DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

1975/162

BASEMENT GEOLOGY OF THE NORTH SEPIK REGION PAPUA NEW GUINEA

by

D.S. Hutchison

1975/162

BASEMENT GEOLOGY OF THE
NORTH SEPIK REGION
PAPUA NEW GUINEA

by

D.S. Hutchison

TABLE OF CONTENTS

TEXT FIGURES

Figure

TABLES

APPENDIX

SUMMARY

The North Sepik region lies in the northwest corner of Papua New Guinea, and is covered by four 1:250 000 Sheet areas.

In 1972 and 1973 BMR field parties mapped the geology of the region as part of a regional mapping program to map the whole of Papua New Guinea. The main aim of the survey was to map the basement rocks exposed in the region, but an additional aim was to become familiar enough with the cover sediments to collate all the information from various petroleum exploration companies which have been working in the region since the early 1920s. This Record deals only with the geology of the basement rocks.

Geologically the region consists mainly of Mesozoic and Palaeogene basement rocks overlain unconformably by Neogene and Quaternary marine and non-marine sediments. The dominant feature is a central east-trending basement axis which separates metamorphic basement in the south from mainly volcanic basement in the north, and which also separates two Neogene flysch troughs.

The central basement axis consists of Upper Cretaceous to lower Miocene marine volcanics and intrusives in the west and north (Bewani and Torricelli Mountains), and complex mixtures of Lower Cretaceous to lower Miocene intrusives and metamorphics in the east (Prince Alexander Mountains). The marine volcanics and intrusives have both tholeiitic and calc-alkaline island-arc affinities.

South of the central axis, sporadic exposures of probable Upper Cretaceous to Eocene greenschist-grade and amphibolite-grade metamorphics have been correlated with the Ambunti metamorphics exposed south of the Sepik River.

Metamorphosed intrusive rocks of unknown age are exposed near Amanab, and unmetamorphosed mid-Permian intrusive rocks occur as stream boulders southwest of Amanab.

North of the central axis, marine volcanics and minor intrusives which have been correlated with the igneous rocks of the Bewani and Torricelli Mountains are exposed sporadically in the coastal hills and on Kairiru Island.

A major complex fault-zone passes through the central basement axis. Large vertical, and probably substantial left-lateral strike-slip movements have occurred within the zone, and have formed northeast, and east-trending anticlinal structures.

Alluvial gold is the only mineral of known economic importance in the region. It occurs in two principal localities - in the Prince Alexander Mountains north of Maprik, and in the Border Mountains near Amanab.

INTRODUCTION

Location and access

The North Sepik region lies in the northwest corner of Papua New Guinea, and includes the triangle of country bounded by the lower Sepik River, the north coast, and the international border with Irian Jaya. It includes parts of the East and West Sepik Administrative Districts, and is covered by the Vanimo, Aitape, Wewak, and Sepik 1:250 000 Sheet areas (Fig. 1).

Wewak (Fig. 2), headquarters of the East Sepik District, is the largest town in the region, and may be reached by ship or air. The town has a reasonable harbour and a sealed airstrip 1550 m long, and has a daily Fokker Friendship passenger service from Port Moresby. From Wewak, the adjacent hinterland is connected by an all-weather road to Maprik, and by other roads (passable in good weather) to Pagwi, Bongos, and Dreikikir. In June 1974, a road connecting Maprik with Lumi was under construction.

Aitape, on the coast midway between Wewak and Vanimo, has a harbour capable of handling small ships in good weather, and two airstrips, including a large (1950 m) sealed strip 12 km southeast of the township. In June 1974, a road connecting Aitape with Lumi was being constructed. Vanimo, headquarters of the West Sepik District, has a large (1600 m) sealed airstrip and a reasonable harbour. Vanimo is connected by road with Wutung, a patrol post on the coast adjacent to the Irian Jaya border, and is served by a twice-weekly air service (Fokker Friendship) from Port Moresby via Wewak. Several other government and mission outposts in the region are equipped with airstrips of various standards and lengths, and are usually served by light aircraft at least once a week.

Population

The population of the region is distributed very unevenly. The area along the southern side of the Torricelli and Prince Alexander Mountains between Lumi and Yangoru is one of the most densely populated in Papua New Guinea, with more than 640 persons/square kilometre (400 persons/square mile) on some tribal lands in the Maprik area (Haantjens, 1968).

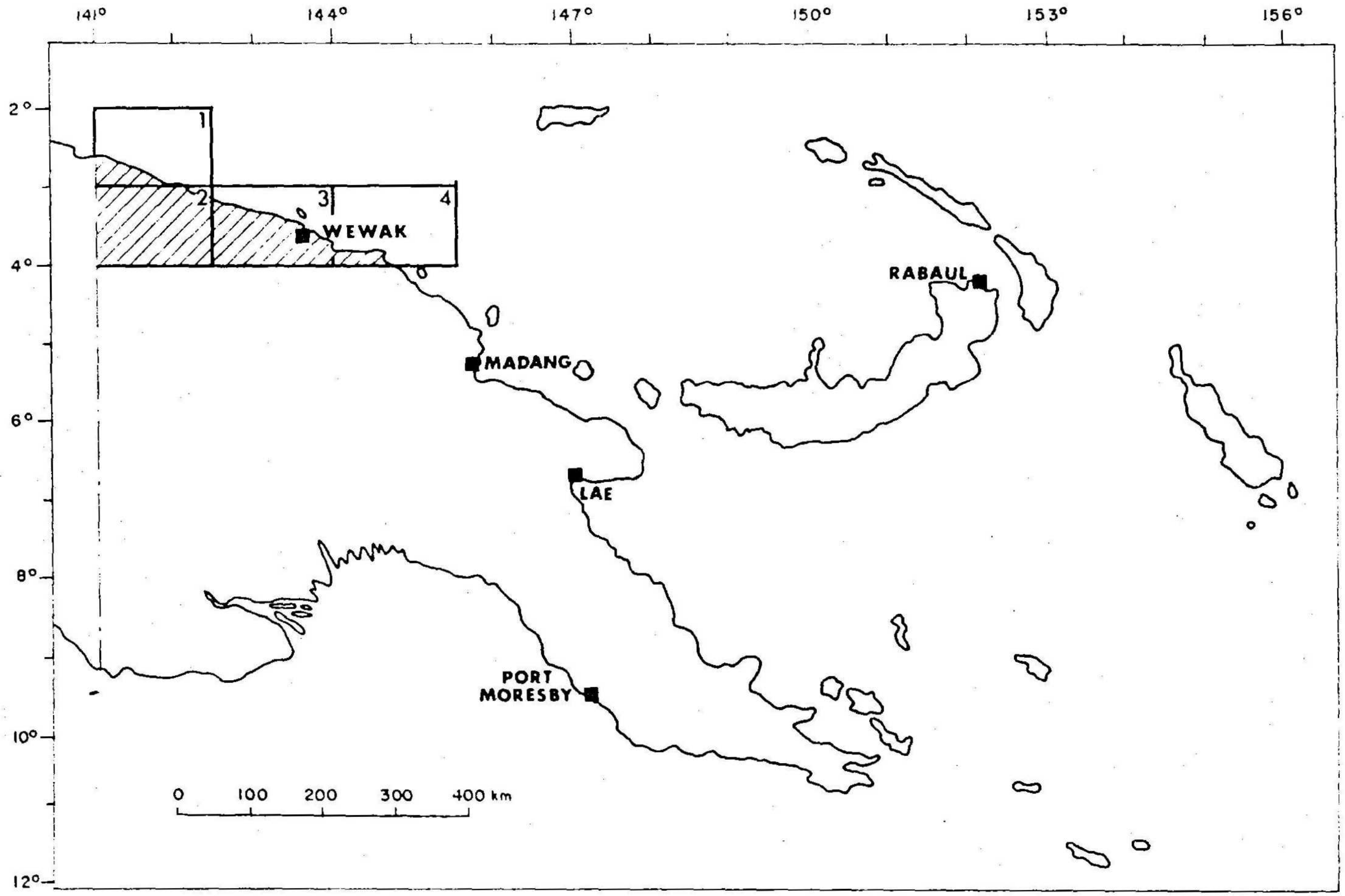


Fig. 1 Location of the North Sepik region in Papua New Guinea (shaded) showing 1:250 000 Sheet areas: Vanimo, Aitape, Wewak, Sepik, numbered 1 to 4, respectively

Record 1975/162 P/A/484

Fig. 2. Township of Wewak. Situated on the coast 100 km west of the mouth of the Sepik River, it is the headquarters of the East Sepik District, and the largest town in the North Sepik region. Neg M/1486 (DBD)

The only other main area of population concentration is in the coastal areas between Aitape and Kaup. The rest of the region is sparsely populated.

Climate and vegetation

The climate and vegetation of the region have been fully discussed in a series of CSIRO landform studies (see Haantjens, 1968 and 1972 a, b), and only a brief summary is given here. In general, the region has a humid tropical climate which is subject to the seasonal influence of the southeast trade wind from May to October, and to the northwest monsoon from December to March. The latter period is generally the wetter although the difference between 'wet' and 'dry' seasons is not marked. Annual rainfall ranges from about 1625 mm (65 inches) in the Sepik plains to about 2500 mm (100 inches) in the coastal areas. Well over 2500 mm can be expected in the central mountain ranges. Mean annual temperatures are about 27°C at the coast, decreasing gradually with elevation. Humidity is always high.

Most of the region is covered by dense tropical rain forest of various types. Areas of swamp vegetation are found in some places along the coast, and along the Sepik River and its tributaries. Kunai grass covers large areas of the alluvial fans of the Sepik plains, and along the southern fall of the Torricelli and Prince Alexander mountains large areas of forest have been cleared for village gardens.

Aerial photographs and maps

Topographic maps at 1:100 000 and 1:250 000 scale are available for the whole area and several series of aerial photographs, at scales ranging from 1:12 000 to 1:85 000, provide an almost complete and excellent coverage of the region. These include both north-south and east-west runs of the CAJ series at about 1:50 000 scale, which cover almost the whole region; and northwest-southeast runs of forestry photographs at various scales, covering the Vanimo 1:250 000 Sheet area and parts of the Aitape 1:250 000 Sheet area. In addition, the extreme western edge of the area is covered by north-south runs of the N.G. border series. A new set of photographs at about 1:85 000 scale of the whole of Papua New Guinea and adjacent islands, including a complete coverage of the North Sepik region, were being made available by the RAAF in June 1974.

Aim of survey and survey methods

The North Sepik region was mapped during 1972-73 as part of the BMR regional geological mapping program in Papua New Guinea, which has now been completed. The main aim of the 1972-73 survey was to map the basement rocks. Petroleum exploration companies have been working in the region since the early 1920s, and an additional aim was to become familiar enough with the cover sediments in order to collate all this additional information.

The results of the mapping will be published in the form of four 1:250 000 geological maps (Vanimo, Aitape, Wewak, and Sepik)* and as a BMR Bulletin. This Record is concerned solely with reporting the results of the work in the basement rocks.

---

* Preliminary editions of these maps are now available.

The 1972 party consisted of D.B. Dow (Party Leader), D.S. Hutchison, M.S. Norvick, and C.E. Maffi, and the 1973 party was D.S. Hutchison (Party Leader), M.S. Norvick, D.B. Dow, B.J. Dawes, and D.E. Mackenzie. Almost the whole of the fieldwork was carried out with helicopter support. A Bell Jetranger was used exclusively during both field seasons. Field base camps were set up at Amanab, Vanimo, and Aitape during 1972, and at Wewak and Aitape in 1973. Fieldwork was carried out during August and September in 1972 (6 weeks) and May and June (6 weeks) in 1973.

The mapping was done almost entirely by foot traverses along stream courses. A traverse party usually consisted of one geologist and one to five Papua New Guinea field assistants, depending on the length of the traverse. Most traverses were of only one day's duration, but some lasted up to three or four days, and on these longer traverses all camping equipment and food was carried by back pack. Where necessary, guides were hired from local villages.

Each traverse party was positioned by helicopter early in the morning, and picked up, usually at a predetermined point, in the early or mid-afternoon to avoid flying in bad weather as much as possible. Red parachute flares were used to pinpoint a traverse party's position on the ground when the pick-up point was in doubt, or could not be reached. The proposed route and duration of each traverse was plotted on a map at base camp in case of contingencies.

Previous geological work

The first recorded geological work undertaken in the North Sepik region were the observations made in 1907 by Father Joseph Reiber, S.V.D., of the Roman Catholic Mission at Berlinhafen (Aitape). He travelled up the Raihu River and penetrated the Torricelli Mountains south of Aitape, before dying of fever (Nason-Jones, 1930). Reiber's work was collated by S. Richarz, who assembled as far as possible and published all the available information relating to the geology of German New Guinea (Richarz, 1910). In 1914 Schultze-Jena made some geological observations whilst engaged on a boundary survey.

Planned geological exploration in the area began in the 1920s with the search for oil (Papp, 1929; Nason-Jones, 1930). Shallow wells were drilled near oil seeps at Matapau, and near the mouth of the Sepik River at Marienberg. Between 1930 and the outbreak of World War II, Oil Search Ltd, Island Exploration Company Pty Ltd, and Australasian Petroleum Company Pty Ltd continued geological mapping. In 1940, N.H. Fisher, while Government Geologist, visited and reported on the gold-bearing area of the Wewak district. The gold is derived from polymict conglomerates at the base of the sedimentary cover, but Fisher also made several observations regarding basement rocks in the Prince Alexander Mountains.

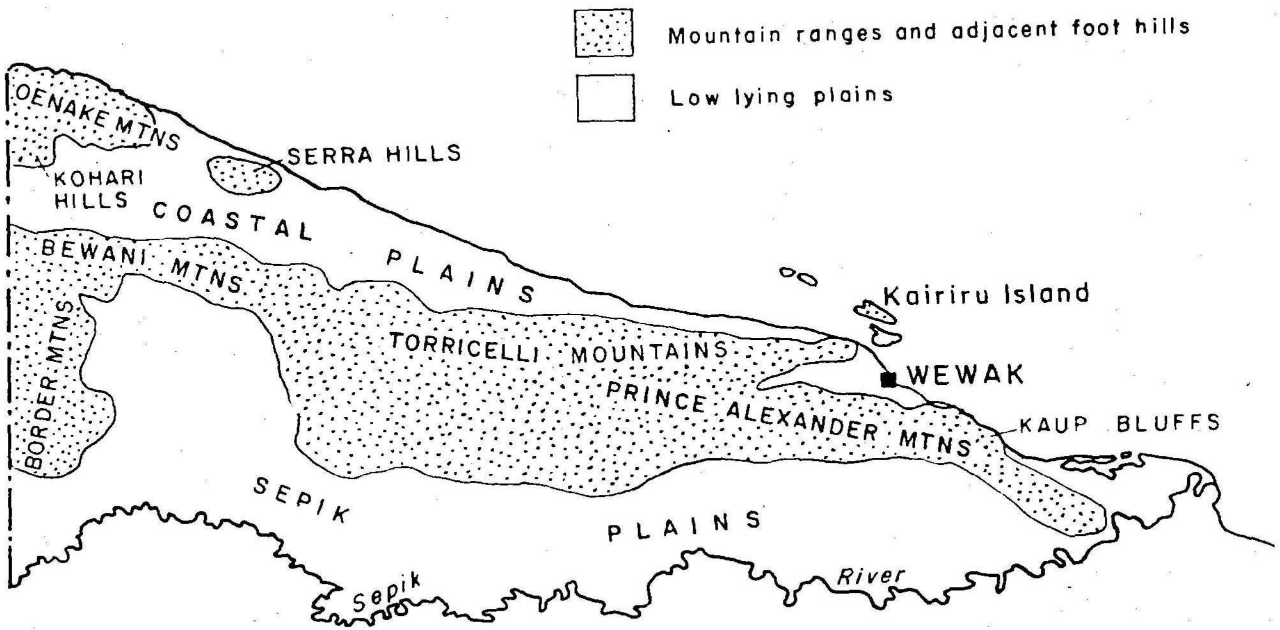
Following the end of World War II, the same oil exploration companies continued geological mapping, but in the 1960s, the work was continued by Continental Oil Co. of Australia and Australian Aquitaine Pty Ltd, who completmented further field work with aeromagnetic surveys over most of the region, and also carried out some seismic surveys. Most of the work was conducted in the search for petroleum, and understandably little attention was paid to the basement rocks although, paradoxically, two of the best known oil seeps issue from sheared igneous rocks. Most of the oil exploration company reports mention little more than that various intrusive and metamorphic rock types were observed as stream boulders. The volcanics received somewhat more attention, as they were long considered to be interbedded with sediments in the basal part of the cover succession.

The first attempt at an overall study of the region was a photogeological assessment of its petroleum potential made by Marchant (1969). Preliminary reviews of the geology of the region have been published by Harrison (1969), Tallard (1970), and van Oyen (1972).

Topography

The region is dominated by a narrow east-trending central mountain range, up to 1800 m high, flanked by foothills on both sides, which merge with coastal plains to the north, and the alluvial plains of the Sepik River to the south. This range comprises, in the west the Bewani Mountains, in the middle the Torricelli Mountains, and in the middle and east the Prince Alexander Mountains, which diverge southeastwards from the Torricelli Mountains northwest of Maprik (Fig. 3).

Fig. 3 Principal physiographic features of the North Sepik region



Record 1975/162

P/A/485

The mountain ranges are rugged, and are cut by short steep streams which are commonly choked with boulders, and have many gorges and waterfalls. The streams characteristically form wide braided channels immediately upon reaching the plains.

In the southwest, the Border Mountains form an area of low hills and dissected plateaux around Amanab. Although of lower elevation than the main range (max. 750 m), the area is rugged and deeply dissected along the border, and an area of impenetrable karst topography is developed in limestone.

In the northwest, coastal hills extend from the border to the mouth of the Bliri River. These hills are called the Oenake Range west of Vanimo, and culminate in Mt Bougainville (1220 m) near the border, and the Serra Hills in the east which are separated from the Oenake Range by the Pual River. The Serra Hills are low (max. 500 m), but deeply incised streams make access difficult.

South of the Oenake Range near the Irian Jaya border, the Kohari Hills form an area of higher relief (max. 720 m) bordering the northern side of the Pual Plains.

Southeast of Wewak a series of coastal hills form the Kaup Bluffs. These reach a maximum height of 550 m west of Tring; they have a steep northern fall to the sea, and in the south fall gently away to the Sepik River.

Other areas of higher relief are the small hills around Aitape, Kairiru Island which reaches a maximum height of 1020 m, and the low hills near Yellow River Mission.

GENERAL GEOLOGY

The North Sepik region straddles the boundary between the northern edge of the 'New Guinea Mobile Belt' (Dow et al., 1972; Bain, 1973; Dow, 1975) and the 'Melanesian Oceanic Province' (Dow, in press). The area is occupied mainly by Cretaceous and Lower Tertiary igneous and metamorphic basement rocks, unconformably overlain by Neogene marine and non-marine clastic sediments (Fig. 4).

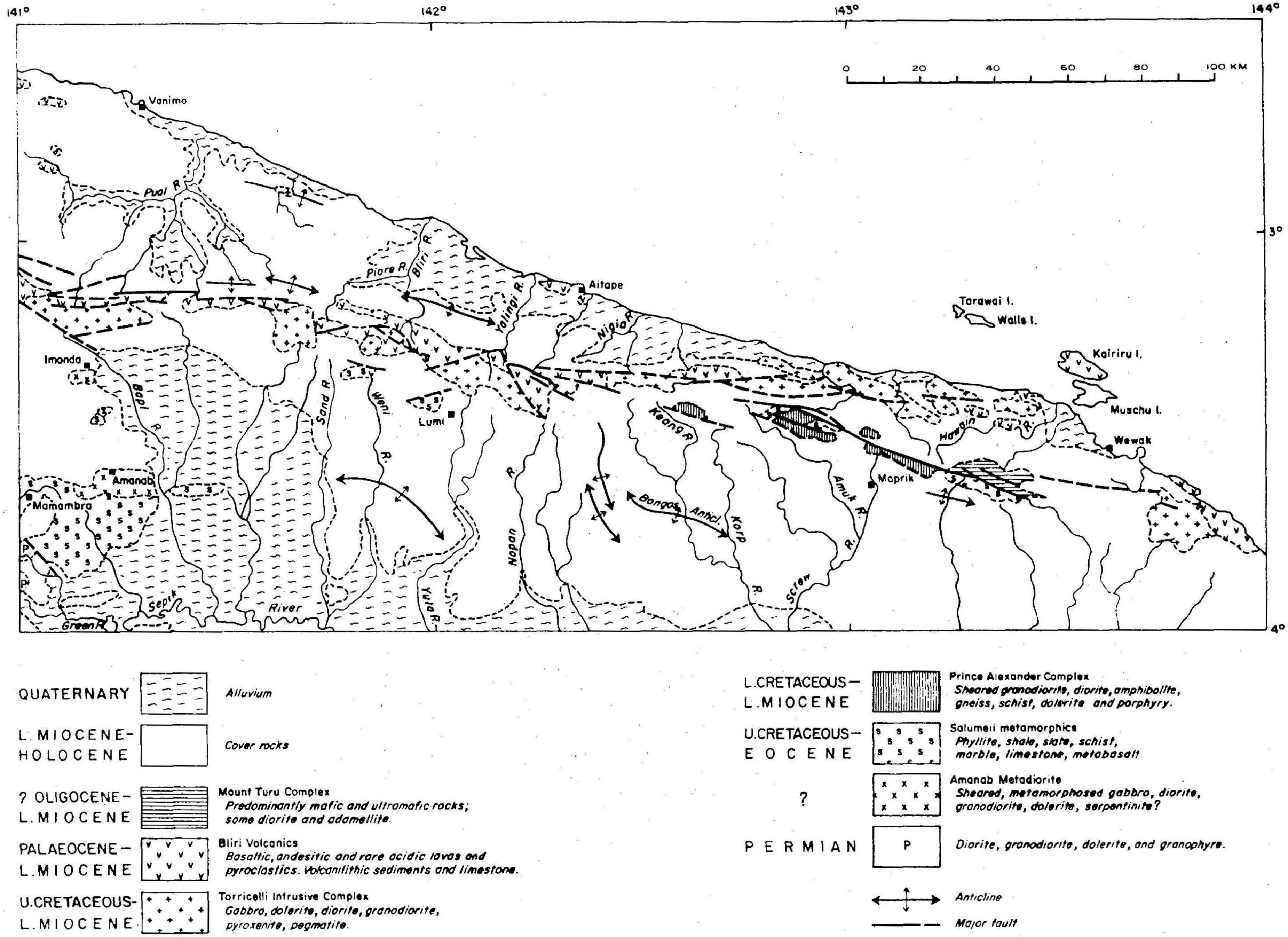


Fig. 4 Sketch map of basement geology of the North Sepik region

The dominant feature of the geology is the central basement axis forming the Bewani and Toricelli Mountains which separates metamorphic basement to the south from mainly volcanic basement to the north. The axis also separates two Neogene flysch troughs - the Aitape Trough to the north, and the Lumi Trough to the south (Fig. 5).

