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Geology of the Aroa-Upper Dilava-Auga-Middle Angabunga Rivers Area, Papua

by

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CONTENTS

TEXT FIGURES AND PLATES

SUMMARY

The area examined in this Note is centred about 70 miles north-northwest of Port Moresby, Papua. Slightly more than three weeks were spent in the field, between 3rd and 27th May, 1968.

Northerly trending schists, semischists and metasediments of the Owen Stanley Metamorphics are flanked to the west by similarly trending, steeply dipping marine sedimentary rocks of the Upper Cretaceous (Senonian) to Lower Miocene 'e' stage Auga Beds, and by the Upper Cretaceous (Senonian) Aibala Volcanics which conformably underlie them (with the youngest rocks lying closest to the Metamorphics). The steep dips and roughly conformable attitude of the Metamorphics and flanking sedimentary rocks have resulted from vertical and transcurrent movement on a number of closely spaced, slightly sinuous, northerly trending strike faults, caused by high angle overthrusting from the east (probably in the Miocene between the 'e' and 'f' stages). Variation of stress during formation of the Metamorphics (deeper seated ?Lower Cretaceous or older Mesozoic sedimentary rocks metamorphosed by the high angle overthrusting) has resulted in variation in metamorphism from incipient recrystallization to the formation of almandine - and some glaucophane - bearing schists. Subsequent retrogressive metamorphism of schists is apparent in many thin sections. Porphyries and fewer intermediate plutonic rocks widely intrude the Metamorphics and, to a lesser degree, the Auga Beds. In the south and west, the area is overlain by two subhorizontal units of volcanic rocks, the Talama Volcanics (?Middle Miocene lower 'f' stage *) and the Mt. Davidson Volcanics (?Upper Miocene to Pliocene), separated by a unit of poorly consolidated sedimentary rocks, the Yaifa Formation (?Upper Middle Miocene). These rocks are broadly warped, with a shallow regional tilt to the southwest.

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* In this report Tertiary 'f' stage is assumed to be equivalent to Middle Miocene, and Tertiary 'f_{1-2}' stage or lower 'f' stage to be the lower part of the Middle Miocene.

INTRODUCTION

The area examined in this Note is centred 70 miles north-northwest of Port Moresby in the Kairuku and Goilala Sub-districts of the Central District of Papua. It lies within the Yule and Buna 1:250,000 map sheet areas, and extends from the coast at Galley Reach, northwards into the mountainous country of the Aroa (Ialoge), Dilava, Auga and middle Angabunga drainage systems. Slightly more than three weeks were spent in the field, between 3rd and 27th May, 1968.

The mapping programme was planned in order to re-examine and correlate areas previously mapped by geologists of the Australasian Petroleum Company and Resident Staff of the Bureau of Mineral Resources (see References), with the principal aim of examining the field relationships existing between the Owen Stanley Metamorphics and the sedimentary rocks flanking them to the west.

Physiography

Within the area mapped there is a gradual rise to the northeast from the coastal foothills near Galley Reach and from the coastal plain near Kubuna, towards the main range which forms the backbone of central Papua (Mount St. Marie, 12,108 feet; Mount Albert Edward, 13,100 feet). The major drainage is deeply incised, giving rise to a steep and often precipitous topography, with ridges rising to over 7,000 feet in the northeast corner of the map area. Shallow dipping volcanic and sedimentary rocks form a thick veneer over part of the area, eroding readily to form dissected plateaux with precipitous sides (the most prominent of which lies to the north of the map area and west of Tapini, Mount Yule, 10,800 feet high). Where the sub-horizontal volcanic and sedimentary rocks have been completely removed, ridges are narrow and steep sided.

Vegetation

Dense rain forest covers most of the area mapped, broken only by small areas of grass, native gardens and secondary regrowth (largely in the populated upper Dilava and Auga Valleys). Rain forest gives way to grassland and open eucalypt forest on the coastal plain below Kubuna. Large rubber plantations have been established on the coastal hills around Galley Reach.

Rainfall

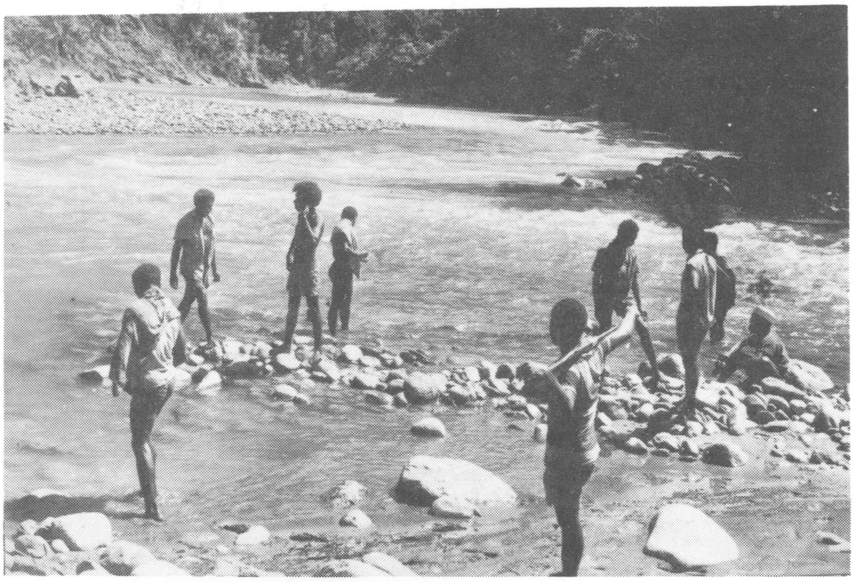
Little is known of the distribution of rainfall in the area mapped. The coastal region is relatively dry, with rainfall figures rising sharply in the foothills and mountains. At Kanosia Estate in the Galley Reach area the average annual rainfall is 60 inches, at Kubuna 107 inches, and at Fane in the Auga Valley 125 inches; rain falls mainly between November and June, largely during the northwest monsoon.

Population and Access

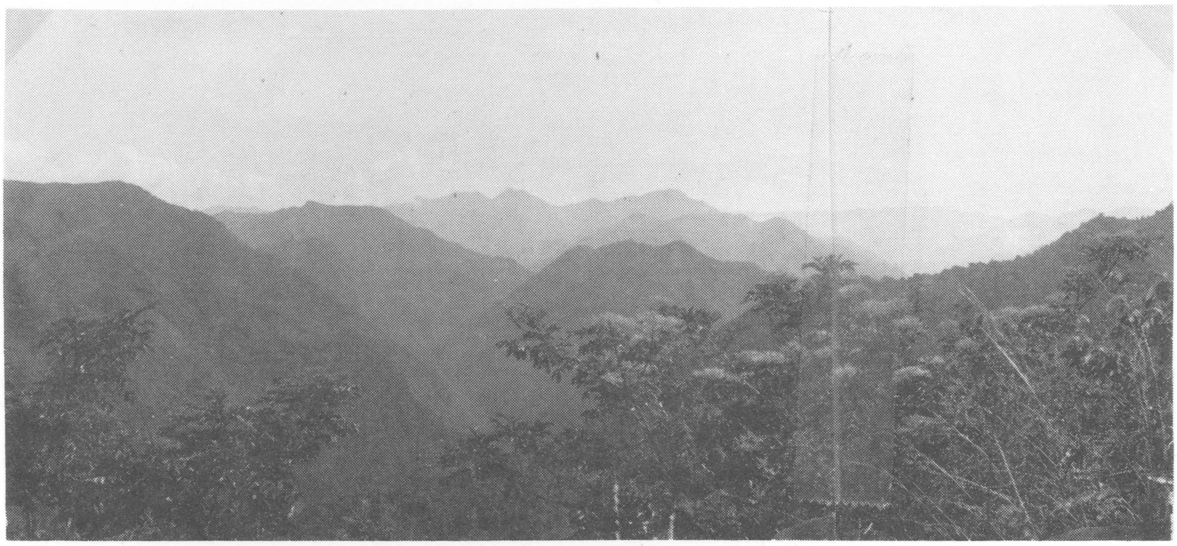
Population in the eastern part of the mapped area is concentrated mainly in the upper Auga and Dilava River valleys, with a small, scattered population centred around several villages (Ialoge and Inai) in the Aroa River headwaters. These people belong to the Fujuge Clan, and are administered from a Sub-district Office at Woitape (which lies to the east in the Vanapa River headwaters). A Catholic Mission has been maintained at Fane in the Auga Valley for more than 60 years; the Mission being part of the Papuan Province of the Mission of the Sacred Heart, which has headquarters at Kairuku on Yule Island, and is maintained by France. At the time of the writer's visit, the Fane Mission was staffed by three French Fathers. Regular visits are made by the Mission Fathers to outstations at Patmos (Inai) and Ialoge in the Aroa River headwaters, and Kodige in the Dilava River headwaters, as well as to mission outstations in the Auga Valley.

In the middle Angabunga River area the population is concentrated at Bakoiudu. The people belong to the small Kuni Clan, who have moved to Bakoiudu in the past six years from villages and hamlets scattered through the lower Auga Valley, lower Dilava Valley and the middle Angabunga River area (with Mission stations being abandoned at Deva Deva, Oba Oba, Maimai and Yaifa). Bakoiudu is a resettlement area in which the Administration is assisting the Kuni people to establish a co-operative rubber plantation; it is reached by a dry weather vehicle road from Kubuna and is administered from Bereina.

Access to the upper Auga Valley is by bridle tracks (graded tracks for mule or horse caravans prepared by the Mission and Administration) from airstrips at Woitape in the east and Tapini in the north. A bridle track links Kodige in the Dilava Valley with Fane in the Auga Valley, crossing the divide in a pass at 6,000 feet. Beyond Kodige the track continues to Ialoge and Inai in the Aroa River headwaters; from Inai there are several major walking tracks to the coast in the Galley Reach area. Secondary tracks and small hunting tracks are numerous throughout the area. Walking along major streams is generally difficult because of the precipitous nature of the country.



AUGA - ANGABUNGA RIVERS JUNCTION



ANGABUNGA RIVER HEADWATERS FROM ABOVE AUGA JUNCTION

OBA OBA MISSION (ABANDONED)

Access into the middle Angabunga River area is by vehicle road to Bakoiudu from airstrips at Kubuna or Bereina (road via Kubuna). From Bakoiudu walking tracks go to the north across the Angabunga River (to Tapini) and to the east between the Angabunga and Dilava Rivers.*

Helicopters are of little use in providing access into most of the area mapped because of the scarcity of natural landing sites.

Object and Method of Work

The principal object of the survey was to obtain geological sections from the metamorphic rocks of the Owen Stanley Ranges, through the sedimentary rocks which flank them to the west. Previous interpretation of the lithologies and structure was based on a section drawn by de Verteuil and Rickwood (1946) from exposures on the bridle track along the southern slopes of the Auga Valley. In 1965 French crossed from Fane to Kodige in the Dilava River headwaters and traversed down the valley to near the faulted margin of the metamorphic rocks, but did not go beyond this. In planning the present survey it was apparent that the best sections would be obtained by traversing along the Auga and Dilava Rivers, as exposure would be fresher and more continuous than on the foot tracks.

Fieldwork by Pratt and Whittle (1958) in the lower Aroa River and middle Angabunga River areas showed a thick sub-horizontal covering of largely volcanic rocks along the edge of the mountains. It was planned to investigate these volcanics in the lower part of the Aroa and Dilava Rivers and in the middle Angabunga River area (which is also the location of a proposed hydro-electric scheme feasibility investigation).

On May 2nd 1968, the writer travelled on m.v. "Kano" to Kanosia, in company with geologists R.J. Tingey and F.D. Hohnen, Technical Officer B.J. Humphreys, two native Technical Assistants and 16 carriers. From Kanosia the party traversed up the Aroa River into its headwaters and crossed to the Dilava River headwaters, where the party split. Tingey and Hohnen traversed down the Dilava River to Bakoiudu, returning to Port Moresby on May 16th; the writer, with Humphreys, crossed to the Auga River headwaters, then traversed down the Auga and middle Angabunga Rivers to Bakoiudu, returning to Port Moresby on May 28th.

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* Before the opening of Woitape airstrip (8 years ago) the Mission maintained a bridle track from Kubuna to Fane, passing through the present site of Bakoiudu. This track has since been largely obliterated between Oba Oba and Popolei (near Fane); with the abandoning of Oba Oba Mission several years ago, the Oba Oba to Bakoiudu section of track is now falling into disrepair.

Aerial photographs from the Mt. Cameron, Ononge, Tully Peaks and Kubuna photomap areas were used in the field, in the preparation of base maps and in photogeologic interpretation.

A large number of thin sections were prepared and examined in Port Moresby by the writer; these are referred to in the text and fuller descriptions are contained in the Appendices.

Microfossil samples collected during the survey were examined by Dr. Belford (Bureau of Mineral Resources, Canberra) - see Appendix III.

A Complementary Investigation Note on the traverse down the Dilava River has been prepared by P.D. Hohnen (see References).

GEOLOGY

Within the area mapped, northerly trending schists and metasediments of the Owen Stanley Metamorphics are flanked to the west by similarly trending, steeply dipping marine sedimentary rocks of the Upper Cretaceous (Senonian) to Lower Miocene 'e' stage Auga Beds, and the underlying Upper Cretaceous (Senonian) Aibala Volcanics (with the youngest rocks lying closest to the Metamorphics). The Metamorphics and, to a lesser degree, the Auga Beds are widely intruded by porphyries and fewer plutonic rocks. In the south and west, the area is overlain by two subhorizontal units of volcanic rocks, the Talama Volcanics (?Middle Miocene 'f_{1-2}' stage) and the Mt. Davidson Volcanics (?Upper Miocene to Pliocene), separated by a unit of poorly consolidated sedimentary rocks, the Yaifa Formation (?upper Middle Miocene).

OWEN STANLEY METAMORPHICS

The Owen Stanley Metamorphics are an undifferentiated succession of metasediments, semischists and low-grade schists cropping out in the area mapped in the Aroa, Dilava and Auga River headwaters. The metasediments are poorly to moderately foliated, generally light coloured, partly recrystallized argillaceous quartzofeldspathic arenites and fine-grained stretched pebble conglomerates, and abundant dark slaty and sheared argillaceous siltstones and shales grading into semischists. Mineral assemblages of the schists generally indicate lower greenschist facies conditions of formation, however almandine is present in some areas, indicating the local development of a slightly higher grade. A large 'lens' of garnetiferous schists trends northwards across the Dilava River into the Auga River headwaters, and the lithologies here include some glaucophane schists; similar garnet schists also crop out east of Fane in the Auga River headwaters. Altered submarine volcanics interbedded with slatey siltstones in the Auga River section probably belong to the Owen Stanley Metamorphics, but may represent a phase of submarine volcanism in the closing stages of deposition of the Auga Beds. Fine-grained ?crystal tuffs are present in the metasediments in the Aroa River headwaters.

There is no evidence of systematic variation from metasediments to adjacent semischists and schists; the latter are probably formed largely from fine-grained argillaceous sediments more susceptible to regional change. The presence of large 'lenses' of more highly metamorphosed rocks indicates that the distribution of stress and temperature during metamorphism was differential. Evidence of retrogressive metamorphism is apparent in many thin sections.

The least metamorphised rocks of the Owen Stanley Metamorphics in the area mapped crop out mainly in the Aroa River headwaters where they are larely medium and fine-grained metasediments and dark semischists and low-grade schists. The coarser clastic fraction of the metasediments (G11B, 12A, 12B, 24) comprises generally subrounded to sub-angular rolled fragments of chert, argillite, kaolinised plagioclase, strained quartz and rare fine-grained volcanics. The generally 'schistose' matrix is made up of fine quartz, illite, ?sericite, chlorite, indeterminate colourless and dark organic material, some calcite and rare epidote. In many instances the flakey clay minerals of the matrix form bands, lenses or sheared-out patches of uniform extinction; in some hand specimens these are dark and appear as hard, long, thin shaley lenses. Slatey and sheared siltstones and shales have a composition similar to that of the matrix of the coarser metasediments; in the semischists recrystallization is more advanced and the schistosity better developed. 'Schistose' foliation appears to be generally parallel to sedimentary bedding, and to the regional structural trends. Quartz and calcite veining is fairly common.

