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THE LESI STRUCTURE, PAPUA

by

M.A. Condon

COMMONWEALTH OF AUSTRALIA

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Report No. 1949/53
(Geol. Ser. No. 36)

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M. A. Condon

Senior Geologist.

CANBERRA, A.C.T. 13th September, 1949.

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SUMMARY.

The Lesi Structure, situated near the coast of the Gulf of Papua, about 100 miles north-west of Port Moresby, was surveyed by plane table.

The physiography of the area is a reflection of geological structure - young fold mountains rising from a gently dipping coastal plain of Tertiary sediments.

The sediments were laid down in the Tertiary Australo-Pacific geosynclinal basin. The rocks exposed on the Lesi structure comprise greywacke, greywacke conglomerate, siltstone and limestone of probably Pliocene age.

There are two formations - the Aro Formation comprising 700 feet of calcareous sediments, and the Lesi Greywacke comprising 1,600 feet of outcropping greywacke with some siltstone, conglomerate and limestone.

The Lesi structure is a domed anticline with vertical closure of about 2,400 feet.

It is believed that a deep test should be drilled on the Lesi structure which, of the structures in Permit No. 6, combines the most promising structural and stratigraphic features.

INTRODUCTION.

A geological reconnaissance of the Papuan Apinaipi Petroleum Company's permit was made by Dr. Mason L. Hill and Mr. Paul Dudley, of Richfield Corporation, California, and Dr. N.H. Fisher and Mr. D. Guppy of this Bureau in November, 1947. As a result of this reconnaissance a detailed survey of the Lesi structure was recommended, and was undertaken by the Bureau of Mineral Resources in the period December, 1948, to February, 1949. The geological party comprised M.A. Condon, Senior Geologist, J. Casey, C.E. Prichard and B.P. Walpole, temporary Geologists Grade I, and W.G. Burns, student Geologist. F.T. Moates was engaged by Papuan Apinaipi Petroleum Co. Ltd. as camp manager.

Situation.

The Lesi Structure is situated in the Gulf Division of Papua about 6 miles from the coast, midway between Kairuku (Yule Island) and Kerema (see Plans Nos. PNG1-6 and PNG-1G-12). The hills which form the outcropping part of the structure extend from Latitude 8° 14' South, Longitude 146° 17' East southerly to Latitude 8° 22' South, Longitude 146° 21' East, a distance of about ten miles. The Kapuri River is 3 miles to the north-west and the Biaru River one mile to the south of the hills. The Structure takes its name from the coastal native village of Lesi. The spelling "Lesi" follows the military maps and Australasian Petroleum Company's usage, although the local pronunciation, close to lair-se, would indicate that the spelling should be "LESE".

Access.

The most direct route into the Lesi Hills is by way of the Lesi Creek - a tidal creek which is navigable by launch to within one mile of the hills (Plan Nos. PNG-IG-12 and PNG-1G-13). The landing at Kiharu is central to the western side of the hills and that at Hereri is closer to the southern end. Access can also be obtained through Popo, on the Kapuri River. In either case, a shallow bar of sand at the mouth of the stream has to be crossed, making the entrance hazardous in a rough sea. The well-drained piedmont apron along the foot of the western side of the hills would be suitable for the construction of a vehicular road. This apron is probably suitable for the construction of an air landing strip, although considerable earthwork would be required. Sea planes or flying boats could probably land on the Lesi Creek near its mouth although, as far as is known, no soundings have been taken. As it is only tidal (except in high flood from the Biaru) the hazard of floating logs is at a minimum.

Water Supply.

Water was obtained from creeks at Aro and Karahure and from a spring at Harisu (Plan No. PNG-1G-13). These supplies were sufficient for the requirements of the six Australians and 25 natives. It seems likely that these streams are reasonably permanent, except after long-continued drought. Larger supplies of fresh water exist on the east side where there are many springs supporting sago palms at the foot of the hills and large lakes said by the local natives to be of fresh water. Access to these is across very thick coarse grass growing in a flat swamp (see Plan No. PNG-1G-12).

Labour.

Local natives from the villages of Lesi, Irava and Popo were employed as labourers, survey helpers and personal servants, on a casual labour basis. This proved very unsatisfactory since few of them were eager to work. One could never be sure that they would return to work after being at home for the week-end. It would appear that, in any future work in this area, it would be advisable to recruit indentured labour.

Native Foods.

Game is fairly plentiful, comprising several varieties of duck and "pigeon", scrub hen, wallaby and wild pig. A good "shoot-boy" should be able to supply sufficient meat for both whites and natives, at least for a small party.

Fruit and vegetable gardens exist at the northern end of the hills but the Lesi people were reluctant to sell. The Popo people supplied pawpaw, sweet potato, corn, pineapples and bananas. Practically nothing was obtained from the Biaru people who own the southern part of the hills, although they have fairly large gardens near Hereri.

Climate.

This area is almost on the western edge of the Port Moresby dry belt which has a definite dry season from March to October and a wet season from November to February. Very little rain falls in the dry season. In the wet season the rain occurs in short periods of high intensity, often during the night.

Rainfall records are available from Kairuku and Kerema (Table I) but the total yearly rainfalls and the monthly distribution are so completely different at these two places that it is impossible to interpolate the probable conditions at Lesi. From the evidence afforded by vegetation it is probable that the annual average and monthly distribution at Lesi is closer to those of Kairuku than Kerema although the period May to November may be not so dry. Table I sets out the monthly average rainfall for Kerema and Kairuku. The prevailing wind during the dry season is the south-easterly which produces big seas, making landings and bar crossings very difficult. During the wet season the wind is much more variable, though chiefly north-westerly. The storms which bring rain are accompanied by strong wind. Within this dry belt temperatures are generally higher and humidity lower than in other coastal parts of the Territory.

TABLE I

AVERAGE RAINFALL

Month	Kerema (25 yr. period) inches	Kairuku (20 yr. period) inches
January	9.44	9.99
February	8.09	10.28
March	10.68	8.56
April	11.26	5.22
May	16.92	1.53
June	16.33	2.11
July	13.12	1.03
August	13.93	0.65
September	12.47	1.62
October	12.32	1.52
November	9.27	2.92
December	7.35	5.59
Annual Average	141.18	51.04

Vegetation.

The vegetation of this dry belt is distinctive - the hills have a typical park-land vegetal cover, sparse eucalypts with coarse grass (see photos). In the gullies and on the flat land above the swamps tropical jungle growth occurs. In the swamps there are either dense mangroves or dense, very coarse grass.

Insects.-

Mosquitoes of several species occur in vast numbers, at least during the wet season. There are day-flying as well as the usual night-flying types. Anopheline species occur in relatively small numbers on the hills but are very numerous on the beach (at Lesi village). Mosquito-proof rooms for eating and working in camp and some form of repellent for field workers are essential if work in this area is to be tolerable.

Flies are present but not in great numbers.

A great variety of moths, butterflies and beetles and some wasps and hornets occur but are not troublesome. "Sweat-bees", which can be annoying to field workers, were encountered in some parts of the area.

Health.

The party had an almost clean bill of health. Paludrine was taken (1 tablet three times a week) as a preventive of malaria and no attacks of fever occurred. All water for drinking was boiled. Salt tablets were carried in the field and taken regularly. Some of the members of the party suffered from heat prostration on several days. This was due to shortage of water, to having no salt tablets or over-exertion. No major accidents occurred. One survey boy cut his foot with an axe but did not cut artery or sinews.

Survey Method.

The whole survey was done by plane table and tacheometric alidade. Two tables were used with topographic acetate sheets. One table covered the area from the north end of the hills to a line easterly from Camp No. 1 at Aro. The second table covered the area between Camp No. 1 and Camp No. 2 at Karahure, the northern part being approached from Aro, the southern part from Karahure. With a new sheet, the first table covered the area between Karahure and Camp No. 3 at Harisu and on a new sheet the second table covered the area from Harisu to the southern end of the hills. Before starting, the adjustment of the alidades was checked and, assuming the swamp water to be at high tide level, a reduced level was carried up to Aro camp with an Abney hand level and staff. One geologist did the table work while another, with native rod-man, located points of geological import, and read dips and strikes with clinometer and military compass.

Orientation of the table was magnetic, using a six-inch trough compass with the table set up between an established peg and the forward peg. The position of the plane table station was established on the sheet by drawing a back ray to the established peg. This method almost halves the number of stations and therefore enables more ground to be covered. Horizontal distances and reduced levels were computed and plotted and contours drawn in the field.

Because of the nature of the country most of the traverses were confined to the ridge and main spurs - as the gullies were generally forested and very seldom had any rock outcropping. Two exceptions were traversed with compass, chain and clinometer.

