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The Geology of the South Sepik Region, New Guinea

by

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SUMMARY

Until 1965 the mountains south of the Sepik River had remained largely unexplored, mainly because the region is very difficult of access; but also because of the inhospitable nature of the country. It is very rugged, wet, and has an unrelieved cover of tropical rain forest: the whole area supports only very few semi-nomadic people and hence tracks are almost non-existent.

The Bureau mapped the area using Hamilton jet-boats in 1966 and 1967 for access to the mountains, and a helicopter in 1967 to position field parties within the mountains.

The South Sepik region occupies a small segment of the fundamental break separating the stable Australian continental block from the oceanic crust to the north. This break, which is marked in the South Sepik region by the Lagaip Fault Zone, has had a profound effect on sedimentation of the region throughout the geological record, for shelf-type sediments were laid down on the continental block, while geosynclinal sediments were being deposited to the north.

The oldest rocks are Middle and Upper Triassic in age and include a widespread and distinctive volcanic unit called the Kana Volcanics. They are succeeded unconformably by a thick sequence of black pyritic shale called the Lagaip Beds, which was laid down south of the Lagaip Fault Zone during the Jurassic and Cretaceous.

North of the fault zone sedimentation also started in the Middle Jurassic with the deposition of a great thickness of marine basic volcanics called the Mongum Volcanics. Shale (Maril Shale and Sitipa Shale) was then deposited in the Upper Jurassic and the eugeosyncline reached full development during the Cretaceous and Eocene when the Salumei Formation, consisting of shale, turbidites, basic marine volcanics, and limestone, were laid down.

A break in sedimentation occurred both sides of the fault zone during the Eocene and Oligocene, after which volcanic rocks and

volcanically derived sediments (Pundugum Formation) were laid down north of the fault zone in the Lower Miocene. To the south the Lower Miocene sediments consist of limestone and marl.(Yangi Beds and TibininiLimestone Member).

The uppermost Lower Miocene saw a climax of the tectonic and igneous activity throughout the northern part of the region. Large plutons (Maramuni Diorite), andesitic plugs and dykes (Frieda Porphyry), and large bodies of peridotite and dunite (April Ultramafics) were intruded at this time. Part of the Salumei Formation was metamorphosed to the greenschist facies of regional metamorphism, and it is thought that glaucophane schist and eclogite (Gufug Gneiss) found as fault wedges north of the Lagaip Fault Zone, were also formed at this time by metamorphism of the Salumei Formation.

This activity was accompanied by island arc vulcanism which deposited the volcanic beds of the Burgers Formation, Karawari Conglomerate, and Wogamush Beds. The upper parts of these formations consist of thick clastic rocks.

The geological history south of the fault zone was markedly different, for folding and faulting was much less intense, and there was almost no volcanic igneous activity. The sediments contrast strongly with those to the north for they consist of limestone and fine-grained calcareous sediments, which constitute the upper part of the Yangi Beds. Volcanic rocks are conspicuously absent, and the only igneous activity recorded at this time was the intrusion of intermediate stocks called the Porgera Intrusives.

After the Miocene the only rocks other than recent alluvium deposited in the map area, are the Hagen Volcanics of probably Pliocene and Pleistocene age, which built up the huge volcanic cones of the Highlands.

The region north of the Lagaip Fault Zone is part of the New Guinea Mobile Belt, and is broken by a complex series of anastamosing faults, most of which have large vertical throws. It is suspected that they are predominantly transcurrent with large right lateral displacements, but this has not been proved. Folding in the Mobile Belt is subordinate to the faulting but the rocks are very tightly folded in places. Most of the movement on the faults appears to have taken place in the Lower Miocene but many have been active till Recent times. South of the Mobile Belt the rocks are generally only broadly folded and broken by a few large faults.

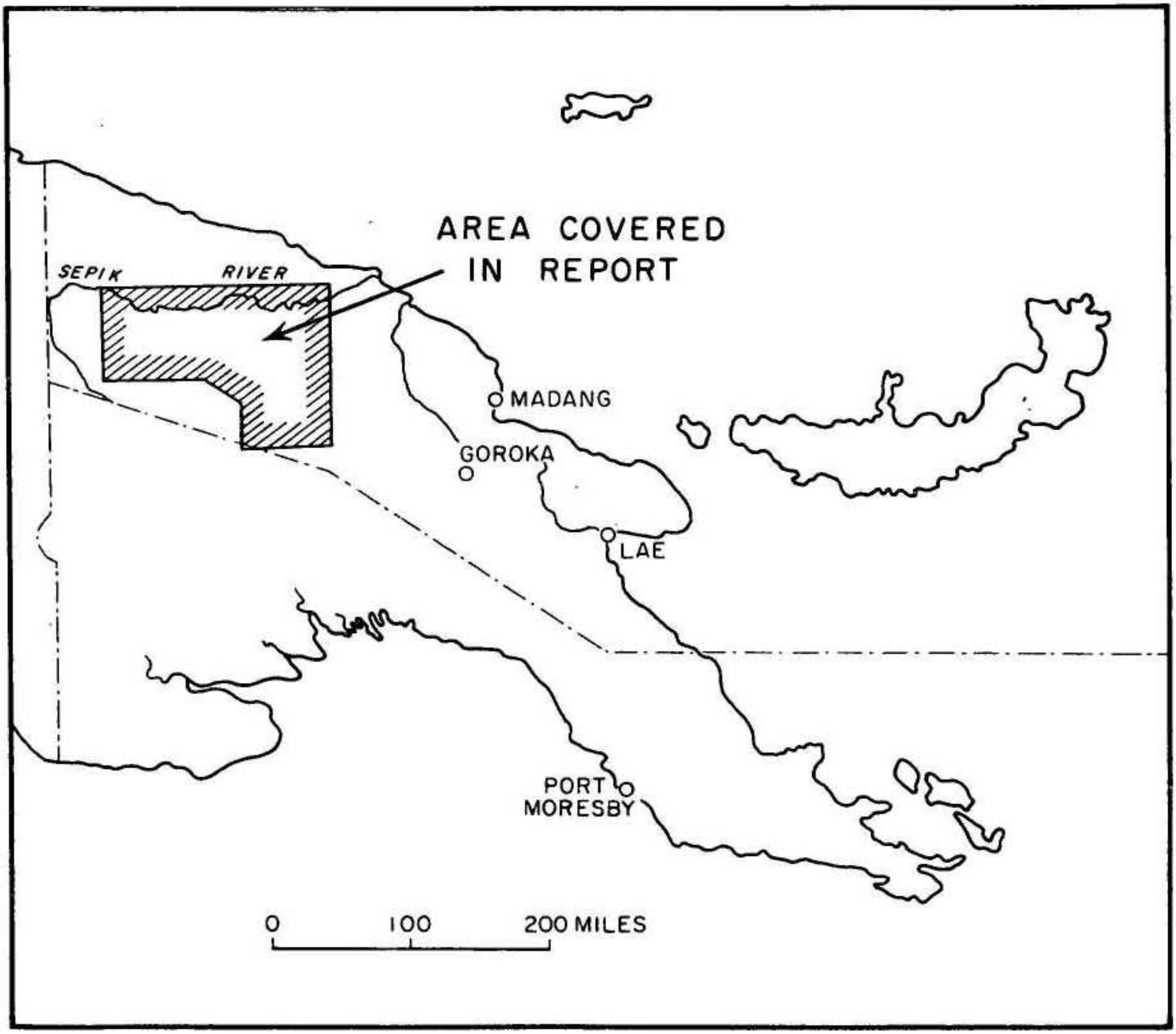
The South Sepik region, despite its inaccessibility, shows some prospect of economic minerals: the Frieda Copper Prospect has most of the features of porphyry copper deposits, and some of the bodies of April Ultramafics could have had economic concentrations of nickel developed on them during tropical weathering.

Most streams contain some gold, and small quantities of alluvial gold and platinum have been produced from the area, but of the gravels tested during the survey, only those of the upper April River show any promise of containing economic concentrations of gold. -- The gravels of the Frieda River however were not tested.

LOCALITY MAP

SOUTH SEPIK REGION

FIG.1



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INTRODUCTION

The northern fall of the Central Range, the largest unexplored area in New Guinea (Locality Map, Fig. 1), separates the swampy Sepik Plain on the north, from the high dissected plateau forming the backbone of New Guinea to the south. The whole region is rugged, bush-covered, and almost uninhabited: the long meandering southern tributaries of the Sepik River provide the only practicable access and as there are very few tracks, travel within the area is extremely slow and laborious.

Mapping of the region is part of a programme to map the mainland of New Guinea at a scale of 1:250,000, so despite the difficulties of access, the mapping was started in June 1966 by a field party consisting of D.B. Dow, J.A.J. Smit, R.P. Macnab, and J.H.C. Bain, and continued in 1967 by the same party with the addition of R.J. Ryburn, and R. Page.

The area mapped in the two field seasons covers the northern fall of the Central Range between the Yuat River on the east and the Frieda River on the west, an area of about 4000 square miles. The Sepik Plain to the north was also mapped, but in much less detail, because such an area, consisting of low hills rising out of the swampy plains, has few outcrops and is geologically unrewarding.

This report incorporates the unpublished results of mapping done by Dow (1962) and Dekker and Faulks (1964), in the south-eastern part of the map area: some remapping of this area was done by the Sepik Party in 1966 and 1967.

Initial planning had shown that if conventional canoes powered by outboard motors were used, the amount of time spent by the party travelling in the unproductive lower reaches of the tributaries would have been inordinately long; helicopters would have speeded up the work greatly, but to mount a party using helicopters exclusively would have been prohibitively expensive. Thus, it was decided to use boats driven by the Hamilton jet units for transport in the lower reaches of the main tributaries. The use of these boats in New Guinea has been reported on by Dow (1967) (Fig.2).

Jet boats were the only means of transport used in 1966, but the experiences of that year showed that large areas of the hinterland were inaccessible from the lower reaches of the rivers, and the 1967 party used a chartered helicopter for 8 weeks to position traverse parties in the more inaccessible localities (Figs. 3 & 4). The use of the helicopter has been reported on by Dow (1968).

PHYSIOGRAPHY

The South Sepik region falls naturally into two simple physiographic divisions: The Sepik Plains on the north and the Central Range to the south.

Sepik Plains

The Sepik Plains cover an area of about 10,000 square miles and are flat and low-lying — the rivers draining them have remarkably low gradients so that most places on the Plains, even up to 300 river miles from the sea, are only 100 feet above sea level. In an area of high rainfall it is inevitable that such low-lying country is perennially inundated and almost the whole area consists of lakes and swamps (Figs. 6 & 7). The only dry land is found along the banks of the larger streams which form levees slightly above the level of the swamps, and on the broad, subdued hills which are remnants of a drowned topography.

The Plains are drained by the Sepik River which flows along the north side of the map area, following a convolute course which is about three times the straight line distance. As can be seen in the aerial photograph (Fig. 5), the river is constantly changing course, by eroding the convex outer banks and depositing alluvium on the inside bends: cut-off meanders forming swamps and oxbow lakes are common. The levee banks each side of the river are commonly the only dry land for many miles, and most of the villages are situated on these.

The levee banks of the Sepik River impound much of the drainage from the Plains forming shallow lakes, the largest and most notable being the Chambri Lakes to the east, and the Amer and Wasui Lagoons to the south, of Ambunti.

Figure 2: Jet-boat negotiating a difficult rapid in the Yuat River.

Neg. GA.9347.

Figure 3: Helicopter pad constructed in the head of the Salumei River. The house is typical of those built along the Central Range between the head of the Krosameri River and the head of the Frieda River. They are built on a large number of stakes driven into the ground; some up to 30 feet high, obviously for defence purposes.
Neg. GA. 638

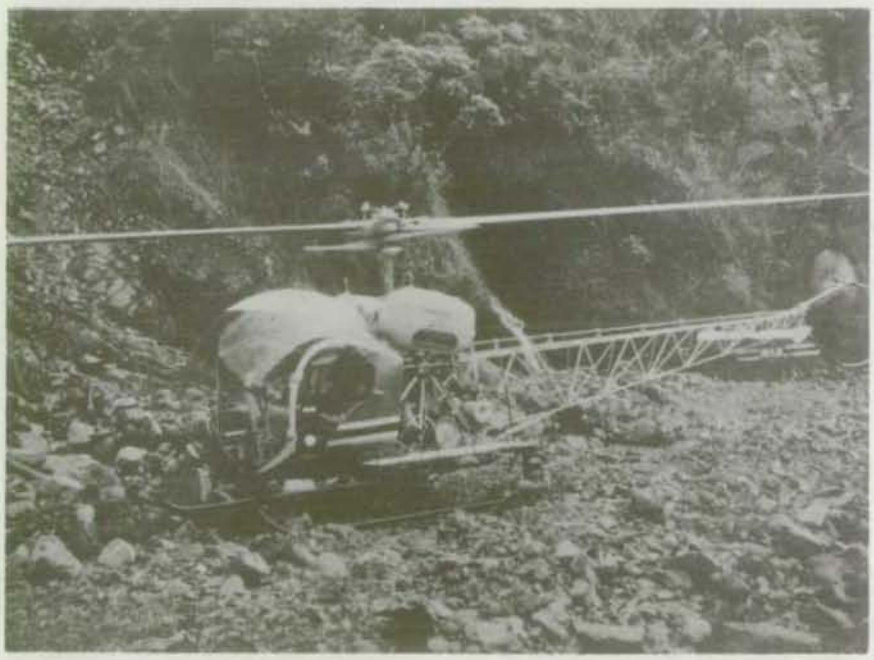


Figure 4: A natural landing site in the head of Bamali River. Scree consists almost entirely of ultramafic boulders, which choke the stream beds and commonly form good landing sites.
Neg. GA.475.

Most of the plains are covered in sago forest which is invariably swampy underfoot, and is virtually impenetrable. Areas more deeply inundated are clothed only in swamp grasses and other water plants which form the floating grass islands seen in Figure 6. They consist of tangled masses of vegetation floating on the lakes at the mercy of the prevailing winds.

The levels of the lakes fluctuate greatly and at times of low water the streams draining into the lakes build levee banks examples of which can be seen in Figures 6 & 7 extending into the lakes.

A common feature of the Sepik Plains are the subdued jungle-covered hills which rise out of the swamps (Fig. 7); they are remnants of a drowned topography, and over most of the area only isolated hills or the tops of ridges are now emergent. The streams which drain these hills are generally very small and completely covered by the bush canopy, and only very few have created openings in the bush sufficient for a helicopter to land. Hence very few geological observations were made on these hills, and the only method of more detailed mapping would be by arduous walking traverses, the geological results of which would not be commensurate with the effort and expense involved.

Though most of the population of the Sepik Plains is concentrated along the major waterways the swamps support quite a large scattered population most of whom live in villages on the margins of the hills (Fig. 8). These people have hunting tracks in the hills and there are sparse tracks joining the main centres of population, but most travel is done by canoe on the lakes, and along narrow waterways which are kept open in the grassy swamps.

The people of the Sepik Plains grow subsistence crops, but sago which is easily won from the ubiquitous sago palms, and fish which abound in the rivers, form the staple part of their diet. Some villages are built on stilts in the middle of large swamps with no dry ground for miles around, and most of these have gardens miles distant which are visited by canoes: some of these people live by foraging, trading, and in the case of the occupants of some villages mainly by prostitution.

The area north of the Sepik River between Angoram and Pagui is exceptional in that it slopes very gently southwards from the Prince Alexander Mountains, and hence is better drained. Impermanent streams follow shallow channels separated by broad, and almost flat interfluves clothed in tall Kunai grass which contrasts with the dense forest filling the stream channels.

The large tributaries of the Sepik River draining the Central Range flow northwards across the Sepik Plains and afford the only surface access to the mountains. They are slow flowing and provide good, if somewhat indirect, boat travel -- some of the rivers follow extremely convolute courses along which the river distance is more than three times the straight-line distance.

Most of the villages in the region are built on the levee banks of the rivers, which in the wet season are only a few feet above river level and are occasionally inundated (Figs. 9 & 10). After prolonged dry weather in the headwaters, the levels of these rivers drop dramatically, and under these conditions the rivers flow between steep muddy banks sometimes as much as 15 feet high.

It is not uncommon for these tributaries to change course drastically when the levee banks have been built too high above the surrounding swamps. Such an old course of the Yuat River which was abandoned before the time of the Behrmann's expedition in 1912 can be seen as a chain of swampy ox bow lakes still with villages lining the banks.

The Hunstein Range is an isolated mountain mass rising out of the Sepik Plains south of Ambunti, and on the few occasions it is free of cloud, it dominates the Sepik Plains. It culminates in a broad peak nearly 5000 feet high and is drained by the Hunstein River which flows northwards to the Sepik River near Ambunti. The whole range is clothed in dense bush and clearings suitable to land a helicopter are very rare; it is perennially cloud-covered and probably has a higher rainfall than the surrounding Sepik Plains.

Figure 5: Mosaic of vertical airphotographs showing the Sepik River immediately downstream of its junction with the April River, which can be seen joining the main river near the bottom left hand corner. Scale: one inch equals one mile.

Figure 6: Lakes south of Ambunti showing the floating grass islands on the lower right. The course of the stream entering the lake is marked by levee banks deposited at times of low water. Neg. GA.470.

Figure 7: Lake south of Ambunti showing the levee banks built out into the lake by the small stream entering from the bottom right. The hills rising out of the swamps in this photograph and in Figure 6 are the remnants of a drowned topography. Neg.GA.829

Figure 8: Typical village in the Sepik swamps. A canoe trail can be seen leading from the lake into the village.

Neg. GA.828

Figure 9: The Bureau of Mineral Resources camp in the April River, showing the helicopter pad in the foreground, and the sleeping and messing quarters on the edge of the bush. The river is running at a high level, but not as high as in Figure 10. Neg. GA.468

Figure 10: The April River camp was flooded on several occasions, so all equipment had to be stored on benches several feet above the ground. Neg. GA.471.

The Sepik Plains offer little by way of exploitable natural resources. Some timber is cut by local people and rafted down the major tributaries to sawmills at Angoram, but because most of the logs have to be hauled long distances through swamps, it seems unlikely that timber milling will develop into a major industry.

With the present high price of crocodile skins, the local people and European hunters are active shooting crocodiles, but such is the competition that very small animals are now shot, and the whole Sepik Plains are in danger of being shot out.

The Sepik people are well known for their expressive carvings, and they make a small income from their export.

Birdlife abounds in the Sepik Plains and wild ducks are a reliable source of food in the lake country. Other native game such as cassowaries, wild pigs, small wallabies are common in the bush country, and it is an advantage to have carriers experienced in hunting with a shot gun.

Insect life is troublesome over much of the Sepik Plains, and the plagues of mosquitoes in some areas defy description. Stops in the swamp country are made a misery,even in daylight, by clouds of biting mosquitoes, but fortunately in the better drained country near the southern mountains there are far fewer mosquitoes and they are generally troublesome only at night.

The other biting insect which causes much discomfort is the bush mite which causes angry red lumps which itch for several days. Some members of the party were particularly troubled by this pest and often a large proportion of their bodies was covered by these bites. As the mite is a carrier for the serious disease Scrub Typhus it is a worthwhile precaution to apply mite repellant (dibutyl phthallate) when walking in infested areas.

Central Range

The second physiographic division is the Central Range which occupies the southern half of the map area. It forms the main New Guinea watershed between the Sepik River on the north, and rivers flowing southwards to Papua. The Range is rugged in the extreme, is bush-covered, and is everywhere above 7000 feet above sea level. The region is one of extreme relief: the Central Range culminates in the Burgers Mountains of 13,000 feet which drop precipitately to the Sepik Plains in a distance of a few miles (Fig. 11).

The part of the Central Range between the Burgers Mountains and the May River is one of the most isolated areas in the Territories of Papua and New Guinea, and is one of the largest areas of unrelieved rain forest. It is deeply dissected and is drained by tributaries of the Sepik River which follow direct and therefore steep courses to the Sepik Plains. The area has a high rainfall, and as most of the major tributaries are widely spaced, they carry large volumes of water. They all are obstructed by deep gorges for much of their length, and are choked by huge boulders, and most are virtually continuous cascades. They are therefore impossible to traverse, and the only good outcrops are provided by the small side streams, but even these are difficult and at times dangerous to traverse.

Only small groups of semi-nomadic people manage to eke out a precarious existence in this area. Disease, the very wet climate, and possibly the depredations of tribal warfare, would appear to be the main reasons for such a limited population because there is no shortage of land for gardens.

The Sepik Party in 1967 made several first contacts with people who live in the more remote parts of the region among whom the people shown in Figure 12 from the headwaters of the April River are typical. They live in huts built on stilts for defence (Fig. 3) and are untouched by European culture -- with one notable exception -- stone axes are a rarity and have been for many years. The region is crossed by several tracks from the Sepik Plains to the Highlands in the south which have been trade routes for many generations, and so steel axes have been known in the region probably since before World War II.

<u>Figure 11</u>: The north face of the Burgers Mountains. The highest peak near the centre is about 13,000 feet high, and the valley floor in the left hand corner is at an altitude of less than 3,000 feet. Neg. GA.832

<u>Figure 12</u>: First contact being made with natives in the headwaters of the Bamali River, a tributary of the April River. The offer of food was a gesture of friendship.
Neg. GA.473.

<u>Figure 13</u>: Men belonging to the Wabia Village in the headwaters of the Frieda River. They were not unduly afraid and one lad came aloft and showed us the location of their village. Neg. GA.482.

Figure 14: The middle reaches of the Karawari River. The river flows along a flat floored valley flanked by vertical cliffs of Karawari Conglomerate up to 3,000 feet high. The river provided excellent jet-boat travel as it consists of long placid pools, separated by shallow gravel bars.

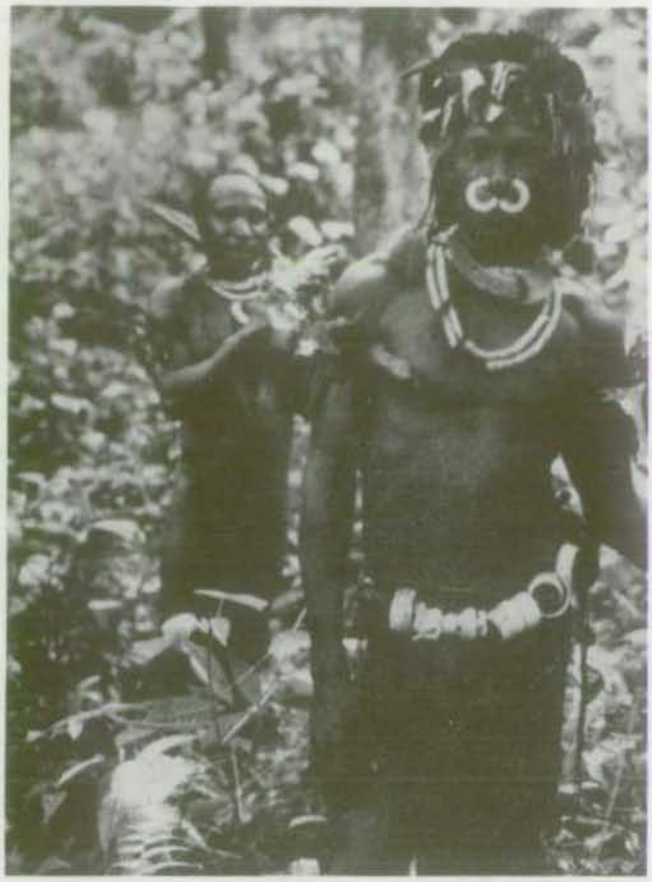


Figure 15: Meakambut warriors first contacted by the Sepik Party. Some owned steel axes which had been traded with neighbouring tribes, but they had never before seen white men.

Small pockets of similar people are found in the headwaters of all the major tributaries, living at altitudes of between 3000 and 8000 feet. Almost all were friendly when contacted, but were generally unco-operative, especially when we managed to convey a desire to follow their tracks.

The people living at the head of the Frieda River (Fig. 13) at the Wabia Hamlets are a very different people who apparently have no communication with the people to the east. They are true Highland people with close affinities with the Telefomin population to the south, and have had contact with Administration patrols for several years. They were friendly and acted as carriers for one traverse party in 1967. One youth had a smattering of pidgin English so communications were above the level of sign language for the first time.

Between the Maramuni and Karawari Rivers the country is quite different and is drained by large rivers flowing in wide valleys flanked by spectacular vertical cliffs of conglomerate up to 3000 feet high (Fig. 14). The valleys generally provide reasonable travelling, but the intervening areas are virtually impassable.

The only people in the area are the Meakambuts, a very small semi-nomadic group who range between the Maramuni and the Lower Arafundi Rivers, and the Pundugums who live at the head of the Arafundi River.

The Meakambuts probably only number about 150 people, and are very shy and elusive. Despite many attempts made by Administration patrols, these people had not been contacted in 1966, and the Sepik Party made the first contact while traversing the area in August 1966 (Fig. 15).

The Pundugums had been contacted by Administration patrols before 1966, and proved quite co-operative. They were recruited by the party as permanent carriers in 1966 and 1967 and proved invaluable, for not only were they our best carriers, but they also knew smatterings of the languages of the surrounding groups.

The south-eastern part of the map area is the only part to have a substantial population, and hence much of the area consists of garden clearings or is clothed in kunai grass (Fig. 16). The forest is prevented from encroaching on these clearings by regular burning off by the local people during hunting forays.

The people living between the Yuat and Maramuni Rivers are called the Wapi and were first contacted by the Administration in 1955. They have been spasmodically patrolled since 1958 but their culture has been little altered. The latest census figures available (taken in 1966), give the population as almost 2000 people. They proved helpful to the Sepik Party and were keen to carry cargo and act as guides. People from the northernmost village which overlooks the upper part of the Yuat Gorge provided great service when they built a wooden railway 300 feet long over large river boulders, over which one of the jet-boats was pulled to bypass a bad rapid in the Yuat River.

Further south, in the headwaters of the Maramuni and Lagaip Rivers and in the watershed of the upper Lagaip River, there is a very large population, and almost the whole area is covered by gardens or kunai grass. The region has been regularly patrolled since before World War II, and is now well served by roads and graded walking tracks. Government stations are situated at Wabag, Laiagam, Wapenamanda, and Kompiam, and there are many mission stations throughout the area.

The Burgers Mountains are the highest mountains of the Central Range and their crest at over 13,000 feet above sea level is above the bush line. Most of the tops are therefore covered with mountain grasses and clumps of stunted shrubs. Some of the small streams draining the tops head in cirque-like hollows and it seems almost certain that the mountains were capped by permanent ice fields during the Pleistocene.

Climate

Most of the region is hot and very humid, and has a moderate to high rainfall spread throughout the year. The Sepik Plains have a moderate rainfall, mostly between 70 and 100 inches per year with a wet season from September to April and a short dry season in June, July and August. (Fig. 17).

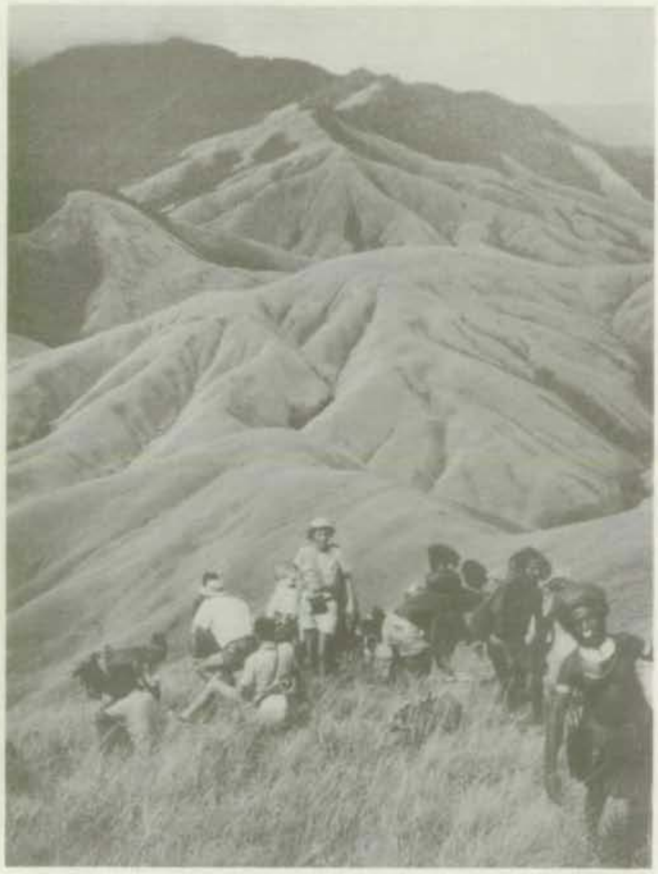


Figure 16: Grass-covered hills above the Yuat Gorge, which are kept free of bush by periodic burning by local natives during hunting forays. The local people are called the Wapi and are seen carrying traverse equipment.

Neg. GA.38.

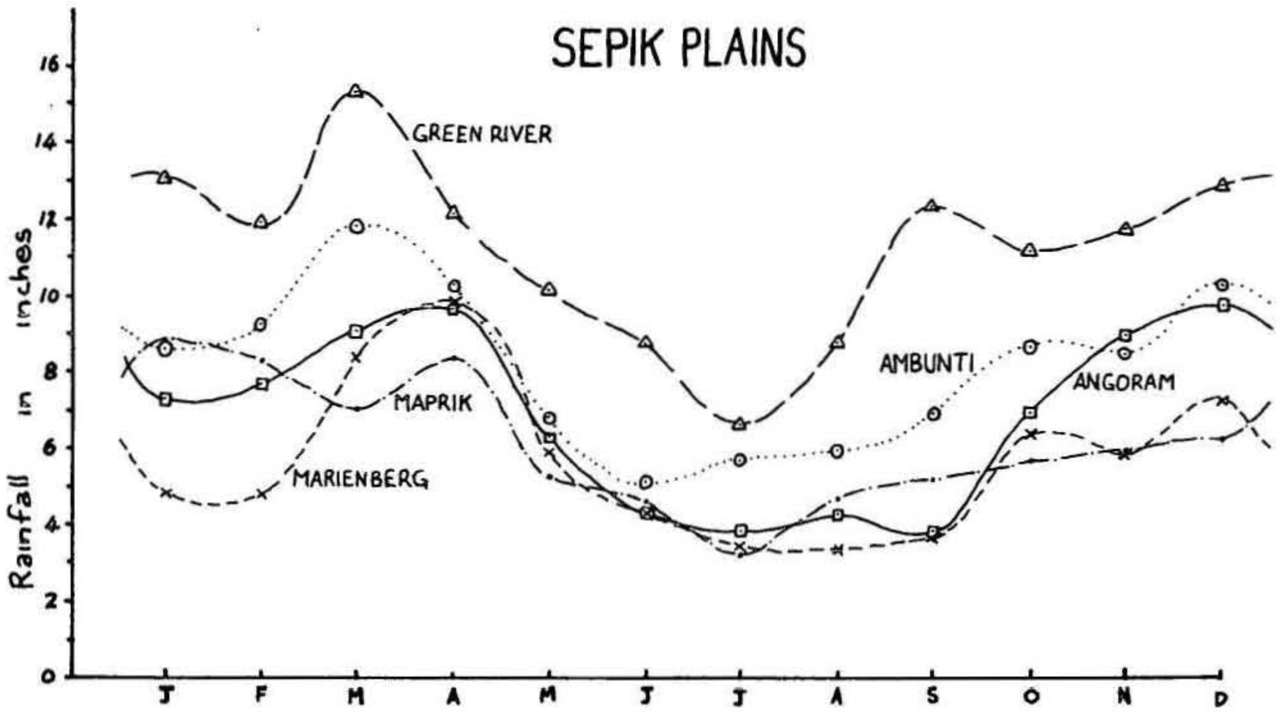


Figure 17: Monthly rainfall for selected areas in the Sepik Plains

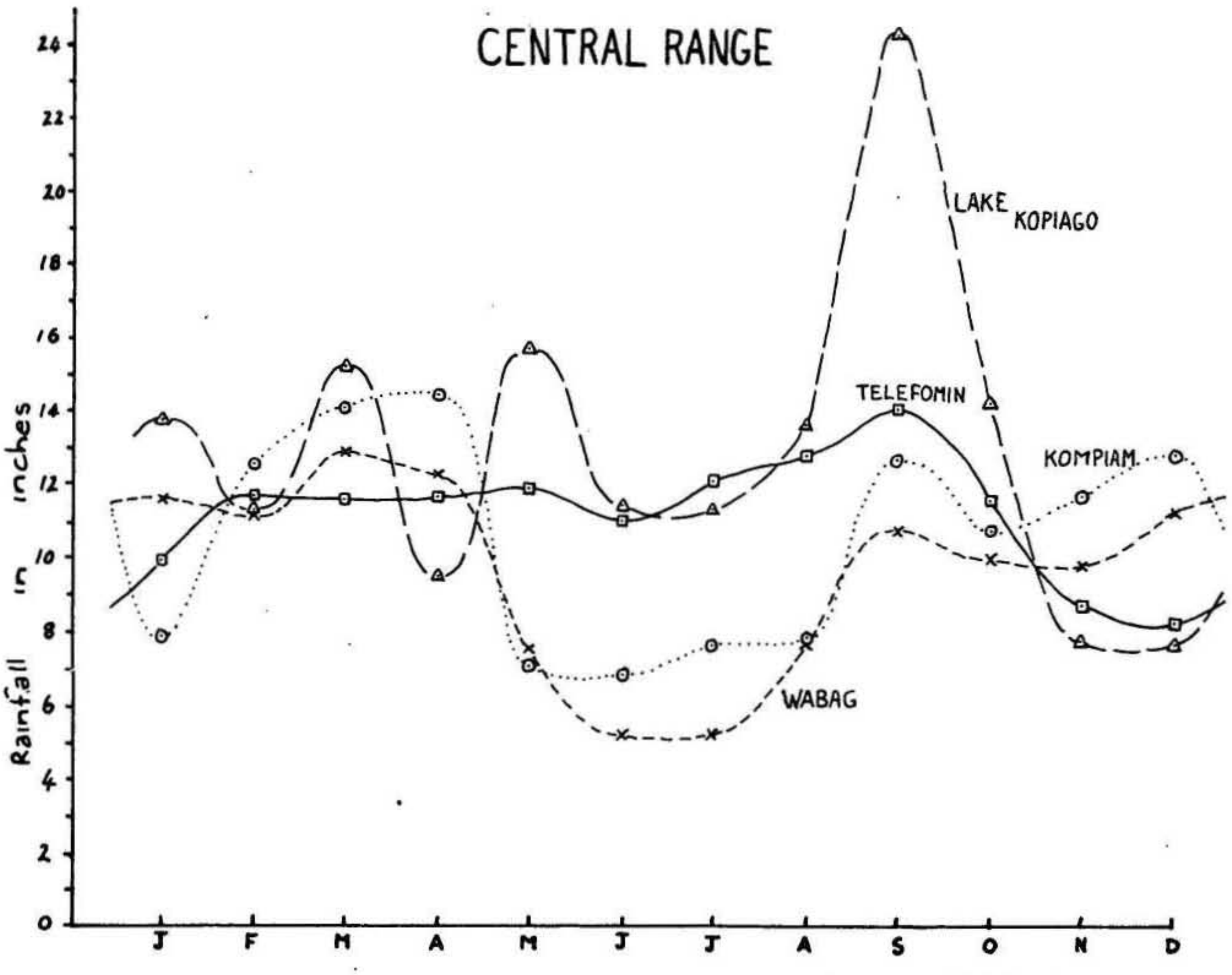


Figure 18: Monthly rainfall for selected areas in the Western Highlands

Rainfall totals for centres considered representative of the Sepik Plains are given below:

Place	Number of years records kept.	Annual Rainfall (in inches)
Ambunti (central)	12 years	98.11
Angoram (eastern)	11 years	82.33
Green River (western)	5 years	135.02
Maprik (northern)	6 years	73.26
Marienberg (eastern)	11 years	69.37

Mornings are generally free of rain, but over most of the plains, helicopter operations can be delayed by ground mist which at times does not rise until 10 a.m. The margins of the plains near the hills are generally less affected by these mists, and during 1967 the Sepik Party was seldom delayed from this cause when operating out of the April River Camp, and Amboin Patrol Post.

The rainfall in the Central Range is much higher, and though no records are available for any localities on the north side of the range, the totals given below and plotted on Figure 18 for localities south of the range, are probably reasonably representative of the map area. The average rainfall is well over 100 inches, and there is a dry season during May, June, July and August, in marked similarity to the Sepik Valley.

Place	Number of years records kept.	Annual Rainfall (in inches)
Kompiam (eastern)	6 years	126.97
Wabag (eastern)	12 years	115.93
Telefomin (west)	11 years	135.58
Lake Kopiago (central)	2 years	156.20

From the Sepik Party's experience in 1967 it is thought that the northern fall of the Central Range between Burgers Mountains and the Frieda River has a much higher rainfall than the rest of the area. The party experienced very heavy rains on most afternoons, and the rivers at all times carried much larger volumes of water than normal for streams draining the same areas in most other parts of New Guinea. Fortunately most mornings were free of rain but the inevitable afternoon rains made setting up camp an unpleasant experience most afternoons.

This high rainfall makes stream traverses more arduous and much slower than in most areas of New Guinea, because even short stream can only be forded at favourable localities. It is frustrating in the extreme to be forced to cut bush laboriously along a cliff on one side of the river while the other side offers easy going.

The regions above 10,000 feet are cold, wet, and almost perpetually cloud-covered. Sodden moss covers ground and trees alike, and camping in exposed localities is not a pleasant experience.

GENERAL INFORMATION

Access

The party used the Sub-district Offices at Angoram and Ambunti (Fig. 19) as supply centres. These are on the Sepik River, and are supplied by coastal trading ships and light aircraft. The Patrol Post at Amboin was used for an advanced base camp, but as this is supplied only by powered canoes, equipment for this and the other advanced base camps in the Yuat, and April Rivers was carried by a 20-foot jet-boat. These three Government centres are part of the Sepik District, and are administered from Wewak. The western part of the area was mapped using May River Patrol Post as the advanced base.

Kompiam in the south-eastern part of the map area is a Patrol Post of the Western Highlands District, administered from Wabag; it has an airstrip capable of taking Piaggio aircraft. The Administration posts at Laiagam and Wapenamanda also have airstrips. The only airstrip on the northern fall of the Central Range is at Pasalagus in the head of the Maramuni River, but safety standards of this airstrip are so marginal that air charter firms refuse to land, and it is used almost exclusively by Mission aircraft.

To gain access to the mountains from the Sepik River centres, 50 miles of swampy Sepik Plain must be crossed, and the southern tributaries of the Sepik River provide the only routes. In their lower reaches these are deep and slowly-flowing, and they provide excellent travel for boats; however, as most follow extremely meandering courses, the river distances are up to three times the straight-line distances.

Figure 19: Ambunti showing the Sepik River in foreground and Sub-District Office and Administration housing on the hill on the right. The airstrip is built on an alluvial fan deposited by the small stream draining the hills in the right background.

Stranded logs and shoals are the only obstructions, but even in times of low water they are generally not troublesome. The level of the rivers fluctuates greatly, and during the wet season they are at or above plain level, but at times in the dry season they flow between steep muddy banks up to 15 feet high.

Within a few miles of the mountains the gradients of the streams are steeper, and gravel banks make their appearance. Log jams are common in these reaches and may provide serious obstacles, especially in times of low water. These gravel reaches generally persist for several miles into the mountains, and while they are impassable to canoes, they are generally navigable by jet-boats. Within the mountains the stream gradients steepen further, the streams are obstructed by gorges and rapids, and the limit of jet-boat navigability is soon reached.

The Yuat River is an exception, for though it flows through a long, steep-sided gorge, it proved navigable for about 35 miles into the mountains. The gorge contains many rapids, but only three were cause for great anxiety when they were being negotiated (Fig. 2). Another was impassable, but one boat was hauled around by means of a wooden track built over the river boulders and this enabled a further ten miles of river to be traversed.