The Prince Alexander Axis diverges southeastwards from the main Bewani-Torricelli Axis, and delineates a third Neogene trough called the Wewak Trough (Fig. 5).

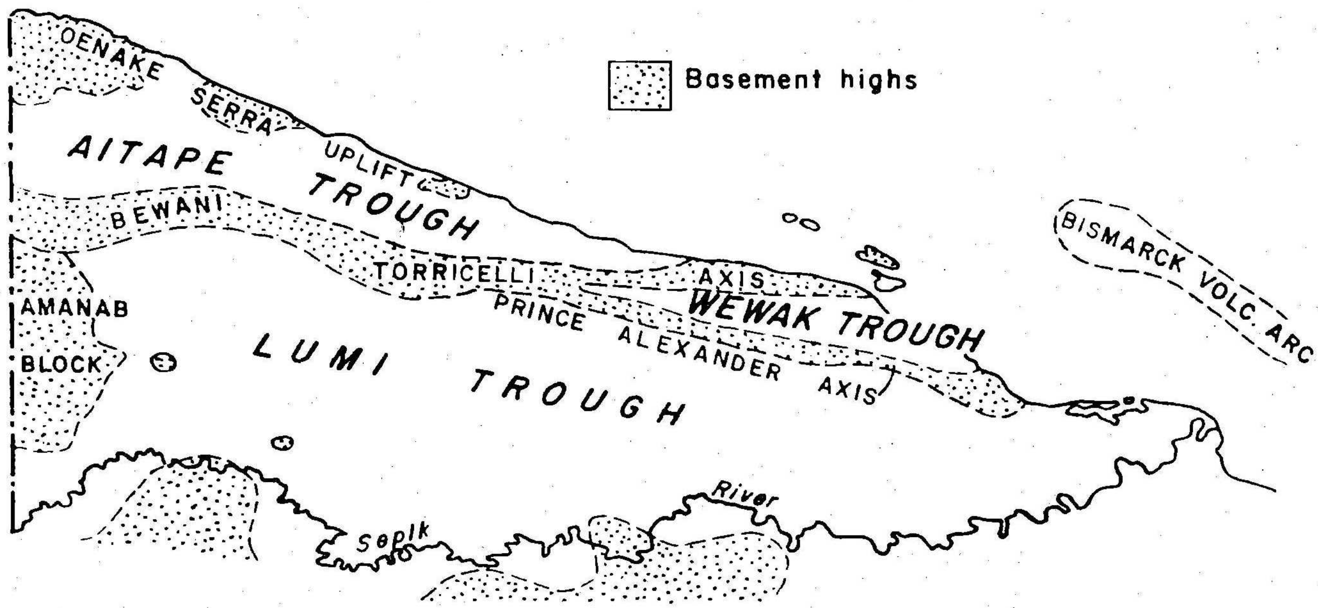
The Bewani-Torricelli Axis consists of volcanics and comagmatic intrusives, of Upper Cretaceous to lowermost Miocene age, which have been divided into two units - (a) Bliri volcanics: marine volcanics which consist of basaltic and andesitic lava, tuff, and agglomerate, abundant intercalations of volcaniclastic rocks, and many small limestone lenses; and (b) Torricelli Intrusive Complex: predominantly gabbroic and dioritic intrusive rocks which are comogmatic with, and intrude, the Bliri volcanics. Similar rocks are also exposed southeast of Wewak and in the Oenake Mountains and Serra Hills along the north coast. The latter topographic features mark the northern boundary of the western Aitape Trough, and were probably uplifted during the middle or late Pliocene.

The Prince Alexander Axis consists of complex mixtures of igneous and metamorphic rocks, of Lower Cretaceous to lower Miocene age, which have been divided into two units - (a) Prince Alexander Complex: a mixture of crushed dioritic intrusives and sheared high-grade metamorphics, intruded by less deformed porphyry dykes and small acid intrusions, exposed in the western part of the ranges; and (b) Mount Turu Complex: an ultramafic-mafic intrusive complex with minor small acid intrusions, exposed northeast of Yangoru in the eastern Prince Alexander Mountains.

Faulting in the central basement axis has been intense, and the whole mountain range represents a large, probably predominantly transcurrent fault system extending from the Irian Jaya border to southeast of Wewak.

South of the central range greenschist and amphibolite facies metamorphic rocks considered to be equivalent to the Ambunti Metamorphics, south of the Sepik River, are exposed sporadically between the Irian Jaya border and Yangoru Patrol Post. The largest area exposed is in the Border Mountains where low-grade metamorphics are intruded by sheared metamorphosed intrusive rocks called the Amanab Metadiorite.

Fig.5 Principal structural features of the North Sepik region



Record 1975/162

P/A/482

No metamorphic rocks have been found north of the central basement axis.

The North Branch of the Green River, southwest of Amanab, contains boulders of unmetamorphosed Permian intrusive rocks.

The basement rocks are overlain by Neogene sediments with an unconformity which, over most of the region, is marked by discontinuous outcrops of either polymict conglomerate or bioclastic limestone, both of lower to middle Miocene age. Foraminiferal evidence places this unconformity within zone N4 of Clarke & Blow (1969) throughout most of the central range. In the eastern Prince Alexander Mountains Pliocene sediments overstep the Miocene, and rest directly on basement.

The youngest sediments in the region are Pleistocene terrigenous gravels in both the Aitape and Lumi Troughs, and Pleistocene to Holocene reef limestones in the Oenake Mountains and near Wewak.

DETAILED BASEMENT GEOLOGY

Details of the basement stratigraphy of the area are summarised in the Appendix.

BEWANI-TORRICELLI AXIS

The Bewani-Torricelli Axis has been divided into two units: (a) Bliri volcanics, and (b) Torricelli Intrusive Complex.

Bliri Volcanics

(informal name, variation of published name Bliri River Beds)

Bliri volcanics is the informal (but valid) name given to the suite of volcanics, associated clastic sediments, and limestone exposed in the Bewani and Torricelli Mountains. This name is a variation of the name Bliri River Beds, first proposed by Raggatt (1928) for a sequence of Miocene marine clastic sediments and limestone cropping out in the headwaters of the Bliri and Weni Rivers. Marchant (1969) redefined the Bliri River Beds to include volcanic intercalations in the lower part of the unit. He was not aware of the unconformity at the top of the volcanic unit, and the Bliri River Beds as defined by him include both basement and cover rocks. Therefore it is proposed that the name Bliri volcanics be applied to the basement volcanics and associated sediments.

Derivation of name

The name of the unit is derived from the Bliri River (otherwise known in its lower reaches as the Arnold River), which is one of the main rivers of the Aitape coastal region. The Bliri River rises in the saddle between the Bewani and Torricelli Mountains, and flows northward to the coast at about longitude 141°58'E (Aitape 1:250 000 Sheet area).

Distribution

The Bliri volcanics are exposed discontinuously in the Bewani and Torricelli Mountains from the Irian Jaya border, in the west, to Cape Karawop and the Hawain River in the east. They are also exposed along the coast and in the coastal hills southeast of Wewak between Dabiap Point and the village of Kaup, and they make up nearly the whole of Kairiru Island. The low hills of volcanics at Aitape, and minor exposures of volcanics in the Serra Hills (in Puari Creek), Oenake Mountains (near Mt Bougainville), and in the Kohari Hills (Bwin or Jassi River) have also been included in the unit.

Type area

The headwaters of the Bliri River south of latitude 3°13'S, which includes the area drained by the Meni, Nenabu, Narkorne, and Neni Creeks, has been designated as the type area. Because of extreme faulting throughout the unit no type section can be designated.

Detailed geology

The Bliri volcanics consist of a mixed sequence of basic to intermediate and minor acid lavas, associated volcaniclastic rocks, and minor clastic sediments and limestone. Minor chert occurs in places.

Lavas are usually red or green, mostly massive, and individual flows are rarely seen. Pillow lavas (Figs. 6 and 7) and associated pillow breccias (Figs. 8 and 9) are abundant throughout the sequence.

The volcaniclastic rocks consist of autoclastic, pyroclastic, and epiclastic types. Autoclastic types include lava breccia (Fig. 10) probably formed by breakup of flows as they moved down submarine slopes and peperitic breccia as defined by Carozzi (1960). Pyroclastic rocks are common and include both crystal and lithic tuff, breccia, and agglomerate (Fig. 11). In places thinly bedded, fine-grained tuffaceous ooze (Fig. 12) occurs. Individual fragments range in size from less than 1 mm to more than 50 cm, and are mostly angular to sub-angular. Some are rounded. Calcareous tuffs and agglomerates contain abundant foraminifera and algal remains, both whole and fragmentary.

Fig. 6. Pillow basalt in Bliri volcanics, Lipan Creek, western Torricelli Mountains. Note matrix of calcilutite between the pillows. Neg GA/6358 (DBD)

A great variety of epiclastic and clastic rocks are present. They constitute about 35 to 40 percent of the sequence and occur both as lateral equivalents of, and intercalated with the volcanics. The predominant types are thinly to thickly bedded, moderately indurated, light to dark grey silty volcanilithic sandstone, lithic greywacke, and siltstone, containing abundant feldspar and red and green volcanic rock fragments. Calcareous rudite and limestone containing volcanic rock pebbles (Fig. 13) are common. Minor dark grey siltstone (generally

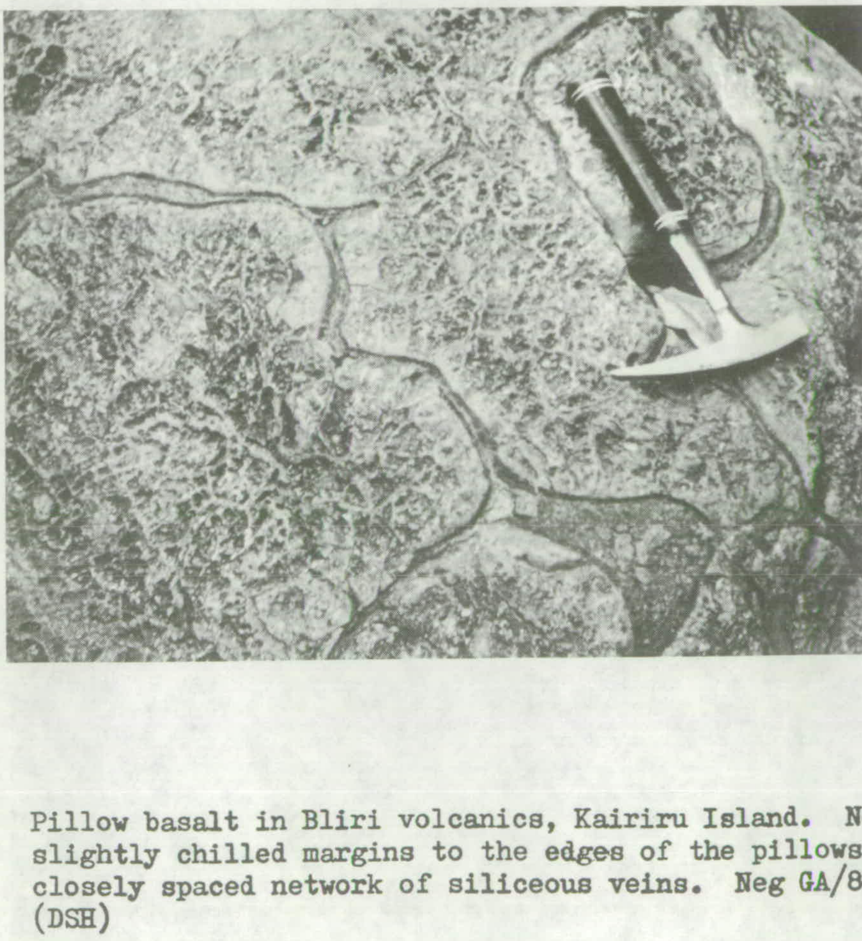


Fig. 7. Pillow basalt in Bliri volcanics, Kairiru Island. Note slightly chilled margins to the edges of the pillows, and closely spaced network of siliceous veins. Neg GA/8309 (DSH)

Fig. 8. Brecciated pillow basalt in Bliri Volcanics. Fragments not dispersed. Northwest of Mt Bougainville, Oenake Mountains.

Neg. GA/6325 (DBD)

Fig. 9. Brecciated pillow basalt in Bliri volcanics, Lipan Creek, western Torricelli Mountains. Dispersal of the pillow fragments has occurred, and a calcilutite matrix has infilled the interstices. Note segment of a pillow with rounnded chilled margin near centre of photograph.

Neg. GA/6357 (DBD)

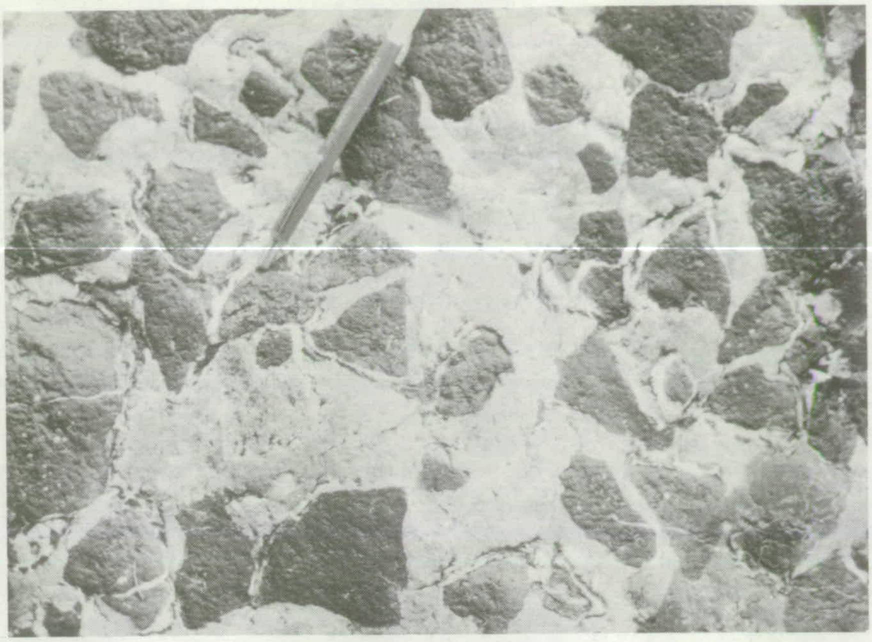


Fig. 10 Basaltic lava breccia in Bliri volcanics, Lipan Creek, western Torricelli Mountains.

Neg GA/6354 (DBD)

Fig. 11. Volcanic agglomerate in Bliri volcanics, Mene Creek, upper Bliri River. Poorly sorted, sub-rounded to angular lava fragments in a matrix of finer volcanic detritus and calcilutite.

Neg. GA/6386 (DBD)

Fig. 12. Thinly bedded, submarine tuffaceous ooze in Bliri volcanics, northwest of Mt Bougainville, Oenake Mountains.

Neg. GA/6331 (DBD)

Fig. 13. Pebbly limestone with rounded to sub-angular volcanic pebbles in a calcilutite matrix in Mene Creek. This rock type occurs in both the Bliri volcanics and in the basal part of the overlying sediments.

Neg. GA/6323 (DBD)

highly indurated and cleaved) and bands of conglomerate occur throughout. The sandstone is typically poorly sorted, and commonly contains irregular lenses and clasts of siltstone and mudstone. Sedimentary structures include graded bedding, fine cross-laminae, and penecontemporaneous slumps, indicating deposition by turbidity currents. Most, if not all the detritus making up the clastic rocks is thought to come from the volcanic sequence. Foraminifera are not common, except for some Lepidocycline-bearing sandstones.

Small limestone lenses occur in both the volcanics and the sediments throughout the formation. These comprise two main types: (i) pink and red to chocolate, deep-water radiolarian and foraminiferal marl; and (ii) grey to white, shallow-water, foraminiferal micrite and calcarenite. All gradations from pillow lava and agglomerate with a limestone matrix through to limestone containing volcanic pebbles are present (Fig. 13). The field name 'volcanic-reef detritus' was given to these volcanic-limestone mixtures.

Planktonic and larger benthonic foraminifera are abundant in the limestone, and provide good age control. The fossil evidence indicates that the unit is made up of two parts - an older part of mainly Eocene age, and a younger part of late Oligocene to earliest Miocene age. The two parts cannot be mapped separately in the field as there is little to distinguish between them lithologically, but the older part appears to contain a greater proportion of volcanics and deep-water limestones, and the volcanics appear to be more basaltic in composition. The younger part appears to contain a greater proportion of andesitic pyroclastic material, a greater proportion of sediments, and more shallow-water limestone lenses.

Faulting within the unit has been intense, and shearing, brecciation, and jointing of the volcanics are common. Large faults are commonly marked by zones of mylonite and crush breccia. Minor disseminated pyrite mineralization occurs in the volcanics, and the rocks along some shear zones are hydrothermally altered and slightly mineralized by pyrite. The faulting has severely disrupted the sequence, and it is therefore impossible to estimate thickness. The thickest undisturbed section traversed was about 2500 m (in Kulanap Creek).

In the Bewani Mountains, volcaniclastic rocks are abundant, and can be seen interbedded with basic lava flows in several places (e.g. in the Puwani River). The sediments are mostly moderately indurated, coarse-grained lithic sandstone with intercalations of siltstone, calcareous siltstone, and shale. Minor bands of conglomerate also occur. The volcanics are commonly sheared green porphyritic and amygdaloidal basalt and pillow basalt, commonly with irregular calcite veinlets. Pink marl is interbedded with the volcanics in several streams (e.g. Kulanap Creek, upper Mili River), and calcarenite lenses of both Eocene and Oligo-Miocene age are common.

In the headwaters of the Bliri River (the type area), both Eocene and Oligo-Miocene volcanics occur. The sequence consists of moderately indurated volcanilithic sandstone, and pebbly sandstone, conglomerate, and siltstone interbedded with volcanics consisting of green porphyritic and amygdaloidal basalts, basaltic breccia, and agglomerate. Pillow lavas with a matrix of calcilutite occur in Mili Creek. Pink, veined marl and foraminiferal calcarenite lenses occur in places. Andesitic and dacitic lavas appear in the sequence in the eastern Bewani Mountains and in the upper Bliri River.

Exposures of Bliri volcanics in the western and central Torricelli Mountains are similar to those farther to the west, but andesitic and acid volcanics are more abundant, and sediment less abundant. In the upper Nigia River a disturbed sequence of argillaceous, red-brown volcanilithic sandstone, basaltic and andesitic tuff and agglomerate, and porphyritic and amygdaloidal lavas is exposed. The lavas range from green basalt through pale greyish green andesite to grey dacite with quartz phenocrysts. Green spherulitic acid lavas and fine marine tuffaceous oozes containing radiolaria, planktonic foraminifera, and abundant volcanic detritus (e.g. pyroxene crystals and glass shards) occur in the upper Raihu River.

In the eastern Torricelli Mountains the unit is exposed as small fault blocks. Volcanilithic sediments and limestone are almost absent, and the rocks are massive green porphyritic and amygdaloidal basalt, pillow basalt, tuff, and agglomerate, all of which are commonly highly sheared and fractured, with epidote and chlorite alteration. Andesitic and acid lavas occur in places (e.g., lower Mabam River). Very fine-grained pumpellyite has been tentatively identified in some lavas from the lower Mabam River area.

Southeast of Wewak, the volcanic sequence is devoid of sediment, and comprises mostly basaltic lava, pillow lava, tuff, and agglomerate. Rhyolite and dacite occur in the lower Lotak River. Between Kaiep and Dabiap Point interbedded porphyritic basalt, pillow basalt, and agglomerate are excellently exposed. The agglomerate consists of rounded to angular fragments of pink and green amygdaloidal lava in a chloritic calcareous matrix.

Volcanics are exposed along most of the coast between the villages of Kaiep and Kaup, and are mixtures of basalt, pillow basalt, tuff, and agglomerate similar to those described near Kaiep. Shearing and brecciation are common and intense, and the rocks are mostly altered. Minor beds of pink marl also occur, but no foraminiferal calcarenite lenses were found.

