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A GEOLOGICAL RECONNAISSANCE IN THE NASSAU RANGE

WEST NEW GUINEA

by

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INTRODUCTION

An attempt to climb Carstensz Pyramid in West New Guinea, the highest mountain in Oceania, was the main objective of the 1961 New Zealand-New Guinea Expedition, for which I was geologist and transport officer. We were the first expedition to use the northern approach to the Pyramid, and the country traversed was completely unknown geologically.

The Pyramid is part of the Carstensz Mountains, which are the culmination of the Nassau Range, the backbone of West New Guinea. The Pyramid is about 17,000 feet high, and the Mountains are capped by a large icefield which was first seen from the south coast by the Dutch navigator, Jan Carstensz, in the seventeenth century. However, it was not until 1912 that the English explorer Wollaston penetrated the southern swamps and foothills, and found the icefalls feeding the Tsinga River (Wollaston 1914). In 1926, the Dutch expedition of Colijn, Wissel, and Dozy (Dozy 1939), travelling from the south coast by way of the Otomana River, reached the Carstensz Mountains and climbed the ice peak of Ngga Poloe. They mapped the geology of the south side of the range, and the Carstensz Mountains, but they did not penetrate north of the main range.

The first exploration north of the main range was after World War II, when two parties of missionaries explored the area between Wamena and the Wissel Lakes (locality map Plate 1). By 1961 several airstrips had been constructed north of the Nassau Range, the nearest being at Ilaga, only five days walk from the Carstensz Mountains.

We planned to fly to Ilaga, then walk to the Mountains, carrying a minimum of equipment, to receive an airdrop. Our plans received a set-back when the Christian Alliance and Missionary Association which controls the airstrip at Ilaga would not allow us to land, and consequently we had to start from the Australian Baptist Mission at Tiom, a further eight days walk from the Mountains (Figure 1). We could recruit only eight carriers so as a further impost we had to carry heavy loads throughout the journey. The natives in the intervening country are hostile and warlike, and we were attacked on the second day out (Temple 1961). Though we eventually evaded the attackers, the rest of the journey was a forced march.

Bad weather during the whole of our stay near the Mountains forced the cancellation of the airdrop, and we had to retreat without making a climbing attempt. As we had been living on native foods from the moment we arrived in Ilaga, and including the walk to the Mountains, our return journey was a matter of survival, and I lost any chance of doing further geological work.

Most of the geology described below was therefore deduced from hasty observations taken during the march. However, as much of the geology of the bare-topped ranges was obvious from a distance, it was possible to gain a good idea of the geology of a much larger area than would normally be possible during such a brief visit.

An inaccurate patrol map was the only one available for the area between Wamena and Ilaga, so I mapped using march time on compass bearings, a suitable method as our pace did not vary greatly, and the native tracks followed constant bearings for many miles at a stretch. The area between Ilaga and the Carstensz Mountains was covered by recently published maps compiled from airphotographs, which we found to be reasonably accurate. As our only barometer was broken early in the trek the heights given in the report were estimated against known heights, such as the Carstensz Mountains, Ilaga, etc. and may be as much as 1000 feet in error. However, our estimates of some features agreed closely with those of pilots flying in the area and the error is probably much less.

PHYSIOGRAPHY

The Nassau Range forms the backbone of the central part of West New Guinea. It is a high, rugged mountain chain, almost entirely bare limestone, cleft by deep, steep-sided ravines, sinkholes, and other solution phenomena. Glacial landforms such as deep U-shaped valleys and cirques are common, and the Range presents a spectacular skyline. Rare patches of snowgrass and concentrations of stunted shrubs in the ravines are the only vegetation.

The Range is between 12,000 feet and 17,000 feet high, and consists of several mountain chains which trend slightly north of west, arranged en echelon. These mountain chains decrease in elevation to both the east and west, finally merging with bush-covered foothills and giving way to a new mountain chain to the north-east.

