GEOLOGICAL REPORT ON A RECONNAISSANCE OF THE MARKHAM AND UPPER RAMU DRAINAGE SYSTEMS, NEW GUINEA.

by

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PLANS.

INTRODUCTION.

GENERAL

The reconnaissance was carried out during portions of 1953 and 1954, and the area investigated lies between Kainandu in the northeastern part of the area and Wau in the south, i.e. the main drainage systems of the Markham and Upper Ramu Rivers (see Plate 1). The main objects of the reconnaissance were to add to the maps already made in the area by other geologists and to examine and determine the extent of the Tertiary rocks lying between the Bismarck Range and the Lower Watut River.

The main method of transport is by aeroplane from the coastal seaport of Lae to the various air-strips in the area. A motor road runs from Wau through Bulolo and Mumeng to Lae, and another road, suitable only for four-wheel drive vehicles, has been opened from Gusap over the Bismarck Range to Kainantu and on to Goroka west of the area shown on Plate 1.

METHOD OF SURVEY

Military one-mile maps of the southeastern part of the area and along the Markham River were used as a base map for the plotting of observations. A photo-interpretation topographical map, produced by G.A.V. Stanley at a scale of 1/100,000, was used in the Kainantu area. Mapping in the central portion of the area was done by pace-and-compass traversing, and the traverses were linked in with the military one-mile maps. The topography of the Langimar-Kareeba area was obtained from military four-mile maps. The final map (Plate 1) was produced on a scale of four miles to the inch.

PREVIOUS GEOLOGICAL WORK

Over a period of years up to the evacuation of New Guinea during World War II considerable regional work was carried out by the Government geologists, N.H. Fisher and L.C. Noakes, in the Morobe District south of Markham River. Detailed work was confined to the Wau-Edie Creek, Bitoi River, and Upper Watut River areas. In 1950 a geological reconnaissance by G.A.V. Stanley of the Central Highlands covered the northern part of the area.

This report gives a summary of the work now completed in the area, but more detailed work remains to be done by the resident geological staff stationed at Wau. The accompanying map (Plate 1) is a combination of mapping by the writer and that by N.H. Fisher and L.C.Noakes in the southern half of the area.

TOPOGRAPHY

RELIEF

The area shown in Plate 1 covers part of the Main Ranges of New Guinea which form the high countainous backbone of the island. Within the area examined, this great cardillera consists of a series of rugged ranges deparated by broad upland valleys. In the northern part of the area the two main ranges are the Bismarck Range and the Kratke Range, with mountain peaks in both ranges exceeding 9,000 feet in altitude. East of the southern part of the Mountains, Kuper Range, and Ekuti Range, all reaching an altitude of 10,000 feet.

The Bismarch Range and southern part of the Kratke Range both rise sharply from the Ramu-Markham Valley: the two ranges are separated by a series of basin-valleys at an average altitude of 5,000 to 6,000 feet. Large lakes occupied some of these valleys, probably in Pleistocene time, and have since been drained. Lacustrine beds deposited here are being dissected during the present cycle of erosion. The Kratke Range divides the northerly-flowing tributaries of the Upper Ramu and Markham River from streams draining south into the Purari River system.

The Bismarck Range trends east-south-east and is chiefly composed of granite and metamorphic rocks, probably Palaeozoic in age; the Kratke Range consists of sedimentary and volcanic rocks of Tertiary age with occasional Palaeozoic remnants exposed as mountain peaks in the range.

South of the Lower Markham River, the Herzog Mountains, Kuper Range, and Ekuti Range are mainly composed of granitic rocks of the Morobe Batholith (Fisher, 1944). The Herzog Mountains and Kuper Range rise steeply from the Huon Gulf and the Ekuti Range constitutes the main divide, separating the southerly drainage of the Papuan fall from the Watut River and its tributaries, which drain to the Markham River.

The long Ramu-Markham valley forms the northern boundary of the area. This trough-like depression runs from Gusap to the coast of New Guinea at Lae and is the south-eastern end of the great Sepik-Markham Depression (Montgomery, Osborne, and Glaessner, 1950). The valley is very flat and is covered by alluvium and grassy swamps. North of this depression lie the rugged Finisterre and Saruwaged Ranges, which rise steeply from the Ramu-Markham valley.

Throughout the area the heavily timbered mountain ranges contrast strongly with the undulating grasslands of the Ramu-Markham valley and the other river valleys.

DRAINAGE

The Upper Ramu drainage system in the north, and the Markham drainage system which covers the majority of the area, are the two main drainage systems.

Upper Ramu Drainage System:

The Ramu River rises 15 miles west-south-west of Kainantu in the mountains between the Bismarck Range and the Kratke Range at about 6500 feet above sea level. It drains eastwards through uplands valleys near Kainantu and then northwards through a deep gorge in the Bismarck Range on to the alluvial grasslands of the Ramu-Markham valley at 1300 feet above lea level. Here it swings sharply to the north-west and flows along its flat valley to join the valley of the lower Sepik River. Numerous tributaries flowing down from the northern flanks of the Bismarck Range join the Ramu River in its flat valley.

Before entering the gorge in the Bismarck Range the Upper Ramu River flows through several large basin-valleys. Lacustrine beds in these valleys are being dissected by the Upper Ramu River and its tributaries in the Kainantu area.

Markham Drainage System:

The Markham River rises in the Finisterre Range north of Gusap and flows in a southeasterly direction along its wide, flat valley to its mouth at Lae on the Huon Gulf.