Access within the mountains proved much more difficult than anticipated. In New Guinea most travel is done on foot using local people as carriers and in populated areas carriers are generally readily available and there is a network of foot-tracks, the worst of which provide much quicker access than breaking virgin bush. In the South Sepik Region however, there are only very small groups of semi-nomadic people, many of whom have had no contact with white people. Thus there are large areas with no tracks at all, and while tracks are known to link the scattered groups of population, it is generally impossible to get the local populace to co-operate to the extent of acting as guides. As a further difficulty each group of people speaks a different language, and as many have never before seen white people, communication was often possible only by sign language.

The densely populated south-eastern part of the map area is well endowed with walking tracks and roads.

Previous Bureau parties in New Guinea used 12 to 14 carriers per geologist, but it was realised early in the 1966 season that the logistics of keeping such large parties in the field were beyond the resources of the party. It was also realised that such large traverse parties would be prohibitively costly the following year when most parties would be positioned by helicopter. The number of carriers was therefore reduced to 5 per geologist towards the end of the season, giving a party capable of travelling up to 7 days away a source of supplies.

Carriers

The success or otherwise of a geological survey in New Guinea depends to a large extent on the calibre of the carriers used. The Sepik Plains support a large number of people who live in villages of the main waterways: as they prefer travelling by canoe, they seldom penetrate the mountains and are of no use as guides in the mountains. They are generally poor carriers, but most speak the lingua franca, Pidgin English; a few of those near the mountains can act as interpreters for some of the mountain people.

Most of the carriers used during the 1966 survey were recruited from Asangmut in the Yuat River, but they proved unsatisfactory.

In the South Sepik region the mountain people do not live in villages, but congregate in small groups of several families each living in huts sited near the family gardens. The soil in the mountains is poor, and new gardens have to be established every year, and it is quite common for a group to move up to ten miles between seasons. They are generally stronger and healthier than the Plains people, and the few recruited from the Pundugum and Bisorio groups in 1966 and 1967 proved excellent carriers. Unfortunately the number of people available from these groups is only small, and even in favourable times when the gardens are established, no more than fifteen men can be recruited from this source.

No doubt the other mountain people living between the Karawari and the Frieda Rivers would have made good carriers had not communication been such a problem.

It appears that if a party is to work efficiently in the South Sepik region it is necessary to recruit labour from outside despite the cost of recruiting and repatriation at the end of the field season. In 1967 the Sepik Party recruited carriers from the Simbai and Asai Valleys over 100 miles to the east, and though of small stature, these men proved excellent carriers.

Airphotographs and Base Maps

Lack of airphotographs and reliable base maps has been a continual handicap since the work started. When it was decided in 1965 to map the area, airphotographs of the eastern part only were available, but as these had been very recently taken (December 1964), and the area was one of top priority, it was thought that photographs of the rest of the area would be available shortly afterwards. Such however has not been the case, and in the last 3 years only very irregular, sporadic coverage, taken at heights ranging from 7000 feet to 25,000 feet, has become available.

Fortunately some of the western part of the area was photographed from 42,000 feet by an R.A.F. Vulcan Bomber in 1963 and this photography though partly obscured by cloud enabled the mapping to proceed in 1967. The programme for 1968 has had to be suspended because of the lack of airphotographs.

Bad weather has been given as the reason for the inability to take photographs during the last 3 years, but during the 1966 and 1967 field seasons there were at least ten days when all the mountains were clear until 11 o'clock in the morning or even later, and on any one of these days most of the area could have been flown. It is difficult to escape the conclusion that bad organization, not bad weather, is the cause of the delay.

The latest maps of the area were published in 1966 on a scale of 1:250,000 by the Royal Australian Survey Corps, but over large areas the only topographic information incorporated is that gained by Behrmann's expedition of 1912 to 1913, and it is not surprising that there are many inaccuracies and omissions.

The topographic base for the accompanying geological map (Plate 1), was compiled from all available airphotographs, which were reduced to give the best fit with the more reliable parts of the published maps. The villages shown were located as accurately as possible from the latest Administration patrol maps.

HISTORY OF EXPLORATION

Discoloured water indicating a large river off the north coast of New Guinea was known to mariners as early as the beginning of the Seventeenth Century, but it was not until 250 years later that the river, the Sepik, was explored by Europeans. The German zoologist Dr Otto Finsch was the first white man to venture inland, when in 1885 he followed the river for 30 miles in an open whaleboat. He showed that the river was large enough to take ocean-going ships, and in the following year von Schleinitz penetrated by steamer for about 200 miles until stopped by sand bars. The party then proceeded by whaleboat a further 40 miles to the Yambon Gate above the present Ambunti. (Souter, 1963)

In 1887 the Sepik River was carrying a greater volume of water, and Dr C. Schrader navigated upstream a total distance of 380 miles in the steamer Samoa.

No more exploration of the waterways of the Sepik River was done until 1910 when a joint Dutch-German expedition led by Dr Leonard Schultze mapped the boundary with Netherlands New Guinea, and penetrated 600 miles up the Sepik River reaching nearly to the Zweifel Gorge through which the river debouches from the mountains. (Schultze, 1914)

None of these expeditions moved far from the main river, and it was left to the expedition of Dr Walter Behrmann in 1912 and 1913 to explore the hinterland. The expedition followed most of the lower reaches of the southern tributaries, where they flow over the Sepik Plain, and during three epic ground traverses, penetrated almost to the main divide. The country was inhospitable and peopled in places by large populations of warlike natives, and the journeys rank with the greatest explorations in New Guinea. (Behrmann, 1923).

On the first, and easternmost traverse, the party followed the lower part of the Keram River to its confluence with the Clay River, which they then followed to its source in the Schrader Range. They completed a memorable journey by crossing the range and descending to the Yuat River at a point not reached again from the Sepik River until 1966 when the Sepik Party explored the Yuat River by jet-boat.

The April River was the waterway used for the next deep penetration south: the party walked from the limit of canoe travel, following the Bamali tributary which was the most direct route to the mountains. They reached the crest of the Central Range, but were at the limit of their resources and they returned quickly by the same route.

The third great journey was made by Dr Thurnwald, who in 1913 traversed the Sepik River almost to its source, reaching a point very close to what is now Telefomin. The party must have made friendly contact with the natives for the next explorers through the area, Karius and Champion, were not troubled when they retraced the German's route in 1927.

During the years following World War I, the Sepik Valley was opened up by Administration patrols, but none penetrated into the southern mountains. However, prospectors were active in the region and some undoubtedly penetrated the northern fringes of the southern mountains, but there is no record of their travels. It is known that a gold strike was made in the Yuat River near its junction with the Maramuni River, but no mining was done. It is reported that Bulolo Gold Dredging Pty Ltd, drilled the lower Maramuni flats with a light percussion drill sometime in the 1930's, but the gold values were not economic. (L. Schmidt jun. pers comm.).

In marked contrast to these peaceful expeditions was the next exploration into the South Sepik area which was made in 1934 by a prospecting party led by Ludwig Schmidt. The party set out from Mount Hagen and prospected north-westwards to the junction of the Maramuni and Yuat Rivers where they ran into serious trouble with the natives.

Ludwig's son, Ludwig junior, was speared while attempting to swim the Yuat River, and was lucky to survive the journey to Angoram for aid. The rest of the party continued the expedition, returning some months later to the highlands, apparently by way of the Karawari and Maramuni Rivers. Ludwig senior was later tried and hanged in Rabaul for the indiscriminate shooting of natives during the expedition.

The following years saw most of the Sepik Plains explored and brought under administration control, but it was not until the 1960's that the southern mountains were again penetrated: the Gadio and Pundugum groups in the watershed of the Karawari River were contacted from Amboin, and the Wapi people on the Yuat-Maramuni divide from Kompian. The latest exploration was done in 1965 when an expedition led by R. Barclay explored the Leonard Schultze headwaters and the Bomali tributary of the April River.

In 1966 when the geological mapping commenced large areas of the South Sepik region remained unexplored.

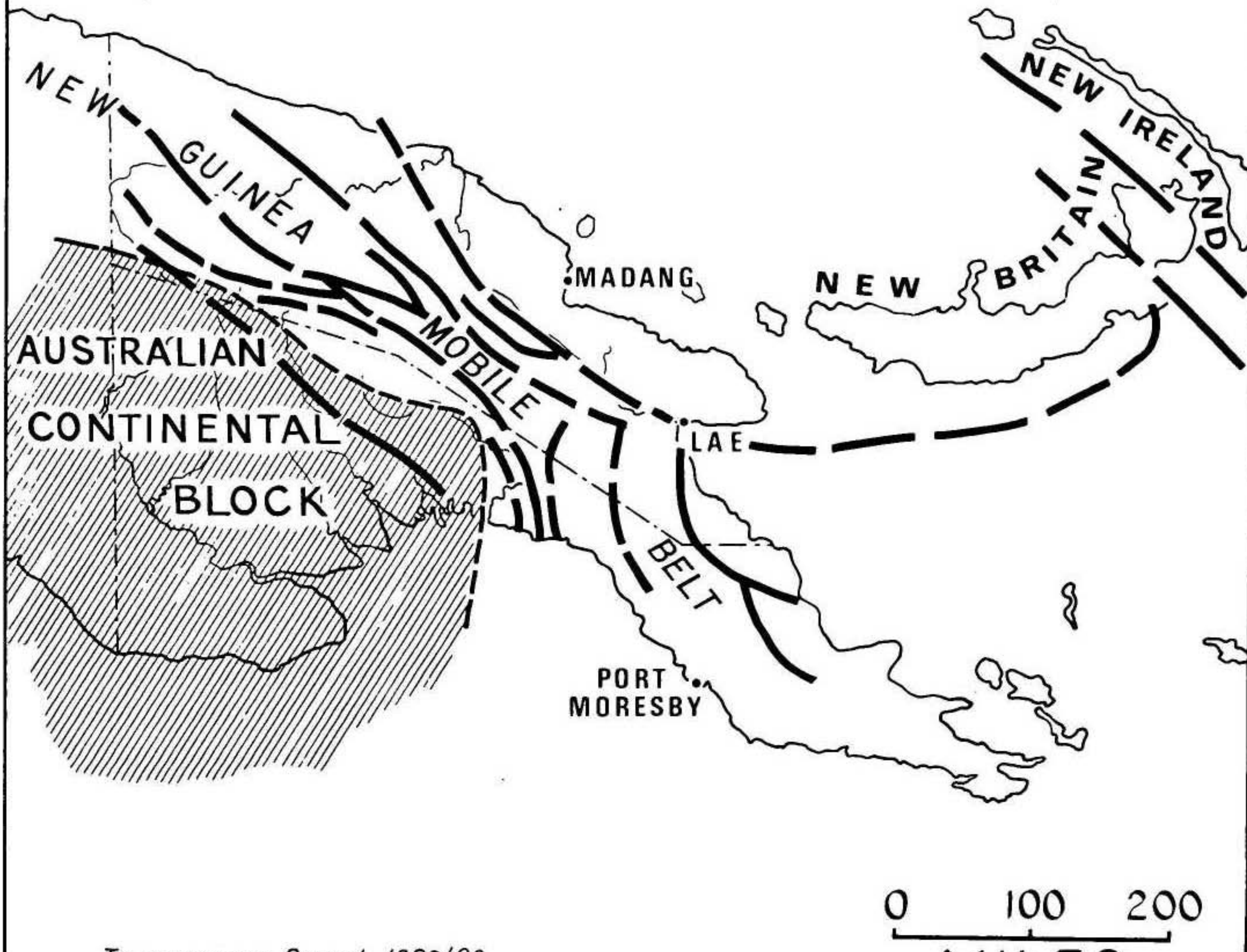
PREVIOUS GEOLOGICAL INVESTIGATIONS

Though there was no geologist with Behrmann's expedition, rock samples were collected and examined petrographically when the party returned to Germany (Behrmann 1923). No further geological work was done in the South Sepik mountains until the present expedition.

The first geological investigations of the Wabag area were made in 1948 by H. Ward (1949) who inspected the gold discoveries at Timun and Porgera Rivers, and F.D. Rickwood (1955) who mapped the Lai Valley. D.B. Dow (1961) made a reconnaissance of the Lau River, and the whole region was mapped by a Bureau of Mineral Resources team in 1963, (Dekker & Faulks 1964).

Fig. 20

POST MESOZOIC STRUCTURAL SKETCH MAP



To accompany Record 1968/80

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OUTLINE OF THE GEOLOGY

The South Sepik region occupies a small segment of the fundamental break separating the stable Australian continental block from the oceanic crust to the north (Fig. 20). This break has had a profound effect on the sedimentation in the region throughout the geological record, for shelf-type sediments were laid down on the continental block while geosynclinal sediments were being deposited to the north.

The break between the two environments is remarkably sharp, and in the map area is marked by the Lagaip Fault Zone which is rarely more than 8 miles wide.

The structure of the two environments also contrasts greatly, for the shelf sediments are relatively undeformed, and are broken by only a few major faults (APC 1961), while the oceanic sediments are intensely faulted along a major tectonic zone we have called the New Guinea Mobile Belt.

Only small fragments of the oldest rocks, extensive unmetamorphosed shelf sediments of Triassic age, are now preserved in the South Sepik region. They are exposed along a narrow horst between the Yuat and Maramuni Rivers as the Yuat Shale (black, well-bedded shale and siltstone of Middle Triassic age), and the Kana Volcanics (thick dacite volcanics, and volcanically derived sediments). The Kana Volcanics are a widespread and distinctive unit and form a very valuable stratigraphic marker where exposed.

Though there is no evidence in the South Sepik region, it is known (Dow and Dekker 1964) that the Triassic sedimentation was followed by quite intense folding and faulting, and a period of erosion.

The Sepik Valley is underlain by large areas of metamorphics called the Ambunti Metamorphics which are metasediments ranging from slate and sericite schist, to muscovite gneiss and amphibolite. Complex intrusive bodies ranging in composition from gabbro to quartz diorite have also been metamorphosed to a similar degree, and are now amphibolite and orthogneiss.

The age of these metamorphics is not known but they may have been formed during the orogeny that deformed the Yuat Shale and the Kana Volcanics.

Sedimentation re-commenced in the map area about the Middle Jurassic and continued apparently unbroken until Tertiary times (Fig. 21). South of the fault a very thick sequence of black pyritic shale and siltstone called the Lagaip Beds, was laid down. The sediments are typical of those deposited in an euxinic environment (Pettijohn 1949), and it seems probable that the sediments were laid down in a narrow trench having a very restricted circulation of water. The trench extended south-eastwards to Papua where it has been called the Kutubu Trough (APC 1961). Towards the top of the formation there are thick beds of pure quartz sandstone which testify to a shallowing of the trough in Cretaceous times.

Eugeosynclinal sediments were laid down north of the fault over most of the area that is now the north face of the Central Range. The sedimentation started in the Middle Jurassic with the deposition of a great thickness (over 8000 feet in places) of basic marine volcanics called the Mongum Volcanics. Grey shale was then deposited in the Upper Jurassic in very extensive shallow seas which extended well beyond the map area to the south-east. The rocks are called the Maril Shale in the eastern part of the map area, and the Sitipa Shale near the April River.

The eugeosyncline reached full development during Cretaceous and Eocene times when the Salumei Formation, consisting of siltstone and fine greywacke, foraminiferal limestone, tuffaceous sandstones and sporadic basic marine volcanics, was laid down.

The volcanic rocks are thicker and more widespread in the Eocene, a quickening of volcanism which was a forerunner to greatly intensified tectonic activity in the Lower Miocene.

This increased activity during the Eocene is reflected south of the fault as a break in sedimentation. The youngest Lagaip Beds known are Palaeocene in age, and not until the Lower Miocene (Tertiary e-stage) was sedimentation re-commenced south of the fault.

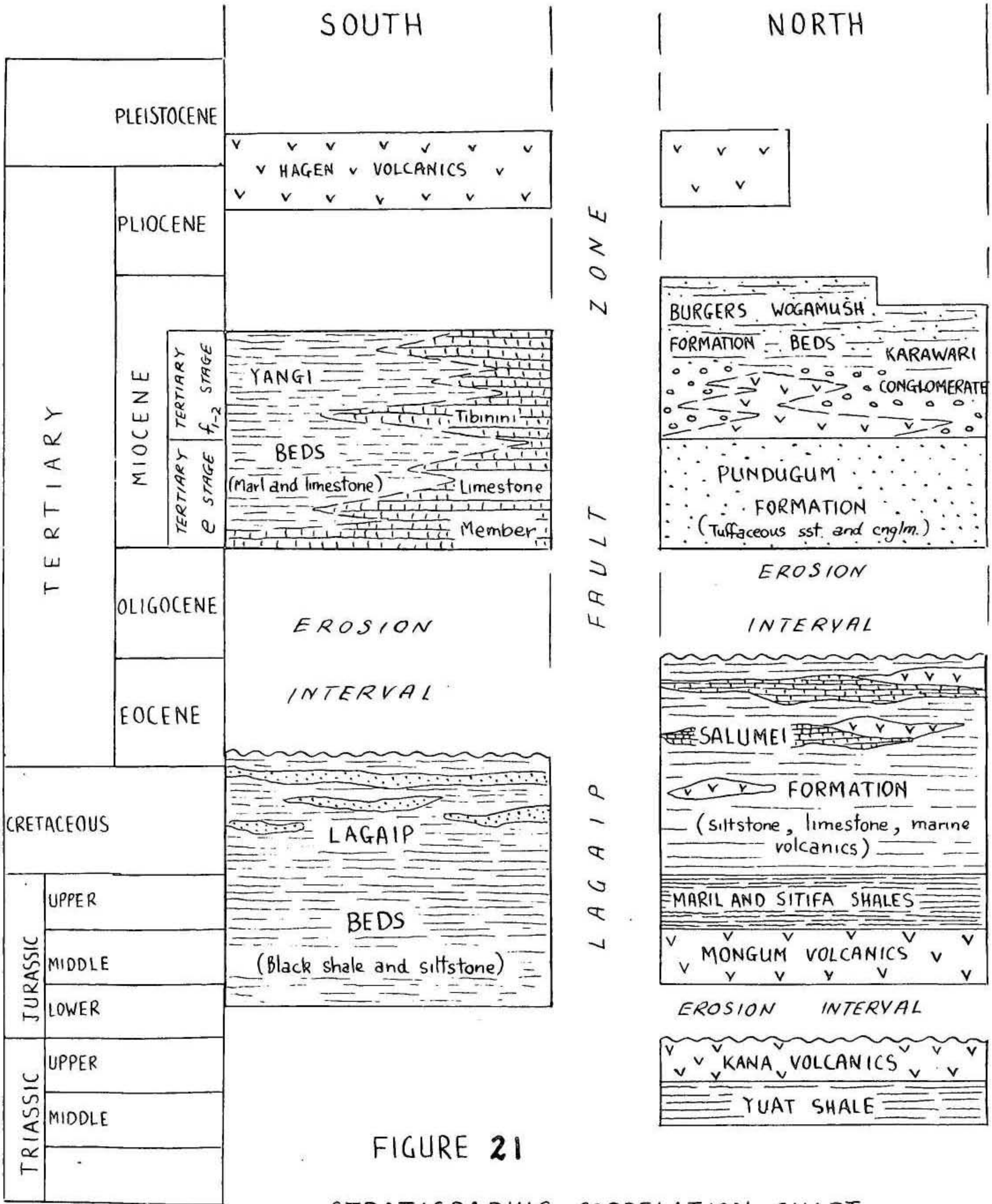

FIGURE 21

STRATIGRAPHIC CORRELATION CHART
SOUTH SEPIK REGION

To Accompany Record 1968/80

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Uplift became more widespread in the Oligocene and the area north of the Lagaip Fault was also exposed to erosion until the Lower Miocene.

Tectonic activity reached a climax in the Lower Miocene, but the contrasting environments of deposition north and south of the Lagaip Fault continued: during the Tertiary e-stage tuffaceous sediments derived from basic vulcanism called the Pundugum Beds were deposited in the north while the lower part of the Yangi Beds was laid down to the south. The Yangi Beds consist of marl and thin-bedded limestone containing the Tibinini Limestone Member which formed a large barrier reef on the northern edge of the continental shelf.

The extrusion of the volcanic rocks during the Tertiary e-stage and f_{1-2}stage times was accompanied by major earth movements, mostly faulting of great magnitude, and widespread plutonic igneous activity. Batholiths ranging in composition from gabbro to granodiorite intruded at this time, are now exposed to erosion, and there is good evidence that they were exposed as early as Tertiary f_{1-2} stage times. The large plutons are confined to the eastern part of the area where the rocks are called the Maramuni Diorite.

Stocks and dykes of andesite porphyry found to the south (Porgera Intrusives) and to the west (Frieda Porphyry), are possibly apophyses of similar batholiths not yet exposed to erosion.

Large irregular bodies of dunite and peridotite called the April Ultramafics now exposed over an area of about 400 square miles were emplaced at the same time, along the imbricate fault zones forming the northern front of the Central Range.

During this igneous activity much of the Salumei Formation was metamorphosed to give a great variety of rocks ranging from slate and sericite schist to biotite and muscovite schist and some glaucophane-bearing schists.

A spectacular suite of glaucophane gneiss and eclogite called the Gufug Gneiss was also formed at this time. It may have been formed from the Salumei Formation by high pressure-low temperature metamorphism, or it may consist of older metamorphic rocks faulted from depth into their present position.

The end of the Lower Miocene (Tertiary f_{1-2} stage) saw a climax in the volcanic activity throughout the New Guinea Mobile Zone. In the map area basic and andesitic island arc volcanic rocks were laid down along with a great thickness of volcanic cobble conglomerate and tuffaceous sediments. In the map area these rocks have been divided into three formations: Burgers Formation, Karawari Conglomerate, and Wogamush Beds which were laid down simultaneously, possibly in separate troughs.

It is quite remarkable that such widespread volcanic activity did not affect the sediments south of the Lagaip Fault, but there is no sign of volcanic detritus in the upper part of the Yangi Beds which was laid down at this time, even though the volcanic rocks to the north of the fault occur within 8 miles of the Yangi Beds in the upper Lagaip River. The continental slope to the south capped by a fringing barrier reef must have been an effective barrier to southward migration of volcanic detritus.

There is no reliable palaeontological dating of the upper part of the Miocene successions, but it seems unlikely that sedimentation continued later than the Middle Miocene.

After the Miocene the only rocks other than recent alluvium deposited in the map area are the Hagen Volcanics of probable Pliocene and Pleistocene age which built up the huge volcanic cones of the Highlands. Lahar deposits filled the Yuat Valley to a depth of several hundred feet as far as the Sepik Plains during the height of the eruptions, probably near the end of the Pliocene.

STRATIGRAPHY

TRIASSIC

The oldest rocks known in the South Sepik region are shelf-type sediments and acid volcanics of Triassic and probably Lower Jurassic age. They show affinities with later rocks laid down in the stable environment of the Australian continental block to the south, and it is thought that they represent wedges of the continental margin faulted into their present position in the New Guinea Mobile Belt.

Yuat Formation. (New name)

Rock Type:	Greywacke, feldspathic sandstone, and black shale.
Distribution:	Confined to the Yuat Gorge.
Derivation of Name:	From the Yuat River.
Type Area:	The Yuat Gorge. No type section was measured.
Stratigraphic Relationships:	The base of the formation is not exposed: it is overlain, probably conformably, by the Kana Formation.
Thickness:	Not measured, but at least 2000 feet.
Fossils and Age:	Ammonites, nautiloids, lamellibranchs, and crinoid stems: Middle to Upper Triassic.

The formation is well exposed only along the Yuat River where the dominant rock-type is a massive black shale; overlying this shale is very poorly exposed tuffaceous greywacke which forms the steep western wall of the Yuat Valley. The formation is about 2000 feet thick but the bottom of the sequence was not seen.

The black shale is at least 300 feet thick, generally massive, indurated, and well-jointed: outcrop is excellent in the Yuat River, and generally fine silty bands can be distinguished on close examination. The shale is richly fossiliferous and contains well-preserved ammonites, nautiloids, and lamellibranchs, abundant crinoid stems, and some rare bone fragments. Rare beds of feldspathic sandstone up to 3 feet thick are interbedded with the shale, and these are brown to grey, fine to medium-grained, consisting of well-sorted grains of sub-rounded quartz and kaolinised feldspar in about equal proportions. Fragments of ferromagnesian minerals are common and there is a small amount of sericitic matrix. The sandstone appears to be derived from an acid volcanic source, and is similar to the tuffaceous sandstone of the overlying Kana Formation.

The shale passes upwards rather abruptly into a dominantly arenaceous sequence. The transition is about 50 feet thick, and consists of light-grey to brown feldspathic sandstone and calcareous sandstone beds three inches to three feet thick, interbedded with subordinate thinly-bedded black and grey shale and siltstone. Thick beds of poorly-sorted quartz sandstone are found here, some crowded with well-rounded pebbles of black indurated shale. Coaly fragments, carbonaceous lenses, and small pieces of bone are found in many of the beds indicating, in the absence of graded bedding, a shallow-water environment.

Overlying the shale member is a sequence 1500 to 2000 feet thick, which though it forms the steep western slopes of the Yuat Valley, crops out only poorly. The only exposures seen were massive to thick-bedded tuffaceous greywacke which is green and highly indurated when fresh, and it appears that the whole section is made of similar rocks. Though the beds have been included in the Yuat Shale, it seems likely that they are the northwestern extension of the Jimi Greywacke which crops out widely at the head of the Jimi River (Dow & Dekker 1964).

S. Skwarko has reported on fossils collected from the Yuat Formation (Fig. 22) as follows:

"The following fossils were identified from four collections:

Locality Ab22: Ambunti 1:250,000 Sheet area. Run Avieme 5 Photo 5003 Point Ab22.

Guineana jimiensis Skwarko, 1966
Gervillia (G.) simbaiana Skwarko, 1966
?Arctohungarites wapii sp. nov.

Locality Ab20: Ambunti 1:250,000 Sheet area. Run Avieme 5 Photo 5003 Point Ab20.

Beyrichites (Beyrichites) yuati sp. nov.
Arctohungarites wapii sp. nov.
Ptychites sp. cf. P. stachei Mojsisovics, 1882
Cenoceras? sp.A
?Cenoceras? sp. A

Locality Ab24: Ambunti 1:250,000 Sheet area. Run Tarua R. R1 Photo 5065 Point Ab24.

Locality Ab45: Ambunti 1:250,000 Sheet area. Run Avieme 5 Photo 5002 Point Ab45.

Gervillancea coxiella Skwarko, 1966
Nuculana (Dacryomya) tarua sp. nov.
Halobiid indet.
Ivaroa maramniensis gen. et sp. nov.

Figure 22: A fragment of Sturia sp., a discoidal ammonite of Anisian to Ladinian age, found in the Yuat Formation, Yuat Gorge.

Neg. G 9510

G. jimiensis and G. simbaiana were recently described from the Upper Triassic Jimi Greywacke of the Bismarck Mountains area (Skwarko, 1967), but although they are thus known to occur in sediments of Carnian-Norian age, their stratigraphic range is not in fact known. Unfortunately, the only other fossil found at the locality Ab22 is a poorly preserved ammonite which may or may not be an Arctohungarites wapii, which occurs commonly in assemblage from locality Ab20. The ammonite Arctohungarites has been hitherto known only from sediments of Anisian age of Northern Siberia.

In the light of present knowledge the age of fossils from locality Ab22 would seem to be Upper Triassic, and this assemblage is hereby tentatively correlated with that of the Jimi Greywacke. Should, however, future collecting from this site verify the association of Arctohungarites with G. jimiensis and G. simbaiana, this dating will necessarily have to be revised.

The assemblage from locality Ab20 is Anisian in age. This is because in addition to Arctohungarites there is Beyrichites which ranges from Upper Scythian to Anisian, and Ptychites, whose known range is Anisian to Ladinian. The possible presence of Cenoceras which is known only from rocks of Upper Triassic to Middle Jurassic age does not, in my opinion, outweigh evidence for Anisian age, and if the two imperfectly preserved specimens do in fact belong to Cenoceras, then the range of this cosmopolitan genus will have to be extended - this on assumption that both the ammonites and the nautiloid were collected from the same stratigraphic horizon.

This is the first record of marine strata and macrofauna of Anisian age on the mainland New Guinea.

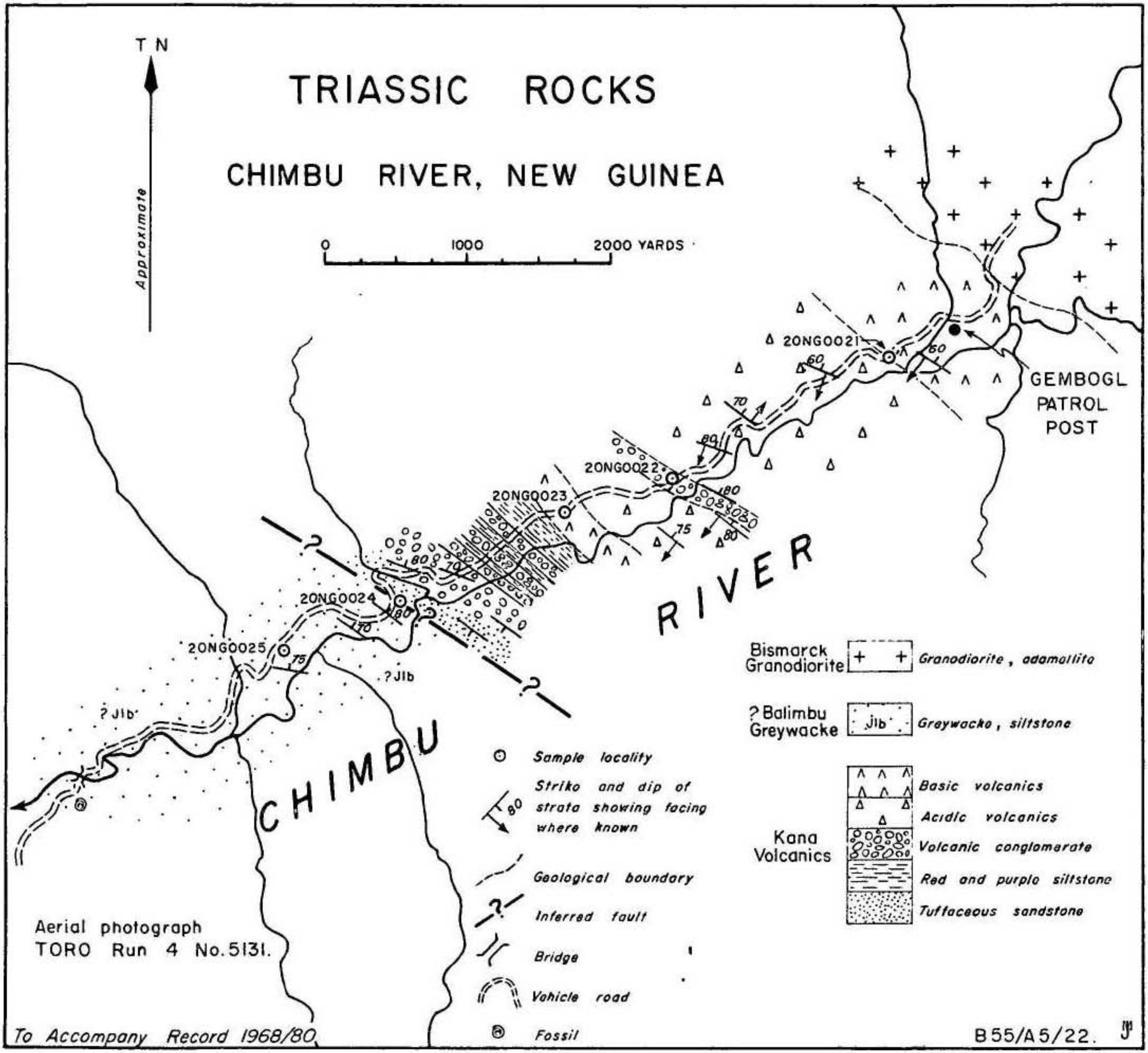
Gervillancea coxiella, like G. jimiensis and G. simbaiana is known hitherto only from the Jimi Greywacke of the Bismarck Mountains and the extension of its time range beyond the Carnian-Norian, if any, is not known. Without additional material forthcoming from the Jimi Greywacke it will not be possible to be certain of the relationship of the two specimens of Nuculana occurring there with the more numerous Nuculanas from the Yuat Shale. Finally, neither the specifically indeterminable Halobiids, nor the new fossil gastropod Ivaroa maramuniensis aid dating at this stage. In summary it can be said that evidence available at present points to Carnian - Norian age of collection from locality Ab45, and implies correlation with the Jimi Greywacke.

Evidence from contained fossils suggests stratigraphic order for the four collections different from that on stratigraphy. This order is as follows: Ab22 and Ab45 seem to be of the same age, viz. Carnian-Norian, and lateral correlates of the Jimi Greywacke; the strata represented by collection Ab20 are older, being Anisian in age; while the age of assemblage from locality Ab24 is older still. The discrepancy between results from different evidence is thus considerable, but may not be surprising in view of the difficult terrain."

Kana Volcanics (old name re-defined)

Rock Type:	Dacitic, rhyolitic, and andesitic tuff, and lavas; tuffaceous sandstone, volcanic pebble conglomerate, and red tuffaceous siltstone.
Distribution:	Crops out as a belt 100 miles long between the lower Maramuni River, and the Chim River to the south-east.
Derivation of name:	Named Kana Formation by Dow and Dekker (1964), after the Kana River, a tributary of the Jimi River which drains the western flank of Mount Herbert. The unit has since been shown to consist mainly of volcanic rocks, so we have used the term volcanics.
Type area:	Dow and Dekker established the Kana River as the type area, but did not measure a section. Later work has shown that the best section is exposed along the Chim River downstream from Gembogl Patrol Post and this has now been set up as the type section. The description of the type section is given below.
Stratigraphic Relationships:	Overlies the Jimi Greywacke, probably unconformably, and is overlain unconformably by the Lower Jurassic Balimbu Greywacke.
Thickness:	About 2000 feet is exposed in the map area, but the type section is about 11,600 feet thick.
Fossils and Age:	The unit contains a fairly widespread macro-fossil fauna which gives the age as Upper Triassic, possibly ranging up to the Lower Jurassic.

Fig. 23


TRIASSIC ROCKS
CHIMBU RIVER, NEW GUINEA
T N
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20NG0021
20NG0022
20NG0023
20NG0024
20NG0025
? Jlb
GEMBOGL PATROL POST
RIVER
CHIMBU
Bismarck Granodiorite
Granodiorite, adamellite
? Balimbu Greywacke
Jlb
Greywacke, siltstone
Kana Volcanics
Basic volcanics
Acidic volcanics
Volcanic conglomerate
Red and purple siltstone
Tuffaceous sandstone
Sample locality
Strike and dip of strata showing facing where known
Geological boundary
Inferred fault
Bridge
Vehicle road
Fossil
Aerial photograph
TORO Run 4 No. 5131.
To Accompany Record 1968/80
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Type Section of Kana Volcanics, Chimbu River. (Fig. 23):

Rocks mapped by Rickwood (1955) as pre-Permian Omung Metamorphics, in the Chimbu River, Western Highlands of New Guinea, were thought from their description (Dow & Dekker 1964) to be correlatives of the Upper Triassic Kana Formation found 10 miles to the north west.

The age of these rocks is important evidence of the age of the Bismarck Granodiorite which Rickwood; MacMillan and Malone (1957), regard as pre-Permian, but which Dow and Dekker, regard as Upper Triassic or younger. The rocks in the Chimbu River are intruded by the Bismarck Granodiorite and if they belong to the Kana Formation then the granodiorite cannot be pre-Permian.

In October 1966 while in the region collecting rock samples for isotopic age determination the senior author traversed the section described by Rickwood, and found that the lower part of the section is almost identical with the type section of the Kana Formation in the Jimi Valley. The Kana Formation is a very distinctive unit and there is no doubt that the rocks in the Chimbu River are a part of it. From about 20 facings found throughout the unit, it appears that the whole section is overturned.

The lower part of the section (Fig. 23) consists predominantly of acid volcanics which had not been seen in the type locality. The section does not appear to be repeated by faulting or folding, and if this is the case, the volcanics total about 9000 feet thick. Subsequent mapping in the Jimi River (Bain and Ryburn in prep.) has shown that similar volcanics are present in the Kana Formation to the south-east of Tabibuga Patrol Post, and in the lower Yuat River 100 miles to the northwest sheared acid volcanics also belong to the same unit.

The Kana Formation in the Chimbu River is in contact downstream with unmetamorphosed, well-bedded greywacke and siltstone which was also mapped by Rickwood as Omung Metamorphics. These bear some resemblance to the Omung Metamorphics in the type locality, but are very similar to the Lower Jurassic Balimbu Greywacke which crops out extensively in the Jimi Valley and with which they have been tentatively correlated. A fragmentary ammonite collected from these rocks, though not identifiable, is almost certainly a Mesozoic fossil (S. Skwarko pers. comm.) and is further evidence that the rocks are most unlikely to be correlatives of the Omung Metamorphics.

Measured Section:

The Kana Volcanics are about 11,600 feet thick in the Chimbu River (Fig. 23). It was not possible in the time available to measure the section on the ground so the thicknesses given below were measured on the airphotographs and are only very approximate. Also, several small reversals of dip were noted during the traverse for which no allowance has been made, so the true thickness is probably somewhat less.

THICKNESS	ROCK TYPE
2000 feet	Pebble conglomerate beds up to 8 feet thick interbedded with red siltstone and fine tuffaceous sandstone. The conglomerate consists of well-rounded cobbles and pebbles and rare boulders of dacitic rocks in a reddish-purple tuffaceous matrix. Some rare basaltic pebbles. Grades upwards into green and reddish-purple feldspathic sandstone (?water-laid tuff), containing rounded pebbles porphyritic andesite and some calcareous nodules. Medium-bedded. Contains some beds of red tuffaceous siltstone and dacite pebble conglomerate similar to the underlying beds. Faulted against Balimbu Greywacke.
600 feet	Red tuffaceous siltstone and shale. Small quartz and feldspar grains can generally be distinguished in the coarser varieties. Massive, jointed, and no bedding seen. Band of dark grey sheared phyllite near top.
600 feet	Green basaltic agglomerate and interbedded basalt pebble and cobble conglomerate. Basalt green and highly epidotized in places.
6000 feet	Mostly well bedded crystal tuff and tuffaceous sandstone consisting of graded beds 2 inches to 12 inches thick (rarely 24 inches) grading upwards into light coloured shale and siltstone. Appear to be mostly acidic. Some dacitic lavas and agglomerate, and rare dacite pebble conglomerate. Intruded by dolerite and gabbro.
2400 feet	Poorly exposed and intruded by many dykes of altered dolerite and gabbro, so original rock type not well known. Some green, highly altered fine-grained basic rocks which are probably basalt lava flows. The only other rock seen was bedded andesitic crystal tuff similar to the overlying volcanics. Intruded by the Bismarck Granodiorite so the bottom not seen.

Petrography (by D.E. Mackenzie)

Nine specimens from the type locality were examined microscopically. They were found to be tuffs, lavas, agglomerates and volcanically-derived sediments, with the single exception of a microdiorite or andesite porphyry, 20NG0021A.

They range in composition from andesite to rhyolite, dacite and rhyodacite being the most common.

All specimens have undergone low-grade regional metamorphism, the least affected being specimens 20NG0024 and 20NG0024B. Albite has replaced the original feldspar in most rocks and chlorite and epidote have developed in all except 20NG0024B. Calcite, actinolite, biotite and muscovite are present in some specimens. Grade of metamorphism ranges from the lowermost greenschist facies (20NG0024B) to the upper greenschist or lower epidote-amphibolite facies (20NG0021B).