The Nassau Range culminates in the Carstensz Mountains, the highest in New Guinea, a truly alpine massif, in the south-western corner of the map area (Fig.4). The massif consists of several peaks over 16,000 feet high encircling an icefield about five square miles in area. The icefield has an average elevation of about 15,000 feet, and it breaks through the surrounding peaks as several steep ice falls.

North of the Carstensz Mountains, and separated from them by the steep scarp of the Nordwand, is a rolling plateau which I have called the Kemaboe Plateau. It is between 10,000 feet and 12,000 feet high above sea level, and is drained by the Kemaboe River on the west, and by the headwaters of the Zenggilorong River on the east. These rivers flow sluggishly, and meander between low, rounded ridges whose relief rarely exceeds 500 feet. Most of the Plateau is covered by snowgrass with patches of stunted scrub or bush, from a few acres to several square miles in area. Where bare limestone is exposed it is dissected by sinkholes, deep solution channels (Fig. 5), and spectacular lapies (Fig. 6), which are difficult and often dangerous to traverse.

Glacial features such as moraine ridges, lakes and tarns, and roches moutonnees abound, and the southern margin of the Plateau is dissected by U-shaped glacial valleys carved during the Pleistocene, by glaciers which had their source in the Carstensz Mountains.

The West and East Baliem Rivers flow along a remarkable trough which I have called the West Baliem Valley (Fig. 3). It is almost straight, and extends from the Ilaga River to Lake Habbema, a distance of 65 miles. It is bounded on the south by a scarp, up to 3000 feet high, which forms the northern front of the Nassau Range. The floor of the valley is nearly flat, and is about 8000 feet above sea level. In its central part piedmont fans from the Nassau Range have pushed the East and West Baliem Rivers to the north, and this section is relatively well drained, but to the west the floor is mainly swampy and imposes very arduous travelling. The valley floor is generally grass-covered, but the sides have dense bush cover, and carry good stands of what appears to be millable timber.

The Great Baliem Valley, which supports the largest population and has the administrative centre of Wamena, is an east-south-eastern, alluvium-filled valley. It is about 20 miles long, and about ten miles wide at it widest part. Like the West Baliem Valley it is fault controlled, and a prominent fault scarp forms the southern margin; gradually rising limestone hills culminating in high bluffs form the northern wall. The Baliem River flows south-eastwards along the Valley, and breaks through the Nassau Range in a magnificant gorge to reach the sea on the south coast.

To a person accustomed to seeing the results of rapid erosion in the high-rainfall areas of eastern New Guinea, the most striking feature of the region is, despite the great elevation and relief of most of the country, the extreme slowness of the erosion. On the plateaux the rivers are at grade, and even after days of continuous rain they are crystal clear, and flow sluggishly. Almost all the exposed rocks of the Range are massive limestone or friable sandstone, so the rivers have no hard detritus to use to erode their beds. Erosion therefore, is almost entirely due to solution of limestone; most of the rivers are saturated with lime, and lime pisolites are at present being deposited in many of the lakes.

The lowering of the base level of the region is controlled largely by the resistant gorges in the lower reaches of the Zenggilorong, Ilaga, and Baliem Rivers. Erosion in these gorges also is very slow because there is no supply of hard detritus from upstream to erode the bedrock.

GEOLOGY

An outline of the stratigraphy of the Nassau Range is given in Table 1:

TABLE 1

SUMMARY OF STRATIGRAPHY

NASSAU RANGE, WEST NEW GUINEA

AGE		UNIT	LITHOLOGY
QUATERNARY		undifferentiated	Peat, gravel, piedmont deposits.
	Pleistocene	Glacial Deposits	Moraine, and glacial outwash deposits
unconformity			
TERTIARY	Lower Miocene (Tertiary e-stage to f_{1-2}-stage)	Meleri Beds	Calcareous siltstone, marl, glauconitic sandstone. Prominent limestone member.
	Upper Oligocene		Andesitic tuff and agglomerate, tuffaceous graywacke, and conglomerate. Minor calcarenite. Coeval porphyritic andesite intrusions.
	Upper Eocene to Lower Miocene (Tertiary f_{1-2}-stage)	Carstensz Limestone	Calcarenite, sandy limestone, algal limestone.
probable unconformity			
?MESOZOIC			Very clean quartz sandstone, quartz siltstone, quartzite, and carbonaceous quartz siltstone. Minor fine-grained limestone

The Range consists of a series of horsts of probable Mesozoic quartz sandstone capped unconformably by Eocene to Lower Miocene limestones called the Carstensz Limestone. The horsts have reacted competently to stress, and the capping limestone is only generally warped. North of the Range are grabens containing Upper Oligocene andesitic volcanic rocks, and marl, calcareous siltstone, and sandstone which is the same age as the limestone of the Main Range.

Pleistocene glacial deposits are extensively developed on the high plateau country north of the main range: they can be divided into Older and Younger Glacials.

? Mesozoic Quartz Sandstone

Quartz sandstone and quartzite crop out between the Melori and West Baliem Rivers, and in the headwaters of the Zenggilorong and Kemaboe Rivers. In addition, piedmont deposits on the north side of the Ilaga Valley are composed almost entirely of quartz sandstone boulders derived from the de Burght Range to the north. An aerial reconnaissance showed that these rocks form an easterly-trending belt from the Zenggilorong River to the Baliem River, and probably beyond Mount Wilhelmina south-east of the map area.

The most common rock type in these Beds is a well-sorted quartz sandstone of remarkable purity. It is a medium-grained to fine-grained, well-sorted, and composed entirely of sub-angular to angular quartz grains: it is generally friable, but with recrystallisation it grades into quartzite. The rock is almost invariably massive, but thin bedding was seen in a few places south of the Meleri River. Much of the sandstone is less well-sorted, and is composed of quartz grains of all sizes down to quartz silt. Some of the finer beds are quartz siltstone, but no argillaceous material was seen in the formation.

South of the Meleri River, rare lenses of very fine-grained white and grey marble up to 50 feet thick were seen.

The nature of the rocks of the de Burght Range north of Ilaga is inferred from boulders in the piedmont deposits and in streams draining the range. The rocks are similar to those south of the Meleri River, but they appear to be more indurated and less well-sorted, probably because the more friable rocks did not survive transportation to the piedmont deposits. In addition, black to dark grey carbonaceous quartz sandstone is common in the piedmont deposits. Laminae, thin-bedding, or cross-bedding can generally be distinguished in the boulders.

Pure quartz sandstone of such great thickness and extent denotes an unusual environment of deposition. It was probably laid down under the sea, as shown by the presence of limestone lenses. The only fossils found in the sandstone were worm casts, and very poorly preserved indeterminate macrofossils near Solstice Pass, which were almost certainly marine. In order to cause the breakdown of all but the most resistant minerals, and to allow the almost perfect sorting which has taken place, the detritus was probably derived from a low-lying landmass, and transported a great distance. Exposure to wave and current action for long periods on a shallow shelf would allow further sorting.

The only evidence for the age of the beds is the fact that they underlie, almost certainly unconformably, upper Eocene limestone of the Carstensz Limestone. Quartz sandstone, quartzite, quartz siltstone, conglomerate, and fine-grained limestone were noted by Wollaston (1914) and Dozy (1936) south of the Carstensz Mountains. These beds were regarded by Dozy as probable Mesozoic. Clean quartz sandstone of Jurassic and Cretaceous age have been recorded in Western Papua (A.P.C. 1961) and it is possible that the quartz sandstone north of the Nassau Mountains is the same age.