Although only about 120 miles in length, the Markham River discharges a great volume of water into the Huon Gulf, because of the large number of tributaries that drain from the mountain ranges on both the northern and southern sides of the Markham valley. Drainage from the north into the river by numerous tributaries has built up a series of piedmont fans as foothills on the southern flank of the Saruwaged Range. The largest tributaries flowing into the Markham River from the north are the Umi, Leron, Irumu and Erap Rivers.

The main tributary joining the Markham River from the south is the Watut River, the headwaters of which are in the Ekuti Range, 10 miles southwest of Wau and about 60 miles south of the Markham River. The upper part of the river flows in a northerly direction until it is joined by the Bulolo R River. About 5 miles farther downstream, the Watut River is joined by the Snake River and flows in a general northwesterly direction through a long tract of gorge. Emerging from this gorge near Marilinan, the Watut River winds its way over alluvial flats to its junction with the Markham River.

The Bulolo River rises near Kudjeru, 10 miles south of Wau, and flows in a northerly direction, parallel to the Watut River, through a broad deep valley to its junction with the Watut River. Tributaries of the Bulolo River discharge from well-entrenched valleys on the western slopes of the Kuper Range and on the eastern side of the divide separating the Bulolo and Watut Rivers.

The head of the Snake River is in the Herzog Mountains and the river flows outhwest through a steep gorge until it reaches Mumeng. Here the river swings sharply round a spur and runs in a southerly direction to join the Watut River at Sunshine.

Two rivers, the Banir and the Langimar, have their source in the rugged mountains west of the Watut River. Both rivers rise near the Papuan border and flow through precipitous gorges and ravines to join the Lower Watut River, four miles south of Marilinan.

On the eastern flank of the Kuper Range lie the headwaters of the Francisco and Bitoi Rivers. These rivers and their tributaries are entrenched in steep valleys and narrow gorges separated by sharp ridges; they drain to the east and flow into the Huon Gulf. North of these streams drainage to the coast flows into the Buang and Bwussi Rivers, which run along steep gorges until they reach the coast. On the southwestern side of the Ekuti Range are the headwaters of the Kapan, Kereeba and Indiwi Rivers. These rivers are deeply entrenched in narrow gorges separated by razorback ridges and they flow southwards to join the Lakekamu River system in Papua.

STRATIGRAPHY.

At the present stage of knowledge of the geology of the area covered by this report, the stratigraphical sequence can only be divided into the following broad groups:

Palaeozoic, Mesozoic, Tertiary, Pleistocene, Pleistocene to Recent, and Recent.

PALAEOZOIC.

Metamorphic Complex:

The oldest rocks of the area occur in the northwestern

Section, where they form the southeastern end of the Bismarck Range. The rocks consist of quartz-mica schist and gneiss, white quartzite, grey quartzite, blue slate, grey phyllite and grey sericite schist. These highly metamorphosed rocks have been strongly folded during regional metamorphism into a metamorphic complex which is considered to form the basement core of the Central Highlands of New Guinea. The strike of the rocks is generally north-south with dips ranging from 50° to vertical.

The age of the metamorphic complex is not known but it is considered to be Palaeozoic. Rocks of Permian age overlying similar metamorphic rocks have recently been found by F. Rickwood in the Wahgi Valley area.

Granodiorite:

The metamorphic complex has been intruded by plutonic rocks which are dominantly granitic. The original magma appears to have been a granodiorite from which more acid and basic types have been differentiated locally. Pegmatitic veins intrude the metamorphic rocks in Efontara Creek, 3 miles northwest of Kainantu. The pegmatite is composed essentially of quartz and felspar together with muscovite and abundant pyrite. More basic differentiates occur near the margin of an intrusion, 7 miles northwest of Kainantu, and in the range to the east of Mt. Yonki. At the head of Yonki Creek tongues and gabbro, ranging from 6 inches to 10 feet in width, have intruded the granodiorite, and veins of white quartz have intruded both the granodiorite and the metamorphic rocks.

Gold mineralization in the Kainantu area, and especially in the Yonki Creek region, is mainly associated with the intrusions of granitic rocks into the metamorphic complex.

MESOZOIC

Kaindi Metamorphics:

These rocks are found in the area south of the lower reaches of the Markham River, i.e. in the southeastern portion of the area shown in Plate 1. They were originally named the "Kaindi Series" by N.H. Fisher (1944). These consist of sandstone, greywacke, shale, phyllite, slate, quartzite, andalusite schist and quartz-sericite schist with interbedded levels of recrystalized limestone. Boulders of sheared conglomerate have been found in Gabensis Creek and the Wafi River; pebbles in this conglomerate consist of quartz and blue slate. The rocks have been folded into sharp anticlines and synclines which trend in a northerly to northeasterly direction. Minor folds have developed on the limbs of the major folds, and the dip of the beds ranges from 25° to 80° but is usually 40°-50°. Local variations in strike and dip are probably due to the large granitic intrusions which occur in the area.

The degree of metamorphism of the Kaindi Metamorphics varies considerably. In some localities fissile slate, quartz-sericite schist, and knotted shist are the main rock types and are the results of strong regional metamorphism of sedimentary beds. In other places, such as the Sunshine-Mumeng area and the Lower Watut River, shale and greywacke show very little alteration.

No fossil remains have been found in lenses of white fine-grained, recrystallized limestone, interbedded with blue slate, in the Snake River area, despite extensive search.