Kana Volcanics in the South Sepik region:

Kana Volcanics crop out in the map area along the divide between the Yuat and Maramuni Rivers are almost identical with the lower part of the formation in the headwaters of the Jimi River. Sheared dacite lavas and crystal tuffs cropping out in the Yuat Gorge also belong to the Kana Volcanics and are very similar to the volcanic rocks seen in the lower half of the type section in the Chimbu River.

The lower half of the Kana Volcanics which crop out poorly in the slopes leading down from the divide to the Yuat River consist mainly of tuffaceous sandstone derived from acidic vulcanism, dacite pebble conglomerate, and some interbedded red siltstone. The upper part of the unit which occurs along the crest of the divide and some distance down the Maramuni fall is poorly exposed, but appears to be finer-grained: the conglomerate is less common, and red and grey siltstone constitute a greater proportion of the unit.

The sandstone is fine to coarse-grained, and grades into pebble conglomerate. It is characteristically light green or grey, and almost invariably contains a large proportion of feldspar, commonly over half the rock.

It is a clean, well-sorted, tuffaceous sandstone, consisting of angular to rounded fragments of volcanic rocks, quartz, and sodic plagioclase (An_{30}). There are some minor fragments of sedimentary rocks and detrital biotite, and small patches of carbonate matrix. Some weathered beds containing very poorly preserved shells are seen in places, and similar fossils may have provided the carbonate seen in the matrix.

The conglomerate is a distinctive rock and consists of well-rounded pebbles and cobbles of dacite, fine-grained acidic intrusives, and quartz, in a coarse-grained tuffaceous sandstone matrix. Another characteristic component is a maroon tuffaceous siltstone which is massive generally indurated, and commonly contains small scattered fragments of feldspar and quartz. Some appear to be water-laid tuff but all trace of their origin has been obliterated by subsequent alteration.

The highly sheared green and purple dacite and quartz feldspar porphyry exposed in the lower part of the Yuat Gorge almost certainly belong to the Kana Volcanics. They appear to be bedded, but it is possible that the banding is a large-scale foliation caused by movement on the Jimi Fault. Small lenses of highly sheared and very highly indurated conglomerate similar to conglomerates found in the formation to the south-west, were seen in the Yuat Gorge, but so highly sheared are these rocks that it is commonly difficult to distinguish the two rock types.

In thin-section most of the rocks are acid volcanics consisting of phenocrysts of quartz feldspar, and fragments of microdiorite in a very fine-grained matrix which displays a marked foliation caused by shearing along the Jimi Fault: in most thin-section the groundmass is recrystallized and consists of very fine-grained quartz, feldspar, sericite, and some epidote.

Fossils have not been found in the lower part of the unit in the map area but in the head waters of the Jimi River good fossil assemblages give the age as Upper Triassic. Poorly preserved fossils found in the upper part of the unit near Yalifa hamlet have been provisionally identified by S. Skwarko (pers. comm.) as Lower Jurassic.

Thus the Kana Formation ranges in age from Upper Triassic probably to Lower Jurassic.

JURASSIC

The stable shelf- environment of the Triassic continued in the South Sepik region into the Lower Jurassic when the uppermost part of the Kana Volcanics were laid down.

A period of earth movement and erosion followed as shown by the marked unconformity in the headwaters of the Jimi River (Dow and Dekker 1964). After intense basic vulcanism which deposited thick marine basic volcanics (Mongum Volcanics) probably in Middle Jurassic times, very extensive shallow seas formed in which a uniform shale sequence was laid down over most of the Highlands of New Guinea. The shale is called the Maril Shale to the south-east-, and it extends into the South Sepik region where it is called the Sitipa Shale. The age of the shale is Upper Jurassic. South of the Lagaip Fault Zone the Lagaip Beds were being laid down in a narrow trough.

Mongum Volcanics.

The name Mongum Volcanics was proposed by Dow and Dekker (1964) for basic submarine volcanics conformably overlying Lower Jurassic Balimbu Greywacke and conformably overlain by Upper Jurassic - Maril Shale in the headwaters of the Jimi River. There the formation is 850 feet thick and consists principally of basaltic agglomerate and pillow lavas interbedded with conglomerate; tuffaceous sediments and minor limestone lenses.

In the South Sepik region, similar basic marine volcanics underly the Maril Shale to the north of Olimos between the Maramuni and Yuat Rivers. The Balimbu Greywacke is absent in this area and the formation appears to rest unconformably on the Kana Formation. Owing to poor outcrop no section could be measured but an approximate thickness of 3000 feet was obtained from measurement on airphotos.

The lower half is made up of amygdaloidal basalt and basaltic agglomerate with interbedded red and green tuffs and tuffaceous greywacke.

In the upper half tuffaceous greywacke and siltstone predominate over basalt and agglomerate; minor pink crystalline limestone and a massive bed of wollastonite - bearing quartzite also occur near the top of the formation. The top contact is taken at the top of the highest volcanic rock.

A small wedge of amygdaloidal andesite, vitric tuff, and lithic tuff belonging to the Mongum Volcanics is upfaulted within Maril Shale further to the west.

In thin section the Mongum Volcanics consist of basaltic and perhaps andesitic rocks in which the plagioclases have been largely albitized and the ferro-magnesian minerals altered to calcite, chlorite, iron ore, albite and quartz. The lithic tuffs consist principally of similarly-altered basaltic fragments. The distinctive massively bedded white quartzite consists largely of detrital quartz with radiating sheafs of wollastonite, isolated prisms of (?)pseudowollastonite, minor scapolite and diopside. This rock was probably deposited as a calcareous quartz arenite and has subsequently been metasomatized by adjacent basic volcanic sills intruded within the Mongum Volcanics.

No fossils were found in this unit but Lower Jurassic fossils in the top of the Kana Formation close by, and Upper Jurassic fauna in the overlying Maril Shale limits the age to Middle Jurassic.

Sitipa Shale (new name).

Rock Type:	Grey and green, generally calcareous, siltstone and shale.
Distribution:	As a thin fault wedge between the Sitipa and Salumei Rivers.
Derivation of name:	From the Sitipa River.
Type area:	The middle reaches of the Sitipa River. No type section was measured.
Stratigraphic relationships:	It is bounded in most localities by faults, but between the April River and the Sitipa Rivers there is one locality where it is possible that the Salumei Formation lies conformably on the Sitipa Shale. Laterally equivalent to the Maril Shale.

Thickness: Not known.

Fossils and age: Lamellibranchs give the age as Upper Jurassic.

Description:

The formation consists of shale and siltstone and very minor impure limestone and fine-grained sandstone. The shale and siltstone are characteristically light-coloured, and are commonly colour-banded light grey and green: grey black and red shale were seen but they are rare.

Outcrops are small and almost invariably massive, and some weather in a manner typical of the Maril Shale of the same age found to the south-east i.e., they form steep banks in the rivers in which the rock frets into small angular fragments about $\frac{1}{4}$ inch across. Where seen the bedding is laminated or thin-bedded and defined by bands of silty material. Very rarely are beds of indurated fine-grained quartz and feldspathic sandstone seen: they are up to 12 inches thick, but are generally much thinner, and commonly show small-scale cross-bedding, and slump structures.

Fossils were found in 4 localities and have been briefly examined by Skwarko (pers. comm.) and are regarded as probably of Kimmeridgian age (Upper Jurassic) and therefore correlatives of the Maril Shale found in the Maramuni River 50 miles to the south-east.

Maril Shale

The name Maril Shale was proposed by Edwards and Glaessner (1953) for a predominantly shale sequence in the Wahgi Valley south-east of the map area. Subsequent mapping has shown that the unit is very extensive, and occurs along the Jimi Valley (Bain et. al., in prep.) to the divide between the Yuat and Maramuni Rivers. In the map area the rocks are mainly dark grey to light grey, commonly calcareous, shale and siltstone containing rare thin beds of indurated quartz sandstone.

Bedding can sometimes be seen in good outcrops either thin-bedding or laminations, but mostly the shale is massive and forms characteristic fretting outcrops described under Sitipa Shale. In the lower Sau River sporadic outcrops of laminated to thin-bedded, pink and cream, quartzite were seen within the Maril Shale but their thickness is not known.

The lower part of the unit, as in the Jimi Valley is coarser-grained and consists mainly of massive dark coloured siltstone which grades imperceptibly into fine-grained greywacke. Thin partings of shale several feet apart can be seen in good outcrops, but generally no bedding is seen.

The shale is intruded by Maramuni Diorite, and the rocks are hornfelsed near the contact. In places they are altered to phyllite, possibly as a result of deformation along the major faults of the region.

Malayomaorica malayomaorica and Inoceramus sp. cf. haasti were collected in the Maramuni area and the lower Sau River, confirming the age of the formation as Upper Jurassic.

The formation in the Jimi Valley and in the map area is much thicker than in the type area of the Wahgi Valley where 3700 feet was the maximum thickness measured by Rickwood (1955). Thus in the Jimi Valley the formation exceeds 8000 feet (Bain et.al., in prep.), and though it is much faulted in the map area it can be seen that the thickness is about the same. It is apparent therefore that the Maril Shale was laid down in a north-west-trending trough between the Maramuni River and the head of the Jimi River. Rickwood has shown that the unit thins markedly to the south against the massif of the Kubor Range, and it is thought that the shoreline was not far to the south.

Ambunti Metamorphics (New name)

Most of the Sepik Valley is underlain by metamorphic rocks which we have called the Ambunti Metamorphics. They range from low-grade slate, phyllite, and sericite schist on the east, to amphibolite facies rocks on the west.

Rock type:	Slate and sericite schist, mica schist containing staurolite, amphibolite, and garnet muscovite gneiss.
Distribution:	Most of the hills rising out of the Sepik Plain between the Leonard Schultze and Karawari Rivers are composed of Ambunti Metamorphics. Several large areas are also exposed south of May River Patrol Post.
Derivation of name:	From the Government station of Ambunti which is built on hills composed of the metamorphics.
Stratigraphic relationships:	Unconformably overlain by Tertiary f_{1-2} stage Wogamush Beds and Karawari Conglomerate. Lateral equivalent is possibly overlain by unaltered Cretaceous sediments to the west of the map area.
Thickness:	Not known.
Age and correlatives:	Possibly pre-Middle Jurassic, or less likely, equivalent of the Lower Tertiary Salumei Beds. The Gwin Metamorphics found in the August River about 30 miles to the west are almost certainly lateral equivalents.

The Ambunti Metamorphics fall naturally into two divisions: (1) low-grade rocks between the Karawari and April Rivers, and (2) higher-grade amphibolites to the west.

(1) Most of the low-grade rocks lie within the area lacking airphotographs, so our knowledge of them is confined to sporadic, widely spaced outcrops along the main stream channels, and from observations made by Behrmann's expedition before World War 1. The rocks seen were all low-grade metamorphic rocks, and are mostly fine-grained slate,

phyllite, and sericite schist, but towards the April River higher-grade rocks occur, mainly fine-grained biotite and muscovite schist. Banded gneisses of the same grade of metamorphism also occur in this area.

In all the low-grade rocks the foliation has completely obliterated the bedding, and now dips at low angles. The strike of the foliation in this region is roughly parallel with the regional west-north-west regional strike of the main faults of the area. Quartz veins are a characteristic feature of the lower-grade metamorphics: they range up to several inches thick and several feet long, and though rather irregular, they tend to parallel the foliation.

The Chambri Diorite intrudes the metamorphics east of Ambunti, and the rocks in this region are higher-grade. Coarse-grained muscovite and biotite schists are common and small metamorphosed intermediate and basic intrusives are found throughout. The basic rocks have been recrystallized to amphibolite, while the intermediate rocks have formed strongly foliated orthogneiss.

Along the April River the rocks are slightly higher grade, and here many exhibit marked gneissic texture. Only one sample of the rocks from this area was examined in thin-section: it is a banded gneiss consisting white lenses of quartz up to $\frac{1}{4}$ inch thick and several inches long intercalated with finely banded biotite gneiss. The lenses are mostly granular quartz, but contain minor albite muscovite, and apatite, the gneiss is dark brown and consists of quartz, biotite, muscovite, albite, some chlorite, and minor iron oxide, sphene and apatite.

(2) The higher-grade rocks west of the April River are better exposed and hence were mapped in more detail. They fall within the amphibolite facies of regional metamorphism. As with the lower-grade metamorphics they exhibit marked foliation which has obliterated the bedding: the foliation also dips at low angles, but the strike ranges widely and no consistent trend was recognized, except over areas of several tens of square miles.

25 thin section of the higher-grade rocks have been examined, and the following rock types were noted: quartz-garnet-muscovite gneiss containing some kyanite and staurolite; biotite-staurolite schist; hornblende-epidote amphibolite; garnet-dolomite-muscovite-quartz gneiss; hornblende-diopside amphibolite; quartz-albite-muscovite schist. Apatite and sphene are common accessories in most of the rocks.

The age of the Ambunti Metamorphics is unknown, but an upper limit to their age is given by the Tertiary f_{1-2} stage Wogamush Beds and Karawari Conglomerate which unconformably overlie them in several places. Other evidence of age is lacking in the map area, but the Gwin Metamorphics found in the August River 30 miles to the west are almost certainly an extension of the Ambunti Metamorphics, and these are stated (Paterson & Perry 1964) to be overlain by unaltered sediments containing Cretaceous foraminifera. However the mapping done in this western area was done without the aid of airphotographs, and a re-examination of the field evidence since the airphotographs have become available, suggests the possibility of structural complications between the Cretaceous rocks and the Gwin Metamorphics. The close proximity of almost unaltered Jurassic Sitipa Shale, and low-grade metamorphic rocks of the Salumei Formation, in the Sitipa River area, should give cause to examine carefully such a critical relationship.

The possibility that the Ambunti Metamorphics are younger than Jurassic, and therefore the same age as the Salumei Beds, while not considered likely by the authors, is a possibility that cannot at this stage be discounted.

CRETACEOUS

The Cretaceous Lagaip Beds continued to be deposited south of the Lagaip Fault Zone, but to the north sediments and interbedded spilites (Salumei Formation)were being laid down in a west-north-west trending eugeosyncline. Sedimentation continued into the Eocene north of the fault.

Salumei Formation (New name)

The Salumei Formation is the name proposed for a monotonous sequence of fine grained marine sediments of Upper Cretaceous to Eocene age, containing sandstone, limestone, and volcanic beds. They crop out from near Kompiam in the south to the Sepik Plains in the north, and to the May River on the west. These beds were previously mapped as part of the Lagaip Beds (Dow et.al.,

1967) but have since been shown to form a distinctive unit. South-west of the April Fault as far as the May River these beds have been metamorphosed to greenschist facies grade and are there known as the Salumei Formation (metamorphic phase) which is hereafter called Salumei metamorphics and is discussed separately.

Rock type:	Mostly fine grained marine sediments consisting of calcareous and non-calcareous siltstone and shale, subgreywacke, and fine grained lenses of limestone and calcarenite. Submarine agglomerates and lavas, and rare volcanic pebble conglomerate have sporadic distribution.
Distribution:	The northern fall of the Central Range between the Tarua River (143°45'E, 5°5'S) and the May River (142° 00'E, 4°45'S).
Derivation of name:	From the Salumei River which drains a large area of these rocks.
Type area:	In the Salumei headwaters (143°00'E, 5°00'S). No type section has been designated.
Stratigraphic Relationship:	The base of the formation has not been seen. The only contacts with older units are faulted, except perhaps in the Sitipa area where it could be conformably overlying Jurassic Sitipa Shale. The formation is overlain unconformably by the Miocene Pundugum Formation and Wogamush Beds.
Thickness:	At least 10,000 feet.
Age:	Upper Cretaceous to Eocene, as based on foraminifera. A fragment of an ammonite belonging to either Polyptychites or Simbirskites found as float by natives in the Wesas River, was probably derived from the formation. Both ammonites are Lower Cretaceous (Neocomian) genera. (S. Skwarko pers. comm.).

General Description

The Salumei Formation is composed predominantly of siltstone and shale, subgreywacke, and sporadic, interbedded submarine volcanic agglomerates and lavas. The sediments are commonly calcareous or micaceous and contain large lenses of limestone and some very minor pebble bands. The beds are generally massive, though coarser-grained laminae can sometimes be distinguished, and some outcrops of siltstone, as in the Karawari River, are thinly bedded. Most shales and siltstones are light to dark grey whilst some are green, buff and red in colour.

Figure 24: Limestone breccia in the Saumei Formation containing poorly sorted, subangular basalt fragments

Neg. GA 637

Figure 25: Indurated laminated to thin-bedded shale and siltstone of the Lagaip Beds in the upper Karawari River.

Neg. G 9513

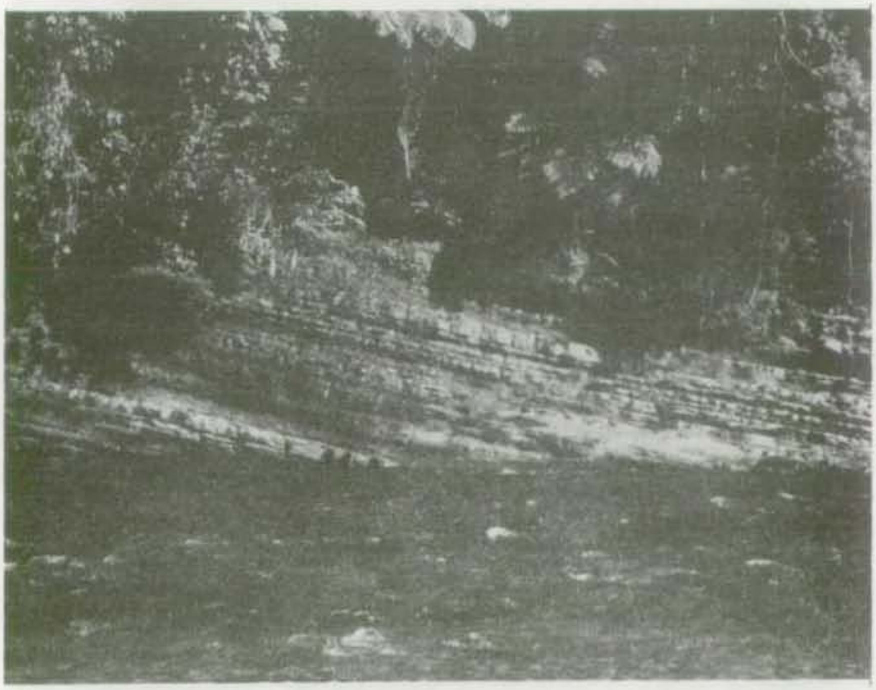


Figure 26: Gently dipping subgreywacke and siltstone of the Lagaip Beds in the upper Karawari River.

Neg. G 9512

thinly bedded. Most shales and siltstones are light to dark grey whilst some are green, buff and red in colour.

The arenites, in many places volcanically derived, are commonly thickly bedded with fine interbeds of siltstone or mudstone and locally micaceous or rich in quartz. The pebble conglomerate contains pebbles of greenish basic volcanics, coloured sediments and some quartz, although locally developed quartz pebble conglomerates are known. In some places the conglomerate is clearly intraformational with big angular, often elongated, fragments of coloured mudstone.

The subgreywacke fraction is commonly dark greenish grey and very well indurated. However, the degree of induration of the fine grained rocks varies greatly and the rocks range from hard silicified rocks near the Maramuni Diorite to almost friable rocks in some areas where they have been little deformed.

Lenses of limestone up to several hundred feet thick and several miles long occur throughout the sequence but are not common. Most are massive, fine grained, buff coloured, and commonly crowded with foraminifera. Some, such as the lens exposed at the head of the Wogupmeri River are coarser-grained and composed of small, well rounded shell fragments and benthonic foraminifera. These lenses generally grade laterally into marly siltstone and commonly contain much non-calcareous clastic material. Many of the coarser limestone lenses are calcarenite breccias rich in foraminifera shelly fragments, and angular volcanic fragments.

Diagnostic foraminifera are common in both the limestone lenses and the fine grained sediments and they show that the Salumei Formation ranges in age from Upper Cretaceous to Eocene. The Upper Cretaceous faunas are commonly planktonic and consist of Globotruncana sp., Gublerina sp., Planoglobulina sp., Pseudotextularia sp., Helerohelix sp., Rugogloberina and Reussella sp., although some benthonic forms are present.

The abundant Eocene fauna are mostly benthonic forms such as Nummulites sp., Discocyclina sp., Fasciolites sp., Biplanispira cf. fulgeria (Whipple), Operculina? sp., "Rotalia", Nummulites cf. javanus, Borelis, Helerostegina, miliotides and Pellatispira sp. Most of the foraminiferal limestones also contain fragments of molluscs, corals, echinoid spines, and bryzoa as well as much algal material.
(pers. comm. D.J. Belford & G.R.J. Terpstra, 1968).

The Salumei Formation was laid down at the same time as the Lagaip Beds but there are no volcanic rocks or volcanically derived sediments in the Lagaip Beds.

Volcanic rocks are a characteristic feature of the Salumei Formation and their presence is one of the criteria by which the formation is distinguished from the Lagaip Beds to the south. The most common rock type is a green or red, massive, and invariably highly altered, basic volcanic rock in which original textures have generally been obliterated. Evidence such as relict pillow structures and the fact that the volcanics are interbedded with marine sediments show that most of them were laid down in a marine environment.

Many of the rocks regarded as lavas in the field were seen on thin-section examination to have relict agglomerate and crystal tuff textures, so it is now uncertain as to the proportion of lavas to pyroclastics. They are all albitized and can be termed spilites.

Reef limestones and breccias are commonly associated with the volcanic rocks, and they commonly contain varying proportions of poorly sorted fragments of basalt ranging from small pebbles to large boulders (Fig. 24). Most of the fragments are angular or scoriaceous. This rock type was probably laid down as part of reefs fringing volcanic islands.

Evidence of the depositional environment of the Salumei Formation is in most cases lacking, but throughout the formation greywacke beds exhibit some turbidite features such as graded bedding, flow casts, and convolute laminations. These are suggestive of a geosynclinal environment.

The formation is so extensively faulted and folded that it was not possible to establish the succession, but both the sediments and volcanics appear to interfinger and lense out over short distances, and it is unlikely that extensive marker horizons occur in the unit.

The only section measured was in the Karawari River north-west of Pundugum Hamlet the one locality where the structure is fairly simple. Here the formation is at least 8,200 feet thick, but the bottom of the unit was not seen and the top is eroded. An almost complete succession may be exposed between the April and Sitipa Rivers, where about 10,000 feet of Salumei Formation is apparently overturned, and could be conformably overlying the Jurassic Sitipa Shale. Thus it appears that the Salumei Formation is at least 10,000 feet thick, but it could be much thicker.

The formation is overlain by the Pundugum Formation, the boundary between the two units being marked by a change to coarser-grained tuffaceous sediments. Pebbles of Eocene limestone in conglomerates near the base of the Pundugum Formation attest to a period of erosion after the deposition of the Salumei Formation, and it is almost certain that a widespread unconformity separates the two units. However, under the prevailing conditions of poor outcrop, inaccessibility of many localities, and structural complexity of the rocks, it was impossible to prove the existence of such an unconformity.

Detailed description

The rocks in the various localities are described in detail below from east to west:

(1) Karawari River north-west of Pundugum Hamlet:

Approximately 8,200 feet of light grey micaceous siltstone and mudstone with calcareous nodules crop out along the Karawari River. They are soft poorly indurated to well indurated, thinly bedded and have a closely spaced fracture pattern in the finer beds. There are some arenaceous beds (from 1-18 inches) within the sequence, (Fig. 26) but these are generally separated by a greater thickness of shaly siltstone which in places is laminated. The beds within half a mile of the Maramuni Diorite are contorted red to buff coloured tuffaceous siltstone. (Fig. 25) They are finely laminated, show much soft sediment deformation (e.g. micro faults) and are highly indurated.

There is a small (8-10 feet) bed of pebble conglomerate near the top of the section.

(2) Between the Wogupmeri River and Kasagari:

The rocks in the head of the Wogupmeri River are only moderately folded and it appears that the section traversed is not of great thickness - probably less than 2000 feet. Shale and siltstone greatly predominate: they are dark grey to light grey, and are generally cleaved and indurated, but show little evidence of recrystallization. The rocks are all massive and no bedding was seen except in the limestone lens described below: many of the shales are calcareous and ramifying calcite veins are common in places.

A gently folded bed of limestone, between 200 feet and 400 feet thick crops out prominently in this locality. It is apparently interbedded with the shale though because of the poor outcrops this was impossible to prove. It is grey to cream, partly recrystallized, calcarenite, containing abundant benthonic foraminifera in places which give the age as Eocene. Bedding is commonly seen as well developed partings giving a flaggy appearance to the outcrop.

Near the crest of the main range between the Wogupmeri and Kasagari Rivers is a polymict conglomerate consisting of well-rounded pebbles and cobbles of quartz, silicified shale, schist, and some gabbro in a tuffaceous sandstone matrix. The rock is moderately indurated, and it is thought that it belongs to the Pundugum Formation. Associated with the conglomerate but seen only as float from the hillsides is a massive dark fine-grained micaceous greywacke, and some basic crystal tuff which probably belong to the same formation. A large number of dykes of porphyry belonging to the Maramuni Diorite intrude both the Salumei and Pundugum Formations in the headwaters of the Wogupmeri River.

Highly indurated and distorted conglomerate found in the Kasagari River and the lower part of the Kasagari River probably also belongs to the Pundugum Formation.

Further upstream in the Kasagari River the rocks are green cream pink or mauve shale or phyllite. No bedding was seen, because the rocks in this region are affected by a very strong cleavage which has obliterated all primary features. The cleavage dips consistently eastwards at 25^{o} to 40^{o}, and appears in the field to have resulted from a major thrust fault.

(3) Between Yokopos River and Sikipas Creek:

An elongated ultramafic body and an adjacent diorite intrusion lying along the watershed between the Yokopos and Wesas Rivers intrude the formation in this area.

To the south of these intrusions the formation is sheared and folded and the section examined cannot be taken as continuous. Slickensided, massive black shales, maroon and greenish-grey hard siltstones, algal limestone and basalt breccia with limestone matrix crop out in the Yokopos River. To the north of the Yokopos River a gently dipping eighty foot thick bed of foraminiferal limestone has yielded forams of Eocene age. The association of limestone and volcanics is characteristic of the Eocene part of the Salumei Formation. Between the Eocene limestone and diorite intrusion black shales, red and green siltstones and fine feldspathic sandstone were seen but extensive shearing and steep dips suggest complex structure; possibly resulting from the emplacement of the adjacent diorite and ultramafic bodies. Numerous dykes and apophyses of andesitic porphyry and microdiorite intrude the formation here.

North of the ultramafic body Eocene forams occur in a marly limestone in Sikipas Creek. The characteristic association of limestones and basaltic breccias were observed in stream boulders. One boulder was observed with scoriaceous basalt fragments in a limestone matrix. Close to the ultramafic body steeply dipping, alternating thin beds of greywacke and siltstone outcrop in Sikipas Creek. These are often slump bedded and are commonly graded. Red siltstone and slump breccia, consisting of rolled fragments and wisps of finely laminated shale in a gritty greywacke matrix, were also seen in outcrop. Complex structure is indicated by shearing and overturned bedding. There are numerous small, sheared serpentine lenses within the Salumei Formation in this area, probably forced up along faults and shear zones.

(4) Between Korosomeri River and Bisorio Village:
Main rock types are light grey to black siltstone and shale which is generally thinly bedded with small light grey finely crystalline limestone nodules. Highly contorted red, light dark grey and purple shale containing volcanic fragments are present and small aplitic intrusives were seen in places.

These are overlain by red shale which is in turn overlain by dark grey to black and green basic volcanic agglomerate which incorporates fragments of the red siltstone and is cemented with a red jasper-like material. Some of the lava has a pisolitic appearance and is dark purple. Overlying these volcanics are thin to medium bedded light and dark grey shale with small limestone nodules and float containing limestone boulders from undisclosed limestone lenses higher in the sequence. These limestones contain Upper Cretaceous foraminifera.

The sequence is then cut by a fault which contains a band of serpentinite about 200 to 300 yards wide. On the other side of the fault are the same grey mudstone-siltstone with thin limestone beds (up to 6"). It was not possible to measure the thickness of this succession.

(5) Between Bisorio Village and Sikipas Creek:
Here the Salumei Formation consistsof light grey rather micaceous sandstone and siltstone with interbedded highly contorted reddish siltstone and limestone. The limestone is very variable and consist of calcarenite, limestone breccia, foraminiferal limestone, and fine-grained buff to dark grey limestone. Conspicuous in float from most of the streams are fine pebble conglomerate, volcanic agglomerate, and volcanic sandstone typical of Pundugum Beds. Micaceous siltstone is only minor constituent. Bedding is confused but there is at least a 1000 feet of beds exposed.

(6) Middle reaches of the Salumei River:

North of Bikalu Hamlet the Salumei Formation consists largely of moderately indurated, well bedded, greywacke and siltstone strongly folded about northwest - southeast trending axes. These rocks are at least 4000 feet thick as measured between adjacent fold axes.

For the most part these greywacke-siltstones have 3 inch - 12 inch thick graded beds micro-cross bedding, convolute lamellae and load structures. At one point a 15 foot bed of dark siltstone containing scattered pebbles of quartz diorite, porphyry, basalt green sandstone and greywacke was seen within a graded greywacke-siltstone sequence. These rocks appear to have been deposited by turbidity currents.

In thin section these greywackes are quartzo-micaceous with much carbonate material in the matrix. Coarser, more gritty beds are present.

Further upstream in the Salumei River the dominant rock types are dark grey, micaceous sandstones and siltstones, generally thin-bedded (2 - 3 inches) and with slumps, graded beds and load casts indicating that this part of the dipping sequence is inverted. Rare beds of conglomerate about 2 feet thick contain pebbles of quartzite, marble, basic volcanics and some coralline debris.

(7) Between April and Sitipa Rivers:

Poorly exposed rocks of the Salumei Formation cropping out between the April and Sitipa Rivers are composed mainly of light and dark grey shale and siltstone with interbeds of about 200 feet of contorted light and buff coloured finely crystalline limestone. The succession includes several hundred feet of dark green coloured volcanic greywacke. Much of the siltstone in the middle of the sequence is tuffaceous and coloured red or green: it contains a thin bed of highly indurated pebble conglomerate. The beds are steeply dipping, to the east but could be overturned. However outcrops were poor and very few bedding planes were observed. The section is believed to be approximately 10,000 feet thick.

(8) Lower Bamali River:

To the south of the April River a large fault block of Salumei Formation occurs within generally low grade Salumei metamorphics.

In this block the Salumei Formation consist mainly of fine-grained sediments containing marine volcanics and limestone lenses. The volcanic rocks are mainly green and red, thin to medium bedded green lavas of intermediate to basic composition, and are interbedded with grey or greenish coarse to fine grained, tuffaceous sandstone. Well indurated quartz sandstone and greywacke, are common, the coarser varieties of which grade into a pebble conglomerate. Most of the volcanics crop out as hard, extensively sheared and jointed mainly fine crystalline flows with many green shards. Some of the volcanics are crystal tuffs, which seem locally to grade into a tuffaceous sub-greywacke or angular grit.

The sequence is approximate 1000 feet thick and foraminifera from interbedded limestone lenses indicate an Eocene age for the sequence.

(9) Head of Bamali Creek

Little altered sediments and intercalated altered basic volcanic rocks occur as fault wedges within ultramafic rocks at the head of Bamali Creek. No idea was gained of either the succession or of the thickness of the rocks, but they are identical with the Salumei Formation mapped to the west and east.

The most common rock types are massive shale and siltstone which varies in colour from grey and black to green or red. Bedding is rarely seen, but where present consists of thin beds of lighter-coloured siltstone.

Light grey or greenish beds of feldspathic sandstone and sub-greywacke occur as beds up to 3 feet thick and make up about 20 percent of the sediments. They are all fine-grained, massive, and quite highly indurated: being resistant to erosion, they mantle hillsides over much of the area.

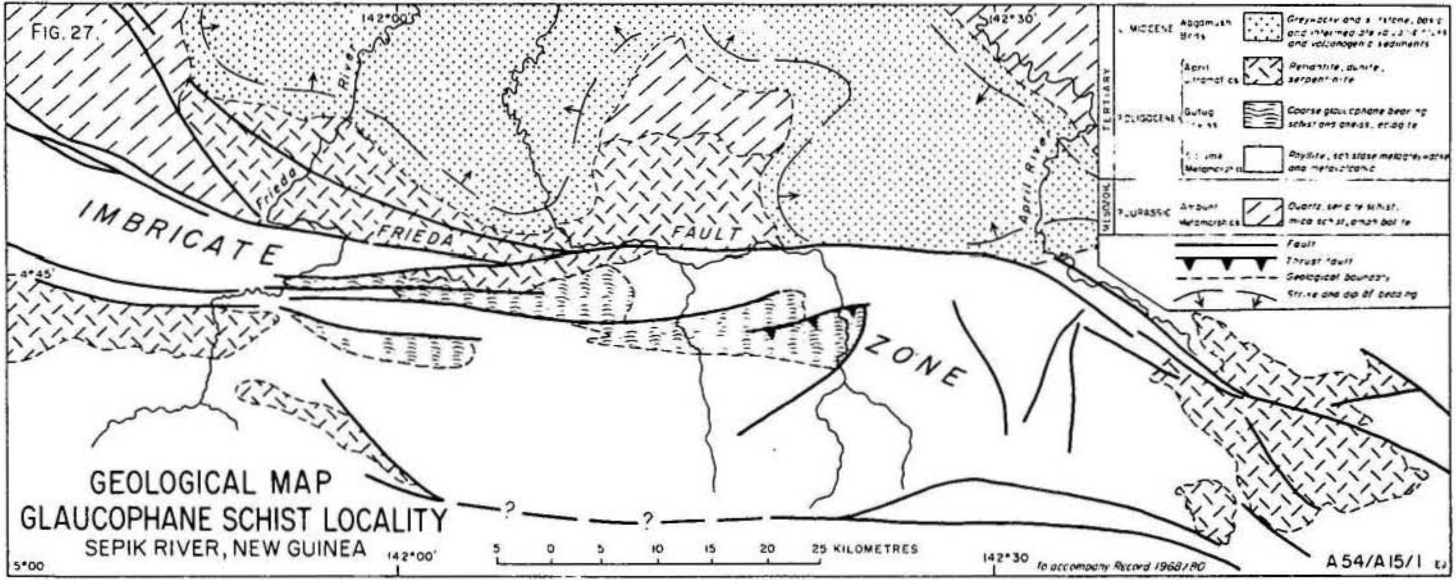


FIG. 27.
142°00'
142°30'
River
Frieda
IMBRICATE
FRIEDA
FAULT
ZONE
April River
4°45'
5°00
TERTIARY
MIOCENE
Abgamush Beds
Greywacke and siltstone, basic and intermediate volcanic flows and volcanogenic sediments
April Ultramafics
Peridotite, dunite, serpentinite
OLIGOCENE
Gutug
Coarse glaucophane bearing schist and gneiss, eclogite
Phyllite, schistose metagreywacke and metavolcanic
MESOZOIC
JURASSIC
Ambunti Metamorphics
Quartz sericite schist, mica schist, amphibolite
Fault
Thrust fault
Geological boundary
Strike and dip of bedding
GEOLOGICAL MAP
GLAUCOPHANE SCHIST LOCALITY
SEPIK RIVER, NEW GUINEA
5 0 5 10 15 20 25 KILOMETRES
To accompany Record 1968/80
A54/A15/1

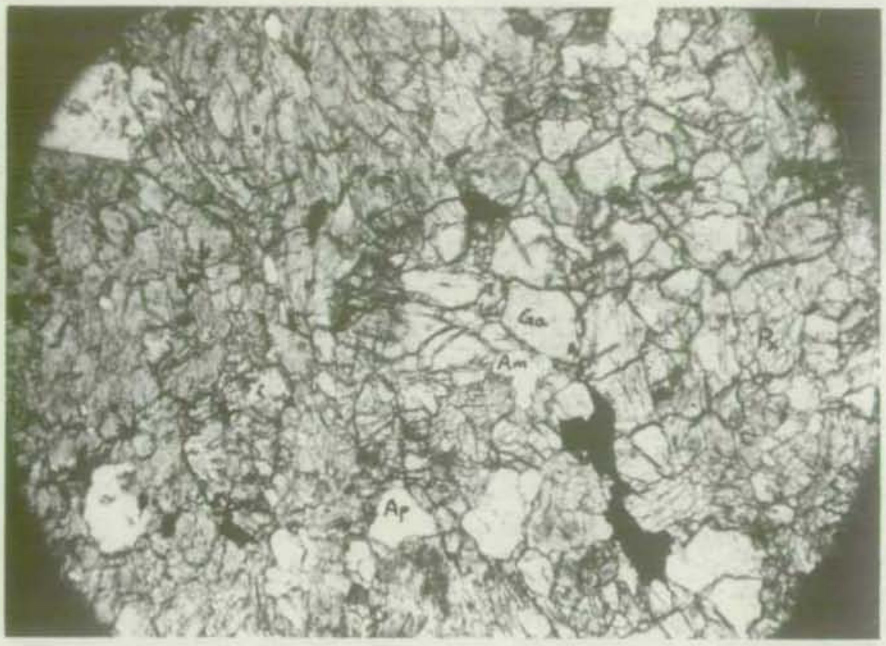


Figure 27A. Eclogite containing some blue-green amphibole and apatite. Pyroxene (Px) Garnet (Ga) Amphibole (Am) Apatite (Ap) Magnification X 35.
Ref. No. 03NG2510 F Neg. M 758

Figure 27B. Quartz, glaucophane, epidote, garnet paragonite schist. 03NG0505 Fl. C Glaucophane (Gl) Paragonite (P) Quartz (Q) Garnet (Ga) Magnification X 35.

Neg. M 758

Several thin sections of these sandstones were examined: all are classed as subgreywacke and are fine-grained and even-grained, consisting of subangular to subrounded grains of quartz, plagioclase, fine-grained rock fragments, and some muscovite, in an originally clayey matrix. In all samples the matrix is recrystallized, generally to sericite and chlorite, though in some muscovite and biotite have formed, and the rocks are classed as quartz mica schist. Epidote, sphene, zircon, and iron oxides are present as accessories.

Lenses of calcarenite up to several hundred feet thick and several miles long are found in this area -- they contain abundant foraminifera in places which give the age of the succession as Eocene, the same as similar rocks from the Salumei Formation elsewhere. The calcarenite is white red or green, generally recrystallized, and commonly fine-grained; little trace can be seen of original organisms, except for patches of well preserved foraminifera, and it is thought that it was deposited in rather deep water.

Almost invariably associated with the limestone are altered basic marine volcanics which in hand specimen are mostly massive dark green rocks in which the original texture is almost invariably destroyed. Only rarely were agglomerate, or pillow textures distinguished. Most of the fragmental volcanic rocks contain varying amounts of calcite, generally as recrystallized fragments which were probably originally fragmentary shells. With increasing calcite content the rocks grade into limestone, and the original sedimentary textures are better preserved.

An unusual rock is a fine red and green calcarenite which contains scattered angular fragments of basalt scattered randomly through the rock.

In thin-section the volcanic rocks are seen to consist of altered basic crystal tuff and agglomerate, and spilitic lavas. The tuff is fine-grained and consist of grains of plagioclase (now altered to albite), quartz, epidote, and pyroxene, in a recrystallized matrix of chlorite, tremolite-actinolite, and epidote. Though appearing massive in hand specimen most of the rocks show a moderate preferred orientation under the microscope.

The agglomerate is fine-grained and consists of subrounded to subangular fragments of basic volcanic rocks, broken crystals of plagioclase (twinned An_{27-28} but now altered to albite), and small fragments of pyroxene (now altered to epidote). There are small amounts of orthoclase and muscovite. Patches and veins of calcite, and zeolite are common.