Kairiru Island has been fully described by Johnson et al. (1972). It is composed almost entirely of altered basalt and pillow basalt, sheared in places, and commonly intruded by dolerite dykes. These rocks are similar to basalts exposed in the Torricelli Mountains, but no definite evidence of their age has been found. At the eastern end of the island, brown calcareous siltstone containing Pliocene foraminifera forms a matrix to basalt pillows. The exact relation is uncertain but it is most likely that the siltstone is much younger than the volcanics, which probably belong to the Bliri volcanics.

The small hills at Aitape are composed of interbedded submarine basaltic breccia, pillow basalt, tuffaceous foraminiferal calcarenite, vesicular andesite, and trachyte. The calcarenite contains abundant bryozoa and shelly, algal, and coral fragments.

In the Oenake Mountains south of Wutung, pillow basalt is associated with beds of manganiferous sediments and deep-water radiolarian tuffaceous ooze (Fig. 12). Pillow lavas also crop out on the north side of the Mosso River.

PETROGRAPHY

Lavas

Table 1 lists the visually estimated modal compositions of eight lavas from the Bliri volcanics. The lavas are almost invariably porphyritic, and all are altered to some degree; they range from basalt through basaltic andesite to andesite and rare dacite. The most

Table 1. ESTIMATED MODAL COMPOSITIONS OF TYPICAL LAVAS FROM THE BLIRI VOLCANICS

Sample Number	Rock Type	Volume % Phenocrysts								Groundmass		Secondary Minerals		Remarks
		Plagioclase	Clinopyroxene	Olivine	Amphibole	Quartz	Opaques	Other	%		%	Mineral	%	
72.25-1387	Altered porphyritic basalt		15							Plagioclase) Clinopyroxene) Glass) Opaques)	85	Calcite) Zeolites) Chalcedony)	20	Flow banding in groundma[s] zeolites and chalcedony occur in circular to elongate cavities
72.25-1389	Porphyritic basalt	10	15				1			Dark, fine-grained) mesostasis of) ? devit. glass)	60	Calcite) Zeolites)	tr. 10	Plagioclase occurs as s[m] acicular phenocrysts wit[h] random orientation
72.25-1392	Porphyritic hornblende-clinopyroxene andesite	20 (An$_{45}$)	2		7	tr.	1	K-feld.	tr.	Dark, crypto-) crystalline mosaic)	67	Zeolites) Epidote)	2 tr.	Plagioclase displays oscillatory zoning; hornblende is brown and commonly rimmed by opaq[ue]
72.25-3552	Porphyritic olivine basalt	12	12	1						Dark, crypto-) crystalline) material contain-) ing plagioclase,) olivine, and clino-) pyroxene micro-) lites)	74	Epidote) Prehnite) Chlorite) Zeolites)	tr.	Phenocrysts up to 3 mm; epidote replaces clino- pyroxene and plagioclase
72.25-1011	Altered andesite	50				10	10					Chlorite) Epidote) Calcite)	20 7 tr.	Non-porphyritic, very f[ine] grained; quartz chlori[te] and epidote are intersti[tial]
72.25-1330	Porphyritic quartz-clino-pyroxene andesite	10	3			5		?K-feld.	5	Dark, crypto-) crystalline mat-) erial containing) crystallites of) clinopyroxene,) acicular plagio-) clase, quartz,) opaques)	65	Calcite) Sericite)	1 tr.	Quartz phenocrysts are angular to sub-rounded
72.25-13258	Porphyritic basalt	25	20							Very fine-grained) crystals of plagio-) clase, clinopyro-) xene, and opaques)	54	Chlorite) Sericite)	1	Plagioclase variably altered; chlorite most
72.25-0587	Altered lava	Remnant phenocrysts of plagioclase, clinopyroxene, minor quartz; v.f.g. groundmass mosaic of ?devitrified glass, sericite, abundant magnetite, calcite, epidote.												

common phenocrysts are plagioclase, augite, olivine, hornblende, quartz, and potash feldspar phenocrysts are rare. The groundmass usually consists of dark grey, submicroscopic material containing very fine-grained crystals of acicular plagioclase, clinopyroxene, opaques, and alteration products.

Plagioclase is the most abundant phenocryst mineral. It usually forms euhedral to subhedral crystals which occur individually or as aggregates, with or without other minerals. The crystals are rarely zoned, and are mostly of tabular or short prismatic habit. Alteration to kaolinite and/or sericite usually precludes determination of the feldspar composition, but in one specimen this was possible (sample 72.25-1392, An_{45}-andesine).

Augite occurs as phenocrysts in most lavas. It forms subhedral to euhedral crystals whose sizes range from less than 0.5 mm to about 3 mm; they are generally short-prismatic, and occur individually or as aggregates, usually without other minerals.

Olivine occurs rarely as phenocrysts. Where present, it usually forms small, fresh crystals in aggregates with augite.

In one specimen of hornblende-clinopyroxene andesite, brown hornblende occurred as phenocrysts commonly rimmed by opaques.

Quartz phenocrysts occur in some andesites, but in general are absent from Bliri volcanic lavas.

Very rarely potash feldspar phenocrysts were noted in some specimens.

A fine-grained or cryptocrystalline groundmass commonly constitutes more than 60 percent of lavas in the Bliri volcanics. Most commonly the groundmass consists of a cryptocrystalline dark mass of ?altered glass containing tiny crystals of acicular plagioclase, clinopyroxene, magnetite, and alteration products. Fine-grained groundmasses commonly consist of elongate tabular to acicular plagioclase crystals with subordinate clinopyroxene and olivine. Flow banding is not common.

Most of the volcanic rocks are altered to various degrees. Chlorite, epidote, calcite, and sericite are the most common alteration products. Chlorite typically occurs as minute radiating flakes in the groundmass of porphyritic lavas where it probably results both from devitrification of glass and the alteration of feldspars. It also occurs as interstitial material in non-porphyritic lavas, and to a minor degree replaces augite phenocrysts. Epidote replaces clinopyroxene and plagioclase, both as phenocrysts and in the groundmass, and also occurs in cavities. Calcite occurs predominantly in cavities and veinlets, and also replaces feldspars. Feldspar phenocrysts are typically cloudy through alteration to sericite and kaolinite. Zeolites (mostly stilbite) and chalcedony are common minerals in cavities. Traces of prehnite have been observed in some cavities and also in the groundmass of some lavas, and probably result from the high-temperature alteration of calcium-rich plagioclase (Deer, Howie, & Zussman, 1966). Very fine-grained pumpellyite has been tentatively identified in the groundmass of some lavas from the eastern end of the Torricelli Mountains.

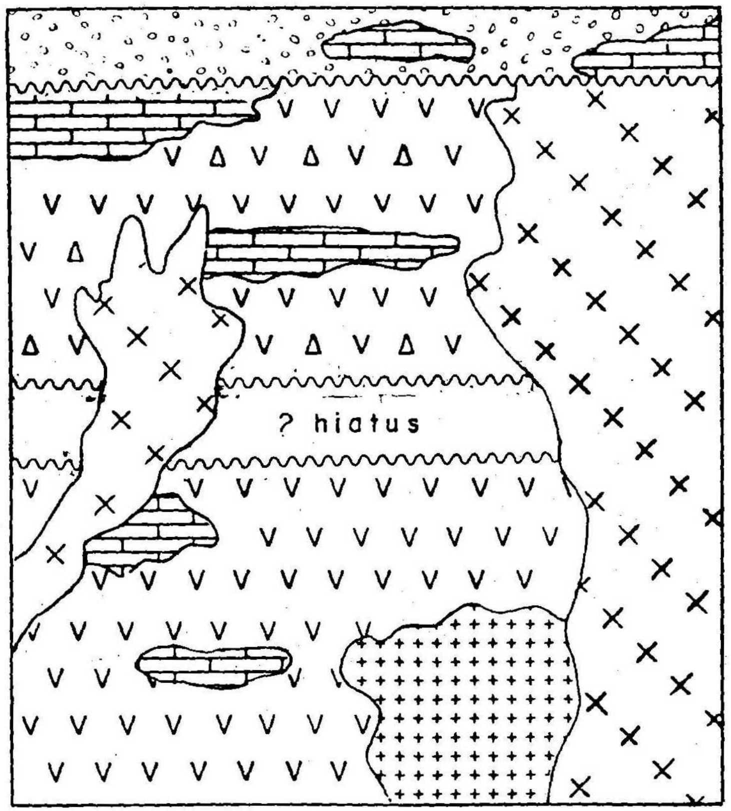
Age and relations with Other Units

Both planktonic and larger benthonic foraminifera occur in limestone lenses throughout the volcanics, the benthonic forms being the more abundant. Definitive ages obtained from these foraminifera indicate that the Bliri volcanics consist of two units - an older unit of Palaeocene to upper Eocene age and a younger unit of upper Oligocene to lowermost Miocene age.

The oldest fossils identified were planktonic foraminifera of Palaeocene age found in the Matapau area. Possible Upper Cretaceous foraminifera in Meni Creek and reworked Upper Cretaceous foraminifera (Globotruncana) in cover sediments from Aliam Creek (D.J. Belford, pers. com.) indicate that the basal part of the sequence is possibly as old as Late Cretaceous. Middle and upper Eocene foraminifers (Ta_3 and Tb stage of Adams, 1970) are common in the upper part of the older volcanics. The most common genera are Nummulites and Discocyclina, and these are usually found in shallow-water bioclastic limestone lenses.

Limestone lenses in the younger volcanics occur widely throughout the Bewani and Torricelli Mountains, and contain abundant late Oligocene to early miocene larger foraminifera (Lepidocydlines and Miogypsinids (Te stage of Clarke & Blow, 1969; Adams, 1970)). No lower or middle Oligocene fossils have identified, and a hiatus comprising letter stages Tc and Td is assumed between the two volcanic episodes (Fig. 14).

Fig.14 Rock relation diagram for the Bewani – Torricelli Axis



COVER ROCKS

Amogu Conglomerate

LOWER TO MIDDLE MIOCENE — *Coarse polymict conglomerate*

Puwani Limestone

Bioclastic foraminiferal limestone

BASEMENT ROCKS

Bliri volcanics

UPPER OLIGOCENE TO BASAL MIOCENE — *Basaltic, andesitic, dacitic lavas and pyroclastics; volcanilithic sediments; limestone*

?U. CRETACEOUS TO UPPER EOCENE — *Basaltic, andesitic lavas and pyroclastics; subordinate volcanilithic sediments; limestone*

Torricelli Intrusive Complex

UPPER EOCENE TO LOWER MIOCENE

UPPER CRETACEOUS

Gabbro, diorite, dolerite, subordinate granodiorite, adamellite; rare harzburgite

The Bliri volcanics are contemporaneous with, and partly intruded by, rocks of the Torricelli Intrusive Complex (Upper Cretaceous to lowermost Miocene) (Fig. 14). They are unconformably overlain by a basal polymict conglomerate (Amogu Conglomerate) and its stratigraphic equivalent, the Puwani Limestone, both of early to middle Miocene age. The youngest foraminifera found in the Bliri Volcanics are of late Miocene age (letter stage UTe), and the oldest foraminifera found in the Amogu Conglomerate are of earliest Miocene age (zone N4 of Clarke & Blow, 1969). Thus the unconformity separating the basement volcanics from the overlying cover sediments lies somewhere within zone N4.

Torricelli Intrusive Complex

(new formal name)

Derivation of name

The name of the Torricelli Intrusive Complex is derived from the Torricelli Mountains (Fig. 3) which are a narrow east-west range of mountains extending from the head of the Bliri River in the west (longitude 142°00'E) to Cape Karawop in the east (longitude 143°28'E).

Distribution

The Torricelli Intrusive Complex is intimately associated with, and has a similar distribution to, the Bliri volcanics. It is exposed discontinuously in the Bewani and Torricelli Mountains from the Irian Jaya border in the west, to Cape Karawop in the east. The complex is also exposed in three places southeast of Wewak: at Cape Terebu, the Letak Creek/Bisil Creek area, and the Tring/Yemogu Creek area. Small exposures of intrusive rocks in the Serra Hills and Kohari Hills are also included in this unit.

In the Bewani Mountains and western Torricelli Mountains, the complex forms large masses in the core of the range, but in the eastern Torricelli Mountains faulting has broken up the complex into a series of smaller irregular bodies. Small faulted blocks of Torricelli Intrusive Complex are also exposed in the upper Bliri River and along the north side of the Bewani Mountains.

Type area

The headwaters region of the Nengo and Yalingi Rivers has been designated as the type area for the complex. These streams drain northward from the western Torricelli Mountains near Mount Somero and Mount Sulen (about longitude 142°05'E) in the Aitape 1:250 000 Sheet area.

Detailed geology

The rocks of the Torricelli Intrusive Complex are mostly medium-grained non-porphyritic gabbro, massive dolerite, diorite, with subordinate monzonite, granodiorite, adamellite, and rare ultramafics. The whole complex is invaded by dolerite dykes in many places. Fine-grained porphyries and late-stage pegmatites also occur. In the complex as a whole gabbroic rocks are predominant.

The relations between the constituent rock types are generally obscured by faulting, but several distinct phases of intrusion have been distinguished.

The complex is strongly jointed, sheared, and brecciated; wide zones of mylonite and crush breccia are common, some being up to 1 km wide. Blocks of serpentinite and serpentinized gabbro have been seen in some shear zones (Fig. 24).

In the western Bewani Mountains the complex is exposed as a large mass in the core of the range, and as a series of smaller faulted bodies to the north.

The core of the range consists of massive, highly jointed, and fractured leucodiorite and microdiorite with subordinate micro-gabbro, massive dolerite, and dolerite dykes. Faulting around the margins of the mass is intense, and has resulted in wide zones of shearing and brecciation.

In the upper Puwani River, highly fractured and jointed, massive leucodiorite is separated from Bliri volcanics by a wide shear zone in which crushed diorite, microdiorite, and dolerite are intermixed with volcanics and sediments. In upper Kulanap Creek, the complex consists of massive, coarse-grained hornblende diorite with fine-grained basic xenoliths, and massive fine-grained melanocratic microdiorite containing xenoliths of granodiorite. The leucocratic rocks are highly jointed and sheared (Fig. 15) and in places are intruded by dolerite dykes 1 to 3 m wide. Boulders of coarse-grained gabbro occur in the stream bed. In the Bapi and Yes Rivers, the complex comprises mostly massive dolerite and microgabbro intruded by leucodiorite. The small, faulted blocks along the north side of the range are mostly fine-grained porphyritic leucocratic intrusives which are usually highly crushed.

In the eastern Bewani Mountains the large mass of Torricelli Intrusive Complex in the core of the range consists mostly of massive jointed dolerite and gabbro intruded by leucodiorite. In the upper Mili River, sheared and jointed massive dolerite has been intruded by jointed leucodiorite. Crushed basalt is intermixed with the instrusives in shear zones. In the upper Piore River, stream boulders are diorite, microdiorite, with subordinate granodiorite and coarse-grained gabbro.

In the upper Bliri River, the Torricelli Intrusive Complex is exposed as small faulted blocks. In Nenabu Creek, green altered andesite porphyry intrudes fine-grained recrystallized limestone of the Bliri volcanics. The porphyry contains angular white siliceous fragments in places, and is cut by zones of hydrothermal alteration up to 3 m wide. In Meni Creek, a small sliver of sheared, chloritized leucogabbro is exposed. In Nepi Creek, massive fine-grained gabbro is commonly veined, altered, and sheared.

In the western Torricelli Mountains (type area), the complex is exposed as a large mass in the core of the range, and consists of massive, highly jointed and sheared, fine to medium-grained gabbro and dolerite, with subordinate more acid phases and rare ultramafics. In Obubu Creek, the rocks are mostly highly jointed microgabbro, intruded by blue-green ?intermediate dykes, coarse-grained leucogabbro, and minor medium to coarse-grained leucodiorite. Cross-cutting shears and leucocratic veins (some coarse-grained feldspathic veins are up to 5 cm wide) are common, and the complex is commonly highly faulted, deformed, and crushed. Alteration and pyritic mineralization occur in places. Cross-cutting altered dolerite dykes and andesitic porphyry appear to be the youngest intrusive rocks. A few pyroxenite boulders were noted in the stream bed.

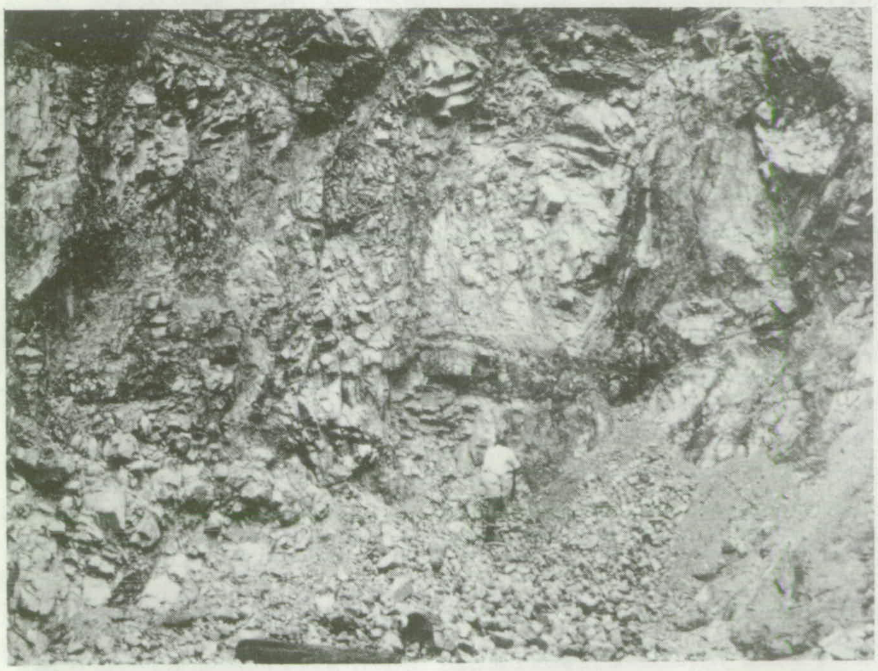


Fig. 15. Faulting, shearing, and brecciation in the Torricelli Intrusive Complex, Obubu Creek, western Torricelli Mountains.

Neg. GA/6366 (DBD)

In the Nengo River, the complex is relatively undeformed, comprising jointed medium-grained hornblende diorite and granodiorite with basic xenoliths, intruded by dykes of dolerite and leucogabbro. South of Mount Gorbu (in the headwaters of the Bliri River), the complex comprises highly sheared and shattered green, pyritic dolerite and microgabbro.

In the middle and eastern Torricelli Mountains, the complex consists mostly of microgabbro and dolerite, which is highly jointed, fractured (Fig. 16), and intensely crushed by faulting. The basic rocks are variously intruded by leucocratic diorite and microdiorite. The rocks are commonly recrystallized and foliated along shear zones possibly as a result of shearing while the rocks were still hot and partly molten (Fig. 17). Irregular quartz and quartz-feldspar veining is a common feature of the complex in this part of the region. Many of the gabbros and leucogabbros are extremely coarse-grained, and pegmatitic varieties (some with crystals up to 5 cm long) are not uncommon.

Fig. 16. Jointing and fracturing in microdiorite, Torricelli Intrusive Complex; Mikem Creek, eastern Torricelli Mountains. Neg. GA/8314 (DSH).

Southeast of Wewak, the complex consists of massive jointed microdiorite and dolerite, and subordinate gabbro and leucodiorite. In Bisil Creek, the complex is very well exposed, and comprises mostly massive and jointed dolerite and microgabbro, with variable shearing and crushing and multiple stringers of highly altered epidote-bearing rock. At one point, a dyke (2 to 3 m wide) of highly propylitized and mineralized white porphyry intrudes sheared and highly jointed epidotized dolerite. This dyke carried abundant disseminated pyrite, and a representative sample assayed 30 ppm Ag and 20 ppm Au (see section on Mineral Deposits). Downstream in Bisil Creek, rare dykes (up to 2 m wide) of leucodiorite intrude sheared altered pyritic dolerite. Highly sheared crushed and altered dolerite and microgabbro are exposed at Cape Terebu.

In Yemogu Creek, highly sheared, jointed, and crushed dolerite, gabbro, microgabbro, and subordinate diorite and granodiorite are exposed.

Fig. 17. Foliated gabbro of the Torricelli Intrusive Complex. Mikem Creek, eastern Torricelli Mountains. Neg. GA/8319 (DSH).

Petrography

Table 2 lists the petrographic features of representative samples of the Torricelli Intrusive Complex. Petrographic descriptions of most of the basic rocks were made by C.J. Pigram of GSPNG. Mineral percentages were visually estimated.

