated the Keang River Beds with the Misa Formation and recognized above them in the Keang River some thin fossiliferous sands, an attenuated Ipe remnant and a full Nanu Formation. These last three members fall within what I regard as possible Unit IV (Nopan River Beds) on the Keang River.

The photographic evidence does not support the APC correlation. For that, it is necessary to have the eastward facies change in Unit IV (rejected above) and a similar change westwards in Unit III from the Wasisi area. There the excellent slopes at the base of Unit III near Aminge Creek, and almost in contact with Unit II, are lost, reappearing perhaps west of Lumi and Manam Creek (MN12,13) just before Unit III is overlapped. These dip-slopes must be basal Tertiary Stage 'h' west of Aminge Creek. If those east of the creek are the same, it is necessary to introduce suddenly in its full development the whole Misa Formation or Keang River Beds between Units II and III.

I think that the difficulties of this interpretation, which can only be explained by a complicated geological history, are too great to be accepted without a critical re-examination of the surface geology, especially when, by making one simple and plausible assumption of faulting and by doubting the accuracy of only one part of the APC correlation (i.e. the identification of the post-Keang River Beds in the Keang River), an interpretation based on the photographic evidence simplifies all the geology enormously.

Montgomery did not have any measured sections for the pre-Nopan River formations in the Lumi area but estimated a thickness of more than 1700 m which compares with an estimate of 1600 m from the photographs. The Keang River Beds were measured as 1200 m thick. Probably there is no serious difficulty regarding thickness in my interpretation.

Units III and IV are not easily separated between the Korp and Nanu (N-Q21,23) Rivers. East of the Nanu River their separate identity is lost and the Pliocene outcrop is undifferentiated on the maps.

In the lower valley of Sarong Creek (Q22) and in the neighbourhood of Uegua (R22) Unit V possibly crops out, being brought back round the nose of the Bongos Anticline. The topography here is like that of the recognizable outcrop of Unit V in the west but this should be checked on the surface.

Regional Correlation of the Pliocene

For the Bewani district Osborne, and for Indonesian territory Visser and Hermes, make the following correlations:

Osborne		Zwierzycki		Visser and Hermes
Bulimp Formation	=	Lignite member	=	Memberamo E
Krisi Formation	=	Macrofossil member	=	Memberamo D
Bewani Formation	=	Sandstone member	=	Memberamo C

Memberamo C is described as dominantly greywacke and sub-greywacke, whereas the Bewani Formation is dominantly argillaceous. The Krisi Formation is of massive sandstone, whereas Memberamo D is described as being of dark grey claystone and sandy siltstone. The Bulimp Formation however agrees with Memberamo E in being essentially arenaceous with lignite beds. Perhaps the correlation of the Krisi Formation is too high and should really be with Memberamo C or there may be change of facies between the type section of the Memberamo and the Bewani area but generally it is clear that these Pliocene rocks represent the closing phases of sedimentation in the geosyncline and finish with terrestrial deposits.

Osborne tentatively correlated the Krisi Formation of the Bewani district with the Romi Formation of the Neni area. That may be right, but certainly Unit IV does not correspond in the two areas. In the Bewani it equals the Krisi Formation strictly; in the Neni it may equal the upper part of the Neni Formation. It is best to regard my divisions as a convenience imposed by the photographic evidence.

Osborne also correlated the Krisi Formation with a sandstone formation in the Unumbu Creek (K4,5) area south of the divide. Although there is no photographic coverage for 20 km eastwards between the Denubu River (KL5), of which the Unumbu is a tributary, and the valley of the Senu River (M7), the APC photogeological maps across this gap show the sandstone of the Unumbu to be almost certainly Unit IV which can be traced thence to Nuku. This correlation of the Nopan River Beds with the Krisi Formation, if confirmed, may supply a link between the Pliocene succession north and south of the mountain divide.

Pliocene in the Coastal Ranges

In the Vanimo area and in the Serra Hills there are large outcrops of limestone. The karst topography makes these perfectly obvious on the photos but the boundary of the limestone is often difficult to decide. The surface knowledge of both areas is poor but the APC geologists seemed satisfied that in the Oenake Mountains, Ijapo and Kohari Hills the limestone or its argillaceous equivalent was strongly unconformable on Bliri rocks and that in the Serra Hills the limestone grades laterally into argillaceous rocks, which they considered to belong to the Romi Formation. Photogeological evidence supports this. In places in the Oenake Mountains the limestone appears to be in unfaulted contact with Unit I rocks. In the Serra Hills there must be facies change between the coastal hills

and Mori 2 village (H10), because otherwise it is not possible to explain the change from a non-karst topography near the village itself to typical limestone country in the hills.

These limestones are no doubt uppermost Pliocene and the lateral equivalent of the upper part of Unit V. According to APC geologists the upper Pliocene marl facies of Unit V occurs as a large outcrop between the Serra Hills and the mountains and between the Neumayer (Pual) (FG3-6) and Piore Rivers. Almost certainly the limestones are the same as those which Visser and Hermes named the Hollandia Formation, and recognized as the lateral equivalent of the Memberamo Formation, in age from T34 to T43, representing shoal developments in positive areas during that period. As it seems that the limestones of the Oenake Mountains and Serra Hills have not yet been named, they should probably now be called the Hollandia Formation.

Superficial Deposits

I have paid little attention to the low coastal areas in the Neumayer (Pual) valley, between the Serra Hills and the Dandrawad River (L22), east of Matapau and near Wewak, nor to the Sepik plain. Presumably all these are covered by recent alluvium.

On the south of the mountains a formation occurs above Unit V between the Sand and Nopan Rivers. This is probably what APC geologists called the 'Sand River Beds'. No doubt it is Pleistocene in age and for convenience it (Photogeological Unit VI) is shown on the maps with the same pattern as the Neumayer Beds north of the mountains, though the two may not be exactly equivalent in age.

The Neumayer Beds (Unit VI) are restricted to areas in front of the mountains where they form flat terraced country (Figure 8) and appear to have been washed out of the mountains as gravel spreads. They could represent the redistribution of the products of destruction by earthquakes because accounts of the 1935 Wewak earthquake show that it produced immense amounts of debris which choked the mountain gorges; yet most of this has already been removed from these gorges. The terraces of the Neumayer Beds cannot be very recent because they are quite deeply dissected by the tributaries of the large rivers. Moreover I am told by Ruxton and Haantjens that there are features of the soil surface and vegetation which show that they are quite old.

There are other patches of similar terrace-like formation within the mountains, as in the Bliri River and Lip Creek (LM10) valleys. These are not thought to be Neumayer Beds because they are presumably higher and are so isolated; probably they are the superficial products of recent earthquakes.

Finally I regard as sub-Recent the raised limestone at Vanimo and Wewak, and along the foothills from Wewak to Terebu, as well as the big spreads which occur over the hills in the Passam - Paliama (Q32) district.

STRUCTURE *

The tectonics of northern New Guinea have been discussed in general terms by Glaessner (1950), Weeks (1959), Thompson and Fisher (1965) and others, usually as a

* Footnote: On the maps two symbols will be noted for less certain faults (a dashed line and a dashed line with question marks). This is a simple mistake which was only realized after the drafting had advanced beyond the point of easy correction. In a study of this nature it is only sensible to distinguish between those faults which are reasonably certain because of good lineaments and displacements of boundaries (solid lines on maps) and those which are less certain by virtue of poor lineaments, bad photography or other such reasons (broken lines with or without question marks on maps).

part of the tectonics of the Circum-Pacific belt; and in more detail by Carey (1958) and by Visser and Hermes. Before turning to general aspects it is necessary to consider the structure of the area of this study, because there seems to be no published account of the whole region; and for this purpose it is best discussed in three parts:

(1) The Bewani, Torricelli and Prince Alexander Mountains;

(2) The Sepik Plains;

(3) The Coastal Ranges and Plains.

A fourth part - The Border Mountains - is dealt with separately.

Bewani, Torricelli and Prince Alexander Mountains

Throughout the area north of the Sepik, with one important exception in the Makafim-Maimai (Q17) district, the point which at once attracts attention is that the strike of the beds is always about 300° wherever a good undisturbed section is known. This strike, with negligible modification, continues west to Geelvink Bay but with a distinct twist to an east-west direction west of the Memberamo River (2°S, 138°E). The photographic dips can be readily appreciated on the maps and perfect examples of this regular strike occur in the Kamen, Humal, Keang, Neni and Lip valleys inter alia. Similarly the axes of all folds except the Makafim-Maimai structures trend roughly north of west, though becoming east-west near the West Irian border. Beyond the border for many miles the north-west trend is resumed. Where asymmetry of folding has been noted it indicates overturning to the north or north-east, e.g. the Barida-Nengian-Wapa'alu structure, the Yabanakuor Anticline (Q22) and the southern flank of the Mabam Syncline. I have seen no mention of overturning to the south. In West Irian south of the Cyclops Mountains (2°30'S, 140°30'E) faulting on the northern flanks of anticlines seems usual.

Folding is not well developed anywhere in Australian territory. Everyone who has worked in the area agrees that faulting is considerable. APC geologists showed only the important faults, many of which they aligned westerly instead of about 30° north of west. Along the northern mountain front, in the so-called Torricelli-Bewani fault system, this is easily understood. From surface work up the rivers APC geologists recognized quite clearly where such faults occurred and naturally were inclined to join their observed faults from one surveyed river to the next on either side, whereas the photographs show that in many places the faults run obliquely with a tendency for a different fault to occur at the point where each large stream debouches onto the coastal plain. Good examples of this occur in the Drelip (LM19), Akanai (LM19) and Drinumor (L20) Rivers. Thus, instead of a single fault or even fault zone along the mountain front, in most places this line is composite made up of many faults running out obliquely through the mountains and complicated by cross faults.

The photographs offer so much scope for inserting faults that any interpretation will be subjective but some trends would probably be accepted generally. The most important is that of faults running 30°-40° north of west. Such are prominent on the south-west slopes of Mt Turu, through the area of Lake Imbia (itself probably fault controlled), in the upperpart of the Screw and Atob (N24) River valleys and north-west in the Tambau (MN20,21), Gwerka (MN20) and Drinumor valleys. The whole zone seems to be formed by a plexus of sub-parallel west-north-west faults. Similar trends are in the Upper Keang valley, across the Yalingi (J-M14,15), along the lower part of the Neni and from the Bliri-Filabu Creek (L13) confluence to the Piore River.

From the photographs it is impossible, and from field evidence often difficult, to be positive about the nature of these faults, beyond the certainty that they are not low-angled thrusts. None of them shows the sinuosity which low-angled thrusting must have in rugged terrain; there are no klippen. On the contrary most of the faults are remarkably

straight and though it would be possible to make a different interpretation by which cross faults turned round sinuously into longer trends I think that this would contravene the probabilities of the photographic evidence.

It seems safe enough to regard most of the west-north-west faults as high-angled thrusts but they are crossed by others running in many directions from which two sets can be considered prominent, one north-east to east and the other north-west to north. These cross-faults must either be conjugate fractures developed under pure shear or tensional fractures in various stages of rotation developed under simple shear. Though the photo-interpretation is inevitably subjective, it is possible to detect a persistent association of apparent sinistral and dextral displacement with the north-easterly and north-westerly sets respectively, as for example in the basement contacts south-west of Mt Turu, in the Screw River drainage north of Maprik, on the flank of the Mabam Syncline and along the boundaries between Units III, IV and V from the Lumi area to the Gedik River.

The faults clearly affect the basement and the high-angled thrusts on west-north-west lines, if caused by pure shear, could increase in hade at depth, but there seems to be no evidence for supposing (Thompson and Fisher; 1965) that late Tertiary to Recent reactivation of the faults in the basic to ultrabasic basement has produced the present tectonic pattern, if that implies that such faults started moving during the Mesozoic. There is no denying however that they could have been initiated at any time between the start of development of the eugeosyncline after the end of the Cretaceous and the final uplift of the areas in late Tertiary or Recent.

The west-north-west faults are essentially strike faults and Osborne (1956), who would probably not have agreed exactly with this trend, clearly thought that they were reversed. 'The Bewani, Torricelli and Prince Alexander Mountains, arranged slightly en echelon, rise steeply in the north along a zone of high-angled thrust faults'. He did not however explain them by any particular stresses. Carey also discussed the matter in his 1938 thesis which I have not seen, but in 1958 he quoted himself sufficiently, and reproduced maps from his earlier paper, to make it quite clear that the geology on which he worked did not differ importantly from the photogeology except perhaps in the Maimai area which we must discuss later. Carey (1958) recognized thrusting and folding on west-north-west lines, just as I do, and said (he quotes his 1938 thesis): 'Every anticline bears the stamp of rotational stress either in the configuration of its axis, its relation to its neighbours, or its association of compression and cognate tension. Almost every thrust, and they are legion, tells the same story, either by its place in the pattern, by its attitude, by the trend of the slickensides on its surface, or through its displacement of the strata, or its association with a complimentary thrust trend. The mountain orogens themselves bear similar testimony, both in their internal architecture and their external trend.'

There are thus two possible causes of the tectonics in our area, one compression in a roughly north-south direction giving rise to pure shear, as was apparently thought by Osborne, and the other rotational left-lateral stress as held by Carey. By simply inspecting a strain pattern it is impossible to decide whether it has been caused by pure shear or simple shear and therefore this photogeological report cannot provide evidence in favour of one or other because except for certain folds and perhaps some faults the tectonics are merely deduced as probable or even only possible on the strength of subjective interpretation of topographical lineaments. Carey's hypothesis of left-lateral rotational stress in a Tethyan Torsion Zone has been more widely discussed than the alternative of north-south compression and I would see no reason for disagreeing with his theory except that I find it hard to believe that 'New Guinea has been sheared westward under a colossal shear system', because in some measure, as will be discussed below, the central trapezoid of New Guinea seems different tectonically from the regions on either side. In Plates 24, 25 and 26 therefore I have interpreted the tectonics as having been

formed by pure shear, not because my interpretation provides any evidence which favours this over simple shear but because of my difficulty in accepting simple shear regionally. An exposition of the pure shear hypothesis may at least stimulate further study of the whole problem and Plate 24 brings out the regional west-north-west strike of the country north of the Sepik, as well as emphasizing the one important interruption of this strike in the Maimai area.

In a narrow zone about 10-15 km wide north of Maimai, perhaps extending across the Torricellis, the regional strike and trend of fold axes is approximately north and in this respect the photogeology differs perhaps significantly from Carey's map (1958) where more folding is recognized with not such a pronounced northerly trend. This is also where APC geologists developed the idea of 'root axials', i.e. lobes of Miocene outcrop extending south from the mountainous area, broadly in antiform, supposed to represent primordial highs which became 'buried hills' but also complicated by faulting. The area is certainly complicated by faulting and generally anticlinal in the Ningil (O16) and Siri (O17) lobes but the explanation, associated as it was with speculation about the performance of the basement from as far away as the Yagroner Hills (P5), seems to be unnecessarily difficult. This twist of strike, as interpreted from the photographs, seems to be a significant departure from the normal direction of compression which would have been caused by east-west rotational stress. Moreover it would have to be explained by a small shear couple but unfortunately this would be dextral causing a 'Z' bend, not sinistral causing an 'S' bend. Under pure shear, as shown on Plate 24, it could have been caused by one coherent block west of the Yelbu River (OP13,14) moving northwards relative to another coherent block east of Bongos (R20). Then the Maimai area would be squeezed and fractured between the two coherent blocks and simple shear could easily have occurred in this zone which seems so anomalous in the general pattern of west-north-west strike, or else the compressional stresses would have been swung round to a more easterly direction with resulting change in direction of the folds, thrusts and conjugate fractures.

Montgomery recognized twenty-nine anticlines in the Sepik district and Osborne recognized several more in the Vanimo-Aitape area. I do not accept most of these because I believe on the photographic evidence that they are either so faulted or so incomplete that they can hardly be called anticlines. These structures are discussed individually later under the Section 'Petroleum Prospects', but meanwhile the general arrangement of folds on the mountain slopes to the Sepik needs mentioning, because this emphasizes the importance of reversed faulting as the dominant feature of the tectonics. West of longitude 143°E, blocks dipping uniformly south-west and synclines are arranged en echelon and are not separated by recognizable anticlines. These are the Mabam Syncline, the Songaien Syncline, the possible Keang Syncline, the Hapmet Creek (O19) block, the Mt Wamil (N18) Pliocene outlier, the Siri Syncline (O17), the Wagasu and Tolgeti (N14) blocks, the Lip Creek block and finally the synclinal development of Unit IV (Nopan River Beds) between the Gedik and Denubu Rivers. Some anticlinal fragments occur in the Amu and Nanu valleys south-east of the Songaien Syncline. These are probably parts of an anticline which should have developed south-west of Songaien, but which has not been fully preserved. Elsewhere anticlines have been replaced by faulting which generally must be reversed, though in the north flank of the Mabam and Songaien Synclines there are strong faults which apparently throw down on the south. However, these can be hardly normal faults under pure shear and perhaps in that case they are reversed in the opposite sense to most of the rest of the reversed faults. They would be more easily acceptable under simple shear as compressional fractures.

Sepik Plains

Montgomery concluded that the basement rose gently from a deep north of the Sepik River and reappeared in the outcrops near the river on the south of the valley. The basement

outcrop in the Weni valley as well as the thinner section measured at Maimai than in exposures nearer the mountains induced him and other APC geologists to believe in 'buried hills' under the structures near the Sepik Plains. The diorite in the Weni River is utterly unexpected and should be re-examined critically before being accepted, because there is no photographic evidence for faulting or folding at this locality. As for the Maimai section the stratigraphy may have been wrongly identified. In spite of much painstaking work round this anticline the field geologists did not recognize faults which seem to be clear on the photographs. If the faults occur but were not suspected in the field, then the field interpretation of other geological aspects may not have been as reliable as has been assumed. However when considering this matter one is handicapped in a photogeological report because the chief evidence available is presumably that of the latest event and one is hardly likely to be able to detect the influence of buried hills, supratenuous folds and such phenomena. In any case my own belief is that in a tectonically complex region like this such concepts are premature until the details of the stratigraphy are much more clearly known.

However one of the striking features of northern New Guinea, both topographically and geologically, is the similarity of the Meervlakte in Indonesian territory with the Sepik valley. The only difference between them is that the Sepik Plains are open eastwards and not closed on all sides by hills or mountains. In both places late Tertiary sediments dip gently southwards under recent alluvium and do not reappear; basement appears in the south of both areas. The Dutch geologists had some geophysical information in the Meervlakte, and Visser and Hermes concluded that 'the gravimetric picture to the extent that it is indicative of structure, and the structural conditions in the surrounding hills suggest that the Meervlakte is a gentle and undisturbed depression, possibly down-faulted along its southern rim'; and also say that 'the southern edge of the Meervlakte is an old line of weakness, and along it the uplift of the central range commenced in T27'.

Because there is almost no geophysical evidence from the Sepik Plains and I have no personal knowledge of the geology along the Sepik River, any discussion will be speculative and subjective, but the basement could be faulted up by one fault or a series of en echelon faults on the southern side of the Sepik Plains. The following considerations support this idea:

(1) Analogy with the Meervlakte where the Dutch geologists, who perhaps had better geophysical evidence, suggest that there is faulting on the south side.

(2) Analogy with the tectonics of the Torricelli-Bewani Mountains where the mountains seem to have been lifted up along west-north-west compressional fractures. It would be more consistent tectonically to assume that a similar tectonic regime affected the southern part both of the Meervlakte and the Sepik Plains than to assume a simple rise of basement from the north.

(3) The improbability of completely disposing of the Mio-Pliocene sediments by simple thinning and overlap on the basement in a distance of 30 km between their southerly outcrops in the area of the Bongos and Yellow (lower reaches of Weni River) Rivers and the appearance of basement near Ambunti and the mouth of the Yellow River respectively. The Pliocene alone is 4000 to 5000 m thick: the upper Bliri is at least 1000 m thick, and the lower Bliri thickness is unknown. Visser and Hermes say 'there can be little doubt that the Auwewa Formation and the Makats and Memberamo Formations underlie Meervlakte...' In spite of Montgomery's doubts on the matter I can see no reason to suppose that the Miocene and Pliocene sediments of the southern slopes of the mountains do not continue to dip under the Sepik Plains in thickness and manner comparable with what is last seen in outcrop. 'Buried hills', in the sense of a buried topography which may occur in more stable areas, do not seem to fit into the tectonic pattern of a disturbed region like this.

Unfortunately the two aeromagnetic reconnaissance lines run across the area by the Bureau of Mineral Resources in 1961 (Young, 1963) were badly located from the point of view of investigating the structure under the Sepik Plains. One was flown south of Vanimo to the Border Mountains and totally missed the area of interest; the other due south from Kairiru Island crossed an area where basement rocks appear not far south of the Prince Alexander Mountains, i.e. at Chuingai (south of mapped areas), and therefore where there is no wide plain south of the mountains without exposure. However the Vanimo-Border Mountains traverse is of interest because a noticeable anomaly trends north-west roughly where the Bapi valley (L2) occurs on my maps or about latitude 3°20'S.* This coincides approximately with probable faulting which also runs north-west and is probably the line along which the tectonic province of the Bewani-Torricelli Mountains with its dominant west-north-west or east-west faults is separated from the apparently more stable area of the Border Mountains where flat-lying Hollandia Formation rests on the basement complex apparently without great disturbance. This in itself suggests that the geological history of the Border Mountains is more complex than elsewhere. Other magnetic trends on east-north-east lines in this area were preferred by Young in his original interpretation but he tells me that there is enough uncertainty in the data to allow either interpretation. It now seems that with a better understanding of the geology the north-west tendency is probably correct.

If the south side of the Sepik Plains is a zone of reversed faulting then the situation would be comparable with that on the north side of the Bewani-Torricelli Mountains, except that, being older, the fault scarp has been eroded away. The assumption is that, whereas the latest uplift of the northern ranges was in the late Tertiary or Recent, leaving a prominent north-facing scarp, the central highlands were finally lifted up at the end of the Miocene and any north-facing scarp formed on the general line of the Sepik River has since been eroded away.

Coastal Ranges and Plains

Although the photogeology is not clear in many critical places and surface information is patchy, there is no doubt that the Oenake Mountains and Serra Hills are uplifted antiforms. In both areas the trends of folds and major faults seem to be west-north-west or even west and in general there is nothing which disagrees profoundly with the tectonics elsewhere except perhaps in the Kohari Hills and Mt Bougainville. Here the folds and strike seem to trend quite differently but both areas are equivocal and more knowledge of them is needed before they can be regarded as providing serious exceptions to the regional tectonics.

There is little evidence of the geology in the coastal plains near Aitape and between the Oenake and Serra Hills and the mountains. The area of the Neumayer (Pual) River system in front of the Bewani Mountains is similar to the Meervlakte and the Sepik Plains - a smaller enclave of alluvium between the southerly dip off the Oenake-Serra highs and the faulted front of the mountains. Across the divide between the Sereri (G-J6-9) and Fivuma (I9-12) Rivers the Pliocene is flat-lying with few faults. If the Imbio (HI6) hill between Boap and Bilia Creeks is composed of Unit II more severe faulting must occur in places. Ruxton tells me that on the evidence of soils, elevations and vegetation CSIRO workers have identified a patch-work of faulted blocks in the alluvial plains south of Aitape and that the faults moved recently, presumably in the 1935 Wewak earthquake. By analogy with what is known in the Memberamo area the sediments dip south rather gently and uniformly from the coastal highs where shallow basement occurs, but they are probably faulted, perhaps more intensely than in their observed outcrop. They also presumably thicken southwards because the Pliocene must be much thinner on

* Young's map shows this anomaly along a river named Sukara (M4), but evidently there is some confusion over names because by measurement the position of this river on his map coincides with the Bapi River of DNM, which I have followed.

the Serra and Oenake uplifts than at the foot of the Bewani Mountains or in the Neni area and because the reef developments of the Hollandia Formation indicate shoal areas to the north. This in fact is almost exactly the situation which the NNGPM geologists proved in the Memberamo delta by seismic and gravity work, and by drilling. In the Tolateri, Kerkberg and Gesa areas (approximately 2°30'S, 137°E - 139°E) Visser and Hermes say that: 'The T43 uplift was considerable:... evidence... indicating a difference in altitude (between occurrences of the Auwewa Limestones) of the order of 8 to 9 km over a distance of 60 km'. At the Bewani mountain-front the uplift is perhaps even more dramatic since the altitudinal difference could be about 6 km over a distance of 12 km or less.

The BMR aeromagnetic traverse south of Vanimo confirms this, showing clearly that magnetic basement is near the surface in the Oenake Mountains and deepens steadily to the Bewani mountain-front where there is an abrupt change. Young (1963) interpreted this 'as a sudden uplift of the magnetic basement by at least 10,000 ft' which agrees reasonably with the geological deduction.

BORDER MOUNTAINS

The geology of the Border (4047), Green (4046) and Yellow (4146) 1:100,000 sheet areas in the south-western corner of the region has not yet been discussed because there is so little information in the area.

There are no photographs and no accurate maps between longitudes 141°15'E and 141°40'E approximately and latitudes 3°15'S and 4°00'S. This is not important geologically because nearly all this area is swamp or alluvial ground without outcrop. However it is a pity that the foothills of the Bewani Mountains and the Yagroner Hills lie respectively in the north and centre of this gap so that the geology cannot be properly completed in those localities.