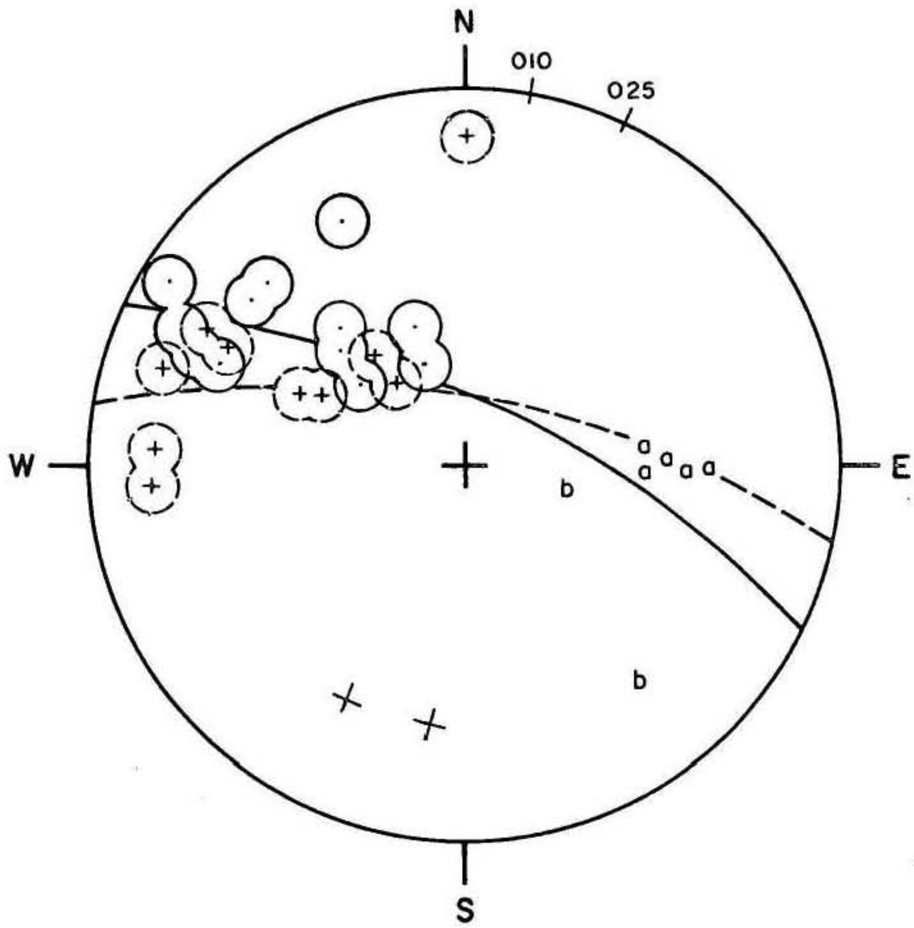
Massive red fine-grained tuff or lava occurs within the metasediments at one locality in the Aroa River headwaters; in thin section (G21A) the rock is seen to be an unsheared fine-grained dacitic crystal tuff (?lava) comprising small grains of kaolinised plagioclase (some sodic) defining a poor flow foliation, and minor quartz and opaque oxide in a dark indeterminate matrix with abundant haematite and some chlorite. Thin beds of finer grained material (not haematitic, light coloured in hand specimen) lie parallel to the 'foliation'.

Metavolcanics in the Auga River are considered to belong to the Owen Stanley Metamorphics, but could equally well represent a phase of Lower Miocene 'e' stage submarine volcanism in the final stages of the deposition of the Auga Beds. The metavolcanics are more than 3,000 feet of hard, green, epidotised submarine volcanics with small deformed lenses of recrystallized grey-brown limestone, interbedded in the upper part with slatey siltstones. Much of the epidotisation of the metavolcanics is about joint planes; shearing and brecciation is common, and also the intrusion of small andesite porphyry and gabbro bodies.

The low-grade schists in the Owen Stanley Metamorphics (G 23, 41, 44A, 44B, 46A, 46B, 51A, 53) are dark, soft, thinly banded quartz-albite-muscovite or sericite (-graphite) schists, in places with interbedded harder green epidote-chlorite-actinolite schists. They have a strong schistose cleavage and are largely the product or low-grade regional metamorphism, but some show evidence of formation by strong dislocation metamorphism. In the coarser-grained schists

FIGURE 1

ORIENTATION DIAGRAM FOR POLES TO CLEAVAGE IN THE OWEN STANLEY METAMORPHICS



Poles to cleavage Aroa and Dilava River headwaters

Poles to cleavage Auga River headwaters

a Lineations in the Aroa River headwaters

b Lineations in the Auga River headwaters

There are insufficient readings to produce accurate conclusions. The probable interpretation is broad warping of the cleavage about an axis plunging 20° to 190° in the Aroa and Dilava Rivers headwaters and 20° to 205° in the Auga River headwaters.

augen-like aggregates of fine quartz and albite are common, and also slightly lenticular porphyroblasts of albite with thin trails of small inclusions aligned parallel to schistosity, indicating growth of the porphyroblasts in a period of metamorphism later than that producing the cleavage; this 'retrogressive metamorphism' is also marked by the recrystallization of coarser unstrained quartz and large flakes of muscovite, many of which cut across the foliation. Where marked compositional and textural changes indicate the orientation or original bedding, schistosity is parallel to this bedding. Dips are steep in an easterly direction, and the foliation is broadly flexed or tightly folded (most probably the former) about an axis plunging approximately 20° to 190° in the Aroa and Dilava River headwaters and 20° to 205° in the Auga River headwaters (see figure 1). Shearing and later deformation of the rocks are apparent, with common local slight to extreme contortion producing marked puckering of the cleavage, polyclinal and isoclinal concentric folds or, in some areas, conjugate folds associated with kink bands. Lineations are present in some outcrops, plunging variably to the east; in several cases the lineations appear to be caused by the intersection of a strain slip cleavage with metamorphic or remnant sedimentary bedding.

Higher grade schists (G 28, 33A-H, 34A-B, 38, 39A-B, 40A-B, 46C-D, 90 and 101) containing almandine crop out in a long lens extending northwards across the Dilava River headwaters into the Auga River headwaters one mile west of Fane; similar schists also crop out to the east of Fane, indicated there by abundant wash in streams flowing into the Auga River from the south. These rocks were formed in areas of locally higher stress and temperature; flow deformation is intense in many places and several periods of metamorphism are indicated in many thin sections. Glaucophane and related blue-green amphiboles are present in several sections, but related minerals indicating the glaucophane-schist facies were not recognised in sections examined by the writer (the presence of glaucophane is not related to metasomatism, but probably indicates physical conditions transitional to those prevailing in the glaucophane-schist facies). Chloritoid schists reported from near Fane by de Verteuil and Rickwood, and by Brouxham, were not seen by the writer.

Metamorphic differentiation in the higher grade schists varies from absent to extreme (in the latter case forming monomінerallic 'veins'). Mineral assemblages include many of the following: albite, quartz, almandine, amphibole, epidote, clinozoisite and muscovite; generally minor chlorite and calcite; accessory sphene and rare pyrite, rutile and tourmaline. These minerals and their occurrences are discussed briefly in the following paragraphs.

Albite occurs in most sections as clear porphyroblasts; in some it occurs as ragged auhedral grains forming bands or lenses, and in some it is interstitial or forms scattered isolated grains. The porphyroblasts are up to 8 mm. across and may be subhedral, irregular or 'augen' shaped; in most sections they are highly sieved (poikiloblastic), enclosing scattered grains or undisturbed trails of fine amphibole, epidote, clinozoisite, muscovite, garnet or sphene, lying parallel to the deformed schistosity (indicating post-tectonic growth of the poikiloblasts). The porphyroblasts are mostly untwinned, but may show Carlsbad twinning.

Quartz is generally present but is less abundant than albite in most rocks (absent in G33G, 39B). It mostly occurs as aggregates of ragged strained grains or with other minerals in lenses or bands; in some sections it forms 'veins' which may be granoblastic and may contain trails of very small 'fish egg' garnets. In some sections, recrystallization to coarser, unstrained grains has taken place.

Almandine is present in most sections, generally as euhedral porphyroblasts (up to 1 cm. across in G90) and small grains. It may be distributed throughout a section, but is generally concentrated in lenses and bands (usually in a ragged quartz mosaic). In some bands the grains are extremely small; trails and streamers of 'fish egg' garnets impart a pink colour in hand specimen to the quartz 'veins' in which they occur. Most of the garnet porphyroblasts are post-tectonic in formation (second period of metamorphism), enveloping trails of fine inclusions, however in some sections (G33G, 40A) the almandine is syntectonic, showing rolled porphyroblasts or flow of the tabular and bladed minerals around porphyroblasts. Many of the larger almandine porphyroblasts are partly altered internally (in fractures) to chlorite (with some muscovite); muscovite flakes and quartz lie marginal to porphyroblasts in some sections. Almandine is generally not present in the glaucophane rocks.

Amphibole is a common mineral in most of the higher grade metamorphic rocks (it is absent in G33C, 33D, 46C, 46D, 90). It is generally bladed in habit, and may be felted where abundant; orientation of grains is generally parallel to schistosity. Optic properties and composition vary, with two or more amphiboles being present in several sections. Pleochroism is mostly from pale green (rarely neutral) to blue-green, or in shades of pale green. Several sections (G33B, 38) contain colourless ?tremolite. Blue-green and lavender or violet glaucophane occurs in several sections (G28, 33H), and is apparently unaccompanied by lawsonite, pumpellyite, jadeite or other minerals indicating the glaucophane-schist facies; the presence of glaucophane in these rocks probably points to physical conditions bordering on those of the glaucophane-schist facies.

Epidote or clinozoisite are present in many sections, occurring together in some, with zoisite also occurring in G34A. They are quite abundant in some rocks, lying roughly parallel to the foliation when tabular. The epidote is granular or tabular, and in many instances is quite fine-grained, forming aggregates in some sections; it is pale yellow and slightly pleochroic in many sections but may be colourless. The extinction angle varies to quite large. Clinozoisite occurs as tabular or bladed crystals, aligned roughly along the schistosity.

Muscovite is generally present, though in some rocks it is only a minor constituent. In many rocks it is confined to definite bands. Large grains are quite common and these in many cases may be due to retrogressive metamorphism or recrystallization (growth following the deformed foliation in some rocks (G34B) and cutting across schistosity in others (G39A).

Chlorite is a fairly abundant mineral in several sections, and is a minor or rare constituent in many. It is pale green or green-brown, and in one section (G33C) occurs both as fine shredded chlorite and as larger flakes. Green chlorite also occurs as a secondary mineral, as an alteration product in fractures in garnet.

Calcite occurs in a number of sections. It is a common interstitial mineral with chlorite in bands of poikiloclastic albite in G33D; in section G46D it occurs in the cleavage and between flakes of schistose muscovite. Ragged patches of calcite are scattered through section G34A.

Sphene is a common accessory in many sections: accessory rutile occurs in G33D and G33F; pyrite is present in G40A, and tourmaline is an accessory mineral in G90.

The genesis of the almandine bearing schists is not known, however it is obvious that many are the product of several periods of metamorphism, and that they have possibly undergone several periods of deformation.

AIBALA VOLCANICS

The Aibala Volcanics (Pratt and Whittle, 1938) are a thick succession of highly jointed, generally easily weathered, altered submarine dolerites and basalts and possibly minor tuffs forming steep slopes and deep gorges along about 10 miles of the middle Angabunga (Aibala) River. They crop out also along the lower Auga River, where they are interbedded in the upper part with thick units of indurated siltstone, and appear to pass conformably upwards into the Auga Beds, which are Upper Cretaceous (Senonian) at the base; in the Dilava River, limestone lenses interbedded in the upper part of the Aibala Volcanics contain Upper Cretaceous (Senonian) foraminifera (Hohnen, 1968). *

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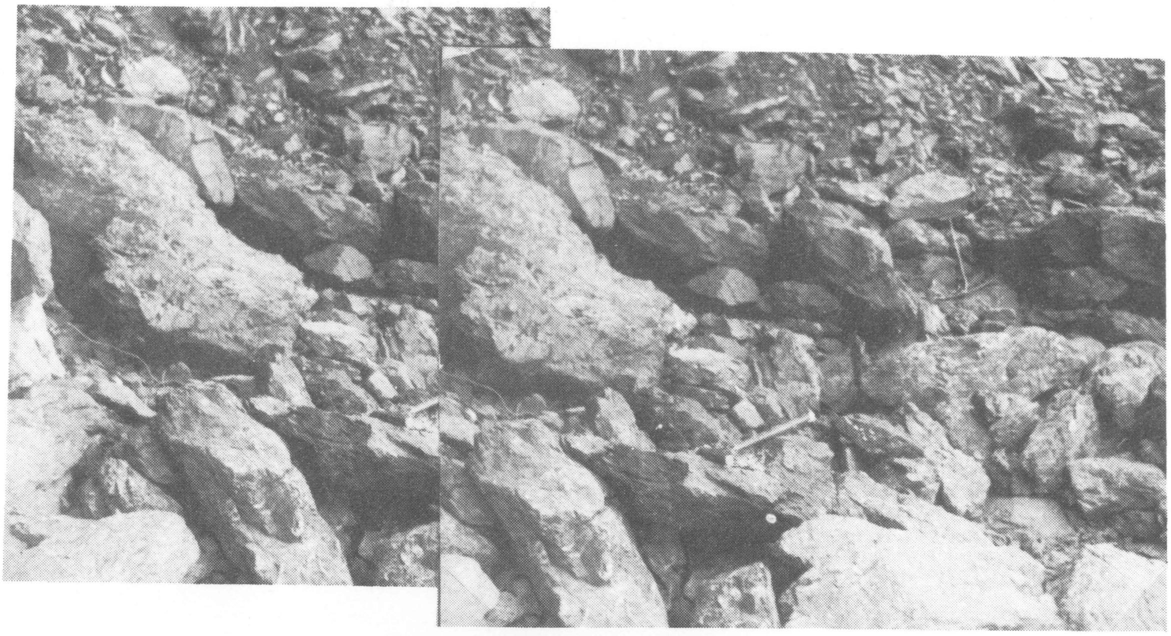
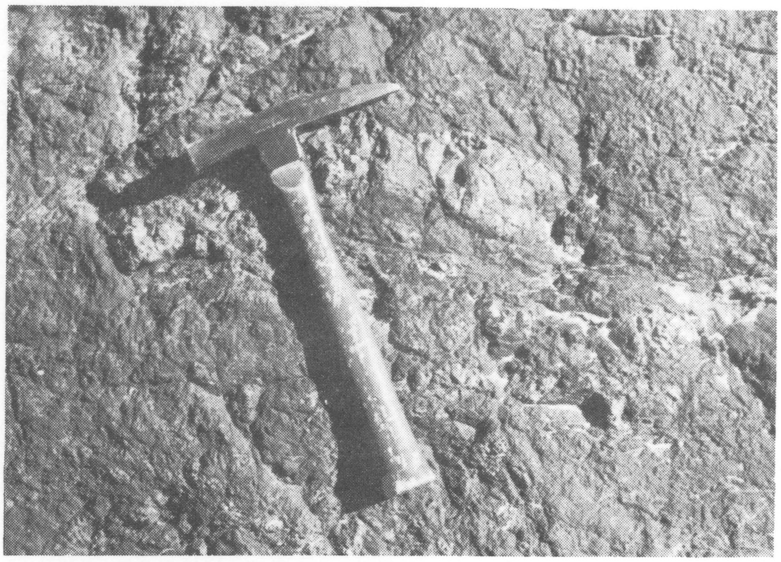
* The Aibala Volcanics were previously thought to be ?Lower Miocene in age, because of incorrect correlation with the sub-horizontal ?Lower Miocene volcanics unconformably overlying the Owen Stanley Metamorphics in the upper Auga River/Vanapa River area. Downstream from the Senonian limestone lenses in the Dilava River, volcanic arenite collected by Hohnen apparently from the Aibala Volcanics contain lower 'f' stage (Middle Miocene) foraminifera; this arenite is considered by the writer to be a down-faulted wedge of Talama Volcanics, but there is a possibility that it represents the true age of the Aibala Volcanics, and limestone and siltstone interbedded in the margin of the Volcanics are fault slivers of lower Auga Beds.

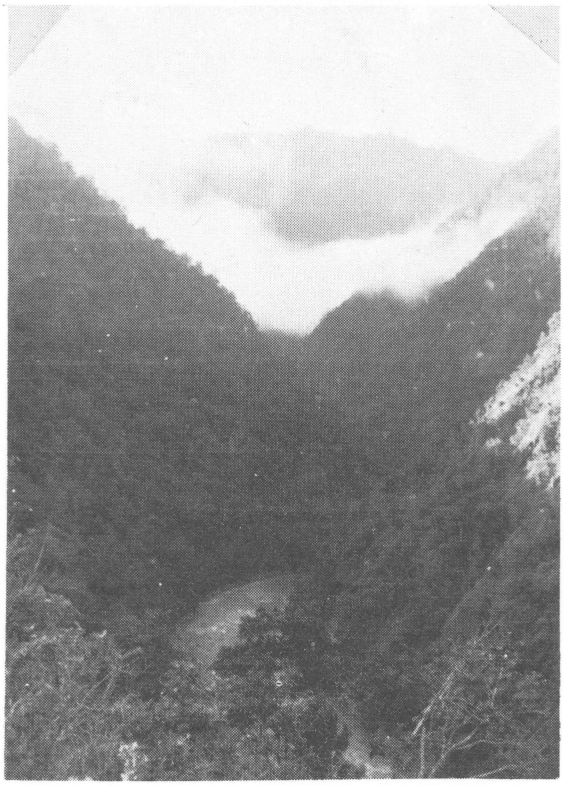
AIBALA VOLCANICS



SOFT-WEATHERING, HIGHLY JOINTED, ALTERED LAVA (STEREO PAIR)

HARD "FLINTY" LAVA





ANGABUNGA RIVER CUT
INTO AIBALA VOLCANICS

The Aibala Volcanics are generally massive and show no indication of attitude. In hand specimen they are dark, closely jointed, sheared and broken gabbroic-doleritic - and basaltic-looking lavas and intrusives, mostly with abundant zeolite and calcite veining, and in places highly zeolitized. Small lenses of very hard fine-grained silicified basalt are common; In places there are large outcrops of similar 'flinty' lavas. In the upper part of the Aibala Volcanics in the Auga River, thick units of easily weathered volcanic rocks are interbedded with indurated siltstones and sandstones containing some calcareous lenses and interbeds; the sedimentary rocks are thin-bedded in places, and some slump deformation is present. The top of the uppermost volcanic interbed is considered to be the top of the Aibala Volcanics and the base of the Auga Beds.