Sampling was generally confined to traverses which had been seen, or were expected, to have fairly continuous outcropping rock.

The field work was inked and geological information plotted on the plane table sheet as soon as closures were established - usually from day to day - and from time to time the information on the sheets was traced on to a single large sheet of kodatrace.

The topographic acetate sheets proved very suitable for this work enabling work to continue in rain. No appreciable shrinkage or swelling was noticed. Inked lines tend to wear off the acetate and the mosquito repellent takes the surface off the acetate and makes difficult the drawing of lines on it. It will crack if folded and tears fairly easily, but in nearly all respects it is better for plane table work than the best paper. A further advantage is its transparency which enables the junction of sheets to be checked without replotting.

Two runs of aerial photos, taken along the structure, were available. These photos were taken in 1938 and many of the prints had faded, and others were practically useless because of scattered cloud. However they were useful in planning the work since they indicated the topography and vegetal cover. Dip-slopes were very conspicuous in the photos of the central portion of the east limb but in the axial region, on the west limb and at either end there was no certain evidence of the direction or amount of dip.

The geographical coordinates shown on Plan PNG-1G-13 are approximate only. They were transferred from the military maps (4-mile series, Yule; 1-mile series, Maiva, Akaifu River, Jokea, Lakekamu River) by reference to natural features. Compass bearings were taken from points on the Lesi structure to prominent points marked on the military map. The points on the structure were plotted on the military map and the co-ordinates then transferred by reference to these points on the military map and on the geological plan.

The permit boundary as shown on the plan is also only approximate in its location in relation both to natural features and to the geographical co-ordinates. Apparently the permit boundary was fixed originally from a description based on a point near Cape Possession. As the precise location of this point and the azimuth of the traverse could alter the position of the permit boundary considerably its inclusion on the plan PNG-1G-13 is intended only as an indication of the relation of the structure to the area of the permit, and to show that a change in the position of the boundary could alter the area of the structure included quite appreciably.

PHYSIOGRAPHY.

The Lesi Hills form a very small part of the recently exposed coastal plain of Tertiary sediments, parts of which have been folded into large folds and eroded (as in the Omeri Mountains and the Tauri Dome). Other parts have been relatively little folded and the folds occur as isolated en echelon structures with unfolded sediments on either side (see plan PNG-1G-12). The hills produced by this folding are being reduced by erosion nearly as fast as they rise. About 3,000 feet thickness of sediments has been removed from the top of the Lesi Hills which are now up to about 450 feet above sea level. It is likely that the hills have never been appreciably higher than that.

The Lesi Hills are topographically asymmetrical in an east-west direction, with a steep western side and a relatively gentle eastern slope (see plan PNG-1G-13). This is not a reflection of asymmetrical structure but is almost certainly due to marine erosion of the western side when the sea reached the foot of the hills (cf. Oiapu Structure at present). The resulting steep gradients in the streams on the western side have resulted in an easterly migration of the drainage divide from its original position at the crest of the structure to one some distance to the east of the structure crest. The drainage pattern is in the main radial, consequent on the original shape of the structure. Subsequent tributaries are located along relatively soft beds (siltstones, friable sandstones) between outcrop-spurs of hard cemented sandstone, conglomerate or limestone. The main spurs between the consequent streams typically exhibit a succession of dip slopes and escarpment slopes. The main valleys are mature with sharp divides and no alluvial flats except at the lower end. The thalweg of the consequent streams is hyperbolic with very steep gradient immediately down from the divide and gentle gradient at the lower end.

A few of the subsequent streams (particularly on the west side) are enlarging along the crestal region (the beginning of the development of a "breached anticline" such as occurs in the Oiapu Structure). The streams on the western side have built up large alluvial fans which meet to form an alluvial apron that is almost continuous between the edge of the hills and the swamp. The swampy plain between the Lesi Hills and the coast is a raised shore platform, with a thin cover of alluvium and marine sands. A former beach, now planted with coconuts, runs north-westerly from Kiharo (plan No. PNG-1G-12). The exposure of this shore platform was probably due to the eustatic fall in sea level which occurred in mid-recent time (Teichert, 1946; Browne, 1945).

REGIONAL GEOLOGY (see Plans Nos. PNG-1-G and PNG-1G-12).

The sediments of the Lesi Structure were laid down in the Tertiary Australo-Pacific geosynclinal basin (Beltz, 1944). It is probable that the central range of New Guinea began its emergence in the Oligocene epoch, at least in the areas of the Bismarck and Owen Stanley Ranges, which were separated during the Late Tertiary period by the Aure Trough, connecting the basins of Northern and Southern New Guinea. The rapidly rising land masses of the present central ranges provided sediment for the adjacent basins, which are characterised by abundance of coarse sediments of greywacke and tuffaceous type. Vulcanism accompanying the uplift contributed pyroclastics, either directly or indirectly to the basins. During most of the Late Tertiary sedimentation, the environment of deposition (at least of that part of the basin now exposed) was estuarine to neritic (shallow-water marine). The sediments and parts of the older floor rocks were moved generally away from the central range apparently along large thrust-faults. Jura-type folding developed where the thrust movements were relatively simple, large folds occurring near the central block and smaller folds, developing later, at a distance from them. The Malalaua-Oroi line of folds is such a second-line fold system separated from the large early folds by an appreciable width of unfolded sediments at present covered by alluvium and swamp (~~the "Inawaringa synclinal" of Oxley~~).

GEOLOGY OF THE LESI STRUCTURE.

Previous Work.

The first recorded geological work done in this area was by H.T. Mayo and J.P. de Verteuil in 1920-21 (Mayo and de Verteuil, 1921). They surveyed the central part of the structure and indicated pitch to the south but not to the north.

L.C. Millward included the Lesi structure in his reconnaissance of the Popo-Maiva area in 1940 (Millward, 1941).

Drilling has been carried out by the Anglo-Persian Oil Company on the Popo Structure (immediately to the north-east of the Lesi structure) and by the Papuan Apinaipi Petroleum Company on the Oiapu Structure 20 miles to the south. No drilling has been done on the Lesi structure.

Lithology.

The rocks exposed on the Lesi structure comprise greywacke, greywacke conglomerate, siltstone and limestone.

The greywacke, which predominates in the outcropping rocks, consists of fragments of slate, schist, quartz, felspar, volcanic rocks and minerals, all sub-angular in shape. In the outcrop it is generally friable but some beds are cemented by calcite into hard calcareous greywacke. Some friable beds contain hard calcareous concretions.

The greywacke conglomerate consists of rounded pebbles of andesite, "diorite", schist, chert, quartz and diabase in a finer matrix of the same materials. Like the greywacke it is in places loose and friable but it is commonly cemented into a hard rock by calcite.

The siltstone is grey, weathering light brown, and in some cases is inter-laminated with greywacke and in others occurs in rather massive beds. Surface outcrops are rather rare, but shallow excavation reveals siltstone in many of the saddles along the ridges. Towards the top of the sequence many of the siltstones are calcareous and are interbedded with thin limestones.

The limestones which are generally in thin beds (up to one foot thick) are typically of the granular precipitated type, white, buff or light pink in colour and generally non-fossiliferous.

Palaeontology.

Previous workers in this area had stated that the rocks were unfossiliferous but many beds containing shelly fossils were found and many of the siltstones are believed to contain micro-foraminifera. Samples of these fossils have been examined by Miss Irene Crespin, and her report is attached as Appendix I. Many of the greywackes and some of the siltstones contain fragmental plant remains and one sandstone contains leaf impressions.

Stratigraphy.

The rocks exposed on the Lesi structure belong to the Pliocene Apinaipi Formation (Millward, 1941) which it is proposed to rename the Apinaipi Group and to subdivide, in this area, into the Aro Formation and the Lesi Formation.

The Aro Formation: The name of this formation is the native name for the area surrounding Camp No. 1 of the party (see Plan No. PNG-1G-13) at Latitude 8°16' South, Longitude 146°17' East, on the Military 1-mile map, Mount Yule sheet, 1942 edition.

Occurrence: It outcrops on the lower slopes of the eastern side of the Lesi hills.

General character: The Aro Formation consists of calcareous sediments - limestone, calcareous siltstone, calcareous greywacke and greywacke conglomerate, the coarser sediments usually cross-bedded.

Thickness: The thickness of the formation is 700 feet.

Fossils: The only fossils are indeterminate plant remains and fossil leaves in sandstone near the top of the formation (Sample F.51).