Photographs cover a strip along the West Irian border about 25 km wide southward from the Bewani Mountains and the Division of National Mapping has published maps of this strip which are used as a base for the enclosed Border and Green sheets. Unfortunately there are some gaps and patches of cloud in this photographic coverage, so that even here the topography is not complete and photo-interpretation is hampered. The only knowledge of the surface geology is provided by a traverse which APC geologists made before the war between the Green River (S1) and Yagroner Hills (Stanley, 1938).

Under these circumstances the interpretation of the geology is doubtful, especially because the topography of most of the mountainous strip along the border has little character. In the Border Mountains between latitudes 3°30'S and 3°50'S there is evidence on the photographs and just enough information from the APC traverse to be certain that limestones, mostly flat-lying, cap the hills which are formed of diorite, serpentine and metamorphics, though the distribution of the different rock types cannot be shown precisely in all places.

Between the Bewani and Border Mountains the topography is largely without character and there is no knowledge of the geology on the surface. Convincing structural lineaments are not seen on the photos and there is little evidence that more than one geological unit crops out except in the Imonda Hills (M12). These hills rise sharply from generally nondescript topography and are sufficiently rugged to suggest that they may be crystalline basement. On the other hand this topography bears a faint resemblance to that of Pliocene outcrops east of the Gedik River, though convincing cuesta topography does not occur. Because there is no clear evidence of the structure it is difficult to believe that these hills are an outlier of Pliocene and I assume that they represent the basement but this should be checked in the field.

There is no change in topographical expression from the lower slopes of the Bewani Mountains in the Bapi and Sukara valleys to Mt Sattel (O3) in the Border Mountains except for the Imonda Hills. Presumably most of the area is underlain by rocks of Unit I, i.e. Bliri River Beds or Makats-Auwewa Formations.

The identity of the limestone in the Border Mountains and Yagroner Hills (the latter of course can only be shown indefinitely on the maps) is not certain. Stanley (1938) says: 'Over almost the entire area which was examined the rocks consist either of very highly folded metamorphics or else of plutonic igneous masses. Upon these rest Eocene limestones (Tertiary Stage a-b) or where these are lacking, basal conglomerates and limestones of the Miocene (Aitape Series Tertiary Stage f)... and the presence of Nummulites, Assilina, and Lacazina in these (i.e. the limestones in the Yagroner Mountains) left no doubt as to their age. The reconnaissance flights to the westward showed that similar limestones were present in the Border Mountains'.

From this it seems certain that the limestone in the Yagroner Hills is Eocene (T1) in age, i.e. belonging to the Bliri River Beds or Auwewa Formation, but the limestone in the Border Mountains may not be the same. The Dutch geologists found a good basal limestone section of the Hollandia Formation in Paoeli (Pau) Creek near Oem (L1) and other exposures south of there, in localities only about 25 km from the karst limestones on top of the Border Mountains in Australian territory. They were confident that these basal Hollandia limestones were T34 in age. The exaggerated karst topography of the Border Mountains is duplicated only in the limestone areas of the Kohari, Iapo, Oenake and Serra Hills where the Hollandia Formation crops out; it is nowhere associated with known outcrops of Unit I, even in the Puwani-Ainbai (J2) structure. Thus the limestone of the Border Mountains probably also belongs to the Hollandia Formation, but this has to be confirmed on the surface. It is unfortunate that the Yagroner Hills have not yet been photographed, so that a comparison of the topography there could be made with that of the Border Mountains.

There is hardly any evidence of structure in this area on the photographs. The Border Mountains are capped by horizontal limestone in many places, but are probably faulted on the northern and south-western flanks, perhaps dominantly on a north-western trend. The Imonda Hills could be folded, and, if this was an anticline, it would bring the basement to the surface, as is supposed. It seems less likely that such folding could be synclinal so that younger Pliocene sediments occur as an outlier.

The grass-land between Iburu (T2) and Abaru (S3), east of the Green River, is distinctly boat-shaped and appears to be formed on low hills rising from swamp on all sides. It is almost certainly the surface expression of an east-west anticline.

GEOLOGICAL HISTORY

This section cannot contribute much to the report because without a better knowledge of the stratigraphy and a closer study of that aspect than I have attempted little can be said about events in earlier Tertiary time. Moreover on the photographs one is only looking at the latest pattern of strain without much chance of separating out early tectonic events from later. However a short account of the broad geological history may be a useful summary of what seems certain.

The Mesozoic and earlier history of the area is unknown but at the start of the Tertiary, or possibly in the late Cretaceous, a eugeosyncline came into being. Presumably it occupied almost the whole area from the present Sepik River to the coast. At first this was the scene of great volcanic activity (which probably waned about the start of the Miocene) with interruptions for shoal limestone deposition and perhaps other sediments at different times and places. As vulcanism waned clastic sedimentation increased with shoal limestones again being formed locally. These extrusives and sediments are all represented by Unit I and

reasons for disregarding the possibility of a major break in the Oligocene (Tertiary Stages 'c' and 'd') have been discussed above. There may however have been local intermittent interruptions in the accumulation of volcanics and sediments before and after Tertiary Stage 'f' or about T27 and T34 times.

Without an exhaustive inquiry it seems that the field evidence provided by APC geologists for a widespread hiatus before the start of Tertiary Stage 'f' is not entirely conclusive partly because the stratigraphy of this part of the sequence has not yet been fully established and partly because it is doubtful whether the contacts described are always sedimentary and unconformable. Visser and Hermes only claimed a hiatus at this level tentatively and were almost equally tentative about a break at the top of the Makats Formation (T33-34 time), except that in places the Memberamo Formation was unconformable on the Auwewa Formation. It is only to be expected that in the eugeosyncline complicated local movement occurred from its start but any emergence was probably not pronounced before the start of Tertiary Stage 'f' (i.e. about T27 time). It could have been more general between Stages 'f' and 'g' (i.e. about T33-34 time).

In any case in the upper part of the Miocene and in the Mio-Pliocene (Tertiary Stages 'f' and 'g') there was a tendency for emergence in the central parts of the geosyncline. Approximately at the end of Tertiary Stage 'f' (T34) the central New Guinea areas probably began to rise along roughly west-north-west faults across the Sepik; at that time the geography of the region perhaps resembled present day geography on the Rai Coast ($5^{o}30'$S, 146°E to 6°S, $147^{o}30'$E), which is backed by the Finisterre Range and faces a chain of islands from Karkar, through Long and Rooke, to New Britain except that the Mio-Pliocene island arc, roughly in the position of today's Bewani-Torricelli Mountains, probably did not contain active volcanoes.

On photographic evidence the area north-west of Lumi certainly emerged during Tertiary Stage 'g' and subsided at the start of Tertiary Stage 'h', because of the clear transgression of the base of Unit III. A second phase of subsidence occurred after deposition of Unit III because of the transgression of Unit IV. But after Stage 'g' much of the region was probably below sea level and received a pile of sediments which filled the trough by late Pliocene or Pleistocene. This is indicated partly by the outliers of Unit III in Lip Creek and Mabam River, which suggest that at one time sediments of early Stage 'h' age extended across the region, and partly by the nature of the Pliocene sediments in the Bewani area (where deposition started with thick foraminiferal marls, became arenaceous in the Krisi Formation and eventually terrestrial or lacustrine with the Bulimp Formation). Presumably there would be ample material available from the rising land masses to the south. Provenance from north of the coastal mountain chain, where oceanic depths are attained at a short distance from the present shore line, seems unlikely and unnecessary. The bathymetry of the area (Krause, 1965) seems to indicate that a Melanesian land mass never existed offshore (van Bemmelen, 1939) and that the axis of Miocene and Pliocene sedimentation was not offshore (Thompson, 1965).

However the coastal range in the Vanimo-Serra area was positive in the late Miocene because of the widespread unconformity below the Pliocene in these districts and no doubt the coastal high provided some sediments then and later. It must have remained elevated in comparison with the trough to the south throughout the Pliocene, because sedimentation was thinner there and in places conditions were suitable for the development of shoal limestone.

Since the end of the Pliocene, uplift must have been considerable along the north-facing front of the Bewani-Torricelli Mountains and, because one is so influenced by the latest events when studying the photographs, I am inclined to think that a great part of the total uplift took place since then; but it is most unlikely that movements of many sorts with active and developing fault lines had not occurred from the start of the geosyncline and continued through the Tertiary. We do not yet know enough about the stratigraphical

details of the region to try to recognize different phases of tectonic development. Doubtless the tectonism is by no means over. Coastal modifications occurred very recently at Sissano Lagoon (I13,14). The Wewak earthquake of 1935 was only the latest example of the upheaval which started with the Pleistocene. The amount of uplift was dramatic along the mountain front and must even have been spectacular in the recent past if the coralline limestones on the road from Wewak to Passam are sub-Recent. There they lie at about 300 m above sea level as an indication of very recent geological events.

The time of original intrusion of the plutonics is doubtful. We know so little about the contacts of these and the nature of the rocks into which they were intruded that any suggestion at this time is speculative; but the period of emergence in the upper Miocene and Mio-Pliocene seems to be the latest time when these plutons could have been formed.

TECTONICS

It is now suitable to consider the wider aspects of the tectonics of New Guinea (Plate 26). Among others Glaessner (1950) and Weeks (1959) have recently discussed the tectonics of the region but a critical examination of their papers need not delay us, because our area of interest in northern New Guinea is submerged by both authors in more general discussion. Moreover Carey's (1938, 1958) much more specific analysis of the area was largely disregarded by Glaessner and probably not available to Weeks, while neither can have had the benefit of Visser and Hermes' work. However each author makes observations which contribute importantly to the present discussion and are worth mentioning here.

Glaessner definitely believed that Kairiru is a volcano which doubtless led him to suggest, rather hesitatingly, that the Melanesian tectonic zones continued into the land of northern New Guinea. Glaessner and Weeks placed the Andesite Line (Solomons Line) between the Pacific Plate and the adjacent continental mass, roughly along the equator, well north of the New Guinea coast, following Macdonald (1949) in this respect, but as they were both dealing with the matter on broad lines on very small scale maps this need not be taken too seriously. Glaessner drew attention to the fact that most of central and northern New Guinea is practically aseismic for intermediate and deep earthquakes when compared with neighbouring regions on the east and west. Weeks' exposition of the formation and development of a mobile belt is most interesting and relevant in the present connexion and he follows many others in suggesting that the whole Pacific region is moving north or north-west relative to the surrounding continents.

Krause's (1965) work has more direct importance on the present study, partly because he deals precisely with the marine geology along the whole coast and partly because he supports and argues strongly for Carey's idea of left-lateral movement through the whole region from the Vogelkop to the Solomons. Let us first discuss Krause's evidence in detail. He says that 'the sea floor must have a history similar to that of northern New Guinea as here discussed, because in part northern New Guinea was sea floor during Cretaceous and Tertiary time, and a continuity of geological structure exists between northern New Guinea and the sea floor to a degree found in very few places in the world'. The first part of this statement can be disputed. If New Guinea has been moved substantially in any direction there need not necessarily have been any close connexion between the geological history of the land and the sea floor as they appear now. The second part in my opinion is simply not correct. The work of Visser and Hermes and the present study show convincingly that the tectonic grain of the land from Geelvink Bay to the Hansemann Coast is parallel or subparallel to the coast. Nowhere do any structures run out to sea at a large angle from the general coast line and, except perhaps at longitude 139°E (near the Tor River and Koemamba Islands) and along the Hansemann Coast, there is no apparent major transverse faulting which can be recognized as probably causing any pronounced displacement of the coast line and continental slope.

Krause bases much of his argument on the correlation of features of the bathymetry with structures on land, some of which west of longitude 135°E are outside the scope of this work. Between longitudes 137°E and 143°E however his correlations seem to me to be speculative, if not fanciful. On the west the bathymetric features are themselves not prominent and the correlations are made across a gap of 100-150 km caused by a much more pronounced feature (Krause's Santa Rosa Basin). In the middle I cannot see the supposedly similar trends. On the east he claims that the trend of the Bewani-Torricelli Mountains continues on the sea floor, which surely is not justified, especially as Kairiru Island is probably not a volcano.

Krause divides his bathymetric chart into a western zone beyond longitude 135°E, which is outside the scope of this study, a central zone of gentle warping of the sea floor between 135°E and 141°E and an eastern zone of extreme vulcanicity between 141°E and 148°E. But it seems that there is a most important and significant subdivision in this eastern zone at approximately 144°E which Krause does not emphasize enough. To the east the sea floor forms a platform at approximately 2000 m from which active volcanoes rise to or near the surface. Bam in the Schouten Islands is the most westerly volcano of the Bismarck arc and it should be noted carefully that the next active volcano to the west is at Ternate in the Halmahera Group 2000 km distant. West of longitude 144°E the sea floor descends rather irregularly and gently, without a clearly defined scarp, over a distance of 100 km to an irregular area at 3000-4000 m depth with a relief of about 1000 m. Another set of volcanoes rises from this irregular area and according to Krause's map their summits lie from 631 to 1153 fathoms below sea level, with the one exception of Wuvulu Island. Krause says that this 'northern inactive Wuvulu group... trends into the Admiralty Islands' but as his map does not extend north and east of Wuvulu this is uncertain. Although he recognizes a difference between the areas of inactive and active vulcanicity and although the data are inadequate, it is at least feasible that the two are more entirely distinct than he imagined and indeed that the inactive volcanoes are part of the Pacific floor rather than an extension of the Melanesian island arcs. This idea will be examined further below.

In summary Krause distinguishes seven characteristic features of the sea floor north of New Guinea 'from east to west':

(1) An active volcanic zone in relatively shallow depths (east of longitude 144°E)*,

(2) An inactive volcanic zone (Wuvulu area)*,

(3) A subcontinental area (less than 1500 fathoms) separated by the inactive volcanic zone from truly oceanic depths to the north-east. (This can hardly mean the narrow continental slope south of the Wuvulu volcanoes. If it refers to the sea floor between longitudes 139°E and 141°E, the description is bad)*,

(4) A trough marginal to New Guinea (Santa Rosa Basin)*,

(5) A general north-south zone of deformation north and west of Mapia Island (1°N, 134°15'E),

(6) A trench west of the area (Krause's Philippine Trench)*, and

(7) A generally smooth or undulating area where the first six features do not dominate the seascape (I cannot identify this definitely because is seems to apply only to the seafloor between longitudes 139°E and 141°E, but the features are said to run from east to west)*.

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* The comments and identifications in brackets are those of the author.

'The initial six features indicate an active tectonic region which is confirmed by minor features of item seven.' I agree that items 1, 4, 5 and 6 do indicate this and it does not matter anyway about item 3. Item 2 may have a totally different significance from that given it by Krause. If item 7 refers to the area offshore from the mouth of the Memberamo to Hollandia, it does not indicate tectonic activity in my opinion; if it is elsewhere, it does not affect my later argument.

Krause's other important contention is that 'large horizontal left-lateral movements characterize northern New Guinea' and that these 'may be part of a shear zone that extends from the Celebes on the west to beyond the Solomon Islands in the east'. At this point we may return to Carey's original hypothesis. He expressed this as follows: 'New Guinea has been sheared westwards under a colossal shear system, on a scale grander than has yet been demonstrated anywhere else on the globe. For the great system of rotational stresses responsible for these phenomena, the name Melanesian Shear System is here proposed... The stresses which are responsible for this great westerly displacement are of continental dimensions. They are probably related to the main architectural pattern of the globe'. This is Carey's (1958) own quotation from his 1938 thesis and accompanying it as Fig. 41a (originally Fig. 23, 1938) is his diagram of the Melanesian Shear System. Along the south of this figure between Australia and New Guinea is a line of passive inertia and along the north of New Guinea is the complementary line of active shear dragging the whole New Guinea rhomb sinistrally westwards. Later in 1958 Carey modified this considerably and postulated that New Guinea and Australia have come into their present position by a combination of sinistral and dextral megashears which essentially squeezed out intervening areas westwards. These have become modern Indo-China, Malaya and Indonesia and left New Guinea and Australia in juxtaposition, New Guinea having been rotated sinistrally from a position east of Queensland to its present position north of Australia. This comes near the end of Carey's fascinating and brilliant exposition of his oroclinal thesis in which he unravels the tectonics of the globe and it is only at this point where it seems to me that there is serious difficulty which however by no means invalidates the whole hypothesis but merely calls for some local modification. Other considerations may call for an originally different position of New Guinea relative to, and perhaps well away from, Australia, but how is this possible when, as far as I am aware or can find out, there is no evidence for a megashear between the Australian continent and New Guinea?

The idea that New Guinea at one time lay east of Queensland originated with du Toit (1937) and, in so far as it required a major crustal break separating New Guinea from Australia, was essentially the same as Carey's hypothesis. Other authors and most recently Rod (1966) have followed du Toit but their arguments based on structural alignments and lithological comparison do not seem to me to be either attractive or convincing. Possibly New Guinea could have moved to its present position before the Mesozoic and the lines of crustal fracture been welded into a geosuture of little or no activity now, but this would then have occurred far too early for their larger arguments.

Here indeed is the dilemma which faces every student of the geotectonics of Australasia, the plausible impossibility of assuming that New Guinea is an integral and northern part of the Australian mass (du Toit) against the unconvincing possibility that New Guinea has moved a considerable distance to its present position. Like Aristotle, I prefer the plausible impossibility.

It would seem that the part of New Guinea south of the central cordillera at least could not have been separated from the Australian continent as recently as the Cretaceous, if at all, and therefore that left-lateral shearing in the Tethyan Torsion Zone, if it occurred, only affected the northern New Guinea area which would, so to speak, have been smeared across the top of continent. Alternatively if New Guinea has been subjected to sinistral rotational stress, Carey's original suggestion of a distorted New Guinea zone north of Australia, not ruptured from the continent, seems much more attractive, but it can still

be questioned whether the whole of this area from Sorong in the Vogelkop to the Solomons should be treated in one piece. If some of it has probably been subjected to sinistral rotational stress, has all of it so suffered? I think there is reason to doubt this.

First from a superficial glance there is obviously a distinction between the tectonic maelstrom west of Geelvink Bay and the more sedate, if complex, tectonics of the central parts of New Guinea. To the west the Vogelkop is clearly involved in the arcing which affects the Banda, Molucca and Halmahera areas and contrasts with generally rectilinear tectonics in the trapezoid of central New Guinea east of Geelvink Bay. It is possible to extend the trend of the main cordillera northwards to the Vogelkop, as Carey did throughout his papers, but even if the bending of trends west of Geelvink Bay is trivial on a world scale under the oroclinal theory it is also reasonable to straighten the bends, again following Carey. If this is done not only would the Geelvink Bay chasm be widened instead of closed but another would be opened in the MacCluer Gulf (2°30'S, 132°30'E). Moreover the double tectonic twist west of Geelvink Bay is arranged as a dextral shear couple under rotational stress and so is anomalous. In this respect then treating all New Guinea as an entity the oroclinal theory breaks down. Moreover if a uniform central intermontane trough exists along the line of the Meervlakte and the Sepik (which is doubtful) it could not be continued across Geelvink Bay because of the strong zone of negative isostatic anomaly on the east of the bay; but Carey himself would probably not now care to maintain this extension of the trough.

Secondly I think a similar distinction should be made on the eastern side of the central New Guinea trapezoid, though here a dividing line is less obvious because land structures in the Madang-Finisterre area tend to parallel the end of the Bismarck arc and because the Ramu-Sepik delta obscures the geology. A conspicuous feature along the valleys of the Markham and Ramu Rivers is inferred usually as one of major faulting and I believe it emerges north of the Ramu-Sepik delta along the line of the Hansemann Coast which interrupts the general coastal trend. It then continues into the nose of the trench on Krause's map between the Schouten Islands and Kairiru. Krause quite logically says that the southeastern continuation of this trench has probably been filled by sediment from the Sepik and Ramu Rivers and longshore currents here are certainly westward because they carry floating rafts of vegetation from the Sepik farther west than Wewak. It is uncertain whether this line continues out to sea or, if it does, in which direction, but at least there seems to be a real distinction between the inactive volcanic region of Wuvulu Island and the active volcanic arc of the Bismarck Archipelago. If the line is continued north along the slope of the sea floor from 1000 to 1500 fathoms, Wuvulu embarrassingly lies to the west. If it is drawn west of Wuvulu, there is no reasonable lineament to follow. This matter can only be decided when the Wuvulu volcanoes have been further investigated and the sea floor north and east of Krause's map surveyed. It will be most interesting to learn whether the composition of these volcanoes is oceanic in contrast to those of the Schouten Islands which Morgan (1966) found to be andesitic, whether they are truncated and whether they are tilted towards the land, as has been detected on sea mounts off the Aleutian arc (Menard, 1964), suggesting down-buckling of the ocean floor under the continent. We need not be particularly worried that Macdonald (1949) included all this area within the Andesite Line because he only treated this part of the Pacific on most general lines and produced no detailed evidence for putting the line on the equator well north of the New Guinea coast. Meanwhile I think that it is a major possibility that the Wuvulu part of the sea floor is oceanic.

It is easy to see, however, that the lineament running from Lae (6°45'S, 147°E) to the coast (Hansemann-Lae Line) cannot be so simple as the one on the east of Geelvink Bay, because some supplementary faulting is needed along the Rai Coast and in the angle of Astrolabe Bay (5°30'S, 146°E) to account for the displacement of what looks like the eastern end of the Bewani Geosyncline to the Adelbert (5°S, 145°30'E) and Finisterre Ranges, but this could easily be imagined.

It is convenient to set out the reasons for distinguishing the central trapezoid of New Guinea from the tectonic maelstroms on either side as follows:

(1) Tectonic contrast across the east coast of Geelvink Bay and across the Hansemann-Lae Line. Besides what has already been said it appears to be difficult, if not impossible, to continue the Sorong Fault zone east of Manokwari (1°S, 134°E). Such a tremendous feature should leave better evidence than there is, if it ran along the north New Guinea coast; nor can it be identified convincingly in the line of the Meervlakte-Sepik River. This line of depressions is not really so uniform and continuous as is usually suggested. It appears to be seriously interrupted by the Border Mountains basement high and by the Nawa-Sobger Line (3°30'S, 140°30'E). Visser and Hermes have suggested faulting on the south side of the line (Meervlakte) and I suspect it also along the line of the Sepik River. However, I think that such faults are probably composite and arranged en echelon like the west-north-west faults in the Torricellis and Bewanis and that anyway it is quite uncertain what sort of faults they may be. One main line of this composite faulting could cause or help to cause the Maimai tectonic twist; a second and more likely one probably separates the apparently stable Border Mountains from the different regime of the Bewani Mountains (see above) and this line probably continues into the Nimboran Fault Zone of Visser and Hermes; a third could be associated with the Nawa-Sobger Line leading to the greatly disturbed area of Wiroe and Toarim (2°30'S, 139°30'E). Such faults would be essentially compressional under either a simple or a pure shear system.

(2) Active volcanoes are absent between Bam and Ternate and this is the only gap in the volcanic chain from north Sumatra to the New Hebrides along an arc of about 80° of longitude. It makes little difference if Kairiru is found to be a volcano.

(3) According to Gutenberg and Richter (1954) the central trapezoid of New Guinea is virtually aseismic as regards earthquakes originating at depths of more than 70 km. Deep earthquakes (> 300 km) have never been recorded and intermediate ones (70-300 km) only along the eastern edge near the Hansemann-Lae Line. Brooks (1965), though only incidentally interested in the depth of earthquake foci, confirms this. Both points (2) and (3) are in contrast to the Banda and Melanesian arcs and show that a young mobile belt does not run through the area.

(4) Viewing the margins of the western and south-western Pacific it is seen that northern New Guinea (and here we would have to include the Vogelkop) is the only gap between the Aleutians and New Zealand where some or all of the concomitants of island arcing do not occur. If such island arcs are regarded as forming in the manner of mobile belts, as described by Weeks (1959), then clearly the New Guinea sector is not at present in any youthful stage of such a belt. It is in fact much more mature, having presumably developed out of such a mobile belt in the late Miocene with the final movements closing the mobile back or hinterland since the Pliocene. The similarity of northern New Guinea indeed lies with the Pacific coast of South America where, as one proceeds away from the ocean, one finds a coastal high, a deep trough and then the main cordillera in much the same relation as the coastal range, the Bewani-Sepik Geosyncline of the late Tertiary and the central ranges of New Guinea, though the amount and intensity of uplift is greater in New Guinea and there are many differences of detail (see Nygren, 1950, and Marchant, 1960, for a comparison with the geology of coastal Colombia and Ecuador).

(5) The probability that oceanic floor and a continental mass come close together along the northern New Guinea coast between about longitudes 135°E and 144°E and are not separated by island arcing or deep trenching. Visser and Hermes clearly assumed that this happens and so did Menard (1964). Krause, perhaps carelessly, speaks of the slope from the land along this coast as the continental slope.

For these reasons then of tectonic pattern, vulcanicity, seismicity, geological structure and relation with the ocean floor it seems that northern New Guinea is distinct from areas to the east and west and that it is not too much to regard it as unique in the western and south-western border of the Pacific which elsewhere has all or some of the characters of a mobile belt or island arcing. Carey points out that the borders of the Pacific Ocean are in a more advanced orogenic stage than those of the Atlantic and that on the west-facing coasts of the Pacific the orogenic belts are still closely attached to their parent continents. It can be claimed that New Guinea differs from the areas to the east and west in the stage of its orogenic development and that here too the orogenic belt is still or has become closely attached to the Australian continent.