In thin section (see Appendix I) the basalts and dolerites of the Aibala Volcanics (G92, 95A, 97B, 98, 99A, B, 101A, B, C, 102), are seen to have an essential tholeiitic composition (when unaltered) of plagioclase and augite, with orthopyroxene present in a number of sections, and interstitial chlorite or chloritised mesostasis and accessory opaque oxide; minor quartz may be present. Plagioclase laths are mostly randomly orientated, but may form radiating aggregates; the texture in several sections is sub-ophitic or ophitic. Mineral grains are generally highly fractured or shattered, and shearing is common. Alteration varies from minor to extreme, with plagioclase altering to kaolin or zeolite, and pyroxene becoming cloudy or altering partly to chlorite or pale green amphibole. In some outcrops, fine-grained basalt has apparently been partly silicified, forming very hard red, black or greenish-white jasper-like lenses and bands in the dark easily weathered lava (G92, 99A); in thin section the basalt texture is seen to be preserved, with randomly orientated pseudomorphs of radiating chalcedony after plagioclase, set in a groundmass of chalcedony with fine epidote and minor calcite (the degree of alteration varies in section G92 in which relatively unaltered parts of the rock comprise laths of plagioclase and small grains of augite and minor orthopyroxene). Veining is generally present in the Aibala Volcanics, and may be chlorite, zeolite, calcite or, in some sections, zeolite-prehnite veining.

Rare indications of attitude in the Aibala Volcanics show them to be steep dipping, at least in the upper part. Because of the scarcity of structural information, and because the succession is blanketed in the west (at the base) by the Talama Volcanics, no accurate estimate of thickness can be made; it is probably greatly in excess of 10,000 feet. The Volcanics were probably poured out onto the ocean floor at considerable depths, with the common intrusion of coarser-grained rocks into the rapidly accumulating volcanic pile.

AUGA BEDS (new name)

The Auga Beds are named by the writer to include all the sedimentary rocks deposited between the end of volcanism in the Upper Cretaceous (Senonian) and the end of the Lower Miocene 'e' stage. In the Auga River section they include the 'Mafulu Group' and 'Kea Formation' of de Verteuil and Rickwood (1946), which crop out along more than 5 miles of the middle Auga River (see Plate 1). The type section is strongly faulted, comprising up to 17,000 feet of predominantly massive shaley and slatey black siltstone and thin-bedded shaley siltstone and fine-grained sandstone, containing in the upper part some inter-bedded indurated coarser-grained sandstone (grit) and pebble conglomerate, and two thick calcareous units.

The lower part of the section ('Kea Formation') is Upper Cretaceous (Senonian) in age, and is faulted against the Lower Miocene 'e' stage rocks of the upper part ('Mafulu Group').* The absence of Eocene rocks from the section is probably due to large-scale movements (overthrusting and strike-slip movement) on several high-angle, slightly sinuous faults which trend northwards into the Tapini area (see plate 5); the abundance of reworked Eocene fauna in 'e' stage rocks points to erosion of poorly consolidated Eocene sediments in some areas.**

The names 'Mafulu Group' and 'Kea Formation' have been replaced by <u>Auga Beds</u> for a number of reasons:

a) Dark shaley siltstones and thin-bedded siltstones and sandstones are the dominant lithologies throughout the Auga Beds with relatively minor units of recrystallized pebbly or sandy limestone and coarser-grained sedimentary rocks in the 'e' stage (and elsewhere in the Eocene); the presence of these lithologies points to the upper Auga Beds but their absence does not necessarily indicate the lower Auga Beds.

b) Sedimentation during deposition of the Auga Beds was probably continuous, although some paraconformities may exist, and the sedimentary provenance remained the same (except for the addition of reworked Eocene material in the lower part of the 'e' stage).

c) Where defined the 'Kea Formation' and 'Mafulu Group' are fault separated; greater thicknesses of the section, including Eocene rocks, are exposed elsewhere and it is not possible to establish the boundaries of the 'Kea Formation' and the 'Mafulu Group'.

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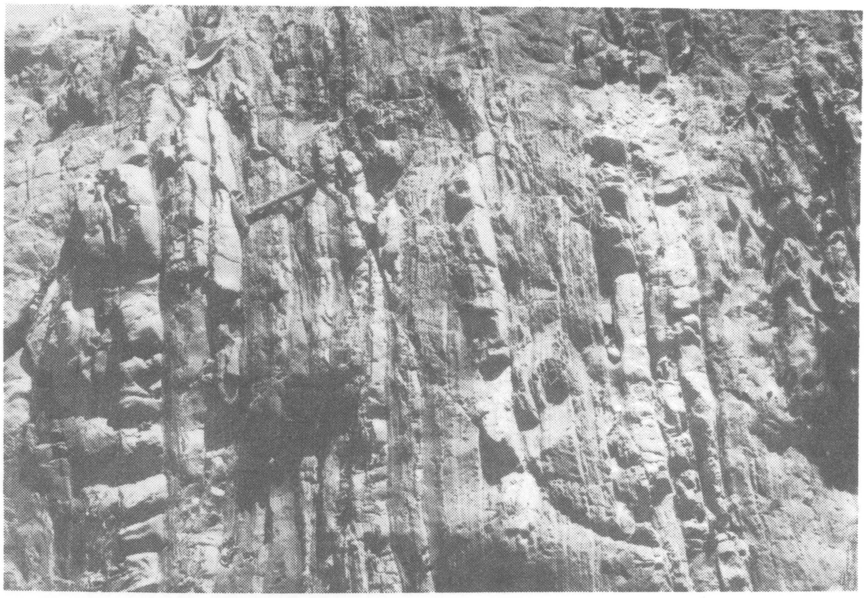
* The 'Mafulu Group' was thought by de Verteuil and Rickwood to be Eocene because no diagnostic 'e' stage fauna were recognised in samples collected by them; equivalent samples collected by the writer yield a lower 'e' stage (?Lower Miocene) age: see P1522, 1523 Appendix III.

** Eocene ages subsequently obtained in the Tapini area could represent reworked Eocene material in which no diagnostic 'e' stage fauna were found, but probably represent remnant Eocene rocks not removed by erosion in the 'e' stage or by subsequent faulting.

AUGA BEDS

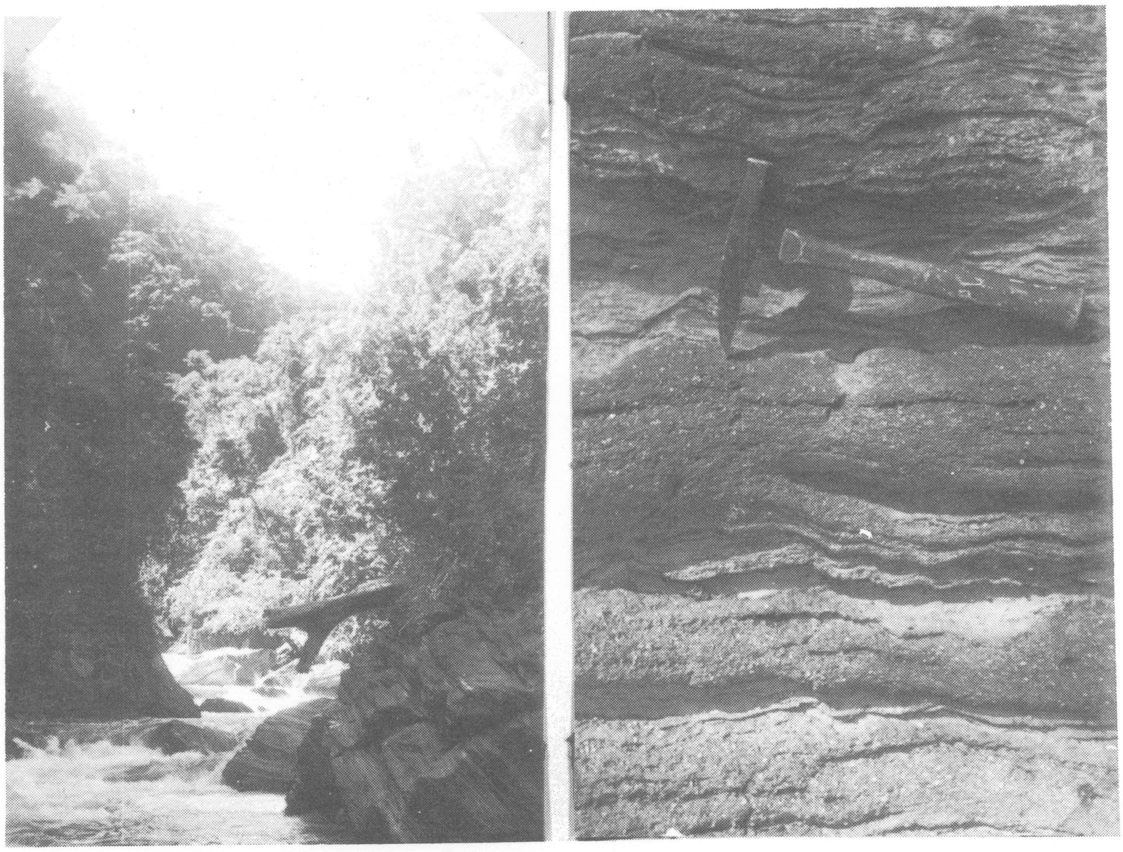


THIN-BEDDED BLACK SHALEY SILTSTONE/SANDSTONE.

BLACK CALCAREOUS SHALEY SILTSTONE/FINE-GRAINED SANDSTONE WITH LIMESTONE NODULES

SILICIFIED, SLUMP DEFORMED THIN-BEDDED ORTHOQUARTZITE (CHERT) IN THE BASE OF THE AUGA BEDS

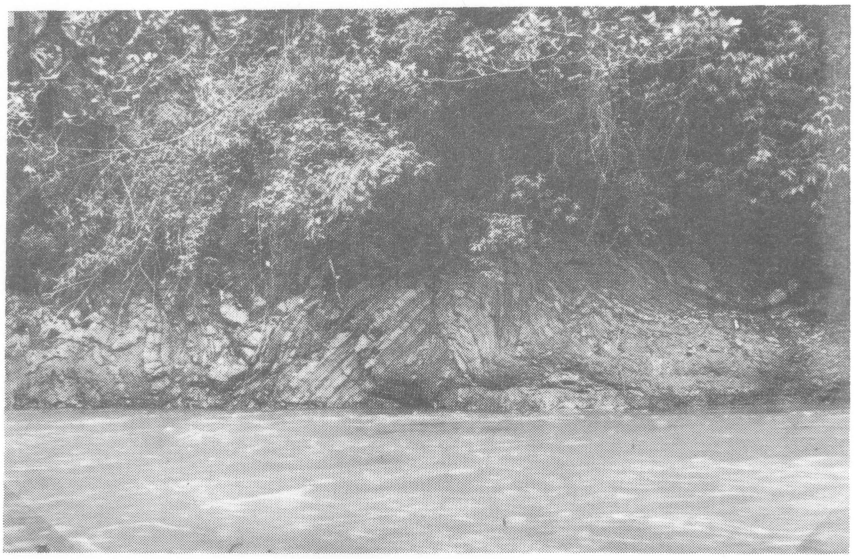
AUGA BEDS

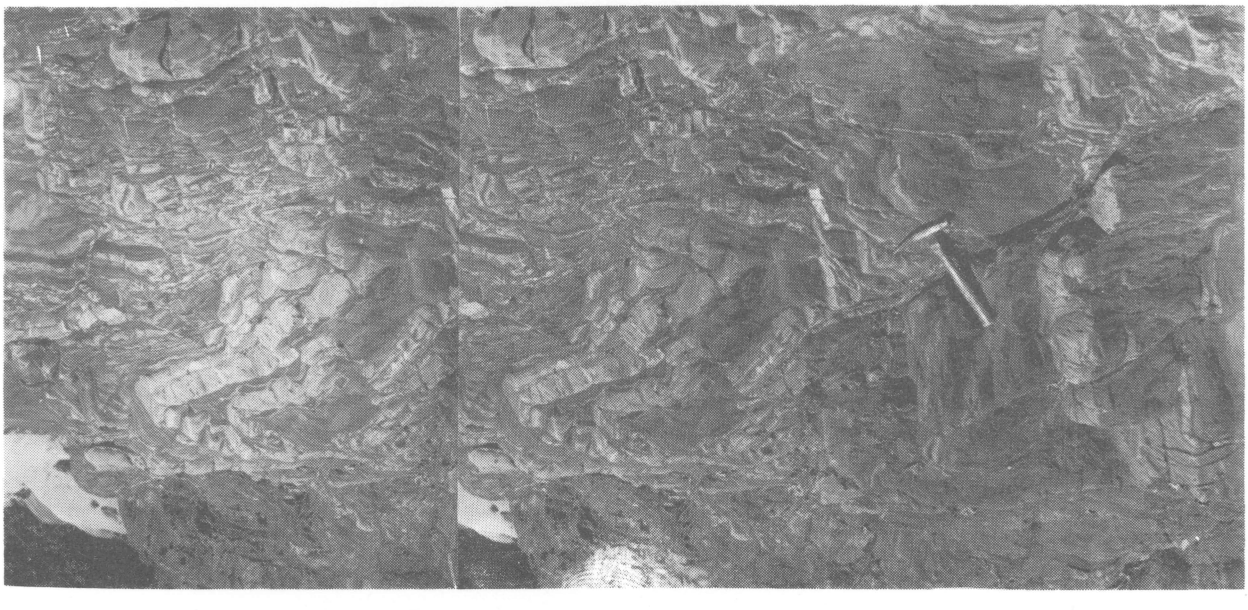


UGU RIVER - RED SANDY MARBLE WITH FINE PEBBLES (G79)

INDURATED PEBBLE CONGLOMERATE

SLUMP DEFORMATION IN THE LOWER PART OF THE AUGA BEDS.





Because of its incompleteness the Auga River section is not a good type section of the Auga Beds; if a better section is found the Beds will be renamed. It may be possible to separate out a number of formations and members within the Auga Beds when there is more detailed mapping and better correlation between areas; photogeologic interpretation is very difficult in the map area.

In many places, particularly in the upper part of the section dark highly sheared siltstones and fine-grained sandstones of the Auga Beds show incipient to marked recrystallization of argillaceous material, developing a good 'slatey' cleavage parallel to bedding; these rocks are lithologically inseparable from many semischists and fine-grained metasediments of the Owen Stanley Metamorphics, and the difficulty of identification is further increased by the parallel regional attitude of the two groups.

The sedimentary provenance during deposition of the Auga Beds was similar to that of the adjacent metasediments of the Owen Stanely Metamorphics; viz; a landmass of quartz-veined metasediments and some low-grade schists intruded by rare intermediate to acid plutonic rocks, with some intermediate and more acid volcanics. Terrigenous material may have been derived from several different sources. Grains are generally well rounded to subangular, and are fairly well sorted. Quartz is the most abundant clastic mineral, in places forming orthoquartzites; it is generally strained and in many cases is vein quartz. Plagioclase is the principal feldspar, although minor orthoclase is present (?some perthitic); grains of both myrmekitic and micrographic quartz-feldspar intergrowths occur. Metasediments comprise the largest part of the lithic fragments (siltstone, argillite, chert, slate), minor fine-grained volcanics are present (some chloritised) and rare crenulated quartz-sericite schist, chloritised ferromagnesian grains and biotite.