The only fossils found in the Kaindi Metamorphics were first discovered by F.W. Whitehouse in 1943 in the Sunshine area near the junction of the Snake and Watut Rivers. Specimens were collected by G.A.V. Stanley in 1946 and examined by M.F. Glaessner (1949) who determined their age as Cretaceous. The fossils are mainly lamellibranchs and gastropods and occur in interbedded shale and greywacke which are not greatly altered from the original sediments. The fossils are considerably distorted owing to the folding and compression of the rocks. The writer has collected specimens from the northern extension of the fossiliferous rocks; fossils are now known to occur over a thickness of rocks of 1000 feet and for seven miles along the strike of the beds. South of Sunshine the fossiliferous rocks are intruded by part of the Morobe Batholith. A close search of locally less-altered beds elsewhere in the Kaindi Metamorphics will probably reveal more fossiliferous beds.

Tentatively the whole of the Kaindi Metamorphics are considered to be of Mesozoic age, but it is quite possible that some of the rocks are older. Detailed work will be carried out in the near future in order to differentiate part of the Kaindi Metamorphics into several stratigraphical units.

Morobe Batholith:

Intruding the Kaindi Metamorphics is a large plutonic mass named the Morobe Batholith by Fisher (1944). He describes it as follows;

> "Though usally referred to by the field term granite, analysis of numerous thin sections cut from specimens collected at various parts of the intrusion, from the centre out to the margins, shows it to be a slightly acidic granodiorite, or adomellite. Average silica content is just below 70 percent. Differentiated phases of the mass have produced, especially around the margins, such types as monzonite, diorite, hornblendite, and even a very little pegmatite".

The batholith forms the main part of the Ekuti and Kuper Ranges and also occurs in the Herzog Mountains at the head of the Snake River, in the Wampit River area, and around Lake Wanum.

It appears that the large Morobe Batholith intruded the Kaindi Metamorphics towards the close of the orogenic epoch during which the Kaindi Metamorphics were folded; the batholith conformed to a considerable extent, to the structural axes of the intruded rocks. The grantic intrusions are generally elongated parallel to the fold axes of the metamorphics and are considered to have been emplaced towards the close or at the end of the Mesozoic era.

Much of the widespread gold mineralization of the Morobe District is associated with the intrusion of the Morobe Batholith.

TERTIARY

Rocks of Miocene-Pliocene Age:

These rocks occur in the area between the southern margin of the metamorphic rocks of the Bismarck Range and the western limit of the Kaindi Metamorphics and Morobe Batholith. This area is the northern extension of the structural unit of New Guinea known as the Aure Trough (Glaessner, 1950). Upper Tertiary rocks extend well to the west and south of the area into Papua, where they are dissected by the Purari and Tauri drainage systems. North of the Markham Valley, sedimentary and volcanic rocks of

Miocene age from the southern flanks of the Finisterre and Saruwaged Ranges. Sedimentary rocks of Tertiary age are not present in the area between the Watut River and the coast of New Guinea. Probably most of this area remained a land mass while the marine sediments were deposited on its western side during Tertiary time. Fisher (1944) states that:

> "The composition of the Tertiary conglomerates to the west and south (in the Langimar-Kareeba area) and the general distribution of the sediments strongly suggest that their component materials were derived from such a land mass to the east."

South of the Bismarck Range the sedimentary rocks consist of interbedded shale, silstone, calcareous siltsrone, sandstone, tuffaceous sandstone, grit, conglomerate and limestone. Fossils collected by Stanley (1950) from the limestone show the age of this sequence to be lower Miocene. The largest limestone lens is the Sonofi Limestone, which is 1100 feet thick and four miles in length. The upper part of the stratigraphical sequence is composed of basic colcanic rocks, mainly basalt and volcanic breccia.

In the Kainantu area, the Tertiary strata are separated from the older metamorphic rocks by an angular unconformity. The younger beds have been folded into broad folds and the dip of the beds ranges from 20° to 50°. One synclinal fold has been named the Orlowat Syncline by Stanley (1950), who estimates the thickness of strata on the northeastern limb of the fold to be 18,300 feet. Undoubtedly a considerable thickness of Miocene rocks is present here, but an accurate estimation cannot be given until detailed work is carried out in this area.

Near the Orlowat River the sedimentary beds have been intruded by a mass of granodiorite, This plutonic rock is a fine to medium-grained horblende-biotite granodiorite which has produced contact metamorphism of the sediments around its margin during its intrusion. Near the granodiorite, dyke-like intrusions of sepentine rock have invaded the sediments along the strike of the strata. The main dyke crops out intermittently for a distance of 4 miles along the strike of the sediments and dips at 70° to the northeast whereas the sediments dip at 45° to the southwest. The maximum thickness of serpentine exposed is 150 feet. Nothing is known about the relationship of the serpentine rocks to the nearby granodiorite.

Several mils west and southwest of Kainantu, small igneous masses intrude the older metamorphic complex. They consist of diorite porphyry, gabbro porphyry and biotite andesite. The largest body occurs at Mt. Munepinks; it is 1 mile by 2/3 mile in area of outcrop and forms a conspicuous mountain near the Kainantu-Goroks road, 6 miles west of Kainantu. Gold mineralization in this area is probably related to this intrusion of diorite porphyry. All the porphyritic intrusions are considered to be late Tertiary in age.