Carstensz Limestone (New Name)

The Nassau Range is composed of a great thickness of Eocene to Lower Miocene limestone which I have called the Carstensz Limestone. The name is derived from the Carstensz Mountains, the highest in New Guinea, which are situated at about longitude 137°10'E, latitude 4°5'S. The Limestone crops out in the map area along the Nassau Range between Carstensz Mountains and the East Baliem River. It overlies, probably unconformably, the probable Mesozoic quartz sandstone and in places is overlain unconformably by Pleistocene glacial deposits.

The rocks of the Limestone are calcarenite, foraminiferal and algal limestone and rare chemically deposited limestone. The most common rock is a fine-grained yellow calcarenite, generally partly recrystallised, which occurs as massive beds up to 200 feet thick. It consists of sub-angular to rounded fragments of calcite, andrare shell fragments; foraminifera can rarely be distinguished under the hand lens. Flaggy calcarenite is common: it is generally fine-grained to medium-grained and is composed of rounded to sub-angular fragments of calcite and shell fragments in a partly recrystallised calcite matrix. Larger foraminifera are commonly seen in hand specimens of these rocks.

Scattered, sub-angular to rounded quartz grains constitute a small proportion of both rock types, and in one sample examined in thin-section, quartz grains make up about half the rock. Brown and green glauconite commonly fills tests of foraminifera, and in one thin-section green glauconite has partly replaced rounded fragments of calcite. Yellow algal limestone was seen in several localities, notably near Geberi Lake. It is thin-bedded and is composed of algae and many algal fragments in a matrix of fine-grained calcite. The rock grades into a very fine-grained crystalline limestone which was probably chemically deposited.

White marble resulting from contact metamorphism was seen near the margins of porphyritic andesite intrusions in the head of the Kémaboe River.

The Carstensz Limestone appears to overlie the Mesozoic sandstone unconformably, but as bedding is rarely seen in the sandstone there was no opportunity to prove this during the march. However, on the east bank of the Zenggilorong River, two miles east of Solstice Pass, flat-lying Carstensz Limestone was seen from a distance overlapping steeply dipping sandstone, and in the same area flat-lying basal limestone occupies hollows up to 100 feet deep in the sandstone.

As rock samples had to be carried out by party members, only limestones with rich assemblages of foraminifera were collected. A total of eleven samples, including four from boulders in the head of the West Baliem River, were examined by Dr. I. Crespin and Dr. D.J. Belford of the Bureau of Mineral Resources. The rocks range in age from Upper Eocene to Lower Miocene, but as no samples of Oligocene age were collected, there is a strong possibility that this was a time of erosion or non-deposition, though no evidence of unconformity was seen within the formation. Upper Eocene limestone is undoubtedly intruded by andesite porphyry in three localities in the headwaters of the Kemaboe River, and it seems likely that this igneous activity took place during uplift in Oligiocene time (see Volcanic Rocks).

The absence of shallow-water organisms indicates that the Carstensz Limestone was deposited in fairly deep water. The paucity of arenaceous and argillaceous material indicates either proximity to a low-lying landmass supplying little detritus, or, more probably, a remote shoreline.

The thickness of the Limestone is not known, but it is at least 3,000 feet, and is possibly much greater.

Andesite Volcanic Rocks

Andesitic volcanic rocks crop out between the head of the West Baliem River and the Zenggilorong River, but they were not examined in detail.

East of Ilaga, massive agglomerate and crystal tuff were seen. The agglomerate consists of angular fragments of andesite porphyry up to one foot across on a medium-grained tuff matrix. The crystal tuff is medium-grained and generally contains abundant broken crystals of sanidine which are resistant to weathering and form a residual surface mantle up to half an inch thick in places.

West of Ilaga some of the volcanics were deposited under water and the rocks are generally well-bedded. The agglomerate is similar to that described above, but the crystal tuff is generally medium-bedded and contains little or no sanidine. Pebble, cobble, and boulder conglomerate are common in this area; the pebbles and boulders are well-rounded, composed mainly of porphyry, basalt, and some quartzite, in a sandy matrix. The quartzite components were almost certainly derived from the Ambum Beds, and are further evidence of the unconformable nature of the contact between these probable Mesozoic rocks and the Tertiary rocks.