On a global basis Carey has argued convincingly for a Tethyan Shear System (or Torsion Zone, as he later called it) and Tanner (1964) has a similar idea in his equatorial belt of maximum deformation; but from the considerations given above I find it difficult to accept wholeheartedly the notion that New Guinea was or is part of such a shear system. Admittedly Carey suggested that 'an important part of the Tethyan Shear System runs to the north of New Guinea', but on the available bathymetric evidence I cannot believe that this is likely. In consequence I have preferred to interpret the local tectonics of the area of study under pure shear and have shown this on Plate 24.

Superficially it could be suggested that the whole of the Australasian continental area, with the New Guinea Geosyncline welded on in front, has been pushed northwards into the Tethyan Torsion Zone or maximum deformation belt, along a sinistral shear on the Geelvink Bay-Sahul Shelf line and along a dextral shear on the Hansemann-Lae Line; but not only would this leave the Vogelkop area on the west anomalous since it cannot have been displaced far from the central New Guinea trapezoid but would call for a megashear right along the Sahul-Geelvink line which is not acceptable under pure shear.

To pursue this inquiry further would be inappropriate because it would take us too far from the area of the present study. Moreover Visser and Hermes have already discussed the tectonic problems of the Vogelkop and West Irian generally with an immense amount of geological and geophysical evidence. However it is reasonable to wonder whether the Australasian continent as it approached the Tethyan Torsion Zone began to impinge on the New Guinea Geosyncline and exert a rigidity to it which it would not otherwise have acquired. Helped by this influence from the south in the last half of the Tertiary that part of the geosyncline north of Australia was closed under compressional stress on north-north-east lines with the development of large wrenches on the east and west which were however not so large as to become megashears. On the west of the central trapezoid such movement though generally in line with the Sahul megashear need not necessarily be a direct continuation of it. Visser and Hermes in fact have a major line of east-west faulting crossing the trend roughly where it crosses the south coast of New Guinea and also, almost en passant, mention a probable northward movement of the central New Guinea trapezoid on the east of the Geelvink Bay line. Meanwhile the Vogelkop area was becoming involved in the complexity of the Banda-Halmahera arcing and there could have been some sinistral rotation of the advancing Australian mass which caused the Vogelkop extension to burrow into and be bent back by the encroaching Banda system. While it was squeezed between the Banda and Halmahera areas, further wrenching (but this time dextral) could have occurred on the west side of Geelvink Bay and thus helped to form this triangular chasm which bears a certain resemblance to the Gulf of Guayaquil in South America (Marchant, 1960). On the east the dextral wrenching was probably more complicated and led to a fracturing of the eastern end of the closing geosyncline north of the rising central cordillera, rather than simply allowing the fractured parts to become involved in the tectonic twisting of the Melanesian arcs. Here too because the Melanesian arcs are not confined to the north and perhaps because of sinistral rotation of the central trapezoid, there would be less tendency to form such a maelstrom as in the Banda area. It could

also be possible that the Melanesian arcs were originally like the Banda arcs and formed another of Tanner's 'mirror-symmetric first-order strike-slip fault systems', but with the northward movement of the central New Guinea trapezoid the southern limb of the system snapped off and was pushed and twisted closer to the northern one. A line of faulting where this snapping could have occurred is across the neck of New Britain between Wide and Open Bays (5°S, 151°30'E) (Thompson and Fisher, 1965).

My conclusion is that it is still far from certain whether New Guinea in whole or in part has been subjected to rotational stress and that the photogeological evidence on which I have mainly relied helps little to decide between pure shear and simple shear as the cause of the regional tectonics north of the Sepik River. My interpretation by pure shear is merely a matter of convenience. As R.P.B. Pitt has pointed out to me, there is one general consideration which suggests that simple shear is the true cause and perhaps suggests it strongly. Throughout the region folds are poorly developed and faults are the dominant feature of the tectonics. In other words there is no development of long bundles of folds which are such a marked feature of some other tectonized geosynclinal regions and which are probably the hall mark of pure shear. Their absence in northern New Guinea is certainly against an interpretation by pure shear.

OIL AND GAS INDICATIONS

Hydrocarbon indications in the region are as scarce as they are in the West Irian sector of the Northern New Guinea Basin.

The best known oil seepages are in Wakip Creek (M24) near Matapau. These were investigated in detail by surface surveys between 1921 and 1939 and by nine shallow holes between 1924 and 1933. The area is extremely complicated but the oil apparently occurs along faults close to basement outcrops and the faults are probably high-angled thrusts hading south, as Montgomery concluded.

The only other occurrence of oil, here accompanied by gas, is near Terebu within the basement outcrop and clearly associated with faulting on the photographic evidence. Stanley visited this seep, but unfortunately I was unable to do so and I have no information about it beyond the fact of its existence.

Neither of these occurrences seems important. Their significance is in showing that oil has been generated probably in pre-Pliocene rocks (Unit I or II). There is no likelihood of any commercial oil accumulation locally and in view of the complicated tectonics, locally and regionally, there should be plenty of opportunity for seepages if oil had been generated in any quantity in the Tertiary sediments. What is depressing is that these and two other seepages (one large and active, the other insignificant) in Indonesian territory are the only ones known throughout the whole of northern New Guinea west of the mouth of the Sepik River.

Oil smell, usually reported as disappearing quickly, was noted by Osborne and Montgomery as follows:

(1) Sereri River - 2 km south-west of Puari (H8) village in the Serra Hills,

(2) Upper Pulan River - in foraminiferal marls,

(3) Me (Puwani) River near junction with Kulanap Creek (J2) and just above the first limestone gorge - in limestones,

(4) Kaune Creek (J12) on the Barida Anticline - in sandy marl,

(5) Near Songaien village.

Gas emanations were reported as follows:

(1) Mili River (J7-4) - 2 km below junction with Yo Creek (IJ6), in sago swamp 500 m from river on right bank,

(2) Tributary forming west branch of Sereri River,

(3) On right bank of Yalingi River about 1 km above junction of Obubu Creek (L14,15),

(4) Negele Creek, near Ha'ap Creek (N26),

(5) I'imbia Creek (O24), tributary of Amu River, east of Humal Creek,

(6) Numbin Creek (O16), tributary of Asinni Creek (O-S15,16), 2 km east of Ningil (O16),

(7) Nanimbe Creek, 1.5 km south-south-west of Munambual (O17),

(8) 1.5 km east of Masan (S39).

Many of these gas shows are associated with brine or hydrogen sulphide springs, and all of those analysed were methane or dry gas. The gas found by NNGPM in wells at Gesa and Niengo in the lower Memberamo area was also methane.

The Ormildah Oil Development Co. Ltd drilled a well (R39) near Marienberg to a depth of 825 m. It was spudded in 1925 and apparently completed in March, 1928. There was some doubt about the identity of the strata penetrated, but Montgomery concluded that the well started in Pliocene and finished in Miocene sediments. There were no significant shows of hydrocarbons.

This and the shallow wells at the Matapau seepages are the only drilling which has been carried out in the region.

PETROLEUM PROSPECTS

It is convenient to divide the region into four parts for this discussion, as follows:

(1) Bewani-Torricelli-Prince Alexander Mountains;

(2) Coastal plains and coastal uplifted areas;

(3) Slopes to the Sepik plains and the plains;

(4) Border Mountains.

Bewani-Torricelli-Prince Alexander Mountains

This part embraces practically all the outcrops of basement and of Units I and II through the centre of the region from the West Irian border to the Hansemann Coast, as well as the foot hills, mostly of Pliocene rocks, along the mountain front of the Bewani Mountains west of the Raihu River. It is hopeless to explore for petroleum in this part of the region, because the structural aspects are unfavourable. On the strength of the Matapau seepages there is evidence for oil generation in Unit I and doubtless that is so because the sedimentation was marine with abundant organisms; but the lower section of Unit I is probably mostly volcanic so that the value of this unit as source beds probably diminishes downwards. Limestone lenses could act as reservoirs where they occur but otherwise reservoir rocks are probably not well developed because the sandy elements are likely to be of greywacke type. Basically the whole region is so broken and without unfaulted anticlines that it would be folly to expect accumulations of any value. This, coupled with formidable problems of access, puts the area out of consideration as an oil prospect.

However the following structures were identified by APC geologists.

(1) Pulan-Ainbai (J2) Anticlines

These form a single faulted structural element on the photographic evidence, as indeed Osborne thought, but as it does not apparently extend west of the Puwani River I restrict it to east of the river and therefore call it the Puwani-Ainbai Anticline. Superficially the limestone core of Unit II rocks appears to be a simple structure for considerable distances, but because it is intimately connected with a fault zone along its southern side and the Pliocene on the northern flank is vertical to overturned it is not a drilling prospect.

(2) Wol (IJ3,4) and Maiu (IJ4) Anticlines

Neither of these seems to be an anticline; there is nothing to suggest them on the photographs and dip reversals are probably due to faulting.

(3) Sumumuni (I5), Yo (J6) and Mili (J7-9) Anticlines

These are supposed to be expressed in Pliocene sediments at the mountain front but are complicated by strike faulting. The Yo Syncline is the only recognizable feature on the photographs. They are all tightly compressed, probably only fault expressions and too small to provide worthwhile drilling prospects.

(4) Bwofa Anticline (J9)

This does not show up on the photographs. Faulting probably causes reversal of surface dips but if there is an anticline here it is merely the faulted western end of the complicated Pinyare fold to be discussed next. The Bwofa area itself certainly would not be a reasonable drilling prospect.

(5) Pinyare Anticline (J10,11)

Parts of this are quite clear on the photos and its position agrees well with that shown on Osborne's map. Unfortunately it is narrow, compressed and disrupted both by longitudinal and cross-faults. Obviously it is not a drilling prospect.

(6) Make (Barida) Anticline (J11)

A small anticlinal nose seen on the photos west of the Bliri River agrees with that shown on Osborne's map but it does not extend across the river into the Barida Hills. It is probably the faulted western end of the much larger Barida structure to be mentioned next.

(7) Barida (J12,13), Nengian (K14), Walwali (K13), Navi (K15) and Wapa'alu (K15,16) Anticlines

The APC geologists took these to be separate structures but they are probably a single anticlinal line disrupted by faulting. On the Barida ridge and in the Oi (K13), Pieni (JKL13) and Faifela (K13) Creeks the core of the structure and its northern flank are highly faulted and overturned. Such a complicated doubtful anticline is not a drilling prospect. Both photographic and surface information suggest that the complication continues along the whole line as far as the Raihu River.

(8) Karaiti (L15), Lupai (L15), Eringi (L15) and Seyum (M15) Anticlines

These were all small narrow folds identified by APC geologists between the Barida-Wapa'alu line and the mountain front. On the photographic evidence there is only a short anticline between the Gumi (L15,16) and Piye (L15) Creeks at the eastern end of the Lupai Anticline. Dip reversal elsewhere is probably caused by faulting. However with a small anticline in the Gumi-Piye Creek area a synform must exist to the north between it and the Barida - Wapa'alu line. There is evidence for this in the upper reaches of Wam Creek

(KL15,16) where it broadly coincides with part of the Lavaiti Syncline (L15) of APC geologists. Even if the anticlines recognized by APC geologists exist they clearly could not be drilling targets because of their small size, narrowness and probable faulting.

(9) Piore Anticline (JK9-11)

This was an extensive (30 km) structure suggested by APC geologists in Unit I and basement rocks between the Piore and Bliri Rivers. On the west just east of the Piore River there is clearly an anticline expressed by probable limestone ridges and crags. It does not extend more than 5 km west of the river and is probably dislocated northward by wrenching for about 2 km so that a remnant occurs on the eastern side of the fault zone. The northern basement ridge between the Mene and Bliri Rivers, from which descend the Serwali, Kunablu and Nibin Creeks (K11), could perhaps be broadly anticlinal, but the supposed structure cannot be recognized elsewhere.

(10) Kiliwas Anticline (K4)

In the area of Unumbu Creek there are undoubtedly opposed dips due to faulting. If an anticline occurs it has no interest for petroleum exploration because of its small size and complexity.

(11) Anticlines in the Matapau-Danmap (M24,25) area

APC geologists recognized a number of small structures here, viz. Djeruen (M25), Dumib (M26), Linihok (M27) and Heliwam (M26). These are all negligible as regards petroleum prospects, if indeed they are anticlines. The Djeruen, Linihok and Heliwam structures are all close to basement in faulted areas and the last two were based on a single stream section. Probably they are expressions of faults. The Dumib structure, which was studied in great detail by Stanley and Hobson (1934), may be anticlinal but nevertheless is very small and severely faulted.

(12) Anticlines in the eastern Torricellis - Malpek (M21), Aramap (N25), Ha'ap Creek (N26) and Ulahu (O26) areas

The Malpek Anticline lies in the zone of strong reversed faulting running up the Mabam and Amu valleys and is probably only an expression of faulting. Ha'ap Creek Anticline is a result of faulting on photographic evidence, as thought by Montgomery ('little more than an anticlinal roll immediately behind a reverse strike fault'). The Ulahu Anticline is not a recognizable fold on the photographs, the whole axial area being a complicated fault zone, and faulting was admitted by Montgomery in the axis. The Aramap Anticline appears on the photos as a small twisted structure complicated by faulting developed probably in Unit II strata and quite useless as an oil prospect.

Finally a number of doubtful structures may be recognized on the photographs. None can be prospective for oil because of the generally unfavourable structural conditions always associated with outcrops of Unit I in which they usually occur and because of the generally unfavourable nature of those rocks (e.g. Auwewa - Bliri equivalents) for the retention of oil, if not for its generation. These possible structures are as follows:

(1) East of the Puwani and south of the Kulanap (J2-3) Rivers: the anomalous rounded topography resembling that of Unit II.

(2) The More-Make Hills north of the Mene-Bliri Rivers with extension across the Bliri to the south-east almost as far as Goiniri (L13) at the head of the Neni and Pieni Rivers. Indistinct limestone ridges, disrupted by faulting, run through this district and probably represent an antiform.

(3) A more distinct faulted anticline in the area of Norkorne Creek on the east of the Bliri River but probably with basement outcrops nearby or in the core.

(4) Between the headwaters of Harech (LM21) and Dandanain (LM21,22) Rivers.

(5) North of Damadid Creek (M22) at the western end of the coastal hills between Matapau and the Dandrawad River.

(6) Between Nimbum and Mima Creeks (M25) south-east of Matapau.

(7) South-west of Wonginara, the divide between the Mabam drainage and Damen Creek (NO28).

(8) Various small structures between the Hawain River and the coastal hills.

(9) At the eastern end of the Mt Turu basement outcrop with extensions eastwards to the upper reaches of the Waringe river system (OP31,32).

(10) Kairiru Island.

Coastal Plains and Coastal Uplifted Areas

Although the Oenake Mountains and Serra Hills are undoubtedly uplifted and generally anticlinal, they are very poor oil prospects. They are severely faulted and basement is exposed just south of Leitere in the Serra Hills. Even if basement does not crop out on Mt Bougainville, it is probably at no great depth. The Tertiary sediments, nowhere very encouraging as reservoirs, must be much thinner here than to the south and there is no evidence of change to an arenaceous facies. Facies change to limestone is known in some areas but this limestone crops out extensively. Finally there is the close similarity with what Visser and Hermes describe at the mouth of the Memberamo where two wells were drilled. Memberamo No. 1 found 1227 m of Memberamo Formation resting directly on fractured and crushed igneous rocks. Niengo No. 1, which had a gas blow-out near the bottom of the hole but the accumulation proved non-commercial, drilled 1969 m of Memberamo Formation resting on green schists. These wells clearly proved a basement high along the coast with a thin Pliocene section overlying it. The magnetic evidence in the Oenake area suggests shallow basement (Young, 1963). Even though there is Miocene (Tertiary Stage 'f' and earlier) in the Oenake and Serra uplifts, it would hardly be worth going to the labour and expense of drilling to find out what is virtually certain - a close similarity with the rest of the north New Guinea coast and no oil.

There is photographic evidence for structures within the general Oenake uplift, e.g. in the Kohari Hills; north of the Jabiri River; 12 km south of Vanimo, near Mt Asowa (F4). The first and last are probably developed in Unit I rocks which are unattractive on present knowledge of lithology and on evidence of disturbance.

The areas outside these hills on the coastal plains and swamps may be considered better prospects but their only attraction is the attraction of the unknown. The beds are probably flat-lying or form a gentle homocline to the south with some faulting. Osborne recognized two anticlines, Puau (I7) and Muru (I6), in the Mili (Bilia Creek) valley, but on the photogeological evidence these do not exist, dip reversal being due to faulting with only a south flank well preserved. Conditions seem very similar to what the NNPGM geologists proved by geophysics and drilling in the lower Memberamo, except that in Australian territory it is doubtful whether there are any gentle anticlines at the foot of the mountains. The coastal ranges are here closer to the mountain front and there is little room for such structures to develop. North of the major reversed faulting which formed the Bewani-Torricelli Mountains, the basement probably rises uniformly towards the coast and is overlain by a decreasing pile of sediments with regional south dip, probably uninterrupted except by faulting. To prove this would need the labour and expense of geophysical surveys, perhaps followed by drilling, none of which is justified.

Slopes to the Sepik Plains and the Plains

Broadly this area is represented by the outcrops of Units III to V and the alluvium of the plains to the south. Throughout this large region Montgomery identified the following structures:

(1) South and south-west of Mt Turu

On the basis of little more than a single stream traverse an anticline was postulated in the Hambili River (PQ29,30) and two more in the Atilem (PQ27) and Panamberi (P-R27,28) valleys east of Yangoru. There is no evidence on the photos for the Hambili structure nor for the north-easterly fold in the Atilem valley. The unnamed anticline is well displayed between Agingun (Q27) and Numburuon (Q28) trending north-west from the Engult valley (P-R28) and is now named the Wulima Anticline after one of the larger creeks which it follows. As an oil prospect it looks inferior because of the reported outcrop of basement in the core and because of some cross-faulting at the north-western end. However it should be re-examined partly to prove the presence of the basement and its relation with overlying rocks and partly to prove that Unit II crops out in the core.

(2) In the Amu, Nanu, and Mihambom (O-Q22,23) river systems

Humal (O23),	Amu (NOP22-24),	Animbe (O22),
Mihambom (O22),	Bilangom (P22),	Wultuam (P22),
Yabanakuor (Q23)		

All were named after creeks or rivers along which they were recognized except the last two which were named after villages. Montgomery admitted that the Humal, Mihambom, Bilangom and Wultuam structures were nothing more than 'anticlinal rolls' interrupting the regional south-west dip but on the photogeological evidence they seem to be simply expressions of faulting.

The Amu and Animbe structures seem to be better developed but Montgomery said that both are much disturbed and in places faulted along the crests. On the photographs there are only two anticlinal fragments which are probably parts of one anticline broken by reversed and wrench faulting. In any case the area is hopeless as an oil prospect because of the narrowness of any possible structures, the tight folding and the amount of faulting.

The Yabanakuor Anticline is farther south toward the Sepik Plains and appears faintly on the photos. Montgomery says that the northern limb is only 600 feet wide with dips rising from 7° to 20° and suggests that unobserved faulting may be present. Though there is no good indication of this on the photographs it seems possible but in any case the structure must be too narrow and asymmetrical to present an attractive drilling prospect.

(3) West of the Korp River

Yuolpa (N18),	Makafim (Q17),	Maimai (R17),
Namblo (Q18)	Bongos (R20),	Wamil (N18),
Unnamed, across Kaifangi Creek (NO14)		Wagir (PQ14),
Alakan (Q14),	Yukilo (Q12)	

The Yuolpa structure, regarded by Montgomery as a plunging nose of no importance, cannot be detected on the photographs. The Wamil line is either caused by faulting or is a plunging nose without closure to the north. The Kaifangi reversal is so small that it may be disregarded. The Wagir and Alakan folds are not seen on the photographs and Montgomery dismissed them as unimportant. The remaining structures are easily seen on the photographs.

Though the Makafim and Maimai structures have always been identified separately, they are better regarded as culminations on a single anticlinal line which has three obvious divisions. The northern part is tightly squeezed, faulted in the crestal area and

cut off at the south by dextral wrenching; it is not an oil prospect. The central part is less compressed but is still sharply folded and seems only slightly more attractive. The southern or Maimai culmination, quite incorrectly termed a dome, is even less compressed but seems to be clearly crossed by one or more sinistral wrenches. It is the most attractive area of the three but its smallness and the faulting detract from its merits.

The Namblo and Bongos Anticlines are probably parts of one fold displaced by sinistral wrenching. The photographic evidence for this is indistinct but plausible. The folds are well displayed on the photographs, though the eastern end of the Bongos Anticline becomes indistinct. Apart from the one postulated wrench fault, they are undisturbed, quite large and appear closed in all directions. These form the only respectable drilling target in the whole region.

The Yukilo Anticline is also well displayed on the photographs which are however poor over the eastern third. There is more faulting here than on the Bongos-Namblo fold and apparently the anticline is breached down to Unit II, though this should be checked in the field. Otherwise its size and reasonable regularity puts it almost, but not quite, in the same class as the Bongos-Namblo Anticline.

A plunging nose east of Nuku, probably not closed to the north, and three or four small and very doubtful folds to the east in the Minjim River area (Q-S30,31) are unimportant and may be disregarded.

Border Mountains

As an oil prospect the whole area is worthless. The Border Mountains, with flat-lying limestone on basement, offer no possibilities of accumulations. The district between the Border and Bewani Mountains is probably underlain by Bliri River Beds (Auwewa and Makats Formations) and is no more promising than similar larger areas already discussed above in the Torricelli and Bewani Mountains. The possible Green River Anticline seems to occur in a tectonic embayment between basement areas and is unlikely to be either structurally favourable or to have a full development of Tertiary sediments. At this time the expense and difficulty of geophysical exploration in the swamps and plains of the Horden-North River area (Sheets 4046-4047) would not be justified, because the surrounding prospects in areas of outcrop are so poor.

Conclusions

Only the southern part of the slopes to the Sepik River out of the whole region presents any oil prospects and within that smaller area only the Namblo-Bongos structure is worth further attention. A reasonably full development of Tertiary rocks probably occurs in the structure because the 'buried hill' theory does not seem applicable; but unconformity or unconformities could be expected roughly between the Pliocene and Miocene at the T27 and T33-34 levels. Oil should have been generated in such a thick pile of sediments which are so rich in foraminifera, but good reservoirs are less likely. The only way to find out is by drilling and at this stage I would suggest a hole on the Bongos Anticline for this purpose. There is no reason for further geophysical or surface investigation. If such a hole had no encouraging oil shows or indication of reasonable reservoir conditions, then the whole region could confidently be dismissed as an oil prospect. Further work would only be justified by reasonable encouragement from such a well.

It may be felt that the Sepik Plains themselves should be explored but under the circumstances such labour and expense would not be justifiable, at least before the testing of the Bongos Anticline. There seem to be two simple possibilities here; either that the basement rises gradually to its outcrops on the Sepik River or that these southern outcrops are brought up by reversed faulting as on the Bewani-Torricelli mountain front. In either

case the oil prospects appear poor; in the first sediments thinning or overlapping southward; in the second tectonic confusion. The only attraction is the wedge-out possibilities in the first case - not a worthwhile target at this time. It would be very interesting academically to have an aeromagnetic survey over the Sepik valley with some reasonable gravity coverage and even a seismic line or two, but in industry such expenditure is not justified now and could only become so with good encouragement at Bongos.

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APPENDIX 1

STRATIGRAPHIC DEFINITIONS AND NOMENCLATURE

The formations mentioned in the text are arranged below in alphabetical order.

Barida Beds

Derivation of name:

Barida ridge and old village of Barida, at approximately $3^{o}10'S$, $142^{o}00'E$, and about 18 km south-south-west of the mouth of Sissano Lagoon, Sepik District, Territory of New Guinea.

Distribution:

In the core of the Barida-Nengian-Wapa'alu anticlinal structure forming the hills of these names, with isolated outcrops westwards along the mountain front to the Mili River.

Lithology:

Generalized summary. Mostly hard white limestone with foraminiferal marl, and tuffaceous sandstone, as well as volcanic agglomerate, and at least one lava flow.

Type area:

The Barida-Nengian-Wapa'alu anticlinal structure.

Type section locality:

West branch of Tomoflu Creek, flowing south from Barida ridge to join Neni Creek.

Thickness:

About 975 m on the Barida ridge: 1220 m in Fieni Creek (J9).

Age:

Mio-Pliocene. Tertiary Stage 'g', or T34-42 (Visser and Hermes).

Fossils:

Foraminifera.

Relations:

Possibly conformable with, but sharply defined from, the overlying Neni Formation; possibly gradational and not clearly defined from the underlying Bliri River Beds; but as the whole area in which these rocks crop out is strongly faulted, the relations of this unit are not yet definitely established.

Synonymy or modification of previous nomenclature:

Originally described as Barida Formation by Osborne (1942).