Age: There is no direct fossil evidence but by structural and lithological correlation it is probably of the same age as the beds which at Oiapu and Popo overlie the Upper Miocene Wedge Hill formation with slight unconformity. It is therefore thought not unlikely that this formation is/Pliocene in age.
Uppermost Miocene or

Relations: The Aro Formation rests conformably on the Lesi greywacke and with it comprises the Apinaipi Group. It unconformably underlies the alluvium of the synclinal swampy flats.

The Lesi Greywacke: The name of this formation taken from the ~~name of the structure~~ derives from the Lesi village (Plan No. PNG-1G-12) on the coast at Latitude 8°18' South, Longitude 146°14½' East, on the Military ¼-mile map, ~~Mount~~ Yule sheet, 1942 edition.

Occurrence: This formation outcrops on the western side, and upper eastern side of the Lesi Hills. The lower part of the formation does not outcrop here but outcrops on the Popo, Jokea, and Oiapu Structures above the Wedge Hill limestone.

General character: The formation consists of greywacke with minor development of siltstone, greywacke conglomerate and limestone (Plan No. PNG-1J-2) - the molluscs indicating brackish-water, estuarine conditions.

Thickness: A thickness of 1,600 feet outcrops on the Lesi Structure and an additional 600 feet probably occurs below this.

Fossils: In the Lesi Structure outcrop there are several beds of shelly fossils (Sample F-17, F-41) some beds containing foraminifera and indeterminate plant remains.

Age: The fossils so far found on the Lesi Structure have not been very helpful in fixing the age of these rocks, indicating a possible age from Upper Miocene to Recent. Fossils found in the bottom of the corresponding formation on the Oiapu Structure indicate that there is very little difference in age between this and the underlying Wedge Hill Formation and Miaru Mudstone and Miss Crespin (Report No. 88/1949, Pal. 16) believes that they are all Upper Miocene. From the nature of the sediments, implying very rapid sedimentation, it may well be that both the Lesi greywacke and the overlying Aro Formation are Upper Miocene in age.

Relations: The Lesi Greywacke conformably underlies the base of the Aro Formation and rests in some places in the Oiapu area with slight unconformity on the Wedge Hill formation.

The Apinaipi Group - The Upper Arenaceous Group of the Anglo-Persian Oil Company geologists (Mayo, 1920, and Mayo & de Verteuil, 1921) has been referred to the Pliocene, chiefly because of its position conformably above the fossiliferous Wedge Hill Formation of uppermost Miocene age, at Oiapu and Popo. At its type locality, the Wedge Hill Formation consists of coral limestone, foraminiferal limestone and siltstone and some greywacke and conglomerate with a total thickness of 1,100 feet. Farther to the north the thick limestones are not present and the equivalent of the Wedge Hill Formation on the

Jokea-Apinaipi anticline are the beds of "marly limestone and bands of shelly limestone, some mudstones, grits and conglomerates, with a few isolated occurrences of coralline limestone" (Mayo and de Verteuil, 1921). The thickness of this calcareous formation is not stated but from the evidence of the report and sections would appear to be of the order of 700 feet. At Popo the calcareous formation between the Miaru Mudstone and the Apinaipi Group is 800 feet thick (Millward, 1941, p.12).

The Miaru Mudstone which at Oiapu underlies the Wedge Hill Formation and which outcrops in the Jokea-Apinaipi and Popo anticlines was found by drilling at Oiapu to have a total thickness of about 2,500 feet, and to be underlain by volcanic rocks (Basaltic agglomerate) which may be the equivalent of the Middle Akaifu River Volcanics (Pratt and Whittle, 1939). These are probably much thinner here than where exposed on the Middle Akaifu River but may well be upwards of 1000 feet thick. Beneath these and separated from them by an unconformity there may be Middle Miocene rocks but because of the distance to the outcrops of these rocks (Karova, Kurai and Yule Island) it is not likely that any estimate of rock types or thicknesses for these older rocks in the Lesi Area would be even approximately correct.

Structure.

The Lesi Structure is a domed anticline with the axis trending about north-north-west (see plans Nos. PNG-1G-14, PNG-1G-15, PNG-1J-2). Much of the western limb has been removed by marine shoreline erosion but it appears likely that the anticline is almost symmetrical except where it is pinched in near the central part of the eastern flank. The shape in cross section approximates the sine-curve type with flattish crest and synclines and steep limbs. Dips in the central portion of the limbs are from 40° to 60°. Along the axis the structure is more asymmetrical, pitching rather steeply to the north (up to 20°) and gently to the south (up to 10°), so that the apex of the structure is nearer the northern end. The only indication of faulting within the structure is at the northern end where the presence of drag effects in dips and strikes and the shape of the outcrop of the Aro Formation seem to indicate a small fault. The actual fault zone lies in a gully and could only be inferred.

Structure-contour plans (Nos. PNG-1G-14 and 15) have been drawn on two horizons - the base of the Aro Formation and the top of the Miaru Mudstone. The contours on the base of the Aro Formation are believed to be reasonably correct as they were based on cross sections and a longitudinal section which were drawn using all dip information obtained, and checked by the position in each section of marker beds - the base of the Aro Formation and two conglomerate beds. This work emphasised the care which needs to be taken in reading and using dips in such coarse sediments - several very steep dips were recorded but by checking the section against the stratigraphic column it was found in each case that these dips were not valid and were almost certainly dips taken on foreset beds. The contours on the top of the Miaru Mudstone are approximate only, for two reasons - the precise depth of the top of the Miaru Mudstone could be established only by interpolation between the Jokea-Apinaipi and the Popo Structures and the detailed shape of the fold, which has been estimated assuming a constant thickness between the base of the Aro Formation and the top of the Miaru Mudstone, will vary according to the changes in the thickness of the sediments between these two formations. However, the contour plan does give an indication of the shape of the fold which may be expected in the strata near the top of the Miaru Mudstone.

In depth, this type of structure produces a very sharp-crested fold (see plan PNG-1G-15) (c.f. the Popo structure which has been eroded into this part of the structure). Faulting and mashing of incompetent rocks tends to occur in the axial region.

The limiting area in determining the amount of vertical closure is the syncline between the Lesi Structure and the south end of the Popo structure (see plan No. PNG-1G-14). By reference to the contours on that plan it will be seen that the vertical interval between the apex and this saddle is 2,400 feet. On the top of the Miaru mudstone the vertical closure (between the same areas) is approximately the same (plan No. PNG-1G-15).

Relation to adjoining structures.

The Lesi Structure is one of many similar folds arranged en echelon from Malalaua (north of the Tauri River) to Oroi (south of Yule Island). In the immediate vicinity of the Lesi Structure are the Popo Structure to the north-east, the Akina and the Apinaipi and Jokea-Apinaipi Structures to the south-east, and the Oiapu Structure to the south. The Lesi structure is connected to both the Popo and Apinaipi structures by synclines. Structural sections from Jokea-Apinaipi to Popo by way of Apinaipi and Lesi indicate that there is no large fault between any of these structures since the top of the Miaru Mudstone can be projected from Popo to the Jokea-Apinaipi on the basis of dip information with very little closing error.

There seems a possibility of a new fold developing to the west of the Lesi Structure, in line with the Oiapu axis. On this line there are two small hills - one south of the Kapuri and one between the Kapuri and Lakekamu Rivers. The Malalaua anticline is also on this line. However, this fold is so small in the area west of the Lesi Structure that it does not change the structural environment in its relation to oil accumulation.

Possibility of Oil Accumulation.

It is generally recognised that there is a direct relation between the size of an oil accumulation and the area of rocks which have supplied oil to the pool, as the run-off of a stream is related to the area of its catchment.

The western flank of the Lesi Structure passes into the south-westerly regional dip with very little interruption, so that the possible drainage area on this side is very large indeed - 16 miles from north to south and an unknown but large distance from east to west. The eastern flank is more confined being shielded by the Popo, Apinaipi and Akina Structures. However, the area between the Lesi axis and the synclinal axis immediately to the east is about 10 square miles.

The lowest part of the Apinaipi Group (that section below the surface on the Lesi Structure) is known by reference to the Popo, Jokea and Oiapu structures to consist of beds of sandstones (greywackes), conglomerate and siltstone with some limestone. Some of the coarser sediments are almost certainly pervious enough to act as oil reservoir rocks. Below this the rock types are the equivalents of the Wedge Hill Formation and the Miaru Mudstone which are not likely to be effective reservoir beds, although they are possible source beds.