Only west of Ilaga was structure observed in the volcanics; here the beds dip to the north at about 40°.

Andesite porphyry crops out extensively between the West Baliem River and Ilaga River. It appears to intrude the surrounding Carstensz Limestone but no contacts were seen. However, exposures were uniform in texture and composition, and in the absence of any volcanic feature it is assumed that most of the rocks are intrusive. They are almost the same composition as the volcanics and are regarded as the intrusive equivalent.

Porphyry of similar composition was seen between the head of the Ilaga River and the Zenggilorong River associated with agglomerate and crystal tuff, and three small bodies of andesite porphyry intrude Upper Eocene limestone in the head of the Kemaboe River.

Eleven representative samples from the above localities were examined in thin section. They are all classed as andesite porphyry and comprise euhedral phenocrysts of plagioclase feldspar, biotite, augite, and hornblende in varying proportions, in a fine-grained matrix which is generally of similar composition. Sanidine is present in most of the samples collected from east of Ilaga; it is generally in accessory amounts but in two samples it occurs as large phenocrysts which constitute about 20% of the rock.

The groundmass is generally fine-grained and is either trachytic or granular in texture.

The rocks are generally metasomatised: the feldspar is kaolinised, commonly to such an extent that the original composition cannot be determined. Ferromagnesian minerals are partly altered to chlorite and iron oxide, but accessory sulphides are generally lacking.

The age of the volcanics is doubtful but the following facts are known:

(1) Andesite porphyry intrudes the probable Mesozoic sandstones, and Upper Eocene Carstensz Limestone.

(2) Basal Lower Miocene marl and calcareous siltstone overlie the volcanic rocks and the basal members are baked by a porphyry intrusion.

It is probable therefore that the volcanics are Oligocene to Lower Miocene in age. Such an age is supported by the fact that nowhere are younger rocks known to be intruded by the porphyry.

West of Ilaga the volcanics were laid down under water but to the east they were probably subaerially deposited. No idea of the thickness of the volcanics was obtained during the survey.

Meleri Beds (New Name)

A sequence comprising mainly marl and calcareous siltstone is called here the Meleri Beds. The name derives from the Meleri River which drains the area west of Tiom.

The rocks crop out on the northern side of the Meleri

Valley faulted against the Mesozoic Sandstone and appear from the air to extend eastwards to the Great Baliem Valley. They are marl and calcareous siltstone with a prominent limestone member (Fig.2), and lenses of calcarenite and minor glauconitic sandstone.

The unweathered marl and calcareous siltstone is light grey to dark blue in colour but weathers to a yellow clay; it is generally massive or thick-bedded and commonly shows current bedding. Interbedded lenses of fine-grained to medium-grained calcarenite are common. Boulders of glauconitic sandstone composed of well-rounded and well-sorted grains of quartz and glauconite in an argillaceous matrix were found in small tributaries draining the north side of the valley, but the rock was not found in situ.

The limestone member is up to 800 feet thick and can be traced from the junction of the Meleri and West Baliem Rivers westwards for at least 16 miles. It is composed mainly of medium-grained calcarenite which shows no bedding, and is partly recrystallised.

Foraminifera from a sample of limestone float gave the age as basal Lower Miocene (e-stage). The sample almost certainly came from one of the calcarenite lenses overlying the limestone member, but there was no opportunity on the traverse to confirm this.

A sequence of marl and calcareous siltstone cropping out at the head of the Ilaga Valley is referred to the Meleri Beds. The rocks are massive grey to yellow calcareous siltstone, and marl, which overlie volcanic rocks in the Ilaga Valley. In places the siltstone is carbonaceous, and in the coarser grade sediments it grades into calcareous quartz siltstone.