One sample of pillow lava was examined in thin-section. It consists of clinopyroxene, plagioclase laths (altered to albite), granules of epidote, and patches of chlorite containing some biotite and muscovite. Patches and amygdales of chlorite, calcite, and zeolites are common.

Also apparently associated with the limestone lenses, but seen in Bamali Creek only as boulders, is a highly indurated pebble and cobble conglomerate consisting of well-rounded components of indurated greywacke and siltstone, and some basic volcanic rocks.

The volcanic rocks and limestones, though they have reacted to stress as competent blocks, are extremely contorted in places and it is thought that they underwent considerable submarine slumping before consolidation.

(10) Headwaters of Frieda River:

To the north of Wabia Hamlet in the headwaters of the Frieda River the beds are predominately light coloured subgreywacke with minor light grey phyllitic shale. The greywacke is volcanically derived and contains much mafic material: it shows good graded bedding with beds containing numerous angular clasts of dark grey or black siltstone (up to 6" long) set in a sandy matrix. The steep ridge behind the village appears to consist mostly of greywacke. Further north there is a succession of interbedded volcanic greywacke and light grey slate and shale with minor hard, red (jasper like) siltstone. This is overlain by a lens of light buff coloured limestone crammed with Eocene foraminifera. The sediments to the north are finer-grained and are predominantly light grey to red and green shale and siltstone, North of Qnamo Hamlet they are sheared and contorted and contain some interbeds of sandstone. Still further north, in the lower reaches of the Kalibai River the rocks are strongly sheared, dark,carbonaceous shale riddled with quartz veins.

Lagaip Beds

The name Lagaip Beds was first used by Dekker and Faulks (1964 unpubl.) for fine-grained marine sediments which crop out in the Lagaip and Lai Rivers in the south-eastern part of the map area. Similar fine-grained Lower Tertiary sediments north of the Central Range were also mapped by them as Lagaip Beds; later, in 1966, the northerly and north-westerly extension of these beds was mapped as Lagaip Beds (Dow et. al. 1967 unpubl.). Since then, mapping has shown that the sediments north of the Central Range are in fact sufficiently distinctive to be mapped as a separate formation -- the Salumei Formation.

The Lagaip Beds have been shown by later mapping (Smit in prep.) to extend westwards as far as the West Irian border.

Rock types: To the west black and dark grey slate, shale, and siltstone, commonly pyritic, and minor sub-greywacke. Thick beds of quartz sandstone are seen towards the top of the unit. To the east the sediments are lighter coloured and almost invariably calcareous: limestone lenses and thin-bedded quartz sandstone are common in places.

Distribution: The upper reaches of the Lai River, along the Lagaip River for its whole length, and westwards to the West Irian border. Fine-grained sediments in the lower Lai and Sau Rivers near the eastern margin of the map area are doubtfully referred to the Lagaip Beds.

Derivation of name: From the Lagaip River.

Type area: The lower reaches of the Lai River; no type section was measured.

Stratigraphic relationships: The bottom of the formation was not seen in the map area, but similar sediments of Jurassic age in the Strickland Gorge (south-west of the map area), are unconformably underlain by granitic rocks. Overlain, probably unconformably, by Lower Miocene marine sediments.

Thickness: Not measured, but of the order of 10,000 feet.

Fossils and age: The oldest fossils found are ammonites of Callovian (top Middle Jurassic) age. Foraminifera ranging in age from Lower Cretaceous (probable Albian) Middle and Upper Cretaceous, to Paleocene have been found at scattered localities throughout the map area.

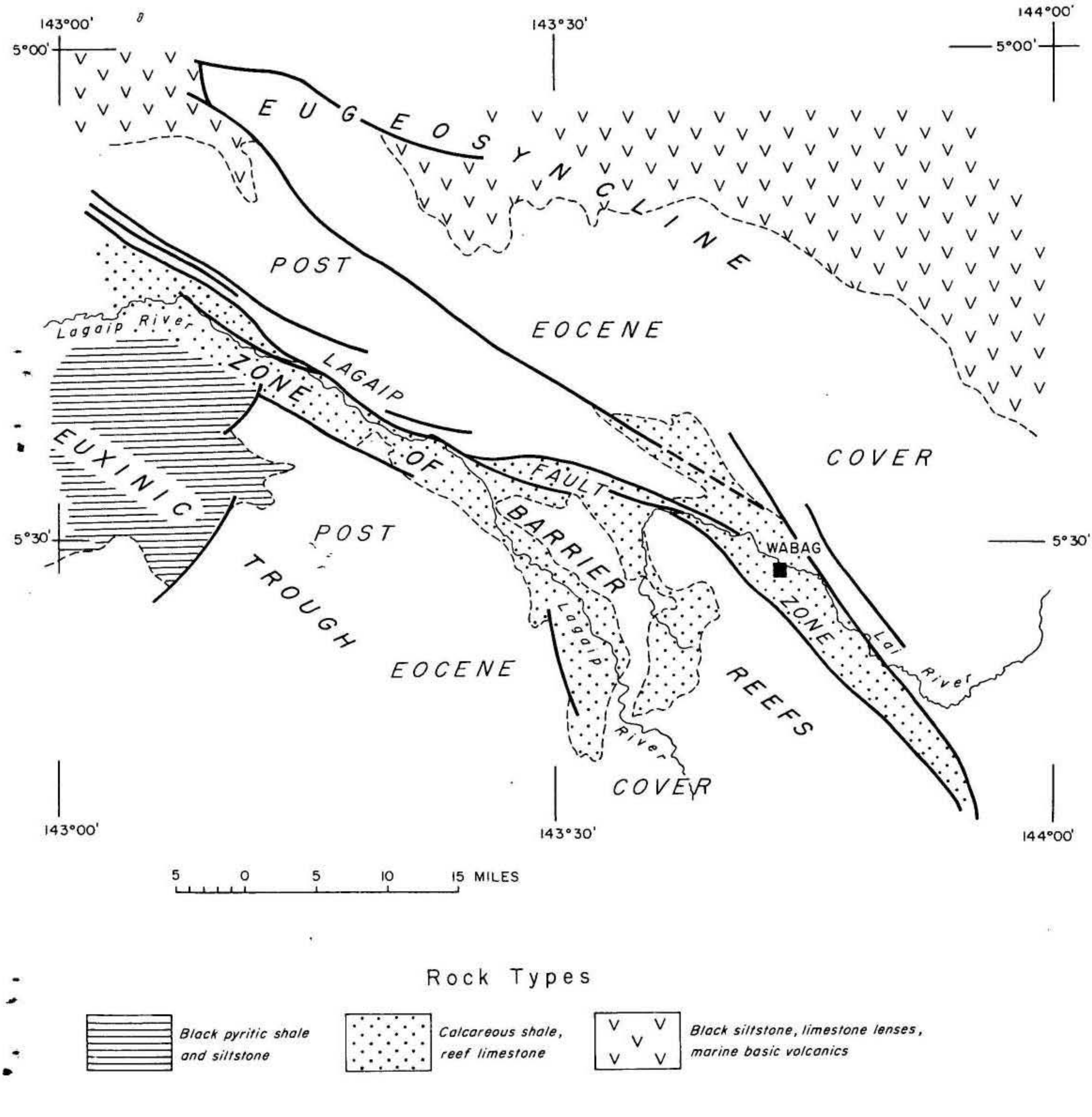
The Lagaip Beds fall broadly into two units but in view of the ruggedness of the terrain and the complex lateral variations seen within the formation in the head of the Lagaip River, it was not possible to map them separately. (1). The rocks west of Porgera are almost all dark-grey and black fine-grained sediments which contain several thick beds of quartzite and quartz sandstone near the top. (2). East of Porgera the sediments are also predominantly fine-grained but they are lighter coloured, commonly calcareous, and contain many patches of fine-grained limestone, most of which appear to be confined to one stratigraphic horizon in the Upper Cretaceous. Also included in the Lagaip Beds in this area are extensive beds of shale and siltstone containing thin beds of fine-grained quartz sandstone (Fig. 29).

(1) Porgera and westwards:

In the Porgera area the Lagaip Beds have been described (Ward - 1949 and Horne, in prep) as steeply dipping grey to black, fine-grained, commonly thinly bedded shale. Thin to medium-bedded quartz sandstone makes up a small proportion of the unit and a massive sandstone bed of unknown thickness composed mainly of fine, well-sorted quartz grains, is present.

West of Porgera the Lagaip Beds consist mainly of fine grained, dark shale and slate with minor coarser grained beds of subgreywacke. The rocks are commonly well indurated, and small quartz veins are common, particularly in the slate. Most of the beds are steeply dipping and highly cleaved: they are much faulted and locally distorted and tightly folded.

PALAEOGEOGRAPHIC MAP OF WABAG AREA DURING THE CRETACEOUS



To accompany Record 1968/80.

B54/A8/16 EJ

Figure 29: Quartz sandstone and interbedded shale belonging to the Lagaip Beds in the head of the Ambum River.

Neg. GA 1078

Figure 30: Tibinini Limestone Member in head of Porgera Valley. Cliffs are about 2000 feet high. Mount Kaijende in the background is also composed of Tibinini Limestone Member.

Neg. GA 1079

Syngenetic pyrite occurs throughout the sequence as nodules, veins, and scattered crystals up to $\frac{1}{4}$ inch across, and boulders and pebbles in float are stained with iron oxides.

Ammonites (Macrocephalites) collected from float, but undoubtedly from within the formation, suggest an Upper Callovian (Top Middle Jurassic) age (S. Skwarko pers. comm.).

Further west are similar dark grey siltstone and shale, which in most places are faulted and folded. Quartzite is prominent and appears to occur in one stratigraphic horizon.

The Lagaip Beds near Telefomin (off the map area to the south-west) consist mainly of dark grey and black slate and shale, interbedded with minor, dark, commonly fine-grained and lighter coloured greywacke. The black slate and shale are locally carbonaceous and the coarser-grained sediments contain detrital mica in addition to sericite flakes which have developed along the cleavage planes. In thick sequences of slate the cleavage has obliterated all traces of the bedding, but where greywacke beds are present, thin bedding can generally be seen. The bedding makes an angle with the cleavage of up to 30°.

In this area the sequence is tightly folded and the rocks are generally well indurated but the metamorphic grade is low. Most of the finer-grained sediments have been transformed into slate, but in the coarse-grained greywacke beds only a widely spaced fracture cleavage has been developed. In some outcrops of massive slate, thin beds of greywacke were observed which had been boudinaged with the long axes of the boudins parallel to the axes of a nearby fold.

In this area andesitic porphyry dykes intrude the Lagaip Beds: they are commonly metasomatically altered. Near the porphyry intrusions abundant quartz veining and heavy pyrite mineralization as veins and concretions up to a foot wide, occurs within the slate.

Ammonites of probable Callovian age have also been collected from this area.

Quartz sandstone is an important constituent of the upper part of the Lagaip Beds in the Telefomin area. An incomplete section was measured as follows.

Thickness	Rock Type
500 feet	Cliff of quartz sandstone, feldspathic and lithic sandstone with glauconitic matrix.
100 feet	Medium to thick-bedded micaceous lithic sandstone and quartz sandstone, with thin interbeds of dark siltstone.
50 feet	No outcrop
80 feet	Thin-bedded light grey quartz feldspar greywacke, interbedded with dark micaceous siltstone.
100 feet	No outcrop
150 feet	Medium to thin-bedded micaceous dark-coloured siltstone.

The quartz sandstone beds appear to be confined to the upper part of the Lagaip Beds and there is little doubt that with more detailed work they could be mapped as a separate unit.

(2) East of Porgera:

The Lagaip Beds cropping out along the Lagaip Fault Zone in the upper reaches of the Lagaip River, and along the Lai River, differ from those to the west: they are lighter coloured; most are calcareous and commonly contain limestone interbeds; and quartz sandstone makes up a much larger proportion of the section, both as massive beds several hundred feet thick, and as thin beds rhythmically interbedded with the shale.

Along the Lagaip Valley between Mokasip Creek and Kepilam, the Lagaip Beds show considerable lateral variation: they consist of light-grey to medium-grey calcareous shale and siltstone which grade on the one hand to calcareous sandstone and on the other, to marl and fine-grained limestone. Clean, well-sorted quartz sandstone beds, from a few feet at several hundred feet thick, are found throughout this area, and are particularly well developed in the west. Most are green or light-grey and show no bedding: they are generally friable and contain glauconite in places.

The limestone is cream or grey, fine-grained, and forms beds and lenses which are resistant to erosion and stand out as cliffs or strike ridges. It grades laterally and vertically into marl, calcareous siltstone, and calcareous sandstone, but appears to be confined to one stratigraphic horizon at least 1000 feet thick which extends from Muriaga to Kepilam. Foraminifera of Upper Cretaceous age have been found the length of this horizon.

Along the south side of the Lai Valley between Lake Iviva and Tchak River, and along the Ambum River, the Lagaip Beds are similar to those of the upper Lagaip River. Fine-grained, light blue or grey quartz sandstone is predominant: it is generally micaceous, commonly contains plant remains, and occurs as beds between 2 inches and 6 inches thick (rarely up to 2 feet thick), interbedded with subordinate shale and siltstone. Graded bedding,micro-cross-bedding, and load casts are common in places. The sandstone grades into grit and fine-grained quartz pebble conglomerate.

The shale and siltstone are almost invariably calcareous and are light grey or light blue (rarely purple or red) in colour. They are generally subordinate to the sandstone, but locally beds several hundred feet thick contain only rare thin interbeds of sandstone. Ramifying calcite veins, and scattered calcareous nodules are common, and pyrite nodules up to 2 inches across have been seen.

Fine-grained, light grey or white limestone is characteristic of this area. It occurs as massive beds 2 inches to 2 feet thick: some rare beds up to 6 feet thick have a flaggy outcrop. Upper Cretaceous foraminifera have also been found in the limestones from this area and it is thought that they probably belong to the same stratigraphic horizon as those in the Lagaip River.

A cold mud spring occurs west of Wabag (Fig.38.) in a swamp formed on calcareous shale and limestone of the Lagaip Beds. Grey mud oozes out of the top of a mound which it has built 25 feet to 30 feet above the surrounding swamp. Pieces of calcite and calcareous shale and rare limonite nodules (probably oxidized pyrite nodules), are rafted up by the mud.

Environment of deposition

The south-eastern part of the map area shows very well the contrasting depositional environments which existed during the Cretaceous and Eocene. North of what is now the Central Range, the eugeosynclinal Salumei Formation, consisting of turbidites, submarine volcanics, and limestone reefs, was being laid down (Fig. 28), at the same time as black pyritic shale and siltstone and some quartz sandstone was being laid down in an euxinic environment in the Porgera area. The euxinic environment extended westwards as far as the West Irian border, and was apparently controlled by a fairly deep, isolated, fault trough which had a fairly restricted circulation of water.

The Lagaip Fault Zone marks the boundary between the two environments, and it also probably forms the edge of the tectonically stable Australian Continental block (see Structure). This marginal zone is between 10 and 15 miles wide, and the sediments deposited here differ markedly from the other two environments. It is postulated that it was a zone of shallow-water, probably with discontinuous limestone reefs, which together with the continental slope to the north, formed an effective barrier to the southward migration of volcanic detritus from the eugeosyncline to the north. The sediments of the zone -- lenses and discontinuous beds of limestone up to several hundred feet thick grading laterally into calcareous siltstone shale and sandstone, and interbedded quartz sandstone containing plant remains -- are consistent with this picture of a shallow-water barrier zone.

TERTIARY

(a) Eocene

Deposition of the Lagaip Beds probably ceased before the Eocene, for the youngest beds known from within the formation are Paleocene, but deposition of the Salumei Formation continued into the Tertiary. However, the youngest beds known in the Salumei Formation are Eocene.

At some time before the Miocene the Salumei Formation was folded and metamorphosed to form the Salumei Formation (metamorphic phase).

Salumei Formation (metamorphic phase)

The metamorphic phase of the Salumei Formation (called here the Salumei metamorphics), crops out between the April and May Rivers, being bounded on the north by the Frieda Fault, and on the south by the Lagaip Fault Zone. The rocks are the metamorphosed equivalents of the rocks found in the Salumei Formation, and consist of slate, phyllite, sericite schist, marble, altered basic and intermediate volcanic rocks, feldspathic quartz sandstone and subgreywacke. Some higher-grade rocks are present, including quartz muscovite schist, and metavolcanics containing lawsonite-glaucophane assemblages.

The slate, phyllite, and sericite schist exhibit a strong cleavage which is commonly strongly folded or crenulated, and in many places they are riddled with small irregular and ramifying quartz veins.

Bedding can rarely be seen in these rocks, but where seen it is extremely contorted, and no logical structural trends can be distinguished.

Only one sample of the fine-grained metasediments, a slightly higher grade quartz muscovite schist, was examined in thin section. It is a fine-grained, greenish-grey schist consisting of angular grains of quartz (40 percent), in a recrystallized foliated matrix of muscovite, quartz, plagioclase, and a distinctive chlorite showing anomalous bright purple birefringence. Biotite,epidote, and iron oxides are accessory minerals. The rock was probably originally a fine-grained greywacke or tuffaceous sandstone.

Beds of massive quartz sandstone and subgreywacke between 6 inches and several feet thick are common throughout the Salumei metamorphics. The rocks are greenish grey or cream in colour and invariably fine-grained and well sorted. In thin section quartz sandstone proved to be the most common rock type: it consists of subangular to subrounded quartz grains, and some angular grains of plagioclase, schist, and biotite; with minor (up to 10 percent) interstitial chlorite, calcite, epidote, albite, sericite, and ?pumpellyite. Sphene and iron oxides are present in accessory amounts.

With increasing matrix the sandstone grades into recrystallized subgreywacke which consists of recrystallized grains of quartz, and a few chert and phyllite fragments, in recrystallized matrix (25 percent), of sericite, quartz, and some chlorite, biotite, prehnite, and epidote.

Volcanic rocks are common, and they show a considerable range in the degree of alteration. The less altered varieties can be seen just west of Bomali River, where massive black slate is interbedded with layers up to 100 feet thick of medium to thick bedded dark basic tuff and dark tuffaceous subgreywacke. The tuff commonly grades upwards into thick beds of angular, coarse to medium-grained subgreywacke. In the shale a fracture cleavage occurs roughly parallel to the axial plane of the folds, but the cleavage is commonly only poorly developed and it is clear that the sequence was more competent than the surrounding massively bedded slates and phyllites which have a well developed cleavage.

In the Bamali River area the volcanics and subgreywackes are commonly still recognisable as such, although sheared, cleaved, and in some places porphyroblastic, with feldspar, chlorite and sericite developed. Fine crystalline tuffs are more affected by the metamorphism and occur commonly as medium-bedded, green schists within more massively bedded, only slightly altered agglomerates and basic flows.

Several of the crystal tuffs were examined in thin section: they consist of broken crystals and fragments of plagioclase (now altered to albite), quartz, fine-grained volcanic rocks, and some fragments of altered pyroxene and orthoclase. Interstitial calcite, epidote, chlorite, and zeolite are present in varying amounts. With increasing metamorphism the rocks grade into recrystallized tuffs in which the original texture has been almost completely obliterated.

Further west in the vicinity of outcrops of the Gufug Gneiss, pressures were apparently much greater and even the coarser grained beds of the Salumei metamorphics have been markedly affected. In these areas semi-schistose meta-greywacke containing porphyroblastic albite and epidote; green-schist, and meta-volcanics, occur interbedded within phyllite and slate. Intra-formational conglomerate consisting mainly of pebbles and fragments of slate within a schistose matrix is also present. The pebbles have been flattened to an extreme degree parallel to the cleavage plane.

Four thin sections of the metamorphosed igneous rocks from this region proved to contain glaucophane-lawsonite assemblages. Two were probably originally basic crystal tuff or fine-grained agglomerate. They now consist mainly of fibrous masses of sodic ?actinolite, lawsonite (as granular aggregates of euhedral or subhedral crystals), and glaucophane. Pyroxene (?omphacite) occurs as clumps of anhedral crystals, some of which are associated with jadeite. Quartz, calcite, epidote, albite and sphene are present, and tiny crystals associated with the glaucophane and actinolite are probably pumpellyite.

The other two samples are probably metamorphosed microdiorite. They show a distinct preferred orientation, and consist of recrystallized quartz and quartz-albite aggregates, separated by fine-grained felted masses of actinolite, chlorite and calcite, containing clinozoisite, lawsonite, and glaucophane.

The contact between the Salumei metamorphics and the Gufug Gneiss where seen, was faulted or consisted of a zone of smaller faults. Although the Salumei metamorphics are of slightly higher metamorphic grade near the Gufug Gneiss (green schists with chlorite - tremolite, albite - epidote - chlorite and some schists with epidote - biotite - muscovite) the true relationship between the two units is not clear, partly due to poor outcrops. The sparse field evidence suggests that there is a gradual transition from the greenschists of the Salumei metamorphics to the glaucophane schist, garnet gneiss,and eclogite of the Gufug Gneiss. Thus, small outcrops of glaucophane schist, garnet-rich amphibolite, and eclogitic gneiss, occur within the slate and phyllite close to the mapped contact. Similarly outcrops of sericitic sub-schist and slate have been found within the Gufug Gneiss. The anomolous outcrops in both units could represent fault wedges brought up from depth, but they could equally well be part of a transition zone.

Although no fossils have been found within the Salumei metamorphics there is no doubt that these rocks are the metamorphosed equivalent of the Salumei Formation. In the area between the Bamali and April Rivers,fault blocks of indurated Salumei Formation occur within the metamorphic phase. In this area also a gradual change was observed, which is best exhibited by the finer grained fraction. Over a zone of approximately 5 miles wide, hard indurated jointed siltstone and shale with an incipient cleavage,grade to well cleaved slates and phyllite, with abundant small quartz veins parallel to the cleavage plane. In the transitional zone limestone lenses are partly or wholly recrystallized to marble but the interbedded massive volcanics are very little altered and show no cleavage. Fine crystalline tuffs were seen to grade into rocks with chlorite and sericite development and with a marked foliation.

Gufug Gneiss (New name)

The name Gufug Gneiss has been given to a spectacular suite of glaucophane bearing schist and gneiss with associated eclogite cropping out as fault wedges within the metamorphic phase of the Salumei Formation.

Rock types:	Schist and gneiss containing glaucophane, epidote, garnet and white mica in varying proportions. Eclogite.
Distribution:	As narrow, fault wedges along the north front of the Central Range between the Leonard Schultze and Frieda Rivers.
Derivation of name:	From Gufug Creek, a tributary of the Leonard Schultze River, where the formation is best developed.
Type area:	Gufug Creek and the other tributaries of the Leonard Schultze River to the west.
Stratigraphic Relationships:	The formation occurs as fault wedges within Salumei metamorphics, but there is some evidence to suggest that there may be a gradual transition from Gufug Gneiss to the Salumei metamorphics.
Age:	Not known but probably not younger than Tertiary f_{1-2} stage.

The principal rock types are hard, coarsely crystalline, blue and green schist and gneiss containing glaucophane; epidote, garnet and white mica in varying proportions. Associated with these, but occurring in minor proportions, is massive eclogite consisting essentially of green pyroxene with pink garnet porphyroblasts up to 3 cm diameter. Other lithologies include quartz and feldspar bearing glaucophane schist, blue-green amphibolite, calcite and dolomite bearing schist, and hard meta-serpentinite (Bowenite).

The Gufug Gneiss appears to have been derived from basic igneous rocks, tuffaceous sediments, calcareous and dolomitic sediments and shales similar to those of the Salumei Formation. Metamorphism has been of the high pressure -- low temperature, glaucophane schist facies type (Fyfe, Turner, and Verhoogen 1959), which has produced similar rocks elsewhere in the Circum-Pacific region.

Stable mineral assemblages in the Sepik glaucophane schists can be divided into three main types:

(1) Glaucophane-lawsonite
(2) Glaucophane-epidote
(3) Sodic pyroxene-garnet

Examples intermediate between these types are numerous.

The glaucophane-lawsonite assemblages are locally developed within greenschist facies rocks of the Salumei Metamorphics, in basic metavolcanic rocks that are texturally little altered. Other minerals occurring in this assemblage include: quartz, albite, pyroxene, epidote, actinolite, chlorite, white mica, calcite, sphene, and pumpellyite(?). Although specifically sought, aragonite has not been identified. The pyroxenes appear to be relict, and appear to range in composition from augite to jadeitic pyroxene (indicated by d221 spacings from X-ray powder photographs). In several specimens actinolite seems to be in stable association with glaucophane.

The glaucophane-epidote assemblages are coarsely crystalline and constitute a large part of the Gufug Gneiss. In addition to plentiful glaucophane and epidote, the following minerals are common: quartz, sodic plagioclase, sodic pyroxene, zoisite, garnet, phengitic mica, paragonite, chlorite, calcite, dolomite, sphene, rutile, and apatite. Aragonite and lawsonite have not been identified. Whereas some glaucophane is very pale, much is strongly coloured and some is crossite (OAP=101). Blue-green amphibole is present in a few specimens and in one case is rimmed with crossite. Pyroxene, generally pale green, is probably of similar composition to the eclogitic pyroxenes. Colourless jadeitic pyroxene is associated with quartz in at least one specimen.

Garnet is commonly associated with glaucophane, epidote and quartz and usually shows some alteration to chlorite. However, some chlorite appears to be stable in the glaucophane-epidote assemblages.

Paragonite (d001 19.2A) and phengitic mica (d001 19.8A) are common and co-exist in several specimens. Dolomite and calcite are common, both singly and together, and in some cases make up the bulk of the rock.

The glaucophane-epidote assemblages appear to have been derived from the basic igneous rocks, greywacke, argillaceous and carbonate-rich sediments of the Salumei Formation.

The sodic pyroxene-garnet assemblages occur as eclogites intimately associated with the glaucophane-epidote assemblages: they also occur as tectonic blocks in the adjacent Salumei Metamorphics.

Euhedral pink garnet porphyroblasts up to 3 cm. in diameter are embedded in a fine-grained granoblastic matrix of green pyroxene. The approximate proportions of jadeite, acmite, and diopside end members in pyroxenes from 4 specimens were obtained by measuring the R.I. and the d221 spacings, and they were found to fall within the aegerine-augite, chloromelanite, and omphacite fields (Essine and Fyfe, 1967).

Glaucophane, epidote, zoisite, and phengitic micas, are common major components: chlorite, sphene, rutile, quartz, sodic plagioclase, and apatite are accessories.

Glaucophane-bearing assemblages are now known from a number of widely dispersed localities within the New Guinea Mobile Belt. Mineral assemblages in the stone implements described by Verhofstad (1965) are of the lawsonite-glaucophane type, and contain sodic pyroxene and pumpellyite(?). They probably originated in the northern fall of the central ranges of West Irian 150 miles west of the Sepik locality.

A crossite sericite schist has been reported from the Cyclops Mountains on the north coast of West Irian, (Gisolf, 1921), and Dallwitz (pers. comm.) has reported a lawsonite 'richterite' leucoxene assemblage from the Waria River in western Papua. Recently, metavolcanics containing glaucophane, epidote, and sodic pyroxene were collected by a Bureau of Mineral Resources party near Mount Suckling in eastern Papua.

The wedges of Gufug Gneiss are fault bounded but some of the faults do not appear to have great displacement. South of Gufug Creek the bounding fault appears to be of small throw and the boundary with the Salumei metamorphics may be transitional. However, it is evident that faulting has played a major part in the positioning of these bodies. A number of isolated lenses and blocks of eclogite and gneiss up to 50 feet across were found within low grade Salumei metamorphics outside the main bodies of Gufug Gneiss, particularly to the north of the easternmost fault wedges. These small lenses are probably tectonic blocks that have migrated upwards in fault zones together with small serpentenite lenses with which they are often associated. The boundaries of these tectonic blocks are commonly very sheared.

Metamorphism of the Gufug Gneiss probably occurred at deeper levels within the Mobile Belt than the Salumei Metamorphics with which it is now associated. The phyllites and subschists of the Salumei metamorphics are mainly low grade greenschist facies although glaucophane-lawsonite assemblages occur locally in meta-volcanics west of Bamali River.

The Salumei metamorphics and the Gufug Gneiss are confined to a unique flexure (Fig.27) where the Frieda Fault Zone changes trend from north-west to east-west. It is thought that the main movement on the fault zone has been right lateral, and if this is the case it would cause the flexure to be a region of compression; and the very local development of the Salumei metamorphics would thus be explained. It is conceivable in such an environment that tectonic over-pressures could be produced to form the high-pressure metamorphics characteristic of the Gufug Gneiss.

The conspicuous absence of dioritic intrusions from this area would also be explained if the area had been one of high compression during the Lower Miocene.

The Sepik glaucophane schists closely resemble those from California, New Caledonia and Celebes, in mineral composition and geological setting. The glaucophane-lawsonite type assemblages closely correspond to types II and III schist of Coleman and Lee (1963) from theCazadero area, California and to extensive glaucophane schists developed within greenschists of north west New Caledonia (Coleman, 1967).

The coarsely crystalline glaucophane-epidote and eclogitic assemblages are well represented in California (Type IV of Coleman and Lee) and in New Caledonia. As in many places along the Pacific margin they are associated with ultramafic intrusion, and probable transcurrent faulting is apparent. The eclogitic assemblages are produced under the same temperature and pressure conditions as the glaucophane epidote assemblages, but under low partial pressure of water vapour i.e., under anhydrous conditions (D. Green pers. comm.).

(b) Tertiary e-stage (Lower Miocene)

After a period of erosion in the lower Tertiary, sedimentation commenced over the whole of the map area early in the Tertiary e-stage: tuffaceous arenites called the Pundugum Beds were laid down north of the Lagaip Fault Zone, while a predominantly calcareous lutite sequence called the Yangi Beds were being laid down to the south.

These two formations are separated by a 12 mile-wide belt of rocks of Miocene age along the Lagaip Fault Zone which cannot be referred to either unit: these sediments have been mapped as Miocene (undifferentiated) and they probably include in places, lateral equivalents of the Burgers Formation (see later). The sediments are predominantly calcareous sandstone and siltstone.

Pundugum Formation (New name)

The name Sau Beds was proposed by Dekker & Faulks (1964 unpubl.) for a thick sequence of arenaceous beds overlying the Salumei Formation in the eastern part of the South Sepik region. Subsequently (Dow et. al. 1967) incorporated the unit in the Lagaip Beds as the Sau Greywacke Member. Subsequent work has shown that these beds warrant formation status, and to avoid confusion it is therefore proposed that the Sau Beds be redefined and renamed the Pundugum Formation.

Definition:

Rock type:	Greywacke, tuffaceous greywacke siltstone, and fine pebble conglomerate with some small lenses of limestone.
Distribution:	Found in the Arafundi watershed, the headwaters of the Maramuni, Tarua, and Sau Rivers and as small faulted wedges in the headwaters of the Krosameri and Salumei Rivers. Although the unit has not been mapped further west, small fault wedges in the Salumei Formation are probably Pundugum Formation. Similar sediments in the Sau Valley have also been mapped as Pundugum Formation.
Type area:	In the Arafundi Valley between the Karawari Fault in the south and Imboin Village in the north.
Stratigraphic Relationships:	The formation overlies the Salumei Formation with probable angular unconformity. It is overlain, probably unconformably, by the Karawari Conglomerate in the type area and by the Tarua Volcanic Member of the Burgers Formation to the south.
Thickness:	A thickness of about 13,500 feet has been estimated from the airphotos in the Kompiam area (Dekker & Faulks, 1964) but it is possible that some part of the formation could have been repeated by faulting. In the Pundugum area the beds are very much thinner being only 1,000 feet measured with a possible maximum of about 3,000 feet.
Age:	Tertiary e-stage (early Lower Miocene to late Lower Miocene.)

The Pundugum Formation in the type area consists of 2000 to 3000 feet of coarse-grained to medium-grained sediments underlying the Karawari Conglomerate. The lower part of the formation consists mainly of light to dark grey micaceous sandstone, siltstone, and mudstone, with interbedded red and cream siltstone, and some quartz pebble conglomerate. The upper part is coarser grained, and contains many thick beds and large lenses of fine pebble conglomerate, coarse grained subgreywacke and tuffaceous sandstone. The conglomerate contains pebbles of quartz, microdiorite, and indurated shale. Although well indurated these beds are not metamorphosed and are only gently folded.

To the south where it is exposed in the headwaters of the Sau, Tarua, and Maramuni Rivers the formation is much thicker, and consists of possibly 13,500 feet of interbedded micaceous greywacke and interbedded siltstone, which become tuffaceous towards the top of the formation. Further west in the headwaters of the Salumei and Krosameri Rivers the sediments are mainly feldspathic subgreywacke, and tuffaceous sandstone, and in addition contain some coralline limestone lenses.

The base of the unit has been arbitrarily placed where the predominantly fine-grained beds of the Salumei Formation give way to arenites. The contact with the overlying Karawari Conglomerate is rarely seen as it is masked by the large flanking talus slopes, but in the one well exposed section traversed, the contact appears to be conformable. Regional considerations however suggest that the contact is an unconformity (see Karawari Conglomerate). Where volcanic rocks are present in the Karawari Conglomerate, the top of the Pundugum Formation is placed at the base of the first volcanic bed, which generally corresponds fairly closely with the first break in slope below the prominent cliffs which make up most of the Karawari Conglomerate. Where the volcanic rocks are absent the base of the first massive conglomerate bed marks the top of the Pundugum Formation.

The contact between the Pundugum Formation and the overlying Burgers Formation to the south is similar in all respects to the contact with the Karawari Conglomerate, and the boundary is defined the same way (see Burgers Formation and Tarua Volcanic Member).

Limestone lenses within the formation contain Tertiary e-stage foraminifera in the headwaters of the Krosameri and Salumei Rivers, and Eocene limestone pebbles have been found in a conglomerate near the base of the formation in the Sau River. The formation cannot be younger than Tertiary e-stage because the basal parts of the overlying formations have been dated as Tertiary f_{1-2} stage. The age of most of the Pundugum Formation is therefore Tertiary e-stage, though it is possible that the lowermost beds are slightly older.

The greater proportion of conglomerate and tuffaceous sediments in the upper part of the Pundugum Formation testify to the quickening of volcanic activity and consequent shallowing of the seas in the region towards the end of the Tertiary e-stage. The volcanic activity reached a climax in the Tertiary f_{1-2} stage when the volcanic rocks of the Karawari Conglomerate, Burgers Formation, and the Wogamush Beds were laid down.

Detailed Description

Light to dark grey mudstone, siltstone and sandstone interbedded with red and cream siltstone have been mapped near Pundugum Village. The dark siltstone and sandstone are micaceous, and the sandstone generally lighter coloured because it is composed predominantly of quartz and feldspar fragments (sample 1192). The bedding ranges from massive to thin bedded; in the massive bedded layers thin micaceous lenses commonly occur parallel to the bedding. In the micaceous lithic sandstones, zones of scattered quartz pebbles as well as layers of fine, well rounded pebble conglomerates are commonly seen. The pebbles are mainly of quartz, but also of dark grey, green and red, indurated shale. The sandstone though subordinate forms a considerable part of the unit throughout.

A section of several hundred feet at the top of the unit in this region consists in the lower part of light to dark sandstones with zones of scattered pebbles and lenses of pebble conglomerate, together with interbedded thin to medium bedded blue green and grey siltstones. Overlying this sequence are coarse, poorly sorted, massive bedded boulder conglomerates, of which the boulders and pebbles consist of microdiorite; dark grey, fine grained sandstone; dark grey black indurated siltstone and mudstone; red and pink siltstone and quartz pebbles. There are no boulders or pebbles of basic volcanics. Interbedded and overlying these boulder conglomerates are medium bedded, grey micaceous sandstone and blue grey siltstones, similar to those underlying the conglomerates.

The beds grade upwards, by an increase in volcanic detritus, into green tuffaceous sandstone and siltstone crystal tuffs, and agglomerate of the Karawari Conglomerate.

Further downstream and to the west of the Arafundi River outcrops of the Pundugum Formation consist of coarse-grained micaceous lithic sandstone interbedded with pebble conglomerates and grey and red siltstones. The outcrops are overlain by the agglomerate and minor basalts of the Karawari Conglomerate. Downstream along the Arafundi River the overlying pyroclasts become interbedded with pebbler and boulder conglomerates and micaceous sandstones and siltstones, testifying to the rapid vertical variation to the Karawari Conglomerate.

The section between Linganas and the overlying Tarua Volcanics near Kompiam is typical of the Pundugum Formation in the headwaters of the Sau, Tarua, and Maramuni Rivers. It was traversed by Dow (1961) who measured the thickness on airphotographs:

<u>Top</u>

3500 feet	Dark grey and blue, highly indurated, greywacke and tuffaceous sandstone which grades into water-laid tuff near the top. The most common rock type consists of subangular fragments of basic igneous rocks, feldspar, and ferromagnesian minerals chaotically dispersed in a fine-grained tuffaceous matrix. These beds range in grainsize from thin-bedded to massive and are interbedded with laminated and thin-bedded siltstone, which comprises about one third of the sequence. Small lenses of argillaceous limestone up to 30 feet thick containing gastropods, bryozoa, and indeterminate foraminifera are common in this member near Kompiam.

2000 feet	This interval is poorly exposed on the line of traverse. It consists mainly of arenaceous sediments similar to the above, intruded by many gabbro and dolerite dykes.
3000 feet	Mainly conglomerate, with well-rounded pebbles of greywacke, siltstone, and quartz, in a sandstone matrix. Micaceous greywacke, and peaty claystone and siltstone containing wood fragments and other carbonised vegetable matter, make up nearly half this interval.
5000 feet	Mainly thick-bedded, coarse to medium-grained micaceous greywacke with thin interbeds of shale and siltstone. The greywacke is dark coloured and consists of sub-rounded fragments of greywacke, siltstone, chert, and quartz, in a fine-grained siltstone matrix. Thick conglomerate lenses are common and consist of schist, quartz, greywacke, and siltstone, in a sandstone matrix. Carbonaceous material is common throughout the section.

<u>Bottom</u>

It is unlikely that the greatly increased thickness in this area is due to repetition by faulting, as the airphotographs show that the formation is between 9000 and 13,000 feet thick along the length of the Central Range between the headwaters of the Korosameri River and the Sau River.

A notable feature of the formation in the Sau River is the presence of conglomerate over 1000 feet thick several hundred feet above the base. It consists of well-rounded pebbles and cobbles of limestone, gabbro and some indurated sediments, in a coarse-grained greywacke matrix. Eocene foraminifera have been found in the pebbles of limestone, testifying to a period of erosion between the deposition of the Salumei Formation, and the deposition of the Pundugum Formation.

In Umala Creek, a headwater of the Korosameri River, a highly indurated green conglomerate is doubtfully referred to the Pundugum Formation. It consists of quartz, chert, and altered basic rocks in a green grit matrix: the pebbles appear to have originally been well rounded, but most are now distorted. The conglomerate is near-vertical and several thousand feet thick.

To the north, near the top of the ridge between Ogolo Creek, and Wisa River, a similar, but much less indurated conglomerate, was seen in outcrop. The occurrence was too small to map, but it probably belongs to the Pundugum Formation.

Yangi Beds (New name)

Yangi Beds was the name proposed by Dekker and Faulks (1964 unpubl.) for Miocene sediments in the southern part of the map area. They grade northwards into the Tibinini Limestone Member.

Rock types:	Mudstone,marl, calcareous siltstone and sandstone. Interbedded limestone.
Distribution:	They make up the dissected plateau forming the divide between the Lagaip and Andebare Rivers in the southern part of the map area. The southern and western extensions were not mapped.
Derivation of name:	Mount Yangi at the head of the Andebare River.
Type area:	Headwaters of the Andebare where the type section was measured.
Stratigraphic Relationships:	Overlies the Lagaip Beds probably unconformably: grades northwards into the Tibinini Limestone Member.
Thickness:	About 5000 feet.
Fossils and age:	Tertiary e-stage foraminifera found in the Waga River. Uppermost beds are probably Tertiary f_{1-2} stage.