TABLE 2. PETROGRAPHY OF REPRESENTATIVE SAMPLES OF THE TORRICELLI INTRUSIVE COMPLEX

(visually estimated)

Ultramafic and mafic rocks

Sample Number	Lithology	Plag. % (comp.)	K-feld %	Cpx %	Opx %	Ol %	Hb%	Other	%	Opaques	Secondary Minerals	%	Remarks
		PRIMARY MINERALS											
72-25-0689	Serpentinized harzburgite			15	23	27				5	Serpentine	30	Serpentine minerals are lizardite, chrysotile, and bastite; bastite has intercumulous form
0745	Altered olivine gabbro	35		30		15				tr.	Serpentine Bowlingite	20 tr.	Annealed texture with many polygonal grains; cross-cutting chalcedony veinlets
1265	Hornblende - orthopyroxene gabbro	65 (An_{49-54})	1	5	12		10	quartz	tr.	4	Calcite Epidote	tr. tr.	Medium-grained, hypidiomorphic-granular to subophitic texture; brownish green late magmatic hornblende
* 2103 B	Hornblende - olivine gabbro	69 (An_{46-59})	2	15	tr.	2	10			tr.	Uralite ?Pyrophyllite	1 tr.	Cpx occurs as large poikilitic crystals with opx exsolution blebs. Greenish brown hornblende
* 3656	Hornblende - microgabbro	65 (An_{50-57})		tr.			25	quartz	2	3	Epidote Clinozoisite Zeolites Calcite	tr. tr. 3 tr.	Hypidiomorphic-granular to subophitic texture. Zeolites (probably stilbite) occur in cross-cutting veinlets

Intermediate and acid rocks

Sample Number	Lithology	Plag. % (comp.)	K-feld %	Qtz %	Bi %	Hb %	Cpx %	Other	%	Opaques	Secondary Minerals	%	Remarks
72.25-*1242	Hornblende-biotite adamellite	30	30	12	5	15				1	Sericite Kaolinite Chlorite Epidote	5 1 1 tr.	Medium-grained allotriomorphic granular to monzonitic texture, zoned feldspars with altered cores. Green to brown hornblende
* 1557	Hornblende granodiorite	45	25	15		10				tr.	Chlorite Kaolinite Epidote Sericite	3 tr. 1 1	Medium-grained allotriomorphic-granular texture; brownish-green hornblende
* 1559	Hornblende diorite	35	20	8		25				1	Zeolites Epidote Chlorite Sericite	4 1 1 4	Slightly brecciated texture, fractured and strained crystals. Zeolites (probably stilbite) occur in cross-cutting veinlets
* 1560	Hornblende granodiorite	45	? 15	15		15				1	Sericite Chlorite Epidote	5 1 1	Fine to medium grained allotriomorphic-granular textur Heavily altered feldspars. Chlorite has pseudomorphed biotite
3543	Hornblende microdiorite	53 (An_{32-44})	2	8		35	tr.			tr.	Epidote	tr.	Fine-grained allotriomorphic-granular texture; plagic mostly andesine with albite rims. Dark greenish-brown hornblende. Accessory sphene
3656	Hornblende gabbro	71 (An_{50-70})					20			5	Zeolites Chlorite Epidote Quartz	2 tr. tr. tr.	Medium to coarse-grained; subophitic texture; hornblende forms large, poikilitic, green-brown crystals
* 3658	Altered hornblende diorite	20	? 5			55				tr.	Quartz Epidote Clinozoisite Prehnite Zeolites Sericite	20	Brown to greenish-brown hornblende, quartz, and zeoli occur in cross-cutting veinlets; epidote, sericite, clinozoisite, and prehnite replace plagioclase
* 3704	Hornblende microdiorite	[illegible]	tr.	tr.		35				1	Epidote Kaolinite	tr. tr.	Hypidiomorphic-granular texture, plagioclase is sodic zoned with albite rims; some amphibole, possibly actinolite

The rocks of the complex range from ultramafic to acid. Ultramafics are very rare, and have been found outcropping only in upper Wiljum Creek, western Torricelli Mountains (specimen 72.25-0689), which is serpentinized harzburgite containing 15 percent clinopyroxene, 23 percent orthopyroxene, and 27 percent olivine. Serpentinite minerals make up 30 percent of the rock, and comprise lizardite and chrysotile after olivine, and bastite after orthopyroxene. Bastite has intercumulus form indicating that the original pyroxene crystals were intercumulus.

Rocks of gabbroic composition are predominant in the complex. They are mostly fine to medium-grained (some coarse-grained) generally with hypidiomorphic-granular and/or subophitic textures, and consist of plagioclase (An_{46} to An_{59}) which makes up more than 60 percent of the rocks, augite (up to 20 percent), common hornblende, and some potassium feldspar and olivine. Orthopyroxene generally occurs only as exsolution blebs in clinopyroxene, but it makes up about 8 percent of one rock.

The hornblende is dark brown or greenish brown, and makes up 25 percent of the rock in one gabbro which contains no olivine or orthopyroxene, only traces of augite, and about 2 percent quartz. Traces of green spinel are present in one sample.

Intermediate and acid rocks are generally subordinate, but in some places (e.g. western Bewani Mountains) they are the predominant rock type. They are fine to medium-grained, allotriomorphic-granular to hypidiomorphic-granular, and consist of andesine plagioclase (30 and 65 percent), potassium feldspar (up to 30 percent), and rare biotite and clinopyroxene. All contain abundant dark green to dark brown hornblende (up to 55 percent) which is the most characteristic feature of rocks of the Torricelli Intrusive Complex.

Most of the rocks are altered, the intermediate and acid rocks being affected to a greater extent than the basic rocks. The alteration is especially intense along shear zones. The most common alteration products are chlorite, epidote, sericite, and kaolinite after feldspar, chlorite after ferromagnesian minerals, and cross-cutting veinlets containing zeolites (mostly stilbite). Calcite, uralite, and clinozoisite are other alteration products in the basic rocks. Saussuritization (prehnite in association with epidote and clinozoisite) is common, especially in finely crushed rocks. Recrystallized quartz is also a common alteration product in sheared rocks. Recrystallization generally occurs around the margins of larger crystals.

Crush breccia, cataclasite, and mylonite occur along shear zones.

Age and relations with other units

Twenty-one K-Ar isotopic age analyses of rocks from the Torricelli Intrusive Complex are summarized in Table 3. The reliable ages range into two groups - a Late Cretaceous group, and a late Eocene to early Miocene group. The Late Cretaceous K-Ar ages of the intrusivès tend to confirm the possible Late Cretaceous foraminiferal dates from the volcanics, and overall, the K-Ar ages of the Torricelli Intrusive Complex are in good agreement with the foraminiferal dates from the Bliri volcanics (Fig. 18).

The older K-Ar isotopic ages (187 m.y., 215 m.y., and 352 m.y.) were determined on minerals with very low percentages of potassium (calcic plagioclase and pyroxene), and display a wide age range (Early Devonian to Late Jurassic); they have not been duplicated, and they cannot be considered reliable ages.

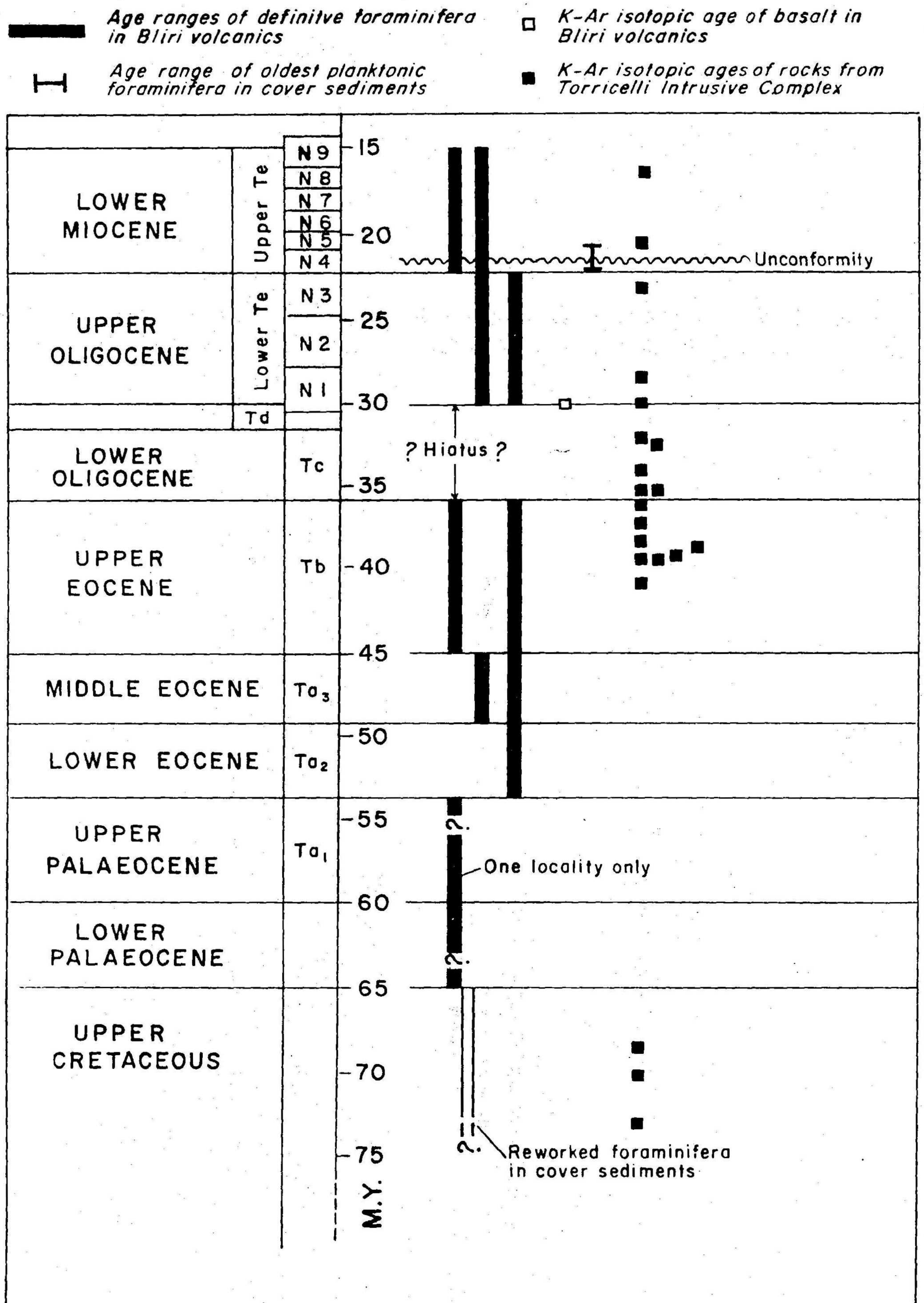
The Torricelli Intrusive Complex intrudes the Bliri volcanics (Fig. 14), and both are unconformably overlain by the Amogu Conglomerate and Puwani Limestone (lower to middle Miocene) and by the Senu Formation (Miocene) in the Bewani and Torricelli Mountains. Southeast of Wewak the complex is unconformably overlain by the Maprik Mudstone and Sargum Conglomerate, both of Pliocene age.

TABLE 3. K-Ar ISOTOPIC AGES, TORRICELLI INTRUSIVE COMPLEX

SAMPLE NO.	LOCALITY			LITHOLOGY	COMPONENT ANALYSED	AGE (x19^6 yr)
72.25-1242	Puwani R.,	141°08'E,	3°10'S	Hornblende-biotite diorite	Hornblende	35.2±1.0
72.25-1265	Kalanup Ck,	141°13'E,	3°10'S	Hornblende micromorite	Hornblende	68.0±4.0
72.25-1557	Filabu Ck,	142°03'E,	3°19'S	Hornblende-biotite diorite	Hornblende	41.3±0.7
72.25-1559	Sugun Ck,	142°10'E,	3°20'S	Hornblende diorite	Hornblende	39.9±1.0
72.25-1560	Yalingi R.,	142°12'E,	3°23'S	Biotite-hornblende-quartz diorite	Hornblende	35.5±0.6
72.25-1562	Nigia R.,	142°19'E,	3°21'S	Hornblende diorite	Hornblende	39.9±0.4
72.25-1572	Bapi R.,	141°10'E,	3°16'S	Hornblende-quartz diorite	Hornblende	37.1±0.5
72.25-2103A	Tokwat Ck,	143°58'E,	3°48'S	Hornblende-pyroxene gabbro	Hornblende	32.1±1.5
72.25-2103B	"	"	"	Olivine-augite norite	Plagioclase	215±20
					Pyroxene	352±35
72.25-3543	Anumb R.,	143°7'E,	3°25'S	Hornblende microdiorite	Hornblende	36.5±1.0
72.25-3596	Piore R.,	141°43'E,	3°14'S	Hornblende-biotite-quartz diorite	Biotite	23.2±0.8
72.25-3631	Yemogu Ck,	143°45'E,	3°47'S	Basaltic porphyry	Plagioclase	187±20
72.25-3633	"	"	"	Hornblende diorite	Hornblende	30.1±1.5
72.25-3655	Ninahog R.,	143°12'E,	3°24.5'S	Hornblende diorite	Hornblende	73.2±2.5
72.25-3656	Damien Ck,	142°49'E,	3°22'S	Hornblende diorite	Hornblende	39.0±1.2
72.25-3659B	Lipan R.,	142°27'E,	3°22'S	Hornblende diorite	Hornblende	70.4±2.5
72.25-3703	Letak Ck,	143°47'E,	3°39'S	Hornblende diorite	Hornblende	32.9±1.8
72.25-3704	"	"	"	Hornblende diorite	Hornblende	38.1±1.8
72.25-3705	"	"	"	Hornblende-augite diorite	Hornblende	34.6±1.5
CO-7082 (ANU-70-1563)	Flangube Ck,	142°04'E,	3°24'S	Porphyritic intrusive	Wholerock	17.3±0.3
					Hornblende	28.1±1.1
CO-7148 (ANU-70-1564)	Manam Ck,	141°58'E,	3°24'S	Adamellite	Biotite	21.0±0.3

Numbers with prefix 72.25 analysed by AMDL (A.W. Webb)
Numbers with prefix CO (ANU) analysed by R.W. Page (BMR)

Fig.18 Chart showing relations between ages of foraminifera in Bliri volcanics and K-Ar isotopic ages from Torricelli Intrusive Complex



Chemistry of rocks from the Bewani-Torricelli Axis

Sixteen intrusives from the Bewani and Torricelli Mountains, one lava from the Bewani Mountains, and two lavas from north of the Torricelli Mountains, near Aitape, were analysed for major elements. The results of these analyses with CIPW norms are listed in Tables 4 and 5. The specimens analysed were selected from samples collected during the course of regional mapping. Thus the sampling is completely random, and the results must be considered as of a reconnaissance nature only.

Most of the specimens are altered and/or weathered to some degree, and many are oxidized to the extent that Fe_2O_3 is equal to, or greater than TiO_2 + 1.5. For these latter specimens, the Fe_2O_3 and FeO values were recalculated such that Fe_2O_3 did not exceed TiO_2 + 1.5, using the procedure described by Irvine & Baragar (1971). In the tables they are marked with an asterisk, and the recalculated iron values are shown in brackets.

In general, the results show that the rocks of the Bewani-Torricelli Axis are low in alkalis, have moderate to high Al_2O_3 contents, (up to 23 percent), and have variable SiO_2 contents (ranging between 44 and 76 percent). Magnesium and calcium values are moderate to high in the intrusive rocks and somewhat lower in the lavas.

Almost all the specimens (except for 2121A and 3656) are hypersthene normative, most are diopside normative, and five are olivine normative. Normative quartz ranges from 0 to 48.52 percent. Normative corundum, indicating an excess of Al_2O_3 is present in three specimens (3.33 percent in 0587).

The FMA diagram (Fig. 19) shows a broad scatter of points with no overall trend. Twelve of the nineteen specimens fall into Kuno's (1966) 'hypersthenic rock series', and, in general, they show moderate 'iron enrichment'. The intrusive rocks are generally more iron-enriched than the lavas. Compared with the island-arc tholeiitic association of Karkar and Manam Islands and the island-arc calcalkaline association of Bougainville (Jakes & White, 1972), the rocks of the Bewani-Torricelli Axis display calcalkaline, transitional to tholeiitic island-arc affinities.

TABLE 4. ANALYSES AND CIPW NORMS - BLIRI VOLCANICS

(All sample numbers: prefix 72.25)

(Analysed by AMDL: direct reading emission spectrography)

OXIDE	*0587	*1387	*1392
SiO_2	60.0	50.0	62.0
TiO_2	0.35	1.0	0.57
Al_2O_3	14.5	15.8	18.0
Fe_2O_3	3.5 (1.85)	5.7 (2.50)	4.4 (2.07)
FeO	2.85 (4.34)	1.65 (4.53)	1.00 (3.10)
MnO	0.08	0.11	0.03
MgO	3.7	5.8	1.5
CaO	3.1	11.3	5.9
Na_2O	2.9	2.1	3.2
K_2O	2.5	1.2	1.9
P_2O_5	0.1	0.2	0.15
H_2O^+	2.70	1.90	0.62
H_2O^-	2.30	2.90	0.66
CO_2	0.65	0.6	0.05
Total S	0.06	0.025	0.02
Cr_2O_3	0.1	0.1	0.1
V_2O_5	0.05	0.05	0.05
Total	99.44	100.43	100.15
Loss on ignition	5.35	5.35	1.20
CIPW NORM			
Quartz	22.06	5.11	20.72
Corundum	3.33	0.00	0.44
Orthoclase	15.70	7.45	11.40
Albite	26.07	18.67	27.49
Anorthite	11.28	31.68	28.40
Diopside	0.00	17.52	0.00
Hypersthene	16.18	11.84	6.94
Magnetite	2.85	3.81	3.05
Ilmenite	0.71	2.00	1.10
Apatite	0.25	0.50	0.36
Calcite	1.57	1.43	0.12

0587 - altered andesite

1387 - zeolitic orthopyroxene basalt

1392 - porphyritic andesite

* Recalculated Fe values are shown in brackets

TABLE 5a. ANALYSES AND CIPW NORMS - TORRICELLI INTRUSIVE COMPLEX

(All sample numbers: prefix 72.25)

(Analysed by AMDL: wet chemical method)

Oxide	1242	*1265	1557	*1558	*1559	1560	*1562	*1572
SiO_2	66.9	44.1	68.4	76.2	59.8	68.5	59.5	60.6
TiO_2	0.37	0.74	0.37	0.16	0.53	0.39	0.40	0.47
Al_2O_3	14.4	19.6	14.1	12.5	16.4	14.1	15.5	15.9
Fe_2O_3	1.71	6.25 (2.24)	1.65	1.75 (1.66)	2.95 (2.03)	1.80	2.15 (1.90)	3.05 (1.97)
FeO	3.25	7.20 (10.81)	2.70	1.65 (1.73)	3.75 (4.58)	2.75	5.00 (5.23)	3.95 (4.92)
MnO	0.08	0.16	0.08	0.04	0.12	0.07	0.13	0.12
MgO	2.05	6.15	1.78	0.37	2.60	1.86	4.25	2.90
CaO	4.80	13.20	4.20	3.40	6.40	4.40	7.05	6.50
Na_2O	3.20	1.17	3.10	3.25	3.60	2.85	2.50	3.25
K_2O	1.16	0.02	1.71	0.17	0.79	1.64	0.98	0.55
P_2O_5	0.05	0.05	0.05	0.03	0.13	0.05	0.08	0.09
H_2O^+	1.40	0.78	1.19	0.51	2.15	0.01	1.75	1.51
H_2O^-	0.15	0.08	0.11	0.11	0.26	1.18	0.21	0.61
CO_2	0.05	0.05	0.05	0.05	0.10	0.25	0.10	0.10
S	0.08	0.02	0.13	0.07	0.04	0.02	0.01	0.03
TOTAL	99.65	99.57	99.62	100.26	99.62	99.87	99.61	99.53
CIPW NORM								
Quartz	29.88	0.00	31.75	48.52	17.52	33.34	18.48	20.12
Corundum	0.00	0.00	0.00	0.98	0.00	0.34	0.00	0.00
Orthoclase	6.99	0.12	10.29	1.01	4.81	0.82	5.93	3.34
Albite	27.61	10.07	26.70	27.61	31.36	24.43	21.66	28.23
Anorthite	21.94	49.01	19.87	16.42	27.05	20.19	28.87	27.91
Diopside	1.44	14.07	0.62	0.00	3.40	0.00	4.72	3.26
Hypersthene	8.67	9.94	7.40	2.55	11.25	7.78	16.32	12.85
Olivine	0.00	11.82	0.00	0.00	0.00	0.00	0.00	0.00
Magnetite	2.53	3.30	2.44	2.42	3.03	2.65	2.82	2.93
Ilmenite	0.72	1.43	0.72	0.31	1.04	0.75	0.78	0.92
Apatite	0.12	0.12	0.12	0.07	0.32	0.12	0.19	0.22
Calcite	0.09	0.12	0.09	0.11	0.23	0.58	0.23	0.23

1242 - hornblende-biotite diorite

1265 - hornblende-orthopyroxene gabbro

1557 - hornblende granodiorite

1558 - biotite microgranodiorite

1559 - hornblende-biotite diorite

1560 - hornblende granodiorite

1562 - hornblende diorite

1572 - hornblende-quartz diorite

* Recalculated Fe values are shown in brackets

TABLE 5b. ANALYSES AND CIPW NORMS - TORRICELLI INTRUSIVE COMPLEX

(All sample numbers: prefix 72.25)

(Analysed by AMDL: direct reading emission spectrography)

Oxide	*1271A	*2103B	2121A	*3543	*3656	3658	*3704
SiO_2	51.0	46.0	51.0	52.5	43.0	50.0	51.0
TiO_2	1.3	0.27	1.5	0.66	0.62	0.80	0.83
Al_2O_3	14.9	23.0	15.6	16.2	23.6	17.0	17.2
Fe_2O_3	3.0 (2.80)	1.9 (1.77)	2.3	3.3 (2.16)	4.8 (2.12)	1.5	2.4 (2.33)
FeO	8.10 (8.28)	3.45 (3.57)	6.85	5.60 (6.63)	5.65 (8.06)	7.80	6.60 (6.66)
MnO	0.25	0.10	0.16	0.19	0.12	0.20	0.21
MgO	4.6	6.7	6.3	5.7	4.1	5.8	5.4
CaO	9.1	17.0	11.8	12.0	14.8	11.7	11.8
Na_2O	2.9	0.90	2.5	2.0	1.4	2.6	2.3
K_2O	0.7	0.1	0.1	0.7	0.1	0.7	0.4
P_2O_5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
H_2O+	3.15	0.53	1.00	0.87	1.60	1.75	1.15
H_2O-	0.24	0.07	0.13	0.13	0.28	0.17	0.10
CO_2	0.05	0.15	0.05	0.25	0.05	0.05	0.10
Total S	0.09	0.025	0.02	0.14	0.19	0.06	0.085
Cr_2O_3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
V_2O_5	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	99.63	100.44	99.56	100.49	100.56	100.38	99.82
Loss on ignition	2.70	0.45	0.69	0.83	1.68	1.50	0.74
CIPW NORM							
Quartz	4.63	0.00	3.76	5.84	0.00	0.00	3.86
Corundum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orthoclase	4.31	0.59	0.60	4.17	0.60	4.21	2.40
Albite	25.55	7.84	21.52	17.07	9.69	22.38	19.78
Anorthite	26.55	58.62	31.60	33.47	58.95	33.23	36.03
Nepheline	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leucite	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	16.01	19.47	21.89	19.89	12.41	20.44	18.14
Hypersthene	15.68	4.24	13.98	14.33	0.00	11.91	14.29
Olivine	0.00	5.76	0.00	0.00	12.37	3.72	0.00
Magnetite	4.23	2.58	3.39	3.16	3.13	2.21	3.44
Ilmenite	2.57	0.51	2.90	1.26	1.20	1.53	1.60
Apatite	0.25	0.24	0.24	0.24	0.24	0.24	0.24
Calcite	0.12	0.34	0.12	0.57	0.12	0.12	0.23

1271A - altered dolerite
2103B - hornblende-olivine gabbro
2121A - hornblende microgabbro
3543 - hornblende microgabbro
3656 - hornblende microgabbro
3658 - altered hornblende diorite
3704 - hornblende microdiorite

* Recalculated Fe values are shown in brackets

TABLE 5c. TRACE METAL CONTENTS OF ANALYSED SAMPLES IN TABLE 5a.