Marl near the base of the sequence in the Zenggilorong watershed has been baked by andesite porphyry which could be either a lava flow, or more probably, a small dyke.

Four samples of the marl containing foraminifera were collected, including one which has been baked by the andesite. The age of the fauna is basal Lower Miocene and the rocks are therefore correlatives of the Meleri Beds.

Poorly exposed marl, calcareous siltstone, and calcareous shale, with many lenses of fine-grained calcarenite, were observed along the Baliem River north of the West Baliem River. These rocks are tentatively referred to the Meleri Beds on the basis of similar lithology. No foraminifera were seen in these rocks.

Glacial Rocks

There is ample evidence that the Nassau Range, and the high plateaux on the north flank, were eroded by an extensive cover of ice during the Pleistocene. The Nassau Range presents a spectacular skyline, being cleft by deep U-shaped valleys and cirques for most of its length, while deep glacial valleys studded with lakes and tarns have been carved north of the Carstensz Mountains.

Glacial deposits called here the Younger Glacials form a discontinuous cover on parts of the main range over 12,000 feet, especially around the Carstensz Mountains but also on the watershed between the Baliem and Ilaga Rivers. Older outwash fans of probable glacial origin have been called Older Glacials.

Older Glacials

These are dissected valley-fill deposits which form rounded north-trending ridges within about five miles of Carstensz Mountains. They are mainly alluvial deposits consisting of angular to rounded boulders of limestone up to several feet across, in a fine-grained calcareous matrix. They are roughly stratified, and dip away from the main range at between 5° and 25° (Fig.7).

They are probably glacial outwash fans resulting from an early glaciation but it is possible that they resulted from rapid uplift of the Carstensz Mountains. They have been deposited on a surface eroded on Carstensz Limestone, and in places rest in valleys over 800 feet deep.

Younger Glacials

Younger Glacials unconformably overlie the Older Glacials: they are best developed near the Carstensz Mountains, but form a discontinuous cover over that part of the region higher than 12,000 feet. They are directly related to glacial valleys which in many cases are carved in the Older Glacials, and consist mainly of terminal and lateral moraines. However in areas of low relief, there is a mantle of ground moraine which was probably deposited under thin ice caps.

The valley glaciers were deeper and longer in the immediate vicinity of the Carstensz Mountains, and were no doubt fed by a large icefield which capped the Mountains. It is therefore puzzling that the large glacial valleys which extend for about five miles east of the Carstensz Mountains are backed only by a narrow, low part of the Nassau Range. The valleys are at right angles to the range, and cannot be matched by any glacial erosion features on the range. Immediately south of the main range in this locality is the awesome drop into the headwaters of the Tsinga River, which must have been eroded before the last glaciation. It is therefore conceivable that the Carstensz Mountains have been moved several miles to the east by clockwise transcurrent movement along the large faults on the north side of the range (see Structure). However, conditions were not ideal during our stay close to the Carstensz Mountains and we could have missed evidence of important feeder glaciers from the Carstensz Mountains, which, if they existed, must have flowed eastwards along the range then turned sharply north.

STRUCTURE

Long straight faults of large displacement are the major structural features of the Nassau Range (Fig. 3). Late Tertiary movement on these faults broke the region into a series of east-west grabens and horsts, and only south of the main range has erosion greatly modified the tectonic landforms so produced.

The faults trend slightly north of west, are invariably straight or slightly curved, and can be traced for up to 80 miles. They generally have imposing fault scarps, and are arranged in an interesting en echelon pattern shown on the Geological Map (Fig. 1).

Each fault has at its western end a large downthrow to the north, which becomes progressively smaller to the east. The total vertical displacement across the Nassau Range however, appears to be constant, and the throw is taken up in each case by an echelon fault to the north. From a distant aerial view on the return journey it seems that the pattern continues to the east of Wamena, and a study of available maps indicated that the same is true of the main range west of the Carstensz Mountains.