Remarks:

From personal experience of some exposures of these rocks including part of the type section I do not think that a complete sequence of these rocks can be properly described at present. On the Barida ridge the succession below the Neni Formation is so much

disturbed tectonically and is often so obscured by a thick travertine cover that I doubt whether a reasonably full or continuous sequence could be found anywhere. Moreover, the presence of much volcanic agglomerate as stream debris and the record of a lava flow seems to me out of place, because this would represent the only volcanic material above the base of Tertiary Stage 'g' in the whole region of the Northern New Guinea Basin. Osborne admitted that the exposure in Fieni Creek is probably the best section of this sequence of rocks and that there both underlying and overlying formations are seen presumably in less equivocal circumstances. Therefore until all these exposures are re-examined critically the rocks are best designated as Barida Beds and not Formation. No doubt there is an interval, broadly representing Tertiary Stage 'g', below the Neni Formation and above the Bliri River Beds, which can be defined as a valid formation but it may be merely misleading to describe it from the Barida exposures and name it accordingly.

Bewani Formation

Derivation of name:

Bewani River, at approximately 3°03'S, 141°03'E, and about 50 km south-south-west of Vanimo, Sepik District, Territory of New Guinea.

Distribution:

Main outcrop on the Bewani mountain front west of the Puwani River to the West Irian border, in a strip about 1.5 to 2 km wide; on northern flank of the Puwani-Ainbai Anticline. Probably crops out in separate fault blocks eastwards along the Bewani mountain front to the Piore River and may occur in the Unumbu valley south of the Bewani mountain divide. Main outcrop is clearly confirmed by photogeology (Unit III).

Lithology:

Generalized summary. Soft massive smoky-blue micaceous mudstone with irregular light grey laminae of fine sand and silt; alternating mudstone and sandstone with some thin hard calcareous bands.

Type area:

The Bewani mountain front between the West Irian border and Puwani River.

Type section locality:

West branch of the Bewani River, for about 2 km in its middle reach, starting about 4 km direct from the junction with the east branch of the river.

Thickness:

At type section 2530 m which is the maximum measured anywhere; elsewhere some of the sequence is probably faulted out.

Age:

Pliocene. Tertiary Stage 'h', or T42-43 (Visser and Hermes).

Fossils:

Not clearly described, but foraminifera must occur and Rotalia is mentioned as having been found.

Relations:

Transitional to overlying Krisi Formation by 150 m of massive sandstone and soft fossiliferous blue-grey mudstone which are included in the Krisi Formation. Contact to underlying Puwani Formation not properly established because of poor exposure and probable faulting, but there could be a downward transition.

Synonymy or modification of previous nomenclature:

This formation was originally described by Osborne (1942) under the name 'Smoky Mudstone Group'. This term is invalid under the rules of the Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964), but nevertheless is entrenched in the APC reports.

Bliri River Beds

Derivation of name:

Bliri River, one of the main rivers of the Aitape coastal region, draining a large area near longitude 142°E, and known as the Rainbrum River in its lower course over the coastal plain, Sepik District, Territory of New Guinea.

Distribution:

Widespread throughout the Torricelli and Bewani Mountains, as well as in the Oenake Mountains of the northern coastal range.

Lithology:

Generalized summary. Mudstone, pebbly mudstone, sandstone, grit and conglomerate with some thick limestone in the upper part, towards the base of which there are also volcanic rocks; greywacke, sandstone, grit conglomerate, lenticular limestone, agglomerate, lava and tuff in the lower part.

Type area:

Drainage area of the upper Bliri River south of latitude 3°13'S.

Type section locality:

None designated.

Thickness:

4500 - 5500 m.

Age:

Eocene (possibly even Upper Cretaceous) to Miocene. Tertiary Stages 'a' to 'f' inclusive, or T11 (?M23) to T33 (Visser and Hermes).

Fossils:

Foraminifera, corals.

Relations:

Possibly gradational and not clearly separated from the overlying Barida Beds; contact with the overlying Puwani Formation in western areas obscured by faulting. Contact with underlying basement complex also usually obscured by faulting, but the upper part probably overlaps the lower part in places, especially south of the mountain divide, where too it is more likely that sedimentary contacts with the basement complex will be found.

Synonymy or modification of previous nomenclature:

Raggatt (1928) originally used this term with no definition and no designation of type area or type section locality, beyond saying that the beds 'outcrop (sic) in the headwaters of the Bliri and Wini Rivers'. Osborne (1942) described most of this sequence under the term 'Bliri Group' divided into upper and lower divisions. His definition was 'the basal series of sediments laid down under geosynclinal conditions, characterised (sic) by consisting dominantly of sediments of mineral origin in contrast to the dominantly organic origin of the overlying Barida/Puwani Formation, and by including all sediments which possess original definitely 'e' and 'f' stage foraminifera'. This definition appears to be partly inconsistent from Osborne's own descriptions and partly questionable from more recent investigations. Though the definition says the 'basal series of sediments', Osborne himself included agglomerates, tuffs and lava flows in his description of the Lower Bliri. From this, one is entitled to extend his term Bliri below the Tertiary Stage 'e', if volcanics continue downwards, because the exposures are so disturbed and chaotic that at present it is impossible to establish an unequivocal section in which the volcanics would be confined to pre-Stage 'e'. Then it is doubtful whether the overlying rocks really are more dominantly organic than the Bliri rocks. This may well be true of the Puwani Formation, though its base is agreed to be faulted out; it would, I think, be dangerous to claim the same for the Barida Beds which to my mind are not yet sufficiently well known to justify such a comparison. In fact the Fieni Creek section of the Barida Beds does not appear to be especially rich in organic limestone and it is perhaps regrettable that this was not established as the type section of the Barida Beds.

On the other hand the definition clearly restricts the 'Bliri Group' to sediments of Stages 'e' and 'f'. Now the age of the volcanics, which are largely confined to the bottom part of the section, is not precisely known; they could easily be earlier than Stage 'e' and even be as old as Stages 'a' and 'b'. In fact this is probable from a comparison with the stratigraphy of Indonesian territory, where Visser and Hermes placed their Auwewa and Makats Formations in the whole interval from Tertiary Stages 'a' to 'f' inclusive. Quite clearly from the published descriptions the Auwewa and Makats Formations broadly correspond to the 'Bliri Group' of Osborne.

Thus there is an insuperable incompatibility between Osborne's definition and description of these rocks. Palaeontologically he restricts them by definition to Stages 'e' and 'f', but his lithological descriptions include volcanics some of which are probably much earlier than Stage 'e'.

We need a name for the rocks between the basement complex and the base of Stage 'g' rocks. These are recognizable on the photographs as Unit I which, though almost always characterless and amorphous, nevertheless can be readily distinguished from the basement below and from the overlying Unit II in some places. Generally speaking the surface knowledge of these rocks is poor, chiefly because a full regular and undisturbed sequence has not yet been found in the region. The Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964) caters excellently for such a situation with its definition of the term 'beds', and it seems that matters are not strained at the present state of knowledge by designating all the rocks of pre-Stage 'g' below the Puwani Formation and the Barida Beds and above basement as the Bliri River Beds. Raggatt's use of the term is too imprecise to invalidate this use, but yet evidently referred to much the same part of the stratigraphic column. Osborne excluded known exposures of definite Eocene (Tertiary Stages 'a' and 'b') limestone from his 'Bliri Group', but there is no point in recognizing them separately as yet, because their occurrence and nature is not well enough known to justify a stratigraphical name. In fact by including them in the Bliri River Beds, we strengthen the similarity with the Auwewa and Makats Formations west of the West Irian border.

Bulimp Formation

Derivation of name:

Bulimp Creek, tributary on right bank of Pulan River at approximately 3°05'S, 141°07'E, about 50 km south-south-west of Vanimo, Sepik District, Territory of New Guinea.

Distribution:

Main outcrop in a strip about 1.5 km wide from the Puwani River west-north-west to the West Irian border; on the northern flank of the Puwani - Ainbai Anticline; probably other outcrops along the Bewani mountain front between Neni Creek and Yalingi River; possibly in the Unumbu valley south of the Bewani Mountains. Main outcrop is clearly confirmed by photogeology (Unit V).

Lithology:

Generalized summary. Typically non-marine conglomerate, grit, greenish sandstone, and blue-green siltstone and mudstone, with carbonaceous streaks and beds, and occasional layers of partly altered woody material.

Type area:

The Bewani mountain front between the West Irian border and the Puwani River, in the middle reaches of the Bewani and Pulan river systems.

Type section locality:

Bulimp Creek from about 1 km above the junction with the Pulan River, at about the point where flat piedmont plains give way to low foothills, upstream for 1.5 km in a direct line.

Thickness:

At type section, 1615 m; in Kowa Creek (I1), tributary of east branch of Bewani River, 1100 m. Maximum unknown, but type section is probably nearly complete, though some of the top of the formation could be faulted out.

Age:

Pliocene. Tertiary Stage 'h', or T43 (Visser and Hermes).

Fossils:

Generally unfossiliferous but some pelagic foraminifera occur.

Relations:

Grades downwards into Krisi Formation through thick-bedded fossiliferous blue-grey mudstone and blue-green sandstone which are included in the Krisi Formation; upper boundary to Neumayer Beds probably everywhere faulted.

Synonymy or modification of previous nomenclature:

Nil. Originally defined by Osborne (1942).

16844/68—6

Ipe Formation

Derivation of name:

Ipe Creek, tributary on right bank of Amu River, at approximately 3°32'S, 142°50'E, or about 27 km south-west of Matapau, Sepik District, Territory of New Guinea.

Distribution:

In the valleys of the Nanu and Amu Rivers, in their upper middle reaches.

Lithology:

Generalized summary. Blue well-bedded to massive foraminiferal marls.

Type area:

In the vicinity of Arasili village (O22).

Type section locality:

In Wahu and Animbe Creeks, south of Arasili.

Thickness:

335 m in type section: 400 m measured in Ninab Creek (O24).

Age:

Pliocene.

Fossils:

Foraminifera, molluscs.

Relations:

Conformable with the underlying Misa Formation. Conformable with, and gradational to, overlying Nanu Formation.

Synonymy or modification of previous nomenclature:

Nil. Originally defined by Montgomery (1943).

Keang River Beds

Derivation of name:

Keang River, at approximately 3°37'30"S, 142°37'30"E, and about 55 km south-east of Aitape or 50 km south-west of Matapau, Sepik District, Territory of New Guinea.

Distribution:

Across the valleys of the Keang, Korp and Mihambom Rivers. Outcrop confirmed on aerial photographs (Unit III).

Lithology:

Generalized summary. Blue-green grit, sandstone and blotchy mudstone, with conglomerate in places.

Type area:

Keang River valley.

Type section locality:

Keang River from a point 1 km in a direct line downstream from the junction with Molang Creek for about 6 km downstream again in a direct line.

Thickness:

1220 m at type section.

Age:

Pliocene.

Fossils:

Foraminifera scarce, fossil wood and resin.

Relations:

The Keang River Beds are conformable on transition beds, 400 m thick, which Edwards recognized as a separate entity between the Keang River and Molang Creek Beds. He also recognized conformably above the Keang River Beds 160 m of a 'Fossiliferous Sandstone' unit, 45 m of the Ipe Formation and 1200 m of Nanu Formation. On the evidence of the photographs it seems probable that these beds above the Keang River Beds are Photogeological Unit IV or Nopan River Beds (i.e. 'Barrier Beds' of APC workers). This is the most important discrepancy between the surface and photogeological interpretations.

Synonymy or modification of previous nomenclature:

Nil. Originally defined by Edwards and Millward (1939).

Krisi Formation

Derivation of name:

Krisi ridge in front of the Bewani Mountains, west of the Puwani River at approximately 3°05'S, 141°05'E and about 50 km south-south-west of Vanimo, Sepik District, Territory of New Guinea.

Distribution:

Crops out from Bulimp Creek to the West Irian border in a strip about 1 km wide; may be represented in the Unumbu valley south of the Bewani Mountains. Main outcrop is clearly confirmed by photogeology (Unit IV).

Lithology:

Generalized summary. Dark blue sandstone weathering brown, fairly common quartz grit bands and lenses, some hard coal seams up to 60 cm thick, some shelly streaks and common thick hard bands of grey mudstone.

Type area:

The Bewani mountain front between the West Irian border and the Puwani River.

Type section locality:

Across the Krisi ridge from Bulimp Creek to the Pulan River.

Thickness:

At type section 1070 m; in Kowa Creek, tributary of east branch of Bewani River, 890 m. Maximum uncertain, but type section is probably complete and thickest.

Age:

Pliocene. Tertiary Stage 'h', or T43 (Visser and Hermes).

Fossils:

Not described.

Relations:

Gradational to overlying Bulimp Formation by about 60 m of blue-green sandstone and fossiliferous blue-grey mudstone. Gradational to underlying Bewani Formation by 150 m of massive sandstone and soft fossiliferous mudstone. Both gradational zones are included in the Krisi Formation.

Synonymy or modification of previous nomenclature:

Nil. Originally defined by Osborne (1942).

Misa Formation

Derivation of name:

Misa Creek at approximately 3°30'S, 142°54'E, tributary on left bank of Humal Creek, and about 25 km south-south-west of Matapau, Sepik District, Territory of New Guinea.

Distribution:

In the valleys of the Nanu and Amu Rivers, and the vicinity of Songaien village.

Lithology:

Generalized summary. Conglomerate, pebbly mudstone, sandstone, impure limestone, well-bedded blue foraminiferal marl, silty marl and silt. Current bedding and calcareous concretions are often conspicuous.

Type area:

In the vicinity of Arasili village.

Type section locality:

In the headwaters of Ipe Creek, tributary on right bank of the Amu River, north of Arasili.

Thickness:

920 m in type section; 950 m measured in Ninab Creek.

Age:

Pliocene.

Fossils:

Foraminifera, corals, molluscs.

Relations:

Conformable with, possibly gradational to, underlying Songaien Formation; conformable with the overlying Ipe Formation.

Synonymy or modification of previous nomenclature:

Montgomery (1943) originally described this unit as the 'Misa Group', on the strength of its 'composite character... which may be regarded as of three members'. Probably the unit can be divided satisfactorily into upper and lower conglomeratic phases, separated by foraminiferal marls, in which case group status could be reintroduced; but until the component formations are properly defined, it is clearly improper under the rules of the Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964) to validate the term 'Misa Group', which must become the Misa Formation.

Molang Creek Beds

Derivation of name:

Molang Creek tributary on left bank of Keang River, at approximately 3°30'S, 142°38'E, and about 52 km south-east of Aitape, Sepik District, Territory of New Guinea.

Distribution:

The valley of the Keang River above the junction of Molang Creek. Outcrop confirmed on aerial photographs (Unit II).

Lithology:

Generalized summary. Sandstone, conglomerate, foraminiferal silty and pebbly mudstone.

Type area:

Keang River valley.

Type section locality:

Keang River upstream from a point 1 km in direct line below the junction with Molang Creek, and then up Molang Creek to its junction with Selo Creek.

Thickness:

1750 m in type section.

Age:

Mio-Pliocene. Tertiary Stage 'g'.

Fossils:

Foraminifera, corals, molluscs.

Relations:

Probably unconformable on underlying Miocene rocks, but this is not proved; conformable with, and gradational to, overlying Keang River Beds.

Synonymy or modification of previous nomenclature:

Nil, though in fact Edwards and Millward (1939) did not use the term Molang Creek Beds when describing the succession perfectly clearly. The term crept in by implication in Montgomery's (1943) regional compilation of the geology, but the definition of these beds must be attributed to Edwards and Millward.

Nanu Formation

Derivation of name:

Nanu River, approximately 3°35'S, 142°50'E, and 30 km south-west of Matapau, Sepik District, Territory of New Guinea.

Distribution:

Upper middle reaches of the Nanu and Amu River valleys.

Lithology:

Generalized summary. Thick partly pebbly current-bedded sandstone underlying interbedded silt, sand and mudstone, with well-bedded and massive foraminiferal marls.

Type area:

The neighbourhood of Arasili village.

Type section locality:

From lower Animbe Creek across the Nanu River to near the village of Emul and then down Tunguor-Tunguor Creek to the Mihambom River.

Thickness:

1310 m in type section.

Age:

Pliocene.

Fossils:

Foraminifera.

Relations:

Conformable with, and gradational to, the underlying Ipe Formation; probably conformable with the overlying Nopan River Beds.

Synonymy or modification of previous nomenclature:

Montgomery (1943) originally described this unit under the term 'Nanu Group'. Probably it can be divided into upper and lower parts, which deserve naming as formations, but until these are better defined it is clearly inappropriate under the rules of the Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964) to call the whole the 'Nanu Group'.

Neni Formation

Derivation of name:

Neni Creek, tributary of Bliri River, at approximately 3°12'S, 142°00'E, and 22 km south-south-west of the coast at Sissano Lagoon, Sepik District, Territory of New Guinea.

Distribution:

On both flanks of the Barida-Nengian-Wapa'alu anticlinal uplift and from there westwards along the foothills of the Bewani mountain front to the Piore River.

Lithology:

Generalized summary. Drab grey foraminiferal marl with pebbly layers, especially towards base, below sandstone and silty micaceous mudstone with thin calcareous sandstone bands, below dominant fine-grained massive sandstone.

Type area:

Southern flank of the Barida-Nengian-Wapa'alu anticlinal structure.

Type section locality:

Tomoflu Creek, tributary on the northern or right bank of Neni Creek.

Thickness:

At type section 1650 m which is probably the maximum known thickness since in other measured sections parts of the sequence are faulted out or there are other uncertainties.

Age:

Pliocene. Tertiary Stage 'h', or T42-43 (Visser and Hermes).

Fossils:

Abundant foraminifera.

Relations:

Boundary to overlying Romi Formation gradational and conformable; boundary to underlying Mio-Pliocene rocks (Barida Beds) may be sharply defined but conformable, though in most places where the junction has been examined faulting probably occurs.

Synonymy or modification of previous nomenclature:

Osborne (1942) originally described this formation under the name 'Neni Group'. Under the rules of the Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964) the term 'Group' cannot here be maintained because the sequence cannot yet be subdivided into valid formations with valid names.

Neumayer Beds

Derivation of name:

Neumayer (Pual) River, draining the Neumayer Plains, which form an arc of flat country between the Oenake Mountains, Serra Hills and Bewani Mountains, south and south-east of Vanimo, Sepik District, Territory of New Guinea.

Distribution:

Along the mountain front across the tributary valleys of the Neumayer (Pual) River; and along the mountain front between the Neni and Nigia Rivers, south-west of Aitape.

Lithology:

Generalized summary. Flat-lying cross-bedded gravel, sand and silt.

Type area:)
Type section locality:)

Neither was designated by APC geologists, nor can either be suggested from photogeology. However, the valley of the Yalingi River north of the mountain front would probably be the correct type area because the APC geologists evidently considered the beds to be well developed thereabouts.

Thickness:

More than 45 m in the Yalingi area; more than 30 m and perhaps more than 120 m in the Neumayer Plains.

Age:

Pleistocene.

Fossils:

None recorded.

Relations:

Unconformable on Bulimp Formation in the Yalingi area; probably mostly fault contact in Neumayer Plains area.

Synonymy or modification of previous nomenclature:

Osborne (1942) and Montgomery (1943) discussed these beds under the names 'Yalingi Formation' or 'Yalingi Series'. Unfortunately the name 'Yalingi' was preoccupied by Raggatt (1928) who used it for the 'Yalingi River and Ulau Beds'; worse still, the beds to which he referred clearly are different from those which APC geologists recognized as the 'Yalingi Formation'. Thus it is now necessary to propose a new name, but the beds are still inadequately defined and described. They correspond to Photogeological Unit VI north of the mountains and may be the rough equivalent of the similar unit south of the mountains.

Nopan River Beds

Derivation of name:

Nopan River, flowing south from the Torricelli Mountains approximately along longitude 142°12'E, Sepik District, Territory of New Guinea.

Distribution:

Along the southern foothills of the Torricelli-Bewani Mountains, bordering the Sepik Plains from the Denubu (Yenabu) River on the west at least to the Korp River on the east. Equals Photogeological Unit IV south of the mountain divide.

Lithology:

Generalized summary. Alternating sandstone, friable sand, blue and varicoloured silt and mudstone, with some conglomerate near the base.

Type area:)
Type section locality:)

Neither can be designated because APC geologists never examined a full section. From the aerial photographs it is clear that a wide uniform outcrop, forming massive and perfect dip-slopes, extends along the southern foothills, as mentioned above, and that the base of this unit is where APC geologists put the base of their 'Barrier Beds'. They studied the formation mostly in the area between longitude 142°E and 142°30'E. Therefore it is reasonable to suggest this for a type area and to point out that the Nopan River section appears to be probably the best for a type locality, because it is evidently little disturbed by faulting.

Thickness:

At least 1500 m estimated from width of outcrop and amount of regional dip.

Age:

Pliocene.

Fossils:

Lamellibranchs in lower part; marine fossils scarce or absent in upper part.

Relations:

Conformable on underlying Pliocene Nanu Formation in suggested type area but unconformable overlap probably develops westward; probably conformable in type area with overlying unnamed unit, but again unconformable overlap probably develops westwards.

Synonymy or modification of previous nomenclature:

Montgomery (1943) partially described this formation as the 'Barrier Beds'. This is strictly not acceptable under the Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964) because the word 'Barrier' is here not a geographical place name. It is also invalid because the term 'Barrier' is preoccupied by formation names on the Australian mainland. I therefore propose the term Nopan River Beds because, judging from the photographs, the section exposed in that river appears to be complete, probably of maximum thickness and probably not greatly faulted; it is certainly near the middle of the outcrop.

Puwani Formation

Derivation of name:

Puwani River, tributary of the Neumayer (Pual) River at approximately 3°05'S, 141°09'E, 50 km south-south-west of Vanimo, Sepik District, Territory of New Guinea.

Distribution:

Between the Maiu and Puwani Rivers, in the Puwani-Ainbai Anticline; and west of the Puwani River to the east branch of the Bewani River. Main outcrop confirmed by photogeology (Unit II).

Lithology:

Generalized summary. Foraminiferal marl with interbedded detrital and reef limestone overlying massive reef limestone.

Type area:

Puwani-Ainbai Anticline between Puwani and Maiu Rivers.

Type section locality:

Puwani (Me) River, below junction with Kulanap Creek for 1.5 km.

Thickness:

365+ m at type section, where the base is not seen.

Age:

Mio-Pliocene. Tertiary Stage 'g', or T34-T42 (Visser and Hermes).

Fossils:

Foraminifera, corals, algae.

Relations:

Possibly but doubtfully gradational to the overlying Bewani Formation; lower boundary nowhere observed, being obscured by faulting.

Synonymy or modification of previous nomenclature:

Nil. Originally described by Osborne (1942).

Romi Formation

Derivation of name:

Village of Romi on Neni Creek, at approximately 3°13'S, 142°00'E, about 22 km south-south-west of the coast at the mouth of Sissano Lagoon, Sepik District, Territory of New Guinea. This village has been moved since Osborne surveyed the district and the site is no longer occupied. The name (now spelt Romei) is at present applied to the village and mission centre on Oi Creek north of the Barida Hills at approximately 3°10' S, 142°03'E.

Distribution:

Large outcrop between the Serra Hills and the mountain front of the Bewanis, i.e. in the divide between drainage areas of the Fivuma and Sereri Rivers; across the middle reaches of all rivers flowing out of the mountains from Neni Creek to the Raihu River; over much of the eastern half of the Oenake Mountains south of Vanimo.

Lithology:

Generalized summary. Foraminiferal marl, silty mudstone, siltstone and mudstone - drab greenish to bluish-grey, usually massive.

Type area:

The southern flank of the Barida-Nengian-Wapa'alu anticlinal trend, in that part of the Neni Creek, Pieni, Nengo and Yalingi Rivers drainage area at the foot of the Torricelli Mountains, extending about 5 km north from the mountains.

Type section locality:

Neni Creek, upstream from the former site of Romi village near where longitude 142°E crosses the stream, for about 6 or 7 km direct.

Thickness:

520 m in the type section; maximum measured as 700 m in Basu River (F-H7) on the western side of the Serra Hills.

Age:

Pliocene. Tertiary Stage 'h', or T43 (Visser and Hermes).

Fossils:

Foraminifera, bryozoa, large molluscs, the last named distinguishing the formation from the rest of the stratigraphical column.

Relations:

Fairly sharply defined, but conformable with overlying Bulimp Formation; gradational to, and conformable with, underlying Neni Formation near the mountains, but apparently overlaps the Neni Formation to rest unconformably on earlier Tertiary (Miocene) rocks in the Serra Hills and Oenake Mountains.

Synonymy or modification of previous nomenclature:

Nil. Originally defined by Osborne (1942).

Songaien Formation

Derivation of name:

Songaien village, at approximately 3°29'S, 142°45'E, 32 km south-west of Matapau, Sepik District, Territory of New Guinea.

Distribution:

Only recognized in the upper middle reaches of the Amu and Nanu River drainage area, approximately centred at 3°30'S, 142°50'E.

Lithology:

Generalized summary. At the base fine-grade conglomerate, grit, sandstone, silt and silty mudstone ('Wundi Member'), underlying massive dark grey foraminiferal marl, in places pebbly, and often slumped ('Songaien Marl Member').

Type area:

Nanu valley south and south-west of Songaien village.

Type section locality:

Wundi Creek for the lower part which Montgomery separated as the 'Wundi Member'. Mindainyamoran and Mindainangara Creeks for the upper part ('Songaien Marl Member'), south of the village of Yasum.

Thickness:

245 m - 'Wundi Member' type section. At least 445 m - 'Songaien Marl Member' type section. Maximum total thickness estimated as 920 m.

Age:

Mio-Pliocene. Tertiary Stage 'g'.

Fossils:

Foraminifera.