Basaltic and andesitic pyroclastics interbedded with siltstones and greywackes (the Middle Akaifu Volcanics) occur to the east of the Inawafunga Syncline. A formation which is apparently similar lithologically to these Middle Akaifu River Volcanics was struck at a depth of 2,215 feet in the No. 1 exploratory test well at Oiapu. This formation was correlated at the time with the pyroclastics which occur in a series of hills at the south-eastern end of the Oiapu Structure (see Papuan Apinaipi Petroleum reports). Millward has pointed out (Millward, 1941) that the degree of plunge required for correlation of the surface pyroclastics with those struck in the bore does not agree with the mapped shape of the structure. It may be suggested that there is a fault between the bore and the surface outcrop but here again surface mapping (by Anglo-Persian Oil Co. and Papuan Apinaipi Petroleum Co. geologists) would appear to eliminate the possibility of faulting on a scale sufficiently large to produce the required throw.

Cores from the Oiapu bores show that the agglomerate below 2,215' in the No. 1 deep test bore and in the No. 2 deep test bore (which started in the outcropping volcanics) are lithologically similar. The outcropping agglomerate is almost certainly part of a volcanic scoria cone, probably submarine. The slope between the north end of the outcrop and the top of the agglomerate in the No. 1 deep test bore (about 10°) is consistent with this explanation. This would make all of the volcanics (including those outcropping) older than the Miaru Mudstone and therefore probably of Middle Miocene age. If this is so, these volcanics almost certainly underlie the same mudstone in the Lesi Structure but are likely to be finer in grain and thinner than at Oiapu. They are not likely to be either source or reservoir beds, although the interbedded siltstones provide possible source beds and pyroclastics are often pervious enough to act as reservoir beds. However, it is felt that any production at depth in the Lesi structure is not very likely from this formation but may be possible from the equivalents here, below the volcanics, of the Middle Miocene limestone, etc., which are exposed at Kairuku.

The oil fields of Klamona, Wasian and Mogoi (Vogelkop, Netherlands New Guinea) produce oil from limestones of Upper Miocene age (Schappli, 1946). These fields are in the western part of the southern New Guinea upper Tertiary geosynclinal basin. The Tertiary sequence in the Vogelkop comprises thin Eocene and Oligocene limestones, 3,000 to 7,000 feet of Miocene limestone, shale, and marl, and 5,000 to 15,000 feet of Pliocene conglomeratic sand, shale and marl with limestone lenses. This section is very similar to that in the Lesi area, the main difference being the presence of volcanic sediments in the Middle Miocene in the latter. This similarity is almost certainly a reflection of the similarity of the situation of the two areas with regard to the edge of the basin.

Seepages, chiefly of dry gas, are known to occur on the Popo and Jokea-Apinaipi anticlines, both of which expose the upper Miocene Wedge-Hill Formation or its equivalents, and the Miaru Mudstone. Several small shows of oil were reported from the Oiapu bores. It thus would appear likely that any oil produced from these possible source beds (the Miaru Mudstone and the Wedge Hill Formation) would have been lost by erosion in the Popo, Jokea-Apinaipi and Oiapu Structures but may well be retained in the Lesi, Apinaipi and Akina Structures. The very absence of seepages on these structures may well mean that the cap rock is sufficiently impermeable to prevent noticeable seepage.

LOCATION OF TEST BORE.

The location of a test bore will be governed by the depth to which it is proposed to drill. If it is proposed only to test the rocks above the Miaru Mudstone the relatively shallow well required (less than 2,000 feet) should be located as near the apex of the structure as practicable but if a deep test to explore the structure in depth is decided on it should start on the western limb some 1,000 feet west of the apex in orderto avoid the apical area in the Miaru Mudstone. The deeper well (say, 10,000 feet) is thought desirable at this stage and in this area since in no other way can the formations at depth be determined.

CONCLUSION.

The shape, size, lithology and stratigraphy of the Lesi Structure and the many points of similarity between it and the producing fields of Vogelkop (Netherlands New Guinea) certainly justify adequate testing of the Lesi Structure. Stratigraphic information available points to the possibility of oil accumulation within 2,000 feet of the surface at the apex of the structure, but so little is known of the rock types at depth that a deep test well, to determine the stratigraphy at depth and to establish the possibility of production from these older beds, seems advisable at this stage. This would indicate the potential value of Permit Area Number 6 as a whole and would eliminate most of the present uncertainty about the advisability of further sub-surface exploration in the Permit Area. For this reason it is recommended that a deep test well, of 10,000 feet rated depth, be drilled on the Lesi Structure, preferably at a site about 1,000 feet to the west of the apex (in order to avoid the drilling difficulties which occur in drilling through the axial region in the mudstone). If an oil accumulation is found within the first 5,000 feet, the Apinaipi structure and the Akina structure will provide similar stratigraphic sections in which similar accumulations may be expected. Any accumulation found below 5,000 feet would point to the possibility of similar accumulations in all of the neighbouring structures - Popo, Apinaipi, Akina, Jokea-Apinaipi and Oiapu.

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APPENDIX I.

Extract from
Micropalaeontological Examination of Rock Samples from the Lesi and Oiapu Structures, Papua.

by

Irene Crespin,
Commonwealth Palaeontologist.

Report No. 88.
(Pal.Ser.No.16).

LESI STRUCTURE.

Owing to the absence of names of villages in the area, the position of the specimens has been fixed by Latitude and Longitude readings. Co-ordinates have been measured from Plan PNG-1G-13 accompanying M.A. Condon's report on the Lesi Structure.

F.1. Lat. 8°15'41"S., Long. 146°16'59"E.

Sandstone with indeterminate plant remains. No microfossils.

F.2. Lat. 8°15'59.5" S., Long 146°17'26"E.

Limonitic clay. No microfossils.

F.3. Lat. 8°15'49.5"S., Long. 146°17'32.5"E.

Brown sandstone with greenish mud balls. No microfossils.

F.4. Same Locality

Ochreous, fine grained, calcareous grit. No microfossils.

F.5. Lat. 8°16'26"S., Long. 146°17'47"E.

Hard, shelly sandstone with indeterminate shell fragments. A thin section of the rock shows fine angular quartz grains, molluscan shell fragments and woody particles.

F.6. Lat. 8°16'28"S., Long. 146°17'42.5"E.

Grey laminated siltstone with fine angular quartz grains. No microfossils.

F.7. Lat. 8°16'12.5"S., Long. 146°17'42.5"E.

Brown calcareous sandstone with poorly preserved molluscan shells.

Pelecypoda: *Dosinia* sp.
Paphia textile (Chem.)
Tellina cf. *striatula* Lam.

Gasteropoda: *Turris* cf. *gendenganensis* (Martin)

F.8. Lat. 8°17'23.5"S., Long. 146°17'35"E.

Ochreous and grey laminated siltstone with minute angular quartz grains. No microfossils.

F.9. Lat. 8°17'25.5"S., Long. 146°17'32"E.

Fine grained compact sandstone with included cherty balls. A thin section shows quartz grains surrounded with a coating of ? siliceous material and indeterminate foraminifera.

F.10. Lat. 8°16'41"S., Long. 146°17'32"S.

Grey, calcareous sandstone boulder with fish scales.

F.13. Lat. 8°15'19.5"S., Long. 146°17'32" E.

Brownish, calcareous grit with indeterminate pelecypoda.

Lat. 8°15'31.5"S., Long. 146°16'59"E.

F.14. Limonitic and grey siltstone and sandstone. No microfossils.

F.15. Limonitic and grey siltstone. No microfossils.

F.16. Fine calcareous sandstone with foraminifera area, and probably derived.

Foraminifera: *Haplophragmoides* sp.

F.17. Lat. 8°15'00"S., Long. 146°17'10.5"E.

Brown, calcareous sandstone with fragments of pelecypoda.

Pelecypoda: *Ostrea* sp., cf. *Arca* sp.

Lat. 8°14'40.5"S., Long. 146°17'07.5"E.

F.18. Limonitic and grey siltstone with sphaerical bodies, cf. radiolaria.

F.18a. Limonitic sandstone.

Lat. 8°15'27.5"S., Long. 146°18'09"E.

F.19. Grey and limonitic greywacke with mud balls. No microfossils.

F.20. Grey to limonitic siltstone. No microfossils.

F.21. Lat. 8°17'46"S., Long. 146°18'16"E.

Brown sandstone with fragments of indeterminate mollusca.

F.22. Lat. 8°17'30"S., Long. 146°18'29"E.

? Worm casts in sandstone.

F.23. Lat. 8°16'03.5"S., Long. 146°17'18"E.

Calcareous sandstone and fine sandstone with poorly preserved foraminifera, corals and bryozoa.

Foraminifera: *Elphidium* sp., *Quinqueloculina* sp.

Bryozoa: *Lunulites* sp.