(Analysed by AMDL)

Sample No.	Cu(ppm)	Pb(ppm)	Zn(ppm)	Co(ppm)	Ni(ppm)	Cr(ppm)	Ag(ppm)	Mo(ppm)
72.25-1242	25	5	40	8	5	5	1	3
1265	70	8	38	25	12	5	1	3
1557	8	5	20	5	5	5	1	3
1558	70	8	20	5	5	5	1	3
1559	50	5	20	8	5	5	1	3
1560	8	8	22	130	5	5	1	3
1562	60	5	35	8	10	12	1	3
1572	38	12	18	8	5	5	1	3

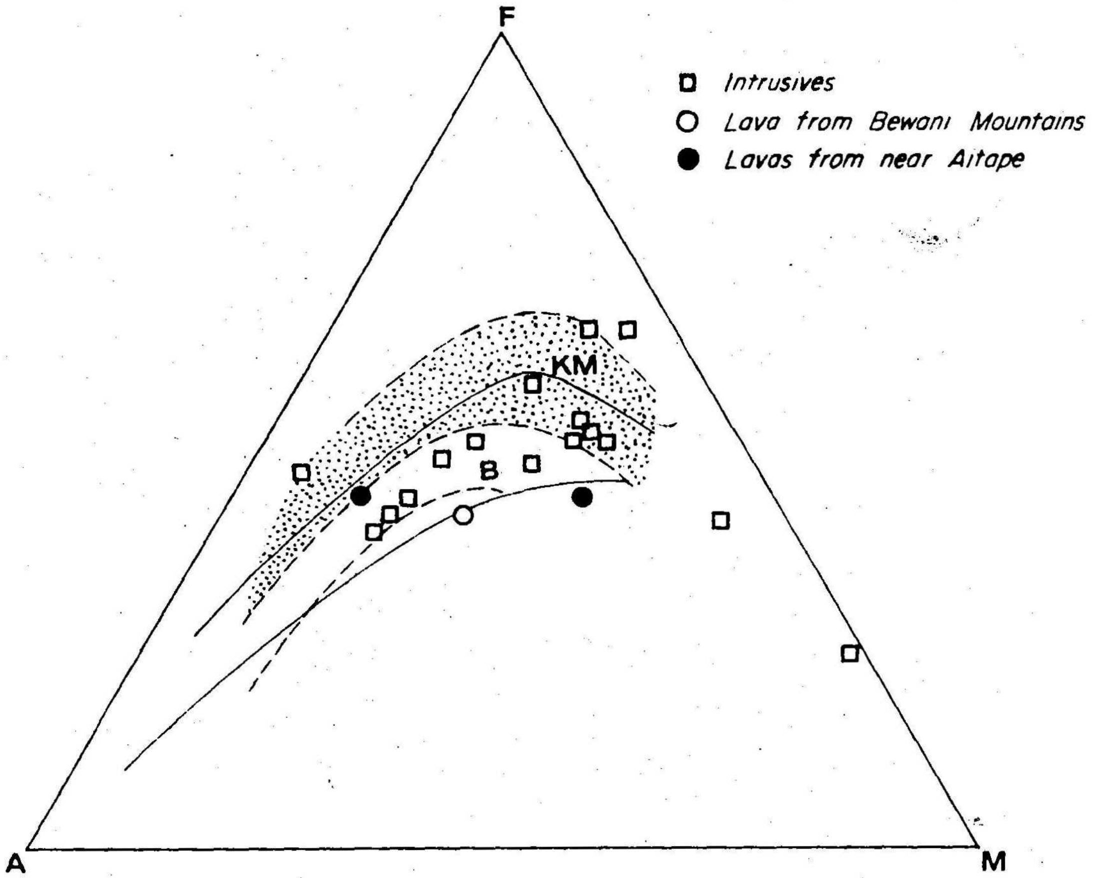


Fig. 19 F.M.A. Diagram of igneous rocks of The Bewani-Torricelli Axis.

Dotted field (KM) - *Island-arc tholeiite association of Karkar and Manam Islands (Jakes & White 1972)*

B - *Island-arc calc-alkaline association of Bougainville (Jakes & White 1972)*

Solid curved lines delimit Kuno's "hypersthenic rock series."

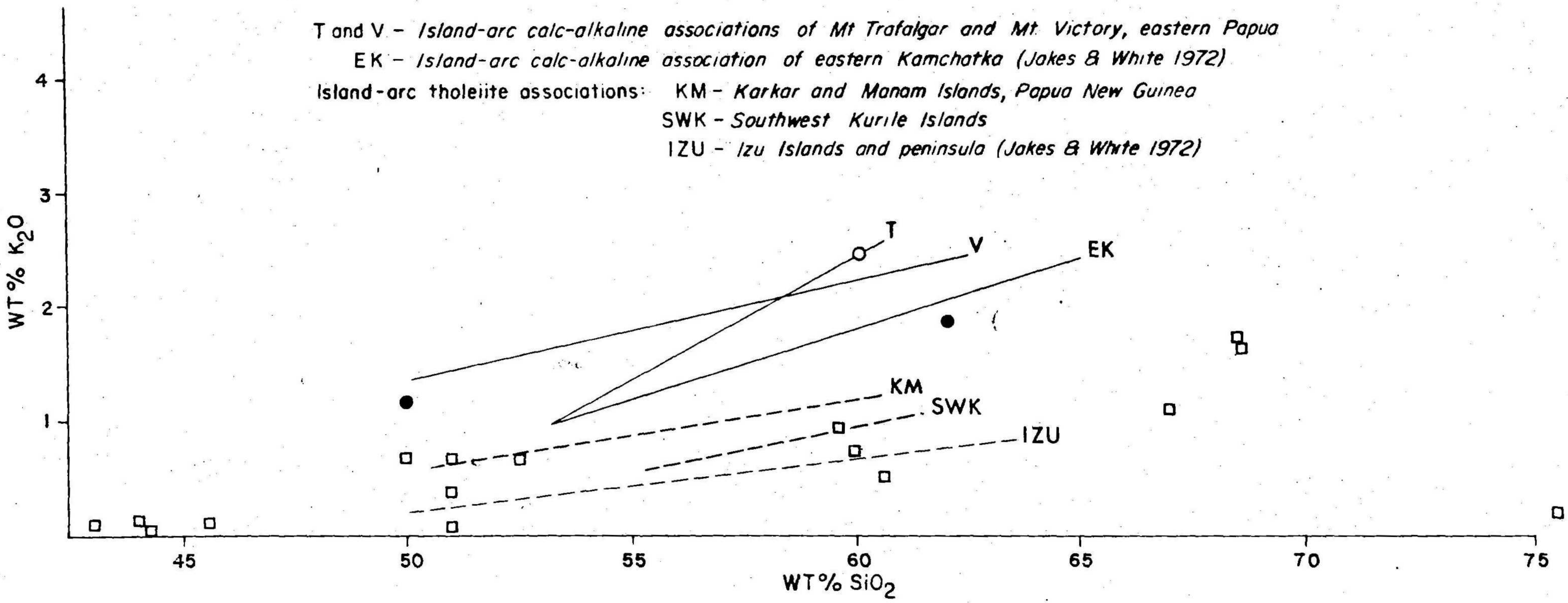


Fig. 20 Weight percent K_2O versus weight percent SiO_2 plot for rocks of the Bewani-Torricelli Axis (Symbols as for Fig. 19)

Figure 20 is a weight percent K_2O versus weight percent SiO_2 diagram. The intrusive rocks display definite tholeiitic affinities when compared with other island-arc tholeiitic associations of Papua New Guinea and elsewhere, and the lavas have closer affinities with the island-arc calcalkaline associations of eastern Papua, and eastern Kamchatka. The apparent grouping of the intrusive rocks in Figure 20 is most likely due to a sampling bias.

To sum up, the rocks of the Bewani-Torricelli Axis have chemical characteristics similar to both tholeiitic and calcalkaline island-arc associations of other parts of Papua New Guinea, and elsewhere in the Pacific region.

PRINCE ALEXANDER AXIS

Basement rocks in the Prince Alexander Axis are made up of two units: (a) the Prince Alexander Complex, and (b) the Mount Turu Complex.

Prince Alexander Complex
(new formal name)

Derivation of name

The name is derived from the Prince Alexander Mountains, an east-southeasterly-trending range in the Wewak 1:250 000 Sheet area between longitudes 142°49'E and 143°37'E (Fig. 3). The mountains form the watershed north of Maprik.

Distribution

The complex is exposed discontinuously in the Prince Alexander Mountains between longitude 142°50'E and longitude 143°11'E, and as a small inlier in the head of Kumberau Creek near the mission airstrip at Dato. In the Prince Alexander Mountains there are two main areas of outcrop - one in the low hills forming the watershed between the east-west sections of the upper Amuk and Danop Rivers, and the other in the core of the range in and between the upper reaches of the Amogu and Ulahau Rivers, north and northeast of Maprik. Small exposures also occur in the upper Atob and Hakup Rivers.

Type area

The area between the upper Amogu River and the headwaters of the Ulahau River has been nominated as the type area. All the rock types making up the complex are found in this area.

Detailed geology

Oil company reports briefly mention boulders of ignous and metamorphic rocks in streams draining the Prince Alexander Mountains, but the only person to describe the rocks of the complex in any detail was Fisher (1940) in his report on the gold occurrences in the area. Marchant (1969) included rocks of the complex in his 'basement complex'. He reported that gneiss occurs near the watershed of the Amogu (Screw) River north of Maprik, and that plutonic rocks are much less common in the Prince Alexander Mountains than elsewhere in the North Sepik region.

The Prince Alexander Complex consists of a mixture of highly deformed igneous and metamorphic rocks of various types. The igneous rocks are all plutonic and are mostly mylonitized fine to medium-grained granodiorite, diorite, and dolerite; less deformed, andesitic dykes and biotite-bearing adamellite and granodiorite are subordinate. The metamorphics are high-grade amphibolite and orthogneiss and subordinate mica-schist. Pyritic quartz veins and disseminated pyrite mineralization are common throughout the complex.

In the western Prince Alexander Mountains (Apa Creek, upper Humal River, and upper Ninab River) the complex consists of highly sheared and crushed leucocratic diorite and granodiorite and subordinate pyritic dolerite. Subordinate quartz-biotite schist and chlorite-epidote schist are intermixed with the intrusives along shear zones. The intrusives are variously recrystallized, highly jointed and fractured, foliated, and chloritized. Foliation consisting of irregular bands of mafic and quartzo-feldspathic minerals was caused by shearing rather than metamorphism. In places, transposition of the foliation along later cleavage indicates two stages of deformation. This secondary cleavage has an irregular but generally east-southeast orientation, and is either vertical or steeply dipping. Intruding these highly deformed rocks are less deformed grey-white andesitic porphyry dykes (in Apa Creek and Ninap River) and biotite adamellite (in Humal River).

In the upper Atob River intense faulting has produced cataclasite from gneiss (Fig. 21).

In the Amogu River, north of Maprik, are exposed mixtures of highly sheared, crushed, and foliated acid intrusives and quartz-feldspar schists. Fisher (1940) described the basement here as a series of metamorphic rocks, intruded by granite, granodiorite, and diorite, with shearing and assimilation around the margins of the intrusions. He also reported that pyritic quartz veins and stringers are common around the intrusive margins. Boulders of amphibolite and high-grade gneiss (Fig. 22) are common in the stream bed, but were rarely seen in outcrop. Some of these boulders show at least two stages of deformation (Fig. 23) and other evidence of a complex history. Boulders of andesite porphyry also occur in the stream bed.

Fig. 21. Cataclasite (originally gneiss) of the Prince Alexander Complex in a tributary of the Atob River, Prince Alexander Mountains. Neg M/1498-10 (DBD).

In the upper Ulahau River, rocks of the complex are mostly highly sheared, shattered, and jointed medium-grained diorite and dolerite. Intense shear zones are up to 1 m wide, and disseminated pyrite mineralization is common. Boulders of amphibolite, foliated gabbro, and diorite occur in the stream bed, but were not found in outcrop.

Fig. 22. Boulder of Lower Cretaceous banded gneiss from the Prince Alexander Complex. Amogu River, north of Maprik.

Neg. M/1485-2 (DBD)

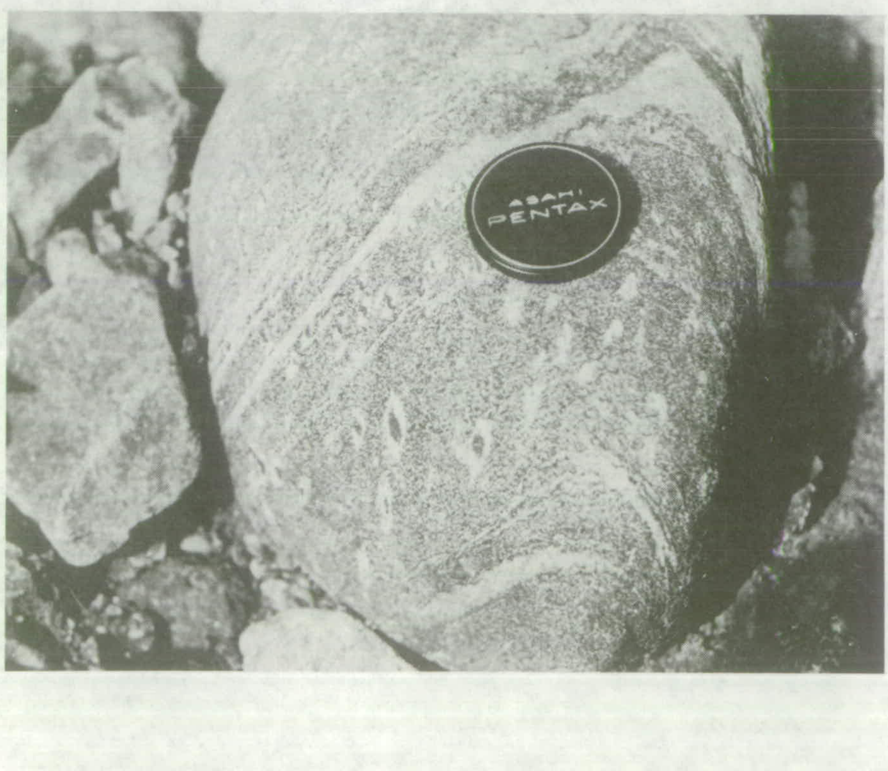


Fig. 23. Boulder of Lower Cretaceous amphibolite from the Prince Alexander Complex (locality as in Fig. 22). S1 foliation has been refolded and ?albite-rimmed hornblende porphyroblasts are aligned parallel to the axial plane of the second-phase folding.

Neg. M/1527-10 (M.N.)

Age and relations with other units

Several K-Ar isotopic age analyses of rocks from the Prince Alexander Complex are summarized in Table 6. Four specimens of amphibolite, one of hornblende gneiss, and one of sheared granodiorite (all from the Amogu River north of Maprik) gave ages ranging from 106 to 114 m.y. (Early Cretaceous). Biotite from a boulder of weathered granodiorite from the Kumerau Creek inlier gave a K-Ar age of 163 ± 3 m.y. (Middle Jurassic), but this result has not been duplicated and should be discounted at this stage, although it could indicate that some parts of the complex are this old. Field evidence indicates that the less deformed andesitic porphyry dykes and biotite-bearing acid intrusions are the youngest rocks in the complex, and this has been confirmed by K-Ar isotopic ages ranging between 19.9 and 24.5 m.y. (late Oligocene to early Miocene). Muscovite from a specimen of pegmatite from the Kumerau Creek inlier gave an age of 21.0 m.y. (early Miocene).

The Kumerau Creek inlier is unconformably overlain by lower to middle Miocene limestone (Puwani Limestone) and by undifferentiated Miocene sediments of the Senu Beds. In the western Prince Alexander Mountains, the complex is in faulted contact with low-grade metamorphics of the Salumei Formation, and is unconformably overlain by various sediments of Miocene and Pliocene age - Puwani Limestone (Miocene) in the Ninab River, Amogu Conglomerate (Miocene) and Senu Beds (Miocene) in the Danop and Amuk Rivers.

In the Amogu River, the complex is unconformably overlain by the Amogu Conglomerate, and in the Ulahau River it is unconformably overlain by the Sargum Conglomerate or Ulahau Fanglomerate of Pliocene age.

Mount Turu Complex

(new formal name)

Derivation of name

The name is derived from Mount Turu (elevation 1219 m) which is situated 7.5 km northeast of Yangoru Patrol Post in the Wewak 1:250 000 Sheet area.

TABLE 6. K-Ar ISOTOPIC AGE ANALYSES, PRINCE ALEXANDER COMPLEX

SAMPLE NO.	LOCALITY	LITHOLOGY	COMPONENT ANALYSED	AGE (x10^6 y)
72.25-1689	Ninab Ck.; 142°57.5'E, 3°31'S	Biotite microdiorite	Biotite	22.5 ± 0.3
72.25-20588	Nyimil Ck.; 142°49'E, 3°28'S	Biotite granodiorite	Biotite	20.0 ± 0.8
77.25-3603	Apa Ck.; 142°50'E, 3°19'S	Biotite porphyry	Biotite	19.9 ± 0.8
72.25-3661	Amogu R.; 143°04.5'E, 3°34'S	Basic porphyry	Plagioclase	24.5 ± 1.0
CO-6002 (ANU-70-1559)	Wambaran Ck.; 142°37'E, 3°27'S	Pegmatite	Muscovite	21.0 ± 0.2
72.25-3662	Amogu R.; 143°04.5'E, 3°34'S	Amphibolite	Hornblende	114 ± 4
72.25-3663	" "	Amphibolite	Hornblende	110 ± 4
72.25-3678	" "	Amphibolite	Hornblende	111 ± 4
CO-833 (ANU-70-1565)	Huaut Ck.; 142°38'E, 3°21.5'S	Weathered granodiorite	Biotite	163 ± 3
CO-6310 (ANU-70-1560)	Amogu R.; 143°04'E, 3°34.5'S	Hornblende gneiss	Hornblende	106 ± 1.5
CO-6310 (ANU-70-1561)	" "	Amphibolite	Hornblende	108 ± 2
CO-6313 (ANU-70-1562)	Amogu R.; 143°04.5'E, 3°34'S	Sheared granodiorite	Biotite	109 ± 1.5

Samples with prefix 72.25 analysed by AMDL (A.W. Webb)

Samples with prefix CO(ANU) analysed by R.W. Page (BMR)

Distribution

The complex is exposed in the eastern Prince Alexander Mountains as a single, elongate body forming the high rounded ridges north and northeast of Yangoru Patrol Post. The ridges culminate in Mount Turu, the highest point in the Prince Alexander Mountains. The body is elongated in an east-west direction, is about 27 km long and 8 km wide at its widest point, and is exposed in and between the upper reaches of the Nagam and Sargum Rivers.

Type area

No single part of the complex has been designated as a type area, though the upper reaches of the streams flowing south toward Yangoru would provide a representative area for the complex.

Detailed geology

Fisher (1940) made the first observations of the geology of the Mount Turu area; he stated that it was composed mainly of slate and schist but makes no mention of igneous rocks, and was obviously referring to the Ambunti Metamorphics which crop out near Yangoru. Marchant (1969) included the unit as part of his 'basement complex'. He mentioned garnet gneiss and hornblende schist from north of Yangoru, and also reported that APC geologists recorded diorite from the area. No mention is made in either report of mafic and ultramafic rocks.