On the northern flanks of the Bismarck Range near the Ramu-Markham valley, siltstone and sandstone with interbedded lenses of limestone overlie the metamorphic complex unconformably. The strike of the beds is southeast and the sediments dip at 45° to the northeast. Lower Miocene fossils have been found by A.K.M. Edwards in limestone near the point where the Ramu River emerges from the mountains onto the flat Ramu Valley.

Miocene fossils have also been discovered by Fisher (Stanley, 1950) in limestone beds outcropping in the Wanton River area. Many large boulders of volcanic agglomerate occur in stremas draining from the mountains into the Wanton and Wamoat Rivers. Undoubtedly a volcanic phase is present in the Upper Tertiary sequence in this area and may be equivalent to the volcanic rocks in the Orlowat River area to the west. Further south the north-north-west strike of the sediments contrasts strongly with the easterly strike in the Wamoat River area. The sediments consist mainly of intercalated calcareous siltstone and sandstone, and, interbedded with the sediments, are beds of volcanic breccia and amygdoloidal basalt. The thickness of these volcanic beds ranges from 5 to 40 feet. Marine fossils collected by the writer from siltstone and limestone in this area are considered to be Upper Tertiary in age.

Along the Namund River, a section of some of the Tertiary rocks was examined. The sequence exposed was:

feet	
2100+	Conglomerate
650	Siltstone and calcareous siltstone
1700	Igneous rock (dacite)
1150	Siltstone and calcareous siltstone
1000	Conglomerate
350	Siltstone and calcareous siltstone
150	Limestone
7100+	

The conglomerate is composed of boulders, up to 2 feet in diameter, of quartz, blue slate, granodiorite, andesite, and basalt, firmly cemented together; it forms steep gorges along the Namund River. The dacite intruded the sediments as a sill before the strata were folded and is found in the same stratigraphical position on either side of an anticlinal fold.

In the Lower Watut area, between the Banir River and Wuruf, the Watut River runs parallel to the north-north-east strike of the sedimentary rocks, The dip of the sediments ranges from 25° to 43° to the east, and the sediments are unconformable with the Kaindi Metamorphics which lie east of the Lower Watut River. Granodiorite is exposed by the Langimar River several miles upstream from its junction with the Watut River. This is a remnant of the Morobe Batholith which is now surrounded by Upper Tertiary sediments, and it has been exposed by erosion.

A reconnaissance of the upper reaches of the Langimar, Kapau and Kareeba Rivers was carried out by Fisher (1935), who discovered that flows of fine-grained basalt, amygdaloidal basalt and hornblende andesite unconformably overlie the older metamorphic rocks and part of the Morobe Batholith in the headwaters of the Kapan River. With regard to the sedimentary rocks of the area, he says:

> "Further on over the divide into the Langimar watershed, the basalts are overlain by a marine sedimentary series consisting largely of conglomerates with intercalated horizons of massive, fossiliferous limestone, mudstone, shale and sandstone. Along the Langimar, these beds are beautifully exposed on the sides of ravines and mountains showing a minimum thickness of probably 3,000 feet".

Fossils collected from the sedimentary rocks were found to be Miocene-Pliocene in age (Fisher, 1935). On the Tauri River, older metamorphic rocks have been exposed near Menyamya by the river cutting through the overlying Tertiary sediments. This has also been seen by Fisher in gorges along the Gumi and Langimar Rivers.

Igneous Rocks in Wau-Bulolo Area:

Igneous rocks in the Wau-Bulolo area have been studied in some detail by Fisher (1939a and 1944). A succession of porphyritic intrusions in the Wau/Edie Creek area are closely related to each other and are considered to be Tertiary in age

The earliest intrusion is the Lower Edie Porphyry, which has intruded the Kaindi Metamorphics near Wau. It has been described by Fisher (1944) as a well crystallised quartz-biotite porphyry which appears to have been intruded at some depth below the surface. After the Lower Edie Porphyry came further intrusions of porphyry in the Wau/Edie Creek area. Fisher (1944) says:

> "As most of these are mutually independent, their exact relationships are difficult to determine, but intrusions occurred at two different periods at least, possibly three, all of which must, at present, be considered together. .... A wide difference in the mode of intrusion from that of the Lower Edie porphyry is apparent, and it obviously took place much nearer the surface."

After these porphyritic intrusions, explosive volcanic activity occurred in the Wau-Bulolo area and volcanic agglomerate and volcanic breccia were deposited. Both volcanic types consist predominantly of pyroclastic material, but the volcanic agglomerate has been deposited mainly under water. A description of the rocks is given by Fisher (1944).

> "These agglomerates consist not only of andesitic or, more accurately, dacitic volcanic material but also of boulders of the metamorphic series, the granodiorite and breccia is composed almost entirely of schist and fragments of the earlier porphyries, little volcanic material being recognisable".

Small bodies of biotite porphyry constitute the latest intrusions into the volcanic breccia. These porphyries are associated with gold orebodies in the Golden Ridges area.

PLEISTOCENE

Kainantu Beds:

Lacustrine beds occur in the open basin valleys near Kainantu. They consist of sub-horizontal clay, sand, gravel, and boulder beds, which were deposited in large lakes in the valleys. Subsequently the lakes were drained and the beds have been dissected by the present drainage system of the Ramu River. The beds are considered to be Pleistocene in age and the maximum thickness is about 100 feet.