F.24. Lat. 8°17'50.5"S., Long. 146°17'50"E.

Greyish sandstone with bands of ironstaining and with microfossils scarce.

Foraminifera: Elphidium sp.

F.25. Lat. 8°18'06.5"S., Long. 146°18'01.5"E.

Calcareous sandstone with poorly preserved pelecypoda.

Pelecypoda: Arca sp.
Arca (Barbatia) sp.
Tellina sp.

Lat. 8°18'06.5"S., Long. 146°18'01.5"E.

F.26. Ochreous marly sandstone. No microfossils.

F.31. Limonitic and fine sandy material. No microfossils.

F.32. Lat. 8°15'4"S., Long. 146°17'46"E.

Sandstone with thin bands of limonite. No microfossils.

F.33. Lat. 8°15'44.5"S., Long. 146°17'47.5"E.

Sandstone and siltstone. No microfossils.

F.34. Lat. 8°15'42"S., Long. 146°17'38"S.

Mud balls in friable greywacke. No microfossils.

F.35. Lat. 8°15'49"S., Long. 146°17'32.5"E.

a. Hard calcareous, limonitic sandstone with casts of indeterminate molluscan shells.

b. Friable, grey to limonitic siltstone. No microfossils.

F.36. Lat. 8°15'53.5"S., Long. 146°17'E.

Greyish to limonitic sandstone. No microfossils.

F.37. Lat. 8°15'59.5"S., Long. 146°17'25.5"E.

Limonitic sandstone. No microfossils.

F.41. Lat. 8°18'38"S., Long. 146°18'06.5"E.

Brownish fossiliferous sandstone with poorly preserved mollusca.

Pelecypoda: Cyprina sp., Unio sp.

Gasteropoda: Melania sp.

F.42. Same Locality

Micaceous sandstone and siltstone. No microfossils.

F.43. Lat. 8°18'37"S., Long. 146°18'30"E.

Yellowish to brownish sandstone and siltstone. No microfossils.

F.44. Lat. 8°18'46.5"S., Long. 146°18'33"S.

Yellowish green to brownish, fine grained sandstone. No microfossils.

F.50. Lat. 8°19'16"S., Long. 146°18'57"E.

Brownish sandstone with plant remains indeterminate.

F.51. Lat. 8°18'35.5"S., Long. 146°19'36.5"E.

Whitish, micaceous sandstone with plant remains indeterminate.

F.52. Lat. 8°18'37"S., Long. 146°19'20"E.

Argillaceous limestone with no determinable fossils.

F.53. Lat. 8°18'38.5"S., Long. 146°19'15.5"E.

Argillaceous limestone with no determinable fossils.

F.54. Lat. 8°20'04"S., Long. 146°18'35.5"E.

Medium grained grit with mud balls. No microfossils.

Notes on Samples.

The rocks examined from the Lesi structure included sandstones, grits, siltstones and argillaceous limestones. Unfortunately few of them were fossiliferous and even when so the fossils were so poorly preserved that specific determinations and sometimes generic determinations were almost impossible. Consequently, it has been difficult to give a definite age to the majority of the samples.

Indeterminate plant remains occurred in Nos. 1, 50 and 51, and the rocks may be as old as Upper Miocene.

Foraminifera were very scarce and were recognised only in four samples, Nos. 9, 16, 23 and 25. The specimen in No. 16 has been referred to *Haplophragmoides* sp.. It has apparently been derived from Mesozoic sediments as its affinities are with species of that age. The broken tests of *Elphidium* and *Quinqueloculina* in Nos. 23 and 25 yield little information as to age except that they are characteristic of assemblages of Upper Miocene to Recent age in the Indo-Pacific.

Sphaerical forms, most probably referable to radiolaria, occurred in sample No. 18 and indeterminate corals and bryozoa on No. 23.

Poorly preserved mollusca were present in samples Nos. 5, 7, 13, 17, 21, 25, 35a and 41. The determinable forms in No. 7 suggest a Pliocene age. The association of large *Ostrea* and *Arca* in No. 17 and of *Unio* and *Melania* in No. 41 is indicative of estuarine conditions during sedimentation.

Some of the unfossiliferous siltstones may be comparable with those from the Oiapu area which are apparently Upper Miocene to Pliocene in age.

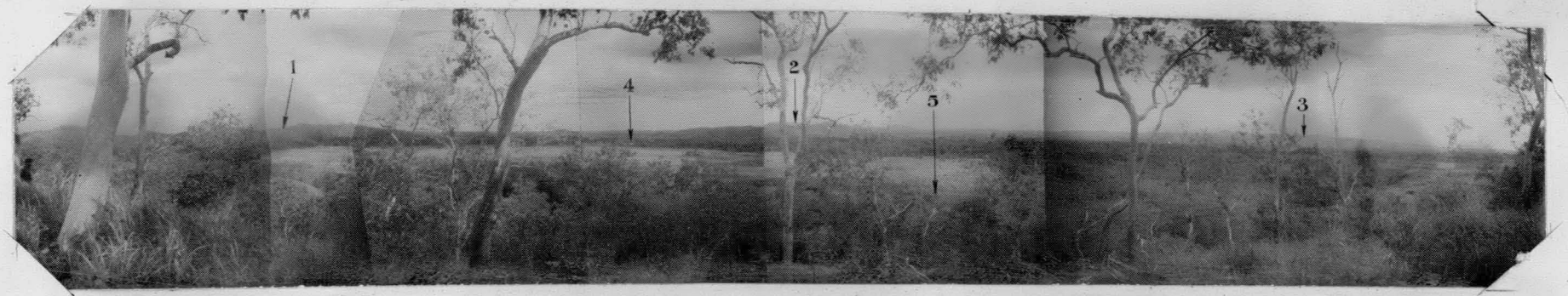


Photo No.1. Panorama from Arika (South End of Lesi Hills) showing:
1. Apinaipi Structure 2. Jokea-Apinaipi Structure
3. Oiapu Structure (North End) 4. Biaru River
5. Grass Swamp

Photo No.2. Panorama from Arika showing:
1. Apinaipi Structure (North End) 2. Akina Structure
3. Inawafunga Syncline 4. Lesi Hills (Central Part)