The de Burght Range is exceptional and appears to be an isolated horst.

The maximum vertical displacement on the faults is not known, but appears to be of the order of 3000 feet to 5000 feet. It is possible that transcurrent movement has taken place along the faults, and it might even be dominant. There is no evidence to support this contention, but the faults are remarkably similar to the Owen Stanley Fault and the Bundi Fault Zone in eastern New Guinea, which show evidence of recent horizontal displacements of several miles (Dow and Davies

1964, and Dow and Dekker 1964). The apparently beheaded glacial valley near the Carstensz Mountain may have been caused by similar transcurrent movement.

Gentle folding and warping of the Tertiary rocks has accompanied the faulting. The rocks of the main range are flatlying or gently folded, except close to the faults, where flat slabs of limestone up to several miles long and ¼ mile long are commonly found dipping steeply towards the faults. These steep dips do not appear to have resulted from drag on the faults but rather by solution of limestone along the fault with subsequent collapse of the limestone roof.

I did not map in the Carstensz Mountains, but Dozy (1936) mapped several tight folds in the area. The fault of the Nordwand separated these tightly folded rocks from gently dipping rocks of the Kemaboe Plateau.

One important observation resulting from the study of the foraminifera by Crespin and Belford, is that the sediments deposited in the area now occupied by the grabens at Ilaga, Tiom, and probably the east Baliem River, differ from sediments deposited at the same time on country now forming horsts. One explanation is that faulting was already active in Lower Tertiary times, and had broken the region into submarine grabens and hosts which controlled the sedimentation. Thus during the earliest Miocene time, fine terrigenous material accumulated in the grabens to form the Mclcri Beds, while organic limestones almost free of terrigenous matter were deposited on the horsts. A similar structural graben under the Huon Gulf south-east of Lae in eastern New Guinea is at present accumulating sediments supplied by the Markham River (W.C. White pers.comm) while reef limestones are forming on the coastal shelf.

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Figure 2: Heading up the Moleri River shortly after leaving Tiom. The valley is underlain by Lower Miocene Moleri Beds: the dip slope in the middle background is formed by resistant limestone, while the bush-covered hill on the extreme left consists of upfaulted Mesozoic ? quartz sandstone. (G5208)

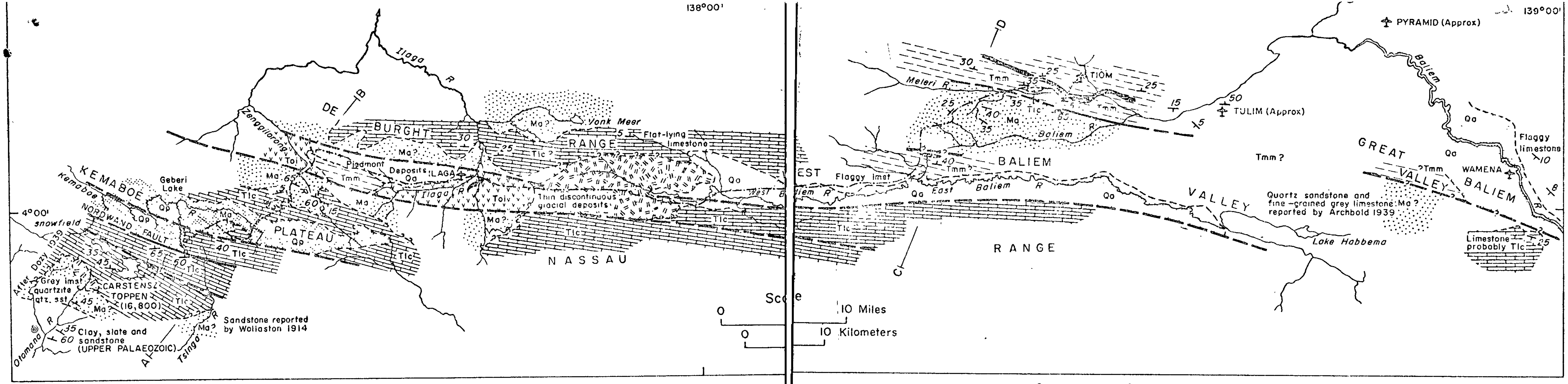
Figure 3: Looking eastwards along the West Baliem River, towards the East Baliem River about 16 miles away. The steep scarp on the right forms the northern front of the Nassau Range, a minor peak of which can be seen on the right. Total relief from the top of the range to the valley floor is about 5000 feet. (G5209).