Otibanda Beds:

A thick succession of lacustrine sediments has been deposited in the large double-basin which forms the valleys of the Upper Watut and Bulolo Rivers. These beds were named the "Otibanda Series" and described by L.C. Noakes (1938b) as follows:

> "The series comprises thick marginal phases of conglomerate beds,.............composed of granite,

porphyry and slate boulders in varying proportions, ...and grits, pebble beds and sand or mud deposits."

Bands of tuff and fine agglomerate are interbedded with the sediments near the base of the beds, in both the Watut and the Bulolo valleys, and these volcanic phases probably originated from intermittent explosive activity during the final stages of the earlier volcanic outbursts.

Bones of the marsupial Nototherium watutense were found in the lacustrine beds in the Upper Watut area (Fisher, 1944) and were identified as being similar to those of Nototherium from Pleistocene swamps of South Australia. The skull of a small Nototherium watutense was discovered by the writer in 1953 in the Otibanda beds at Koranga Creek.

In places the lacustrine beds are tilted and gently folded. This is attributed mainly to the earth movements which terminated the deposition of the beds and caused the draining of the original lake. The writer agrees with Fisher (1944) that the outlet from the lake was through the low Zenag Gap near Mumeng and into the Wampit River. It is also thought likely that, at an early stafe in its life, the Watut River flowed in this direction and along the present route of the Wampit River to join the Markham River.

PLEISTOCENE TO RECENT

Grouped under this heading are piedmont and volcanic deposits to which a definite age cannot be given but which are considered to be older than the extensive areas of Recent alluvium along the Markham, Ramu and Watut Rivers.

Piedmont Deposits:

Extensive piedmont deposits, several hundred feet in thickness, are present along the foothills on the northern side of the Markham valley. They consist of beds of ill-sorted gravel, sand, and silt, which slope gently from the mountains towards the Markham valley. The deposits have been laid down by streams draining from the Saruwaged Range and are being dissected by the present-day streams, which flow south into the Markham River.

In the Mumeng area, terraces of detrital material occur along the western side of the valley of the Lower Snake River and also form the wide Zenag Gap north of Mumeng. These piedmont deposits reach a maximum thickness of 400 feet near Zenag, and consist of ill-sorted angular and sub-angular material, swept down by streams and landslides from the mountains to the west and deposited in the Zenag Gap.

Detrital material has been brought down from the slopes of Mt. Kaindi west of Wau and has formed piedmont deposits on top of the Otibabda Beds on the southwestern side of the Bulolo alluvial wash which, in the Koranga area, are being extensively worked for their high gold content.

Volcanic Deposits:

Acid volcanic rocks occur in the Bismarck Range about 7 miles north of Kainantu. They consist of rhyolite flows and rhyolitic breccia lying sub-horizontally as a capping on Metamorphic and granitic rocks of the basement. The Present erosion cycle has removed most of the volcanic capping. The maximum thickness observed was 600 feet and the age of the volcanic rocks is considered to be between Pleistocene and Recent.

A succession of rhyolite flows and rhyolitic breccia, similar in appearance to the acid volcanic rocks mentioned above, occurs at Koranga near Wau. The volcanics lie on top of the piedmont deposits and dip gently to the southeast at angles up to 15°. The thickness of the volcanic beds is estimated to be 180 feet.

RECENT

Extensive deposits of alluvium occur in the long, wide valley of the Markham River and in the northwestern continuation of this valley along the Ramu River. The lower part of the Watut River, the main tributary of the Markham River, flows over wide alluvial flats which join the alluvial plains of the Markham River. Alluvium also occurs along the coastline of New Guinea at the mouths of streams flowing into the Huon Gulf.

Stream gravels and terraces have formed extensive placer deposits along the valleys of the Bulolo and Watut Rivers.

STRUCTURAL GEOLOGY

The area can be divided into four main structural units:

1. Central Highlands
2. Morobe Arc
3. Northern Extension of the Aure Trough
4. Ramu-Markham Depression

CENTRAL HIGHLANDS

The southeastern end of the Bismarck Range consists of a strongly folded metamorphic complex, intruded by granitic rocks, which is considered to form the basement core of the Central Highlands. The folding of the metamorphic rocks is very complex and the dominant trend is meridional or slightly east of north. Numerous minor folds and flexures are present and are well exposed in road cuttings between Kainantu and Goroka. The folding of the metamorphic rocks and subsequent intrusions of granitic rocks probably took place in late Palaeozoic time. In the Western Highlands Permian rocks are known to overlie both the metamorphics and the Kubor granite.

The moridional trend seen in the metamorphic complex cuts sharply across the east-south-east elongation of the Central Highlands. This elongation has previously been regarded as the structural trend of the whole of the Central Highlands but may not be so in the southeastern end of the Central Highlands. Stanley (1950) noticed the meridional trend in the metamorphics and he states that N. Osborne recorded the same feature while studying aerial photographs of part of the Central Highlands. Possibly the trend reflects trends in the northern extension of the Australian Shield, and the east-south-east elongation of the Central Highlands is simply a topographical feature, at least in the southeastern end of the Bismarck Range.

MOROBE ARC

The mountainous region south of the lower reaches of the Markham River consists of Kaindi Metamorphics and the intrusice Morobe Batholith. Part of the Kaindi Metamorphics are known to be Cretaceous in age, and at the present time all these metamorphics are classed as Mesozoic in age. The area is the northern part of the Morobe Arc (Glaessner, 1950), which continues in a southeasterly direction into the Owen Stanley folded zone.