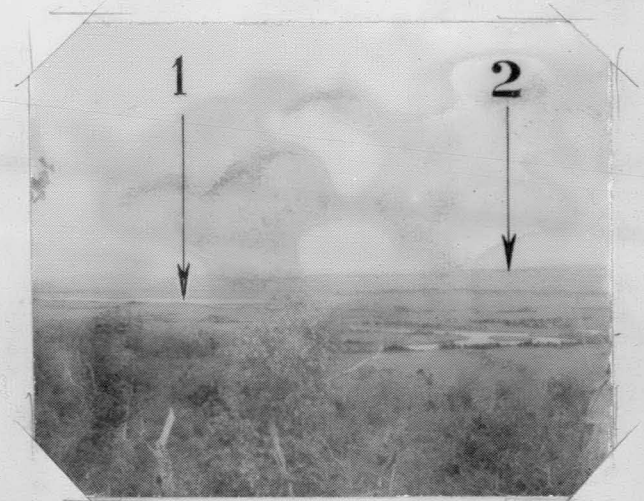
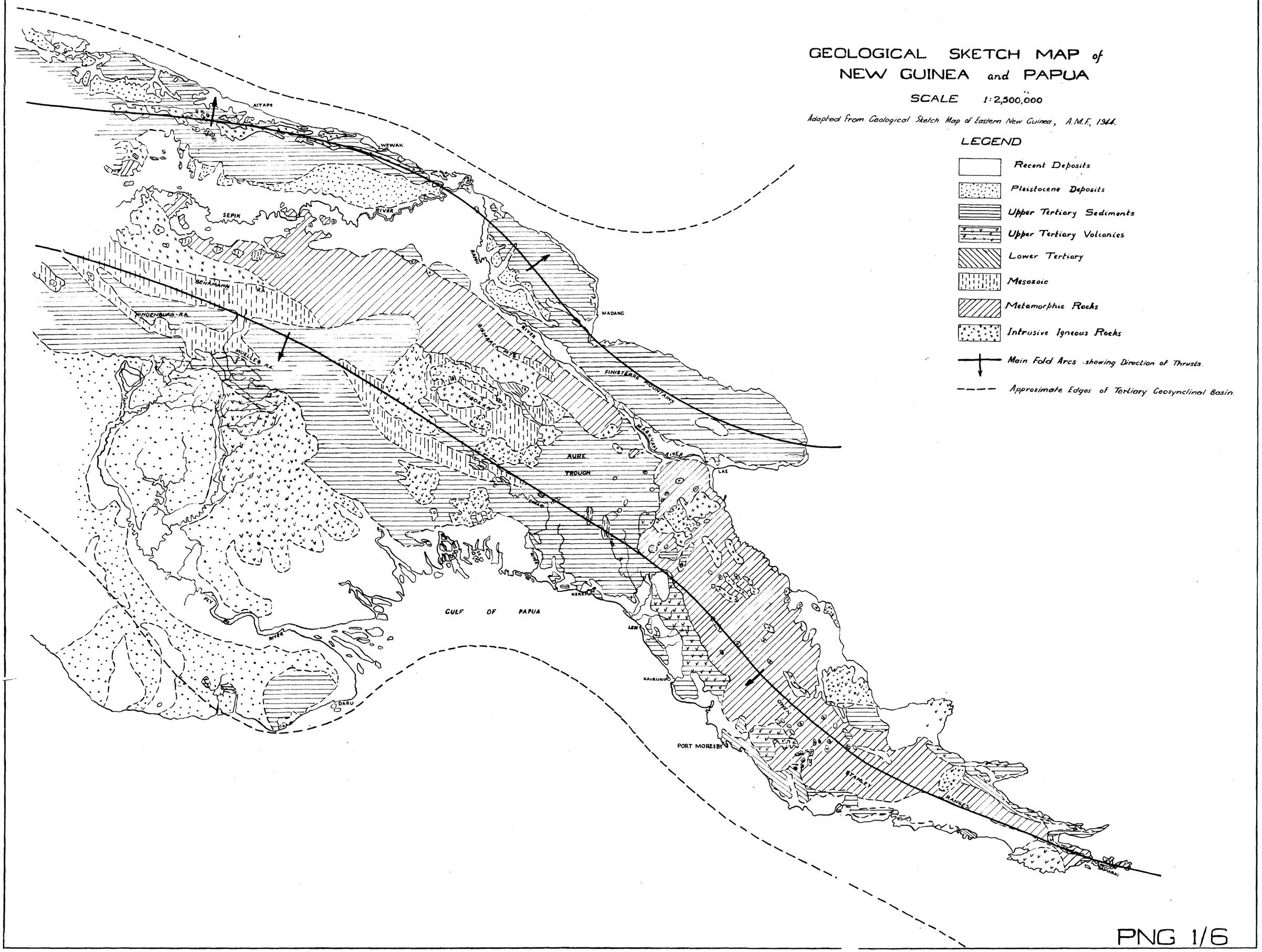
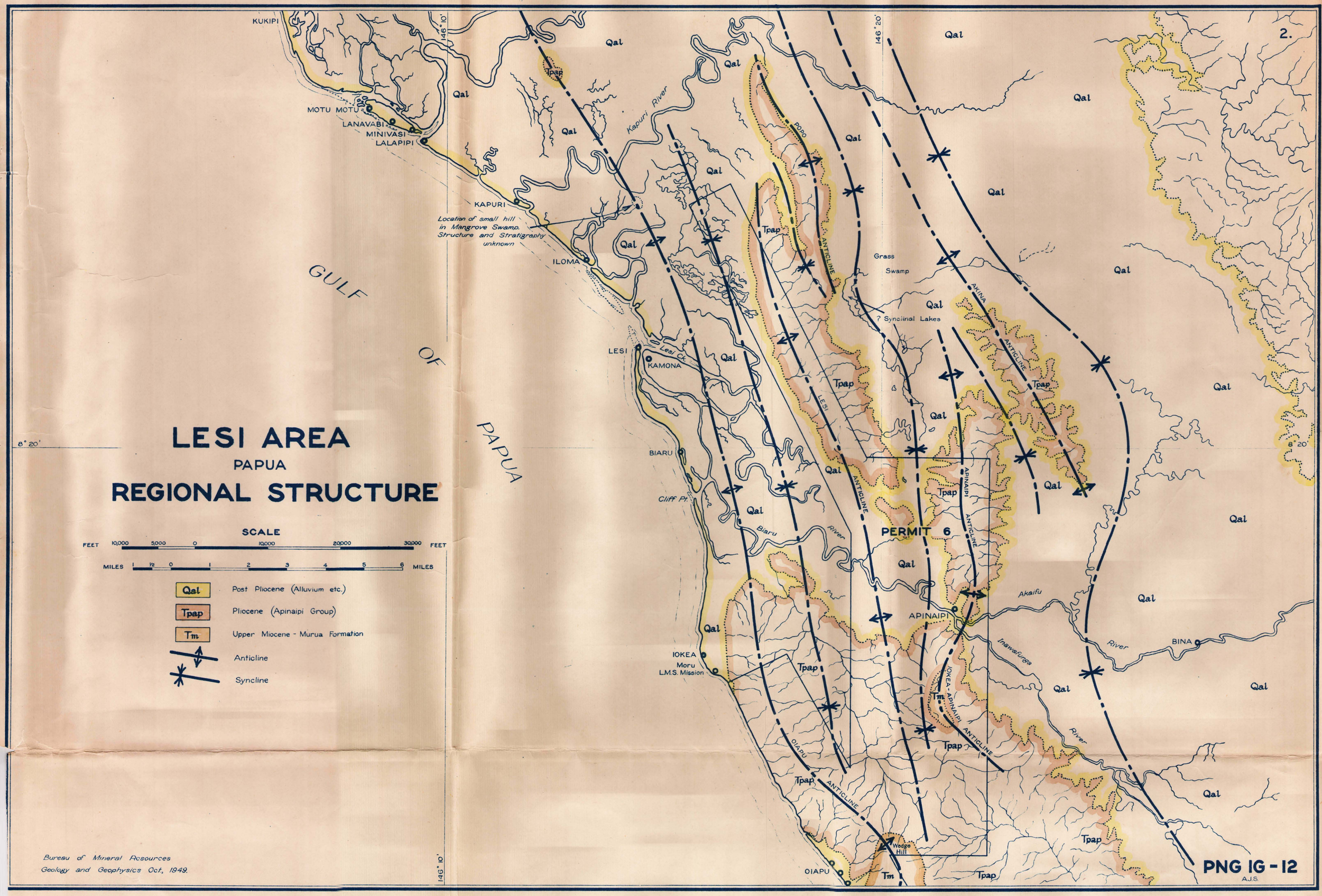
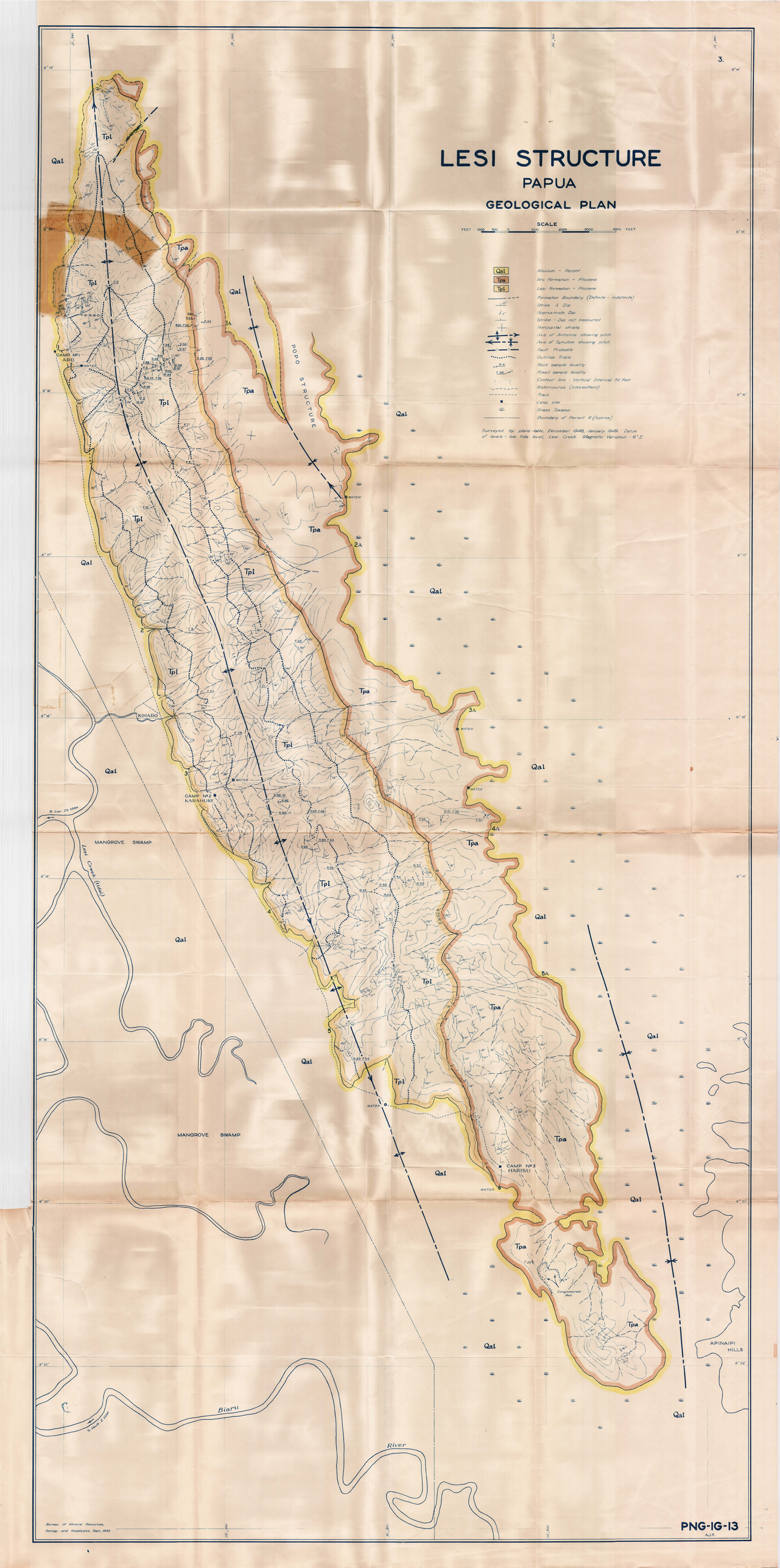