Dekker and Faulks (1964 unpubl.) describe the Yangi Beds as follows:

"In the McNicoll Range south of Porgera, thick limestone beds containing chert are interbedded with calcareous shale. Grey friable sandstone containing carbonaceous plant remains also contain thin interbeds of shale. Further to the south in the headwaters of the Andebare River, at least 8000 feet of interbedded mud, silt, sand, and chalk were measured. These sediments are exceedingly rich in foraminiferal remains. The chalky limestone has a distinctly fetid odour although on analysis, it was found to contain no hydrocarbons."

A summary of the type section, measured by chain and compass in the head of the Andebare River, is given by Dekker and Faulks:

	incomplete
1100 feet	Fine, grey, muddy siltstone
?(b)1400 feet	Grey siltstone with calcareous cement
-- -- --	Probable faulted synclinal axis -- -- --
(b) 1500 feet	Massive, grey foraminiferal mudstone
(a) 1500 feet	Calcareous muddy silt and sandstone Limestone bed shown on section near base.
-- -- --	Probable faulted anticlinal axis -- -- --
(a) { 800 feet	Calcareous sandstone with chalk and calcilutite beds. Some limestone beds shown, near top.
(a) { 400 feet	Muddy sandstone
(b) 600 feet	Grey, massive mudstone.
	incomplete

Though the beds along the line of section all dip to the north, the airphotographs show quite plainly that they have been folded and faulted. The measured section therefore probably consists of the same 3000 feet of sediments repeated by a syncline and anticline which have been overturned to the south and faulted along their crest and keel.

The thickness of the Yangi Beds cannot therefore be determined accurately but from an examination of the airphotographs the total is not likely to exceed 5000 feet.

Tibinini Limestone Member (New name)

Dekker and Faulks (1964 unpubl.) proposed the name Tibinini Limestone for the very thick limestone which forms spectacular cliffs on the south side of the Lagaip Valley. It is here proposed to change its status to member of the Yangi Beds.

Rock types:	Grey to white generally fine-grained limestone. Some calcareous shale interbeds.
Distribution:	Along the south side of the Lagaip Valley between Porgera and Kepilam.
Derivation of name:	From Tibinini village.
Type area:	Cliffs north of Mount Kaijende.
Stratigraphic relationships:	Overlies the Lagaip Beds unconformably; probably grades laterally into Yangi Beds.
Thickness:	Not measured, but between 3000 feet and 4000 feet.
Fossils and age:	Tertiary f_{1-2} stage foraminifera have been determined in the uppermost beds on Mount Kaijende. Only long-ranging Miocene foraminifera have been found in the rest of the unit, but it seems likely that the lower half is Tertiary e-stage.

The Tibinini Limestone Member forms the spectacular cliffs (Fig.30) which bound the head of the Porgera Valley and the southern flank of the Lagaip Valley near Tibinini village. The elevated surface of the limestone is weathered into a karst topography of gigantic scale -- spires and aretes of limestone several hundred feet high are common on Mount Kaijende.

The Tibinini Limestone Member consists of about 3000 to 4000 feet of massive to thick bedded fine-grained grey to white limestone containing interbeds of marl and some chalky beds crowded with macro-fossils including corals. It is generally recrystallized and it is uncommon to find diagnostic foraminifera: Tertiary f_{1-2} stage forms were found in place near the summit of Mount Kaijende (sample supplied by Dr. P. Williams A.N.U.), and boulders in float derived from Mount Kaijende (sample supplied by Dr. M. Bik, C.S.I.R.O., Land Research unit).

Near Kepilam the Tibinini Limestone Member can be seen on the airphotographs to unconformably overlie a large, steep, fold in the Lagaip Beds. However, as is usual in New Guinea, the contact has been seen in only a few places, over a distance of only a few feet, and no unconformity was detected. The youngest fossils found in the Lagaip Beds are Paleocene, and it is believed that the absence of Eocene and Oligocene strata has resulted from a period of erosion before the Tertiary e-stage.

Though evidence is lacking, it seems probable that the Tibinini Limestone Member grades laterally into the Yangi Beds.

Chuingai Limestone (New name)

The name Chuingai Limestone is given to coralline limestone forming the main masses of the Chuingai Hills to the north of the Sepik River (143°35'; 4°5') and mapped in 1929 by S. Papp (1929) of the Anglo-Persian Oil Company.

Rock type:	Whitish and yellowish, sometimes compact, coralline limestone. Some thin foraminiferal limestone beds.
Distribution:	Forming the rough topography of the Chuingai Hills, ten miles north-east of Timbunke village on the Sepik River.
Derivation of name:	From the Chuingai Hills
Type area:	Chuingai Hills
Stratigraphic Relationship:	Rests unconformably on the Ambunti Metamorphics.
Thickness:	Not measured but probably no more than 200 feet.

Age: Contains Miocene foraminifera but according to F. Chapman (in Papp, 1929) some forams are of Pliocene aspect. Probably Upper Miocene.

The Chuingai Limestone is well bedded, individual beds sometimes attaining a thickness of 20 feet. The limestone has weathered to a rough,picturesque topography and several caves are known to exist in the area.

Papp (1929, p.74) correlated the limestone at Chuingai Hills with similar limestones further to the east at Marienberg and other nearby areas where they overlie Miocene strata. The age indicated by foraminifera (Papp, 1929, p.75) is ambiguous and the limestones could be of Pliocene age.

Undifferentiated Miocene

Sediments of Lower Miocene age (probably Tertiary e-stage) which cannot be referred to either the Pundugum Formation or the Yangi Beds, have been mapped as undifferentiated Miocene.

They crop out as a 10 to 15 mile wide belt along the northern side of the Lagaip Valley between the head of the Salumei River, and the southern margin of the map area.

The rocks are only slightly indurated and consist almost entirely of calcareous sediments; mainly calcareous siltstone, marl, and calcareous quartz sandstone. They are generally thin-bedded to medium-bedded, and are commonly highly contorted, mostly as a result of slumping before consolidation.

Red and green marl and calcareous siltstone were seen in places, and appear to be restricted to one stratigraphic horizon overlying a thick bed of limestone which forms prominent hogsbacks in the vicinity of Yeim Village. The limestone is indurated, cream, or less commonly pink, and is invariably fine-grained; it grades vertically and horizontally into indurated marl, and has a maximum thickness of about 1000 feet.

The southern part of the belt is made up of finer-grained sediments more akin to the Yangi Beds. A small part of the section was measured by Dekker and Faulks (1964).

450 feet	Thin-bedded calcareous shale
450 feet	Fine-grained white limestone
700 feet	Grey fine-grained, thin-bedded calcareous shale.

(b) Tertiary f_{1-2} stage.

The increased volcanic activity near the end of the Tertiary e-stage reached a climax during the Tertiary f_{1-2} stage when discontinuous island arc volcanics were laid down across the map area. These volcanic rocks and derived coarse-grained sediments have been mapped as three units, the Burgers Formation, Karawari Conglomerate, and Wogamush Beds.

The upper parts of these formations may be younger than f_{1-2} stage, but the only foraminifera found are long-ranging Miocene genera: it is thought that the formationsdo not extend beyond the Middle Miocene.

<u>Karawari Conglomerate</u> (New name)

Karawari Conglomerate is the name chosen for a sequence of massive conglomerate and volcanic rocks, which crop out between the Arafundi and Wogupmeri Rivers, along the middle reaches of the Karawari River.

Figure 31: Benches of Karawari Conglomerate in a tributary of the Arafundi River. Progress up streams in this region is soon halted by waterfalls and cliffs hundreds of feet high.

Neg. GA 484

Figure 32: Basaltic to andesitic agglomerate near the base of the Karawari Conglomerate, eastern side of the Arafundi River.

Neg. G 9511

Rock type:	Pebble and cobble conglomerate, and pebbly sandstone. There are thick lenses of basic and intermediate volcanic rocks at the base of the unit.
Distribution:	The headwaters of the Karawari River.
Derivation of Name:	Karawäri River.
Type area:	The Arafundi River; no type section was measured.
Stratigraphic Relationships:	The relationships with underlying units is not clear. It is the equivalent of the Tarua Volcanic Member and the Burgers Formation in the south and the Wogamush Formation found farther to the west of the map area.
Thickness:	At least 2,000 feet.
Fossils and Age:	No fossils were found in the unit. It overlies Lower Miocene (Tertiary e-stage) Pundugum Formation and is almost certainly the same age as the Burgers Formation (Tertiary f_{1-2} stage).

Detailed Description:

The Karawari Formation crops out as large, gently dipping, massive slabs, terminated by vertical cliffs. The cliffs are up to 2000 feet high and unclimbable so that only the basal part of the formation can be examined in outcrop. For information on the upper parts of the unit one has to rely on derived boulders and many of the less resistant rocks may not have survived transport in the rivers.

The boundary between the Pundugum Formation and the Karawari Conglomerate appears to be gradational, and it is placed arbitrarily at the lowermost cliff-forming conglomerate, even though there are conglomerate beds within the Pundugum Formation. Where volcanic beds are present, the boundary is placed at their base.

The Karawari Conglomerate consists mainly of massive pebble and boulder conglomerate, basic to intermediate agglomerate and lava, and tuffaceous sandstone; It is however, a very variable unit, with rapid lateral and vertical changes.

The conglomerate is an extremely variable polymict conglomerate within which the larger components are generally well-rounded. The beds are characteristically massive, and form spectacular cliffs up to 2,000 feet high, cleft by very narrow deep ravines. The only bedding is defined by vague lenses of sandstone, pebbly sandstone, and minor grey and red siltstone.

In the Arafundi area volcanic rocks occur in the basal part of the formation. The overlying conglomerate is composed almost entirely of volcanic components in a tuffaceous matrix, and it grades into agglomerate and crystal tuff (Fig. 31). In the Karawari River, there are very few volcanic pebbles in the conglomerate, and quartz, indurated sedimentary rocks, schist, limestone and microdiorite make up the bulk of pebbles and boulders. It has to be noted, however, that boulders of a well sorted, mainly quartz pebble conglomerate occur also in the Arafundi area, in the upper part of the unit.

The volcanic rocks are predominately agglomerate consisting of basalt and andesite, as rounded fragments up to one foot across, set in a crystal tuff matrix. (Fig. 32). The presence of basalt lava flows is inferred from the abundant large basalt boulders seen in many of the streams in the Arafundi River tributaries, but they were not found in outcrop.

Several thin-sections from the volcanic members have been examined; the rocks range in composition from basalt to andesite, basaltic andesite being the commonest. The basaltic andesite, consists of phenocrysts of plagioclase (An_{40-60}), orthopyroxene, and clinopyroxene, in a groundmass generally composed of glass, iron oxides, and microlites. Perlitic cracking has been noted in the more glassy varieties, and trachytic texture is common in the less glassy. These rocks grade on one hand into andesite, and on the other hand into olivine basalt. The andesite is very similar to the basaltic andesite and differs mainly in the composition of the plagioclase feldspar which is about An_{40}.

The basalt is porphyritic, consisting of plagioclase and clinopyroxene phenocrysts set in a crystalline matrix of feldspar and pyroxene, iron oxide, and generally olivine. The olivine is also commonly found as phenocrysts.

The Karawari Conglomerate is a correlative of the Burgers Formation and the Wogamush Beds. The three formations crop out as isolated units but are all characterized by rapid deposition of coarse-grained detritus from andesitic and basic vulcanism. They overlie Tertiary e-stage and older rocks, and the Wogamush and Burgers Formations have been dated by foraminifera as Tertiary f_{1-2} stage.

The relationship between the Karawari Conglomerate and the underlying Pundugum Formation is not fully understood. Much of the evidence, given below, indicates a large hiatus between the two formations, but such a break is not seen in the outcrops, for continuous sections across the boundary have been examined in which there is no sign of a break. The nature of the deposits, composed as they are of lensing conglomerate and agglomerate, could easily mask an unconformity, particularly if the hiatus was caused by a series of small earth movements during deposition.

The evidence for the hiatus is as follows:

(1) Tertiary e-stage limestone pebbles are found in the Karawari Conglomerate.

(2) In the middle Karawari River there is structural discordance between the two units for the Pundugum Formation is more steeply folded than the Karawari Conglomerate immediately overlying. The Pundugum Formation is also much thinner in this locality than it is to the south, probably as a result of erosion before the deposition of the Karawari Conglomerate.

(3) The Maramuni Diorite intrudes the Pundugum Formation but not the Karawari Conglomerate, and pebbles of micro-diorite almost certainly derived from the Maramuni Diorite are found in the Karawari Conglomerate in places.

(4) The Karawari Conglomerate rests directly on Ambunti Metamorphics which abut against Pundugum Formation near the Sepik Plain. Considerable faulting must have taken place between the deposition of the Pundugum Formation and the Karawari Conglomerate.

It seems possible that faulting started during early Lower Miocene Times (Pundugum Formation) and while the Maramuni Diorite was being emplaced at depth, sedimentation of the Karawari Conglomerate continued in down faulted areas. The conglomerate beds would have resulted from the accelerated erosion which followed uplift of the horsts. At a fairly early stage erosion had exposed the upper parts of the Maramuni Diorite, thus giving the pebbles and boulders of microdiorite found in the Karawari Conglomerate.

The volcanic rocks at the base of the Karawari Conglomerate could have been the surface manifestation of the intruding diorite, and certainly the volcanic rocks show the same range in composition as the Maramuni Diorite.

Burgers Formation (New name)

The name Burgers Formation was first proposed by Dekker & Faulks (1964 unpubl.) for a thick Miocene sequence capping the eastern end of the Central Range.

Rock types: Great variety of volcanically derived sediments, waterlaid tuff, greywacke and siltstone. Minor coralline limestone. Basic and intermediate volcanic rocks are named Tarua Volcanic Member.

Distribution: The formation makes up the crest of the Central Range between Burgers Mountains and Mount Hagen.

Derivation of Name:	Burgers Mountains.
Type area:	Burgers Mountains. There is no single type section: several sections spanning most of the formation were measured at various localities along the north side of the Central Range between Burgers mountains and the head of the Sau River.
Stratigraphic Relationships:	The Tarua Volcanic Member occurs at the base of the formation and appears to unconformably overlie the Pundugum Formation. In places the volcanic member is missing and the sedimentary rocks of the Burgers Formation rest on the Pundugum Formation, apparently unconformably. The top of the formation is faulted.
Fossils and Age:	Foraminifera collected from impure limestone just above and at the base of the volcanic member give the age as Tertiary f_{1-2} stage. The age of the upper part of the formation is not known, though poorly preserved foraminifera show that it cannot be younger than Miocene. It is thought however that it is probably little older than Tertiary f_{1-2} stage.
Thickness:	6000 feet measured in the Burgers Mountains.
Definition:	Where volcanic rocks are present, the base of the formation is put at the first major volcanic bed. Where the volcanics are absent the boundary between the Pundugum Formation and the Burgers Formation is gradational over several hundred feet, and it is put arbitrarily at the first major volcanic pebble conglomerate. This generally is a massive resistant bed at least 100 feet thick.

Description:

The Burgers Formation is mainly marine and is made up almost entirely of detritus derived from intermediate and basic vulcanism of the Tarua Volcanic Member. It shows extreme lateral variation, and the rock types range from submarine (and possibly subaerial) lavas agglomerates and tuffs (Tarua Volcanic Member described below), to waterlaid tuff and agglomerate, volcanic pebble cobble and boulder conglomerate, and calcarenite containing much volcanic detritus. Impure coralline calcarenite lenses are common near the base of the unit, and micaceous greywacke and siltstone are found throughout.

The type section was measured along a gorge in the headwaters of the Maramuni River which cuts across the south-eastern end of the Burgers Mountains at an altitude of about 8,000 feet. The section is on the north-eastern flank of a major syncline and the formation dips consistently at a high angle to the south-west, but because the stream traversed was so rugged a section could not be measured on the ground. However a good estimate of the thickness was obtained from the air-photographs.

The type section contains no volcanic rocks but grades laterally to the south-east into the Tarua Volcanic Member. It is about 6000 feet thick and consists mainly of well-bedded to massive dark grey andesitic crystal lithic tuff almost all of which were laid down in water. The base of the formation in this locality consists of dark andesitic tuff and andesite cobble conglomerate. A 600 feet thick massive bed of andesite cobble conglomerate having a coarse grained tuffaceous matrix, occurs at about 400 feet from the base and coralline limestone lenses and thin limestone beds rich in indeterminate gastropods, bivalves, corals and bryozoans are common at about 3000 feet from the base. Minor dark coloured siltstone is found throughout the section but towards the top these are more common, and the coarser sediments are dark tuffaceous sandstones and grits.

In thin section the crystal lithic tuffs are seen to be all intermediate in composition and consist of broken crystals of andesine-labradorite, hornblende and augite, and fragments of andesitic volcanic rocks.

The major syncline is faulted along its keel so the measured section is not complete but it is thought that no great thickness of section is missing. The south-western limb of the syncline also contains about 6000 feet of section as measured on the airphotographs, but the regional structure, and facings obtained from some of the beds near the keel of the syncline, show that the limb is overturned.

Only the uppermost beds were examined on this limb of the syncline and they are mostly well-bedded feldspathic sandstone of variable grain size, crystal lithic tuffs and interbedded dark coloured siltstones -- virtually indistinguishable from the uppermost rocks on the north-eastern limb. There are a few thin horizons of shelly beds containing poorly preserved macrofossils.

Elsewhere the formation is similar to the type section. There are a few small faulted outliers north-west of the Burgers Mountains in the headwaters of the Salumei River which contain a great variety of rock types. They range from micaceous tuffaceous sandstone containing much carbonaceous material (plant remains and thin coaly seams are common), pebble to cobble conglomerate containing rounded to angular megaclasts of basalt and andesite, limestone, coral, quartz, and rare coal. Calcareous beds ranging from marl, to tuffaceous calcarenite, and coralline limestone were also seen. Volcanic rocks are prominent in the outliers, but they grade imperceptibly into the sediments and could not be mapped separately. The most common types are basalt and andesite agglomerate, agglomerate with a calcarenite matrix, and rare lava flows.

The age of the formation is given by a small lens of impure coralline limestone collected near the base of the sedimentary rocks about four miles west-south-west of Kompiam. Foraminifera were determined by Belford as

Lepidocyclina (N.) ferreroi

Lepidocyclina (N.) sp.

Miogypsina sp.

Elphidium sp.

giving the age as Tertiary f_{1-2} stage (uppermost Lower Miocene).

Tarua Volcanic Member (New name) by R.W. Page

The name Tarua Volcanics was proposed by Dekker & Faulks (1964 unpubl.), but it grades laterally in the Burgers Formation and it is here proposed to change its status to Member of the Burgers Formation.

Rock types:	Intermediate and basic volcanic rocks. Minor conglomerate, sandstone and siltstone..
Distribution:	The volcanics crop out as a north-west, south-east-trending belt between Burger's Mountains and Kompiam.
Derivation of Name:	From the Tarua River where the volcanics have their maximum development.
Type area:	In the headwaters of the Tarua River.
Stratigraphic Relationships:	The Tarua Volcanic Member appears to unconformably overlie the Pundugum Formation. It constitutes the base of the Burger's Formation, into which it grades vertically and laterally.
Fossils and Age:	Foraminifera from the bottom of the Member give the age as uppermost lower Miocene (Tertiary f_{1-2} stage). As the bottom of the Burger's Formation is the same age, the Tarua Volcanic Member must lie wholly within the Tertiary f_{1-2} stage.
Thickness:	Maximum thickness approximately 9000 feet in the section cut by the Tarua River; generally less than 5000 feet thick.
Definition:	The base of the Member is defined at the incoming of volcanic igneous rocks which unconformably overlie the Pundugum Formation. Towards the top of the Member, lavas are less prominent and gradually give way to volcanically-derived sediments of the Burger's Formation.

Description:

The Tarua Volcanic Member consists of intermediate to basic submarine volcanics containing minor conglomerate and finer tuffaceous sediments. The volcanic belt is about 45 miles long on the north eastern limb of the Lai Syncline (Dekker & Faulks, 1964).

The sections traversed are very variable in both thickness and rock type. The member is approximately that mapped by Dow et. al. (1967 unpubl.), but mapping in 1967 has shown that coarse-grained tuffs and tuffaceous sandstones in the Maramuni River are part of the member. The volcanic pile in the Tarua River was also found to be much thicker than indicated the previous year by photo-interpretation.

Conglomerate beds are developed sporadically in the member: unsorted pebbles and cobbles up to 6 inches across are mainly porphyritic lava fragments, with some gritty sandstone pebbles in a feldspathic sandy matrix. This matrix is identical to tuffaceous sandstone which also occur as individual beds. The sediments are light grey or dirty green depending on the proportion of feldspathic to ferromagnesian detritus. Angular well-sorted grains of andesine, pyroxene, hornblende minor opaques and rock fragments occur in a carbonate-rich cement. The fresh clear nature of the grains in the sandstones probably indicates rapid transport and sedimentation from the volcanic terrain.

Dykes of augite microdiorite and hornblende microdiorite intrude sediments and volcanics particularly in the lower part of the Tarua Volcanic Member. These may have acted as feeders for vulcanism higher in the sequence.

The section of volcanics between Kompiam and Birap exposes widespread massive agglomerate beds with intercalated lava flows. The agglomerate consists of completely unsorted lava blocks up to a few feet across and in a fine crystal tuff matrix. Microscopically the matrix also reflects an abundance of volcanic rock fragments as well as feldspar and ferromagnesian grains. Relicts of devitrified glass are seen but are generally chloritized or replaced by calcite.

The great bulk of the lavas are andesites which have many affinities with the calc-alkaline suite. They are porphyritic and generally slightly altered. Euhedral zoned phenocrysts (up to 5 mm across) of clinopyroxene (diopsidic augite), plagioclase (An_{20} - An_{50})

and hornblende are characteristic and several andesites from the Sau River section contain up to 15% olivine phenocrysts, but this is uncommon. The groundmass ranges from an intergranular texture of andesine clinopyroxene, opaque mineral (± hornblende) to types which were once glassy. The latter now consist of chloritic aggregates whose glassy origin is suggested by relict shapes outlined by tiny granules of sphene. The alteration of the volcanics introducing zeolites, calcite chlorite was a late magmatic or early diagenetic process.

Foraminifera from the bottom of the Tarua Volcanic Member in the Maramuni River were dated as Tertiary f_{1-2} stage, and as the bottom of the overlying Burgers Formation is also Tertiary f_{1-2} stage, the deposition of the whole of the volcanic member must have occupied only a short period of time.

Wogamush Beds (New name)

Rock types: Mostly dark micaceous sandstone and subgreywacke. At base either intermediate and basic volcanic rocks or volcanically derived conglomerate.

Distribution: North of the Frieda Fault between the April River and May River Patrol Post. Western limit of the beds not yet mapped.

Derivation of name: From the Wogamush River, a major southern tributary of the Sepik River.

Type area: Headwaters of the Wogamush River. The type section was measured in a small north-flowing creek between the lower reaches of the Leonard Schultze and Frieda Rivers.

Stratigraphic relationships: Unconformably overlies Ambunti Metamorphics and April Ultramafics. Relationships with Salumei Metamorphics and Frieda Porphyry not known.

Thickness: At least 8000 feet.

Fossils and age: Tertiary f_{1-2} stage foraminifera found in limestone lenses near the base; age of upper part not known but unlikely to be younger than Middle Miocene.

Most of the formation consists of black, dark blue, or medium grey micaceous quartz sandstone, which grades with increasing matrix and feldspar content, into subgreywacke. The rocks are almost invariably fine-grained, moderately indurated, and most beds grade upwards into siltstone or very fine-grained sandstone. The formation is generally medium-bedded to thick-bedded, though massive beds up to 6 feet thick have been seen.

Volcanic rocks of unknown thickness occur at the base between the April River and the Wogamush River. They are very similar to the volcanic rocks of the Karawari Conglomerate to the east and consist of hornblende andesite and basalt, lavas and agglomerate. Some andesitic crystal tuff beds are found.

Patches of vesicular and amygdaloidal basalts capping the hills to the north of the junction of the Sitipa and April Rivers, are probably remnants of a once extensive cover of volcanic rocks of the Wogamush Beds.

As the dip of the Wogamush Beds in this locality could not be accurately determined the thickness of the volcanic rocks is not known, however, they appear to be of the order of 1000 feet at their thickest.

Where the volcanic rocks are missing a conglomerate several hundred feet thick is found at the base of the formation. This basal bed is very variable, but the most common rock type is a cobble or pebble conglomerate consisting of well rounded components of hornblende andesite, and basalt, in a tuffaceous sandstone or crystal tuff matrix. Pebbles of diorite, serpentinite, and some limestone (one contains Tertiary e-stage foraminifera) have been found within the conglomerate, but they are rare.

The matrix of the conglomerate is very variable and all gradations from crystal tuff and tuffaceous sandstone containing shelly material, to calcarenite and coquinite were seen. Lenses of coaly material and some plant fragments are not uncommon.

The greatest thickness of the Wogamush Beds was traversed in a creek between the Leonard Schultze and Frieda Rivers. Measurements made on the airphotographs show the formation to be about 8000 feet, thick in this region.

The beds unconformably overlie Ambunti Metamorphics, April Ultramafics, and the Frieda Porphyry cropping out north of the Frieda Fault. Nowhere are they seen overlying the Salumei or Pundugum Formations, but the presence of Tertiary e-stage foraminifera in a pebble in the basal conglomerate suggests that the Wogamush Beds unconformably overlie both.

Tertiary f_{1-2} stage island arc vulcanism

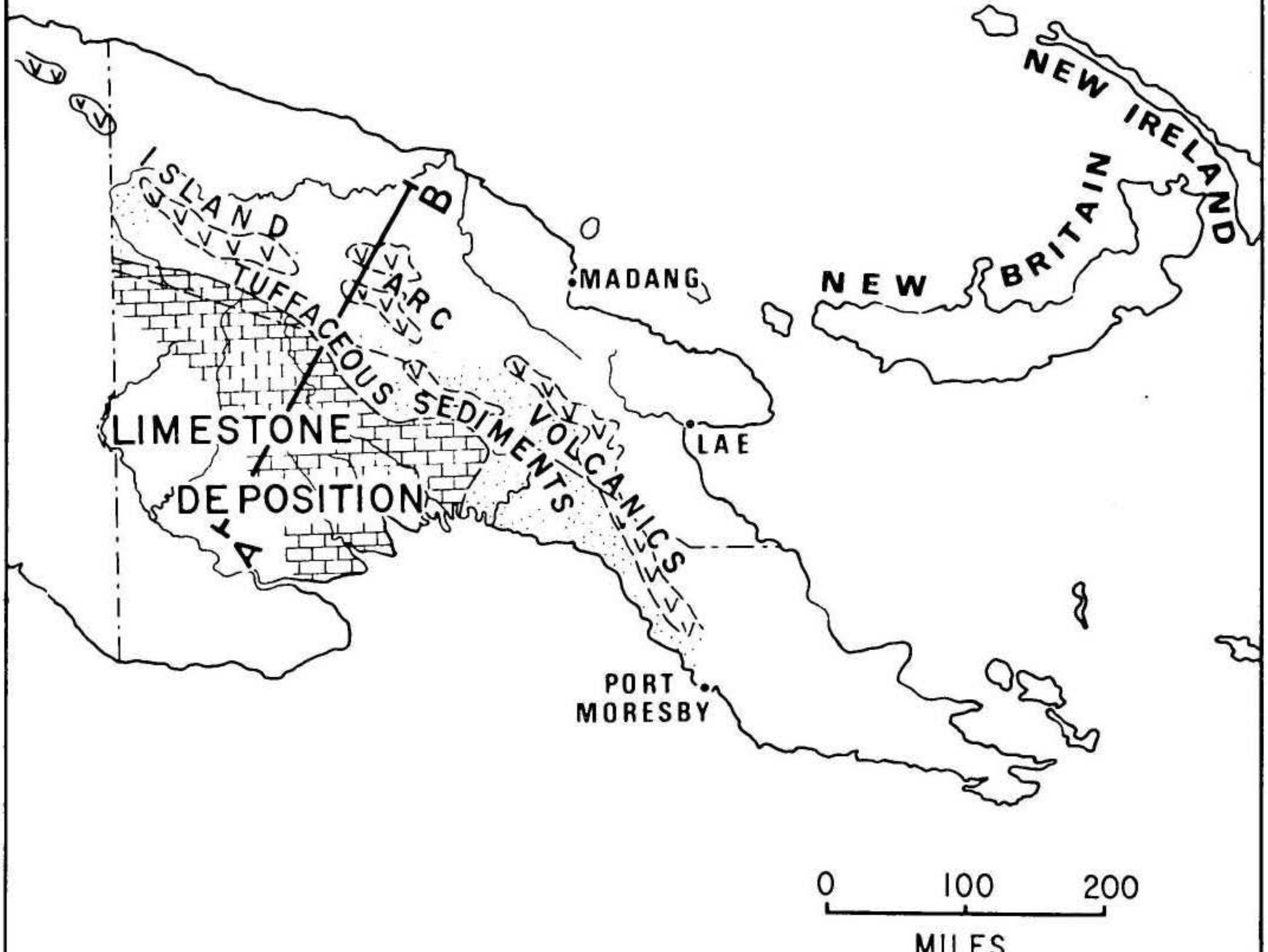
The Tertiary f_{1-2} stage volcanics and sediments of the South Sepik region are part of a belt of volcanic rocks and volcanically derived sediments which extend from the north-western part of the map area, south-eastwards along the Highlands of New Guinea, to central Papua (Fig. 33). The formations making up this belt are listed below from north-west to the south-east: Wogamush Beds, Karawari Conglomerate, Burgers Formation, Daulo Volcanics and Asaro Conglomerate (MacMillan & Malone 1960), Lamari Conglomerate (Dow & Plane 1964), and the Langimar Conglomerate (Smit in prep.). All these units except the Karawari Conglomerate have been reliably dated by limestone lenses near the base of the sedimentary rocks containing Tertiary f_{1-2} stage foraminifera.

Almost identical volcanics underlying volcanically derived Tertiary f_{1-2} stage sediments (Yapsiei Volcanics of Paterson & Perry 1964) cropping out near where the Sepik River crosses the West Irian border, are almost certainly a part of the same belt.

All these formations are remarkably similar, and they undoubtedly were formed by a chain of island arc volcanoes which extended along the Highlands of New Guinea from the West Irian border, at least as far as the Langimar River, a distance of over 300 miles. Similar volcanics are found along the north coast of Papua and these may represent a continuation of the belt.

Figure 33

PALAEOGEOGRAPHY
(TERTIARY $f_{1\text{-}2}$ STAGE)



To Accompany Record 1968/80

P/A 214

The following characteristics of the formations indicate that the belt was formed by island arc vulcanism:

(1) The volcanic rocks are sporadically distributed along the belt. They are up to 9000 feet in regions of maximum development, but they generally lense out within a few miles. The main exposure of the Tarua Volcanic Member, which is about 25 miles long, is one of the largest bodies of volcanics mapped and probably represents the outpourings of a group of volcanic islands.

(2) Most of the volcanics mapped appear to be submarine and though subaerial volcanics must have been deposited, they probably did not survive erosion.

(3) The rocks show extreme lateral variation from lava and agglomerate to a wide range of volcanically derived sediments: most striking are the great thicknesses volcanically-derived conglomerates which are developed near the volcanic centres.

(4) Patches of coralline limestone, up to several miles across and hundreds of feet thick, are sporadically developed throughout the belt, generally within the conglomerate. They represent coral reefs which fringed the volcanic islands when the volcanoes were active.

The sediments laid down in New Guinea at this time exhibit a quite remarkable change towards the south-west, showing quite conclusively that to the south-west of the island arc the northern extension of the Great Barrier Reef was being laid down on the stable Australian continental block in south-western Papua. Thus, the volcanic sediments of the island arc grade south-westwards through a belt of tuffaceous greywacke, to the extensive platform cover of limestone and interbedded marl, which occurs over much of south-western Papua (A.P.C. 1961).

(d) Pliocene to Pleistocene

There is no record of sedimentation in the map area after about the Middle Miocene. At some time in the Pliocene andesitic and basaltic eruptions began, which built up huge volcanic cones throughout much of the Highlands of New Guinea. Most of these volcanoes had reached full development by the Pleistocene for the larger ones were glaciated in the Pliocene. Volcanic rocks from Mount Hagen volcano (Hagen Volcanics) occur in the south-eastern corner of the map area.

Hagen Volcanics (New name)

Volcanic rocks consisting of pyroclastics, lavas, lahar deposits, and associated alluvial and lake deposits, resulting from the vulcanism of the large volcanic cone of Mount Hagen have been called the Hagen Volcanics. Ward (1949 unpubl.) referred to the outcrops of basalt agglomerate and volcanic ash on the Lai River as the Mount Hagen Volcanics, and Dow (1961 unpubl.) proposed the name Hagen Volcanics for the volcanic material derived from Mount Hagen volcano.

Rock types:	Andesitic and basaltic crystal tuff, agglomerate, and lavas. Lahar deposits, and alluvial and lake deposits caused by damming of river valleys by the volcanics.
Distribution:	Hagen volcano and environs. Remnants of a crystal tuff mantle from the volcano are widespread, and lahar deposits fill the head of the Wahgi and Nebilyer Valleys and the gorge of the Yuat River to the Sepik Plain. The upper part of the Lai Valley and the lower part of the Jimi Valley are filled with alluvium deposited when the river valleys were dammed by the vulcanism.
Derivation of name:	Hagen Range.
Type area:	Hagen Range.

Figure 34: The Lai-Jimi Plain near the confluence of the Lai and Jimi Rivers. Huge volumes of volcanic detritus from Mount Hagen Volcano, transported mainly as lahars (volcanic mud flows), filled the river valleys to form the plains.

Neg. GA 481

Stratigraphic relationships:	The volcanic rocks fill valleys deeply incised in the youngest marine sediments in the area, the Burgers Formation of Tertiary f_{1-2} stage age.
Thickness:	Very variable: at least 8,000 feet thick in the middle reaches of the Lai River.
Age:	Hagen volcano is deeply dissected and was glaciated during the Ice Age; it is therefore probably Upper Pliocene or early Pleistocene in age. Small volcanoes in which the cone form and explosion craters are well preserved testify to more recent volcanic activity in the region (Sugarloaf Volcanics).

Description:

The Hagen Range is made up of at least two large extinct volcanic cones which were erupted on a rugged land surface making up the divide between the Wahgi and Lai Rivers. The volcano is well preserved on the eastern and southern sides where it has been protected from erosion by the huge mantles of lahar deposits which spread many miles from the base of the cone.

On the north and east the volcano has been vigorously eroded by the Lai River, and almost none of the original cone forms can now be seen(Fig. 35). Headward erosion of streams draining the flanks has resulted in the central portion of the volcano being hollowed out into a huge erosion caldera removing any trace of the original crater.

The range is over 12,000 feet high and the well-preserved cirques, some containing small lakes, testify to glacial erosion during the Ice Age.

A large proportion of the pyroclastic material was carried away from the volcano by lahars: much travelled eastwards, filling the head of the Wahgi Valley with a huge mantle of ill-sorted volcanic material. The original land surface in this direction had a fairly gentle relief, and the deposits are but little dissected. Probably just as much lahar material flowed to the west and north, but the deep Lai-Yuat gorge had a steep gradient which channelled the lahars 70 miles to the Sepik Plain (Fig. 34).

The headwaters of the Lai River were dammed by the volcano, and as a result, alluvial deposits fill the valley to a depth of several hundred feet.

A small volcanic centre at the crest of the Lai-Sau divide spilled basalt lavas down the Sau valley, a remnant of which forms the airstrip at Kompiam (Fig. 37), and another underlies the village of Linganas. It is thought, because of the advanced dissection of this volcano, that it was active at the same time as Hagen volcano.

Rock types:

The cone of Hagen volcano is made up of interbedded ash, agglomerate, and subordinate lava flows. No systematic work has been done on these rocks and their composition is known only from 4 thin sections of lavas examined by Dekker and Faulks (1964), and five thin sections of a representative sample of lava types in lahar deposits in the Yuat gorge.

The lava flows all proved to be olivine basalt consisting of phenocrysts of plagioclase (labradorite), olivine, and subordinate pyroxene (mostly augite), in a groundmass of similar composition. Apatite and iron oxides are accessory minerals.

A large proportion of the volcanic fragments in the lahar deposits are porphyritic andesite consisting of phenocrysts of plagioclase (An_{60-65}), hornblende, and some pyroxene, in a fine-grained groundmass of plagioclase, pyroxene, microlites, and iron oxide. Some have a strong trachytic texture.

Figure 35: Dissected volcanic aprons making up the western flank of Mount Hagen Volcano. The Lai Gorge is out of sight in foreground.

Neg. GA 1075

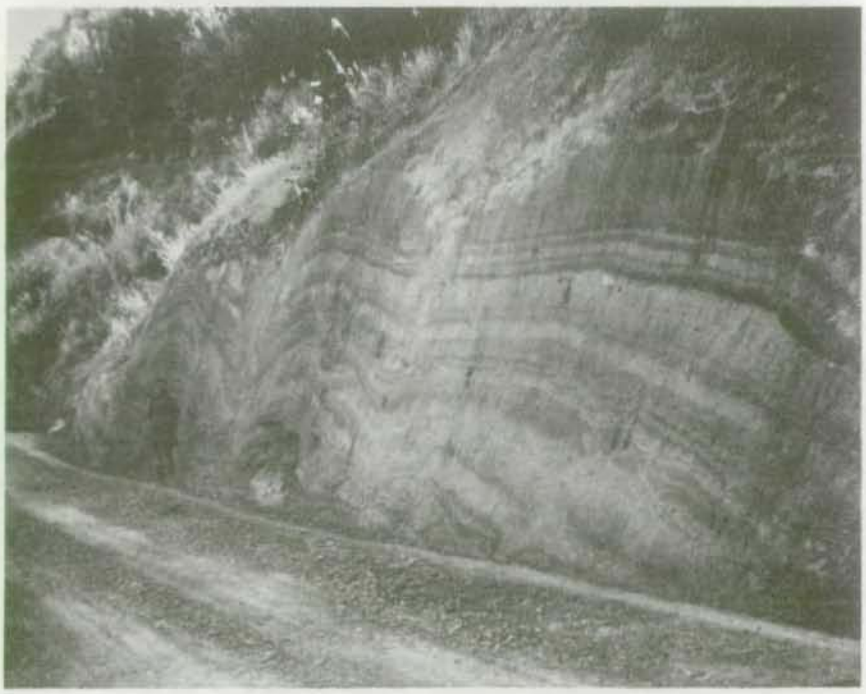


Figure 36: Subaerial ash exposed in road cutting between Wapenamanda and Wabag. Could belong to either Mount Hagen Volcanics or to Sugarloaf Volcanics.

Neg. GA 1081

Figure 37: Kompiam Patrol Post built on a remnant of a basalt flow which filled the Sau Valley for part of its length. The Sau River flows away from the camera in a gorge to the left. The lava originated at the head of a tributary stream on the right.

Neg. GA 3616

Figure 38: Mud spring in Lagaip Beds 10 miles west-northwest of Wabag.

GA 1073

The greater incidence of andesitic rocks in the lahar deposits is probably due to the explosive nature of andesitic eruptions, and hence the greater likelihood of their being incorporated into the lahars.

The subaerial ash deposits mantling much of the Wabag area (Fig. 36) were examined briefly under the microscope. They consist mainly of shards and angular fragments ranging in size down to very fine dust of volcanic glass, broken crystals of hornblende, plagioclase, and some augite.