There is a swing in the strike of fold axes in the metamorphic rocks from meridional in the area south of Wau, to northeast in the Herzog Mountains and near the Markham River. Rocks older than the Kaindi Metamorphics probably occur in the mountain ranges of the Morobe Arc. Highly metamorphosed schists and gneisses are known to be present in the Owen Stanley Range, which is the southeastern continuation of the Morobe Arc, but may not be exposed in the Morobe Arc.

The formation of the Morobe Arc, by the folding of the Kaindi Metamorphics and subsequent intrusion of the Morobe Batholith, is considered to have occurred in late Mesozoic, or possibly early Tertiary, time. The Morobe Arc does not continue through to the Central Highlands but swings to the northeast in the area north of Wau. Its continuation may be present as the basement rocks of the Northern Ranges which lie to the north of the Lower Markham River. The tectonic history of the Kaindi Metamorphics has been quite different from that of the gently folded, unmetamorphosed, Mesozoic sedimentary rocks of the Central Highlands.

Folded metamorphic rocks, lithologically similar to the Kaindi Metamorphics and intruded by granitic rocks, form the basement of the island of New Britain (Noakes,1942). These rocks may be a contination of the Kaindi Metamorphics of the Morobe Arc.

NORTHERN EXTENSION OF THE AURE TROUGH

Regarding the Aure Trough, Glaessner (1950) states:

> "This term was adopted by the geologists of the Australasian Petroleum Company for an area of very thick Late Tertiary sediments occupying a large area north of Kerema on the Gulf of Papua. This area is strongly folded. The folds exhibit a remarkable virgation, with one branch following the regional strike northwest while the other trends northward into the mountains, apparently crossing the main range and reaching the Lower Markham Valley."

The northern extension of this Aure Trough occupies the area between the Central Highlands and the Morobe Arc. The thick succession of Upper Tertiary sedimentary and volcanic rocks in the area has been broadly folded, probably during a major orogeny in late Pliocene time. Two main trends are apparent in the folding of the rocks. In the northern part of the structural unit, the trend swings from southeast in the west to east-north-east in the east. In the southeastern part, near the Morobe Arc, the trend is dominantly north-north-east. This latter trend is a continuation of the northerly trend known to exist in the eastern part of the Aure Trough further south in Papua.

The Aure Trough sediments may extend north into the Saruwaged and Finisterre Ranges, or they may terminate at the Markham valley. Upper Tertiary sediments exist north of the Markham valley, but nothing is known about their relationship to the Upper Tertiary sediments of the Aure Trough. The influence of strike faulting, as has occurred in the Aure Trough in Papua, on the Tertiary sediments in the northern part of the Aure Trough may have been considerable; but much more information is required about this feature.

RAMU-MARKHAM DEPRESSION

The Ramu-Markham Depression is the southeastern part of the great Sepik-Markham Depression (Montgomery et al., 1950), which separates the Northern Ranges and the Central Highlands of New Guinea and extends from the Dutch border through Australian New Guinea to the Huon Gulf.

The Ramu-Markham Depression is a trough-like depression of structural origin, which was probably formed during late Pliocene or early Pleistocene time. It appears to be a trough-fault which developed along an earlier zone of weakness. Uplift of both the floor and sides of the trough during earth movements probably caused the floor to sag below the sides of the trough and form the large trough-fault.

ECONOMIC GEOLOGY

GOLD AND SILVER

Production:

The area shown in Plate I is the major part of the Morobe Goldfield. 98 percent of the total production of gold and silver of the Territory of New Guinea has been derived from this goldfield. Gold produced from the Morobe Goldfield up to June, 1954 totalled 2,934,937 fine ounces, valued at £29,348,325. Production of silver has been incidental to gold-mining operations and, up to June, 1954, totalled 1,816,389 ounces valued at £285,489.

Dredges owned by Bulolo Gold Dredging Ltd., working along the Bulolo and Watut valleys, have won about 60 percent of the total gold production of the goldfield; about 32 percent has been won by other alluvial methods and only about 8 percent by lode mining.

Gold Production, Morobe Goldfield

Territory of New Guinea

Year	Alluvial (fine oz.)	Dredging (fine oz.)	Lode (fine oz.)	Total (fine oz.)	Value (£A)
Prior to 30/6/30	197,896			197,896	843,308
1930-31	29,824		34	29,858	154,046
1931-32	48,518		2,600	63,485	434,352
1932-33	46,236	62,635	13,042	121,913	925,899
1933-34	46,969	91,653	25,759	164,381	1,345,801
1934-35	41,185	124,681	29,736	195,602	1,730,644
1935-36	42,828	123,715	22,984	189,527	1,657,979
1936-37	49,077	136,867	30,152	216,096	1,901,989
1937-38	59,279	133,553	19,963	212,795	1,855,684
1938-39	48,216	159,769	21,228	229,213	2,116,117
1939-40	63,268	180,857	27,450	271,575	2,878,353
1940-41	63,329	173,833	18,873	256,035	2,733,880
1941-42				90,192	965,044
War	----------------	no production	----------------	----------------	----------------
1945-46				521	5,607
1946-47				18,002	193,713
1947-48				81,245	882,012
1948-49				89,764	974,540
1949-50	14,448	68,624	272	83,344	1,186,790
1950-51	18,906	66,917	853	86,676	1,342,756
1951-52	17,911	84,642	6,499	109,052	1,689,401
1952-53	19,303	111,827	6,602	137,732	2,133,698
1953-54	15,987	61,909	12,136	90.033	1,396,712
Total				2,934,937	29,348,325