In the Auga River the uppermost volcanic unit of the Aibala Volcanics is overlain by at least 3,000 feet of generally highly slump deformed thin-bedded shaley black siltstone and fine-grained sandstone, which is separated by a major strike fault from at least 5,000 feet of undeformed Upper Cretaceous (Senonian) siltstone, thin-bedded with some sandstone in the lower part and generally massive in the upper part. This is separated by another major strike fault from 800 feet of red gritty and pebbly recrystallized limestone, with a dense grey limestone at the base containing lower 'e' stage (?Lower Miocene) foraminifers and abundant reworked Eocene fauna. Overlying this is continuous outcrop of 8,000 feet of generally regularly bedded rocks, comprising 4,500 feet of shaley black siltstone with numerous indurated sandy and pebbly interbeds, overlain by 800 feet of light-coloured sandy calcareous rocks and a further 2,500 feet of black siltstones, thin-bedded and sandy in the lower part and massive and highly sheared in the upper part. Overlying this, separated by a major fault, are 3,000 feet of altered submarine volcanics which are interbedded in the upper part with sheared phyllitic black siltstones and fine-grained sandstones presumed to belong to the Owen Stanley Metamorphics. If these volcanics are Lower Miocene in age, the thickness of the Auga Beds is increased by more than 3,000 feet and the top was not seen in the Auga River.

The Auga Beds are discussed in greater detail in Appendix I.

TALAMA VOLCANICS

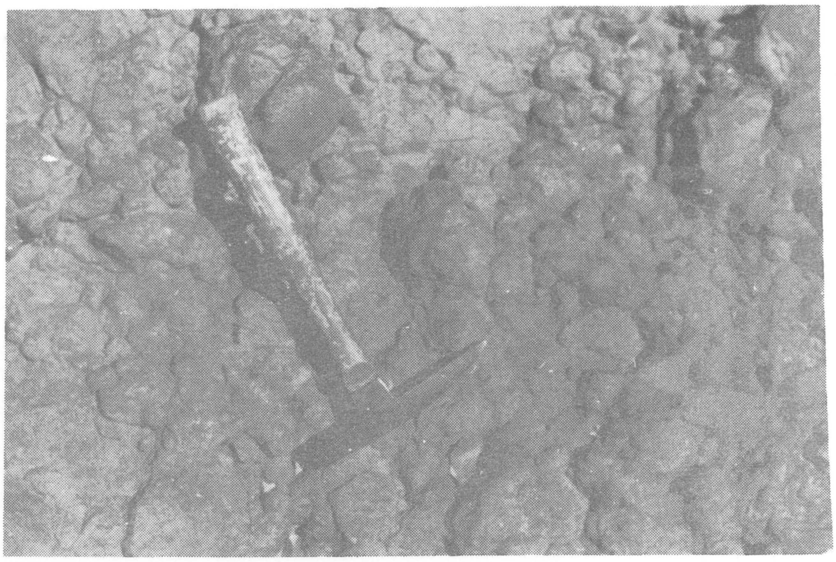
In the west and south, the area mapped is overlain by two apparently conformable units of shallow dipping volcanics, separated by a unit of soft sedimentary rocks. These are the Talama and Mt. Davidson Volcanics and the Yaifa Formation (Pratt and Whittle, 1938, names formalized by Sturmfels, 1957).

The lowest volcanic unit, the Talama Volcanics, is a unit comprising up to 3,000 feet of thick-bedded basaltic and fewer andesitic subaerial agglomerates, tuffs and lavas of probable Middle Miocene lower 'f' stage age. It was named by Pratt and Whittle for its outcrop in Talama Creek, a tributary of the Angabunga River, and was examined by the writer in the Aroa, Angabunga and Dilava Rivers, and on the divide between Kodige and Fane; it is known to crop out extensively to the east of the area mapped, as far as the Vanapa River, but was there correlated with the Aibala Volcanics, which were considered to be Lower Miocene in age (de Verteuil and Rickwood, 1946 and Brouxhon, 1965). The Volcanics unconformably overlie the Owen Stanley Metamorphics and the steeply dipping Aibala Volcanics and Auga Beds; an 'f_{1-2}' stage age for the Volcanics would correlate with the observed pattern elsewhere in the New Guinea mainland, where major deformation took place in mobile belts in the Miocene between the 'e' and lower 'f' stages, with subsequent erosion being followed by extensive 'f_{1-2}' stage volcanism.

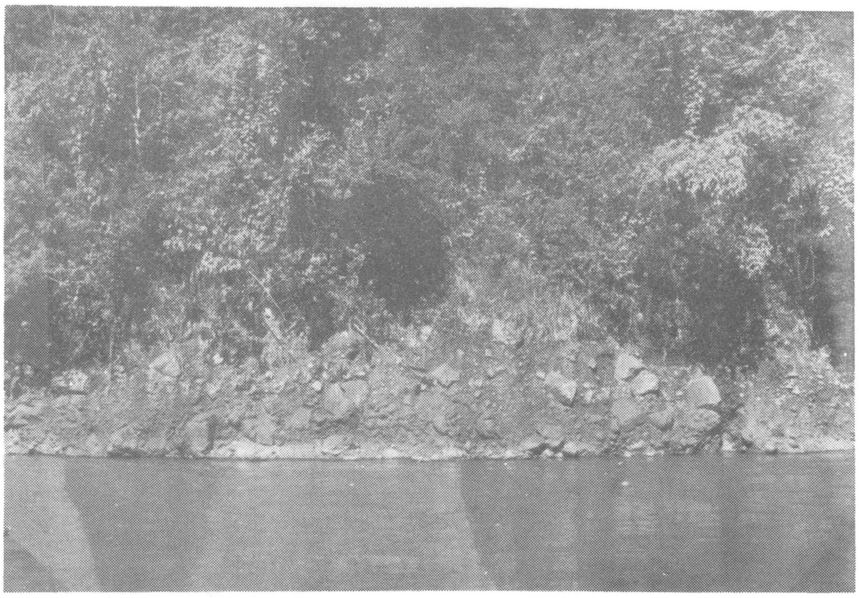
Pyroclastics predominate greatly over lavas in the Volcanics. They are generally massive or thick-bedded agglomerates, comprising moderately rounded cobbles of basalt, up to 9 inches across, in a tuffaceous matrix. Inter-bedded crystal tuffs are much less common. Angular agglomerates and breccias are associated with lava flows in a number of places. Porphyritic augite basalt is the most common rock type, with minor olivine or lamprobilite grains present in some sections (see Appendix II). Some of the basalts are vesicular. The composition of the interbedded andesitic rocks is augite andesite, or augite-hornblende (or lamprobolite) andesite in which brown biotite may be present.

In the Aroa River area the Talama Volcanics were laid down on an uneven surface of steeply dipping semischists and metasediments of the Owen Stanely Metamorphics. Many lenses of well sorted fine agglomerate, tuff, tuffaceous siltstone and clayey mudstone are interbedded in the base of the succession, indicating distribution by streams, in part at least, at the onset of volcanism; the 'Plant Remains Group' of Pratt and Whittle, 1938, is one such lens, 10 feet thick and containing well preserved leaf moulds. Higher up, the succession is massive and coarsely bedded agglomerate, with lavas and some tuff, and there is no indication of sorting or distribution by water. The Thickness of the Talama Volcanics does not exceed 3,000 feet.

TALAMA VOLCANICS



BLOCKY LAVA IN THE BASE OF THE VOLCANICS



ANGULAR AGGLOMERERATE IN THE TOP OF THE VOLCANICS

On the divide between Kodige and Fane the Talama Volcanics crop out as lavas, tuffs, and quite hard agglomerates (with cobbles generally less than 4 inches across). The volcanics here were previously correlated with the Aibala Volcanics (de Verteuil and Rickwood, Brouxhon), but there is neither lithological nor photogeological evidence to support this. To the east, between the Vanapa, Auga, Dilava and Arca Rivers, the Talama Volcanics are predominantly basalt lavas and agglomerates, with tuffs common in the basal section; minor andesite interbeds are present (Brouxhon, 1965).

In the middle Angabunga River area the Talama Volcanics form the narrow, steep sided Yaifa Gorge. Above the gorge the base of the Volcanics rests unconformably on the Aibala Volcanics and dips south and southwest at 30 to 40 degrees. Below the gorge dips are less than 20 degrees, shallowing downstream to sub-horizontal in the overlying Yaifa Formation and Mt. Davidson volcanics; it is probable that the eastern edge of the volcanics is a monoclinal warp (see plate 3). Near the base of the succession thick lava flows are common, and these in places are blocky; many of the agglomerates are volcanic breccias (one with angular boulders up to 4 feet across); tuff interbeds show graded bedding, and minor pillow lava is present in the river wash (some of these may be marine). The Yaifa Gorge is cut into interbedded agglomerate, lava and minor tuff. Below the gorge is a 200 feet thick section of tuff and volcanic conglomerate with a tuffaceous matrix,* overlain by several hundred feet of basic lavas, volcanic breccias and tuff, which is in turn overlain by up to 500 feet of boulder conglomerate, comprising rounded boulders of augite (-lamprobolite) andesite in a soft tuffaceous matrix; the conglomerate grades up into the soft sedimentary rocks of the Yaifa Formation; it is here considered to be the basal member of the Yaifa Formation.

The tuffs and volcanic conglomerates immediately below the Yaifa Gorge are easily weathered and allow the river to spread before it is again constricted by the overlying lavas. These lavas are vesicular in many places, rarely becoming scoriaceous. Small lenses of tuff and mudstone lying in pools on top of flows were deformed by succeeding flows; many flows were thin and narrow, following depressions.

THE YAIFA FORMATION

The Yaifa Formation comprises up to 1,000 feet of generally thick-bedded, easily weathered fluviatile sedimentary rocks, derived largely from a volcanic provenance and partly from a 'basement' of hard schists and metasediments. It was named by Pratt and Whittle for its outcrop in the vicinity of Yaifa village (now abandoned since the establishment of Bakoiudu).

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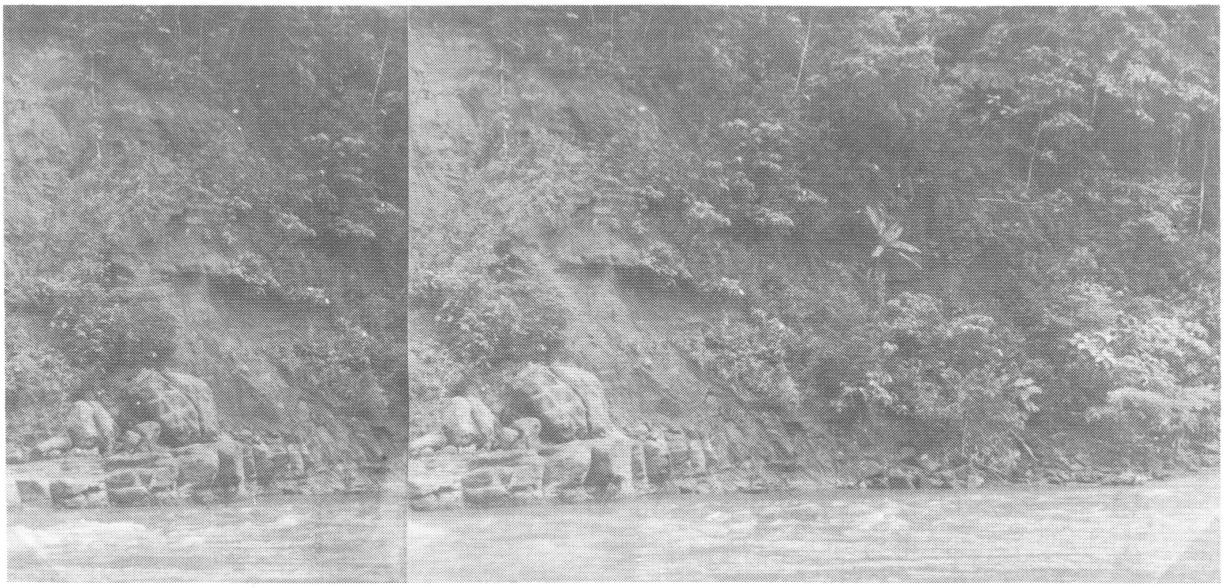
* This section was mis-interpreted by Sturmfels (1957) as constituting the intersection of the Yaifa Formation by the Angabunga River: the mistake was probably due to the relocation of the main Maimai track and bridge across the Angabunga River between 1938 and 1957.

YAIFA FORMATION

BASAL CONGLOMERATE - ULU CREEK



THICK-BEDDED SANDSTONE/SILTSTONE - ANGABUNGA RIVER
(Stereo pair).

The Yaifa Formation overlies the Talama Volcanics with apparent conformity, and passes upwards without depositional break into the Mt. Davidson Volcanics of probable Upper Miocene to Pliocene age. Its age is unknown, but could be Middle to Upper Miocene. The Yaifa Formation was examined by the writer in the Angabunga and Dilava Rivers; it is correlated with the 'Lolorua Sedimentary Series' of Pratt and Whittle in the Galley Reach area.

At the base of the Yaifa Formation is a conglomerate member which exceeds 500 feet in thickness in a small side creek (Ulu Creek) of the Angabunga River, and attains a thickness of several hundred feet in the Dilava River. The conglomerate is made up of generally widely separated, well-rounded boulders of andesite in a soft, clayey tuffaceous matrix. It is mostly massive, but may be thickly bedded, and contains in places lenticular bands of soft, clayey tuff less than 5 feet thick. The boulders are generally from 6 inches to 18 inches across, but may be up to 4 feet across; they are composed of hard porphytitic augite and augite-lamrobolite andesite (G111, 114). In several bands the boulders become quite angular. Scattered quartz, hard schist and metasediment pebbles occur throughout, becoming common in the upper part, which grades upwards into about 500 feet of bedded tuffaceous sandstone, siltstone, mudstone and claystone, with lenses and thin bands of pebbly tuffaceous sandstone and fine conglomerate. These sediments are very soft, with irregular thick bedding; they dip gently to the west and southwest. Carbonaceous plant remains were found at a number of localities.

In the upper part of the Yaifa Formation, at the mouth of the narrow gorge (Kobe Gorge) into which the Angabunga River flows below Yaifa, the sediments become coarser, with beds of conglomerate up to 20 feet thick interbedded with thick bands of tuffaceous sandstone and pebbly tuffaceous sandstone. The conglomerates are made up of cobbles and boulders, up to 18 inches across, of lava, tuff and metamorphic rocks, and pebbles of quartz, in a soft tuffaceous matrix. One fine-grained conglomerate examined in thin section (G120A) contains well rounded pebbles up to 5 mm. across of argillite, chert, basic and intermediate lavas, slate and sericite schist, with a calcite cement. The succession grades up into basic tuffs, agglomerates and lavas of the overlying Mt. Davidson Volcanics.

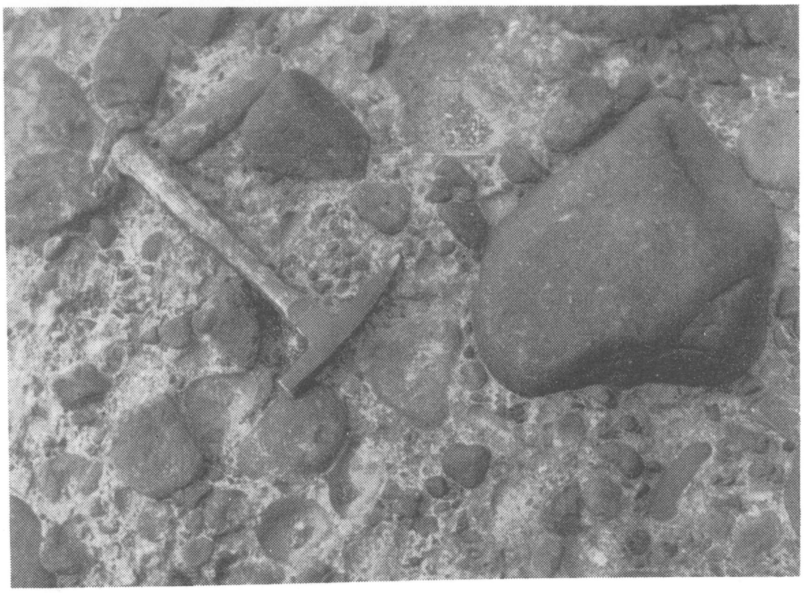
Much of the clastic material in the Yaifa Formation was derived by reworking of the underlying Talama Volcanics, some was derived from the metamorphic terrain to the northeast, and much, particularly the fine tuffaceous material, was the product of contemporaneous volcanism.

MT. DAVIDSON VOLCANICS

The Mt. Davidson Volcanics are more than 2,000 feet of basic pyroclastics and lavas forming prominent cliff scarps north of the middle Angabunga River. They were named by Pratt and Whittle from Mt. Davidson immediately north of the river, and crop out extensively to the north and west, they are correlated with the Kanosia Volcanics

MOUNT DAVIDSON VOLCANICS

MT. DAVIDSON, LOOKING OVER THE TOP OF THE YAIFA GORGE (TALAMA VOLCANICS) FROM OBA OBA



BASALT COBBLES IN A CRYSTAL TUFF MATRIX IN THE BASE OF THE MOUNT DAVIDSON VOLCANICS to the south, in the Galley Reach area. Their probable age is Upper Miocene to Pliocene (Sturmfels, 1957).