The unit is a faulted intrusive igneous complex composed predominantly of mafic and ultramafic rocks in about equal proportions; subordinate diorite and rare dolerite, biotite adamellite, and biotite granodiorite are also present. In outcrop the rocks are commonly faulted and sheared, and as a consequence are foliated, mylonitized, and altered.

In the upper Sargum River, the complex consists of moderately faulted and sheared gabbro, diorite, and fine-grained green porphyritic ?dolerite, all invaded by dolerite dykes. Boulders of biotite granodiorite occur in the stream bed.

In the upper Sosorem River, the complex is a faulted, sheared, and highly jointed mixture of microdiorite, microgabbro, and minor ultramafics, intruded by dolerite dykes. Pyritic quartz veins are common, and some of the rocks are foliated and recrystallized.

Strongly sheared and foliated, coarse-grained diorite with minor pegmatitic phases are the most common rocks in the upper Nagam River, and in the headwaters of the streams north and northeast of Yangoru Patrol Post, the complex consists of ultramafics and minor gabbro and diorite. In the latter streams, the rocks are mostly fresh, but are altered in and near shear zones. Little evidence was found in field relations to indicate the sequence of intrusion, as most contacts are faulted. Dolerite dykes are obviously a later phase, and K-Ar isotopic evidence indicates that the acid intrusions are probably a late phase also.

Petrography

Table 7 presents a petrographic summary of selected representative samples of the complex. Petrography was done by C.J. Pigram of GSPNG. A wide range of ultramafic rocks is present including clinopyroxenite, websterite, wehrlite, and lherzolite. Clinopyroxene (generally augite) is the dominant mineral component. Orthopyroxene occurs in some specimens, and sphene, magnetite, and titanomagnetite are common accessories. Textures range from coarse-grained granular in undeformed rocks to granoblastic and nematoblastic in deformed varieties. Intercumulus texture is present in some specimens.

The mafic rocks typically have ophitic and subophitic texture, and range from troctolite through olivine gabbro to hornblende gabbro. The percentage of olivine ranges widely (e.g. from 5 percent in a uralitized olivine gabbro to 70 percent in a troctolite). Amphibole occurs in variable but mostly small amounts, and orthopyroxene appears to be absent except as small exsolution blebs in clinopyroxene. Orthoclase (5%) was present in one specimen of olivine gabbro.

The intermediate rocks range from olivine diorite through clinopyroxene diorite to hornblende diorite; most have medium-grained allotriomorphic-granulartextures, and nearly all contain a blusih green amphibole which commonly constitutes up to 50 percent of the rock. In some specimens, the amphibole reveals two stages of development, and is often secondary.

One sample was collected of biotite adamellite which contained 20 percent quartz, no amphibole, and accessory sphene, zircon, and apatite.

TABLE 7. PETROGRAPHY OF REPRESENTATIVE SAMPLES OF THE MOUNT TURU COMPLEX
(Petrography by C.J. Pigram, GSPNG - mineral percentages visually estimated)

Sample No.	Rock Type	Olivine	Clinopyroxene	Orthopyroxene	Plagioclase	Other	Secondary Minerals	Remarks
ULTRAMAFIC ROCKS								
72.25-2067	Uralitized websterite		50 (augite)	20 (enstatite)			20 hornblende ? Ca silicates	Both pyroxenes replaced along fractures an cleavage by amphibole and ?Ca silicates
72.25-2070	Serpentinite					magnetite sphene	30 antigorite 70 (liz/chrys.)	Sphene derived from Ti in titanomagnetite via leucoxene during serpentinization
72.25-2076	Serpentinite	45		5		10 opaques	20 bastite 20 ant./liz./chrys.	Precursor was harzburgite; relict polygonal texture of olivine preserved by magnetite during serpentinization
72.25-2077	Clinopyroxenite		90 (augite)	trace			10 hornblende	Slightly uralitized; blebby exsolution of opx. in augite
72.25-2125 A	Wehrlite	60	20			trace of opaques	20 serpentine	Clinopyroxene has intercumulous texture: cross-cutting veinlets of fibrous chrysoli
72.25-2134	Serpentinised lherzolite	30	12	12		opaques	50 serpentine	

MAFIC ROCKS	Rock Type	Olivine	Clinopyroxene	Amphibole	Plagioclase	Other	Secondary Minerals	Remarks
72.25-2130	Uralitized dolerite		35 (augite)		45 (An_{53})	5 opaques	20 (amphibole)	Sub-ophitic texture
72.25-2131	Sheared troctolite	70	5 (augite)		25			Olivine is fractured with undulose extinct most of plag. crushed and stressed
72.25-2132	Uralitized olivine gabbro	5	45	5	45			Ophitic texture
72.25-3214	Foliated olivine gabbro	30	10 (augite)		55	5 (orthoclase)		Possibly a troctolite

INTERMEDIATE AND ACID ROCKS	Rock Type	Olivine	Clinopyroxene	Amphibole	Plagioclase	Other	Secondary Minerals	Remarks
72.25-2115 A	Olivine diorite	15		40 (prob. secondary)	35	10 (orthoclase)	? Epidote	Cataclastic texture, bent plag. lamellae a undulose extinction of many crystals. Mir recrystallisation
72.25-2126	Pyroxene diorite		10	40	50			
72.25-3215	Diorite			40	60 (An_{34})			
72.25-2115 C	Adamellite				40	30 orthoclase 20 quartz 8 biotite (sphene 2 (zircon (apatite	Traces of sericite, muscovite and epidote	Granular, xenomorphic texture

Most rocks in the complex are altered, especially near shear zones. Serpentinization of ultramafic and mafic rocks has produced antiogrite, lizardite, and chrysotile after olivine, bastite after clinopyroxene, and also sphene and abundant magnetite. Sphene is derived from the titanium in titanomagnetite which is released to form leucoxene, which in turn is converted to sphene (C.J. Pigram, pers. comm.). The relict polygonal texture of olivine is commonly preserved by magnetite.

Both the ultramafic and mafic rocks are uralitized, the usual product being a blue-green amphibole (uralite) after clinopyroxene.

Saussuritisation is common in sheared and deformed rocks such as those found in the large fault zones in the upper Mindjim and Nagam Rivers. The rocks are crushed, mylonitized, and commonly foliated and recrystallized, and have commonly been converted to phyllonite. Saussuritisation generally affects the finer crushed plagioclase fragments, which are altered to epidote and ?zoisite. The highly deformed rocks are commonly rich in amphibole, much of which is probably secondary, and many are foliated.

Age and relations with other units

The complex is unconformably overlain along its northern side by the steeply dipping Sargum Conglomerate of probable Pliocene age, and in the east and south east by Pliocene Maprik Mudstone. Along its southern side, the complex is in contact with metamorphics; the contact is partly faulted and apparently partly intrusive. If the intrusive relation is correct, the age of metamorphism (Oligocene) places a lower age limit on the complex. Two K-Ar isotopic ages have been determined on rocks from the complex (Table 8).

TABLE 8. K-Ar ISOTOPIC AGE ANALYSES, MOUNT TURU COMPLEX
Analyses by AMDL (A.W. Webb)

SAMPLE NO.	LOCALITY	LITHOLOGY	COMPONENT ANALYSED	AGE ($x10^6$ yr)
72.25-2115 B	Sargum R.; 143°16'E, 3°35'S	Olivine gabbro	Plagioclase	188 ± 50
72.25-2115 C	Sargum R.; 143°16'E, 3°35'S	Biotite granodiorite	Biotite	18.2 ± 0.8

Biotite from the boulder of biotite adamellite was dated at 18.2 ± 0.8 m.y. This age is similar to that obtained from the youngest rocks (which are of similar lithology to the biotite adamellite) in the Prince Alexander Complex to the west, and probably places an upper age limit to the complex. Plagioclase from an olivine gabbro was dated at 188 ± 50 m.y. but because of the low percentage of potassium in the sample and the large standard deviation, the age is not considered valid. On the foregoing data the age of the complex is probably Oligocene to lowermost Miocene.

Origin of the ultramafics

The presence of cumulus and intercumulus textures in some specimens, the apparent gradation from plagioclase-free ultramafic through troctolite to gabbro and diorite, and the presence of clinopyroxene as a dominant mineral phase are all features which suggest that the rocks in the complex are cumulates. They appear similar in many respects to the rocks which make up the Gabbro Zone, and the Cumulus member of the Ultramafic Zone in the Papuan Ultramafic Belt (Davies, 1971). This suggests that all the rocks in the complex (except probably the biotite adamellite) are cogenetic, and that the ultramafics are differentiates.

The Papuan Ultramafic Belt is similar to Mediterranean ophiolites, Alpine-type peridotite-gabbro complexes, and ocean-floor rocks (Davies, 1971, p.40), and Davies considers that the rocks in the belt (except for the non-cumulate ultramafics) developed from a parent basalt magma generated in the mantle, and intruded along a tensional zone in oceanic crust. He considers that the Belt was overthrust southeastwards into its present position and that the non-cumulate ultramafics at the base represent a segment of pre-existing mantle.

The Mount Turu Complex is situated in a major fault zone; however, there is no evidence for thrusting, and non-cumulate ultramafics appear absent. This suggests that the complex possibly originated from a basaltic magma which was generated in the mantle, and intruded along a major deep-seated fault zone. Differentiation could have produced ultramafic, gabbroic, and dioritic differentiates. In the absence of chemical data this hypothesis cannot be tested.

METAMORPHIC BASEMENT

Metamorphic rocks are exposed as scattered inliers south of the central basement axis. These are mostly pelitic rocks which have been correlated with the Salumei metamorphics (Dow et al., 1972) exposed south of the Sepik River, and which are thought to underlie most of the Lumi Trough.

Near Amanab, meta-intrusive rocks have been mapped as a separate unit (Amanab Metadiorite).

AMBUNTI METAMORPHICS

Derivation of name

The name Ambunti Metamorphics was erected by Dow et al. (1972; p.23) for greenschist and subordinate amphibolite grade metamorphosed marine sediments and volcanics which are exposed south of the Sepik River, between the Karawari and May Rivers.

Distribution

Ambunti Metamorphics are exposed sporadically in the North Sepik region south of the main ranges, from the Irian Jaya border in the west to south of Mount Turu in the east. The main area of exposure is in the Border Mountains, where greenschist-grade pelitic metamorphics form most of the basement outcrops. A small inlier of greenschist-grade metamorphics is exposed in Upper Manam Creek, northwest of Lumi, and boulders of garnet schist are abundant in the upper Gwenilif River, although none have been seen in outcrop. In the western Prince Alexander Mountains, Ambunti Metamorphics occur as small faulted blocks and slivers south of the upper Danop River, and as a larger mass south of the Mount Turu Complex, near Yangoru patrol post. Small outcrops of metamorphics are exposed in the core of the Panamberi Anticline (upper Panamberi River) and in the Hambili Anticline (upper Trubum River), south of Yangoru Patrol Post. Metamorphics also form the small hills at Yellow River Mission, near the Sepik River in the southern part of the Aitape 1:250 000 Sheet area. Pebbles of metamorphics occur in conglomerates near Samap, southeast of Wewak, but no metamorphics have been found cropping out in this area.

Type area

For a full description of the Ambunti Metamorphics see Dow et al. (1972, p.23).

Detailed geology

The metamorphics in the north Sepik region are poorly exposed. They are dominantly pelitic and of greenschist grade but range up to amphibolite grade. They have been correlated with the type Ambunti Metamorphics from south of the Sepik River on the basis of lithology.

In the Border Mountains, the metamorphics are phyllite, low-grade pelitic and calcareous schist with some interbedded green metavolcanics, and subordinate shale, slate, and limestone. In the Dio River south of Amanab, they grade over a distance of 8 km from highly indurated grey siltstone, sandstone, and calcareous sandstone, with lenses of limestone and recrystallized marl in the north, through strongly cleaved shale and metasediments, to slate with several sets of cleavage in the south. The slate passes into micaceous phyllite with incipient segregation banding. In places, the phyllite is tightly folded and highly contorted, and shows pseudo-augen structures. Downstream the slate and phyllite grade into micaceous and chloritic schist with interbedded green metavolcanics. West of the Dio River the metamorphics are mostly contorted micaceous phyllite, sericite schist, quartz-mica schist, and rare beds of metavolcanics.

The dominant metamorphic foliation or cleavage trends east-southeast, and is mostly steeply dipping. Kink-banding occurs in places.

Intrusive rocks have been observed as stream boulders in many places in the Border Mountains (e.g. porphyry boulders in the upper Dio River) where metamorphics crop out. These have rarely been seen in outcrop, and their relation with the metamorphics is unknown. They are probably post-metamorphic intrusions and possibly the equivalents of the Oligo-Miocene stocks intruding the Ambunti Metamorphics south of the Sepik River (Dow et al., 1972).

In Manam Creek northwest of Lumi, a small inlier of grey micaceous phyllite and marble intruded by diorite is exposed.

In the western Prince Alexander Mountains, metamorphics occur as small faulted blocks and slivers of low-greenschist-grade rocks. In Nyimil Creek, alternating shale, quartzite, marble, and grey phyllite (partly carbonaceous) have been intruded by small bodies of diorite, and dykes of porphyritic microgabbro. In the upper Humal River, the metamorphics are mostly low-grade micaceous and chlorite-epidote schists with minor carbonaceous slate and phyllite. Shearing is common, and elongate augen structures are found in the chlorite schists. In Kumba and Mindil Creeks, the metamorphics are adjacent to the major Prince Alexander Fault Zone, and are consequently very highly sheared and crushed, resulting in a mixture of metabasalt, slate, thinly bedded fine-grained marble, sheared conglomerate, and other sediments. In Mindil Creek, a very similar sequence of highly sheared metabasalt, limestone, slate, phyllonite, and granodiorite is intermixed with highly sheared conglomerate, sandstone, and siltstone. The zone of shearing in Mindil Creek is about 1 km wide.

South of Mount Turu the metamorphics are generally of higher grade than elsewhere in the North Sepik region. The rock types are remarkably uniform throughout the exposed mass, consisting mainly of bluish grey quartz-muscovite-biotite schist, commonly with large garnet porphyroblasts. Other common rocks are hornblende-chlorite schist, muscovite-chlorite schist, and chlorite-epidote schist; schistose chloritic metabasalt, foliated metagabbro, and metadiorite are subordinate. Minor amphibolite and muscovite-biotite gneiss also occur. Quartz veins and pyrite mineralization are commonly associated with the bluish grey quartz-mica schist. The metamorphic foliation has a general east-southeast trend, and is vertical or steeply dipping.

In the middle reaches of the Wuro River a small sliver of quartz muscovite schist is associated with phyllonite in a fault zone.

The bed of Gwenilif River, west of Lumi, contains many boulders of metamorphics; these include coarse-grained garnet-bearing mica schist and amphibole-chlorite schist, and chlorite-epidote schist (?metavolcanics). No outcrops of metamorphics were found in the area, and the boulders appear to come from beneath patches of Puwani Limestone upstream, which apparently rest partly on metamorphic basement.

The small hills of metamorphics at Yellow River Patrol Post were visited during the BMR West Sepik survey in 1971. The only outcrop examined was in a road cutting near the patrol post where hornblende-feldspar gneiss intruded by diorite was exposed (H.L. Davies, pers. comm.). Residual boulders of hornblende gneiss and a 'clinopyroxene-rich rock' were found near the Patrol Post.

Age and relations with other units

Limestone lenses in the metasediments exposed in the Dio River south of Amanab and in the Yagroner Hills contain the Eocene larger foraminifera *Discocyclina* and *Nummulites* (D.J. Belford, pers. comm.). From a small stream south of Amanab, a boulder of recrystallized limestone containing Upper Cretaceous larger foraminifera (*Pseudorbitoides* and *Globotruncana*) is assumed to come from the metamorphics. On this evidence, the age of the metamorphosed sediments range from Late Cretaceous to Late Eocene. South of Amanab, the metamorphics are unconformably overlain by unmetamorphosed limestone containing probable upper Oligocene larger foraminifera (*Lepidocyclina*, D.J. Belford, pers. comm.), suggesting that the rocks were probably metamorphosed in the lower to middle Oligocene.

The metamorphics in Manam Creek and in the western Prince Alexander Mountains are very similar in grade and lithology to those exposed in the Border Mountains, and have been correlated with them on this basis. Those exposed near Yangoru and seen as boulders in the Gwenilif River are of higher grade than other metamorphics in the North Sepik Region but are similar in grade and lithology to Ambunti Metamorphics exposed in the upper May River, east of Mount Kasa (May River 1:250 000 Sheet area). The rocks at Yellow River are also of higher grade than type Ambunti Metamorphics, but again are similar rocks in the upper May River.

In the Border Mountains, the Ambunti Metamorphics are unconformably overlain in the north and west by flat-lying lower to middle Miocene Puwani Limestone, in the north by undifferentiated Miocene clastic sediments, and in the south by Pliocene clastic sediments. In Manam Creek, the metamorphics are again unconformably overlain by Puwani Limestone and also by Miocene clastic sediments of the Senu Beds. In the western Prince Alexander Mountains, they are in faulted contact with the Prince Alexander Complex, and are unconformably overlain by the Senu Beds and by Puwani Limestone in the upper Ninab River. In the Yangoru area, the metamorphics are apparently intruded by the Mount Turu Complex; they are unconformably overlain along their southern side by the Pliocene Maprik Mudstone, and at their western end by the Sargum Conglomerate (Pliocene).

Amanab Metadiorite

(new formal name)

Derivation of name

The name is taken from the government outpost of Amanab, headquarters of the Amanab Sub-district, in the West Sepik Administrative District (about 100 km south of Vanimo, grid reference 141°12'E, 3°34'S).

Distribution

The Amanab Metadiorite is poorly exposed over an area of 50 to 75 km^2 around Amanab in the Border Mountains, and also in the hills south of Imonda. The best exposures are in Yuva and Hinibi Creeks near Amanab.

Type area

The designated type area is the headwaters of Yuva Creek which rises about 6 km west of Amanab, and flows eastward to the Bapi River, passing about 1 km south of Amanab airstrip.

Detailed geology

The Amanab Metadiorite consists mainly of sheared metadiorite with subordinate metagabbro, metagranodiorite, and dolerite dykes.

The least deformed rocks are only slightly sheared and altered, the alteration generally being restricted to chloritization of ferromagnesian minerals. The highly deformed rocks are strongly sheared and recrystallized, often with subfoliated texture; silicification and alteration of feldspars to chlorite and epidote is obvious.

In the head of Yuva Creek, metagabbro grades downstream into moderately sheared foliated and recrystallized metagabbro, and to highly sheared schistose basic rocks which are almost completely recrystallized. Overlying Miocene Senu Beds (usually conglomerate) are involved in the shearing in places, indicating that some of the faulting and deformation is post-Miocene.

In a small creek south of Amanab, highly sheared serpentinite is intermixed with sheared chloritized diorite and granodiorite.

In Hinibi (Bwambudini) Creek east of Amanab, the rocks are much less deformed, and are chloritized coarse-grained granodiorite, diorite, and gabbro, and subordinate dolerite. Quartz veins (up to 1.5 m wide) and xenoliths of green, altered lava are common. South of Imonda, the unit is very poorly exposed. Boulders of sheared gabbro occur in the small stream south of the patrol post and one outcrop of sheared, foliated metagabbro was found in the Bapi River, southeast of the patrol post.

Age and relations with other units

There is no direct evidence to indicate the age of the unit. No contacts were observed with the Ambunti Metamorphics, which are exposed nearby. It is probable that the igneous rocks making up the unit intruded the Metamorphics before both were metamorphosed. The grade of metamorphism is low in the Border Mountains, and was not sufficient to totally obliterate the igneous fabric of the rocks. Metamorphism probably occurred in the lower or middle Oligocene, thus placing a probable upper age limit to the Amanab Metadiorite. No criteria for fixing a lower age limit are known.

Near Amanab the Metadiorite is unconformably overlain by Miocene sediments (Puwani Limestone, Amogu Conglomerate, Senu Beds), and south of Imonda most of the unit is obscured by patches of flat-lying Puwani Limestone.

OTHER BASEMENT ROCKS

Ultramafic Rocks

In many streams draining the Bewani and Torricelli Mountains, small to medium-sized boulders of sheared and serpentinized ultramafics and gabbro are common. These rocks were rarely seen in outcrop; where observed, they occurred as rounded to subrounded blocks in shear zones - for example in the upper Nigia River, where an almost vertical shear zone several metres wide contains large (up to 1.5 m across), semi-rounded blocks of serpentinite, pyroxenite, and serpentinized gabbro in a matrix of sheared serpentinite gouge and other small rock fragments (Fig. 24).

These blocks have clearly been squeezed up from depth along the fault zone, and indicate the deep-seated nature of many of the faults in the North Sepik region.

Small slivers of highly sheared dark green rocks which are probably serpentinite crop out in a small creek south of Amanab. These rocks do not appear to be related to a major fault zone, and are possibly phases of the Amanab Metadiorite, with which they are associated. Stanley (1938) reported scattered outcrops of similar rocks east of Amanab.

In the Oenake Mountains, a small pod of serpentinite crops out on the north side of the Moso River valley, and boulders of serpentinite occur in the stream south of Wutung, northwest of Mount Bougainville. Small serpentinite boulders also occur in Manda Creek and adjacent streams (10 km west of Vanimo).