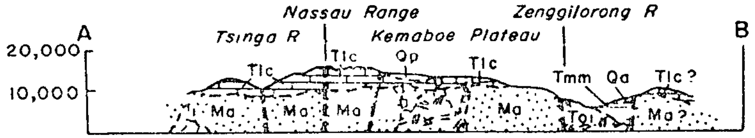
Figure 4: The north-eastern face of the Carstensz Mountains covered by a sprinkling of fresh snow. The peak of Ngga Poloe can be seen almost obscured by cloud on the left, and the edge of the icefield can be seen on the extreme right. All the rocks showing are Carstensz Limestone. (G5215)

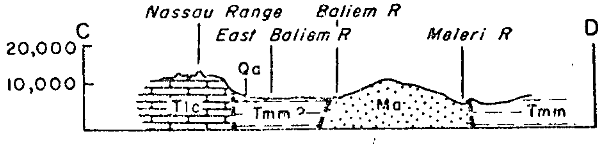
Figure 5: View from the head of the Zenggilorong River looking south towards a saddle in the Nassau Range. The gentle dips shown are typical of the Carstensz Limestone in the Nassau Range. The snowgrass in the solution channels in the foreground often covers deep clefts, and we generally used the intervening plates of limestone as stepping stones, an arduous method, but not as hazardous as walking between. (G5203).

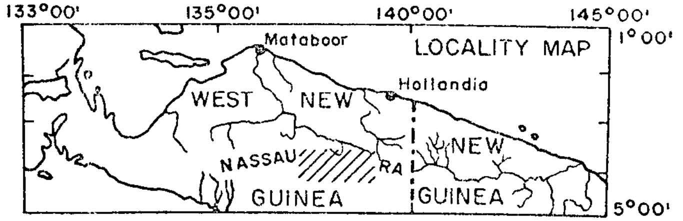
Figure 6: Lapies in Carstensz Limestone. Fortunately such areas were small, and we always managed to by-pass the worst. (G5206)

<u>Figure 7</u>: Unnamed lake in the head of the Kemaboe River, which was eroded by the later glaciation. The sloping beds behind the lake are outwash deposits consisting of angular and rounded boulders of limestone in a fine-grained calcareous matrix, which are regarded as outwash fans resulting from an earlier glaciation. (G5214)









REFERENCE

QUATERNARY	Undifferentiated		Qa	Peat, gravel, piedmont deposits
	PLEISTOCENE	Glacial Deposits	Qp	Moraine, glacial outwash deposits
TERTIARY	LOWER MIOCENE	Meleri Beds	Tmm	Calcareous siltstone, marl Calcarenite
	OLIGOCENE		Toi	Andesitic tuff and aglomarate, tuffaceous greywacke and conglomerate Calcarenite Porphyritic andesite
	EOCENE TO MIOCENE	Carstensz Limestone	Tlc	Calcarenite, algal limestone
MESOZOIC ?			Ma	Quartz sandstone, quartzite, micaceous quartz sandstone, grey limestone

- — — — *Geological boundary position approximate*
- —?—?— *Geological boundary inferred*
- *Fault, broken where approximate, queried where inferred*
- *Strike and dip of strata*
- *Strike and dip of major joints*
- —·—·— *Route followed*
- *Landing ground*