The Volcanics were not examined in detail by the writer; basal sections were examined in the Angabunga and Dilava Rivers, and deeply weathered agglomerates and tuffs near Bakoiudu, but the generally precipitous nature of outcrop in the area prevented the examination of a more complete section. The Volcanics dip southwest under the coastal plain. Thickness has been estimated from aerial photographs.

In the Angabunga River, tuffaceous sandstones and conglomerates of the Yaifa Formation grade upwards into tuffs, volcanic conglomerates and agglomerates of the Mt. Davidson Volcanics. The tuffs are soft, waterlaid crystal tuffs containing large, well preserved grains of augite. The agglomerates comprise fragments of augite basalt and olivine-augite basalt, much of which is scoriaceous, in a soft crystal tuff matrix. A sample of basalt from agglomerate near Bakoiudu (G121) was seen in thin section to contain rare phenocrysts of orthopyroxene as well as augite.

In the Dilava River, scree of vesicular olivine basalt (G131) and a small gorge of tightly packed agglomerate (fragments up to 4 inches across of pyroxene basalt, G132) marks the locally faulted base of the Mt. Davidson Volcanics. These rocks are overlain by moderately dipping massive boulder agglomerate (boulders up to 2 feet across) with beds of tuff 6 inches to 4 feet wide, grading upwards into 200 feet of volcanic conglomerate comprising rounded boulders (up to 3 feet across but generally less than 18 inches) of basalt (much of which is vesicular) in an abundant tuffaceous matrix, with irregular tuff beds up to 5 feet thick.

INTRUSIVE ROCKS

The Owen Stanely Metamorphics and, to a considerably lesser degree, the Auga Beds are intruded by both plutonic and porphyritic rocks, with porphyries being the more abundant and widespread.

a) Porphyritic Rocks

Porphyritic intrusions into the Owen Stanley Metamorphics are widespread throughout its area of outcrop, particularly in the Aroa River headwaters. Most of these intrusives are hornblende andesite porphyries, in which alteration varies from absent to extreme; many of the altered porphyries are pyritic and appear leucocratic in hand specimen. Small dolerite intrusions are less numerous, but intrude both the Metamorphics and the sedimentary rocks of the Auga Beds, particularly in the Auga Valley. Porphyritic diorites and granodiorites occur, but these are largely related to the plutonic rocks.

In thin section the andesite porphyries (G13, 14A, 18, 19A, 19B, 26C, 48A), typically comprise scattered phenocrysts of euhedral plagioclase up to 2mm. long (many showing good oscillatory zoning, varying from fresh to partly or completely altered to sericite, ?kaolin, calcite and some chlorite and epidote), lesser hornblende (pale green-brown to olive green when fresh, generally partly or completely pseudomorphed by chlorite and calcite, with some epidote, pale green amphibole and opaque oxide), and scattered granular opaque oxide, in a cloudy quartzofeldspathic groundmass with small patches of calcite and rarer chlorite. The groundmass is silicified in the leucocratic altered porphyries, and contains abundant sericite flakes and, in one section, scattered epidote grains, calcite and fine sphene. In several unaltered porphyries the groundmass is made up of clear plagioclase and interstitial feldspar and quartz. Scattered pyrite grains, often embayed, are present in the altered porphyries.

Dolerite occurs as narrow dykes and sills, and in small irregular bodies. It is generally hard and poorly jointed; alteration is mostly minor but varies to extreme. A quartz dolerite intruding the schists near Fane is seen in thin section to comprise sub-ophitic, partly sericitised sodic labradorite, hornblende and minor biotite (associated with the hornblende) and interstitial quartz, with accessory magnetite or ilmenite and apatite. Further down the Auga River a dolerite intruding the Auga Beds comprises extremely sericitised and kaolinised plagioclase, smaller (partly interstitial) augite and enstatite (the former partly altered to pale green amphibole and green chlorite) and interstitial green chlorite, quartz and some micrographic quartz/feldspar. Skeletal grains of ilmenite, largely altered to sphene, are common, and a few grains of iron ore occur. Minor secondary epidote occurs throughout.

A thick 'basalt' dyke (G20) is intruded into a wide zone of fault breccia in the Aroa River headwaters; this comprises fine plagioclase laths (less than 0.2 mm. long), interstitial feldspar, chlorite, some quartz, granular opaque oxide and abundant small patches of calcite.

(b) Plutonic Rocks

The distribution of plutonic rocks is less widespread than that of the porphyries. Several small bodies of diorite crop out along the upper Aroa River, and abundant diorite/granodiorite wash sheds into its headwaters from the Mt. Cameron Range. Scattered small bodies of similar 'dioritic' plutonics crop out in the upper Dilava and Auga Valleys, and gabbro intrudes metavolcanics in the Auga River section.

Abundant medium to fairly fine-grained plutonic wash is present in the northeastern headwaters of the Aroa River, draining from the Mt. Cameron Range (G14B, 26A, 26B, 26D, 26E). These rocks are mostly dioritic in composition, and many are pyritic; thin veins of more acid composition are common. They are massively jointed, hard, and generally fresh. Thin section examination shows them to be largely diorities, varying in composition to granodiorites; veining is granitic and granophyric. The maximum grain-size varies from 2 to 3½ mm. and the essential composition is 65 to 80% plagioclase, 5 to 20% interstitial quartz and orthoclase, and 15 to 20% generally altered hornblende. Plagioclase varies in composition from sodic andesine to sodic labradorite; it is fractured in several sections and is commonly partly altered to sericite, with lesser calcite and minor epidote. Orthoclase is absent or a very minor constituent of the diorite; interstitial quartz is generally present but makes up less than 10% (quartz and orthoclase together make up 20 to 25% of the granodiorite). Ferromagnesian minerals make up to 15 to 20% of the rock, mostly in the form of green-brown hornblende partially altered to chlorite, calcite, epidote, rare brown biotite and sphene (the hornblende and secondary ferromagnesian minerals in some sections may be replacing primary augite). Primary biotite may be present in small amounts in the diorite, and is a major ferromagnesian mineral in the granodiorite (G26E). Accessory opaque oxide and pyrite may be present. Veining in the diorite/granodiorite is granophyric with a granite margin (G14B), or granite (G26E).

Lower down the Aroa River, below Ialoge village, the stream cuts through a 600 yard gorge of diorite (G15). Further downstream, below Inai village, a large body of massively jointed, fine-grained porphyritic augite diorite (G8) intrudes slatey schists and is overlain by the subhorizontal volcanic succession. This diorite is composed of small phenocrysts of plagioclase, pale green augite and some brown biotite, with rare pale green actinolite, set in a relatively coarse groundmass of plagioclase, quartz, augite, biotite, opaque oxide and minor brown chlorite.

Plutonic wash in the upper Dilava and Auga Rivers indicates small scattered intrusions in their headwaters. In a small tributary of the Dilava River, plutonic float includes biotite-hornblende (-augite) diorite/monzonite (G29A) and biotite-hornblende (-augite) adamellite (G29B). In these rocks orthoclase is more abundant than in the diorite/granodiorite of the Aroa River, relict augite is present (largely replaced by pale green hornblende), and large sieved biotite flakes are common. In the Auga River headwaters plutonic float is generally similar to that of the Dilava River. Float shedding from intrusions into the metamorphics includes fine-grained hornblende diorite (G48B), augite-biotite adamellite (G60A) and a fine-grained hornblende-biotite-augite diorite with large augite phenocrysts (G60B). Some of this float is pyritic, and some contains abundant pyrrhotite. Micrographic quartz/orthoclase intergrowths are common in the adamellite (G60A) and augite is a primary mineral (partly altered to actinolite). Augite is present in the fine-grained hornblende-biotite-augite diorite (G60B) only as large exotic zoned xenocrysts, indicating the hybrid nature of the rock.

Metavolcanics in the river section below Bella Vista Village (see plate 1) are intruded by granodiorite porphyry (G62A) and altered and brecciated coarse-grained gabbro (G62B, 63). The granodiorite porphyry is hard and massively jointed, occurring as small irregular bodies; in thin section it is seen to be made up of phenocrysts of euhedral plagioclase, rounded quartz, ?orthoclase, and chlorite after ?hornblende, in a quartzofeldspathic groundmass; it is probably related to the plutonic rocks and not the porphyry suite. The gabbro intruding the metavolcanics occurs as irregular discordant bodies, generally altered and in many instances sheared and brecciated. In thin section the rock is seen to comprise large grains of plagioclase (partly or completely altered to sericite, kaolin and zeolite) and augite, with accessory ?ilmenite altering to leucoxene. Where sheared the rock has a cataclastic texture. It is cut by zeolite and pennine chlorite veins.

Downstream, fine-grained granodiorite/adamellite (G69) intrudes the boundary between thin-bedded shaley siltstone and sandstone, and limestone of the Auga Beds. The intrusive rock is leucocratic and hard, comprising equigranular quartz (50%) highly kaolinised feldspar (45%, plagioclase much in excess of orthoclase) and 5% pale green chlorite.

STRUCTURE

The most prominent structural feature in the map area is the relatively consistant regional attitude of the Owen Stanley Metamorphics and the adjacent Auga Beds, striking roughly north and dipping steeply to the east.

This has resulted from high angle overthrusting from the east, causing vertical and transcurrent movement along a number of slightly sinuous faults which trend roughly north in the map area; tilting and rotation of blocks about an axis which probably plunges south at a shallow angle has produced the conformable regional dip. Increase and variation in stress to the east has caused varied mild regional metamorphism of the deeply buried sedimentary rocks (?Lower Cretaceous or older Mesozoic) thrust up against the Lower Miocene rocks of the Auga Beds; these rocks are the Owen Stanley Metamorphics, in which metamorphism becomes more uniform and marked to the east and northeast towards the Owen Stanley Fault (on the north flank of the central cordillera). If the age of the Talama Volcanics is Middle Miocene 'f_{1-2}' stage, then most of the regional deformation took place in the Miocene between the 'e' and 'f_{1-2}' stages, the onset of deformation probably terminating the 'e' stage deposition; this correlates with a similar period of major deformation elsewhere on the New Guinea mainland.

The internal structure of the Owen Stanley Metamorphics is largely unknown, because of scarcity of field data. Cleavage developed in the low-grade schists is roughly parallel to origonal sedimentary bedding, where the latter is recognisable. Puckering and fine crenulation of the cleavage is common, and extreme local contortion by polyclinal or isoclinal concentric folding and, in places, conjugate folding associated with kink bands; broad warping or tight folding (the latter unlikely) is suggested by the stereographic net plotted from scattered observations of the attitude of cleavage (see figure 1). A second period of metamorphism indicated by thin section examination of many of the low-grade schists, was not accompanied by major deformation.

Large scale tectonic structures are not present in the Auga Beds, except for several major strike faults. Shearing and the development of incipient slatey cleavage is apparent in some shaley siltstones, and in several places further deformation has been expressed by kink banding. Extreme soft sediment (slump) deformation is common in thin-bedded siltstone/sandstone successions in the lower part of the Auga Beds and in the sedimentary units interbedded in the top of the Aibala Volcanics.

Strong jointing and shearing of the Aibala Volcanics are very common; little is otherwise known of the structure because of lack of indications of orientation.

The eastern edge of the subhorizontal volcanic and sedimentary rocks in the middle Angabunga River area appears to be a monoclinal warp (see plate 3), with dips of up to 40° to the southwest being measured in the base of the Talama Volcanics. To the southwest and west the dips shallow rapidly, and the rocks are broadly warped with a shallow southwest dip.

GEOLOGICAL HISTORY

A complete geological history cannot be reconstructed within the map area because of removal of part of the stratigraphic column by faulting.

The oldest rocks of known age are the Upper Cretaceous (Senonian in the upper part) Aibala Volcanics; it is probable that the Owen Stanley Metamorphics, for which no age has been established, are older, originally comprising massive, dark siltstones and shales, with interbedded quartzofeldspathic and lithic arenite and fine conglomerate, deposited probably during the Lower Cretaceous or earlier Mesozoic times; minor limestone and submarine volcanics are present in the Metamorphic succession. The lithologies of the Metamorphics suggest deposition under generally quite, fairly shallow water marine conditions on a shelf or in a marginal basin some distance from the shoreline. The detrital material comprises quartz, plagioclase, chert, argillite and slate, and is generally fairly well sorted and rounded in the coarser-grained rocks (where subsequent deformation has not destroyed the original texture).

The Aibala Volcanics represent a period of very active upper Cretaceous submarine (deep water) volcanism, with the accumulation of a thick pile of tholeiitic basaltic and doleritic submarine lavas, intruded by gabbroic - and doleritic - looking sills and dykes. Tuffaceous rocks may also be present, particularly in the upper part where massive volcanics are interbedded with thick units of fine-grained marine sedimentary rocks.

Following the cessation of volcanism at least 8,000 feet of fine-grained black marine sedimentary rocks were deposited (lower part of the Auga Beds); these rocks are massive shaley siltstones, thin-bedded siltstones and fine-grained sandstones, and some mudstones; they are calcareous in part and strongly slump deformed in the lower part. The environment of deposition is one of fairly quiet shelf or basin conditions in deep water at some distance from the source of terrigenous material. The sedimentary provenance is similar to that of the Owen Stanely Metamorphics; quartz is the most common detritus, with some plagioclase and minor chert, argillite and fine-grained intermediate volcanic rock. A Senonian age has been obtained from a specimen collected from the upper part of this section (de Verteuil & Rickwood, 1946).

The uppermost exposures of Senonian rocks in the Auga River section are faulted against lower 'e' stage (?Lower Miocene) limestone in which there is an abundance of reworked Eocene foraminifera. Immediately overlying this limestone are calcareous sandstones and conglomerates in which the clastic material includes abundant fragments of reworked, poorly consolidated red (haematitic) mudstone derived by the fragmentation of penecontemporaneous (?Eocene) sedimentary rocks. It is probable that sedimentation continued from the Upper Cretaceous into the Eocene with little or no break, but with intermittant shallowing of the seas to permit the development of a number of reef/shoal limestones and calcareous units containing abundant larger foraminifera. Sedimentation continued to the 'e' stage with differential uplift and shallowing of the seas causing reworking of some Eocene sediments; erosion of Eocene deposits in the 'e' stage has possibly removed much of the Eocene succession in some areas.

The 'e' stage rocks (the upper part of the Auga Beds in the Auga River section) are more than 8,000 feet of dark shaley and slatey marine siltstones, in places with indurated sandy and pebbly interbeds, and two thick units of calcareous rocks; they were deposited in a fairly deep water shelf or basin environment which was subject to intermittant shallowing. Terrigenous material is coarser and more abundant in much of the section than it is in the lower Auga; microfossil remains are scarce in spite of the periods of shallowing and two periods of strong carbonate development. The sedimentary provenance remained apparently unchanged from that of the lower Auga Beds and the Owen Stanley Metamorphics, except for the addition of reworked Eocene material. The emergent landmass was obviously one of quartz-intruded metasediments and some low-grade schists, possibly with flanking newly emergent Eocene sediments; intermediate volcanics are in evidence, and clasts derived by weathering of intermediate plutonic rocks.

Metavolcanics, apparently interbedded in the Owen Stanley Metamorphics, may belong to the 'e' stage succession, representing a phase of active submarine volcanism in the final stages of deposition of the Auga Beds.

Sedimentation was terminated in the 'e' stage by the onset of a period of intense deformation, marked by high angle overthrusting from the east which caused steep tilting of the Auga Beds, Aibala Volcanics and Owen Stanley Metamorphics by rotation between a number of slightly sinuous north trending strike faults. Stresses associated with the overthrusting caused induration and low-grade regional metamorphism of the deeper-seated sedimentary succession thrust up against the 'e' stage rocks of the Auga Beds; these are the Owen Stanley Metamorphics. Retrogressive metamorphism of the low-grade schists is apparent in thin section, but this is not associated with major deformation and cannot be related to any known event; it is possibly related in some way to the widespread intrusion of porphyries and intermediate plutonic rocks into the Metamorphics and, to a lesser degree, into the Auga Beds.

Up to 3,000 feet of predominantly basic pyroclastics and lava flows, the Talama Volcanics, wore deposited on the unevenly eroded surface of the upturned Owen Stanley Metamorphics, Auga Beds and Aibala Volcanics, probably in the Middle Miocene 'f_{1-2}' stage. These thick, uniform deposits are lacustrine in part and may be marine in part, but the full mechanism of distribution is unknown. They are conformably overlain by 1,000 feet of poorly consolidated lacustrine sedimetnary rocks, the Yaife Formation, derived from reworking of the underlying volcanic rocks, from the emergent 'e' stage and older rocks, and partly from contemporaneous volcanism. They are probably Middle to Upper Miocene in age, and grade upwards without break into more than 2,000 feet of basic pyroclastics and lavas, which probably range from Upper Miocene to Pliocene in age. Near the coast, at Arapokina, there are marine intercalations in these subaerial volcanics.