Lahar deposits:

The lahar deposits filling the Yuat Gorge are a chaotic mixture of agglomerate, volcanic breccia, conglomerate, sandstone, and lenses of basalt lava. Many of the deposits are massive, almost completely unsorted, and consist of volcanic fragments up to six feet across and randomly distributed in a tuffaceous matrix. There is generally an admixture of normal river gravels most of which are well rounded and in places these form large lenses.

Patches of basalt lava up to several hundred feet long are exposed at many places in the Yuat Gorge, and though these are almost invariably badly broken up and commonly highly contorted, it is almost inconceivable that they could have travelled 70 miles from Hagen volcano. They are much more likely to have been extruded from vents in the area, and to have flowed down to the Yuat River, finally being incorporated in the lahar deposits. Small remnants of basalt lavas are found capping some of the ridges west of the Yuat Gorge, and it is possible that these have the same origin.

QUATERNARY

Recent

Sugarloaf Volcanics (New name)

North of Giluwe Volcano, extending northwards almost to the Lai River, is a lava field which post-dates the Giluwe, and probably the Hagen Volcanics.

The field is about 30 miles long by a maximum of 12 miles wide and is largely composed of coalescing lava domes, the more recent of which are shown on the geological map. Most are smooth cumulo-domes which do not have craters, but some are small ash cones with well marked craters. Several explosion craters with no obviously related lavas are found throughout the lava field, the largest of which contains a lake and is over half a mile in diameter.

Outcrops of the volcanics have been observed from only 5 localities on the northern margin of the field. Lavas ranging from olivine basalt to hornblende andesite, and andesitic ash and fine agglomerate were noted, but none has been examined in thin section.

Other small volcanic cones are found in the Lai Valley east of Wabag and at Kepilam Village in the headwaters of the Lagaip River, and these are referred to the Sugarloaf Volcanics because they are of andesitic composition and are probably of the same age.

Alluvium

The Sepik Plain is composed of an unknown thickness of fine-grained alluvium. Grey and black carbonaceous silt makes up most of the exposures seen in the river banks, but the composition of the underlying sediments is not known.

Brown tuffaceous sandstone forms the banks of much of the Yuat River in the Sepik Plain. It is composed of clay, quartz grains, glass shards, and broken ferromagnesian minerals, most of which apparently was derived from the Hagen Volcanics. Near the mountains fine gravel and pebbly beds are predominant.

East of the Yuat River the alluvium of the Sepik Plain has been uplifted about 30 feet, and it is now dissected by a fine dendritic drainage. It is possible that this uplift was due to recent movement on the Jimi Fault.

INTRUSIVE ROCKS

Hunstein Complex (new name)

Mount Hunstein, north of the junction of the April and Sitipa Rivers is composed of a variety of basic igneous rocks ranging from unaltered gabbro similar to the Maramuni Diorite to plutonic and volcanic rocks which have been metamorphosed to the greenschist facies. Quartz biotite gneiss, and sheared and recrystallized serpentinite are also found.

Outcrops in the Hunstein Range are poor, so the relationships of the various rock types are not known, but from the few outcrops seen the metamorphics and the gabbro seem to be intimately mixed.

The rocks belong to the greenschist facies of regional metamorphism, about the same grade as the nearby Ambunti Metamorphics in the lower April River near Nikaium Hamlet. It is thought that the complex was an inhomogeneous basic pluton, which, during intrusion incorporated much of the surrounding country rock near the margins, and was later affected by the same metamorphism which formed the Ambunti Metamorphics. The less altered gabbro probably belongs to the Maramuni Diorite but it could not be mapped separately.

Lenses of uralitized gabbro cropping out along the Frieda Fault have been mapped as Hunstein Complex. In hand specimen they are green, highly altered, fine-grained, and inhomogeneous rocks containing irregular white patches which are probably altered feldspar. Most show a rudimentary foliation. They were not examined in thin section but they appear in hand specimen to be identical with metamorphosed gabbro 03NG006C from Mount Hunstein described below. These rocks are probably fragments of a deep-seated gabbro plutons which have been brought to the surface by movement on the Frieda Fault, at the same time being metamorphosed to the greenschist facies.

Petrography by D.E. Mackenzie

11NG006A

Hand specimen

This rock is dark grey-green, flecked with buff and criss-crossed by narrow, buff-coloured veinlets. It is medium-grained, and shows some evidence of shearing.

Thin section.

Under the microscope, the rock can be seen to consist of granular masses of yellow-brown epidote, about 1mm across and fibrous clumps of pale green actinolite, which form a pseudo-granular igneous texture. Between the actinolite and epidote are patches of fine-grained recrystallized quartz, and albite, and small aggregates of pale green chlorite. Small crystals of sphene, and fine dusty hematite, often forming aggregates, are scattered sparsely through the rock. The veinlets are fine-grained crystalline aggregates of prehnite, epidote, and a little actinolite, quartz and albite. Actinolite appears to have replaced hornblende or pyroxene, and epidote and albite have replaced plagioclase, possible in a gabbro.

11NG0006C

Hand specimen

0006C is a coarse gneissic rock, with lenticular dark grey-green ferromagnesian masses about 3 mm long separated by white quartzo-feldspathic bands about 1 mm wide.

Thin section

The rock consists of irregular, distorted relict pyroxene (pale yellow-brown augite) altered in part to actinolite, and averaging 3 millimetres long, set in a strongly foliated groundmass of actinolite (fibrous aggregates and scattered acicular crystals), chlorite, quartz (granular), a little albite, some well-crystallized colourless zoisite, epidote-clinozoisite and accessory sphene. The dark minerals tend to clump together to give a knotty, mottled texture. The vein-like, white bands are finer-grained aggregates of epidote-clinozoisite, with a little quartz, actinolite, albite, sphene and opaques.

This rock may be a metamorphosed pyroxene diorite or gabbro.

11NG0007

Hand specimen

This is a rock with an unusual appearance - large (averaging 1.2 cm across) black hornblende phenocrysts set in a dark olive-green granular groundmass (grainsize 0.5-1mm), flecked with smaller black crystals of hornblende. The phenocrysts are subhedral or anhedral.

Thin section

The hornblende (20% of rock) forms large zoned phenocrysts (with brown cores and green to green-brown margins) and small (0.3-0.5 mm) brown-green crystals in the groundmass. The large crystals are crowded with inclusions of colourless clinopyroxene, these inclusions being concentrated in the outer parts of the phenocrysts. Clinopyroxene (70%) and small hornblende crystals form the granular groundmass, with a little interstitial plagioclase (10% of rock) and accessory sphene and opaques. The pyroxene has a 2V of 60 to 65° and is probably diopsidic augite. The plagioclase is andesine, An_{50}.

The rock would be classed as a hornblende-plagioclase pyroxenite or a hornblende-pyroxene gabbro, in which hornblende has developed at the expense of pyroxene.

<u>11NG0009A</u>

In hand specimen 0009A is a fine-grained green rock with a strongly sheared (slickensided) appearance. The cut surface reveals a dark-light green mottled texture.

In thin section, the dominant mineral is antigorite, forming 90% of the rock, with minor opaques in clusters of irregular grains (forming masses up to 1 mm across), and sparsely scattered minute grains of sphene (?). The antigorite forms a dense mass of interlocking fibres and irregular plates, with a strong preferred orientation, presumably due to shearing.

The rock is a serpentinite.

<u>11NG0009B</u>

This is a dark greenish-grey banded schist showing slickensiding, with very dark green-grey bands up to 1 mm thick separated by pale mottled grey and green bands (quartzofeldspathic).

In thin section, the assemblage can be determined as follows: quartz, albite, epidote-clinozoisite, actinolite, prehnite, pumpellyite(?), sphene.

Quartz and albite are concentrated in the lighter bands as a fine mosaic specked with epidote and actinolite crystals. Epidote-clinozoisite forms small equant crystals scattered evenly throughout the rock, whereas actinolite is concentrated in the schistose dark bands, with patches of prehnite. Pumpellyite (not a certain identification) occurs as tiny rounded grains clustered together in the quartz-albite-rich bands. It is difficult to distinguish from grains of epidote-clinozoisite of the same size.

The rock is a banded schist of the lower greenschist facies.

Chambri Diorite (new name)

Chambri Diorite is the name given to a large body of diorite between Ambunti and Chambri Lakes.

The only samples collected were from Aibom Village, but as the diorite has a characteristic dendritic drainage pattern developed on it, the outline of the intrusive mass can be photo-interpreted with confidence.

The samples are all coarse and even-grained, and show a crude foliation due mainly to the alignment of plagioclase prisms. In thin section, plagioclase crystals (An_{43}), some of which have curved twin planes, make up about 80 percent of the rock; K-feldspar amounts to between 5 and 8 percent of the rock, and is generally finely microperthitic. The main ferromagnesian mineral is hypersthene (about 10 percent of the rock) which is partly replaced by small crystals of hornblende and biotite growing parallel to the strongest cleavage set. Clusters of red-brown biotite plates make up about 5 percent of the rock; magnetite and apatite are the accessory minerals.

The age of the Chambri Diorite, even within broad limits, is not known; it intrudes the Ambunti Metamorphics of unknown age, and is overlain by Recent alluvium.

April Ultramafics (new name)

Numerous bodies of ultramafic rocks ranging in size from a few feet to many miles long, which intrude the pre-Miocene undermass are called the April Ultramafics. The name is derived from the headwaters of the April River where they are extensive and were mapped in some detail in 1967.

Intrusions of April Ultramafics were found between the Maramuni River (143° 45', 5° 00') and the westward limit of mapping in the Frieda River (141° 40', 4° 45'), but the main bodies occur in the middle reaches of the April, Leonard Schultze and Frieda Rivers. Reconnaissance in 1967 indicated that ultramafic rocks extend westward into the headwaters of the May River, and are probably related to ultramafics in the northern fall of the Central Ranges of West Irian.

The ultramafic bodies range from ubiquitous, small, sheared, serpentinite lenses occurring principally within fault zones, to large irregular masses of dunite and peridotite, the largest of which is thirty six miles long by six miles wide at its widest point, in the Leonard Schultze and Frieda Rivers. The bodies are typically elongated west-north-west to east-south-east, parallel to the regional structural trend.

The larger bodies have margins that are characteristically sheared and serpentinized, and in many cases they are bounded by faults. Although it is difficult to determine the dip of the contacts most structural features adjacent to and within the margins point to sub-vertical or steeply dipping contacts. However, in the case of the ultramafic bodies within the Lagaip Fault Zone at the head of Bomali River it is thought that the contacts dip moderately to the south-west, and that they are tabular sheets incorporated within the Lagaip Fault (see cross section A B C).

The larger intrusions are mainly composed of massive crystalline peridotite and dunite, much of which is of fresh appearance in hand specimen. Serpentinization is apparent in varying degrees in many areas within the larger bodies but principally in the peripheral zones and along interior shear zones. The smaller bodies tend to be completely serpentinized, though relict pyroxenes (bastite) are often visible in the serpentinites. Layering, although not common, was seen at some localities and within ultramafic float. It generally takes the form of alternating pyroxene rich and olivine rich layers.

Pyroxenites are subordinate but widespread, either forming layers in dunite or peridotite, or more commonly cross-cutting dykes. The latter may have been formed by hot, silica saturated vapour that has altered the adjacent peridotite along fissures within the body, (Turner and Verhoogen 1960, p.316). A similar explanation may account for the light coloured veins and dykes of hydrogarnet; tremolite, sericite and carbonate which are common in the margins of some bodies.

Along the margins of many of the ultramafics are small bodies and blocks of gabbro and hydrothermally altered sediments commonly enclosed by sheared serpentinite. These are evidently tectonic inclusions derived from the surrounding rock during emplacement. Some streams draining the ultramafics are choked with large boulders from these tectonic inclusions.

Petrography

Dunite:

In hand specimen the dunites are greenish-grey, coarsely crystalline with some visible crystals of pyroxene and chrome spinel. In thin section they consist principally of granular magnesian olivine showing varying degrees of strain and cataclasis. In some specimens crushing is such that they can be referred to as dunite cataclasites (e.g. 03NG0009). Some serpentinization is apparent in many specimens that appear fresh in hand specimen (e.g. 03NG0002A). The pyroxene (less than 10%) is generally orthopyroxene (enstatite, bronzite) although clinopyroxene appears as exsolution lamellae within some of the orthopyroxene. Chrome spinel is always accessory and ranges from reddish-brown picotite to virtually opaque chromite.

Peridotite:-

Apart from their higher pyroxene content (by definition more than 10%) the peridotites are similar in texture and mineralogy to the dunites. Most peridotites examined in thin section contain orthopyroxene (enstatite or bronzite) as the main constituent additional to olivine and may be classed as harzburgites. The pyroxene content of the peridotites rarely exceeds 30%, and the average composition of the bulk of the April Ultramafics would appear to be close to the boundary between orthopyroxene rich dunite and olivine rich harzburgite. Some peridotite specimens contain appreciable clinopyroxene which in the case of 03NG0014 and 03NG2627A is roughly equal to the orthopyroxene, thus placing them in the lherzolite range. Specimen 03NG0006 contains about 20% clinopyroxene and 5% orthopyroxene and may be called a wehrlite.

Serpentinite:-

Sheared serpentinites consist mainly of a felted mass of antigorite which often has a preferred orientation. Some small serpentinite lenses in the metamorphic phase of the Salumei Formation contain a hard form of serpentinite known as bowenite which consists of a mass of coarse grained interlocking antigorite plates (03NG2510A). In unsheared serpentinites relict crystals of serpentinized pyroxene (bastite) are often seen.

Pyroxenite:-

Only two pyroxenites were examined in thin section. Specimen 11NG2036A consists of 60% clinopyroxene with exsolution lamellae of orthopyroxene 35% olivine and 5% chrome spinel. Specimen 11NG2630 is a very coarse grained pyroxenite consisting mainly of clinopyroxene with some enstatite and serpentinized olivine. A specimen of float from the Frieda River (03NG0533C) is a serpentinized banded peridotite in which the pyroxenite layers consist of clinopyroxene (diallage) and the olivine-rich layers have been completely serpentinized.

Age of Emplacement

As the April Ultramafics intrude the Salumei Formation they must have been emplaced after the Eocene. They are unconformably overlain by late Lower Miocene (f_{1-2} stage) Karawari Conglomerate in the Maramuni River and by the similarly dated Wogamush Beds in the April, Leonard Schultze and Frieda Rivers. Ultramafic pebbles were found in the base of the Wogamush Beds.

The relationship with the Lower Miocene (Tertiary e-stage) Pundugum Formation is uncertain as in the few places where ultramafics are juxtaposed the contacts are apparently faulted.

The relationship of the April Ultramafics to the Maramuni Diorite is also in doubt. Nowhere were the ultramafic rocks seen to be intruded by diorite but hydrothermal alteration of ultramafic rock along the boundary between adjacent diorite and ultramafic bodies in the Yokopos River (143° 5', 4° 50') may have been caused by intrusion of the diorite.

As in other orogenic belts the emplacement of the ultramafics apparently coincided with the folding and faulting of the geosynclinal pile.

Mode of Emplacement.

It would seem from the lack of contact metamorphism and the sheared nature of the margins that the ultramafic bodies were emplaced at low temperatures and in an essentially solid state. (c.f. Turner and Verhoogen, 1960, p.321). Semi-rigid masses of peridotite probably forced their way up through the incompetent geosynclinal sediments by a process of faulting aided by the lubricating nature of the serpentinite margins. (Raleigh and Paterson, 1965). The universal straining and cataclasis of the peridotites and dunites, readily seen in all thin sections, lends weight to emplacement in the crystalline state.

The consensus of opinion regarding the origin of alpine ultramafics is that they are derived from the upper mantle (e.g. Hess, 1960). Such would appear to be the case with the April Ultramafics. Similar conclusions have been reached regarding the origin of the Papuan Ultramafic Belt by J.E. Thompson (1957 unpubl.) and H.L. Davies (1967 unpubl.).

Maramuni Diorite (new name)

The Maramuni Diorite consists of a number of intrusive bodies ranging in size from batholiths to small dykes. These rocks occupy a large part of the eastern part of the South Sepik region, mapped in 1966. Similar rocks of uncertain affinities occur in the headwaters of the April River.

The bulk of these rocks are dioritic although most bodies are of very variable composition and range from ultramafic to acidic. In most of these bodies changes in composition are gradational and it is thought that differentiation of the original magma, accompanied by contamination played a large part in the forming of the different rock types.

These rocks have been sub-divided into the Yuat Intrusives (mainly granodiorite) consisting of 2 batholiths and numerous small apophyses on the east; the Karawari Intrusives (mainly diorite) - a larger body and many apophyses on the west; and a number of smaller porphyritic bodies associated with the main intrusions and at Porgera in the south-west.

The Yuat Intrusives occupy a north-west-trending horst of Mesozoic sediments whilst the Karawari Intrusives form the bulk of a more westerly trending fault block of Tertiary sediments. The Porgera Intrusives occur as small stocks and dykes in late Mesozoic/early Tertiary sediments.

Figure 39: Hornblende-biotite-micrgranodiorite (Maramuni Diorite - Lower Maramuni River). Showing quartz (Q) and Kfels (KF) moulded onto tabular plagioclase (P) crystals. Hornblende (H) and biotite (B) occur as discrete crystals. Ref. No. - 11NG1150 X 35 magnification.

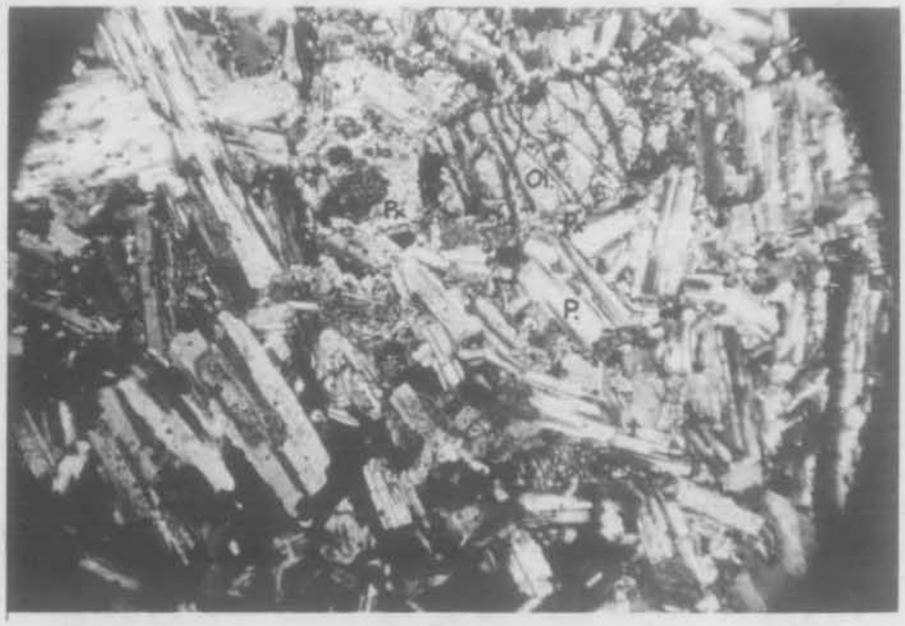


Figure 40: Olivine bearing pyroxene diorite (Maramuni Diorite - Lower Arafundi River area). Note granular pyroxene (Px) mantling lone olivine (Ol) phenocryst and filling interstices between interlocking plagioclase crystals (P).
Ref. No. 11NG1170 X35 magnification.

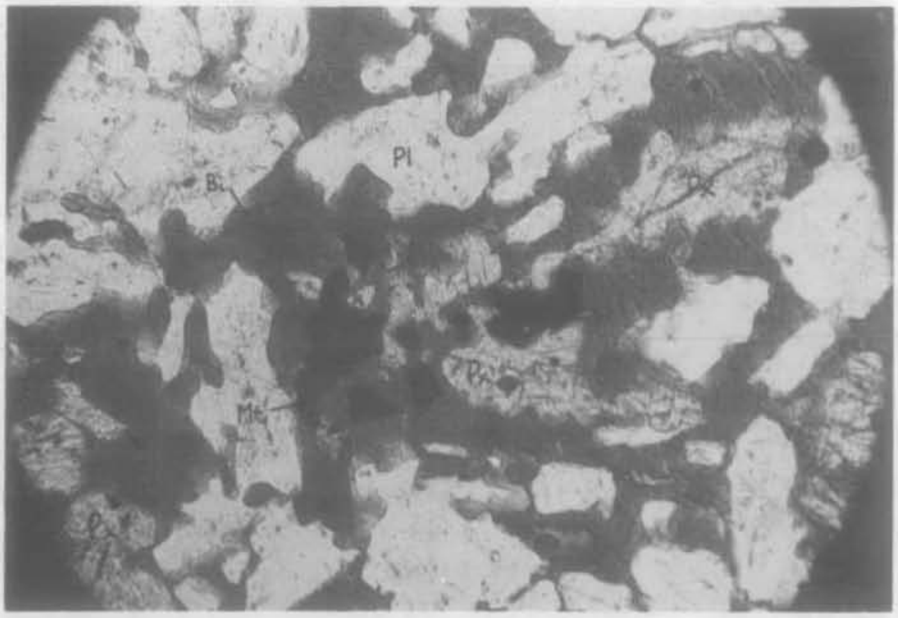


Figure 41: Hornblende-biotite-olivine diorite (Maramuni Diorite). Note Biotite (B) replacing pyroxene (Px) and the rounded "granulite type" grain boundaries revealed under high magnification.
Ref. No. 11NG1170E X80 magnification.

(1) Yuat Intrusives

The northern most batholith of the Yuat Intrusives was systematically sampled at quarter mile intervals across the body, and a reasonably representative collection was made of the southern body.

The two bodies are composed predominantly of microgranodiorite with minor diorite phases, small remnants of crystal tuff (found within the northern body) and some small aplitic veins and dykes. The apophyses are almost all intermediate porphyry. The granodiorite is a fairly uniform hornblende-biotite-microgranodiorite with a typically plagidiomorphic texture (Fig. 39). It contains quartz (20%) plagioclase (45%) K feldspar, (14%) hornblende, biotite (20%) and accessory iron ore, sphene, zircon and apatite (1%). The quartz is mostly unstrained allotrimorphic and to some extent interstitial.

Graphic intergrowths of quartz with K feldspar occur in some specimens. Raguin (1965) calls this texture micropegmatite and suggests that it is due to corrosion of the feldspar by quartz. Plagioclase occurs mainly as idiomorphic tabular crystals of labradorite An_{51-54} (as determined by albite-carlsbad twinning and the optic axial figure). Normal and oscillatory zoning is present and in some cases it is quite pronounced. Most crystals are crazed and slightly sericitised from the core outward. K feldspar is predominantly orthoclase with minor microcline, and occurs mostly as irregular grains moulded on plagioclase. Light to heavy kaolinisation has occurred in the orthoclase but to a lesser extent in the microcline. Mafics consists of partially and completely chloritised and epidotised hornblende and biotite crystals. Accessory minerals include iron ore and small discrete grains of sphene, zircon and apatite. Alteration of the constituent minerals varies from specimen to specimen but is in general moderately developed. The hornblende and biotite are most altered, some of the plagioclase crystals are almost completely made over to sericite, and much of the K feldspar is heavily kaolinised.

Textural variation in this rock type is particularly small, with the exception that the margins of the batholiths are noticeably finer grained, and tend to be somewhat porphyritic.

The large number of strongly zoned plagioclase crystals and the quartz-feldspar intergrowths suggest rapid cooling of the magma and high level emplacement. The rocks of the apophyses and margins are discussed below.

(ii) Karawari Intrusives

The Karawari Intrusives are much more variable than the Yuat Intrusives and although the bulk of the rocks are tonalitic and dioritic, a large proportion are more basic. Some dacitic crystal tuff occurs in the western extremity of the batholith. Extreme local relief in the area of these intrusives prevented close sampling of the massif and many rock types have been seen only in the stream float.

Pyroxene, quartz, gabbro is a major rock type, and consists of tabular labradorite crystals (An_{60-64}), irregularly-shaped grains of clinopyroxene, and small amounts of interstitial quartz and kaolinized feldspar. Opaque minerals make up 2 percent to 5 percent of the rocks. The rocks are even-grained (hypidiomorphic granular), and are similar in texture to the finer grained varieties of the Yuat intrusives. However, they differ from the micrograndiorite of the Yuat Intrusives in that hornblende and biotite are generally very minor or absent altogether, pyroxene is invariably present and often dominant, and plagioclase is much more basic than in the Yuat Intrusives.

These rocks grade into porphyritic quartz diorite which consists of phenocrysts of andesine (An_{45} (core) to An_{15} (rim)), in a finer-grained groundmass of quartz, ferromagnesian minerals, and small granules of opaque minerals. Hornblende and pyroxene are almost invariably present, while biotite is generally present in subordinate quantities. In rare cases biotite is predominant.

Most variable and most intimately mixed are the basic phases of the complex. Hornblende gabbro, hornblendite, pyroxenite, and anorthite gabbro are common. The anorthite gabbro is almost identical to gabbro associated with the April Ultramafics and has a distinctive gabbroid or granulitic texture. It is composed of clear fresh subhedral laths and rounded grains of anorthite An_{95-100}, clinopyroxene partly or wholly altered to green-brown hornblende, rounded and embayed blebs and aggregates of magnetite and small discrete grains of accessory sphene, apatite and epidote. Some varieties grade into coarse, almost pegmatitic types with hornblende crystals up to 4 cm in length. Such a variety of rock types within a single batholith suggests that most have been formed by differentiation of a basic magma.

Comparison of Yuat and Karawari Intrusives

The Karawari and Yuat Intrusives show fairly consistent differences and they could have been formed from different magmas, but as each intrudes different rock types (Tertiary Lagaip Beds in case of Karawari Intrusives and mainly Mesozoic Kana Formation and Maril Shale in case of Yuat Intrusives) the differences may in part be due to the contamination of the same magma. This phenomenon may also explain the atypical Yuat Intrusive in the north-western part of the northern batholith where it intrudes Lagaip Beds. The rocks there closely resemble the Karawari Intrusives in that they contain pyroxene and olivine (11NG1170 A,E, D, Figs. 40 and 41). Alternatively these rocks could be hybrids formed by contamination of the granodioritic magma by more basic, magma.

A recent geochemical survey of the area by W.J. Atkinson of Conzino Riotinto of Australia (1967) has revealed differences in the trace metal content of the Yuat and Karawari Intrusives that can be related to the composition of the adjacent sediments. The mean copper contents of the intrusives reflects these differences: the Yuat Intrusives contain only 31-32 ppm copper; while the Karawari Intrusives contain 56 ppm copper. The mean Cu content of Mesozoic sediments intruded by the Yuat Intrusives is significantly lower (28 ppm) than that of the Lagaip Beds (45 ppm) intruded by the Karawari Intrusives.

The Karawari Intrusives also carry a correspondingly higher concentration of Ni and Ag. Some gold production is associated with these rocks of higher Ag content (e.g. Timun River).

(iii) Porphyry Phase

(a) Yuat & Karawari Porphyries.

Microporphyritic varieties of the previously described rocks occur in the margins of the larger bodies and in numerous small stocks and dykes. The porphyritic marginal zones tend to be up to several hundred of feet wide with a gradual transition from porphyritic micro-diorite (resembling some volcanic porphyries in texture) to normal granodiorite. The majority of the porphyritic apophyses occur within the Lagaip sediments surrounding the northern Yuat batholith and Karawari batholith. Most are very small bodies only hundreds of feet across and many were seen only as boulders in streams. The persistence over large distances of the plutonic rocks in stream float (generally as disproportionately large percentage of that float) has revealed the presence of many very small intrusions.

The leucocratic porphyritic microdiorites generally contain up to 5% quartz and 40% plagioclase (An_{50-55}) as phenocrysts with about 30-70% of altered feldspathic groundmass. The phenocrysts, especially the quartz, are commonly embayed or corroded, and the groundmass is finely crystalline. Plagioclase is generally twinned, zoned, heavily crazed and sericitised. Melanocratic types contain pyroxene and hornblende but lack quartz. Some hornblende phenocrysts show iron stained reaction rims and most are corroded and chloritised. Many of the porphyritic bodies carry 5% (and some as much as 10%) disseminated pyrite.

The texture of the rocks and the nature of the phenocrysts clearly indicates that these porphyries crystallised under near-volcanic conditions, and they are indistinguishable from many of the nearby volcanic rocks of the Tarua Volcanic Member.

(b). Porgera Intrusives

These rocks consist of a number of small irregular stocks and dykes of porphyritic microdiorite together with minor monzonite and soda trachyte phases.

The microdiorite contains phenocrysts of sericitised plagioclase (andesine range), with minor chloritised and sericitised granules of augite and pale yellow brown anhedral chloritised hornblende. The groundmass is composed of highly altered finely crystalline plagioclase, augite, hornblende, opaques and apatite. Although a small amount of quartz occurs as anhedral granules it is thought to have been formed by deuteric alteration of the primary constituents. Much carbonate material (and alteration product) is present*.

In the vicinity of Porgera the porphyry has presumably mineralised the Lagaip Beds as gold is shedding from stockworks of quartz veins in the country rock.

Petrogenesis of the Maramuni Diorite

In a differentiated intrusion the rocks first formed are represented by a more basic phase at the roof or at the borders of the batholith, possibly as a "congealed" phase of finer grain. Such fine grained basic varieties are found in abundance within the Maramuni Diorite especially in the Karawari Intrusives and they indicate that probably only the top of the body has been exposed. "The rocks which follow constitute a more acidic phase and may dislocate and partially modify the portions first crystallised".(Raguin p. 132.). This is clearly illustrated in large boulders in the upper Karawari River where multiple injection and brecciation of several rock types has occurred.

* Petrographic determination by A.M.D.L. (Dekker & Faulks, 1964)

Similarly, tonalite and gabbro at the head of a small tributary of the Lamant Creek have been dislocated and cemented by granodiorite and porphyritic pyroxene leuco-diorite. It is thus assumed that most of the rock types present in the Maramuni Diorite were formed by differentiation (probably from a granodioritic magma). However the effects of assimilation are imposed on the massif at many parts along the border. Evidence of this assimilation exists in the form of a border zone rich in inclusions (xenoliths), veined with aplite and having a heterogeneous texture (porphyritic). In addition one instance of orbicular structures in the granodiorite has been observed in the Lamant Creek (Fig. 42 & 43). It is generally considered (Raguin 1965, Johannsen 1941, Palmer et. al., 1967), that the orbs in orbicular granites are due to the partial assimilation and recrystallisation of foreign inclusions or to segregation from the same magma (Johannsen 1941). Assuming the nucleii to be small inclusions Eskola (1938) explained the orbicular facies as a metasomatic process with crystallisation directed outwards from the centre of the orbicules (i.e. centrifugal migration of more basic material into the surrounding granite.).

Inclusions are commonly ringed with mafic minerals (esp. biotite) followed by a fringe enriched in feldspar. However in parts choked with inclusions the fringes are diffuse and discontinuous. According to Raguin (p. 79) biotite fringes do not necessarily imply important migration of material although Walton (1952) describes biotite fringes derived from transformation of hornblende by potash diffusion from surrounding granite. Such a transformation appears to be the case in many inclusions in the Maramuni Diorite (e.g. 12NG0512). Inclusions are mostly small (2-4 inches) but many larger angular blocks and rounded "pillows" up to several meters in diameter occur. Basic pillows are similar to those described by Blake (1966), but not nearly so numerous.

The many dykes and apophyses that accompany the main intrusive bodies have the appearance of having crystallised under conditions similar to those of volcanism. A period of volcanism commenced in the late stages of the crystallisation and emplacement of the plutonic rocks and continued for sometime thereafter as evidenced by the andesitic/dacitic tuffs and lavas in the overlying Tarua Volcanic Member of the Burgers Formation.

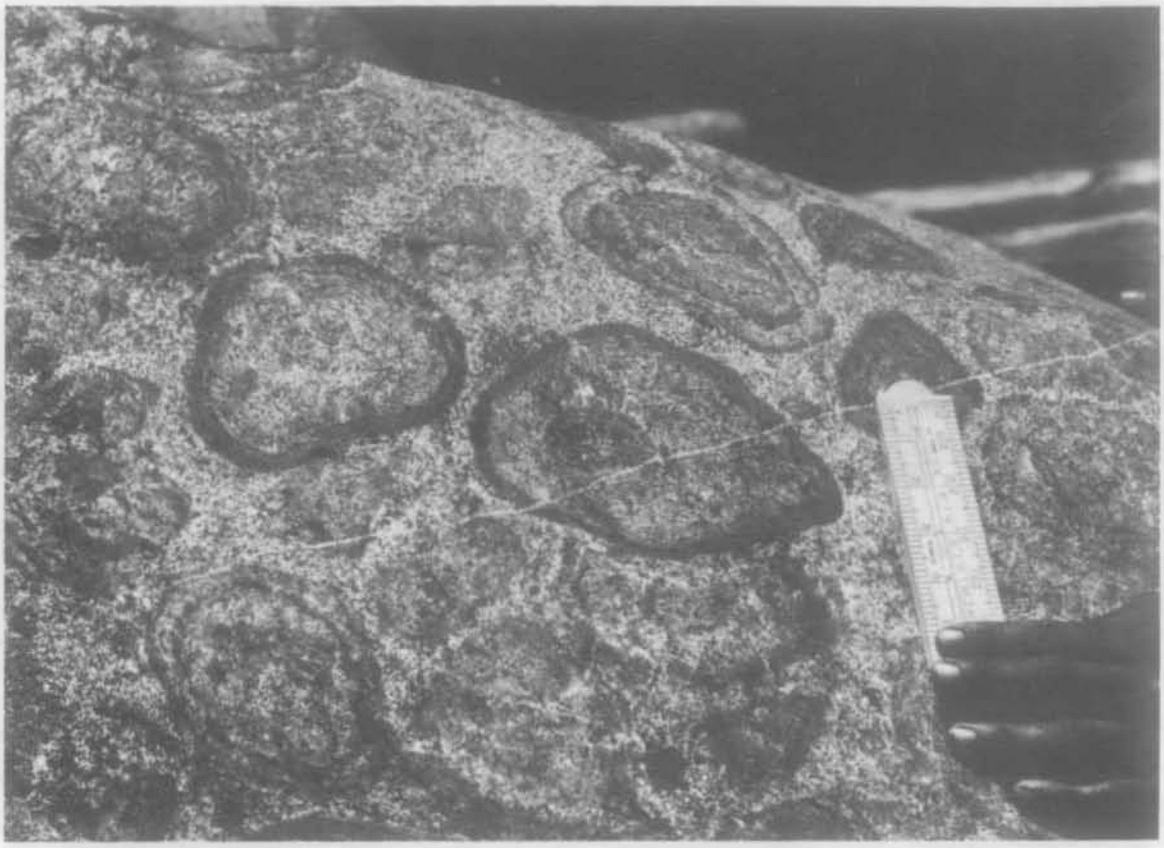


Figure 42: Boulder of orbicular granodiorite diorite from the Lamant Creek, a tributary of the Tarua River. Sample locality 12NG0508.

Neg. GA 837

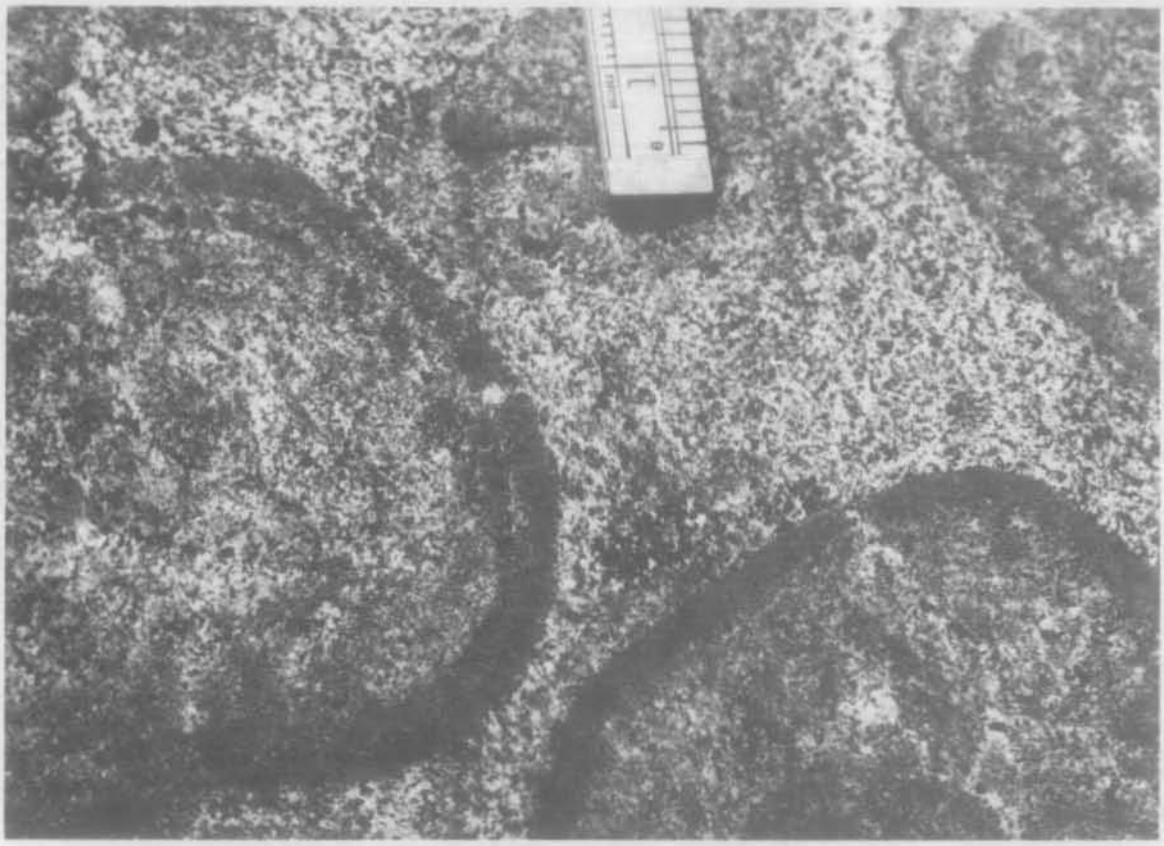


Figure 43: Closer view of 3 orbicular type xenoliths shown in Figure 42. Showing outer mafic shell and well defined boundaries.

Neg. GA 836

Mode and Depth of Emplacement

The Lagaip sediments around the Karawari Massif show evidence of slight updoming. The volume of the intrusion, however, is much larger than the space provided by this updoming and the intrusion is thought to have been emplaced by faulting and stoping. Most of the intrusion/country rock contacts are in fact faulted.

An estimate of the depth at which the Maramuni Diorite was emplaced is based on very scant evidence i.e. the nature of intruded Lagaip sediments away from the narrow metamorphic aureole and the petrographic evidence of rapid cooling. However, both these factors indicate that the Diorite was emplaced at a very shallow depth, probably between 5,000 - 10,000 feet.

Age of Intrusion

It is probable that all the intrusive bodies that comprise the Maramuni Diorite with the possible exception of the Porgera Intrusives, are upper Lower Miocene in age.

Karawari Intrusives have intruded Pundugum Formation (Lower Miocene (Tertiary "e" stage)) but are not known to have intruded younger rocks. Very soon after intrusion, the diorite must have been faulted up several thousand feet thereby becoming exposed to erosion, since pebbles of the diorite are found in increasing quantities towards the top of the Karawari Conglomerate (Tertiary f_{1-2} stage). Some volcanic activity connected with the pluton continued throughout the period of erosion as evidenced by interbedded lavas and diorite pebble conglomerates in the lowermost part of the Karawari Conglomerate.

The Yuat Intrusives could possibly be older, because over most of the region they intrude only Mesozoic rocks. Only the north-western part of the northern batholith, and part of the southern batholith in the Lamant Creek area are known to intrude Salumei Formation, and there the rocks are not typical of the Yuat Intrusives, but more closely resemble the Karawari Intrusives. However, it is more likely that contamination by the assimilated Lagaip Beds has caused the slightly different composition in these restricted areas.