In a road cutting west of Manda Creek, a sliver of serpentinite occurs in a small thrust zone in Puwani Limestone. These rocks were first reported by Nason-Jones (1930), who described greenish black or streaky green serpentinite containing veins of fibrous grey-green chrysotile from Sito Hill, 8 km west of Vanimo township. He named these rocks the Oenake Series. He also described serpentinite fragments in tuffs of his Lower Aitape Group (Bliri volcanics), but does not specify from what locality (Nason-Jones, 1930, p. 43). This suggests that at least some of the serpentinite emplacement was pre-Miocene. Ultramafic rocks have been described from adjacent parts of Irian Jaya (Cyclops Mountains) by Schultze-Jena (1914), Zwierzijeki (1924), Visser & Hermes (1962), and Reynolds et.al. (1973). Visser & Hermes reported serpentinite pebbles in the Auwewa Formation (equivalent to Bliri volcanics), and state that, as this formation is locally of Late Cretaceous age, emplacement of the serpentinites must have occurred before the Late Cretaceous (Visser & Hermes, 1962, p. 123).

Fig. 24. Vertical shear zone containing ultramafic and gabbroic blocks and fragments in serpentinite pug. Torricelli Mountains.

Neg. GA/6388 (DBD)

Permian Intrusives

In the Green River (North Branch), 29 km southwest of Amanab in the Border Mountains, many large boulders of intermediate and acid leucocratic intrusive rocks occur in the stream bed. These are nearly all medium to coarse-grained, hornblende-bearing quartz diorite and granodiorite, with subordinate diorite and tonalite, and rare leucocratic granophyre. Most of the rocks contain biotite in small amounts, and one sample of diorite contained pyroxene. Feldspars are commonly altered to sericite and kaolinite, and biotite to chlorite. Hornblende is usually fresh.

Nine K-Ar isotopic age analyses from boulder samples collected in the river at a single locality are summarized in Table 9. The ages range from 242 to 257 m.y., and their mean is 249 m.y. (mid-Permian). The boulders of coarse-grained leucocratic intrusives come from Irian Jaya, and outcrops in the stream where the boulders were collected are of altered jointed dolerite. It is not known whether or not the dolerite is part of the Permian complex.

STRUCTURE

Faulting

Geological structure in the North Sepik region is dominated by a major, almost continuous fault system through the central ranges which extends from the Irian Jaya Border to southeast of Wewak. The width of the zone of shearing and brecciation associated with this faulting ranges from 2 to 6 km, and the major faults within the zone are closely spaced en echelon or anastamosing fractures which trend roughly parallel to the mountain range (aligned between 080° and 100°). The dominant trend in the Bewani Torricelli Axis is approximately east, but in the Prince Alexander Axis it is about 095°. Small splinter faults and cross-faults are common, and these often offset or terminate the larger faults. Deformation within the zone is intense, and many closely spaced shears involve both basement and cover rocks. Accordingly, relations between the various rock types in the zone are complex and confused.

TABLE 9. K-Ar ISOTOPIC AGES OF PERMIAN INTRUSIVE ROCKS

Analysed by AMDL (A.W. Webb)

SAMPLE NO.	LOCALITY	LITHOLOGY	COMPONENT ANALYSED	AGE (x 10^6 yr)
72.25-1156	N. branch Green R.; 141°01'E, 3°46'S	Hornblende-quartz diorite	Hornblende	242 ± 5 249 ± 5
72.25-3574	" "	Hornblende-pyroxene diorite	Hornblende	257 ± 7
72.25-3577	" "	Hornblende granodiorite	Hornblende	255 ± 7
72.25-3579	" "	Hornblende-biotite tonalite	Hornblende	257 ± 7 255 ± 7
72.25-3580	" "	Hornblende-biotite granodiorite	Hornblende	243 ± 7
72.25-3582	" "	Hornblende-biotite-quartz diorite	Hornblende	243 ± 7
72.25-3583	" "	Hornblende-biotite granodiorite	Hornblende	246 ± 7

Continuous shear zones range in width from less than a metre to a kilometre or more. Major faults are invariably almost vertical or steeply dipping, whereas minor faults range between vertical and almost horizontal. Thrusting is developed to a minor degree in the smaller faults.

Horizontal and sub-horizontal slickensides indicate that movements along the major faults were probably largely transcurrent, although substantial vertical movements have undoubtedly occurred. For example, along the north side of the western Torricelli Mountains (in the region of the Pieno, Yalingi, and Raihu Rivers), an estimated vertical displacement of 2000 to 3000 m has occurred along the major faults. The north block has been dropped down relative to the south, bringing upper Pliocene sediments into juxtaposition with basement.

No direct field evidence was found to indicate the sense of horizontal movement indicated by slickensides. Three rather poor fault-plane solutions are available for earthquakes in the North Sepik region (Johnson & Molnar, 1972; Ripper, 1975). These solutions indicate a combination of strike-slip movement and compressional overthrust with the compressional axis aligned southwest. Possible sinistral strike-slip movements can be inferred, but the data must be considered dubious.

In a few shear zones in the Bewani-Torricelli Axis (e.g. in the upper Nigia River) subangular to rounded pebbles and blocks of serpentinite and coarse-grained altered gabbro in a matrix of sheared serpentinite were observed (Fig. 24). These blocks have undoubtedly been squeezed up along the shear zones from great depth and indicate the deep-seated nature of many of the major faults.

The dominant easterly trend in the fault zone is interrupted and offset in places by complex anastomosing, northwest-trending splay-fault zones. These splay-fault zones consist of a mass of curved, anastomosing faults which throw rocks of several different units together in what is, in effect, a large-scale tectonic breccia composed of blocks with dimensions measurable in kilometres. Northwesterly-trending, tightly folded and often faulted anticlines are generally associated with the splay-fault zones. Several of these zones occur along the Bewani and Torricelli Mountains - in the upper Puwani River, the Bilia River, the upper Piore River, and the upper Bliri/Peino Rivers area. Complex, anastomosing faults also occur in the Matapau area. At the extreme eastern end of the large fault zone southeast of Wewak, the dominantly easterly trend is cut off by a southeasterly trend.

Approximately north-trending faults occur in the western Torricelli Mountains, and seem to be related to a large north-south anticlinal feature (including the Makofin and Maimai anticlines) to the south, in the upper Wagasu and Kumal Rivers. North-trending faults also occur at the western end of the Bewani Mountains.

Faulting in both the Bewani-Torricelli Axis and the Prince Alexander Axis involves cover as well as basement rocks. In both axes, Miocene and Pliocene sediments have been severely disrupted, but younger sediments have been only slightly affected. This suggests that large movements within the fault system ceased at the end of the Pliocene.

In the Prince Alexander Axis, most of the deformation in the basement rocks took place before intrusion of the lower Miocene porphyry dykes and small acid intrusions, but in the Bewani-Torricelli Axis there is no evidence to indicate when faulting began. The southeasterly-trending faults in the Prince Alexander Axis appear cut off by the easterly-trending faults in the Bewani-Torricelli Axis. Since the end of the Pliocene, only minor movements have occurred in the major fault system, and the Pleistocene and younger sediments have been affected mostly by warping and block-faulting due to uplift.

The major east-trending fault zone in the North Sepik region is the eastward extension of the Sorong fault zone of Irian Jaya (Tjia, 1973). This fault zone is 4 to 8 km wide, and was interpreted by Visser & Hermes (1962, p. 159) on stratigraphic evidence to be a strike-slip fault along which about 350 km of left-lateral movement has taken place since middle or late Miocene time.

South of the main fault zone faulting is minor. Cover sediments are disrupted in places, and block-faulting occurs in limestone in the Border Mountains. The presence of unmetamorphosed Permian rocks in juxtaposition with Cretaceous to Eocene metamorphics southwest of Amanab implies a major basement fault here; if such a fault exists, it is now largely obscured by younger sediments.

North of the main ranges, small ultramafic bodies in the Oenake Mountains indicate deep-seated basement faulting here, and blueschist-grade metamorphics in adjacent Irian Jaya (Van der Wegen, 1971) suggest a possible former subduction zone in this region. A small thrust containing serpentinite slivers has disrupted Miocene limestone west of Vanimo. Miocene and younger limestones in the Oenake Mountains and Pliocene limestone in the Serra Hills have been disrupted by tensional block-faulting due to uplift and warping which began in the Pliocene, and is continuing today.

Folding

Northwest-trending anticlines associated with northwest-trending splay faults along the north side of the Torricelli and Bewani Mountains have already been described. In addition, several sets of northwest-trending anticlines occur elsewhere on both sides of the range. These northwest-trending structures are probably related to left lateral transcurrent movement along the major fault zone.

In addition to these, an east-west trending set of anticlines parallel to, and along, the north side of the Bewani and Torricelli Mountains extends from the Raihu River in the east to the border and probably beyond. These are tightly folded structures with steep, often overturned northern limbs, and they are invariably highly faulted. Small slivers of basement have been reported (Nason-Jones, 1930) from the cores of some of them (e.g. the Barida Anticline).

In the east, the anticlines form a single set of structures separated from the main fault zone by a broad synclinal feature about 7 km wide. To the west this synclinal feature disappears, and the anticlines merge with the main fault zone west of the Mili River. In places in the west, the anticlines form double rather than single sets of structures. These tightly folded asymmetrical features probably indicate a roughly north-south compressional stress.

South of the main fault zone, folding in the older sediments adjacent to the zone is complex, but generally on a small scale and often complicated by faulting. Farther to the south, in the Lumi Trough, large broad anticlinal features occur in the cover sediments. These mostly trend northwest (some north), and are probably drape structures over pre-existing basement horsts. In some places these horsts have remained active through much of the sedimentary history of the trough (M.S. Norivck, pers. comm.).

Folding is not apparent in the basement volcanics, where the structure is dominated by intense faulting. Steeply inclined strata can be seen in many places, but this can be attributed entirely to tilting by fault movements.

MINERAL DEPOSITS

The only known mineral of economic importance associated with the basement rocks of the North Sepik region is alluvial gold. Other minerals which occur in minor amounts are platinum, nickel, and copper.

GOLD

The alluvial gold occurs in two principal localities - (a) in the Prince Alexander Mountains north of Maprik, and (b) in the Border Mountains near Amanab. The gold is at present being mined by villagers at both localities (Fig. 25), and the deposits appear to offer an ideal opportunity for co-operative mining by local villagers.

(a) Prince Alexander Mountains

Fisher (1940) has given a detailed account of the alluvial gold occurrences in the Prince Alexander Mountains. He reported that gold was first discovered in the upper Siling River about 15 km east of Mount Turu in 1934, and that this appears to be the most easterly known gold occurrence in the Prince Alexander Mountains. The most recent work by BMR (1972/1973), has shown that gold occurs as far west as Kumba Creek (grid reference YB120170, Suain 1:100 000 topographic Sheet). Local villagers were carefully questioned to determine which streams carried gold, and which areas had been previously worked. On the north side of the ranges, gold occurs in most streams between the Siling River and Kumba Creek, but on the south side, gold-bearing streams are confined to the area between about longitude 143°00'E (west of the Amogu River) and longitude 143°16'E (Fig. 5). Fisher (1940) showed that gold mining was mostly confined to the upper sections of the streams, above gorges which have acted as bars, allowing the formation above them of a series of flats and terraces in which the gold was concentrated. The main gold workings are in the Womisis and Atob Rivers, northwest of Maprik, and in the upper Hawain River, north of Mount Turu.

Fig. 25. Villagers sluicing gold bearing gravel in the upper Amogu River, Prince Alexander Mountains.

Neg. M/1485-20 (DBD)

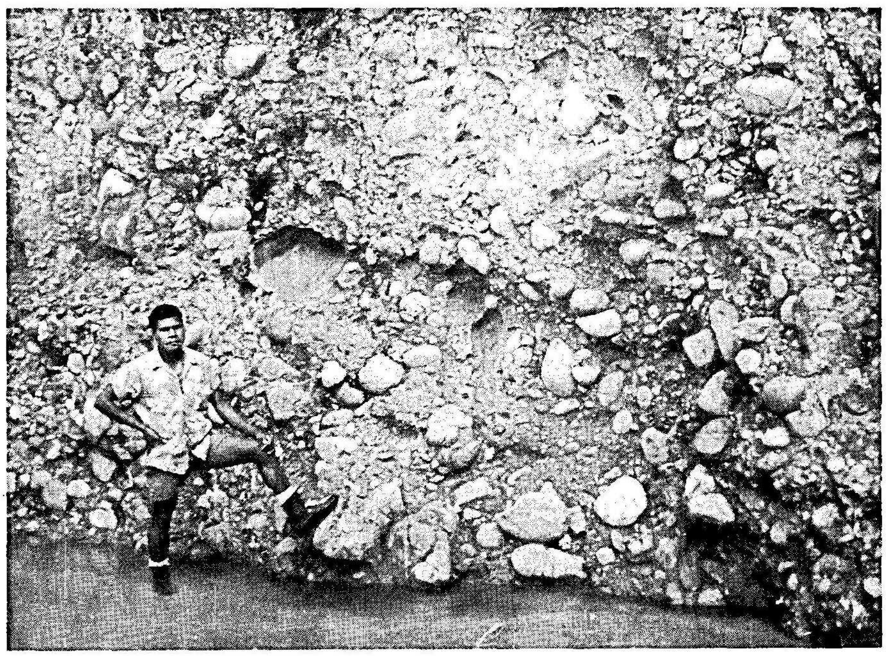


Fig. 26. Gold-bearing basal polymict conglomerate (Amogu Conglomerate) in the upper Amogu River, Prince Alexander Mountains.

Neg. M/1498-5 (DBD)

Geological Controls

Fisher (1940) showed that the immediate source of the gold is coarse, basal polymict conglomerate (Fig. 26) which rests directly on, or very close to basement in the Prince Alexander Mountains, citing as evidence:

(i) gold occurs in streams which expose conglomerate, but not basement;

(ii) the universally waterworn nature of the gold; and

(iii) the lack of specimen stone (i.e. gold associated with quartz or fragments of rock).

The present survey has shown that the basal conglomerate in the Prince Alexander Mountains are probably of two different ages. From Kumba Creek east to the Amogu River they are of lower Miocene age, but east of the Amogu River in the headwaters of the Ulahau River, the basal conglomerate has been correlated with the Pliocene Sargum Conglomerate which oversteps the Miocene, and rests directly on basement.

The conglomerates which occur higher in the sedimentary sequence contain only very sparse fine gold or no gold at all.

It is apparent that the age of the conglomerate is not an important factor in determining whether or not it is auriferous; the critical factor is that it should be a conglomerate resting on, or not far above, basement. Thus it is reasonable to assume that any stream in the Prince Alexander Mountains which drains a polymict conglomerate resting directly on or very close to basement will probably carry alluvial gold.

Nature and source

Fisher (1940) **stated** that the most typical features of the gold in the Prince Alexander Mountains are its high quality and its waterworn appearance. Fineness as high as 969 has been recorded, and the values are mostly between 900 and 940. Fisher also stated that the gold varies considerably in coarseness and that two principal types occur; a coarser variety with rounded or somewhat flattened grains, and a finer flaky variety well waterworn and flattened. He was of the opinion that both types show evidence of considerable transport by water.

Associated with the alluvial gold is abundant magnetite, some ilmenite and garnet, and small amounts of platinum. Native copper and silver have been reported from the Atob River.

The primary source of the gold is undoubtedly the basement rocks in the Prince Alexander Mountains, although the exact nature of the source is still uncertain. The only mineralization observed in basement rocks were a few pyritic quartz veins and some disseminated pyritization in the Prince Alexander Complex. Ten random rock samples from this complex (mostly pyritic intrusives) were analysed for their gold content along with several other trace metals (Table 10). All of these samples assayed below 3 ppm Au (i.e. below the detection limit for the method used), and values for the other metals were normal for these type of rocks. The fact that gold occurs in conglomerates associated with both the Mount Turu complex and the Prince Alexander Complex suggests that original gold mineralization may have been introduced by the lower Miocene intrusives (porphyry dykes, biotite adamellites), which are the only rocks common to both complexes. However, no direct evidence has been found to support this hypothesis.

(b) Border Mountains

Alluvial gold occurs in the Border Mountains in two main localities; in the streams around Amanab (Yuva Creek and Hinibi Creek), near the villages of Wofneri, Ifraininag, and Seraninag, and in the headwaters and associated streams of the Dio River near the village of Mamambra, southwest of Kamberatoro.

Nature and source

The gold around Amanab is apparently a rough 'honeycomb' variety (W. Babbington, pers. comm.), indicating that it is near the lode source. The nature of the source, however, is uncertain although the abundance of milky quartz in the creeks (Carpentaria Exploration Co. Pty Ltd, Final Report, P.A. 153, N.G.) suggests that the source is probably quartz veins associated with the meta-intrusives exposed around Amanab.

Near Mamambra, most of the streams drain low-grade metamorphics, and the only indication of a possible source are porphyry boulders in the stream bed.

(c) Other alluvial gold occurrences

Traces of alluvial gold are known from several streams in the Bewani and Torricelli Mountains (e.g. between the upper Yenabu and Wuro rivers, W. Babbington, pers. comm.), and from Letak Creek and nearby streams, southeast of Wewak. In an eastern tributary of Letak Creek a zone 5 m wide of propylitized and mineralized porphyry was found during the BMR survey. Samples from this zone assayed 30 ppm Ag and 20 ppm Au. The creek had been previously worked for gold well downstream below a gorge, but apparently not upstream. Immediately below the mineralized porphyry the stream has a gentle gradient, and would probably be worth further investigation.

It is probably safe to assume that any stream draining intrusive basement rocks in the North Sepik region carries some trace of gold.

PLATINUM

Alluvial platinum and minor gold were recovered from creeks near Kilifas (location: 56 km south of Vanimo, longitude 141°22'E, latitude 3°12'S, Aitape 1:250 000 Sheet area) by W. Babbington in April, 1968, while he was employed as a prospector by the Papua New Guinea Government. The platinum is restricted to a small area around Kilifas, and is erratic in its occurrence; it is of no commercial significance.

The immediate source of the material is a Pliocene polymict conglomerate which has been exposed to erosion by steep folding. The original source is unknown.

The area south of Imonda has been prospected for platinum by Carpentaria Exploration Co., but with no encouraging results.

NICKEL

The northwest part of the Vanimo 1:250 000 Sheet, between Vanimo township and the border and up to 16 km inland, has been prospected for lateritic nickel by Carpentaria Exploration Company. Two possible localities of mineralization were delineated: (1) the Moso River valley south of Old Musu where nickel is associated with ultramafic intrusives on the north side of the valley, and (2) south of Wutung, northwest of Mount Bougainville. Initially, nickel values up to 24 000 ppm and a few high Cr and Co values were obtained from soil samples, but follow-up work failed to reveal extensive mineralization.

Lateritic nickel of economic grade is known from adjacent parts of Irian Jaya (Reynolds et al., 1973), but in the absence of any large ultramafic bodies east of the border there seems little chance of an economic deposit being discovered in the Oenake Mountains.

There are four slightly anomalous nickel areas near Mount Turu, but these are of no economic interest.

COPPER

At the extreme western end of the Bewani Mountains, a large mineralized shear zone was found in the upper Keerom River. The rocks in the zone are mostly sandstone, siltstone, and mudstone of the Bliri volcanics intruded by dolerite and altered leucocratic porphyry. All the rocks in the shear zone are hydrothermally altered and epidotized, and they contain widespread pyrite in both disseminated and vein form. Three random rock samples were analysed for their trace metal content but no anomalous values were recorded (Table 10).

More recently, P.L. Lowenstein of GSPNG made a more thorough investigation, and discovered a zone of hydrothermal copper mineralization farther upstream. Part of his initial report to the Chief Government Geologist is given below.

"Examination of float in the Keerom River about 400 m above the West Irian border marker (grid ref. WB 004428) confirmed the presence of pyrite in boulders of weakly mineralized porphyry and epidote-veined metasediment.

The proportion of mineralized float present in the river was found to increase upstream over the next 4 km until thermally metamorphosed and sheared mudstone with abundant epidote veining was found to crop out in a gorge. The mudstone has been faulted and contains pyrite and shear zones filled with clay gouge. Highly altered, mineralized porphyry has been intruded into the sheared epidote-bearing mudstone and crops out intermittently.

A few hundred metres further up the stream (grid ref. WB 018458) there is a recent slump in the right hand bank of the river which has exposed an east-west striking mineralized zone about 30 m wide consisting of altered and sheared mudstone and clay gouge containing numerous stringers and veins of pyrite and at least one vein of massive chalcopyrite/pyrite up to 15 cm in thickness. Numerous boulders of hornfelsed mudstone containing epidote veins and epidote-bearing altered porphyry occur at the foot of the slump.