The subhorizontal volcanic and sedimentary succession is faulted and gently warped, the eastern margin in the middle Angabunga River area being a fairly tight monoclinal warp; uplift associated with the faulting, gentle folding and shallow tilting has elevated the uppermost volcanics to more than 10,000 feet above sea level at Mt. Yule, north of the map area.

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APPENDIX I

AUGA RIVER SECTION

General description

The Auga River section is the section exposed along the Auga River from below Bella Vista on the south slopes of the middle Auga valley, downstream to its junction with the Angabunga River (see Plate 1). It contains over 25,000 feet of sedimentary and volcanic rocks (see Plate 2), of which at least 17,000 feet belongs to the Auga Beds. In other areas it is probable that the stratigraphic column is more complete, as the Eocene and possibly part of the Upper Cretaceous rocks have been removed from the Auga River Section by faulting.

Traverse detail:

G59. Crenulated black phyllitic siltstone with small rafted fragments of light grey fine-grained sandstone. Thin quartz veins cut the rock. Downstream indurated, sheared, fine-grained ?sandstone is interbedded with the phyllitic siltstone.

Interbedded with these metasediments are thick bands of hard, green, epidotised, hornfelsic-looking submarine volcanics with small deformed lenses of recrystallized grey-brown limestone. Wash in the river suggests that these volcanics are also interbedded in the metasediments above G59.

G62. Continuous outcrop of massive metavolcanics (as above), epidotised about joint-planes. Intruded by small bodies of andesite porphyry and gabbro. Sheared in many places and strongly brecciated at its base above the river junction (G63). The unit of metavolcanics is 3,000 feet thick.

G64. River junction (top of the "Mafulu Group" of de Verteuil & Rickwood and ?top of the Auga Beds). Highly sheared black phyllitic siltstone with sheared-out lenses of dark sandy siltstone. Along this section of the river, shearing is parallel to "schistosity" of phyllitic sediments and to sedimentary bedding.

G65. Phyllitic black siltstone continues downstream. At G65, a 20' bed of fine-grained, dark grey argillaceous sandstone or quartz greywacke is interbedded with the siltstone. The sedimentary rocks are cut by quartz and calcite veining.

G66. A short distance downstream the massive phyllitic siltstone gives way to a succession of thin-bedded (up to 6") shaley black siltstone and fine-grained dark argillaceous sandstone, with a number of interbeds of argillaceous sandstone up to 30' thick. This section has very regular bedding and continues downstream to G69.

The unit G64 - G69 is 2,500 feet thick.

G69. A medium-grained dioritic (fine-grained granodiorite/adamellite) intrusion at the top of a gorge cut in calcareous sediments.

G70, 71. 800 feet of light-coloured, predominantly calcareous sedimentary rocks, comprising grey marble, grey marble with thin yellow sandy beds, yellow sandy marble, yellow quartz sandstone and red-green argillaceous calcareous rocks with quartz pebble bands.

The original limestones have been largely recrystallized; in many cases the resulting marble has been sheared, with minor subsequent recrystallization.

There is no sign of microfossils in the thin sections examined.

G72 - G78. 4,500 feet of generally indurated black shaley siltstone, often with fine quartz pebbles, and black sandy shale, black pebbly sandstone and beds of pebble conglomerate. In places the succession is red-weathering. It is thin-bedded in part and contains a number of fossiliferous (broken molluscs) sandy shale units, several of which contain small black nodules of fine-grained limestone and one of which contains small, well-preserved gastropods. In the lower part, the section contains some calcareous sediments (G78A), and thin beds of very hard, light-coloured quartz sandstones (orthoquartzites - G78B, 78C). The sandstones are principally hard, dark lithic arenites, containing quartz, some plagioclase and abundant fragments of siltstone, slate, argillite, chert and rare intermediate volcanics. The conglomerate beds range up to 15' thick, containing well-jointed pebbles up to 3" across of quartz and metasediment.

An interbed or sill of intermediate volcanic rock (lava or porphyry) crops out at G73 (probably the former because of a small quantity of similar looking clastic material in the sandy siltstones of the succession) and dolerite intrudes the section at G77.

Bedding orientation is regular throughout the section.

G79. 800 feet of a distinctive reddish calcareous succession with a characteristic weathering surface, comprising thin-bedded and massive marble (generally gritty), calcareous sandstone (grit) and calcareous pebble conglomerate, and underlain by fine-grained red-green calcareous sandstone. The red colour of the succession is due to the presence of haematite-stained mudstone, sometimes very abundant, which was probably largely derived from the reworking of penecontemporaneous sediments. Other clastic fragments are generally well-rounded and include quartz, metasediments, some plagioclase and rare microfossil fragments. The calcite cement is generally coarsely crystalline. Variation within the succession is only in abundance and grainsize of clastic material; where this is absent, the rock is a marble.

Dips at the bottom of the succession are as low as 45°.

G80. Dense light-grey limestone, containing foraminifera indicating a lower 'e' stage (?Lower Miocene) age, and containing abundant reworked Eocene fauna. Outcrops of this unit were not found in the river, but abundant scree and rubble at the foot of the slopes suggest that up to 200 feet thickness of this limestone underlies the above succession (G79).

No outcrop for a short section.

G81. Fine-grained brown sandy shale, strongly jointed and easily weathered. No outcrop, then black shale on the other side of the river, with a 20 foot bed of ?fine-grained dark sandstone.

G82 - G88 Further downstream, on the other side of the river, thin-bedded black shales and fine grained dark sandstones crop out.

Outcrop is not continuous in the section G80 to G83. If the section is not structurally interrupted or repeated, then there is at least 5,000 feet of vertical, north striking dark shaley siltstones, apparently massive in the upper part, and thin-bedded with fine-grained dark sandstones in the lower part. An Upper Cretaceous (Senonian) age was obtained for these rocks by de Verteuil & Rickwood, 1946.

G83. Outcrop of tightly folded, thin-bedded black shaly siltstone and fine-grained dark sandstone. Immediately downstream, thinly bedded indurated shaley siltstone and fine-grained, light coloured quartz sandstone (orthoquartzite) strikes at 290^{o} (roughly at right-angles to the regional strike), and dips vertically. The outcrop is intruded by altered dolerite. The rocks of this section are probably separated from the regularly bedded rocks of the upstream section by a concealed fault.

Downstream from G83 is continuous outcrop of intensly slump folded, thin-bedded black shaley siltstone and fine-grained sandstone, with scattered small, dark limestone nodules. In places, the deformation has obscured the general orientation of the strata, but in less deformed sections the regional strike of the rocks varies from 240 (060) to 300 (110) degrees, and dips are generally steep to both the north and south with some vertical, and some horizontal (in field hinges).

Similar outcrop continues downstream for one and a half miles to G88, with a varying degree of deformation. In the lower part of the section the regional strike swings in a northerly direction (from 060 to 360^{o}), while the dip remains steep or vertical. Strike readings in this section of the river (G83 to G89) suggest a broad, regional fold; it is possible that these strike changes have resulted from large-scale fault movements and are only relatively local features. The total thickness of the slumped siltstone/sandstone succession from G83 to G88 may be as little as 3,000 feet (because of the regional strike largely follows the river).

G88 - G91 G88 is sheared, broken, closely-jointed black siltstone. One hundred yards downstream (G89) massive greenish shaley siltstone crops out, giving way to black shaley siltstone. Further downstream (to below G91) alternating massive and thin-bedded shaley and sandy siltstone crops out, slump folded in places, calcareous in places, generally indurated and often highly broken and sheared.

G92. At G92, fairly deeply weathered, massive, highly sheared and broken fine-grained black volcanic rock with broken "chert" fragments forms continuous outcrop along several hundred yards of river. These rocks have the appearance of indurated, fine-grained sediments, but in thin section they are seen to be fine basalts, with small ?silicified lenses. They mark the top of the Aibala Volcanics.

For several miles below this, to G97, outcrop includes both volcanic rocks (broken, jointed, altered, generally easily weathered dolerities and basalts) and indurated sedimentary rocks (fine-grained sandstones and siltstones with some calcareous lenses and interbeds, thin-bedded in places, with some slump deformation). At G97, dolerite is intruded into or interbedded with indurated claystone. Below this (G98 to G102) is massive altered dolerite and basalt.

Petrography

G59B Jointed, sheared, phyllitic black siltstone with small fragments of fine-grained light coloured sandstone.

Thin Section: Fragments of fine-grained argillaceous quartz sandstone (quartz greywacke) in black phyllitic siltstone, with narrow quartz veins.

The fine-grained sandstone (grainsize to 0.4 mm) comprises abundant angular to subangular quartz fragments, minor lithic fragments (chert, some fine-grained ?chloritised lava), plagioclase and rare hornblende and biotite, in an abundant (30%) recrystallized argillaceous matrix (pale green chlorite, sericite, some indeterminate isotropic material). Reaction between matrix and fragments is common, with fragments being absorbed marginally.

The phyllitic siltstone comprises scattered fragments (quartz, some lithic fragments) in a phyllitic argillaceous matrix (sericite, colourless chlorite, auhedral ?quartz, opaque material) which displays chevron folding (kink banding). Ptygmatic folding of quartz veins has taken place. Fragments of silty chloritic and organic argillites are also present. Initial fragmentation of the rock may have taken place in soft sediment state. Quartz veining cuts the rock (irregular mosaic of ragged, strained quartz grains).

G62C Hard, fine-grained, pale green epidotised volcanic rock.

Thin Section: The rock is a fine-grained lava altered almost completely to colourless chlorite, quartz and fine epidote. The original texture (pilotaxitic) is preserved in parts. The rock is cut by a calcite vein.

G62D Hard, sheared, veined, green volcanic rock.

Thin Section: The rock is a sheared, altered dolerite. In the less sheared parts it is composed of fresh, pale brown augite set in ragged chlorite, quartz, epidote, calcite and sericite. Where highly sheared the augite is absent, the rock comprising quartz, epidote dust, chlorite and some calcite. Calcite and minor quartz occurs in irregular veins and small patches.

G62E Hard, light grey, fine-grained (recrystallized) limestone, from within the altered submarine volcanics.

Thin Section: The rock is a fine-grained limestone or marble, made up of a microcrystalline mosaic of calcite with very minor silt-sized epidotised and chloritized "lithic" fragments. Bedding is poorly defined by a slight flattening of the calcite grains, and by stringers of brown-stained ?organic material.

G64 Moderately hard shaley black siltstone with quartz and calcite veining.

Thin Section: The rock is sheared sandy siltstone comprising scattered sandsized subangular to subrounded grains, up to 0.4 mm. in diameter, of quartz (slightly undulose extinction), lithic fragments (fine-grained quartzo-feldspathic rock, some chert and a few chloritized fragments), some plagioclase and one grain of myrmekite in a recrystallized, largely isotropic matrix (clay and some chlorite minerals, some fine epidote and small calcite growths, with small silt-sized fragments). Reaction between matrix and fragments has taken place; shearing in the rock is parallel to the sedimentary bedding of the matrix. Calcite and minor quartz veining cuts the rock.

G65A Hard, dark, sheared, fine-grained sandstone with quartz and calcite veining.

Thin Section: The rock is a fine-grained argillaceous sandstone or quartz greywacke, comprising angular to subangular fragments, generally less than 0.4 mm. across but up to 0.8 mm., of quartz, minor chert, argillite and ?chloritized lava, and scattered plagioclase (apparently largely oligoclase), in a fairly abundant (15 to 20%) recrystallized matrix. The quartz has undulose extinction and much appears to be vein material. Several grains of micrographic quartz-feldspar are present and one grain of brown biotite. The recrystallized matrix comprises flakey illite and some sericite and chlorite, with an indeterminate colourless mineral, some fine epidote and stringers of organic material. Reaction with fragments is common. Irregular calcite and quartz veins cut the section.

G66A Hard, dark, quartz veined, fine-grained sandstone.

Thin Section: Similar to G65A, perhaps with less matrix, slightly more abundant plagioclase, and more pronounced reaction between matrix and fragments. Several chloritised ferromagnesian grains are present and minor opaque oxide. Irregular veins of fine and coarse-grained quartz, and minor calcite cut the rock.

G66B Fairly hard shaley black siltstone with minor calcite veining.

Thin Section: Shaley siltstone, comprising angular to subangular silt-sized particles of quartz and indeterminate fine-grained lithic fragments, with minor bent chlorite, muscovite and biotite flakes, in a recrystallized argillaceous matrix with abundant stringers of dark organic material. The matrix is reacting with fragments. Sedimentary bedding is accented by recrystallized matrix and organic material; mesoscopic current bedding is defined by the latter. Calcite veining cuts the rock.

G70A Fine-grained, grey-white marble with small patches of green ?chloritic material.

Thin Section: The rock is a sheared marble with a small amount of argillaceous material and scattered quartz fragments (less than 0.3 mm. across). Calcite makes up more than 95% of the rock in the form of small elongated sheared grains, "flowing" round larger (up to 2.5 mm.) grains which often show deformed cleavage. A small amount of post-shearing recrystallization of the calcite has taken place. The argillaceous material consists of small ragged lenses of chlorite, ?illite, and sericite (some larger flakes of muscovite). Small grains of quartz with undulose extinction are scattered throughout, and several grains of epidote occur.

G70B Fine-grained pale red-green calcareous sandstone with small scattered quartz pebbles.

Thin Section: The rock is a calcareous argillaceous sandstone, comprising scattered, rounded grains up to 3½ mm. across and smaller (less than 0.4 mm.) angular fragments, set in an abundant argillaceous, calcareous matrix. The larger grains include quartz (some vein quartz) with undulose extinction, and some slate, argillaceous metasediment and one grain of crenulated quartz-sericite schist. Calcite fills fractures in the quartz grains. The smaller grains are largely quartz, with lithic fragments and some plagioclase and scattered opaque oxide. The matrix makes up 40% of the rock and comprises ?illite, sericite, some chlorite, and microcrystalline calcite (which varies to a major component and is recrystallized to large grains in several highly calcareous areas). Minor organic material is present.

G71A A light grey marble.

Thin Section: The rock is a sheared recrystallized limestone, comprising a sheared mosaic of calcite with relict strained grains up to 2 mm. across, containing scattered fragments up to 1 mm. across of quartz, chert and slate and minor small irregular lenses of argillaceous material. Alignment of elongated calcite grains defines a poor foliation.

G71B Fairly fine-grained yellow sandstone with calcite veining.

Thin Section: The rock is a quartz sandstone or grit, composed of tightly packed angular to subrounded grains, up to 1.7 mm. across, of quartz, lesser plagioclase and some orthoclase, with minor recrystallized matrix of flakey sericite and some chlorite and calcite. Reaction producing sericite has taken place at grain boundaries and interfaces and internally in fractures. Undulose extinction of quartz is common, and minor sericitisation of feldspars. The rock is cut by irregular calcite veins.

G71C Yellow-white sandy limestone.

Thin Section: The rock is a sandy limestone (marble) or calcareous grit, comprising angular to subrounded grains, up to 0.8 mm. across, of undulatory and granular quartz, with some plagioclase and minor orthoclase, set in an abundant (50%) largely recrystallized calcite cement. Grain boundaries often show marked reaction (absorption) with the calcite. The feldspar grains are masked by fine ?kaolin.

G71D Smooth weathering grey marble with thin beds of more resistant rough weathering sandy marble.

Thin Section: The Rock is a thin bedded marble and calcareous grit, comprising scattered subangular to subrounded grains of quartz (undulatory extinction, calcite in fractures) and some plagioclase (up to 1.8 mm. across), with rare fragments of slate and some lenses of argillaceous material, set in recrystallized calcite. The calcite varies from 40 - 50% by volume to more than 95% in the latter case forming bands of marble (1 cm. wide in the section).

G73A Hard grey quartz-veined pebbly sandstone.

Thin Section: The rock is a lithic sandstone, comprising tightly packed subangular to subrounded grains, generally less than 1.5 mm. across but up to 5 mm. of quartz, lithic fragments and some plagioclase, with minor argillaceous matrix. The quartz grains are crushed and show undulose extinction and plagioclase often shows bent twin lamellae. The lithic fragments are principally siltstone and argillite (both with some quartz veining), with lesser chert and some intermediate volcanic rocks. Minor secondary epidote and rare calcite occurs throughout. Irregular quartz veining cuts the rock and several thin quartz-calcite joints infillings.

G73B Hard black muddy sandstone.

Thin Section: The rock is a lithic sandstone, composed of fairly tightly packed subangular to subrounded grains, up to 0.75 mm. across of lithic fragments, quartz, some plagioclase and minor calcite, in a dark mud matrix with some calcite and a few epidote grains (the matrix is partly recrystallized to illite, sericite and ?chlorite - it is more abundant than in G73A) The lithic fragments are siltstone, shale, argillite, chert and minor fine-grained volcanic rock. Calcite is more abundant, both as clastic grains and in the matrix, in a band roughly 1 cm. wide.