Although the Porgera Intrusives intrude Upper Cretaceous Lagaip Beds they show a marked similarity to the ?Upper Miocene Frieda Porphyry and may not in fact be part of the Maramuni Diorite.

Frieda Porphyry (new name)

Frieda Porphyry is the name proposed for a number of predominantly porphyritic intrusive bodies, ranging in size from small stocks, dykes to bodies several miles across, in an area about 20 miles south of May River Patrol Post. Although these rocks are similar to the Maramuni Diorite mapped further to the east, they are separated from them by an area of high grade metamorphic rocks and ultramafic intrusions.

The bulk of the rocks in the smaller bodies are hydrothermally altered hornblende andesite porphyry (Fig. 44) and tuff. The larger bodies, especially to the north, are predominantly microdiorite microgranodiorite and micromonzonite, all of which have a somewhat porphyritic texture. Some bodies have been stressed and are gneissic in texture (03NG0038). Hydrothermal alteration has formed alunite, sericite, chlorite secondary albite, quartz, kaolinite and epidote in varying amounts and combinations. One particularly distinctive rock type is an iron stained (limonite after pyrite) white kaolinitic looking porphyry (03NG2537) that contains about 70% alunite 20% quartz and 10% finely disseminated pyrite. The formation of alunite in both andesite tuffs and porphyries appears to be intimately linked with the sulphide mineralisation which is particularly widespread in these intrusive bodies (see Economic Geology).

There is some doubt as to the age of the Frieda Porphyry, and it may consist of intrusives of 2 different ages.

The smaller, more porphyritic stocks south of the Frieda Fault intrude Salumei Formation (Tertiary "e" stage), but their relationship with the Tertiary f_{1-2} stage sediments in the region is not known. The volcanic rocks associated with the porphyry are interbedded with marine sediments which appear to be overlain conformably by Tertiary f_{1-2} stage limestone. Thus it appears that the southern bodies were intruded during the early part of the Tertiary f_{1-2} stage i.e. at the same time as the Maramuni Diorite.

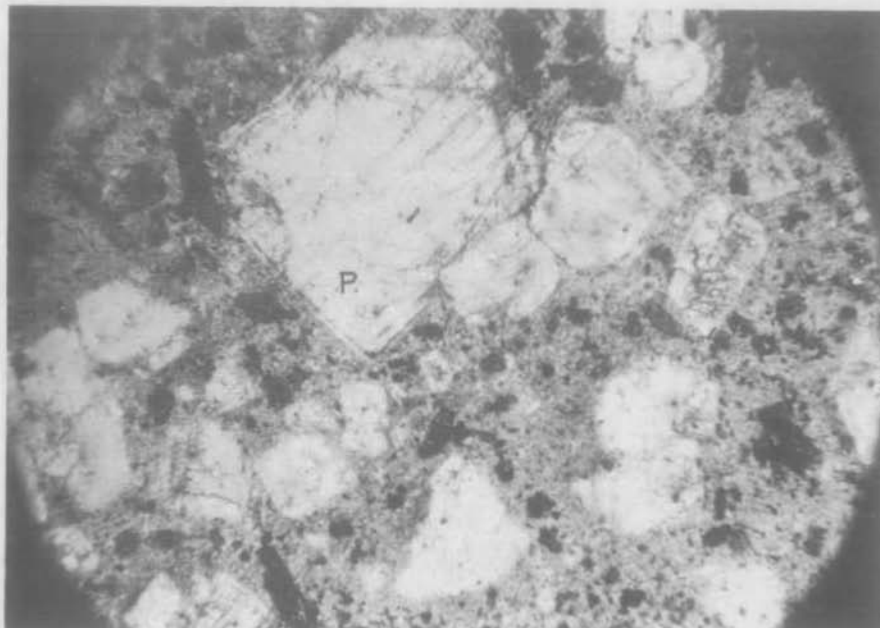
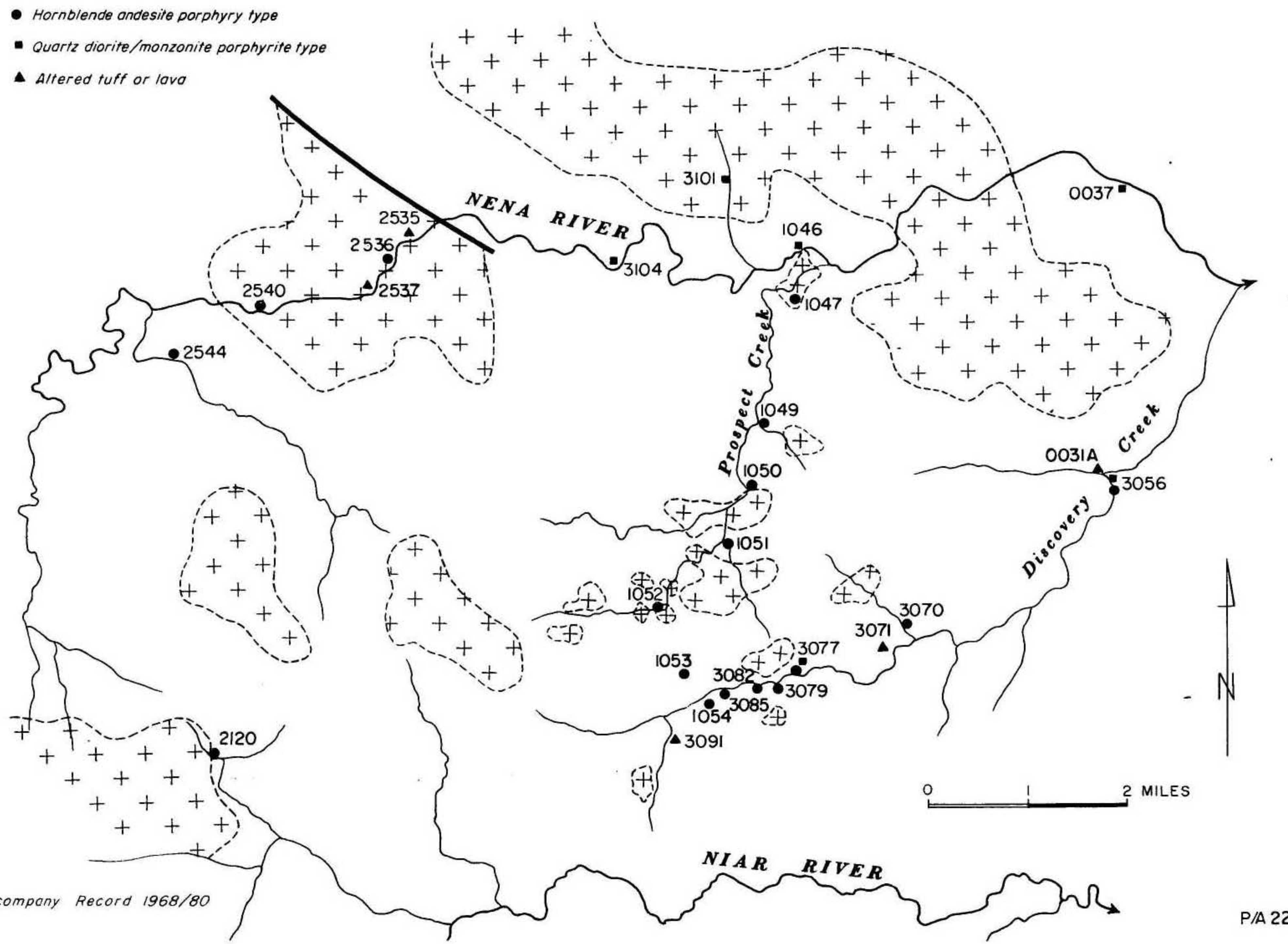


Figure 44: Hornblende andesite porphyry (03NG2513c) Frieda Porphyry. Note the crazed tabular laths of andesine (P) and highly ferruginised finely recrystallised glassy felspathic groundmass. The groundmass contains chlorite, kaolin, quartz, sericite and finely disseminated granules of pyrite. X35 magnification.

Neg. M 758

SAMPLE LOCALITIES - FRIEDA PORPHYRY

Fig. 45 A

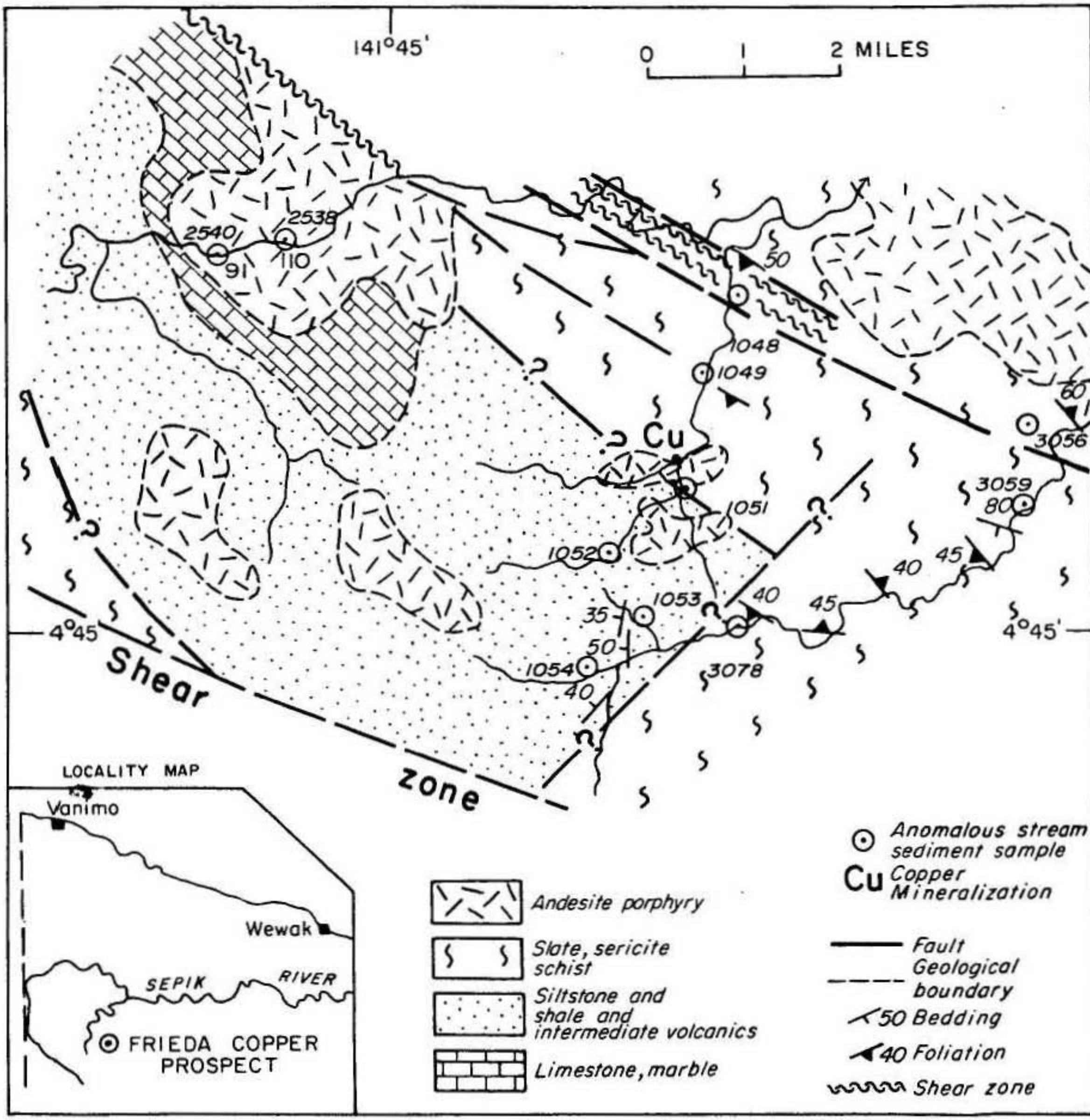


To accompany Record 1968/80

P/A 220

FRIEDA PROSPECT
SEPIK RIVER N.G.

FIG. 46



To Accompany Record 1968/80

P/A196

The larger bodies north of the Frieda Fault are overlain unconformably by the f_{1-2} stage Wogamush Beds and they could be the same age as the Maramuni Diorite, but they could be older, as the youngest rocks they intrude are the Jurassic? Ambunti Metamorphics.

The porphyritic bodies were extensively sampled, and thin section examination (Mackenzie & Bain, 1968) has shown that they can be divided into three groups:

(1) Hornblende andesite porphyry

These rocks contain plagioclase (30-65%) and mafic (10-20%) phenocrysts set in an altered feldspathic groundmass (25-60%). Finely disseminated opaques make up 2-5% of the rock.

The plagioclase crystals are mostly strongly zoned, idiomorphic, heavily crazed fractured andesine and show signs of incipient sericitisation. Many are short stumpy and have rounded ends. In some rocks the plagioclase crystals are extensively fractured and the fragments somewhat dispersed. The mafic minerals are mostly iron stained, brown, corroded, euhedral crystals of hornblende. Many are partly or completely chloritised. Some clear, relatively fresh euhedral pyroxene crystals are found in some specimens.

The groundmass commonly consists of highly ferruginised finely recrystallised glassy feldspathic material. It is generally strongly kaolinised with local development of chlorite, calcite, quartz, sericite and opaques. In many specimens the groundmass contains plagioclase microlites which tend to be aligned parallel to the crystal faces of the phenocrysts. Opaques consist of clusters and finely disseminated granules of pyrite much of which is now latered to limonite.

(2) Hydrothermally altered tuffs and ?lavas

It is difficult to be sure of the original nature of these rocks as the later alteration has almost completely changed the mineralogy and obliterated the original texture.

Some specimens show alteration of sericite, quartz, secondary albite and chlorite whilst some have been almost completely altered to alunite and secondary quartz intimately mixed in an irregularly grained mosaic. Numerous small angular fragments of ?zircon, ?apatite occur throughout many of the specimens (especially 03NG2537). Finely disseminated pyrite (with chalcopyrite and chalcocite) commonly forms up to 10% of the rock. In places it is altered to reddish brown limonite.

(3) Quartz diorite and monzonitic porphyrite

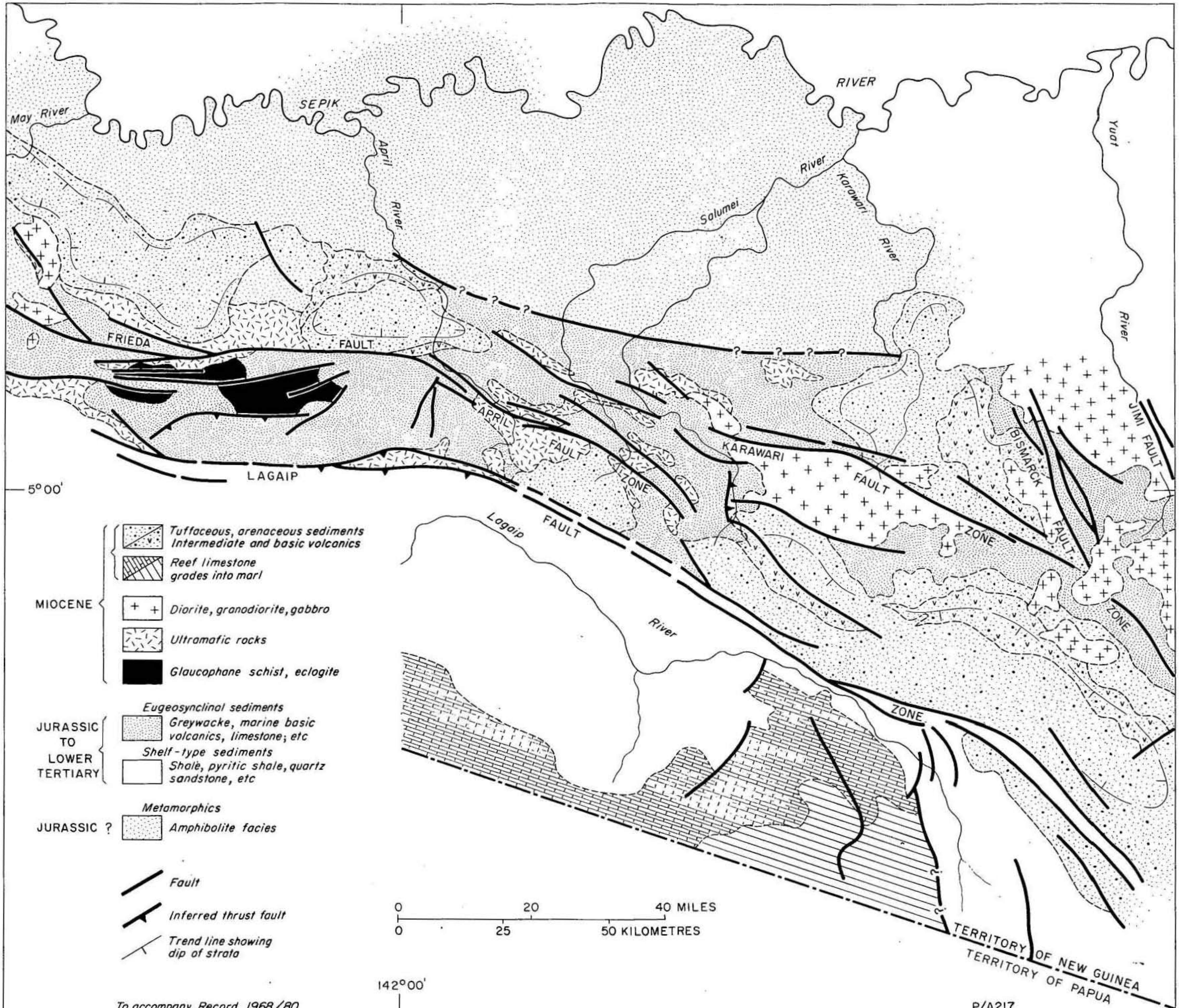
These rocks contain from 50-75% of fresh, zoned, complexly twinned idiomorphic plagioclase (Andesine An_{43}) and up to 5-10% interstitial quartz. K-feldspar may be present up to 25% as large poikolitic plates moulded on plagioclase. The remainder of the rock consists of mostly euhedral greeny brown hornblende, (12-25% with accessory sphene and apatite. Opaques form 2-3% of the rocks. Alteration is mostly slight and consists of chlorite (after hornblende and plagioclase) and some sericite (after plagioclase).

STRUCTURE

NEW GUINEA MOBILE BELT

The region south of the Lagaip Fault Zone is structurally a part of the stable Australian continent (Figure 20), whereas the northern region is a small segment of a tectonically unstable belt called the New Guinea Mobile Belt (Dow in prep.). The Mobile Belt wraps round the Australian continent and forms the transition from a continental to an oceanic structural environment.

The Mobile Belt has been broken into a great many long, narrow wedges by a complex system of great faults or fault zones, most of which have proven vertical displacements exceeding 5000 feet: displacements



STRUCTURAL MAP: SOUTH SEPIK REGION
TERRITORY OF NEW GUINEA

Fig 47

of the order of 20,000 feet are not uncommon. Where seen the faults are mainly subvertical and their other characteristics, such as their great length (some have been traced with reasonable certainty for a total distance of 500 miles), and straight or gently curved traces, all suggest a predominantly horizontal displacement, but only rarely has this been proved.

It is surprising in such an area of intense tectonic activity, that folding has played only a subordinate part in the deformation: the folding is generally broad and simple, and the exceptions are confined to incompetent sediments. In many places the effects seen could be due mainly to slumping before consolidation; in other places intense folding is fairly local and is caused by high shearing stresses near the major fault zones.

Over much of the South Sepik region folding is more intense and the Salumei Formation in the area between the head of the April River and the Frieda River it is generally tightly folded -- faulting however is still the dominant mechanism.

DESCRIPTION OF FAULTS OF THE SOUTH SEPIK REGION

The faults of the South Sepik region are concentrated in zones several miles wide consisting of several major shears (Fig. 47). They trend generally west-north-west, though local flexures occur, such as the change to an east-west trend shown by both the Lagaip Fault Zone and the Frieda Fault in the western side of the map area. The Bismarck Fault Zone and the Jimi Fault also trend at an angle to the regional trend in the map area, though on a regional scale this is also seen as only a local flexure. The zones form part of an anastamosing pattern characteristic of the New Guinea Mobile Belt.

The faults generally show up on the airphotographs as discontinuous lineaments marked variously by; straight stream courses, straight escarpments, or narrow trenches. The fault zones are susceptible to erosion, and good exposures are rare, but wherever seen they consist of zones of mylonitization and shearing up to a quarter of a mile wide. Sheared and plastically deformed horsts hundreds of feet long are commonly incorporated in the zones, and lenses thousands of feet long are not uncommon. The faults almost invariably dip within a few degrees of the vertical, and their trace is little affected by topography.

The total displacement on the faults is not known. The vertical displacement can generally be calculated with reasonable accuracy, but there is almost no evidence showing the magnitude, or even the sense of any transcurrent component, though the general characteristics of the faults strongly suggest that the faults are predominantly transcurrent.

Jimi Fault:-

The Jimi Fault is exposed at several places in the Yuat Gorge where it is marked by zones several hundred feet wide of cataclasite, mylonite, and sheared dacite porphyry. The shear zones where seen, are subvertical, but no idea of the total displacement could be obtained. The eastern block has been downthrown by at least 15,000 feet since Upper Cretaceous times, but it is not known when the movement took place.

Bismarck Fault Zone:-

The Bismarck Fault Zone in the map area is about 4 miles wide and consists of several steeply-dipping and anastamosing faults. It has brought Salumei Formation and Karawari Conglomerate in contact with Mesozoic rocks, a downthrow to the west of at least 10,000 feet.

Some of the major faults of the zone are crossed by the Maramuni Diorite which is apparently little affected and it seems that most of the displacement occurred before the intrusion of the diorite in the Tertiary f_{1-2} stage. This could explain the weak physiographic expression of the fault over most of its length.

Karawari Fault Zone

The Karawari Fault Zone has downthrown Tertiary f_{1-2} stage rocks to the north by about 15,000 feet. As would be expected of a fault with such a large amount of recent displacement, it has a very prominent physiographic expression over most of its length: is bounded on the south by the very steep northern face of the Burgers Mountains (Figure 11), and is marked by the straight valley of the upper Karawari River.

The Karawari Fault Zone could not be mapped in the country of low relief in the Sepik Plains, but a fault mapped in the middle reaches of the April River is almost certainly part of its north-western extension.

April Fault Zone

The April Fault Zone is roughly parallel with the Karawari Fault Zone and has similar characteristics. Its south-eastern and north-western extremities have not been traced -- to the south-east it was lost in the rugged mountains of the main range, and it is overlain by Wogamush Beds to the north-west.

Fault wedges of Burgers Formation which have been incorporated into the fault zone in the south-east, showing that some post - f_{1-2} stage movement has taken place, but most movement is older, because the main faults do not displace the Wogamush Beds.

Frieda Fault

The Frieda Fault trends roughly east west and has probably the most marked physiographic expression of any of the faults of the South Sepik region. It is marked by a narrow trench over its whole length in the map area. The main rivers change course dramatically where they cross the fault indicating that important transcurrent movement has taken place recently. The north-western extension of the fault was not mapped, but a strong physiographic break can be seen from the air trending west-north-west across the May River into the unmapped country of the West Range.

The Frieda Fault has been seen in outcrop only along the Leonard Schultze River where it consists of a steeply-dipping shear zone at least 100 feet wide, in Salumei Formation and serpentinite. In places highly altered gabbro is incorporated in the shear zone.

The only proven displacement on the Frieda Fault occurred after the Tertiary f_{1-2} stage for it has downthrown the Wogamush Beds to the north by several thousand feet.

Lagaip Fault Zone

The Lagaip Fault Zone marks the boundary between the moderately deformed Mesozoic and Tertiary rocks to the south, and the New Guinea Mobile Belt to the north. It also marks the change from pyritic black shale on the south, to eugeosynclinal sediments containing basic marine volcanics on the north. It has little physiographic expression and it can seldom be confidently traced on the airphotographs. Some of the other fault zones of the region owe their poor physiographic expression to the fact that they have undergone little movement since the Tertiary f_{1-2} stage, but the Lagaip Fault Zone has been active until Recent times. For instance, Lake Iviva was formed by warpings associated with recent movement on one of the faults of the zone, and the extrusion of the Sugarloaf Volcanics appears to have been controlled by the south-eastern extension of the fault zone. Thus the lack of physiographic expression must have some other origin, possibly the small amount of vertical displacement: rarely can vertical throws exceeding 2000 feet be proved.

The fault zone has been mapped with varying reliability for 180 miles from Mount Giluwe to the western margin of the map area. Its south-eastern extension is not known, as it is obscured by the Pliocene to Pleistocene Volcanics of Mount Giluwe; its westerly extension has not been mapped, though it is strongly suspected that the fault zone extends westwards into West Irian.

Inferred fault bounding the Sepik Plains:

Between the April and Karawari Rivers the Salumei Formation makes a straight contact with the Ambunti Metamorphics. Exposures are very poor in this region of low weathered hills, but it is thought that the contact is an east-west trending fault which joins with the April Fault Zone in the middle reaches of the April River. The Karawari Conglomerate is not affected where it crosses the fault in the Karawari River, so any movement must have taken place before the Tertiary f_{1-2} stage, thus explaining the weak physiographic expression of the fault.

The throw on the fault is not known, but the juxtaposition of high-grade metamorphics and unaltered Salumei Formation suggests that the southern block has been downthrown many thousand feet.

The north-westerly extension of many of the faults of the South Sepik region is obscured by alluvium of the Sepik Plains, but it seems likely that they continue across the plains in a general north-westerly direction to join with major faults in the mountains north of the Sepik River (Fig. 48). The evidence supporting this is tenuous at best, but the distribution of the Ambunti Metamorphics (Fig. 48), suggests that they occur in 2 fault blocks bounded on the north-east by these faults: the first fault is an extension of the Bismarck Fault Zone which passes to the north-east of Ambunti; and the second an extension of the Karawari Fault Zone which passes to the north-east of May River Patrol Post. Both these postulated extensions coincide with a marked changesin the course of the Sepik River which may owe their origin to recent vertical movement on the faults.

If it is accepted that the fault zones cross the Sepik Plains, it can be seen that they join with major faults which displace the crystalline rocks of the North New Guinea Basin (Marchant in press).

TRANSCURRENT DISPLACEMENTS ON THE FAULTS

Though it cannot be proved, we suspect that the fault zones of the South Sepik region are predominantly transcurrent.

In common with faults of known transcurrent displacement in New Zealand (Wellman 1952, Suggate 1963) the major faults are characterized by their great length, steeply-dipping fault planes near the surface, and straight or gently curved traces. Many streams change direction abruptly where they cross those faults showing recent displacement, but only rarely is the change in direction a reliable indication of the direction of the transcurrent movement. A major fault in the Bismarck Range north-west of Goroka (Fig. 48) has been shown fairly conclusively (Dow & Dekker 1964) to have undergone right-lateral movement of at least 7000 feet since the major river valleys were formed.

The only indication of transcurrent movement on faults of the Sepik region, is the apparent 16 miles right-lateral displacement of the crystalline core of the mountains north of the Sepik River, by the extension of the Bismarck Fault Zone.

If this picture of right-lateral transcurrent faulting is accepted, then the local development of the Salumei metamorphics between the April and Frieda Rivers is explained. The major faults in this region trend roughly east-west (Fig. 27), and the area between the Lagaip and Frieda Faults is therefore one of maximum compression where low-grade metamorphism would be expected. One would also expect the faults to have an overthrust component where they trend east-west: this appears to be the case with the Lagaip Fault Zone, for the ultramafic rocks in this area are bounded by faults which dip at between 30° and 50° to the south. The Frieda Fault however is steeply dipping in the only locality where it was seen in outcrop. The Gufug Gneiss is restricted to the same area and it is conceivable that in such a compressive environment, tectonic overpressures could be produced to form the high pressure metamorphics characteristic of the gneiss.

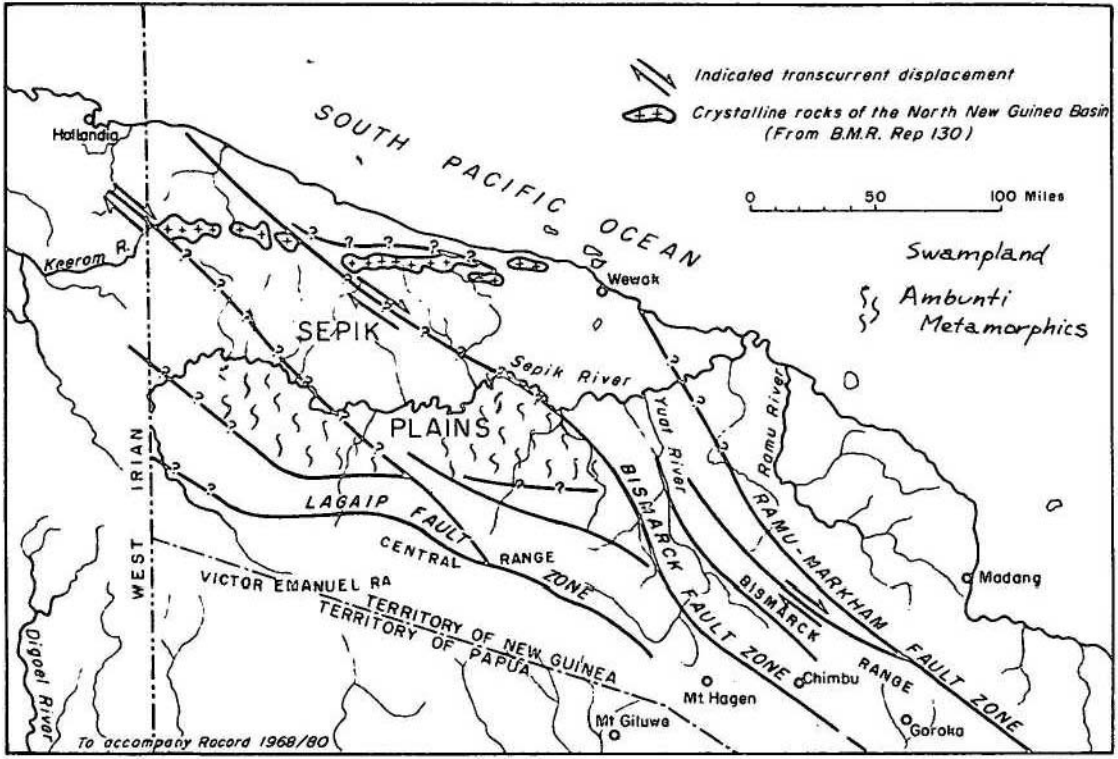


Fig. 48. MAJOR FAULTS - SEPIK REGION P/A 218

Showing postulated trends across the Sepik Plains

It is also considered significant that the Maramuni Diorite is absent from this zone (Fig. 47) for less compressive areas to the east and west would be a more favourable environment for these intrusions.

Previously it has been assumed that the lowlands of the Sepik Plains were caused by faults trending roughly east-west, (Krause 1965 for instance), but the distribution of the Sepik swamps shown on Figure 48 suggests that they were probably controlled by the Bismarck and Karawari Fault Zones where they cross the Plains. It is postulated that the swamps are areas of downwarping resulting from recent compressive forces acting in a roughly north-west/south-east direction -- the same forces which produced the transcurrent displacements on the faults.

ECONOMIC GEOLOGY

The extreme inaccessibility of almost all the map area imposes economic disadvantages on any mineral deposits discovered in the South Sepik region. Mining costs in such a remote locality would be very high, mainly as a result of the very great capital costs involved in constructing roads, and to be economic, any deposit would need to be either high grade, or of very large tonnage.

Several areas are geologically favourable environments for large tonnage low-grade orebodies, so despite the handicaps imposed by the remoteness, it is recommended that further prospecting work be carried out.

The most promising is probably the Frieda Copper Prospect which is an area of several square miles in which disseminated copper mineralization is associated with hydrothermally altered stocks and dykes of andesite porphyry. Also promising are the large areas of dunite and peridotite exposed over about 400 square miles of the South Sepik region and it is thought that some areas may contain lateritic concentrations of nickel and cobalt.

Alluvial gold and platinum are found in many of the streams draining the Central Range, but only in the April River were prospects thought to be worth further investigation. Unfortunately no testing for gold was done on the alluvials in the western tributaries of the Frieda River, but it is thought that the area could possibly contain economic deposits.

COPPER

Frieda Prospect

During the initial reconnaissance of the Frieda River area, boulders of highly altered andesite porphyry containing abundant disseminated pyrite and some scattered chalcopyrite were noted in a tributary of the Frieda River about 20 miles south of May River Patrol Post. (Fig. 46) Some boulders with sparse stockworks of quartz veins containing patches of chalcopyrite were also seen.

Subsequent traverses up the major side streams showed that the source of the boulders was an area of several square miles of Salumei Formation intruded by high-level stocks and dykes of andesite porphyry, all of which were very highly hydrothermally altered. Alteration has obscured most of the original textures of the rocks but it was thought that some could have been volcanic, an observation subsequently borne out by thin-section examination.

A zone of highly mineralized porphyry about 300 feet wide containing some chalcocite and chalcopyrite was found in one of the tributaries, but because the exposure is so poor it could not be adequately sampled. No idea was gained of the overall grade of the lode.

Stream sediment samples collected in the prospect area contain anomalous copper, averaging six times background, and ranging up to 24 times background (Table II). The anomalous streams drain an area of more than 8 square miles.

The geological features of the prospect:- high-level stocks and dykes of intermediate porphyry, ubiquitous and almost complete hydrothermal alteration of the porphyries, the intensity of the sulphide mineralization, and the large area giving stream sediments anomalous in copper, all point to mineralization of the porphyry copper-type (Titley and Hicks, 1966).

The rocks of the prospect area are mainly fine-grained sediments similar to the Salumei Formation to which they have been tentatively referred. The area is complexly faulted and it is difficult to be certain of the field relationships, but it appears that the sediments pass conformably upwards into a sequence containing much more extensive pyroclastic rocks than found in the upper part of the Salumei Formation, or even the Pundugum Formation which overlies the Salumei Formation to the east. It is therefore possible that the upper part of the sequence is the lateral equivalent of even younger beds, the most likely being the volcanic rocks at the base of the Wogamush Beds. However, it was impossible on the scale of mapping undertaken to separate out these beds.

The fine-grained sediments are composed mostly of light to dark grey micaceous siltstone which is indurated but shows little sign of recrystallization. It is mostly massive but in places contains thin interbeds of coarser-grained siltstone and fine sandstone. Graded bedding and slump structures were observed in some of the coarser beds.

Minor interbeds of andesitic tuff, green intermediate lavas, and fine to coarse-grained tuffaceous greywackes are found in places, and these appear to grade upwards into massive andesitic welded tuffs and red and green volcanic agglomerate and volcanic breccia very similar in thin-section to the porphyry intrusions.

A bed of limestone several hundred feet thick in the north-west of the prospect area appears to be only gently folded, and it probably overlies the rest of the sedimentary rocks. Lithologically it is similar to the limestone lenses found elsewhere in the Salumei Formation, but foraminifera give its age as Tertiary f_{1-2} stage i.e. the same as the Wogamush Beds to the east. Other small limestone lenses south of the prospect area are also Tertiary f_{1-2} stage, but these are near a north-east-trending fault, and they may represent faulted remnants of the large limestone bed.

The sediments of the prospect area, with the possible exception of the limestone bed, are intruded by many stocks and dykes of andesite porphyry called the Frieda Porphyry. The porphyry and the volcanic rocks are closely related.

The rocks are hydrothermally altered hornblende andesite porphyry and tuff. The alteration products are alunite, sericite, chlorite, albite, quartz, kaolinite and epidote in varying amounts and combinations. A consistent feature is the almost complete alteration of most of the samples. One particularly distinctive rock is a white, partly iron-stained (limonite after pyrite) porphyry containing about 70 percent alunite, 20 percent quartz, and 10 percent finely disseminated pyrite. Alunite is widespread and appears to be linked with the sulphide mineralization.

Pyrite is by far the most common sulphide mineral and is found finely disseminated throughout all the porphyry and volcanic rocks, in places making up about 50 percent of the rock. Chalcopyrite makes up only a small proportion of the sulphides but it is widespread: it occurs mainly as finely disseminated grains, but boulders of porphyry with stockworks of quartz veins containing chalcopyrite were found in streams draining the prospect.

As mentioned previously it is difficult to relate the geology of the prospect area with the regional geology further east. The limestone is the same age as tuffaceous calcarenite lenses found at the base of the sedimentary rocks of the Wogamush Beds 40 miles to the east, and it seems likely that the intermediate volcanic rocks and intrusives are the same age as the volcanic member of the Wogamush Beds. If this is true, the conformable contact of the volcanic rocks with the siltstone of the Salumei Formation is difficult to reconcile, for elsewhere there is a considerable thickness of Pundugum Formation and an unconformity between the Salumei Formation and the volcanics.

It is possible that all the sedimentary rocks of the prospect area are younger than the Salumei Formation and are merely a finer-grained, dominantly marine phase of the volcanic member of the Wogamush Beds.

Minor Copper Occurrences.

Minor scattered grains of chalcopyrite were found at several localities but only in one, found in the headwaters of the Clay River just off the map area to the east (Dow et. al., 1967), is the geological setting considered sufficiently favourable to warrant geochemical prospecting of the general area. The chalcopyrite was found as rare scattered grains in basic igneous rocks of the Kumbruf Volcanics, and thin-section examination showed that the rocks had been metasomatically altered, probably by an acidic or intermediate pluton. Further evidence for the existence of such pluton is given by an area of dendritic drainage seen on the airphotographs 4 miles to the east, which can be fairly confidently predicted to be underlain by a feldspathic igneous intrusion.

Dekker and Faulks (1964) report small nodules of bornite in reddish marl of the Lagaip Beds between Laiagam and Muriaga, a selected sample of which assayed 2.95 percent copper. Sparse secondary copper minerals can be found lining small joints over a fairly large area, but it seems unlikely that the occurrence is of economic importance.

Streams draining the area do not contain sediments anomalous in copper. Stream sediments in small tributaries draining the main range in the head of the April River contain anomalous copper. The rocks of the area are extremely faulted Salumei Formation intruded by altered gabbro and ultramafic rocks. The region is rugged in the extreme, and as the anomalies are not of great magnitude, it is thought that the chances of finding economic copper mineralization are poor.

GOLD SILVER AND PLATINUM

Gold silver and platinum are the only minerals produced in the map area

(i) Porgera Valley

Alluvial gold was first reported in the Porgera Valley in 1938, and it has been mined spasmodically ever since, mostly by indigenous miners.

The area was visited in 1948 by Ward (1949), and subsequently by officers of the Mines Division, Department of Lands Surveys and Mines who traced the gold to its source. Horne(in prep.) visited the area in 1963 and mapped the main lodes, and later Bulolo Gold Dredging Co. Ltd., and Carpentaria Exploration Pty. Ltd., tested the lodes by diamond drilling. The results were apparently unfavourable for no further work has been done.

The gold which is alloyed with considerable silver, is shedding from stockworks of quartz veins in the Lagaip Beds near the margins of small dioritic intrusions, (Porgera Intrusives). Sphalerite, pyrite, galena, and some chalcopyrite are commonly associated with the gold mineralisation. Some of the porphyry stocks have covers of soil containing residual concentrations of very finely divided gold.

(ii) Timun River

Gold and platinum were discovered in the Timun River near Kompiam by N. Rowlands in 1948, and was later worked by the brothers L. and M. Wilson until the 1960's. Returns were very poor and the total recorded production is small. Ward (1949) visited the area in 1948, and Dow (1961) described the prospect. During the course of a geological reconnaissance Dow found promising gold prospects in the Lamant River, which the Wilson Brothers later visited and worked for some years.