TABLE 10. TRACE METAL ANALYSES OF SOME NORTH SEPIK BASEMENT ROCKS

(Analysed by AMDL)

x - element not detected

ASSAY RESULT IN PPM
(with detection limits in brackets)

SAMPLE NO.	FIELD NAME	SAMPLE TYPE	UNIT	LOCALITY	1:250,000 SHEET AREA	Cu (0.5)	Pb (1)	Zn (20)	Ag (0.1)	Au (3)
7225 - 0007	Intrusive	Float	KTt	Upper Bapi R.	Aitape	400	1	80	0.1	x
0094	Pyritic? amphibolite	Outcrop	KT a	Dio R.	"	50	20	40	0.1	x
0096	Pyritic qtz-mica schist	Float	KT a	"	"	100	10	x	0.1	x
0091	Altered volcanic	Float	Tb	Robin R.	Wewak	50	5	80	x	x
0496	Sheared, altered ?dolerite	Outcrop	?	"	"	30	1	50	x	x
0679	Altered ultramafic	?		Omgan Ck.	Aitape	400	1	x	0.1	x
0680	Amygdaloidal lava	?	Tb	Omgan Ck.	"	30	1	40	0.3	x
0738	Altered lava	Outcrop	Tb	Harech R.	Wewak	500	3	x	0.1	x
1100	Altered, pyritic dolerite?	Outcrop	KTt	Upper Keerom R.	Aitape	30	3	x	x	x
1109	Altered, pyritic ?lithic sst	Float	?Tb	"	"	30	3	80	x	x
1110	Altered dolerite?	Outcrop	KTt	"	"	30	3	x	x	x
1128	Fe stained ? intrusive	Float	?KTt	Upper Bapi R.	"	500	20	x	5	x
1488	Pyritic andesite	Float	Tb	Yemogu Ck.	Wewak	1	1	50	x	x
1670	Altered, pyritic volcanic	Outcrop	Tb	Men Ck.	"	3	1	x	x	x
1690	Altered, pyritic porphyry	Float	KTp	Minab R.	"	100	20	30	3	x
1691	Silicified, pyritic granodiorite	Outcrop	KTp	"	"	200	1	x	0.1	x
1706	Sheared, altered microdiorite	Outcrop	KTp	Upper Amogu R.	"	20	5	200	0.1	x
1709	Pyritic vein quartz	Outcrop	KTp	"	"	10	5	x	x	x
1718	Pyritic vein quartz	Outcrop	KTp	Numba Wan Gold Ck.	"	20	3	x	x	x
1760	Silicified granodiorite	Float	KTp	Upper Kumerau Ck.	"	1	1	x	x	x
1767	Propylitized porphyry dyke	Outcrop	KTp	near Pungalo Village	"	5	1	x	30	20

TABLE 10 contd.

2008 B	Pyritic rhyolite	Outcrop	Tb	Letak R.	Wewak	10	5	x	x	x
2112	Pyritic leucodiorite	Outcrop	KTt	Ningoanye Ck.	"	50	5	x	x	x
2137	Altered pyritic dolerite	Outcrop	KTt	Letak R.	"	500	5	30	x	x
3028	Pyritic diorite	Float	KTt	Upper Danop R.	"	30	3	30	x	x
3041	Pyritic quartz-feldspar gneiss	Float	?KTp	Danop R.	"	3	1	30	x	x
3500	Pyritic siltstone	Outcrop		Mikem Ck.	"	30	3	100	x	x
3518	Sheared leuco-intrusive	Outcrop	KTp	Humal R.	"	20	1	20	x	x
3531	Sheared, pyritic ?granodiorite	Outcrop	KTp	Ulai Ck.	"	10	10	x	0.1	x
3564	Highly sheared acid intrusive	Outcrop	KTp	Kumba Ck.	"	20	3	20	x	x
3595	Sheared, pyritic microdiorite	Outcrop	KTt	Piore R.	Aitape	1	1	20	x	x
3601	Sheared dolerite	Outcrop	KTp	Apa Ck.	Wewak	20	3	100	x	x
3606	Pyritic granodiorite	Float	KTp	"	"	20	5	x	x	x

The mineralized zone lies along a fault which separates the hydrothermally altered epidote-bearing mudstones from a short section of relatively unaltered black shales and mudstones containing plant fragments. A short distance further upstream there are massive boulders and major outcrops of fresh unmineralized feldspar.

Samples of massive chalcopyrite-pyrite ore with some sphalerite were obtained from the mineralized vein system. Highly altered sulphide and epidote-bearing porphyry occurs in the vicinity. Numerous thin veins of anhydrite cut the sheared and hydrothermally-altered mudstone close to the mineralization.

Slumps, disturbed ground and an elongate vegetation anomaly (in which the trees are smaller and have yellowish green foliage) extends at least 0.5 km uphill and to the east of the vein outcrop, indicating a strike extension of the mineralized zone in that direction.

The above evidence indicated the presence of hydrothermal copper mineralization along a fault system that may be associated with a mineralized porphyry intrusion.

The mineralization was not detected by geochemical stream sediment reconnaissance surveys carried out while the area was held by CRA under P.A. 60 NG in 1968, and by B.H.P. under P.A. 233 NG in 1972.

In view of the porphyry type association it is recommended that further investigation should be carried out by a government geologist."

In recent years, surveys by various companies over the region have found several small pyritic-cupriferous vein sulphide deposits of no commercial significance. They usually occur in small fractures or shears. Examples of these are: (1) near Mambuk village in the vicinity of Mount Turu, where a sample of chalcopyritic vein material was found; (2) in Neni Creek (locality 142°01'E, 3°17'S, Aitape 1:250 000 Sheet), where a specimen was found of vein material consisting mostly of cuprite and native copper, with minor hematite and copper sulphate (J.A. MacDonald, A.N.U., pers. comm.) and (3) in the upper Nigia River, where a large shear zone in sediment contains altered andesite porphyry and pyrite-chalcopyrite mineralization. Metal assays of random basement samples (Table 10) reveal up to 500 ppm Cu in igneous rock at scattered localities, but no significant mineralization was detected.

The island-arc nature of the Bliri volcanic arc is considered to be a promising environment in which to find porphyry copper deposits, and several surveys of the area have been undertaken to search for them, but without success. A few areas of slightly anomalous stream sediment copper values have been outlined, but these are probably due either to the cupriferous vein deposits described above, or to the presence of volcanic rocks.

The apparent lack of porphyry-type copper mineralization in the area can possibly be explained by depth of erosion. The mountains have been subjected to uplift and erosion since the early Miocene, and the intrusive rocks now exposed mostly represent the crystalline cores of early Miocene or older intrusions. Any porphyry-copper type mineralization would have occurred at the top of the intrusions, and hence would have been removed by erosion long ago.

BEACH SANDS

Examination of the beach sands near Wewak has shown that they contain less than 3 percent of magnetic minerals, including only traces of ilmenite and zircon.

ROAD-BUILDING MATERIAL

Most of the igneous basement rocks exposed in the region would be suitable for road-making aggregate, but at present they are remote from any roads, and only stream gravels derived from the basement rocks are likely to be used for this purpose in the foreseeable future. Uplifted Holocene limestone, readily accessible near Wewak and near Vanimo, is easily crushed, and provides most of the road-surfacing material used in these areas.

ACKNOWLEDGEMENTS

The author wishes to thank the staff of the Geological Survey of Papua New Guinea and the many Government officers in the survey area for their assistance with administrative and logistic problems.

The willing help given by the people of Papua New Guinea is also gratefully acknowledged.

REFERENCES

ADAMS, C.G., 1970 - A reconsideration of the East Indian Letter Classification of the Tertiary: Bull. Br. Mus. nat. Hist. (Geol.)., 19(3), 137.

BAIN, J.H.C., 1973 - A summary of the main structural elements of Papua New Guinea. In COLEMAN, P.J., (ed.) - THE WESTERN PACIFIC: ISLAND ARCS, MARGINAL SEAS, GEOCHEMISTRY, 147-61. Perth, Univ. W. Aust. Press.

CAROZZI, A.V., 1960 - MICROSCOPIC SEDIMENTARY PETROGRAPHY. N.Y. & London, Wiley.

CLARKE, W.J., and BLOW, W.H., 1969 - The interrelationships of some late Eocene, Oligocene and Miocene foraminifera and planktonic biostratigraphic indices; Proc. 1st Int. Conf. Planktonic Microfossils, Geneva, 2, 82-97.

DAVIES, H.L., 1971 - Peridotite-gabbro-basalt complex in eastern Papua; An overthrust plate of oceanic mantle and crust; Bur. Miner. Resour. Aust. Bull. 128.

DEER, W.A., HOWIE, R.A., and ZUSSMAN, J., 1966 - An introduction to the rock-forming minerals. London, Longmans Green.

DOW, D.B., 1975 - Geology of Papua New Guinea: In KNIGHT, C.L. (ed.) - THE ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA; 1, METALS. Melb., Aust. Inst. Min. Metall.

DOW, D.B., SMIT, J.A.J., BAIN, J.H.C., and RYBURN, R.J., 1972 - Geology of the South Sepik region, New Guinea; Bur. Miner. Resour. Aust. Bull. 133.

FISHER, N.H., 1940 - Geological report on the gold-bearing area of the Wewak District. Rep. geol. Surv. Terr. N. Guinea.

HAANTJENS, H.A. (ed.), 1968 - Lands of the Wewak - Lower Sepik area, Territory of Papua and New Guinea. CSIRO Land Res. Ser. 22.

HAANTJENS, H.A. (ed.), 1972a - Lands of the Aitape-Ambunti Area, Papua New Guinea: Ibid., 30.

HAANTJENS, H.A. (ed.), 1972b - Land resources of the Vanimo area, Papua New Guinea: Ibid., 31.

HARRISON, J., 1969 - A review of the sedimentary history of the Island of New Guinea: J. Aust. Petrol. Explor. Ass., 9(2), 41-8.

IRVINE, T.N., and BARAGAR, W.R.A., 1971 - A guide to the chemical classification of common volcanic rocks. Canad. J. Earth Sci., Vol. 8, 523-48.

JAKES, P., and WHITE, A.J.R., 1972 - Major and trace element abundances in volcanic rocks of orogenic areas: Geol. Soc. Am. Bull., 83, 29-40.

JOHNSON, R.W., TAYLOR, G.A.M., and DAVIES, R.A., 1972 - Geology and Petrology of quaternary volcanic islands off the north coast of New Guinea. Bur. Miner. Resour. Aust. Rec. 1972/21 (unpubl.).

JOHNSON, T., and MOLNAR, P., 1972 - Focal mechanisms and plate tectonics of the southwest Pacific. J. Geophys. Res., 77, 26.

KUNO, H., 1966 - Lateral variation of basalt magma type across continental margins and island-arcs. Bull. Volc., 29, 195-222.

MARCHANT, S., 1969 - A photogeological assessment of the petroleum geology of the Northern New Guinea Basin, north of the Sepik River, Territory of New Guinea. Bur. Miner. Resour. Aust. Rep. 130 (PNG 4).

NASON-JONES, J., 1930 - Geology of the Finsch coast area, northwest New Guinea, Vol. III. The Oil Exploration work in Papua and New Guinea conducted by the Anglo-Persian Oil Company on behalf of the Government of the Commonwealth of Australia, 1920-1929. London, H.M.S.O.

PAPP, S., 1929 - Geological notes on the Hansemann coast between Wewak and Kaup, Mandated Territory of New Guinea, Vol. II, 86-91. The Oil Exploration work in Papua New Guinea conducted by the Anglo-Persian Oil Company on behalf of the Government of the Commonwealth of Australia, 1920-1929; London, H.M.S.O.

RAGGATT, H.G., 1928 - A geological reconnaissance of part of the Aitape District, Mandated Territory of New Guinea. Proc. Roy. Soc. Qld, 40(7), 66-90.

REYNOLDS, C.D., HAVRYLUK, I., BASTAMAN, S., and ATMOWIDJOJO, S., 1973 - The exploration of the nickel laterite deposits in Irian Barat, Indonesia. Geol. Soc. Malaysia Bull., 6, 309-23.

RICHARZ, P.S., 1910 - Der geologische bau von Kaiser-Wilhems-Land nac dem heutigen Stand unseres Wissens. Neues Jb. Miner., 39, 406-536.

RIPPER, I.D., 1975 - Some focal mechanisms in the New Guinea-Solomon Islands region, 1969-1971. Bur. Miner. Resour. Aust. Rep. 178 (PNG 8).

SCHULTZE-JENA, L., 1914 - Forschungen im Innern der Insel Neuguinea. Mitteilungen aus den deutschen Schutz-gebeiten. Berlin, Erganzungsheft No. 11.

STANLEY, G.A.V., 1938 - Report upon the geological reconnaissance of the Border Mountains, Sepik District, T.N.G. Rep. for Australas. Petrol. Co. Pty Ltd (unpubl.).

TALLARD, C.A. 1970 - Exploration in the Australian Trust Territory of New Guinea. J. Aust. Petrol. Explor. Ass., 10(2), 74-7.

TJIA, H.D., 1973 - Irian fault zone and Sorong Melange, Indonesia. Sains Malaysia, 2(1), 13-30.

VAN DER WEGEN, G., 1971 - Metamorphic rocks in West Irian: Scripta Geol., 1, 1-16.

VAN OYEN, F.H., 1972 - Trough evidence along the southern foothills of the Prince Alexander Mountains (Sepik District-New Guinea). J. Aust. Petrol. Explor. Ass., 12(1),74-8.

VISSER, W.A., and HERMES, J.J., 1962 - Geological results of the exploration for oil in Netherlands New Guinea: Kon. Ned. Geol. Mijn. Genoot., Vol. 20, spec. No.

ZWIERZIJEKI, J., 1924 - Verslag over geologishmijnbovwkundige onderzoekingen in een geoleelte van Noord Nievw Guinea. Jaarb. v.h. Mijnwezen, 50th year, Verhand, Pt 1, with Atlas.

APPENDIX

BASEMENT STRATIGRAPHY

AGE	UNIT OR FORMATION	ESTIMATED THICKNESS (m)	ROCK TYPE	LANDFORM & AIRPHOTO PATTERN	ECONOMIC AND ENGINEERING ASPECTS	REMARKS
?Oligocene to early Miocene	Mount Turu Complex Tt		Predominantly mafic and ultramafic rocks including serpentinite, websterite, clinopyroxenite, wehrlite, lherzolite, troctolite, gabbro, olivine gabbro, olivine diorite. Some diorite; rare dolerite and biotite adamellite	Forms the prominent Mt Turu	Some areas of slightly anomalous Ni but almost no economic possibilities for lateritic nickel. Possible source of road-making aggregate	Outcrop area confined to elongate E-W body (27 km long, up to 5 km wide) about Mt Turu, which forms the highest peak in the area. In contact with KTa (contact partly faulted and partly ?intrusive). Pliocene and Quaternary sediments. K-Ar age of biotite adamellite is 18.2 ± 0.8 m.y. Probably spurious K-Ar age (one gabbro sample) of 188 ± 50 m.y.
late Eocene	Oimale Volcanics Ted	Unknown	Chloritized amygdaloidal glassy basalt; some andesite, submarine lava breccia, agglomerate; minor tuff; basic dykes and small intrusions	Low sharp-crested ridges, incised valleys; dendritic drainage		Small hills rising from alluvial swamps S of Sepik R. in SW of Sheet area, more extensive in May River Sheet area, where it outcrops around the N slope of the Landslip Ra; unconformable under Quaternary alluvium. Age from one K-Ar isotopic determination of 39.6 m.y.
?Palaeocene to earliest Miocene (partly Ta_3-Tb and LTe-UTe)	Bliri volcanics Tb	2500-1000	Basic to minor volcanics and volcanically derived sediments with minor limestone lenses. Volcanics include red and green basalt, pillow basalt (often brecciated and fragmented), red and green basaltic tuff, agglomerate, breccia, andesite, andesitic tuff and agglomerate lava, green peperite; rare dacite and rhyolite. Volcanilithic sediments include moderately indurated light to dark grey mudstone, pebbly mudstone siltstone and lithic sandstone with abundant volcanic detritus, minor conglomerate. Sediments commonly rich in foraminifera. Pink and brown radiolarian and foraminiferal marl, and buff to white foraminiferal, bioclastic limestone	High sharp ridges with steep slopes; streams often obstructed by gorges and waterfalls. Numerous landslides	Minor disseminated pyritic mineralization; minor alteration with sulfide mineralization along shears. Poor economic possibilities. Possible source of road-making aggregate	Partly Palaeocene to late Eocene, and partly late Oligocene to earliest Miocene, based on foraminifera evidence. Older part has smaller sedimentary component and volcanics are more basic. Deep-water marls more common in older part shallow-water calcarenites more common in younger part. One K-Ar age (basalt) of 30.4 m.y. Intense faulting and shearing precludes mapping the older and younger parts separately. Intruded by KTt. Unconformably overlain by Miocene, Pliocene and Quaternary sediments.
Late Cretaceous to earliest Miocene	Torricelli Intrusive Complex KTt		Predominantly medium-grained gabbro, olivine gabbro, hornblende gabbro, dolerite, pyroxene diorite, diorite, monzonite; subordinate granodiorite and adamellite; rare pyroxenite, hartzburgite; rare pegmatitic and porphyritic equivalents of some types. Minor serpentinite and sheared gabbro in large shear zones	Rugged topography forming mountainous areas of high sharp ridges. Streams cut deep gorges with many waterfalls. Numerous landslides	Minor disseminated sulfide mineralization (mostly pyrite). Minor alteration and sulfide mineralization along shears. Mineralized porphyries SE of Wewak and along N side of Sewani Mts are source of some alluvial Au. Possible source of road-making aggregate	Highly faulted, sheared and fractured, variable (mostly minor) hydrothermal alteration. Irregular criss-crossing, feldspathic veinlets. Several K-Ar ages ranges from 73.2 m.y. to 17.3 m.y. Intrudes Tb. Unconformably overlain by Miocene, Pliocene, and Quaternary sediments. Minor KTt within Tb in some areas
Late Cretaceous to Eocene (partly Maastrichtian and Ta_3-Tb) (?some Jurassic)	Ambunti Metamorphics KTa		Predominantly phyllite, quartz-mica schist, quartz-epidote-mica schist, garnet mica schist; subordinate shale, slate and metasediments with foraminiferal limestone lenses, marble and metavolcanics. Minor amphibolite and gneiss locally. Tightly folded with general ESE foliation in Border Mtns	Generally subdued, dissected, but rugged topography, with intricate, incised drainage in Border Mtns; and subdued topography with knife-edge ridges and intricate dentritic drainage near Yangoru	Very minor disseminated pyrite mineralization but little economic potential. Alluvial gold west of Amanab (near border) probably derived from porphyries intruding KTa	Shale, metasediments, phyllite and mica-schist in Border Mtns.; Slate, phyllite, marble, metavolcanics in W. Prince Alexander Mtns.; garnet-mica-epidote schist with minor gneiss and phyllite near Yangaru; amphibolite and quartz-mica schist near Imonda; phyllite in Manam Ck., garnet-mica schist in Gwenilif R. Limestone lenses in meta-sediments contain U. Cretaceous, Eocene, and U. Eocene larger foraminifera. Unconformably overlain by Miocene, Pliocene and Quaternary sediments. Probably intruded by KTm before metamorphism. Relation with P unknown

AGE	UNIT OR FORMATION	ESTIMATED THICKNESS (m)	ROCK TYPE	LANDFORM & AIRPHOTO PATTERN	ECONOMIC AND ENGINEERING ASPECTS	REMARKS
Eocene	KTc		Nummulitic limestone	Long, narrow, resistant ridge of Yagroner Hills. Also forms resistant ridges in Oia R.		Long, narrow lenses in KTa. Contain Eocene larger benthonic foraminifera
Early Cretaceous to earliest Miocene	Prince Alexander Complex KTp		Mostly crushed and mylonitized, fine to medium-grained, granodiorite and diorite (in places layered or foliated). Also metadiorite; dolerite, amphibolite and orthogneiss. Subordinate mica-schist, biotite adamellite, biotite granodiorite and grey-white porphyry dykes	Generally recessive topography with fine, intricate drainage pattern	Disseminated and vein sulfide mineralization which was probably the primary source of alluvial gold in Prince Alexander Ra. Little economic potential. Possible source of road-making aggregate	Small inlier in headwaters of Kumberau Ck, N of Gato Mission. Otherwise exposure confined to Prince Alexander Ra. between Nyiail Ck in W almost to Mt Turu in E. Intense faulting with confused relations. High-grade metamorphics and some sheared intrusives have K-Ar ages of 106-114 m.y. (Early Cretaceous) and are probably oldest rocks in complex. Adamellites and porphyry dykes are less deformed, have K-Ar ages of 19.9-22.5 m.y. (earliest Miocene), and are youngest rocks in complex. Unit has faulted contact with KTa and is unconformably overlain by Miocene, Pliocene, and Quaternary sediments.
?pre-Oligocene	Amanab Metadiorite KTa		Predominantly sheared, subfoliated metadiorite, subordinate metagabbro, and metagranodiorite intruded by dolerite dykes. Original intrusives partially to completely converted to chlorite, epidote, secondary quartz, and clinozoisite	Subdued topography with low rounded ridges and small, incised streams around Amanab	Possible source of alluvial gold in streams around Amanab. Source of road-making aggregate .	Variable deformation and metamorphism. Appears to grade into KTa in places, although probably intruded into KTa before metamorphism. Unconformably overlain by Miocene, Pliocene and Quaternary sediments
?pre Miocene	U		Predominantly sheared serpentinite	Small faulted pods and slivers	Minor anomalous lateritic nickel. No economic possibilities	Small outcrop S of Sepik R., where it extends into May River Sheet area and may be a continuation of the April Ultramafics (Dow et al., 1972). Scattered boulders and rare outcrops in Bewani and Torricelli Mts.; few scattered outcrops south and east at Amanab; serpentinite occurs in shear zones in small pods, and as scattered boulders in Genake Mts. Serpentinite pebbles in volcanic agglomerate reported by Mason-Jones (1930). Stanley (1938) reported scattered outcrops near Amanab and related them to similar rocks in the Genake Mtns.
Mid-Permian	P		Predominantly medium to coarse-grained, biotite and hornblende-bearing granodiorite, diorite and quartz diorite. Subordinate hornblende tonalite, leucocratic granophyre, and dolerite			Observed only as boulders in the Green R. derived from Irian Jaya. Several K-Ar ages of 242-257 m.y (M. Permian); correlated with Kubor Granodiorite. Associated with cobbles and pebbles of dacitic volcanics which possibly correlate with Kana Volcanics. Relation with KTe unknown