G73C Hard grey pebbly sandstone.

Thin Section: The rock is a lithic sandstone, comprising fairly tightly packed angular to subrounded grains, generally less than 1 mm. across but up to 1 cm. of quartz (generally granulated with undulose extinction; a lot of vein material), lithic fragments (argillite, siltstone, chert, some fine-grained quartz schist, some ?devitrified volcanics and clastic calcite with some recrystallized fossil remains) and some plagioclase, in a recrystallized argillaceous matrix with calcite cement (matrix and cement make up 5 - 10% of the rock). The metasediment fragments are cut by thin quartz veins.

G73D Light coloured plagioclase porphyry or porphyritic lava.

Thin Section: The rock is an intermediate lava, comprising indistinct euhedral marginally zoned plagioclase phenocrysts up to 3.5 mm. long (altering internally to ?kaolin and small patches of chlorite and calcite) and a few ferromagnesian pseudomorphs in calcite, chlorite and some fine epidote, with scattered grains of iron ore, set in a groundmass of small tabular plagioclase grains and minor interstitial chlorite and granular iron ore in small patches of optically continuous feldspathic material.

G78A Dark pebbly sandstone with scattered ?brachiopod remains.

Thin Section: The rock is a pebbly limestone, composed of well rounded scattered pebbles (up to 8 mm. across) of shale, siltstone, chert and (one pebble)brown calcilutite, set in a matrix of smaller (generally less than 0.5 mm.) sub-angular to subrounded fragments of quartz, argillite, siltstone, chert, some plagioclase and intermediate lava (similar to G73C) and several epidote grains, in abundant (70%) partly recrystallized brownish calcite with minor argillaceous and brown organic material. The matrix defines a poor sedimentary foliation. Several cross-sections of ?brachiopod shells (calcite) occur in the section.

G78B Hard light grey-green silicified sandstone (quartzite) with thin quartz veins.

Thin Section: The rock is a quartz sandstone (orthoquartzite) comprising fairly tightly packed subangular grains of cloudy quartz (generally less than 1.5 mm. across), minor plagioclase and ?perthitic orthoclase grains with minor matrix of fine quartz and some plagioclase, fine-grained authigenic quartz and rare argillaceous material. Rarely calcite cement is present. The quartz is highly granular, with undulose extinction; outgrowth of grains is apparent in parts of the section and small areas of ?recrystallized quartz or irregular quartz veining. Plagioclase twins are bent and fractured. Very thin calcite joint infillings cut the section.

G78C Hard grey sandstone with quartz veining.

Thin Section: The rock is a quartz sandstone. It is similar to G78B but contains less quartz. It is composed of fairly tightly packed subangular grains (up to 1.5 mm. across) of quartz, some plagioclase, minor orthoclase, argillite, chert, and ?altered glassy volcanic, with a matrix of fine quartz and some feldspar, some authigenic quartz, and argillaceous organic material. Outgrowth of undulose granulated quartz is common, and bending and granulation of plagioclase twins. Myrmekitic and micrographic quartz-plagioclase intergrowths are present in several grains. The rock is cut by thin calcite veins (joint fillings).

G79A Reddish calcite-veined medium-grained marble.

Thin Section: The rock is a marble, containing 5 - 10% subangular grains (less than 1 mm. across) of quartz and lesser chert, with minor argillite and plagioclase, and small deformed lenses of argillaceous material (some haematitic) set in recrystallized calcite (grains up to 2 mm. across).

G79B Rough weathering red calcareous sandstone.

Thin Section: The rock is a calcareous sandstone, composed of well rounded to subrounded grains, generally less than 2 mm. across of quartz, siltstone argillite, chert, sericitised plagioclase, slate, fine-grained intermediate lava (similar to G73C) and a few calcareous microfossil (?algal) remains in an abundant (40 - 50%) recrystallized calcite cement with a few small quartz fragments and rare patches of argillite (illite or sericite).

G79C Red pebble conglomerate composed of red shaley fragments and some quartz pebbles in a white calcite cement.

Thin Section: The rock is a calcareous pebble conglomerate comprising abundant rounded to angular fragments, up to 3 mm. across, of reddish haematite-stained argillite, some with deformation indicating fragmentation and transportation while still poorly consolidated (probably reworking of penecontemporaneous sediments), and scattered rounded to subrounded fragments (from less than 1 mm. to more than 6 mm. across) of quartz, chert, indurated argillite, some intermediate lava, and a few microfossil remains, set in a coarsely crystalline calcite cement (15 - 20%) with a few lenses of organic material and argillite.

G79D Fine-grained red-green calcareous sandstone.

Thin Section: The rock is a calcareous sandstone, composed of subangular to subrounded grains, generally less than 0.5 mm. across, of quartz (undulose extinction, granulated) and some highly altered sericitised) fine-grained lithic and feldspar fragments, chert and plagioclase, in an abundant (50%) recrystallized matrix of flakey (shredded) sericite and lesser pale green chlorite with calcite cement (often recrystallized). Grain boundaries are often indistinct because of sericite growing from the margins.

G81 Calcite veined brown shaley siltstone.

Thin Section: The rock is a fine-grained lithic sandstone, comprising subangular fragments, generally less than 0.35 mm. across, of argillite, chert, some quartz are rare clastic calcite, in an abundant chloritic argillaceous matrix with irregular calcite, organic material, opaque oxide and scattered pyrite cubes. Calcite-zeolite veins cut the rock. A rough sedimentary foliation is defined by alignment of grains and streaking out of the matrix.

G83A Silicified fine-grained grey quartz-veined sandstone (quartzite) similar to G78B.

Thin Section: The rock is a fine-grained quartzite, comprising sub-angular fragments (generally less than 0.3 mm. across) of quartz, some chert and minor plagioclase, with interstitial fine-grained authigenic quartz cement, and minor argillaceous matrix with fine epidote. The quartz grains often have undulose extinction, and show outgrowth of authigenic silica. Narrow, straight quartz veins (?intersecting joint system infillings).

G83B Black shaley siltstone.

Thin Section: The rock is a shaley siltstone, with scattered angular silt-sized fragments of quartz and minor plagioclase, in a recrystallized "schistose" matrix of ?illite or sericite, chlorite and fine epidote, scattered opaque oxide and rare pyrite. Elongated patches of brown matrix (?illite) occur throughout (emphasising the "schistosity").

G83C Dark fine-grained dolerite.

Thin Section: The rock is an altered dolerite, made up of plagioclase laths up to 2 mm. long (altering extensively to sericite and kaolin) and smaller partly interstitial augite and enstatite grains (clinopyroxene altered in places to pale green amphibole and green chlorite), and interstitial green chlorite, quartz and some micrographic quartz/feldspar. Skeletal grains of ilmenite, largely altered to fine sphene, are common, and a few grains of iron ore occur. Minor secondary epidote occurs throughout.

G85 Fine-grained grey sandstone with calcite veining.

Thin Section: The rock is a fine-grained sandstone, comprising sub-angular to subrounded grains, generally less than 0.3 mm. across, of quartz, with some plagioclase, chert and argillite, and rare fine-grained intermediate volcanic rock, in a fairly abundant argillaceous matrix with fine epidote throughout, and minor calcite.

G89 Greenish-grey shaley siltstone.

Thin Section: The rock is a shaley siltstone, composed of silt-sized fragments of quartz and some plagioclase, in an abundant recrystallized matrix composed largely of sub-parallel flakes of sericite, with some ?authigenic quartz and scattered fine ?sphene.

G92 Hard, finely-jointed red, green and black, quartz-veined silicified ?siltstone or basalt; partly jasper-like in appearance.

Thin Section: The rock is an altered (silicified) basalt, which is largely completely altered with the basaltic texture preserved as small randomly orientated pseudomorphs after feldspar (generally pale green radiating aggregates of ?chalcedony, in places secondary quartz) in a groundmass of ?chalcedony, fine epidote and minor calcite (or, in places, forming an ophitic texture in opaque oxide). In several relatively unaltered portions of the section, the rock comprises laths of plagioclase and small grains of clinopyroxene and minor ?orthopyroxene. Chalcedony veins cut the rock.

G93 Hard, grey-brown fine-grained ?quartzite.

Thin Section: The rock is an indurated sandstone composed of tightly packed angular fragments up to 0.6 mm. across of quartz, abundant partly altered plagioclase (some sericitised and kaolinised orthoclase), some chert and rare epidote, with a minor recrystallized intergranular matrix of green chlorite and fine epidote. The rock is cut by thin quartz-prehnite veins.

G94 Fairly soft, highly jointed blue-green dolerite with white veining.

Thin Section: The rock is an altered dolerite composed of moderately fine-grained (1 mm.) euhedral, partly altered (chlorite, ?sericite) plagioclase, augite, scattered opaque oxide and minor interstitial chloritised mesostasis. In the highly altered areas, the plagioclase is highly kaolinised, the augite is very cloudy, green chlorite is common and zeolite may be present. The alteration may be largely diagenetic and partly due to weathering. Veins of green chlorite cut the rock, and irregular veins of quartz-prehnite.

G95A Hard, dark, fine-grained lava or indurated mudstone, highly jointed and white veined.

Thin Section: The rock is a fine-grained (?intermediate) lava, composed of randomly oriented plagioclase laths (generally less than 0.3 mm. long) interstitial feldspar, abundant green chlorite, calcite and granular opaque oxide, minor brown biotite and scattered quartz. Some aggregates of green chlorite and fine sphene may be pseudomorphs after a ferromagnesian mineral.

G95B Hard dark, jointed lava or indurated mudstone with white veining.

Thin Section: The rock is an indurated claystone, made up of very pale brown, almost isotropic ?clay minerals with rare siltsized quartz fragments. It is cut by quartz and quartz-calcite (quartz marginal) veins.

G96 Dark brown fine-grained marble.

Thin Section: The rock is a marble, comprising streaked out (schistose) calcite, partly recrystallized, with small chlorite lenses.

G97A Fine-grained, hard black lava or indurated mudstone, fairly strongly jointed.

Thin Section: The rock is an incipiently recrystallized claystone comprising illite or sericite, fine quartz and fine isotropic material. Very fine silt-sized particles of quartz are scattered throughout. Small incipient spherules of near-isotropic material have resulted from the exclusion of micaceous minerals from small areas. Thin quartz veins cut the rock.

G97B Fairly soft, jointed, gabbroic-looking dolerite.

Thin Section: The rock is a dolerite comprising euhedral plagioclase (up to 4 mm. long, generally highly kaolinised internally) intergranular cloudy augite, scattered large embayed iron oxide grains, interstitial green-brown chlorite and rare quartz.

G98 Soft, greenish-white zeolitised gabbroic-looking dolerite with zeolite veins.

Thin Section: The rock is a zeolitised sheared dolerite. Shearing is intense, and largely predates zeolitisation, the less sheared portions consisting of pseudomorphs of zeolite after plagioclase, granulated augite, opaque oxide grains and minor chlorite. The highly sheared parts of the rock comprise small augite grains in fairly fine-grained zeolite. Zeolite and zeolite-prehnite veins cut the rock (optical properties indicate that the zeolite is probably scolecite, except for variable (to high) extinction).

G99A Hard, green-white, fine-grained rock forming a small lens in hard dolerite.

Thin Section: The rock is a ?silicified altered fine-grained lava, comprising a very fine interlocking mesh of thin acicular crystals (? pseudomorphs after plagioclase) and interstitial quartz with fine ?sphene. The mineral replacing plagioclase laths is not identified but has the following characteristics:

> Moderate R.I. - (greater than quartz), moderate birefringence, Parallel extinction, No optic figure obtainable, One good cleavage (001).

Small patches of prehnite are present and thin fractures filled with quartz.

Narrow crush zones cut the rock (one of these contains green secondary chlorite).

G99B Hard black medium-grained dolerite.

Thin Section: The rock is a dolerite, comprising shattered euhedral partly kaolinised plagioclase (up to 1.5 mm. long) and abundant cloudy augite (partly altered to secondary amphibole and green chlorite) and minor ?enstatite; with scattered embayed, sieved and skeletal opaque oxide, minor interstitial green chlorite and rare quartz. The texture is sub-ophitic, in places ophitic. Thin crush zones, in which the grains are highly granulated (small fragments in rock dust), cut the rock.

G101A Moderately soft grey-green gabbroic-looking dolerite.

Thin Section: The rock is an altered dolerite, composed of highly kaolinised plagioclase (clear marginally, up to 2 mm. long) and augite, with interstitial chlorite, minor quartz and large grains of opaque oxide. The augite is partly altered to green amphibole and to green-brown chlorite (as with the interstitial chlorite, this has a high birefringence and may be a weathering product of earlier chlorite).

G101B Fairly hard, fine-grained grey-green dolerite.

Thin Section: The rock is a slightly altered basalt, made up of partly kaolinised plagioclase (less than 1 mm. long), abundant granular augite and hypersthene, opaque oxide (some ilmenite altering marginally to sphene), interstitial green chlorite and minor quartz. Zeolite veins cut the rock, and part of the section is zeolitised and chloritised.

G101C Hard, jointed black basalt and greenish-white ?silicified lava (the latter similar to G99A). In hand specimen the rock is obviously silicified. Prehnite may be present.

Thin Section: The rock is a ?silicified altered fine-grained lava, comprising a very fine interlocking mesh (?after plagioclase) of a mineral ?similar to that in G99A, and interstitial quartz. Brown isotropic patches cut by veins similar to the above undetermined mineral, and patches of chloritic material occur.

G102 Fine-grained, jointed black basalt with white zeolite veins.

Thin Section: The rock is a basalt, comprising plagioclase (some sodic, some in radiating aggregates), pyroxene (both clino and orthopyroxene, often in sheath-like aggregates), opaque oxide and interstitial brown glass. The rock has a shattered, granular appearance, though largely unsheared. It is cut by zeolite veins.

APPENDIX II

PETROGRAPHY

OWEN STANLEY METAMORPHICS:

i) Metasediments:

G11B Poorly foliated argillaceous arenite comprising subrounded to subangular fragments of argillite, chert, kaolinised plagioclase and altered fine-grained volcanics (rarely up to 4 mm. across) in a "schistose" argillaceous matrix made up of quartz, illite or sericite, chlorite and some dusty sphene, epidote and calcite, with small cubes of authigenic pyrite. The "schistosity" of the matrix is defined by streaked out trails and patches of the micaceous minerals.

G12A Moderately altered thin-bedded mudstone made up of deformed black and white layers. The light coloured layers comprise pale green chlorite, often forming trails in randonly oriented sericite, quartz, dusty sphene and some calcite. The dark layers are indeterminate in part, containing little chlorite or sphene, and abundant bands of opaque (?organic) material. Shearing and "schistosity" are more apparent in these bands, which are also roughly crenulated in part. Displacement across joints and narrow crush zones is common.

G12B Slatey argillaceous siltstone comprising "schistose" fine illite or sericite, chlorite, quartz and indeterminate colourless mineral and organic material, with scattered angular silt-sized fragments or quartz (with marginal sericite growths), and some sheared out bands and lenses of illite or sericite and chlorite. Large fragments made up of granular quartz and clear calcite, with cloudy calcite, probably represent fragmented and deformed vein material (several poorly deformed veins of similar composition are present) but may represent coarser-grained calcareous interbeds.

G21A Fine-grained red ?tuffaceous sedimentary rock, generally massive but with thin light coloured interbeds.

Thin Section: The rock is a fine-grained crystal tuff (?lava) comprising small grains of kaolinised plagioclase (some sodic) defining a poor flow foliation, and minor quartz and opaque oxide, in an abundant dark indeterminate matrix with abundant fine haematite and some chlorite. Thin beds of finer grained material (not Haematitic) lie parallel to the "foliation" and thin calcite and chlorite veins cut the rock. The rock appears to be unsheared.

G21B Poorly foliated rock made up of roughly lenticular grey calcite (50%, up to 1 cm. long) set in moderately hard, ?muddy material.

Thin Section: Irregular lenses and aggregates of calcite (largely fine-grained, some recrystallized to a coarser mosaic), set in radiating aggregates of partly cloudy zeolite, with minor brown chlorite and sphene. The rock may be a highly sheared calcareous sediment which has been subsequently zeolitised.

G24 Semischist (highly sheared quartz greywacke) comprising rolled rounded to subangular (up to 0.3 mm.) fragments of sericitised or kaolinised plagioclase and strained quartz in a fine schistose matrix of quartz, colourless indeterminate material and streaked-out bands and lenses of sericite and chlorite, with calcite and some organic material, and dark streaks of ?argillaceous material. Relict elongate grains are rolled into the schistosity.

ii) Low-grade Schists:

G23 Quartz-sericite schist comprising alternating quartz and sericite rich bands. The quartz bands are made up of an equigranular mosaic of clear unstrained quartz, generally about 0.15 mm. across in places very fine, with some plagioclase grains altering to sericite, scattered patches of sericite and minor sieved, very pale green amphibole. The sericite rich bands comprise fine randomly orientated sericite altering to muscovite plagioclase largely altered to fine sericite, minor green chlorite, quartz and rare epidote. Accessory anhedral pyrite occurs throughout.