In the Timun River the gold and platinum apparently originated in the Maramuni Diorite, which in this area is a very complex mixture of diorite, gabbro, and serpentinite. Only small concentrations of the precious metals were shed directly by the Diorite, but by a fortuitous set of circumstances, they accumulated in thin, rather restricted lake beds near the head of the Timun River. These beds now give only poor prospects, but the concentrating action of the Timun River and its tributaries has made the recent river gravels worth working.

In the Lamant River the gold originated in stocks of highly propylitized andesite porphyry which are now shedding considerable fine gold. The river immediately below the porphyry stocks has a low gradient and gold has been concentrated both in the stream channel and the low terraces flanking the river.

Gold is carried by almost all the streams draining the Maramuni Diorite, but none seen offered economic prospects, generally because the amount of gold shedding is very poor, but also because the streams are almost invariably steep. Before World War II a gold strike was reported in the Lower Yuat River, and several prospectors visited the area, but no mining was done. Probably as a result of the rumours, the alluvium of the Maramuni River above its junction with the Yuat River was tested by percussion drilling (L. Schmidt pers. comm.), but very little gold was found.

During a brief reconnaissance up the April River in 1966 the Sepik Party discovered alluvial gold and platinum in the main river above the junction with Bomali River. Prospects were regarded by the senior author as reasonably good but no further work has been done on the gravels. Despite the difficulties of access the area is worthy of the attentions of an experienced prospector and a box team to test the terraces flanking the main river.

The platinum is shed from the April Ultramafics which make up a large proportion of the rocks of the region, but the origin of the gold is not known. Boulders of hornblende andesite porphyry containing much pyrite make up a small proportion of the gravels of the April River, and from previous experience it is believed that the source of these has also shed the gold. However, the porphyries were not found in place during the present survey.

NICKEL

Under favourable circumstances, of which low relief and intense tropical weathering are probably the most important, peridotite and dunite, form economic concentrations of nickel in the overlying soils.

Some areas of the South Sepik region offer these two conditions and despite the problems of access it is thought that the ultramafic rocks are worthy of more detailed investigation than was possible during the present survey.

All the ultramafic rocks examined were either dunite, peridotite, or serpentinite derived from these, and preliminary assays indicate that the fresh rocks contain about .2 percent nickel. Sediments from streams draining these rocks as expected, contain high nickel values, generally between 800 and 2000 parts per million. Random soil and sediment samples taken in the headwaters of small tributaries between the April and Sitipa Rivers range up between 2000 and 4000 parts per million nickel. These results are significant in that they show the high average nickel content of the ultramafic rocks and also that some concentration of nickel has taken place in the soils.

The most favourable areas are those in which the ultramafic rocks have low relief and the hills near the Sepik Plain therefore offer the most promise. Hand augering has proved the most satisfactory method of preliminary testing soils overlying ultramafic rocks in other parts of New Guinea, and it is recommended that a program of scout drilling be done on the ultramafic bodies at the head of Sikipas River and in the middle reaches of the Sitipa River, to test the depth and nickel content of the overlying soils.

REGIONAL GEOCHEMISTRY

To aid in the location of mineralised zones, samples of stream sediment were collected from the main streams and small tributaries throughout the area and analysed in the Bureau of Mineral Resources laboratory at Canberra. Wet samples of sediment collected from the stream beds were sieved in the field through 80 mesh nylon screens into small plastic bags. Excess water was poured off and the bags sealed. Analysis was made at the end of the field season using Atomic Absorption methods.

The locations of the 246 samples analysed are shown on Plate and the results are given in Table VI.

Two areas of anomalously high copper values were delineated. In the Frieda Prospect area maximum values (980 ppm) are as much as 24 times the background (40 ppm) whilst a lesser anomaly of 120 ppm (3 times background) is revealed in the headwaters of the April River. Anomalously high nickel values (up to 1760 ppm) occur in the areas of ultramafic rocks especially along the April River.

The anomalous areas are discussed in more detail in the sections on copper and nickel. Following the release of the report on the Bureau's 1966 field season (Dow et. al., 1967) C.R.A. Exploration Pty. Ltd., geologists carried out a reconnaissance geochemical survey of the area covered in that report as well as part of the Schrader Range and Hunstein Mountains. Numerous samples of stream sediment were collected and analysed for Cu, Pb, Zn, Ni, Co, and Ag by T. Langman and C.J. Reddell using an Atomic Absorption Spectrophotometer (Atkinson 1967).

No anomalous values that could not be explained as variations in local background metal content were detected. However, the analyses revealed regional differences in metal content characteristic of the various bedrock units (Table V). In fact Atkinson (1967) notes that several formations are "characterised by significantly high or low Cu contents and this is reflected in well marked regional Cu patterns". He goes on to say that:

> "The areas occupied by the Jurassic-Triassic sediments can be readily discarded as being of no interest because of the extremely low (26 to 29 ppm) mean background Cu value. When considering the dioritic bodies, the Yuat Intrusives, which carry mean values of only 31 and 32 ppm would also seem to indicate environments not particularly conducive to porphyry Cu mineralisation. On the other hand, it appears from one erratically high value of 75 ppm Cu from a diorite-porphyry apophyse at the northern end of the Yuat South batholith, that the marginal, more basic phases, may be more favourable as target areas.
>
> Of particular significance is the difference in mean Cu content of the Karawari Intrusives (56 ppm) compared with the Yuat Intrusives (31-32 ppm), both included by Dow in the Maramuni Diorite. Dow has already pointed out lithological variations between these rocks and although he accepts that they may have formed from separate magmas he favours the possibility that chemical variations in the rocks assimilated during intrusion may account for these differences. Geochemical evidence points to the latter process as the Cu content of the Triassic-Jurassic sediments intruded by the Yuat Intrusives is significantly lower (28 ppm) than that of the Lagaip Beds /Salumei Formation/ (45 ppm) assimilated by the Karawari Intrusives. It would appear from this that the Karawari Diorite and in particular the smaller intrusives in the Tarua-Timun Rivers (mean Cu content 62 ppm) constitute far more favourable environments for the concentration of Cu than the batholiths adjacent to the Yuat River. Although the higher Cu values representative of the Karawari Intrusives have not resulted in the detection of anomalous levels they do emphasise the fact that in the search for porphyry-copper type deposits areas of intruded host rocks with significantly higher Cu backgrounds should be favoured as target areas for investigation. At this stage it can be pointed out that the Karawari Intrusives also carry higher concentrations of Ni and Ag than the Yuat Intrusives and that this feature is reflected in the composition if the intruded sediments".

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TABLE 1

APPROXIMATE COMPOSITIONS OF SOME SPECIMENS OF MARAMUNI DIORITE

Specimen No.	Locality	Plagioclase %	Plagioclase Av_{An}	Zoning	Kfel %	Qtz %	Hbl %	Bi %	Accessories %	Remarks
Yuat Intrusives										
11NG0578 A	L. Maramuni R.	43	-	Yes	12	22	21	(much epidote) pseudomorph)	1 opaques epi. sphene	Hornblende biotite micro-granodiorite
11NG0566	L. Maramuni R.	48	An_{54}	Yes	23	16	11	-	2 sphene, epidote, opaques, zircon.	Hornblende biotite micro-granodiorite
11NG0582	L. Maramuni R.	51	-	Yes	12	14	20	-	1 sphene epi.	Hornblende biotite microgranodiorite
12NG0514	Lamant Creek	70	An_{38}	Yes	-	18-20	8	1-2	2 opaques	Hornblende biotite microtonalite
12NG0512	Lamant Creek	80	An_{42}	Yes	-	1-2	20	2-5	3-5 opaques and epidote	Microdiorite (contains many small, more basic xenoliths)
Karawari Intrusives										
11NG0115 (3)	Wogupmeri R.	65-70	An_{50}	rim An_{26}	-	5-10	20-25	-	5 opaques & epidote apatite	Quartz Diorite
11NG0115 (5)	Wogupmeri R.	55-60	-	Yes	-	15-20	20-25	-	2-3 opaques	Hornblende Tonalite
11NG1190	Upper Maramuni R.	40	-	Yes	20	30	-	10	Very minor opaque and apatite	Biotite Granodiorite
11NG0609	Karawari R.	75	An_{62}	Yes	5-10	5-7	c'px 10		2-5	Pyroxene quartz diorite
11NG0605	Karawari R.	85-70	An_{95-100}		-	-	25-30	-	5 magnetite	Anorthite Gabbro
11NG0102	Wogupmeri R.	50			-		45	-	1-2 magnetite	Anorthite Gabbro 5% olivine

Specimen No.	Locality	Plagioclase %	Plagioclase Av_{An}	Zoning	Qz %	Px %	Hbl %	Bi %	Accessories %	Groundmass % & nature	Remarks
Porphyry Phase											
11NG0112	Wogupmeri R.	35-40	An_{40}	Yes	-	10	15	-	5-10	30-35 v. altered felsp.	Diorite Porphyrite
11NG0117	Korosameri R.	30	-	Yes	5		5 Chlorite		-	60 fine felsp and chlorite	Altered microdiorite Porphyrite
11NG0556	Yuat R.	45	64	Yes	-	2-5	-	-	5 (in G.M.)	50 mostly plag. with granules of px, hbl, access.	Porphyritic Qz Microgabbro
11NG1187	Upper Maramuni R.	40	-	Yes	these minerals present as small granules in the groundmass					60 finely divided felsp and chlorite	Leuco microdiorite porphyrite

TABLE II

APPROXIMATE COMPOSITIONS OF SOME SPECIMENS OF FRIEDA PORPHYRY

Specimen No.	Locality	Plagioclase %	Zoning	Av_{An}	Qtz	Hbl	Opaques	Chlorite	Sericite	Alunite	Other Accessories	Remarks
Hornblende andesite porphyry type												
03NG1053	Discovery Ck.	50		An_{42}	5-10	Chlorite	3	15	10	-	Calcite 10	Heavily altered; hornblende replaced by chlorite.
03NG2536	Nena River	40		An_{34}	-	20	-	-	-	-	Epidote	Heavily altered; kaolinised granular groundmass.
03NG2540	Nena River	65	Strongly cracked and zoned. Incipient sericite		-	5-10	5	Highly ferruginised glassy groundmass containing kaolin: chlorite and disseminated pyrite.				
03NG3070	Discovery Ck.	70	Zoned	An_{35}	5	1	2	5	5	-	Calcite 5 Biotite 5	Heavily altered: many replacement minerals
Quartz diorite/monzonitic porphyrite type												
03NG1046	Nena R.	62	Zoned	An_{44}	8	15	1	-	-	-	Kfels 10 Sphene tr.	Hornblende diorite
03NG3077	Discovery Ck.	65	Zoned	An_{36}	5	10	5	3	5	-	Biotite 5 Apatite 1 Epidote 1	Partially altered hbl-bi-diorite porphyry.
03NG3101A	Nena R.	55	Zoned	An_{44}	10	15	2-3	-	-	-	Kfels 17 sphene 1	Hornblende monzonite
Altered tuffs and lavas												
03NG0031A	Discovery Ck.		?Albite 5-10		40	-	5	-	-	45	-	Alunitised andesite tuff.
03NG2535	Nena R.		?Albite 3%		15	-	7	-	-	75	-	Alunitised andesitic tuff.
03NG2537	Nena R.		?Albite 5		65	-	limonite 5-10	-	-	20-25	Zircon 1-3	Alunitised andesitic ?lava or ?tuff.

TABLE III

RETURN OF FINE GOLD PRODUCED PORGERA LOCALITY

YEAR ENDED	GOLD FINE OZS	PLATINUM FINE OZS	SILVER FINE OZS	ACTUAL VALUE OF BULLION GOLD $ c.	PLATINUM $ c.	SILVER $ c.	TOTAL $ c.
1949	133.577	-	21.57	2875.27	-	8.35	2883.62
1950	426.672	-	67.27	11904.56	-	34.34	11938.90
1951	153.322	-	24.29	4750.41	-	16.19	4766.60
1952	84.352	-	14.08	2613.50	-	10.45	2623.95
1953	276.778	-	42.05	8575.52	-	26.72	8602.24
1954	177.017	-	47.09	5983.19	-	29.03	6012.22
1955	335.784	-	55.89	10493.26	-	39.59	10532.85
1956	150.608	-	23.95	4706.50	-	17.77	4724.27
1957	345.720	-	53.79	10803.79	-	39.68	10843.47
1958	146.474	-	6.81	4577.38	-	4.89	4582.27
1959	362.906	-	53.92	11340.85	-	40.38	11381.23
1960	363.172	-	55.87	11349.12	-	41.70	11390.82
1961	438.853	-	94.99	13714.19	-	65.73	13779.92
1962	732.288	-	114.99	22884.14	-	100.89	22985.03
1963	654.310	-	109.16	20447.21	-	102.01	20549.22
1964	1301.731	-	278.74	40679.08	-	277.76	40956.84
1965	1042.060	-	293.48	32561.58	-	279.25	32840.83
1966	613.432	-	201.51	19169.44	-	218.88	19388.32
1967	1280.697	-	330.45	40021.35	-	348.70	40370.05
1968	1019.234	-	191.46	31850.83	-	307.26	32158.09
	10038.987	-	2081.36	311301.17	-	2009.57	313310.74

TABLE IV

RETURN OF FINE GOLD PRODUCED TIMUN RIVER LOCALITY

YEAR ENDED	GOLD FINE OZS	PLATINUM FINE OZS	SILVER FINE OZS	ACTUAL VALUE OF BULLION: GOLD $ c.	PLATINUM $ c.	SILVER $ c.	TOTAL $ c.
1949	No production	-	-	-	-	-	-
1950	78.700	4.874	18.12	2438.38	276.01	9.61	2724.00
1951	No production	-	-	-	-	-	-
1952	200.700	10.865	43.97	6218.35	695.35	28.05	6941.75
1953	3.500	.943	1.06	108.84	60.35	0.65	169.84
1954	49.720	5.417	11.85	1540.49	375.77	7.26	1923.52
1955	68.751	3.896	7.78	2154.72	271.69	4.77	2431.18
1956	104.690	7.643	22.89	3271.55	579.61	15.02	3866.18
1957	72.370	10.598	19.11	2261.56	834.58	12.80	3108.94
1958	246.730	31.199	62.40	7710.31	1709.98	43.16	9463.45
1959	122.600	15.097	25.48	3831.25	449.60	18.52	4299.37
1960	46.760	2.779	12.24	1461.24	51.97	8.12	1521.33
1961	18.500	2.159	4.16	578.12	112.27	2.75	693.14
1962	57.672	4.539	15.82	1802.23	236.01	10.91	2049.15
1963	65.780	5.158	17.50	2055.62	261.27	15.33	2332.22
1964	38.430	1.932	9.12	1200.93	103.92	8.48	1313.33
1965	26.549	4.288	5.90	829.65	284.40	5.81	1119.86
1966	8.300	..244	2.16	259.35	20.49	2.41	282.25
1967	3.850	-	.78	120.32		.71	121.03
1968	1.091	-	.23	34.10		.33	34.43
	1214.693	111.631	280.57	37877.01	6323.27	194.69	44394.97

N = No. of Samples
M = Arithmetic Mean
R = Range of Values
(5) = No. of Samples when fewer analysed for CxCu and Mo.

TABLE V

MEAN METAL CONTENT AND RANGE OF VALUES FOR THE PRINCIPAL ROCK UNITS

RESULTS FROM:- Atkinson, 1967

Parts per million, minus 80 mesh, wet sieved stream sediment

ROCK TYPE		N		COPPER	LEAD	ZINC	NICKEL	COBALT	SILVER	Cx COPPER	MOLYBDENUM
TARUA VOLCANICS		2	M	107	32	90	45	45	3.0	5.5	< 1
			R	100-115	30-35	85-95	35-55	45	3.0	3.5-7.5	< 1
MARAMUNI	Yuat R. Nth.	13	M	31	47	90	34	31	1.0	2.3(5)	< 1 (5)
			R	25-45	30-85	35-165	10-55	15-50	< 1-2	1.0-3.5	< 1
	Yuat R. Sth.	22	M	32	38	62	26	25	1.3	2.0	< 1
			R	20-75	15-90	20-110	10-50	10-60	< 1-3	1.0-6.0	< 1
	Tarua-Timun	17	M	62	48	112	48	30	2.1	3.7	< 1
			R	50-75	30-65	85-150	25-70	10-55	< 1-4	2.5-6.0	< 1
	Karawari-Korosomeri	27	M	53	40	72	49	35	1.4	3.4(17)	< 1
			R	35-90	25-50	35-140	25-85	25-50	< 1-3	1.0-6.0	< 1-1
DIORITE		79	M	45	42	81	40	30	1.4	3.1	< 1
			R	20-90	15-90	20-165	10-85	10-60	< 1-4	1.0-6.0	< 1-1
APRIL ULTRAMAFITES		30	M	39	32	79	336	38	1.4	3.4	< 1
			R	12-55	15-50	30-135	110-1650	25-85	< 1-3	1.0-5.0	< 1
LAGAIP BEDS		54	M	45	38	107	58	33	1.3	2.6 (42)	< 1
			R	25-65	15-70	45-235	15-135	15-115	< 1-4	0.5-6.0	< 1
KERAM BEDS		30	M	58	32	87	59	28	1.3	3.1	< 1
			R	35-75	15-45	55-255	30-130	10-55	< 1-3	1.5-5.0	< 1
"SOUTH SCHRADER" BLACK SHALES		8	M	44	34	96	95	31	< 1	2.9	< 1
			R	30-60	30-40	80-110	40-180	25-40	< 1-1	2.5-3.0	< 1
JURASSIC-TRIASSIC		12	M	28	35	62	32	25	< 1	2.2	< 1
			R	15-50	30-50	35-85	10-75	15-30	< 1-3	1.0-5.0	< 1
"HUNSTEIN" BEDS		13	M	29	17	35	66	24	< 1	2.3	< 1
			R	12-45	< 10-40	15-90	25-125	15-30	< 1-1	1.0-6.0	< 1
ASAI BEDS		11	M	26	20	53	36	18	< 1	1.7	< 1
			R	15-40	15-30	35-75	20-40	10-25	< 1	1.0-3.0	< 1-1

TABLE VI

ANALYSIS OF STREAM SEDIMENT SAMPLES FROM THE SEPIK AREA, T.P.N.G.

by

D.W. Bennett

The following results were obtained for the determination of trace metals in 246 stream sediment samples from the Sepik area, T.P.N.G., submitted by D.B. Dow and party. Determinations were by the Atomic Absorption method following digestion with hydrochloric acid. All results are in parts per million.

Sample No.	Cr	Mn	Co	Ni	Cu	Zn	Pb	Cd.
03NG0001	38	620	20	104	54	67	< 10	
0002	228	570	58	800	34	38	< 10	
0006	92	890	24	210	46	93	12	
0008	118	570	20	96	48	52	< 10	
0009	146	600	24	102	44	62	< 10	
0010	114	510	20	74	52	50	< 10	
0010	64	720	24	64	54	76	< 10	
0013	68	570	26	230	42	82	< 10	
0014	60	450	14	88	28	64	< 10	
0021	114	520	20	90	40	80	< 10	
0028	44	660	18	56	44	100	12	
0032	154	1050	38	530	44	90	12	
0038	52	600	12	44	44	44	< 10	
0039	60	540	16	52	44	48	< 10	
0040	34	570	16	48	56	70	< 10	
0501	56	830	24	138	62	102	12	
0503	34	650	18	56	38	138	12	
0509	320	910	42	330	74	94	< 10	
0512	52	790	22	52	46	90	12	
0516	44	680	20	44	44	100	12	
0518	60	520	16	66	30	84	10	
0520	52	520	18	48	36	102	12	
0523	16	870	18	36	48	122	26	
0530	68	1050	26	92	92	108	12	
0532	102	690	24	156	62	67	< 10	
1001	88	390	20	84	34	114	12	
1001A.	8	390	18	29	10	108	20	

TABLE VI - 2

Sample No.	Cr.	Mn	Co	Ni	Cu	Zn	Pb	Cd
03NG1005	114	680	22	132	43	93	12	
1009	16	320	18	22	28	135	10	
1013	700	380	32	360	43	26	< 10	
1018	100	600	22	88	48	78	< 10	
1020	76	620	18	126	30	122	12	
1027	178	600	24	172	38	70	< 10	
1031	44	730	18	20	74	75	15	
1034	22	390	14	12	44	56	< 10	
1035	118	770	26	76	69	56	< 10	
1036	44	610	16	34	40	80	10	
1039	114	540	16	21	28	34	< 10	
1040	150	680	22	54	60	59	< 10	
1041	80	680	24	62	74	60	< 10	
1042	96	440	14	54	24	39	< 10	
1043	72	580	18	78	8	52	< 10	
1046	42	660	22	150	48	86	10	
1048	48	410	10	40	320	104	16	
1051	115	520	18	115	980	93	18	
1052	16	500	8	16	162	164	20	
1053	22	1010	20	54	285	300	60	
1054	42	960	18	44	102	215	100	
03NG2086	64	540	20	82	70	48	< 10	
2100B	50	660	20	115	68	105	20	
2105	44	1570	24	24	30	80	10	
2503	48	160	6	20	10	22	< 10	
2505	32	690	20	46	42	102	10	
2508	42	460	26	34	38	56	< 10	
2510	52	600	24	54	66	66	< 10	
2513	60	430	28	52	44	46	< 10	
2514	76	290	20	64	42	28	< 10	
2518	195	460	16	120	33	66	< 10	
2531	320	660	24	150	39	73	< 10	
4 2533	120	560	22	90	42	56	< 10	
2538	6	50	2	6	110	21	< 10	

TABLE VI - 3

Sample No.	Cr	Mn	Co	Ni	Cu	Zn	Pb	Cd
03NG2540	28	400	10	28	91	100	< 10	
2541	6	240	4	6	48	46	< 10	
2543	26	1000	20	30	70	195	20	
03NG3056	44	940	24	68	100	180	70	
3057	445	770	34	215	94	90	< 10	
3059	100	780	24	146	152	86	10	
3062	32	740	18	42	60	108	10	
3064	20	860	18	41	55	100	20	
3068	24	820	18	41	57	108	20	
3070	38	780	20	54	60	116	15	
3073	24	920	20	40	60	150	40	
3077	28	880	18	41	69	120	20	
3078	72	1050	20	96	114	210	60	
3082	140	840	24	158	60	98	10	
3087	24	1170	12	28	60	190	80	
3088	104	780	20	102	46	100	10	
3098	8	600	12	6	18	34	< 10	
3100	8	600	10	4	18	32	< 10	
3101	6	500	10	4	18	28	< 10	
3102	8	630	12	8	14	38	< 10	
3104	56	640	22	164	44	80	10	
11NG0002	400	710	50	720	44	68	< 10	
0006	150	360	18	72	40	25	< 10	
0007a	108	410	18	52	40	37	< 10	
0007b	104	500	26	112	34	43	< 10	
0008	240	600	32	170	45	52	< 10	
0014	265	1040	82	1500	26	48	< 10	
0032	300	640	50	900	40	60	< 10	
0080	5	380	8	< 5	18	-	15	3
0081	5	430	10	< 5	18	-	< 10	9
0082	12	570	18	< 12	12	-	< 24	< 5
0083	< 5	720	16	< 8	12	-	20	< 3
0084	27	940	27	25	25	-	27	5
0085	19	570	16	19	25	-	19	< 3
0088	25	800	27	35	15	-	32	2
0089	43	630	< 35	< 30	57	-	< 60	< 11

TABLE VI - 4

Sample No.	Cr	Mn	Co	Ni	Cu	Zn	Pb	Cd
11NG0090	32	950	25	32	32	-	82	< 5
0093	185	1050	45	70	58	-	27	< 2
0105	95	760	32	160	46	-	21	10
0110	52	750	32	92	45	-	20	5
0111	220	950	45	95	70	-	25	45
0114	120	970	41	125	83	-	19	11
0115A	40	1200	30	45	75	-	< 20	15
0115B	80	1400	35	69	74	-	29	3
0116	35	850	25	22	58	-	20	11
0121	85	1200	45	60	55	-	40	20
0122	38	540	25	21	46	-	21	< 3
0125	72	640	25	65	73	-	12	2
0126	140	580	37	340	53	-	15	11
0127	135	860	37	195	60	-	15	9
0128	65	740	25	90	43	-	22	4
11NG0509	16	720	12	24	24	64	< 10	
0513	400	720	80	1500	38	43	< 10	
0514	170	800	38	115	115	72	< 10	
0515	88	780	32	95	125	76	< 10	
0516	92	760	36	105	120	76	< 10	
0517	215	780	40	300	84	76	< 10	
0526	1400	880	98	1620	18	52	< 10	
0528	520	860	82	1020	28	56	< 10	
0529	290	700	32	340	35	76	< 10	
0569	740	640	95	70	28	-	45	< 2
0570	230	850	45	40	25	-	40	< 2
0574 magnetic fraction	690	890	92	70	20	-	47	< 2
non-magnetic fraction	52	1200	57	52	93	-	45	< 2
0591	165	1700	40	50	25	-	40	2
0593	110	1500	40	47	20	-	32	2
0594	150	1600	42	52	23	-	32	2
0595	62	1030	35	45	48	-	32	5

TABLE VI - 5

Sample No.	Cr	Mn	Co	Ni	Cu	Zn	Pb	Cd
11NG1016	28	740	18	44	45	NS	15	-
1018	28	600	14	46	32	NS	10	
1029	120	740	20	104	46	52	< 10	
1030	48	580	18	66	38	80	10	
1051	18	410	14	28	24	92	10	
1057	78	920	24	90	44	92	10	
1064	150	560	26	210	25	84	< 10	
1066	285	580	38	420	30	35	< 10	
1067	72	460	14	140	25	92	10	
1068	230	560	26	260	28	84	< 10	
1072	30	390	14	44	28	96	10	
1073	92	580	22	148	44	96	< 10	
1075	520	680	82	1600	14	29	< 10	
1076a	104	1220	24	132	68	92	< 10	
1105	48	1600	30	65	85	-	17	< 2
1107	35	1200	31	78	81	-	17	< 2
1110	100	730	31	72	65	-	< 10	< 2
1114	125	780	37	97	69	-	< 10	5
1115	62	1150	27	62	70	-	< 30	31
1116	8	500	15	15	25	-	15	< 2
1118	155	900	34	77	48	-	10	2
1120	65	830	25	44	33	-	10	< 2
1121	18	670	19	27	36	-	15	2
1124	18	600	15	17	21	-	< 10	< 2
1128	30	1000	27	21	44	-	12	< 2
1132	15	650	12	17	21	-	10	< 2
1133	10	480	10	10	18	-	10	< 2
1136	60	600	25	45	30	-	25	< 2
1138	87	750	25	62	69	-	< 10	< 2
1140	18	730	19	12	38	-	12	< 2
1141	20	520	17	17	25	-	20	< 4
1142	59	1000	26	26	65	-	50	< 3
1143	20	850	19	12	48	-	25	< 2
1144	18	1150	19	10	45	-	30	< 2
1162	15	780	31	32	53	-	20	4

TABLE VI - 6

Sample No.	Cr.	Mn	Co	Ni	Cu	Zn	Pb	Cd
11NG1165	32	780	25	57	40	-	15	2
1168	35	1900	34	49	60	-	20	< 2
1171	35	3400	47	97	85	-	25	< 2
1173	340	1020	57	450	40	-	< 10	< 2
1181	270	900	47	610	38	-	12	< 2
1183	40	830	27	62	41	-	12	< 2
1200	45	880	27	97	61	-	12	< 2
1501	18	880	20	20	45	-	22	< 2
1505	25	1050	20	10	50	-	15	< 2
1506	13	830	20	10	40	-	15	< 2
1509	15	800	15	20	25	-	22	< 2
1510	33	1050	25	47	43	-	17	< 2
1517	33	630	15	27	25	-	17	< 2
1521	25	450	15	35	35	-	15	< 2
1525	35	980	25	30	43	-	17	< 2
1528	40	1100	25	52	53	-	15	6
1533	60	1500	35	65	58	-	15	3
1534	58	1000	30	102	50	-	17	< 2
1574	18	650	12	15	20	-	15	< 2
1583	23	1020	25	32	45	-	< 10	< 2
1595	23	1020	25	32	45	-	10	< 2
1599	35	980	25	32	38	-	12	< 2
1602	20	700	25	17	70	-	10	2
2005	20	550	15	25	15	85	< 20	
2006	12	660	24	50	50	165	15	
2009	20	410	14	32	26	75	10	
2009	34	600	18	32	43	53	< 10	
2013	68	660	30	54	102	102	< 10	
2014	16	540	12	22	32	67	10	
2015	24	540	12	52	34	73	< 10	
2016	59	360	12	88	17	66	10	
2018	18	700	14	28	34	96	10	
2019	12	630	12	14	27	66	10	
2023	50	430	20	100	30	80	10	
2026	170	630	22	195	32	71	10	

TABLE VI - 7

Sample No	Cr	Mn	Co	Ni	Cu	Zn	Pb	Cd
11NG2028	26	1080	20	36	74	80	10	
2030	24	460	20	60	34	105	15	
2031	34	400	14	36	28	59	< 10	
2031*	8800	6200	520	400	88	200	< 10	
2032	50	760	24	94	44	88	10	
2032a	36	510	16	46	33	71	< 10	
2036	310	700	42	520	50	80	< 10	
2036*	1060	1700	200	2400	27	54	< 10	
2037*	1600	3200	420	3850	42	86	< 10	
2042*	480	1840	215	2250	20	80	< 10	
2044	500	840	90	1420	34	54	< 10	
2045*	900	1650	195	2350	30	72	10	
2046	1220	1080	128	1760	22	65	< 10	
2048*	4700	3700	220	2200	30	120	< 10	
2050*	700	2900	420	4100	24	82	< 10	
2051	210	780	64	1020	32	60	< 10	
2053	260	430	24	270	84	40	10	
2053	1250	580	28	240	42	64	15	
2060	1080	1280	122	1550	44	71	< 10	
2070	395	740	90	1550	18	34	< 10	
2076*	1400	1760	280	3950	34	73	< 10	
2511	265	1140	28	142	48	122	15	
2512	235	660	54	720	43	62	< 10	
2533	68	500	18	80	38	64	10	
2536	320	700	40	390	28	86	10	
2540	270	420	32	330	62	36	10	
2550	12	500	14	16	29	65	10	
2551	24	620	22	32	42	84	10	
2554	44	580	22	52	29	88	10	
2561	56	820	22	84	52	93	10	
2589	235	540	32	390	36	65	10	
2598	34	780	30	98	64	105	15	
2600	105	960	34	155	82	93	< 10	
2604	90	640	30	165	28	98	10	
2619	170	700	40	350	52	60	< 10	

TABLE VI - 8

Sample No	Cr	Mn	Co	Ni	Cu	Zn	Pb	Cd
11NG2632	355	840	78	1000	28	59	< 10	
2634	28	740	16	40	33	78	10	
2638	26	1060	20	58	40	84	10	
2639	28	660	10	10	30	48	< 10	
2642	12	560	12	38	27	68	10	
2643	20	740	12	16	22	115	15	
2651	16	440	14	24	22	58	10	
2673	50	600	16	40	30	76	10	
12NG0513	30	800	16	16	76	62	10	

* Soil sample

NS-not significant, since the sample was in a paper bag (see Laboratory Report No. 24, 1967).

All the samples contained less than 1 ppm cadmium except Nos 03NG1053 and 11NG1016 each of which contained 1 ppm.

Samples 11NG0528 and 11NG2632 were collected at the same site on different dates.

TABLE VII

SPECTROGRAPHIC ANALYSIS OF SAMPLES FROM WABAG TNG.

by

E.J. Howard and A.D. Haldane

Semiquantitative estimations were made of the nickel, cobalt, copper, vanadium, molybdenum, tin, lead and beryllium content of stream sediment samples from Wabag TNG. The samples were submitted by F. Dekker.

The following results are expressed in parts per million.

Sample No.	Ni	Co	Cu	V	Mo	Pb
F1	20	20	20	70	-	a
F2	15	15	10	50	-	5
F5	20	20	20	150	-	5
F10	15	20	15	100	-	a
F13	10	15	10	50	-	a
F16	5-	20	30	150	-	5
F17	20	20	30	150	-	5
F18	10	15	15	30	-	5
F20	15	20	20	150	-	a
F24	20	15	15	100	-	a
F25	20	15	15	70	-	a
F27	20	15	20	70	-	5
F30	20	15	20	70	-	a
F31	20	20	20	70	-	a
F35(1)	15	15	15	50	-	a
F35(2)	20	20	20	100	-	5
F39	20	15	20	50	-	5
F42	20	20	15	70	-	5
F53	10	15	15	70	-	5
F56	5-	15	10	100	-	a
F57	5-	15	10	100	-	a
F59	5-	15	15	70	-	a
F60	5-	15	10	70	-	a
F63	15	15	15	50	-	10

TABLE VII - 2

Sample No	Ni	Co	Cu	V	Mo	Pb
F509	60	30	30	70	-	5-
F537	80	30	30	150	-	5
F544	60	20	50	150	-	5
F512	60	30	30	200	-	a
F548	30	30	20	200	-	a
F549	30	20	20	70	-	5
F589	60	20	20	100	-	a
F511	30	20	10	200	-	a
F7	40	20	20	150	-	5
F550	30	20	20	100	-	5
F515	80	30	30	100	-	5
F506	60	20	20	100	-	a
F539	40	20	30	150	-	5
F504	40	30	20	200	-	a
F529	30	20	20	100	-	a
F544	40	30	20	150	-	10
F517	40	40	30	200	-	a
F584	20	30	20	300	-	a
F585	10	15	20	70	-	5
F586	15	20	20	70	-	a
F587	15	20	30	150	-	a
F588	30	20	20	50	-	5
F502	15	30	30	300	-	a
F503	60	40	30	100	-	a
F513	60	30	20	100	-	a
F52 -	Insufficient sample for analysis					
F839	5-	5-	25	5	-	-
F173	30	60	100	100	-	200
F101	10	60	25	500	-	-
F812	5	80	50	700	-	-
F803	5	20	25	500	-	20
F218	10	20	25	300	-	10
F778	100	20	40	200	-	20
F848	5	5	15	10	-	10
F836	150	20	25	200	-	-

TABLE VII - 3

Sample No	Ni	Co	Cu	V	Mo	Pb
F858	10	15	15	200	-	-
F843	10	10	25	10	-	-
F854	12	20	15	100	-	70
F84	5	5	15	20	-	-
F816	12	30	40	200	-	20
F245	60	20	40	500	-	-
F802	30	30	40	500	-	-
F226	30	15	25	100	-	-
F777	200	20	25	200	-	-
F222	12	15	40	100	-	-
F842	10	15	20	50	-	-
F841	10	15	15	200	-	-
F833	20	20	25	200	-	-
F851	10	15	25	200	-	-
F47	15	20	15	100	-	10
F847	10	15	10	150	-	-
F89a	5-	20	50	200	a	30
F89b	100	60	25	200	a	a
F89c	20	30	50	200	a	10
F266	5-	5	40	100	5	300
F267	20	15	5	100	a	70
F269	5-	15	10	200	a	50
F273	10	10	15	50	5	300

Tin and beryllium were not detected in any sample.

Plate Nos. 504, 505, 506, 673, 716

Lab. serial No. 1069

TABLE VIII

ANALYSES OF SOME ULTRAMAFIC ROCKS FROM THE SOUTH SEPIK REGION, N.G.

by

A.D. Haldane

Atomic absorption determination of trace metals in samples of ultramafic rocks, collected by the Sepik Party, and digested in HCl (and in some cases, also in HF), gave the following results.

Sample No	%Ni	Co(p.p.m.)	Cu(p.p.m.)	Zn(p.p.m.)	Notes
11NG0004	0.19	110	15	30	
0004A	0.20	95	25	30	
0005	0.18	110	25	40	
	0.19	90	25	40	repeat
0006D	0.002	25	470	70	
	0.004	35	500	30	HF digestion
0014	0.16	95	5	30	
0014A	0.20	90	15	40	
0015	0.18	105	20	30	
0015A	0.19	85	25	< 5	
0016	0.18	85	5	40	
0513A	0.19	110	10	30	
0523A	0.19	85	20	35	
0523B	0.19	90	5	95	
	0.20	100	10	110	repeat
0523C	0.21	110	20	120	
	0.22	120	20	150	repeat
0524C	0.16	85	< 5	25	
0524E	0.20	90	20	45	
	0.20	110	20	110	
1041	0.18	85	20	30	
2036A	0.16	25	30	90	
	0.16	90	30	110	repeat
2040C	0.02	30	145	65	
	0.02	35	160	60	HF digestion
2075	0.16	95	15	30	
2510	0.19	90	10	35	
2523	0.18	45	10	120	

TABLE VIII - 2

Sample No	%Ni	Co(p.p.m.)	Cu(p.p.m.)	Zn(p.p.m.)	Notes
11NG2523	0.19	60	10	120	repeat
2525	0.19	85	15	N.D.	
	0.18	95	10	110	repeat
2528	0.15	65	15	40	
2529	0.17	80	20	100	
	0.17	90	20	110	repeat
2545	0.19	85	20	30	
2624	0.18	75	25	40	
	0.18	75	25	105	repeat
	0.19	90	25	120	repeat
2627D	0.02	20	30	20	
	0.03	35	40	20	HF digestion
3003	0.16	50	5	35	
3004	0.15	75	35	110	
	0.16	85	35	110	repeat
3006	0.17	90	20	30	
3010	0.20	135	5	25	
3013	0.21	135	30	60	
	0.22	130	35	180	repeat
3061	0.001	< 5	< 5	30	
	0.005	30	20	130	HF digestion
03NG0002	0.21	95	5	30	
0002A	0.20	90	10	35	
0006	0.19	100	5	50	
0009	0.24	100	10	30	
0022	0.04	35	15	40	
	0.06	40	15	40	HF digestion
0024	0.08	40	40	40	
0030A	0.20	90	5	25	
0030Z	0.20	95	5	30	
0044	0.20	90	35	20	
0044A	0.18	95	15	35	
0046	0.16	90	5	40	
0046A	0.20	100	< 5	25	

TABLE VIII - 2

Sample No	%Ni	Co(p.p.m.)	Cu(p.p.m.)	Zn(p.p.m.)	Notes
C3NG00468	0.20	90	10	30	
0505	0.14	75	5	40	
0506	0.16	75	25	45	
0533A	0.07	65	140	35	
	0.07	80	135	30	HF digestion
0533C	0.07	50	115	40	
	0.08	70	120	30	HF digestion
0533D	0.17	100	< 5	35	
2510A	0.10	55	5	30	
3036	0.19	100	5	30	
3036A	0.18	80	10	25	
3036B	0.17	80	15	20	
3042	0.004	5	35	10	
	0.026	60	50	220	HF digestion
3044	0.15	85	15	20	
3055	0.15	70	25	50	
3063	0.17	95	< 5	35	
3067	0.17	90	30	35	
3082	0.02	20	20	35	
	0.06	55	40	170	HF digestion
3091	0.18	80	35	40	
3097	0.20	95	35	40	
3103	0.008	25	55	45	
	0.013	40	250	50	HF digestion

PLATE 1

To accompany Record 1968/80

GEOCHEMICAL SAMPLE LOCALITY MAP
SOUTH SEPIK REGION
TERRITORY OF NEW GUINEA
1968
Scale 1:250,000
2508 Stream sediment sample
0506 Total rock analysis
F850 Stream sediment samples collected by Dekker and Faulk.
1052 Anomalously high Cu value
2100 Anomalously high Mo value
0032 Anomalously high Ni value.
Plate 2 To accompany BMR record 1968/80
HUNSTEIN RANGE
DOUBLE MOUNTAIN RANGE
CENTRAL RANGE
SCHATTEBURG MOUNTAINS
Leonard Schultze (Waleu) River
Wogamush
Lagaip River
Porgera River
Kaiya River
Maramuni River
Ambum River
Lai River
WABAG
LAIAGAM
PORGERA
KOMPIAM