Relations:

Relations with underlying Bliri River Beds not established. Conformable with, perhaps gradational to, overlying Misa Formation.

Synonymy or modification of previous nomenclature:

Nil. Originally defined by Montgomery (1943).

'Sand River Beds' (Informal name)

Derivation of name:

Sand River, one of the major rivers flowing south from the Torricelli-Bewani Mountains, approximately along longitude 141°45'E, Sepik District, Territory of New Guinea.

Distribution:

Along the northern edge of the Sepik Plains approximately between longitudes 141°E and 142°E.

Lithology:

Generalized summary. Current-bedded sand and silt with distinctive red colour.

Type area:)
Type section locality:)

Not designated, but APC geologists recognized this unit in 'the country west of the Nopan River'. As it is doubtful whether the division corresponds with a Photogeological Unit, it is at present impossible to suggest a suitable type area or type section locality.

Thickness:

Unknown, but probably small.

Age:

Pleistocene.

Fossils:

Fragmentary lamellibranchs.

Relations:

Reported to be 'clearly unconformable on steeply dipping beds' at Bis Creek (Q11) near Maurom.

Synonymy or modification of previous nomenclature:

Montgomery (1943) referred to these beds as the 'Sand River Series', which is clearly inadmissible under the rules of the Australian Code of Stratigraphic Nomenclature (Geol. Soc. Aust., 1964).

Remarks:

These beds cannot be properly described or defined at present, nor can they be certainly correlated with a Photogeological Unit. In my opinion they probably represent Unit VI which occurs between the Sepik Plains and clearly dipping Pliocene rocks from the Sand River to the Nopan River, since this unit seems to be generally flat-lying and probably unconformable on underlying beds, as well as cropping out well in the Sand River itself. On the other hand Montgomery certainly correlated them with what I recognized as Photogeological Unit V. I think this may be wrong because Unit V clearly has a well expressed dip everywhere in its outcrop, appears to be broadly conformable with Unit IV (Nopan River Beds), except that overlap may occur westwards along the boundary, and probably hardly crops out in the Sand River because of faulting. Moreover as support for the correlation with Unit VI and against correlation with Unit V, APC geologists suggested that the 'Sand River Beds' were 'equivalents of the Yalingi Series of the Aitape-Vanimo region to the north of the mountains'. On photographic evidence Unit V could never be so correlated. For completeness of discussion of the stratigraphy, it is necessary to recognize the term 'Sand River Beds', even if they cannot yet be defined.

APPENDIX 2

MICROPALAEONTOLOGICAL EXAMINATION OF OUTCROP SAMPLES FROM NEW GUINEA

by

G.R.J. Terpstra **

Eight samples collected and submitted by S. Marchant from outcrops in New Guinea have been examined for microfossils.

The following results were obtained:

MA 14 *4447: 3°25'S, 143°26'E.
Roadside between Karawop Point and Boiken Mission. Calcareous soft sandstone; few poorly preserved foraminifera.
Age: Indeterminable.

MA 17 *4447: 3°29'S, 143°29'E.
Roadside near Hawain Bridge, west of Wewak. Marl with bands of sandstone. Preservation fair.
Age: Probably upper Miocene to lower Pliocene.

MA 18 *4547: 3°36'S, 143°39'E.
Wewak-Maprik road about four miles from Wewak. Marl. Well-preserved foraminiferal fauna.
Age: Near boundary upper Miocene to lower Pliocene.

MA 19 *4547: 3°38'S, 143°38'E.
Wewak-Maprik road about ten miles from Wewak. Marl. Well-preserved foraminiferal fauna.
Age: Near boundary upper Miocene to lower Pliocene.

MA 20 *4546: 3°42'S, 143°31'E.
Tangori, Wewak-Maprik road. Marl. Well-preserved foraminiferal fauna.
Age: Near boundary upper Miocene to lower Pliocene.

MA 21 *4546: 3°43'30"S, 143°30'30"E.
Minjim River Crossing, Wewak-Maprik road. Marl. Well-preserved foraminiferal fauna.
Age: Near boundary upper Miocene to lower Pliocene.

MA 22 *4446: 3°42'S, 143°28'E.
Minjim River, west of Sassoia. Marl. Well-preserved foraminiferal fauna.
Age: Near boundary upper Miocene to lower Pliocene.

MA 23 *4547: 3°38'30"S, 143°38'30"E.
MP/11 on Wewak-Maprik road. Marl. Well-preserved foraminiferal fauna.
Age: Near boundary upper Miocene to lower Pliocene.

** Bureau of Mineral Resources, Canberra. 16 September, 1966.

* Four-figure (4447) = Official 1:100,000 topographical sheet number. Co-ordinates are approximate.

Conclusions

The samples MA18, 19, 20, 21, 22 and 23 contain well preserved fairly rich planktonic faunas, indicating for all the same stratigraphical level: upper Miocene.

On a recent attempt to fix the upper Miocene - lower Pliocene boundary, Orville L. Bandy (Micropaleontology, 10 (1), January, 1964) discussed the Miocene-Pliocene succession of the Philippines (Iloilo, Southern Panay); he selected Sphaeroidinella dehiscens dehiscens and Pulleniatina obiquiloculata as species to mark this boundary. Other authors however have different views. These species do occur in the samples examined apart from others, however, indicating upper Miocene. In view of this the faunas may well derive from beds near the boundary between upper Miocene and lower Pliocene or in other words from fairly high upper Miocene strata.

MOLUCCAS – NEW GUINEA

STRUCTURAL INTERPRETATION

(after Visser and Hermes)

Scale 1:10,000,000

200 0 200 400 600 MILES

200 0 200 400 600 800 1000 KILOMETRES

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Reference

- Continental margin
- Zones of negative isostatic anomaly
- Epicentres of deep and intermediate earthquakes
- Volcanic arcs with positions of active volcanoes
- f—f Main fault zones
- Highs
- \+ Gravity maxima
- – Gravity minima
- 1500 Areas of deep water: maximum depth in metres
- Depression

Bathymetric contours (after Krause, 1965)

Depth in fathoms

0 1000 1500 2000 2500

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Drawn by: J. L. McGovern

MINDANAO
PHILIPPINE DEEP
9032
3400
5100
TERNATE
4180
HALMAHERA
4750
SULA
SORONG FAULT ZONE
SOUTH WESTERN ARC
VOGELKOP
1000
2000
Geelvink Bay
1500
CELEBES
CERAM
BURU
5800
MEERVLAKTE
SEPIK PLAINS
WAKDE IS
NINGO IS
HERMIT IS
ADMIRALTY IS
BISMARCK ARCHIPELAGO
NEW IRELAND
NEW BRITAIN
5100
WEBER DEEP
7440
KEI IS
ARU BASIN
3650
ARU IS
ARC
BANDA
INNER
OUTER
5400
WETAR
FLORES
TIMOR
3370
TIMOR DEEP
3310
SOUTH WESTERN ARC
ARAFURA SHELF
SAHUL SHELF
NEW GUINEA
STABLE CONTINENTAL AREA
LAE
PACIFIC OCEAN
TIMOR OR ARAFURA SEA
INDIAN OCEAN
DARWIN
GULF OF CARPENTARIA
CORAL SEA
AUSTRALIA

FIRST EDITION 1967

Plate 26, BMR Report 130

EXPLANATORY SHEET

TO ACCOMPANY

1:100,000 PHOTOGEOLOGICAL MAPS OF NEW GUINEA, NORTH OF SEPIK RIVER

SYMBOLS

Photogeology

- Geological boundary
- Geological boundary uncertain
- Dip slope
- Dip slope doubtful
- Horizontal bedding
- Horizontal bedding doubtful
- Slight dip
- Slight dip doubtful
- Ridge or trendline
- Ridge or trendline doubtful
- Anticline showing plunge
- Anticline doubtful
- Syncline showing plunge
- Syncline doubtful
- Major fault
- Minor fault
- Major fault doubtful
- Minor fault doubtful

(see note in text, under 'Structure')

Regional dip and strike from A.P.C. data

- Horizontal
- <10°
- 10°–29°
- 30°–49°
- 50°–69°
- 70°–89°
- Vertical
- Overturned

Oil indications and well

- Oil and gas show
- Gas show
- Gas show position uncertain
- Gas show doubtful
- Oil smell
- Oil seepage
- Group of oil seepages
- Dry hole abandoned

Topography

- Motor road
- Motor road position uncertain
- Vehicle track
- Vehicle track position uncertain
- Path
- Village
- Airstrip
- Mountain top
- • 1250 Elevation in metres a.s.l. approximate
- Landslip
- Spring: SW—Brine; H_2S—Sulphurous; H—Hot
- Drainage
- Lake
- Swamp
- Grassland

PHOTOGEOLOGICAL UNITS

QUATERNARY

- Raised coral
- Alluvium
- Terraces
- VIo — Photogeological Unit VI

TERTIARY

- Vℓ — Hollandia limestone
- V — Photogeological Unit V
- IV — Photogeological Unit IV
- III — Photogeological Unit III
- II — Photogeological Unit II
- I — Photogeological Unit I
- "Yagroner Limestone"

BASEMENT

- B_3 — Metamorphics
- B_2 — Varied: doubtful rock types
- B_1 — Mainly plutonic

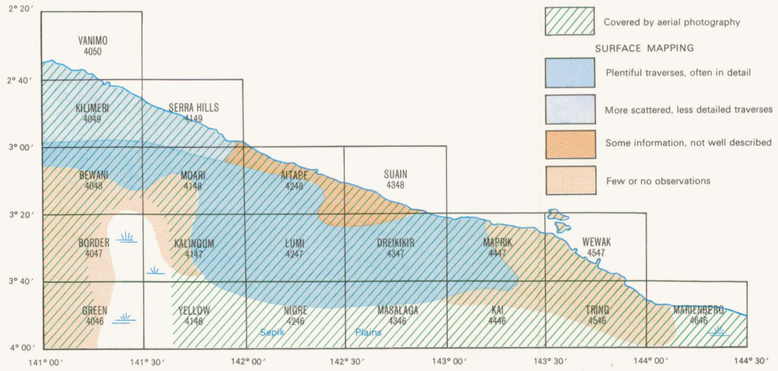
GENERAL NOTES

The maps have been compiled from a study of the available photographs of the area, as shown on the Geological Reliability Diagram, supplemented by surface information recorded by geologists of the Australasian Petroleum Company Pty. Ltd. The grading of this is also shown on the Geological Reliability Diagram.

Regional magnetic declination is between 4.5 and 5 degrees East with very small annual increase.

Spelling of place names in New Guinea is difficult. Therefore no attempt has been made to follow any standardized system or to achieve orthography. Only a selection of villages is shown on the maps and their locations may not be correct because they are liable to be moved and even to change their names. As many names as seem reasonable have been given for rivers and creeks, for these are more permanent than village names.

GEOLOGICAL RELIABILITY DIAGRAM



TOPOGRAPHICAL RELIABILITY DIAGRAM

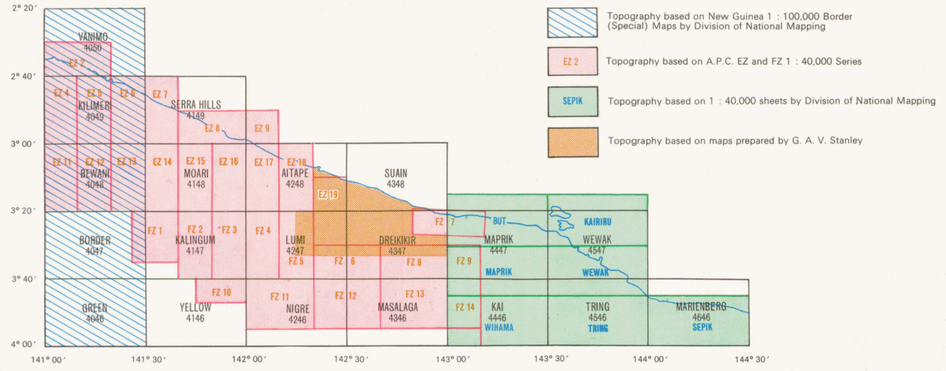


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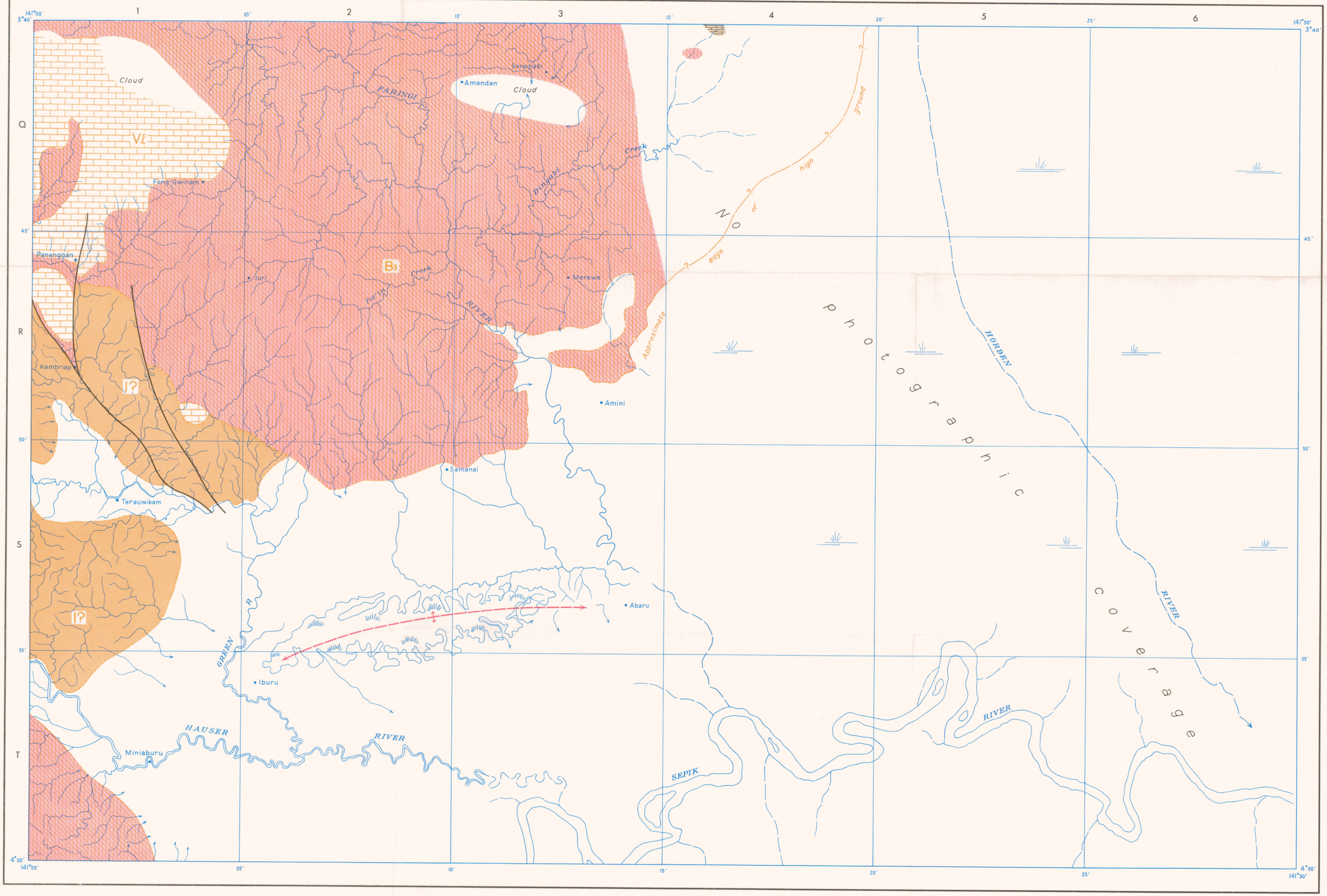
Plate 1, BMR Report 130

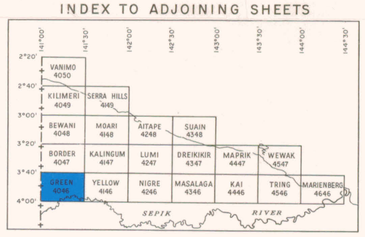
NEW GUINEA 1:100,000

GREEN

PHOTOGEOLOGICAL SHEET 4046



INDEX TO ADJOINING SHEETS



Scale 1:100,000

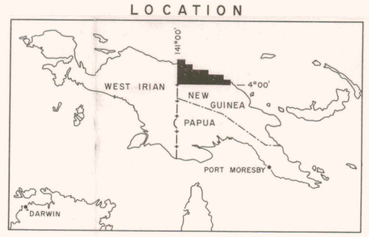
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



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Topography based on New Guinea 1 : 100,000 Border (Special) Map Sheet 2 by Division of National Mapping.

Universal Transverse Mercator Projection.

FIRST EDITION 1967

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Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 2, BMR Report 130

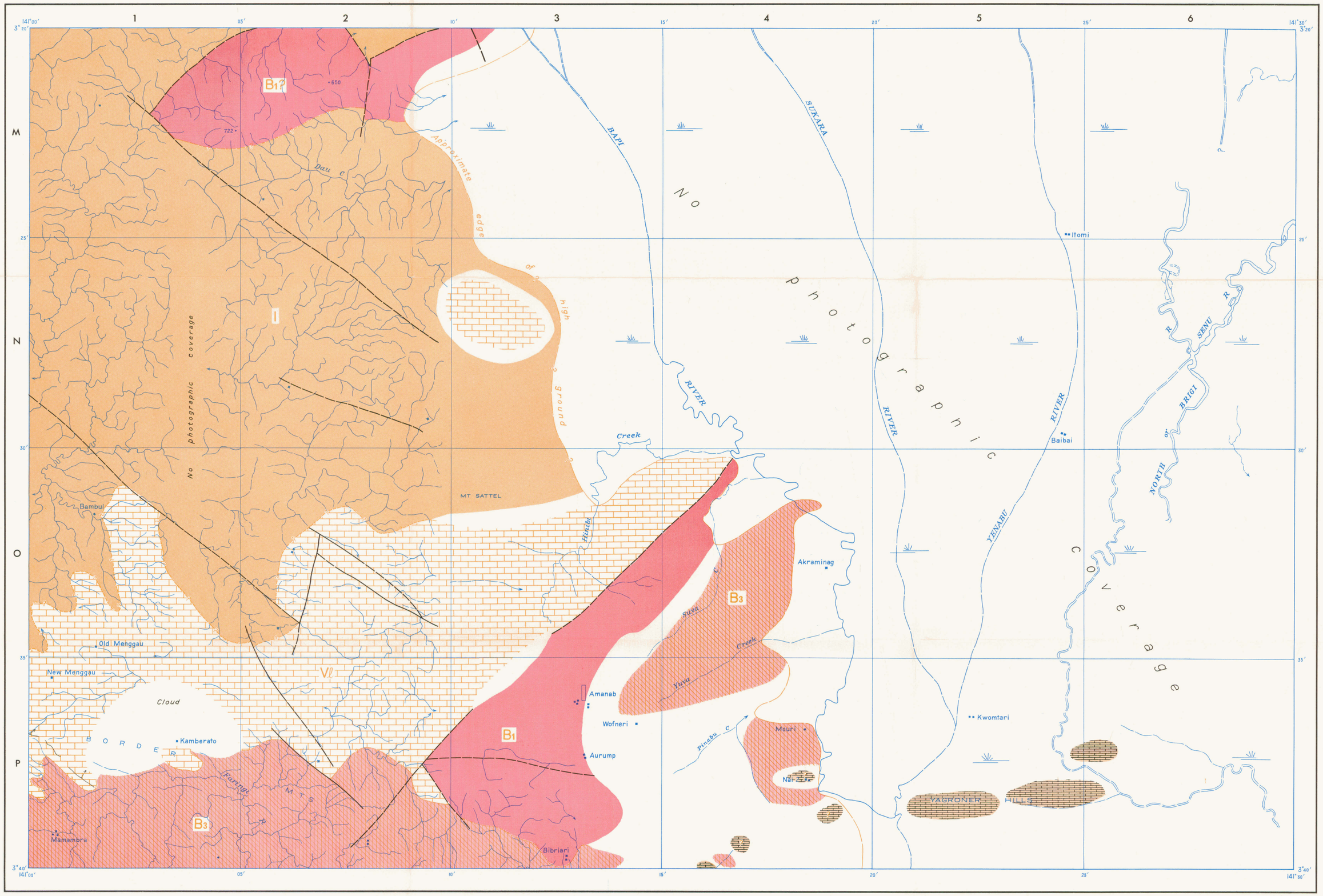
GREEN 4046

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

BORDER

PHOTOGEOLOGICAL SHEET 4047



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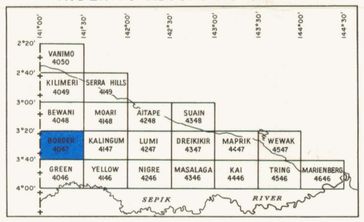

Scale 1:100,000

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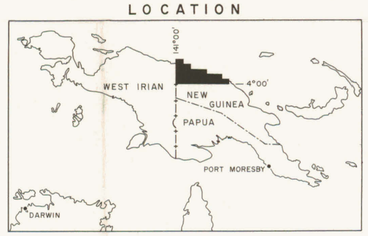
1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



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Universal Transverse Mercator Projection.

FIRST EDITION 1967

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Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 3, BMR Report 130

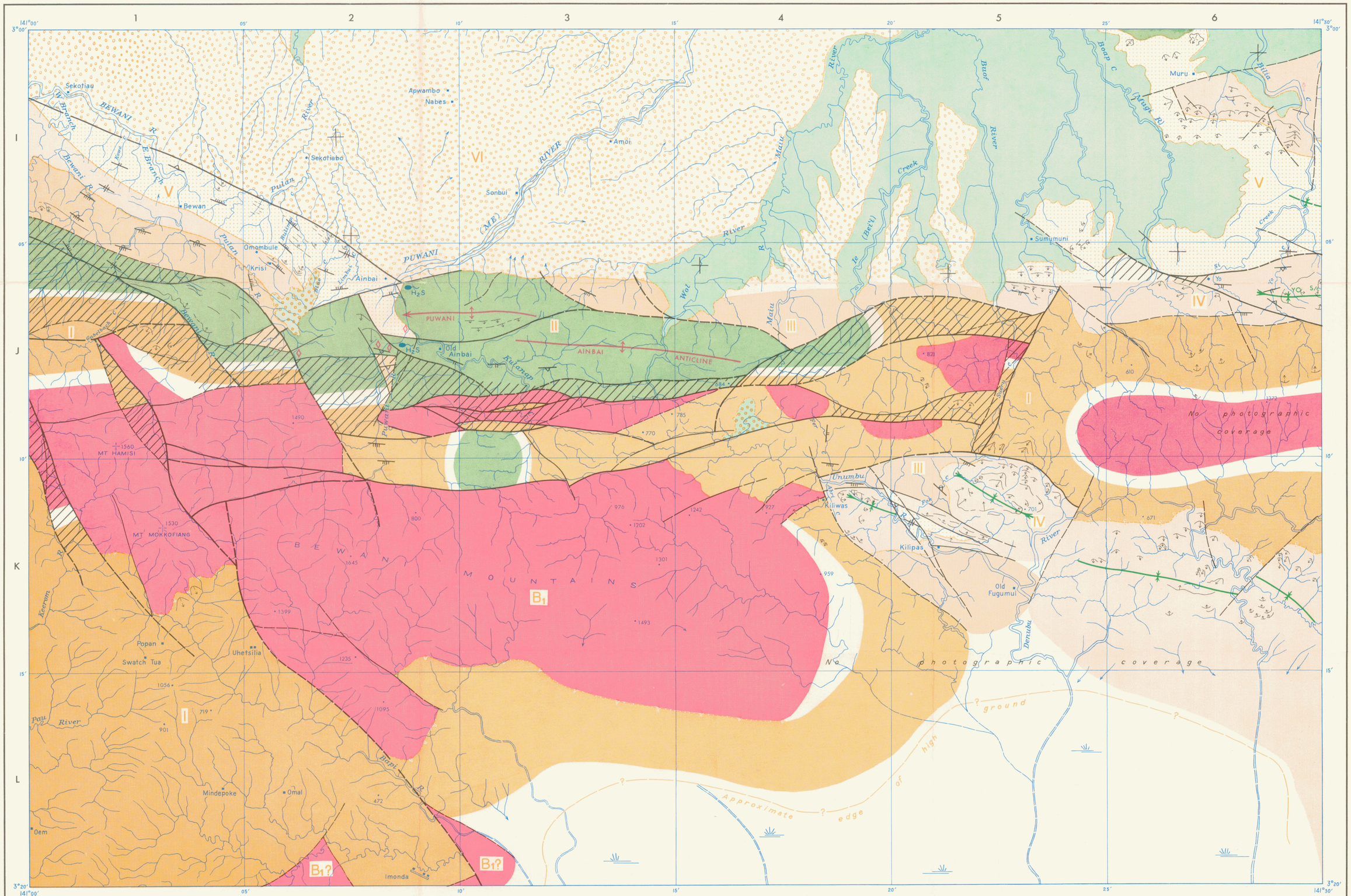
BORDER 4047

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

BEWANI

PHOTOGEOLOGICAL SHEET 4048



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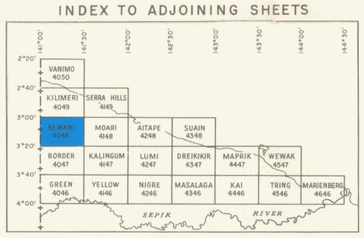