Alluvial Mining:

Gold was first discovered on the Morobe Goldfield by W. Park in 1922 at the mouth of Koranga Creek, 3 miles north of the present township of Wau. In 1926 the rich alluvial deposits of Upper Edie Creek were found by Royal and Glasson and, after a rush of prospectors to the Wau/Edie Creek area, the development of the goldfield proceeded at a rapid rate. The first dredge began operations in 1932, and by 1940 eight dredges, all owned by Bulolo Gold Dredging Ltd., were operating in the Bulolo and Watut valleys. Apart from the extensive alluvial deposits of the Wau-Bulolo area, payable gold has been won on the coastal fall of the Kuper Range in the Bitoi River and Black Cat Creek, in a tributary of the Wampit River, in the Waime River, in tributaries near the mouth of the Wanton River, and in the headwaters of the Ramu River. In the Upper Ramu area most of the gold has been won from Yonki Creek, Ornapinka Creek, Barola Creek, Efontera Creek and Biakura Creek.

With regard to the source of the alluvial gold in the Wau-Bulolo area, Fisher (Nye and Fisher, 1954) states:

> "The principal sources of the gold of the Morobe district is the area at the head of Edie Creek, where it occurs as small rich stringers throughout an area of hydrothermally-altered schist - known as 'mudstone' - adjacent to intrusives of quartz porphyry, also hydrothermally altered and also carrying gold. These porphyries are of late Tertiary age and the gold associated with them is only 500-600 fine, but several other earlier porphyries of similar composition also introduced gold of different but slightly higher fineness, apparently mainly in small stringers like the later occurrences. Away from the Wau-Edie Creek area most of the gold is derived from mineralization associated with the extensive Morobe granodiorite batholith or related intrusives. All this granitic gold is of higher fineness, generally 850-900 parts per thousand."

In the Upper Ramu area the gold is derived from mineralization associated with granitic and porphyritic intrusions into the metamorphic rocks. Variations in the fineness of this gold are attributed to the different types of intrusions. As noted by Fisher (1945), gold is associated with magnetite at Yonki Creek and near Barola Creek, where several magnetite-gold lodes have been discovered.

Lode Mining:

In a goldfield which has produced nearly 3,000,000 fine ounces of gold, the only workable lodes so far discovered are near the head of Edie Creek and in the Golden Ridges area. Regarding the Upper Edie Creek lodes, Fisher (Nye and Fisher, 1954) states:

> "The outcrops of all these lodes consisted of soft manganiferous material with some quartz, and at deeper levels the lode material consisted of quartz and/or calcite with some rhodochrosite and a small proportion of Sulphides. Values decreased generally from the surface downwards, particularly below the zone of oxidation."

In the golden Ridges area the lodes occur in volcanic breccia, considered to be late Tertiary in age, wh has been intruded by the latest porphyries. The largest lodes are the Golden Ridges (now worked out), Upper Ridges, Anderson's Creek, and Golden Peaks. Near the surface the lodes consist of soft manganiferous minerals carrying more than one ounce of gold per ton; at shallow depth the lodes change to bodies of solid calcite with varying amounts of quartz, pyrite, and rhodochrosite. The gold content decreases rapidly below the manganiferous ore.

An outline of the geology and ore occurrences of the Wau/Edie Creek area is given in a paper by Fisher (1939a).

Outside the Wau/Edie Creek area, a magnetite lode has been developed near Barola Creek, five miles west-south-west of Kainantu (Mackay, 1953). The lode consists mainly of magnetite, hematite, and quartz, containing an average of 10 to 15 dwt. of gold per ton. Only one parcel of gold, about 50 ounces, has been obtained from this mine up to date, although several hundred tons of ore are at grass.

About 8 miles west of Mumeng, a prospector named Wharton operated a small open-cut near Subroar Creek for 6 months before the war. The open-cut is located on the edge of a body of granodiorite intrusive into grey banded slate. Joints in the granodiorite near its contact with the slate are filled withquartz and iron oxides and carry a small amount of gold. Wharton crushed the material from the joints in a small one-head battery. This gold occurrence is far too small and low-grade to be operated at the present time.

Fineness of Gold:

As stated earlier, the fineness of gold varies considerably in different areas according to its source. A full description of the fineness of gold in the Morobe Goldfield is given by Fisher (1945). His results are summarised below:

"1. The latest mineralization in the Edie Creek area, associated with quartz-biotite porphyry and with intense general metasomatism, produces gold, both in small stringers and in large manganiferous lodes, of fineness about 530 parts per thousand.

2. Mineralization of apparently the same period in the Golden Ridges area introduced gold of rather higher grade, 620 or thereabouts.

3. Certain other porphyries,....belonging to this general period of intrusive activity,....are associated with gold of value 550 to 570.

4. The earlier, deeper-seated porphyries of the Lower Edie type introduced gold of fineness 730 to 790, maximum range 650 to 800.

5. Gold derived from granodioritic sources is very consistently 860 to 890 in value.

6. The total range in mixed parcels is 460 to 935...."

PLATINUM AND OSMIRIDIUM

Very small quantities of platinum and osmiridium have been found in parcels of alluvial gold won from the headwaters of the Ramu River. The minerals have apparently been shed from dykes of serpentine in this area and occur as fine disseminations in the serpentine. Total production has only been a few ounces.