Photo No.3 From Arika looking North-east
1. Synclinal Lakes
2. Omeri Mountains


GEOLOGICAL SKETCH MAP of
NEW GUINEA and PAPUA
SCALE 1:2,500,000
Adapted from Geological Sketch Map of Eastern New Guinea, A.M.F. 1944.
LEGEND
Recent Deposits
Pleistocene Deposits
Upper Tertiary Sediments
Upper Tertiary Volcanics
Lower Tertiary
Mesozoic
Metamorphic Rocks
Intrusive Igneous Rocks
Main Fold Arcs showing Direction of Thrusts.
Approximate Edges of Tertiary Geosynclinal Basin.
AITAPE
WEWAK
SEPIK
RIVER
BISMARCK RANGE
MADANG
BISMARCK SEA
FINISTERRE MOUNTAINS
MAMBERAMO RIVER
LAE
AURE TROUGH
KUMDAWA
BEHRMANN RA.
HINDENBURG RA.
MUELLER RA.
FLY RIVER
GULF OF PAPUA
KEREMA
LEIN
KAIRUKU
OWEN STANLEY RANGES
PORT MORESBY
DARU
SAMARAI

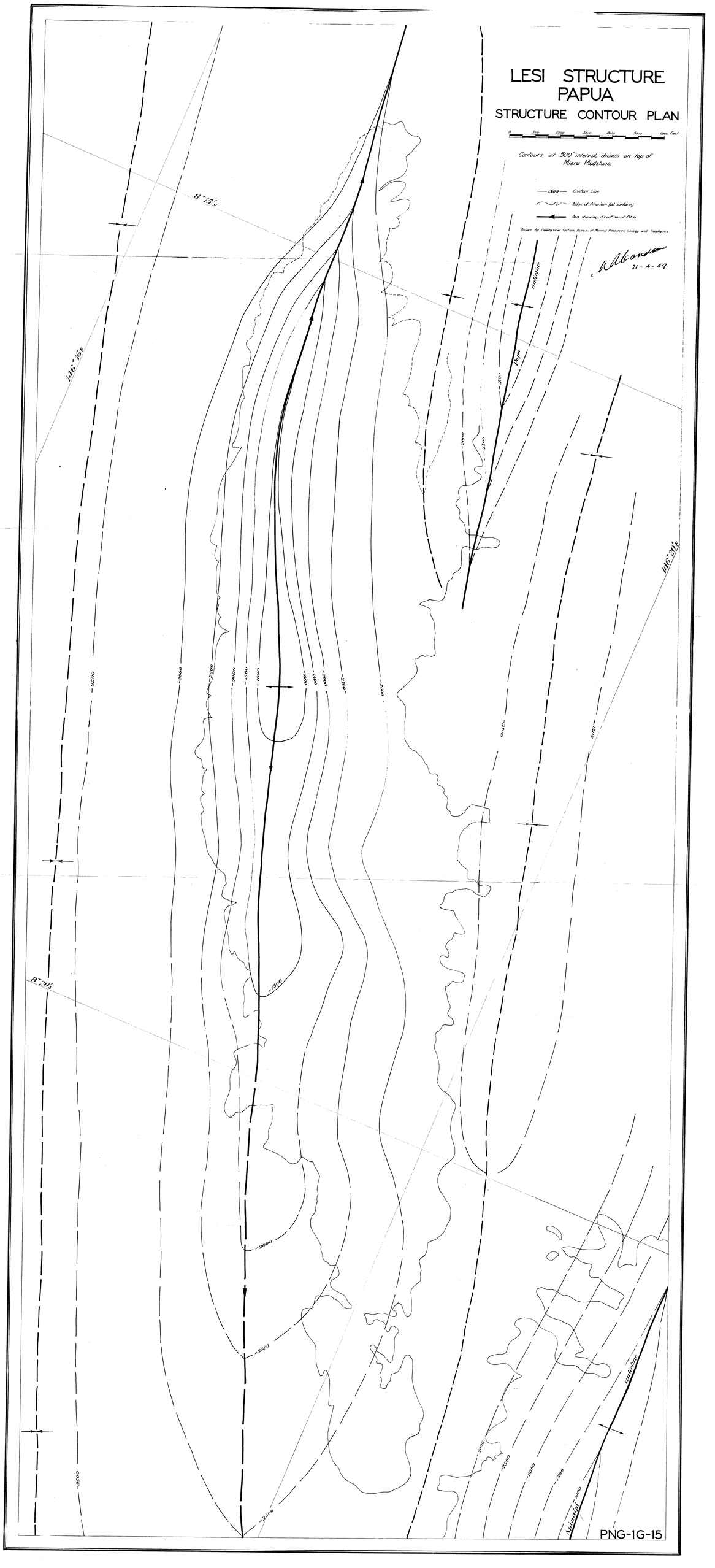
PNG 1/6


2.
LESI AREA
PAPUA
REGIONAL STRUCTURE
SCALE
FEET 10,000 5,000 0 10,000 20,000 30,000 FEET
MILES 1 ½ 0 1 2 3 4 5 6 MILES
Qal Post Pliocene (Alluvium etc.)
Tpap Pliocene (Apinaipi Group)
Tm Upper Miocene - Murua Formation
Anticline
Syncline
Bureau of Mineral Resources
Geology and Geophysics Oct, 1949.
GULF OF PAPUA
KUKIPI
MOTU MOTU
LANAVABI
MINIVASI
LALAPIPI
KAPURI
Location of small hill in Mangrove Swamp. Structure and Stratigraphy unknown
ILOMA
LESI
KAMONA
Lesi Ck
Kapuri River
BIARU
Cliff Pt
Biaru River
IOKEA
Moru L.M.S. Mission
OIAPU
Wedge Hill
APINAIPI
Akaifu River
Inawaturgea
BINA
PERMIT 6
Grass Swamp
? Synclinal Lakes
POPO ANTICLINE
AKINA ANTICLINE
LESI ANTICLINE
APINAIPI ANTICLINE
IOKEA-APINAIPI ANTICLINE
OIAPU ANTICLINE
146° 10'
146° 20'
8° 20'
PNG IG - 12
A.J.S.


3.
LESI STRUCTURE
PAPUA
GEOLOGICAL PLAN
SCALE
FEET 1000 500 0 1000 2000 3000 4000 FEET
Qal Alluvium - Recent
Tpa Aro Formation - Pliocene
Tpl Lesi Formation - Pliocene
Formation Boundary (Definite - Indefinite)
Strike & Dip
Approximate Dip
Strike - Dip not measured
Horizontal strata
Axis of Anticline showing pitch
Axis of Syncline showing pitch
Fault Probable
Outcrop Trace
Rock sample locality
Fossil sample locality
Contour line - Vertical Interval 50 feet
Watercourse (intermittent)
Track
Camp site
Grass Swamp
Boundary of Permit 6 (Approx)
Surveyed by plane-table, December 1948, January 1949. Datum of levels - low tide level, Lesi Creek. Magnetic Variation - 6° E
CAMP Nº1 ARO
POPO STRUCTURE
KIHARO
CAMP Nº2 KARAHURE
MANGROVE SWAMP
Lesi Creek (tidal)
CAMP Nº3 HARISU
APINAIPI HILLS
Biaru
River
Bureau of Mineral Resources, Geology and Geophysics, Sept. 1949
PNG-IG-13
A.J.S.