Scale 1:100,000

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1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION

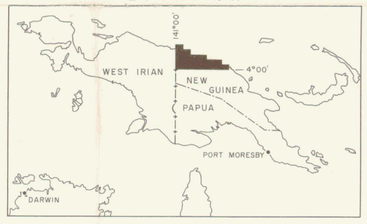

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Plate 4, BMR Report 130

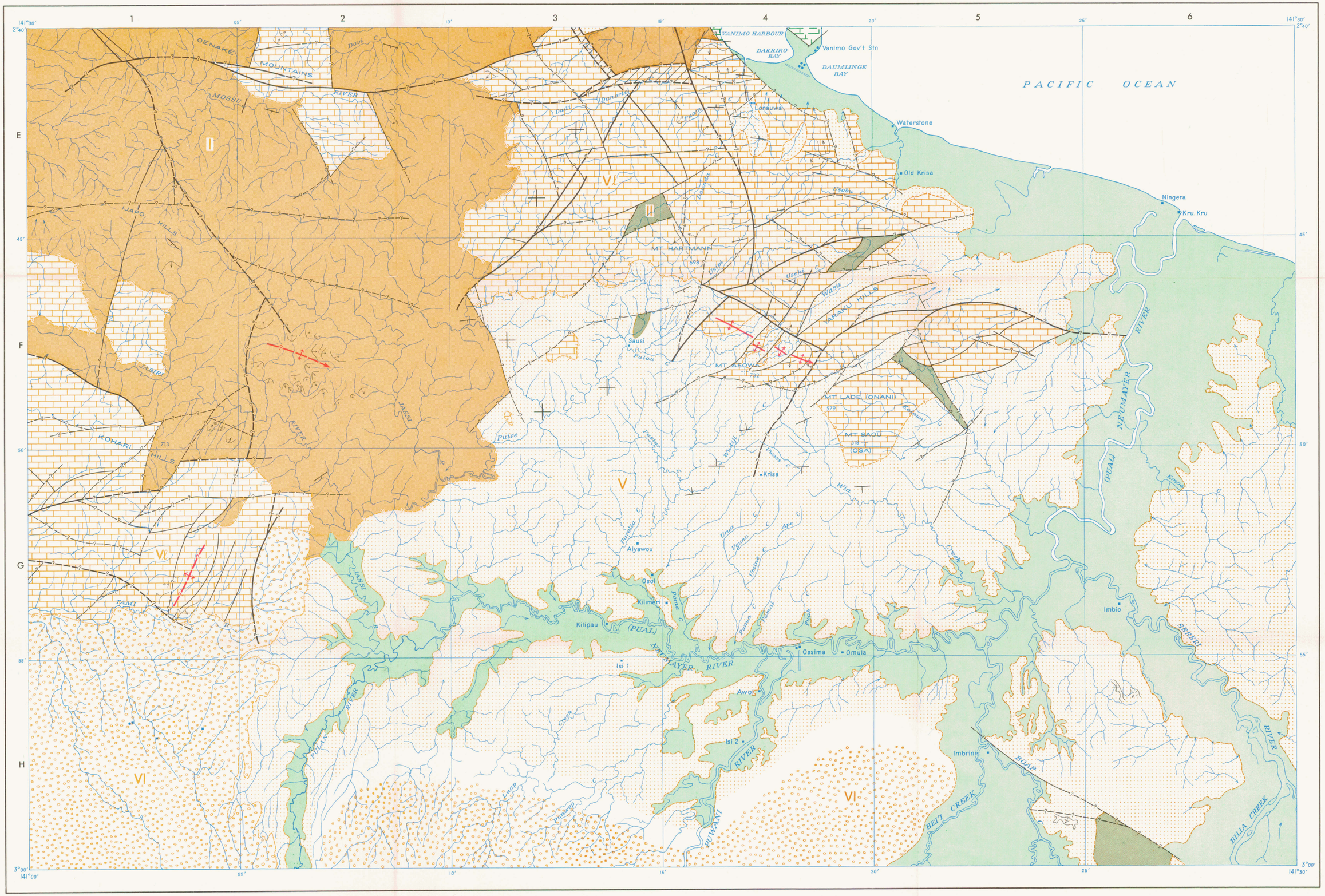
BEWANI 4048

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

KILIMERI

PHOTOGEOLOGICAL SHEET 4049



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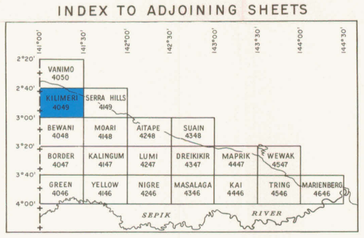

Scale 1:100,000

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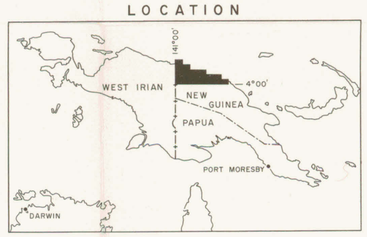
1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



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Topography based on New Guinea 1 : 100,000 Border (Special) Map Sheet 1 by Division of National Mapping, supplemented by A.P.C. EZ 4, EZ 5, and EZ 6 sheets.

Universal Transverse Mercator Projection.

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Plate 5, BMR Report 130

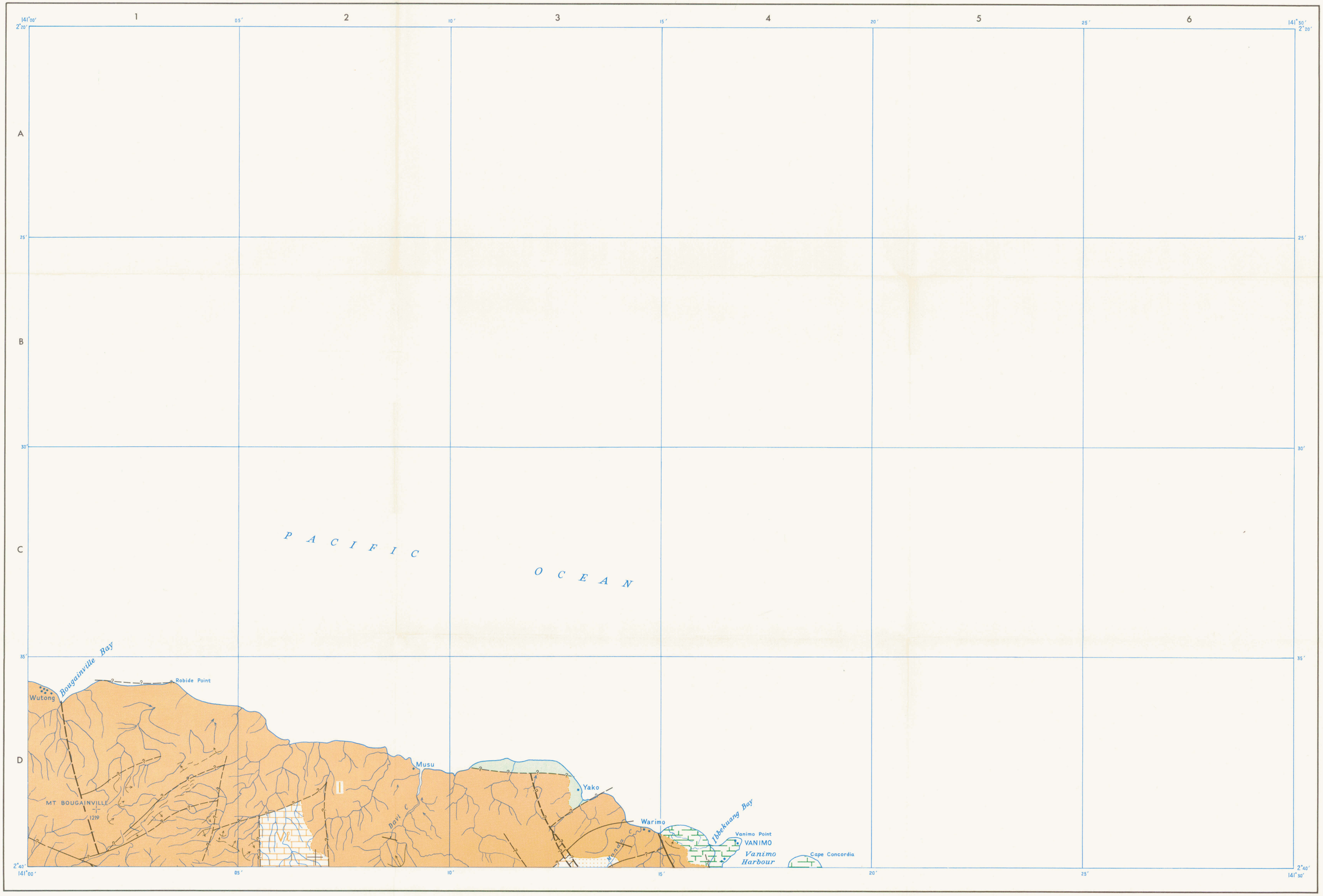
KILIMERI 4049

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

VANIMO

PHOTOGEOLOGICAL SHEET 4050



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Universal Transverse Mercator Projection.

FIRST EDITION 1967

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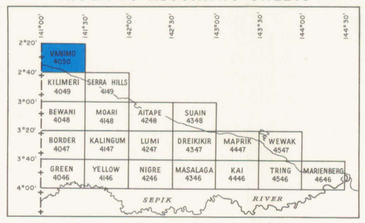

Scale 1:100,000

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1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION

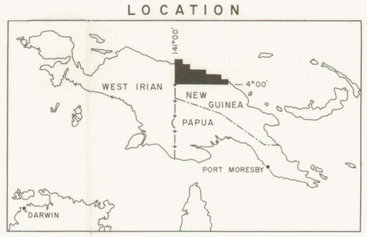

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Plate 6, BMR Report 130

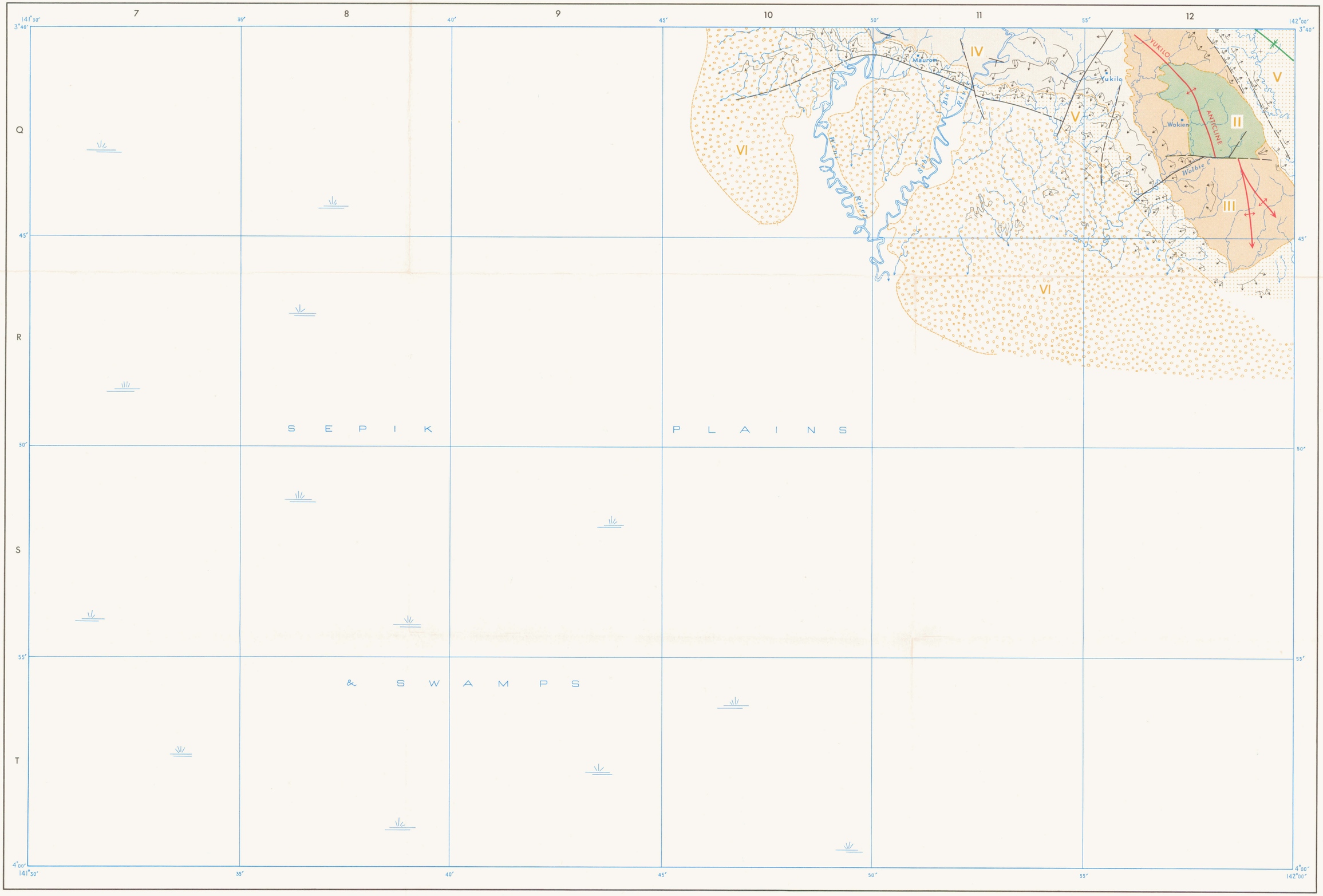
VANIMO 4050

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

YELLOW

PHOTOGEOLOGICAL SHEET 4146



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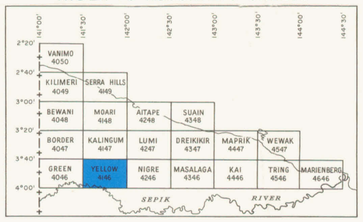
INDEX TO ADJOINING SHEETS



Scale 1:100,000

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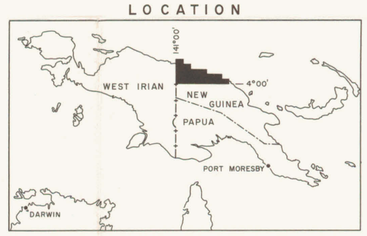
1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
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Plate 7, BMR Report 130

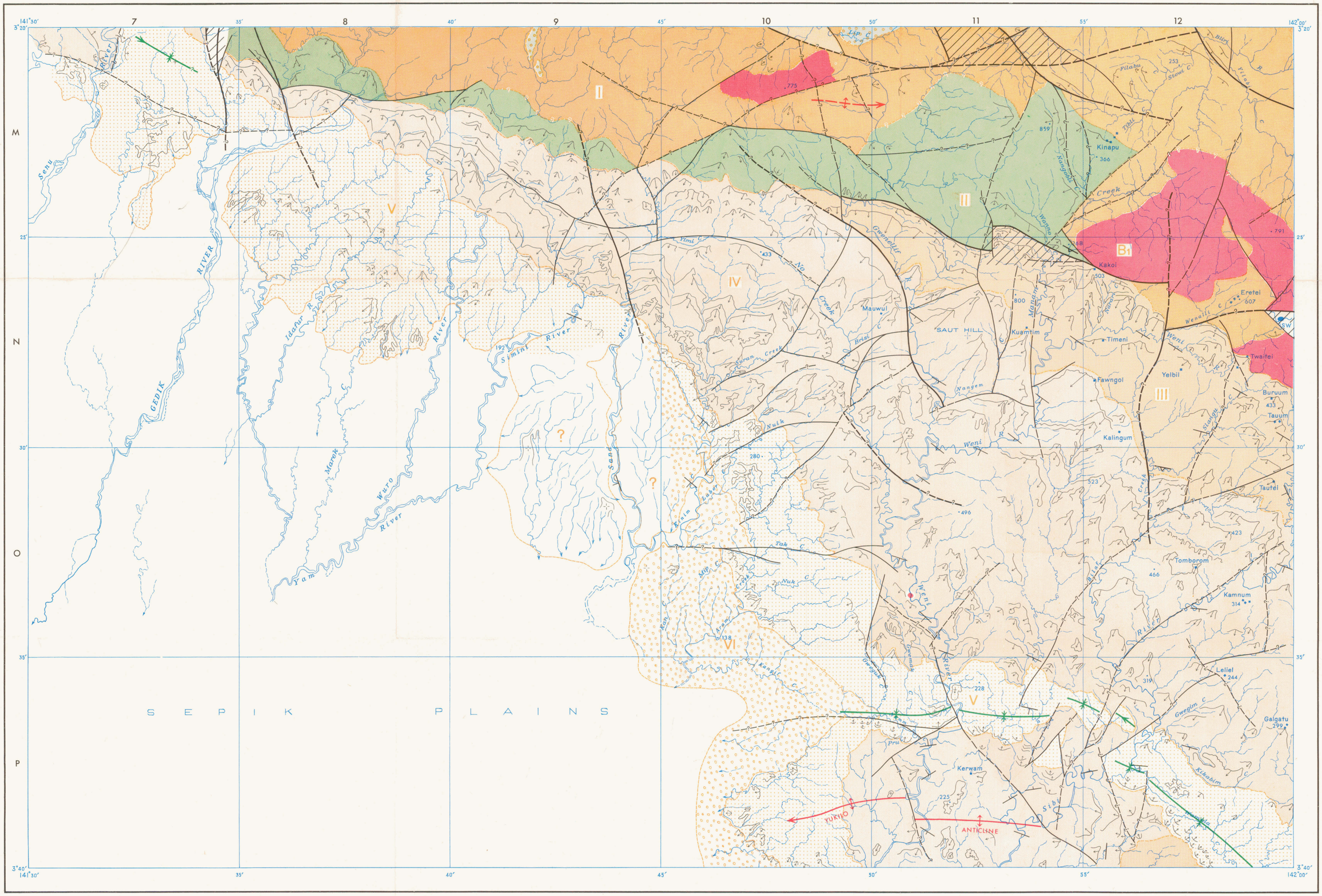
YELLOW 4146

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

KALINGUM

PHOTOGEOLOGICAL SHEET 4147



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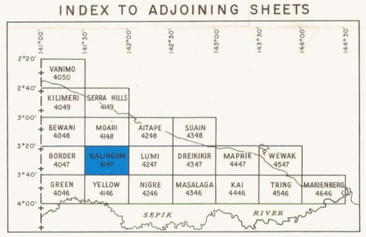

Scale 1:100,000

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1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

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LOCATION

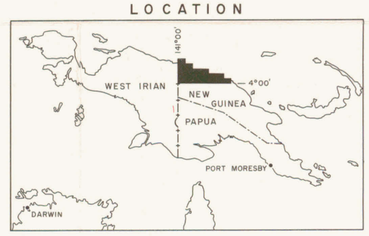

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Plate 8, BMR Report 130

KALINGUM 4147

TERRITORY OF NEW GUINEA

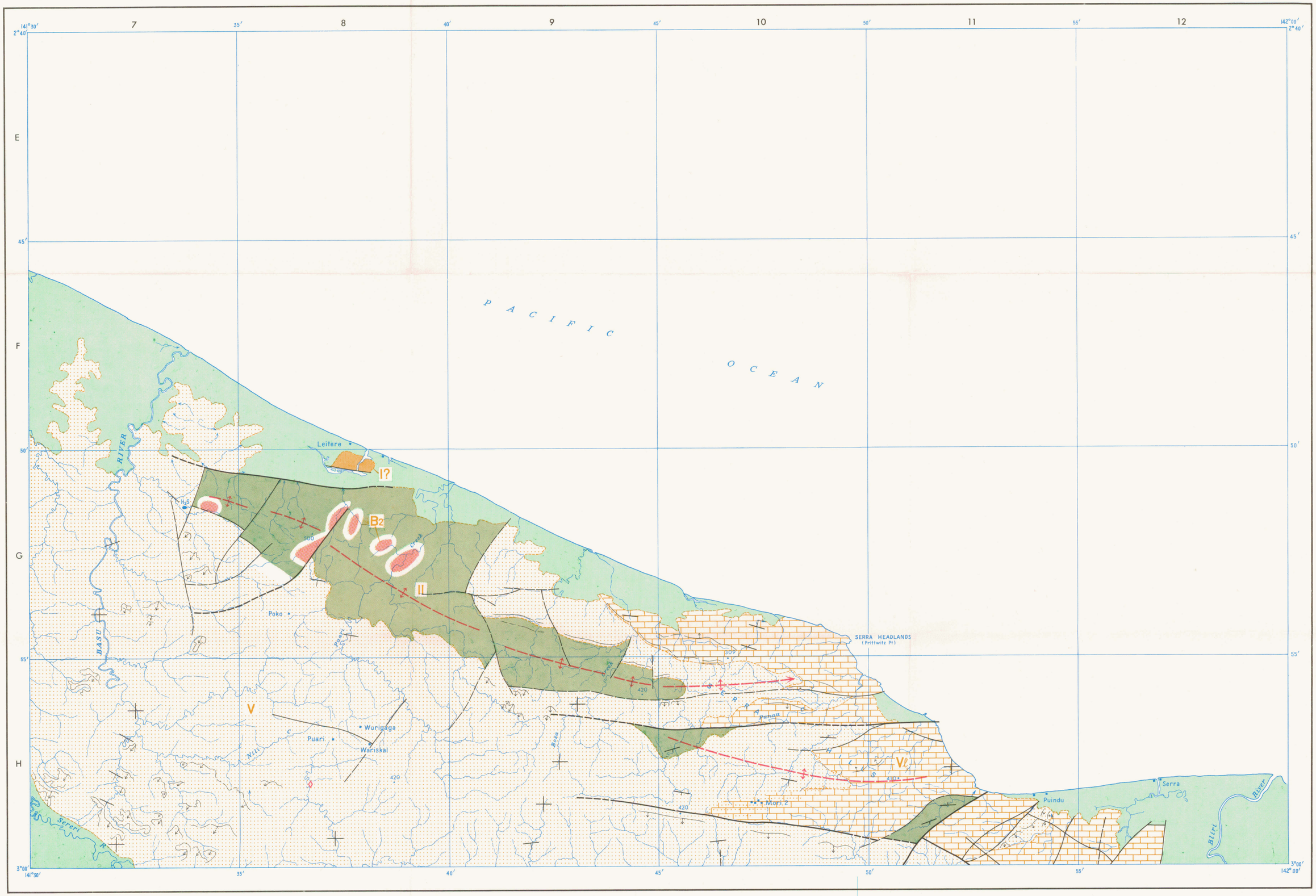
PHOTOGEOLOGICAL SHEET 4148 NEW GUINEA 1:100,000 MOARI

PHOTOGEOLOGICAL SHEET 4148 NEW GUINEA 1:100,000 MOARI

NEW GUINEA 1:100,000

SERRA HILLS

PHOTOGEOLOGICAL SHEET 4149



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Universal Transverse Mercator Projection.