COPPER

A small copper lode, occurring in micaceous schist, crops out in Yonki Creek, 5 miles northeast of Kainantu. The lode is exposed along a length of 15 feet and is 6 feet in width. The strike of the lode is 040° with a dip of 80° to the south, and another small lode outcrop lies 45 feet farther along the strike of the lode. The lode consists of malachite, azurite, magnetite, hematite, and quartz. Hand-picked ore assayed 30 percent copper, but assays of samples taken across the full width of the lode would probably show 5 to 8 percent copper. A trace of gold is also present in the ore. The leaseholders hope to sink a shaft on the lode at some future date but there appears to be no possibility of developing this lode at the present time owing to the size of the lode and the remoteness of the area.

RECOMMENDATIONS FOR FUTURE WORK

Initially, future work should be limited to the two surveys listed below. These surveys are both of a detailed nature, and after they are completed further work in the area can be planned by the resident geological staff stationed at Wau.

1. A plane-table survey, probably at a scale of 400 feet to the inch, along the Lower Watut River from Sunshine, where Cretaceous fossils have been found, to the junction of the Banir River with the Lower Watut River. The traverse can then be continued up to the Banir River to its headwaters in the Kratke Range.

The object of this survey would be to get information about the structure, stratigraphy, and age both of the Kaindi Metamorphics along the Lower Watut River and of the Upper Tertiary sediments in the Banir River area.

2. A detailed survey of an area running south from Aiyura over the Kratke Range into the headwaters of the Lamari River. From this survey information regarding the stratigraphical sequence of the Tertiary rocks forming the northwestern part of the Aure Trough could be obtained.

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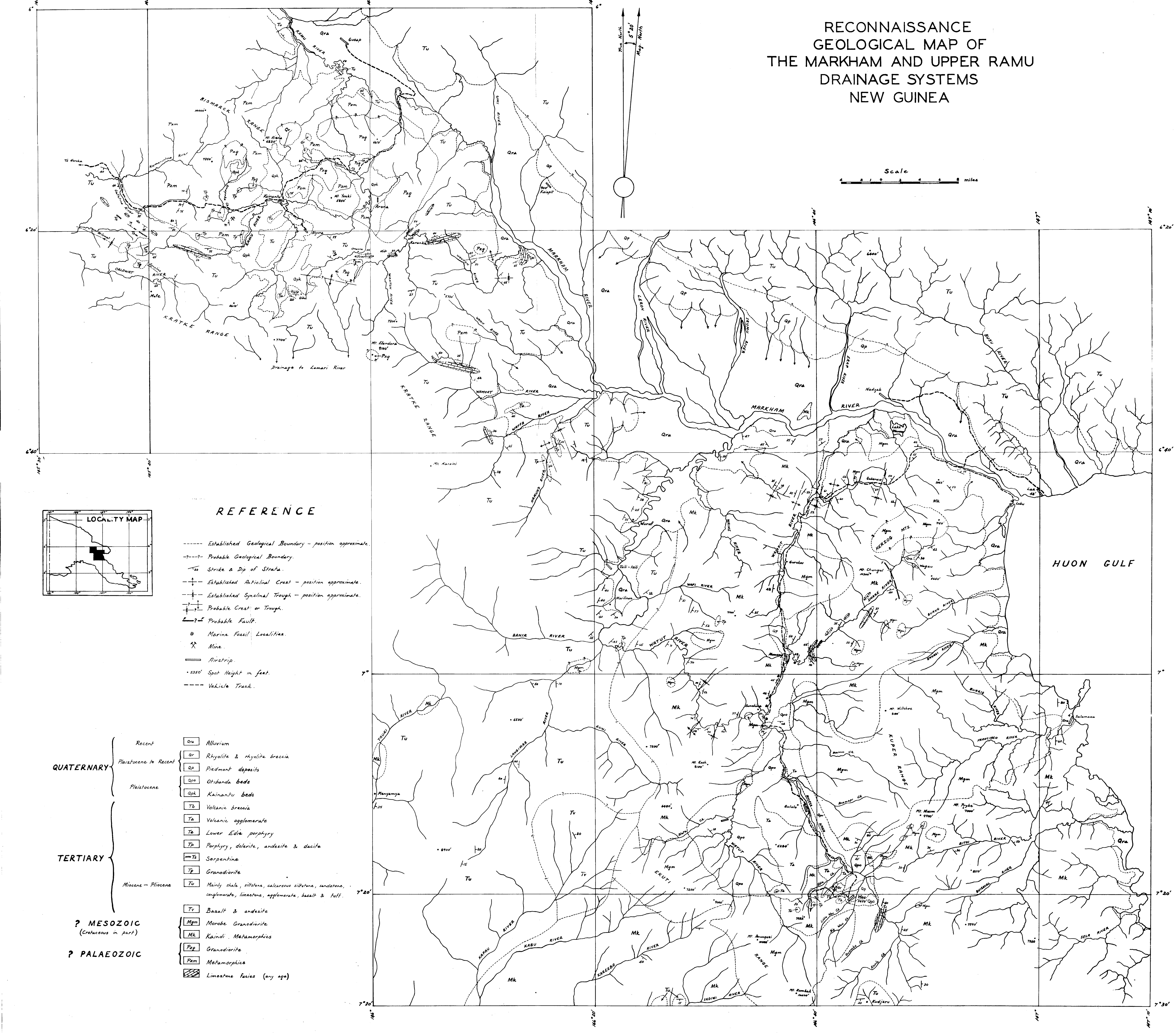
PLATE 1



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