LESI STRUCTURE
PAPUA
STRUCTURE CONTOUR PLAN
0 500 1000 2000 3000 4000 5000 Feet
Contours at 100 ft. interval, drawn on base of Calcareous beds 800 ft below top of Apinaipi Formation.
Heights referred to Sea Level.
Contour Lines
Edge of Alluvium
Axis showing direction of Pitch
Fault
Drawn by Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics.
M.A. Condon
21-4-49
8°15's
140°10's
140°20's
8°20's
Approximate Position of Synclinal Axis
Apinaipi
Structure
PNG-1G-14

LESI STRUCTURE
PAPUA
STRUCTURE CONTOUR PLAN



Contours, at 500' interval, drawn on top of Miaru Mudstone.

Drawn by Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics.

21-4-49.

PNG-1G-15

LESI STRUCTURE

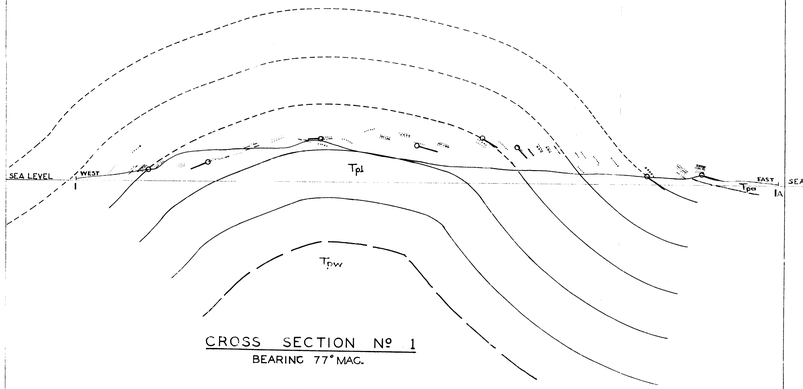
STRUCTURAL SECTIONS AND STRATIGRAPHIC COLUMNS

SCALES

CROSS SECTIONS AND COLUMNS

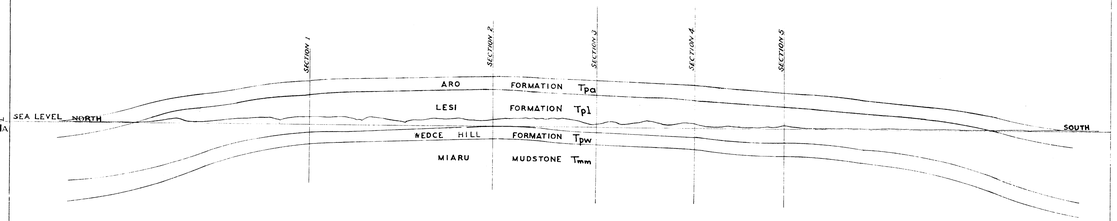
AXIAL SECTION

21-4-49.



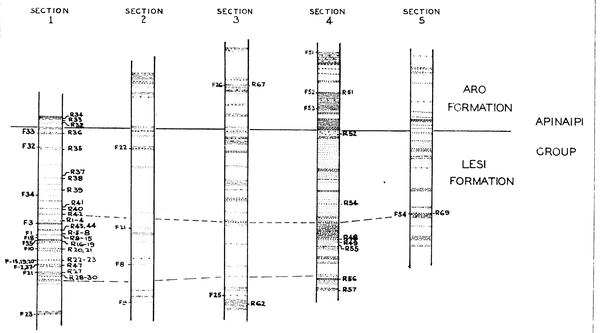
CROSS SECTION Nº 1

BEARING 77° MAG.



AXIAL SECTION

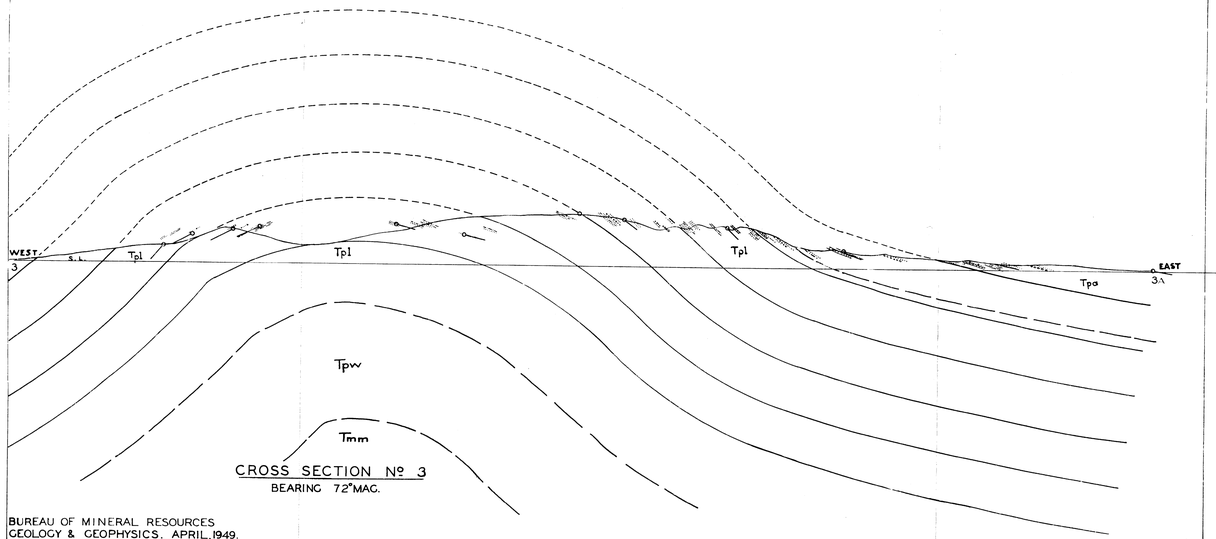
LOOKING EAST



STRATIGRAPHIC COLUMNS

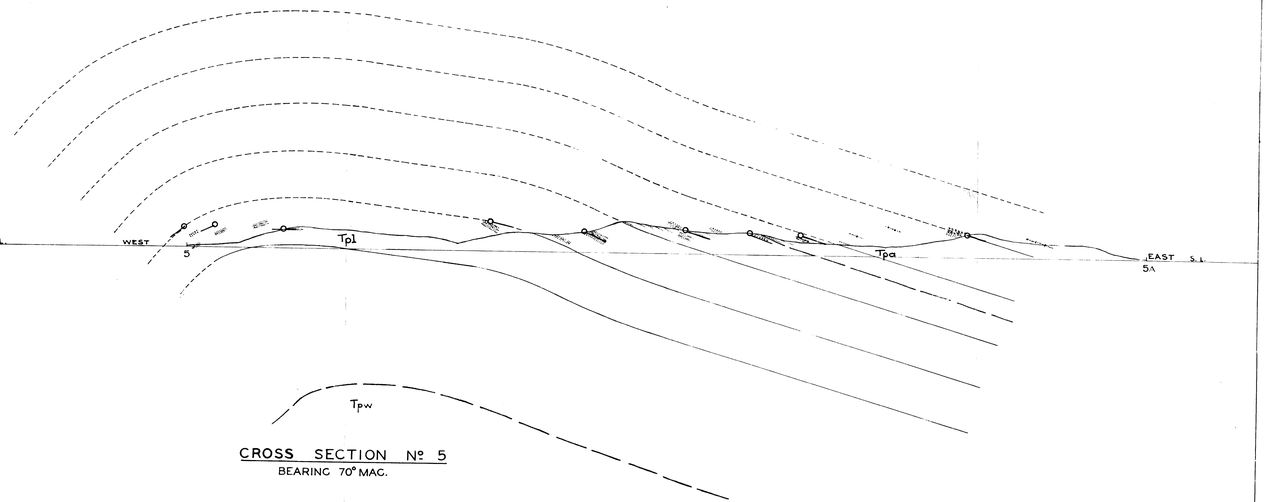
LEGEND

- Conglomerate
- Fine Conglomerate
- Pebbly Sandstone
- Sandstone (Greywacke)
- Red Calcareous Sandstone
- Siltstone
- Calcareous Siltstone
- Limestone



CROSS SECTION Nº 3

BEARING 72° MAG.



CROSS SECTION Nº 5

BEARING 70° MAG.

BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS. APRIL, 1949.

PNG IG-17