FIRST EDITION 1967

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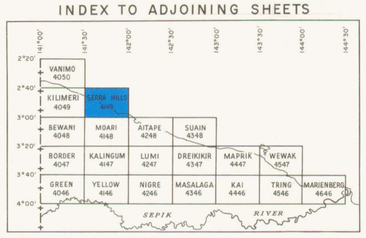

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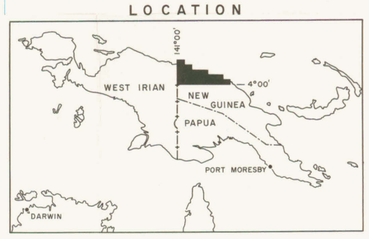
1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



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Cartography by: K. Matveev, Petroleum Exploration Branch BMR
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Plate 10, BMR Report 130

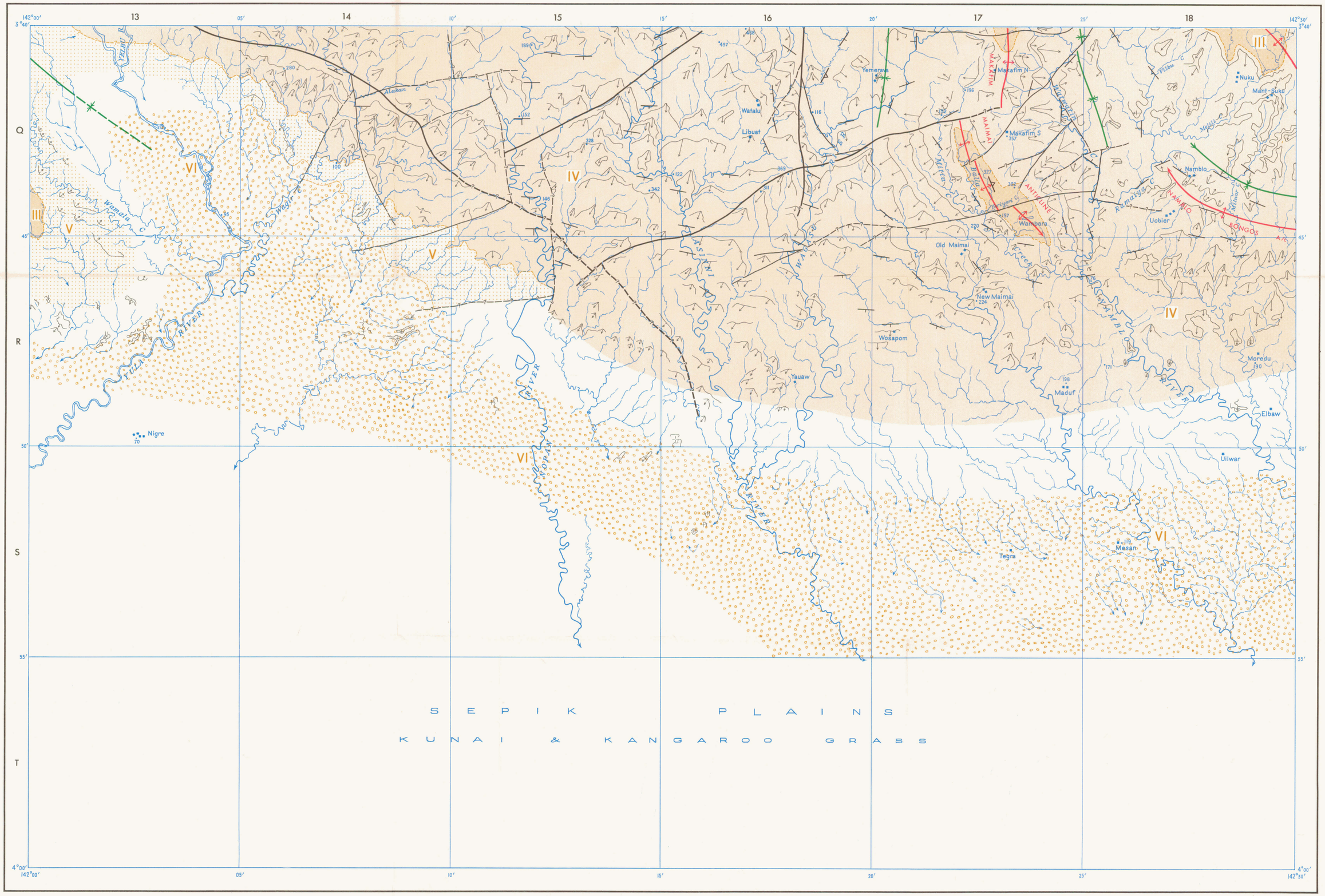
SERRA HILLS 4149

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

NIGRE

PHOTOGEOLOGICAL SHEET 4246



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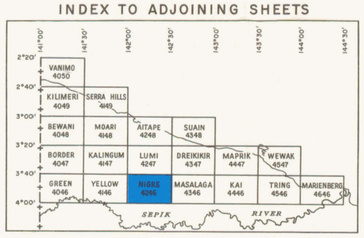
Universal Transverse Mercator Projection.

FIRST EDITION 1967

INDEX TO ADJOINING SHEETS



Scale 1:100,000

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1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

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LOCATION

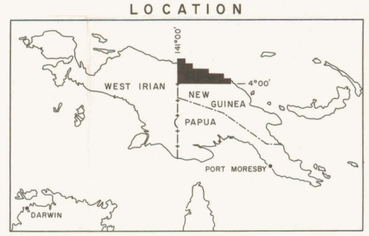

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Plate 11, BMR Report 130

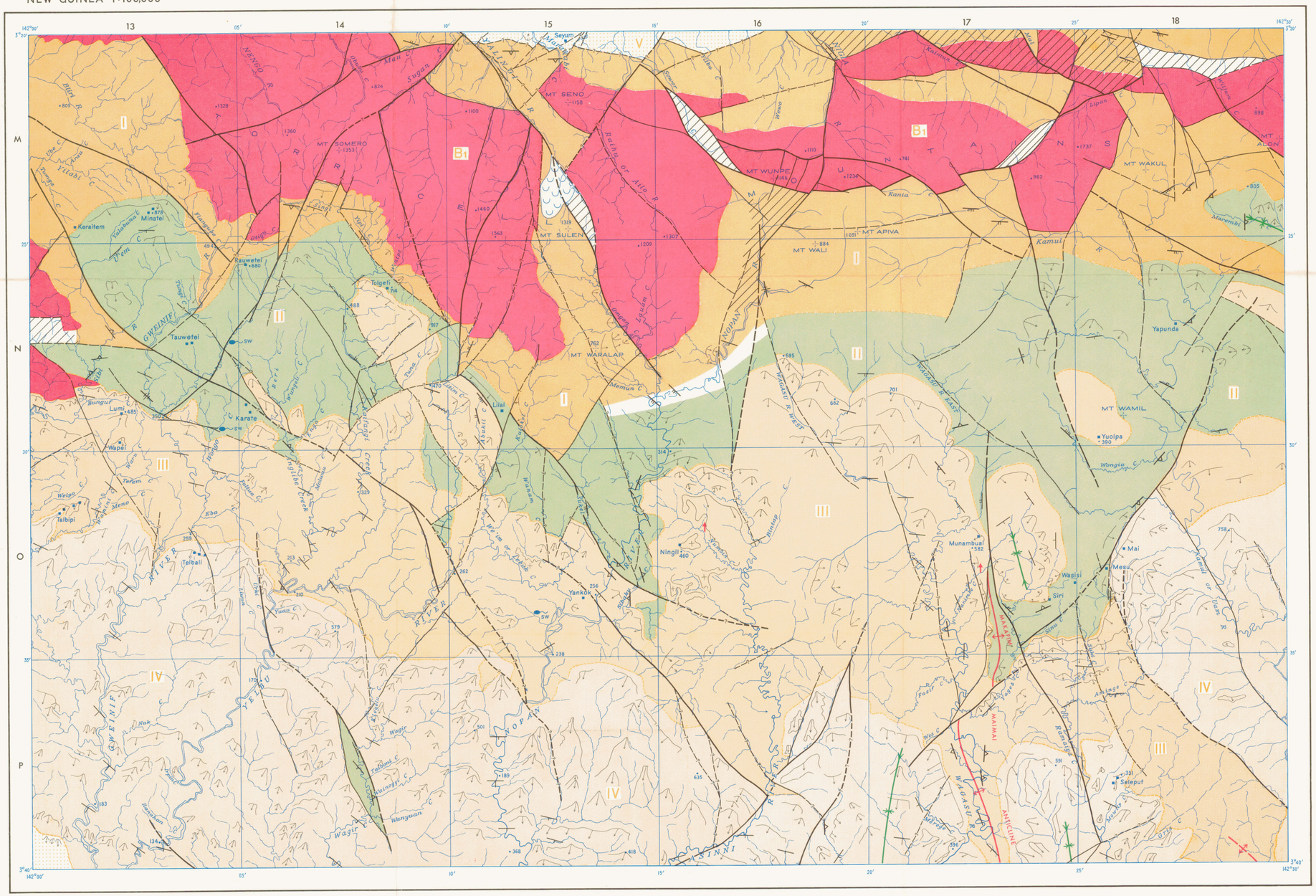
NIGRE 4246

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

LUMI

PHOTOGEOLOGICAL SHEET 4247



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FIRST EDITION 1967

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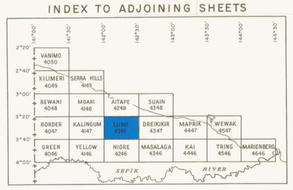

Scale 1:100,000

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1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION

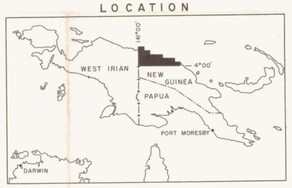

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Plate 12, BMR Report 130

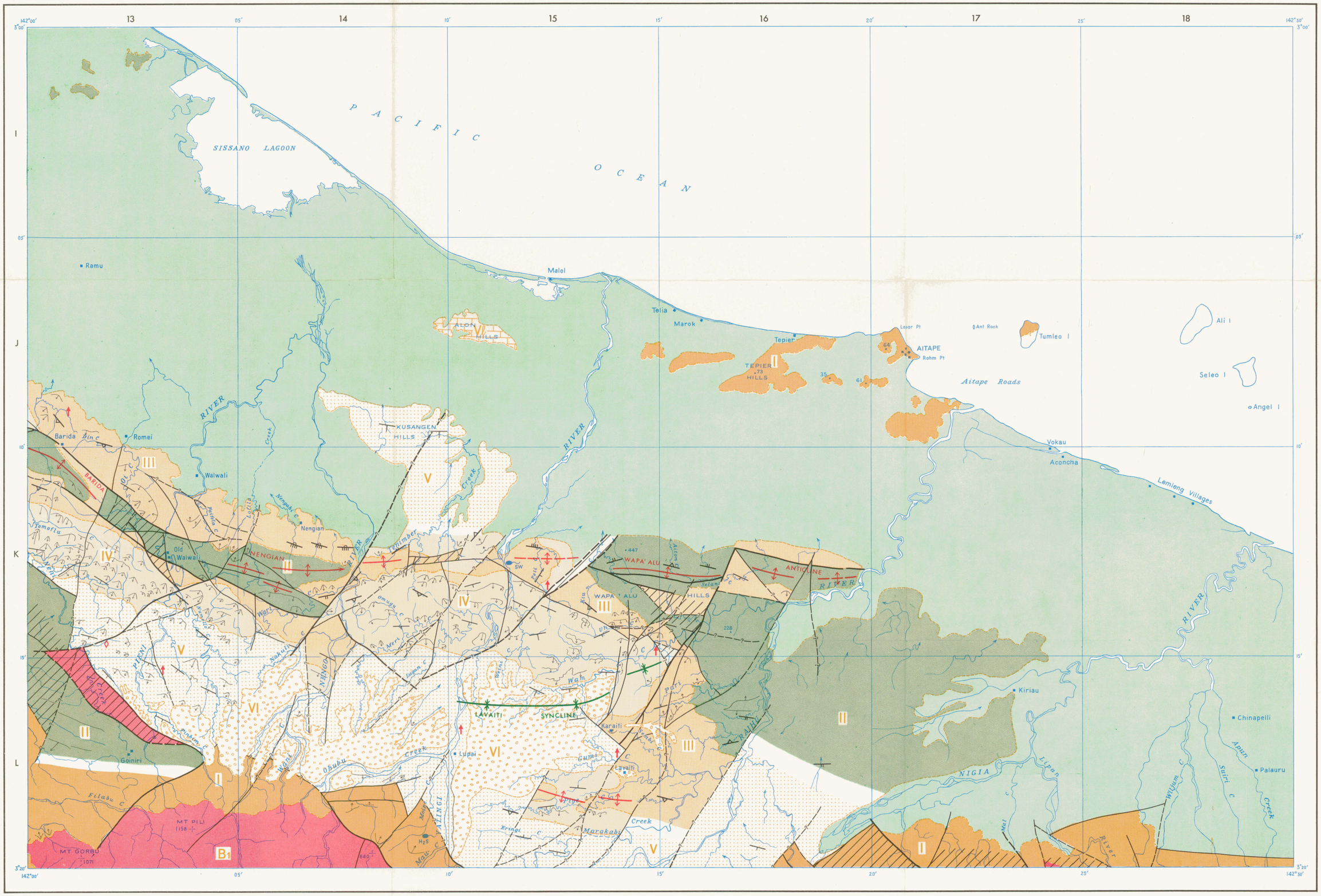
LUMI 4247

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

AITAPE

PHOTOGEOLOGICAL SHEET 4248


PACIFIC OCEAN
SISSANO LAGOON
Ramu
Malol
Telia
Marok
Tepier
AITAPE
Rohm Pt
Lajar Pt
Ant Rock
Tumleo I
Ali I
Seleo I
Angel I
Aitape Roads
Vokau
Aconcha
Lemieng Villages
ALOM HILLS
TEPIER HILLS
KUSANGEN HILLS
Barida
Romei
Walwali
Old Walwali
Nengian
NENGIAN
BARIDA
WAPA' ALU
ANTICLINE
HILLS
LAVAITI SYNCLINE
Karaiti
Lavaiti
Lupai
Kiriau
Chinapelli
Palauru
NIGIA
MT PILI 1158
MT GORBU 1071
Goiniri
Fitabu C
Obubu Creek
Marakabi Creek
Eringi
Mai C
Mai River
Wilum C
Suiri C
Apun Creek
Lipan
RIVER
Sepik
Wam
Yuri
Gum
Pari
Selang C
Nengah C
Lucia C
Ritsia C
Temomflu
Nakuti C
Omugu
Mer
Lugan C
Yuat
Waria
Pyalang C
Yaka C
Yaki C
Yuri C
Pyri
Eringi
Maik C
Mai C
Yaki
Yuri
Pari
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Yuri C
Yaki C
Yaka C
Pyri
Pyri C
Yuri C
Yaki C

NEW GUINEA 1:100,000

MASALAGA

PHOTOGEOLOGICAL SHEET 4346



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Topography based on A.P.C. FZ 12 and FZ 13 sheets.

Universal Transverse Mercator Projection.

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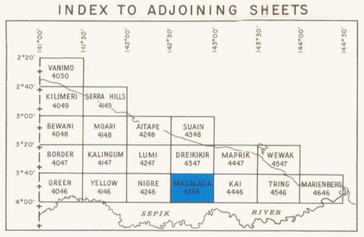


Scale 1:100,000

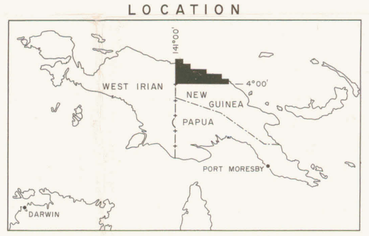
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
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Plate 14, BMR Report 130

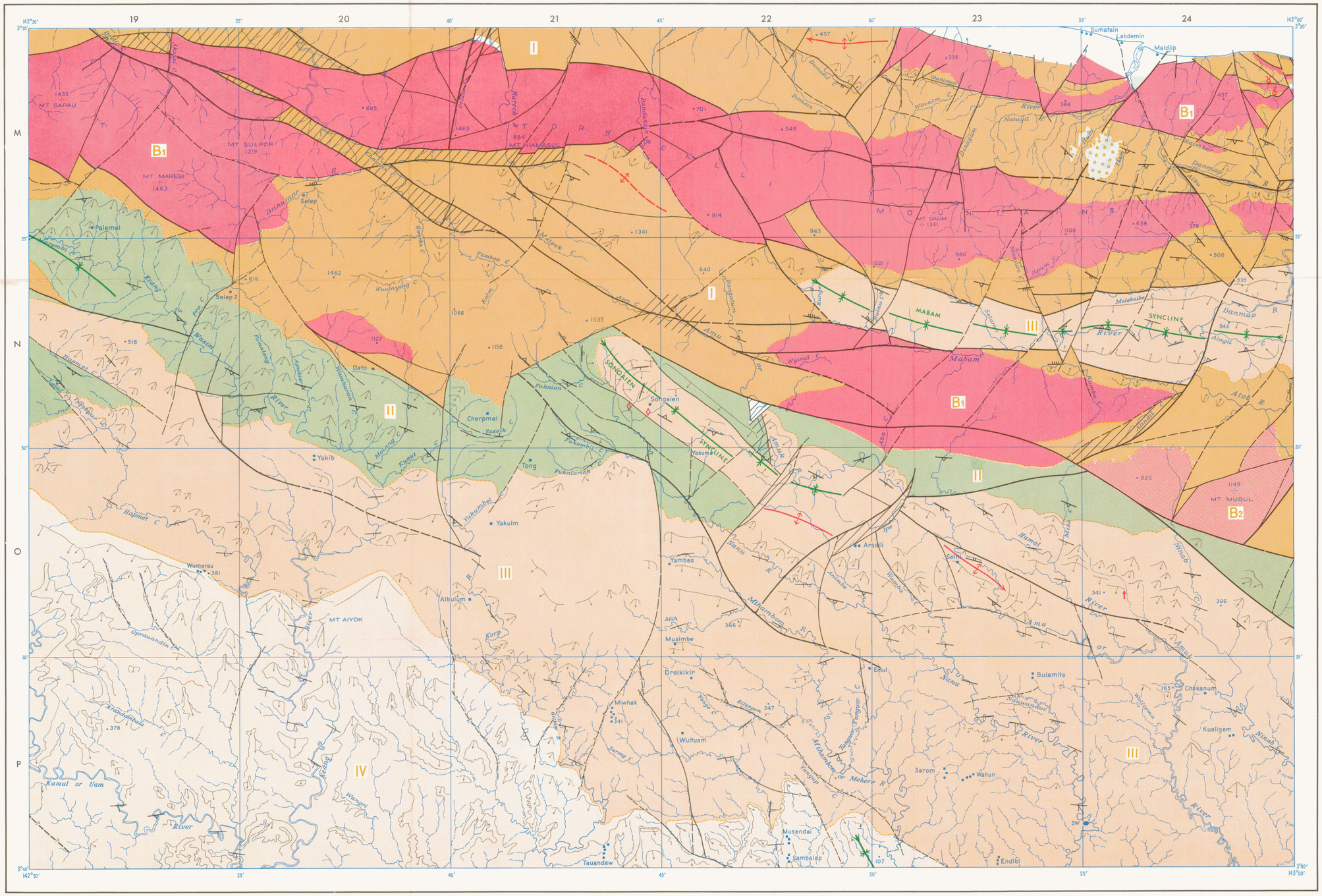
MASALAGA 4346

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

DREIKIKIR

PHOTOGEOLOGICAL SHEET 4347


142°30'
19
35'
20
40'
21
45'
22
50'
23
55'
24
143°00'
3°20'
M
25'
N
30'
O
35'
P
3°40'
Sumatain
Labdemin
Maldjip
MT SAPAU
1432
MT SULPOR
1219
MT MAREBI
1463
MT NIAMASUI
884
MT DAUM
1341
MT AIYOK
MT MUDUL
1149
B1
B2
I
II
III
IV
Palemel
Selep
Selep 2
Dato
Cherpmel
Yakib
Yakulm
Tong
Wumersu
Albulum
Songaien
SYNCLINE
MABAM
Arandi
Yambes
Musimbe
Dreikikir
Emul
Wultuam
Miwhak
Tauandaw
Musendai
Sambalap
Bulamita
Chakanum
Kualigem
Sarom
Wahun
Endibi
Drinumor River
Kamul or Vam River
Mabam River
Danmap River
Nimai River
Arau River
Amau River
Nimai R
Azoa R
Korp R
Mis R
Ipe
Yasum
Yasum Syncline
Songaien Syncline
Malakaibe Syncline
Mis Syncline
Mis Anticline
Mis Fault
Mabam Fault
Dreikikir Fault
Yambes Fault
Mis Thrust
Mis Overthrust
Mis Overfold
Mis Syncline
Mis Anticline
Mis

NEW GUINEA 1:100,000

SUAIN

PHOTOGEOLOGICAL SHEET 4348

142°30′ 19 35′ 20 40′ 21 45′ 22 50′ 23 55′ 24 143°00′

3°00′ I 05′ J 10′ K 15′ L 3°20′

P A C I F I C O C E A N

Paup Villages

Yakamul Villages

Ulau Villages

Chalour C

Akanai Creek

Afua

Selep

Dribumor R

Nturnen C

Harech R

Dandanain R

Dandrewad R

Charok

B1

142°30′ 35′ 40′ 45′ 50′ 55′ 143°00′ 3°20′

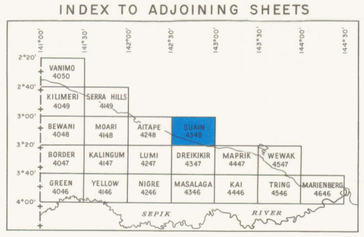
Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Topography based on maps prepared by G. A. V. Stanley.

Universal Transverse Mercator Projection.

FIRST EDITION 1967

INDEX TO ADJOINING SHEETS



Scale 1:100,000

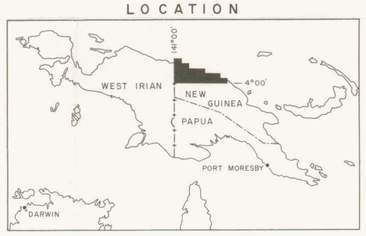
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 16, BMR Report 130

SUAIN 4348

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

KAI

PHOTOGEOLOGICAL SHEET 4446

143°00′ 25 05′ 26 10′ 27 15′ 28 20′ 29 25′ 30 143°30′

3°40′ Q 45′ R 50′ S 55′ T 4°00′

Samgik · Wora · Tamaui · Hayfield · Bugiwara (Yenigo) · Gwalip · Wingei · Watabung · Agingun · Numburuon · Neimo · Handara · Sassola · Hanyak · Yekimboie · Wahain · Munji Haranji · Haripmor · Kaubari · Turengi · Bararat · Kiniambu · Kworo · Dumbit · Bengaragum · Witipe 2 · Witipe 1 · Roma · Yuwanjungai · Kunjingini · Serangwantu · Mangul · Yambi Agr. Stn · Munji · Mangugu · Kupmabit · Kwimba · Nagotimbi (Kai) · Kosimbi · Pangeimbit · Makambu · Kamarangu · Timbunangua · Sotangi · Kwalianga

Wulima Anticline · Engut River · Hambili or Hambre River · Minjim R · Amik or Amik R or Screw River · Kwanti Creek · Antiam R · Panumbari River · Trumbum River of Engut · Hambili or Hambre River · River

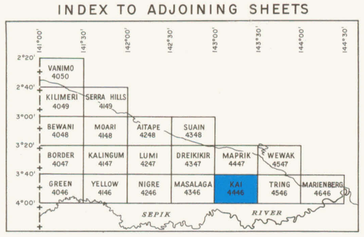
II III

S E P I K P L A I N S

K U N A I & K A N G A R O O G R A S S

143°00′ 05′ 10′ 15′ 20′ 25′ 143°30′ 4°00′

INDEX TO ADJOINING SHEETS



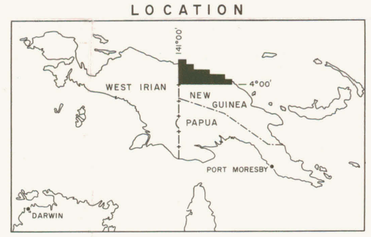
Scale 1:100,000

1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

LOCATION



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Topography based on 1 : 40,000 sheets compiled by Division of National Mapping: Maprik West, Maprik East, Wihama West and Wihama East.

Universal Transverse Mercator Projection.

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Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 17, BMR Report 130

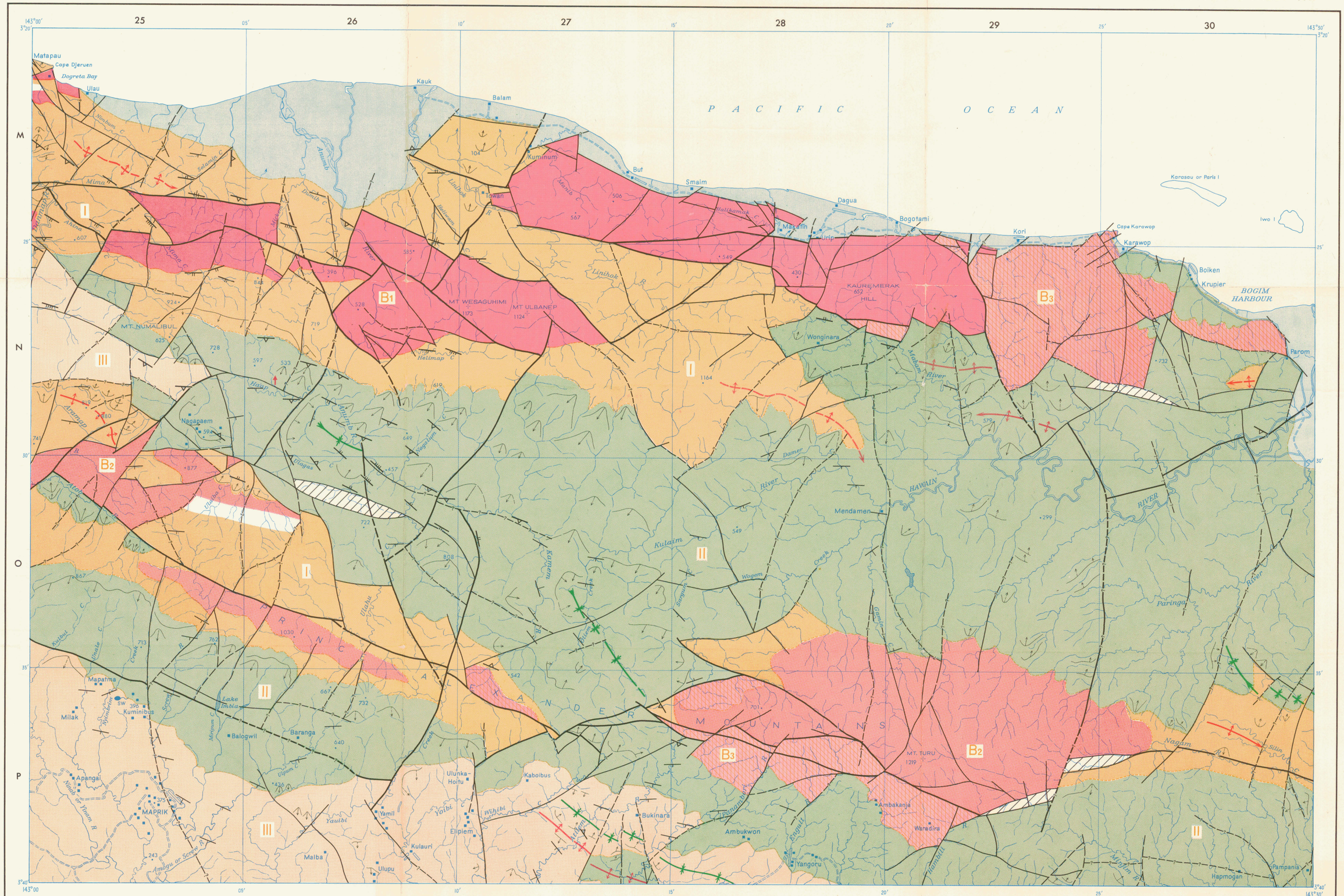
KAI 4446

TERRITORY OF NEW GUINEA

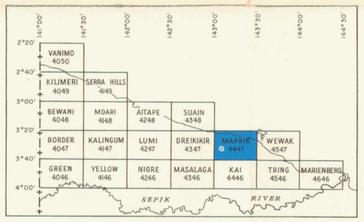
NEW GUINEA 1:100,000

MAPRIK

PHOTOGEOLOGICAL SHEET 4447



INDEX TO ADJOINING SHEETS



Scale 1:100,000

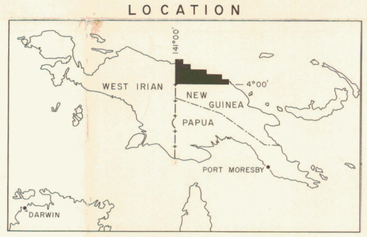
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Topography based on 1 : 40,000 sheets compiled by Division of National Mapping: But West, But East, Maprik West and Maprik East.

Universal Transverse Mercator Projection.

FIRST EDITION 1967

Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 18, BMR Report 130

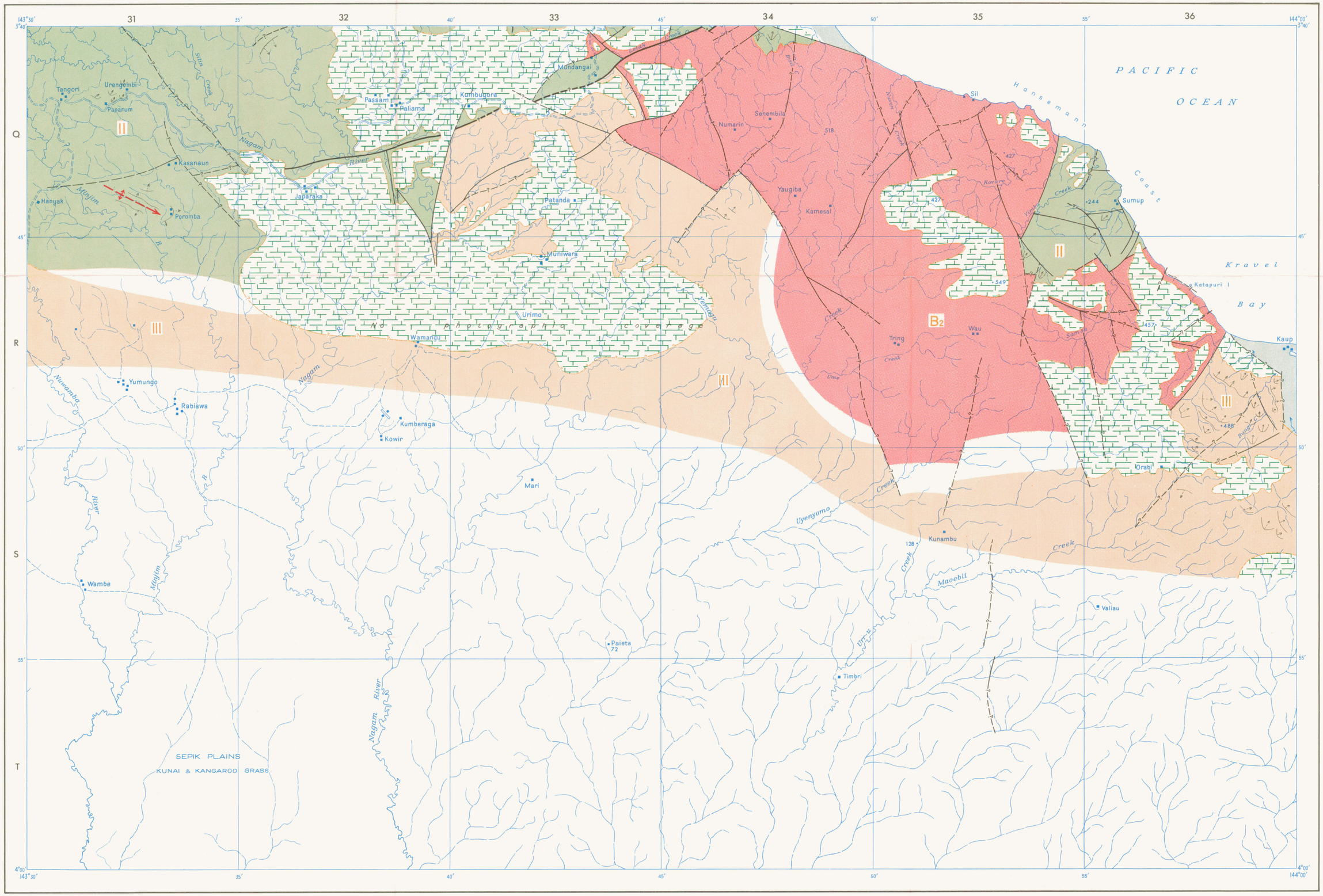
MAPRIK 4447

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

TRING

PHOTOGEOLOGICAL SHEET 4546



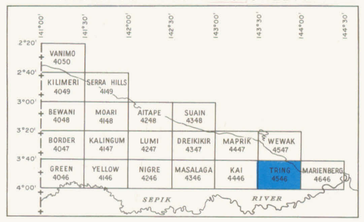
Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Topography based on 1 : 40,000 sheets compiled by Division of National Mapping: Wewak West, Wewak East, Tring West and Tring East.

Universal Transverse Mercator Projection.

FIRST EDITION 1967

INDEX TO ADJOINING SHEETS



Scale 1:100,000

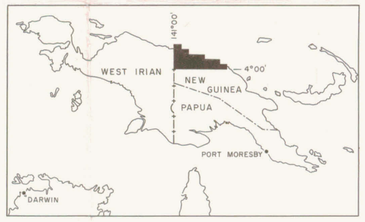
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 19, BMR Report 130

TRING 4546

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

WEWAK

PHOTOGEOLOGICAL SHEET 4547

143°30′ 31 35′ 32 40′ 33 45′ 34 50′ 35 55′ 36 144°00′

3°20′ M 25′ N 30′ O 35′ P 3°40′

VICTORIA BAY H

MT MALANGIS 1021

Karagur

Kairiru

I

+732

Seresin

Napakoi

Yawik

Brauniak

Cape Musokalang

Cape Saum

Muschu I

Muschu Plantation

Cape Barabar

Warag

Cape Somein

Cape Warbu

Cape Kalang

Cape Pus

DALLMAN HARBOUR

Raboin I

Cape Wom

Magarara

Yarabi

Yarapos

WEWAK

Wewak Pt

WEWAK HARBOUR

Army Camp

Cape Moem

BORAM BAY

Boram Pt

Warima

Wirui Airstrip

Waringe R.

Sauri

Boram Airstrip

DOVE BAY

Wirui R.

Dwelamba (Koigin)

503

366

MT CHIBURANGU

II

Marik

Mandi

Dabiap Pt

Forak

B2

Kalep

Cape Terebu

Musangun

Balik Creek

Terebu

NIGHTINGALE BAY

Zimbamba R.

Numaken

Simblangu

Hamberaui

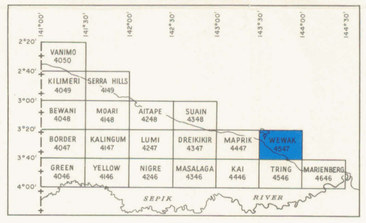
Brandt R.

Letuk

396

P A C I F I C O C E A N

INDEX TO ADJOINING SHEETS



Scale 1:100,000

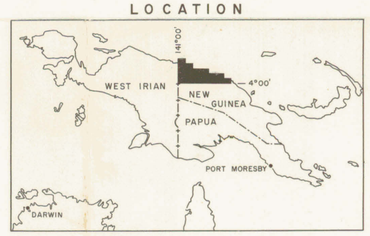
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Topography based on 1 : 40,000 sheets compiled by Division of National Mapping: Kairiru West, Wewak West and Wewak East.

Universal Transverse Mercator Projection.

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Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 20, BMR Report 130

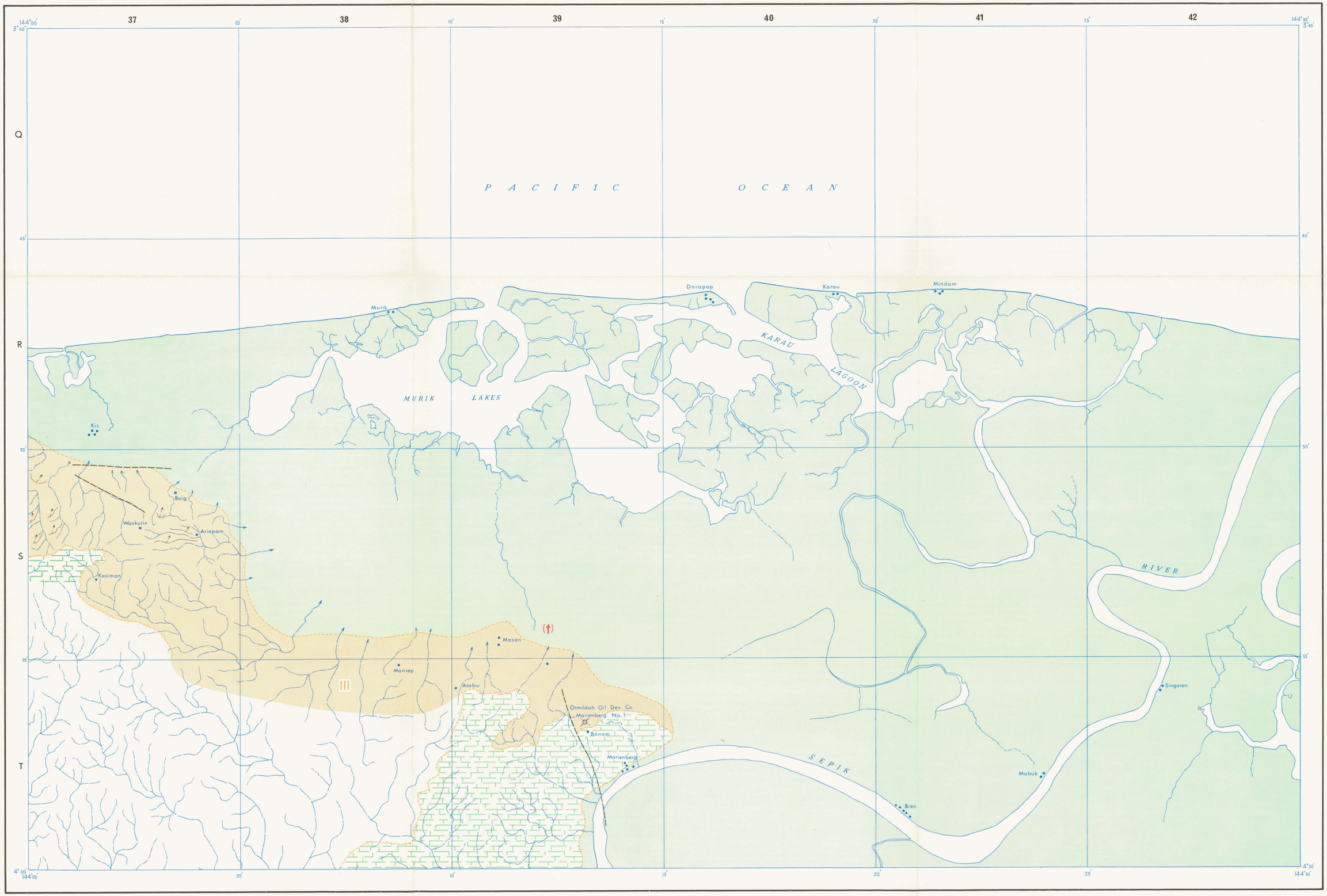
WEWAK 4547

TERRITORY OF NEW GUINEA

NEW GUINEA 1:100,000

MARIENBERG

PHOTOGEOLOGICAL SHEET 4646



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Topography based on 1 : 40,000 sheets compiled by Division of National Mapping: Sepik West and Sepik East.

Universal Transverse Mercator Projection.

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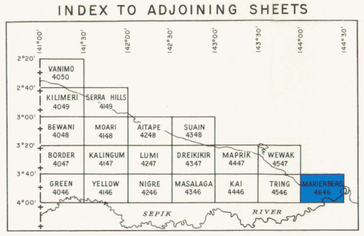


Scale 1:100,000

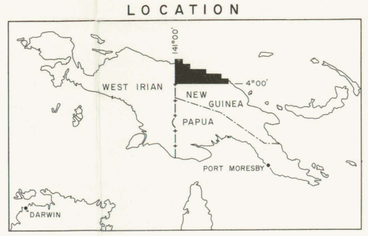
1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometres

Elevations in metres

CROWN COPYRIGHT RESERVED

LOCATION



Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: J. L. McGovern, H. Zimmermann, L. Petkovic

Plate 21, BMR Report 130

MARIENBERG 4646

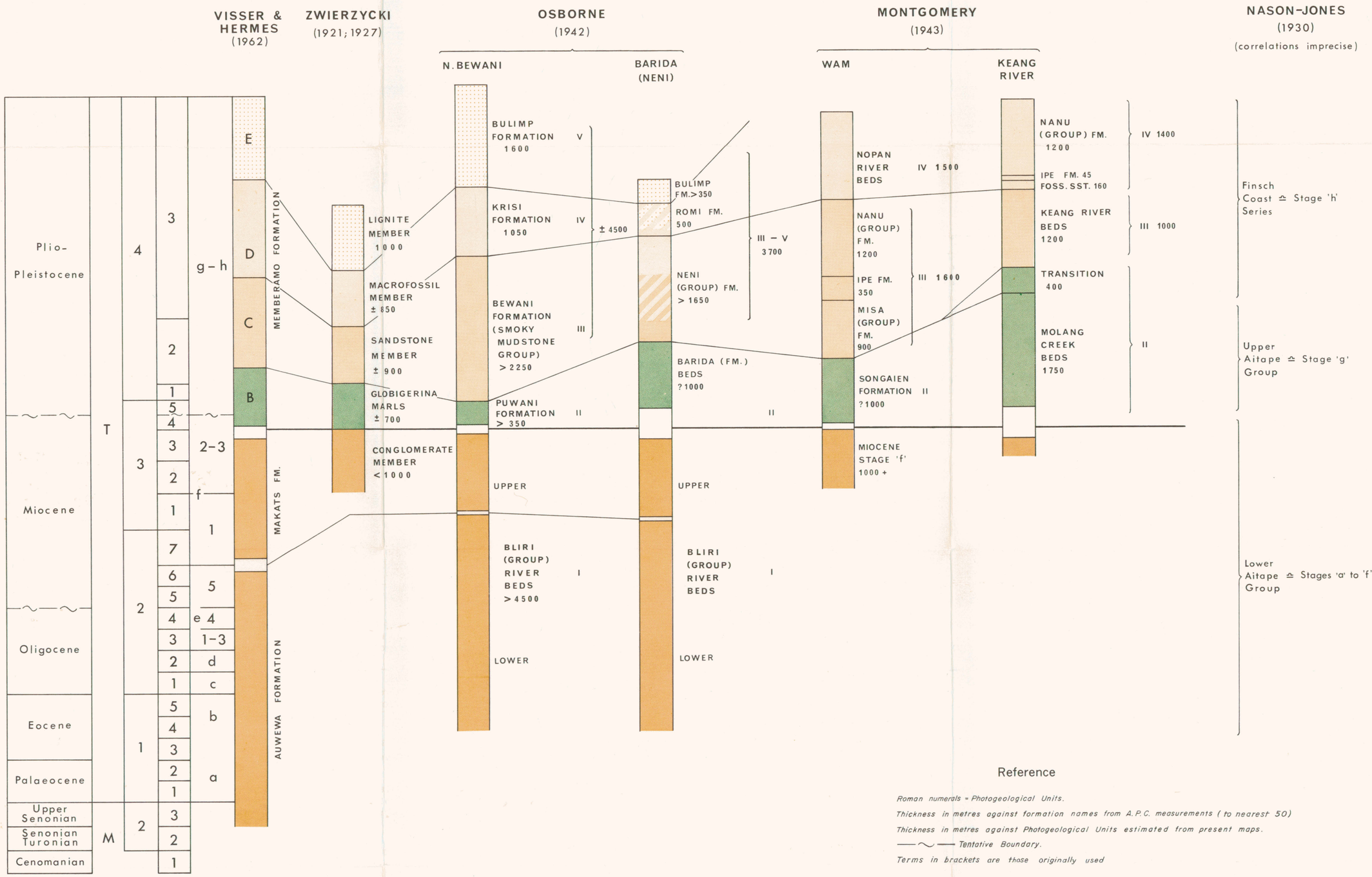
TERRITORY OF NEW GUINEA

NEW GUINEA

STRATIGRAPHIC CORRELATION CHART

NORTH OF SEPIK RIVER

Vertical Scale 1:40,000



Reference

Roman numerals = Photogeological Units.

Thickness in metres against formation names from A.P.C. measurements (to nearest 50)

Thickness in metres against Photogeological Units estimated from present maps.

—~— Tentative Boundary.

Terms in brackets are those originally used

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Plate 22, BMR Report 130

NK

NEW GUINEA

TYPE AREAS AND TYPE SECTION LOCALITIES

NORTH OF SEPIK RIVER

Scale 1:500,000

10 0 10 20 30 MILES

10 0 10 20 30 40 50 KILOMETRES

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Cartography by: K. Matveev, Petroleum Exploration Branch BMR
Drawn by: L. Petkovic

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Reference

Type areas

Type section localities

1	BULIMP FORMATION	Same type area
2	KRISI FORMATION	
3	BEWANI FORMATION	
4	PUWANI FORMATION	
5	BLIRI RIVER BEDS	No type section locality
6	ROMI FORMATION	Same type area
7	NENI FORMATION	
8	BARIDA BEDS	
9	NOPAN RIVER BEDS	
10	NANU FORMATION	Same type area
11	IPE FORMATION	
12	MISA FORMATION	
13	SONGAIEN FORMATION	
14	KEANG RIVER BEDS	
15	MOLANG CREEK BEDS	

PACIFIC OCEAN

VANIMO

OENAKE MOUNTAINS

Nammuree (Paul) R.

NEUMAYER PLAINS

Pulin R.

Puwani R.

Bewani R.

Serere R.

Firuma R.

Rainbrum R.

Sissano Lagoon

Piore R.

AITAPE

Yalings R.

BEWANI MOUNTAINS

Usumpha R.

WAPA'ALU HILLS

BARIDA

Rolim R.

Nigie R.

Bliri R.

TORRICELLI MOUNTAINS

Dumpla R.

LUMI

Danmap R.

MATAPAU

Jasumi R.

Kairiru I.

Muschu I.

Hawain R.

WEWAK

Buin R.

Wewi R.

Wagaw R.

MAIMAI

Yuki R.

Kraus R.

Keang R.

Nanu R.

Milambam R.

Amni R.

MAPRIK

PRINCE ALEXANDER MOUNTAINS

Nagam R.

Parcki R.

Yinaing R.

Pasuamberi R.

Sand R.

Yellow R.

Green R.

Nopan R.

Screw R.

Bogeas R.

SEPIK RIVER

Plate 23, BMR Report 130

NEW GUINEA

REGIONAL TECTONIC MAP

NORTH OF SEPIK RIVER

Scale 1:500,000

10 0 10 20 30 MILES

10 0 10 20 30 40 50 KILOMETRES

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Reference

- Geological boundary
- Anticline showing plunge
- Syncline
- Fault reversed, apex in direction of hade
- Fault transcurrent
- Faults
- Fault zone
- Regional strike and dip of beds
- Direction of principal stress
- Coastal Range (assumed where broken)
- Mountain highs
- A — B Line of cross sections (Plate 25)

- Alluvium
- Photogeological Unit VI
- Hollandia limestone
- Photogeological Units III, IV and V
- Photogeological Units I and II
- "Yagroner Limestone"
- Basement

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Universal Transverse Mercator Projection.

Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966
Cartography by: K. Matveev, Petroleum Exploration Branch BMR
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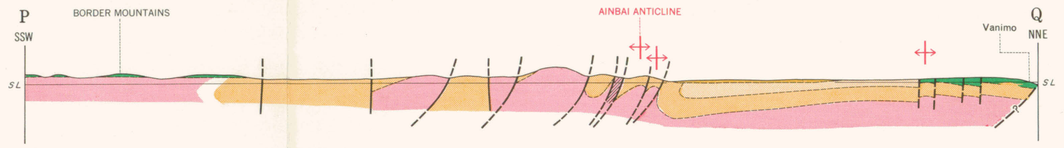
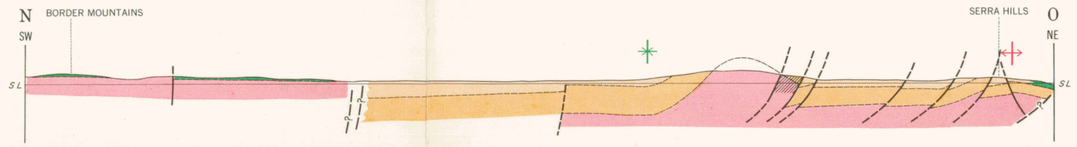
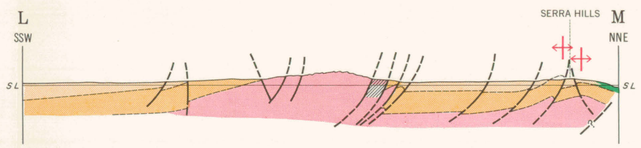
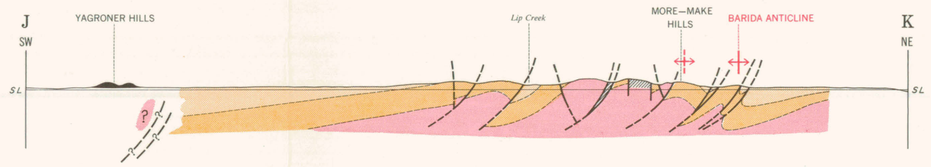
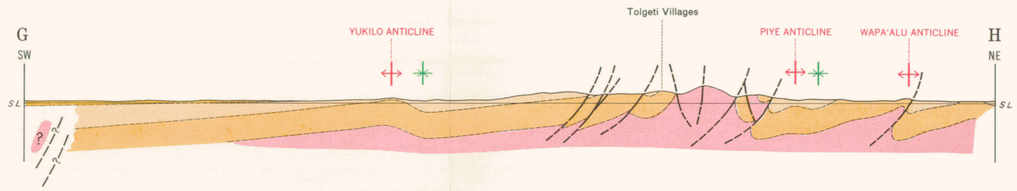
Plate 24, BMR Report 130

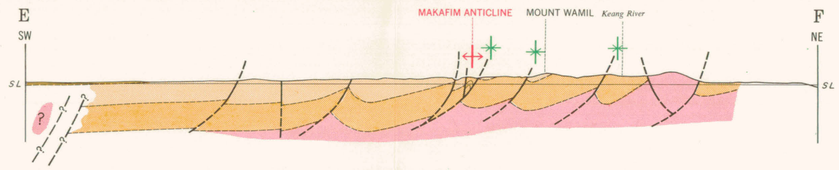


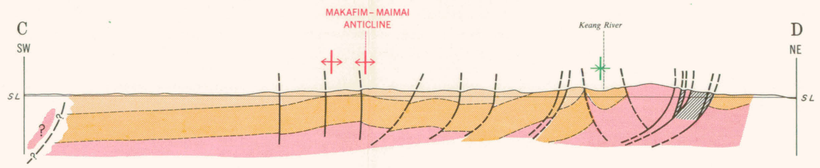


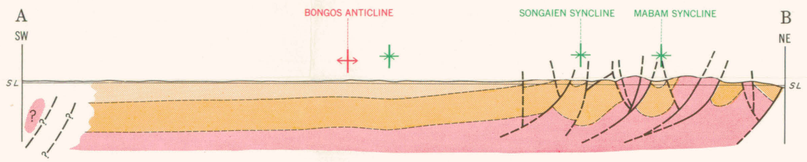












FIRST EDITION 1967

SIMPLIFIED
GEOLOGICAL CROSS SECTIONS
NEW GUINEA, NORTH OF SEPIK RIVER

Scale 1:500,000

5 0 5 10 15 20 25 Miles

5 0 5 10 15 20 25 30 35 Kilometres

$\frac{V}{H} = 1$

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Reference

- * Photogeological Unit VI
- * Hollandia limestone
- Photogeological Units III, IV, and V
- Photogeological Units I and II
- * "Yagroner Limestone"
- Basement

* Patterns used on REGIONAL TECTONIC MAP

- *Anticlines*
- *Synclines*
- *Faults*
- *Fault zones*
- *Hypothetical faults*

Geology compiled by: S. Marchant, Nov. 1965–Dec. 1966

Drawn by: J. L. McGovern

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.

Plate 25, BMR Report 130