G41 Quartz-sericite schist comprising a fine mosaic of recrystallized quartz and scattered ragged kaolinised plagioclase, with streams and patches of fine sericite, quartz, kaolined or sericitised plagioclase, brown biotite, rock dust and some chlorite. Accessory opaque oxide is scattered throughout. The rock is a product of intense shearing.

G44A Quartz-albite-muscovite-chlorite schist comprising a fine mosaic of slightly elongated quartz and clear albite, with flowing streams of fine muscovite, chlorite, minor epidote, fine opaque material and rare sphene. Recrystallization into larger grains is more advanced in some bands; the dark bands define an intense mesoscopic deformation. The rock is a product of intense shearing.

G44B Quartz-albite-epidote-actinolite schist comprising highly schistose bladed actinolite (colourless to very pale green), with abundant granular yellow epidote, quartz and albite, some calcite, chlorite and rare sphene. There is very little metamorphic differentiation. Several quartz veins and veins of carbonate and fine epidote cut the rock.

G46A Albite-amphibole-clinozoisite schist comprising small sieved porphyroblasts of clear albite up to several millimeters across, some finer albite and quartz, and abundant pale green to blue-green amphibole and epidote (some pale yellow) with lesser calcite, muscovite and chlorite and rare sphene. The tabular minerals define a good wavy schistosity.

G51A Albite-actinolite schist comprising abundant small poikiloblasts up to 1 mm. across of albite (with inclusions of clinozoisite, some amphibole and muscovite lying parallel to the foliation) in schistose actinolite with zome clinozoisite, albite and ?quartz and rare muscovite and sphene, and trails of indeterminate material. Accessory opaque oxide is scattered throughout. The rock has a good wavy schistosity.

G51B Breccia pipe within epidotic greenschist. The rock looks in hand specimen like an indurated dark gritty siltstone. It is seen in thin section to comprise angular to subrounded fragments up to 4 mm. across of metasediments (chert, argillite, slate), low grade schists (quartz, sericite, some carbonate, rare epidote and chlorite), marble, plagioclase intrusives, plagioclase and quartz, in a groundmass of fine angular quartz and feldspar and indeterminate material with some sericite and epidote.

G53 Quartz schist comprising parallel "veins" of equigranular quartz with some slightly ?kaolinised plagioclase and rare chlorite, alternating with thin streams of fine red-brown biotite, sericitised feldspar, indeterminate colourless and opaque material (?rock dust), quartz and chlorite. The rock is a product of extreme shearing (dislocation metamorphism).

iii) Higher-grade Schists:

G28 Ragged strained quartz, granular pale lemon yellow epidote (forming aggregates which look like fissure fillings in places) and thin wavy bands of felted blue-green and lavender amphibole (?glaucophane), with minor green chlorite, fine granular sphene and scattered calcite. Bands of quartz and amphibole define a strong schistose foliation.

G33A Muscovite, very pale green amphibole, clinozoisite, large porphyroblasts of untwinned albite (highly poikiloblastic, enclosing abundant grains of muscovite, amphibole and clinozoisite) and minor sphene bands and lenses of poikiloblastic almandine (up to 2 mm. across) generally associated with ragged strained quartz and coarse muscovite flakes with some calcite. The elongated ferromagnesian minerals define a good foliation, particularly large muscovite flakes scattered through the muscovite-amphibole-clinozoisite bands.

G33B Ragged quartz, porphyroblasts of albite and smaller garnets (almandine), highly deformed streams of fine cloudy sericite (some recrystallizing to muscovite), colourless amphibole, chlorite, minor brown ?biotite, and trails of opaque material with accessory pyrite. Growth of the porphyroblasts and some quartz mosaics post-dates the strong deformation.

G33C The rock is well foliated with differentiation of minerals into veins or bands; it is made up of quartz, albite, chlorite (some shredded, some coarse), muscovite, almandine, calcite and sphene. Large porphyroblasts of albite up to 8 mm. across (with trails of fine opaque material and rough bands of scattered euhedral almandine crystals up to 0.6 mm. across) occur in wide irregular bands of chlorite, muscovite, almandine and minor sphene. The individual minerals may be spread throughout or concentrated in aggregates or roughly defined bands. A band up to 6 mm. wide of quartz (mosaic of small, slightly strained grains) contains "veins" of quartz, trails of very fine garnets and a band with scattered muscovite flakes. Deformation of the foliation is apparent in the bands of bladed ferromagnesian minerals and trails of garnet. The albite and possibly the larger almandine porphyroblasts post-date deformation.

G33D Scattered large poikiloblastic grains of albite (up to 6 mm. across) enveloping fine almandine garnets, irregular lenses and bands of pale green-brown chlorite, fine anhedral quartz (in places forming rough bands with chlorite and, rarely, garnets or muscovite), interstitial calcite (particularly in a wide "band" of albite poikiloblasts with interstitial chlorite and calcite), and rare sphene and rutile. The foliation is defined by lenses and bands of chlorite and lenticular mosaics of quartz.

G33E Well foliated schist comprising albite, epidote (and ?clino-zoisite), pale green to blue-green amphibole, muscovite, almandine, quartz, rare chlorite and sphene. The rock is largely made up of fairly fine granular epidote with some muscovite and scattered garnets (up to 1.5 mm.) and minor interstitial albite and quartz. Patches occur (?irregular bands) with coarser and more abundant muscovite, albite and quartz. Garnets often have associated marginal muscovite and are in places partly altered to green chlorite. Strong deformation of the rock is apparent in the deformation of trails of minerals and of the poor to moderate schistosity.

G33F The section consists of a band of albite-almandine-amphibole, separated from a band of albite-chlorite-muscovite-amphibole (-almandine) by a $1\frac{1}{2}$ cm. band of quartz-almandine. The quartz-garnet band is made up of "veins" of ragged strained quartz and trails, some quite dense, of very fine garnets. The "veins" are coarsest marginally and in the centre of the band. Rare calcite is present (the band is pink in hand specimen; as with other rocks of the suite the pink colouration is caused by the presence of very abundant, very fine garnets, generally in "granoblastic" quartz. Marginal to this is a band comprising poikiloblastic albite and almandine, up to 1.5 mm. across, with "interstitial" pale green or colourless to pale blue-green amphibole and scattered sphene. On the other side of the quartz-garnet band, the composition is albite and minor quartz, muscovite, chlorite, pale green to pale blue-green amphibole calcite, small garnets, minor sphene and rare rutile. The foliation is defined by quartz "veins", trails of garnets and the alignment of some chlorite and muscovite.

G33G Scattered porphyroblasts up to 2 mm. across of clear albite (with small inclusions parallel to schistosity) and fewer almandine porphyroblasts (inclusions in some are arranged in a circular pattern indicating rolling during formation), abundant very pale green-brown to pale blue-green amphibole, clinozoisite, minor chorite, quartz and muscovite, and some calcite, with accessory sphene. The elongated minerals define a good schistosity. There is not metamorphic differentiation.

G33H Glaucophane schist comprising glaucophane (colourless (X) to lavender (Y) to pale violet blue (Z), pale green to blue-green amphibole (some marginal to glaucophane), abundant pale yellow epidote, albite and calcite with accessory sphene. Bladed and flakey minerals define a strong schistosity.

G34A Highly deformed schistose muscovite, actinolite (some rimming rare glaucophane), bladed epidote, clinozoisite (some zoisite), calcite, almandine (some rolled porphyroblasts), minor albite, rare chlorite, accessory sphene. It is obvious that the rock is the product of several periods of metamorphism.

G34B Abundant albite poikiloblasts up to 1½ mm. across and some quartz, patches of highly pleochroic neutral to dark-blue-green (some violet) amphibole with abundant yellow epidote and some green chlorite, muscovite and minor biotite, accessory sphene. Intense deformation of the rock is apparent in the deformation of mineral bands (and trails through the albite poikiloblasts). The growth of muscovite largely follows the deformed foliation. Two periods of metamorphism are obvious.

G38 The main part of the section comprises abundant large subhedral porphyroblasts of albite (up to 4 mm. across, with fine amphibole and sphene inclusions sometimes forming a foliation not parallel to schistosity) in a "groundmass" of colourless amphibole (? tremolite), green-brown chlorite, calcite, quartz and some sphene. In a zone at one end of the section the groundmass and albite porphyroblasts contain trails of abundant small garnets. At the other end of the section muscovite and garnet are common and the albite phenocrysts are fewer and smaller and crowded with garnets; several narrow "veins" of quartz and garnet occur and the schistosity is better developed. Thin calcite veins cut the rock.

G39A Thin "veins" of ragged highly strained quartz; bands of quartz pale green to olive green amphibole, scattered muscovite and some green chlorite and epidote and in places scattered small garnets; bands of quartz with minor amphibole, muscovite and epidote, but very abundant fine garnets; wide trails of very fine garnets (like fish eggs) with minor quartz. Alignment of elongated minerals and segregation into bands define a very good schistosity. Some flakes of muscovite cut across this. The rock is a product initially of severe dynamic metamorphism. Trails of fine garnets are pink in hand specimen, forming bands several millimeters wide. Some retrogressive metamorphism has taken place.

G39B Small lenticular porphyroblasts ("augens") of albite scattered abundantly in schistose pale yellow-green amphibole, green chlorite, muscovite, clinozoisite and abundant accessory sphene. Thin calcite veins cut the rock, which is highly schistose.

G40A "Veins" of quartz and of albite (largely mutually exclusive) and irregular lenticular porphyroblasts of albite, small porphyroblastic garnets (up to 1 mm. across) and schistose pale green to colourless amphibole, epidote, chlorite and accessory sphene and pyrite. A wide band of fine ragged quartz and fine garnets is present. Cross-cutting veins of albite branch from the metamorphically differentiated "veins". Bladed minerals flow around the garnet porphyroblasts.

G40B Ragged porphyroblasts of albite up to 2½ mm. across, irregular lenticular patches of albite and quartz, and scattered garnet porphyroblasts up to 3 mm. across (with chlorite and some sericite in fractures), and "schistose" bands of muscovite, quartz, some chlorite and minor clinozoisite.

G46C Ragged mosaic of strained quartz with some albite and fairly abundant epidote, clinozoisite and muscovite flakes, some chlorite and rare sphene. Large highly sieved almandine porphyroblasts up to 4 mm. across occur throughout, enveloping abundant quartz grains and altering in part to chlorite. The rock is poorly to moderately foliated.

G46D "Veins" of ragged strained quartz with some albite and scattered long parallel flakes of muscovite; irregular "bands" of muscovite, quartz, albite, scattered euhedral almandine, some chlorite and, in places, calcite (generally in cleavages and between flakes of the schistose muscovite). Several large porphyroblasts of albite are also present (up to 6 mm. across) with included quartz and garnet (in one, droplets of quartz define a deformed foliation). The muscovite defines a good schistosity.

G90 Large almandine garnets up to 1 cm. across (altering in fractures to green chlorite and some muscovite, some with abundant included quartz) set generally in a mass of fine granular epidote with some quartz, albite, muscovite, chlorite, a few grains of tourmaline and rare sphene. At one end of the section, large garnets are set in coarse strained ragged quartz and albite, with some foliated tabular epidote, muscovite, some chlorite a few grains of tourmaline and rare sphene. Schistosity is most pronounced where the granular epidote is not massive.

G101C Pale green to dark bluish-green amphibole, epidote, albite, lesser muscovite and some quartz, minor chlorite and rare red-brown biotite. The rock is well foliated and shows a slight tendency for light and dark minerals to segregate.

AIBALA VOLCANICS: (see Appendix I)

AUGA BEDS: (see Appendix I)

TALAMA VOLCANICS:

(i) Aroa (Ialoge) River Headwaters:

G7A Basalt. Phenocrysts of pale green augite, up to 2 mm. long, smaller fresh plagioclase laths and scattered grains of opaque oxide, in a groundmass of fine plagioclase and cryptofeldsite, with granular opaque oxide and some augite, and small patches of brown chlorite with some calcite (?vesicles). A rough flow foliation is defined by the phenocrysts.

G7B Porphyritic augite basalt. Phenocrysts of green augite up to 1 cm. across (some with small inclusions of olivine altering to iddingsite) and smaller green to colourless augite, colourless olivine and some plagioclase (with small inclusions), in a groundmass of plagioclase, interstitial feldspar, granular augite and opaque oxide.

G11A Plagioclase lava (?trachyte). Small euhedral laths and grains of feldspar (?plagioclase; with simple or no twinning, some of the larger grains zoned and internal alteration to kaolin and some calcite), in a fine dark indeterminate groundmass with some granular opaque oxide. Reaction between groundmass and phenocrysts is apparent. The rock has a pronounced trachytic flow texture.

(ii) Middle Angabunga River:

G103 Augite-biotite-hornblende andesite. Phenocrysts less than 1 mm. long of plagioclase, pale green augite, biotite (pale to dark brown, some brown and only mildly pleochroic; looks secondary), hornblende (green and sieved, some brownish and zoned) and opaque oxide, in a groundmass of fine plagioclase, interstitial feldspar and granular opaque oxide, with minor calcite. A faint flow foliation is defined by the matrix. A small zenolith is made up of fine brown biotite, augite, plagioclase and opaque oxide.

G104 Fine-grained basic tuff. Poorly sorted angular fragments, generally less than 0.5 mm. in size of plagioclase, pale green augite, lava (fine-grained plagioclase lavas with some augite and rare biotite; sometimes highly oxidised) rare hornblende and biotite and opaque oxide, in an abundant dark, indeterminate matrix. Unbedded in thin section.

G107 Augite basalt. Phenocrysts of augite up to 2 mm. across, and smaller phenocrysts of plagioclase (some partly chloritised) and euhedral pseudomorphs of pale brown chlorite with reddish brown

?haematite rims (after ?pyroxene) in a feldspathic groundmass with very fine granular augite and opaque oxide, and small chlorite filled ?vesicles.

G108 Augite basalt. Phenocrysts of augite up to 1 mm. long and some red-brown ?lamprobolite (being replaced internally by chlorite), set in smaller plagioclase laths with interstitial feldspar and minor pale brown chlorite (some replacing plagioclase).

G109 Augite - lamprobolite ?basalt. Phenocrysts of pale green augite up to 1 mm. long, fewer smaller lamprobolite phenocrysts (some altering to colourless ?chlorite internally) and small highly altered plagioclase grains (to colourless ?zeolite), with interstitial fine plagioclase, feldspar and granular opaque oxide, and numerous chlorite or zeolite lines, zeolite filled (or empty) vesicles. A small (3 mm.) basalt xenolith of similar composition (but with oxidised matrix) is present.

G116 Vesicular augite basalt. Augite phenocrysts up to 3 mm. long, and rare small grains of ?lamprobolite altering to chlorite, in a groundmass of fine untwinned plagioclase laths, interstitial feldspar, chloritised glass and scattered opaque oxide, augite and ?lamprobolite, and irregular vesicles lined with brown-green chlorite and filled with zeolite.

(iii) Middle Dilava River:

G123A Augite andesite. Abundant phenocrysts of plagioclase (well twinned, some with oscillatory zoning, up to 2 mm. long) and lesser augite and scattered small grains of opaque oxide in a very fine groundmass of plagioclase, interstitial feldspar and some fine granular opaque oxide.

G123B Augite-hornblende Andesite. Similar to G123A, but with phenocrysts of brown to brown-green hornblende, often rimmed by fine opaque oxide.

G124 Augite basalt. Phenocrysts of pale green augite up to $2\frac{1}{2}$ mm. long, and olivine (up to $1\frac{1}{2}$ mm. across) completely altered to iddingsite and chlorite, with a few grains of opaque oxide, in a groundmass of fine plagioclase, interstitial feldspar, some chlorite, granular pyroxene and opaque oxide, and patches of chlorite and scattered larger plagioclase grains altering to green-brown chlorite.

G126 Augite basalt. Phenocrysts of slightly sieved pale green augite up to 3 mm. long, and ?amphibole completely altered to pale brown ?chlorite with scattered chlorite lined vesicles in a very fine-grained groundmass of plagioclase, interstitial feldspar and minor chlorite, and some granular augite and opaque oxide.

YAIFA FORMATION:

G111 Augite Andesite (boulder in conglomerate). Phenocrysts of plagioclase up to 2½ mm. long (often zoned, fairly well twinned) pale green augite and grains of opaque oxide, in a cryptofeldsitic groundmass.

G114 Augite-lamprobolite andesite (boulder in conglomerate). Well zoned (oscillatory) phenocrysts of plagioclase up to 2½ mm. long, pale green augite and lamprobolite, in a cryptofeldsitic groundmass with scattered small grains of opaque oxide.

G120A Calcareous conglomerate. Well-rounded pebbles up to 5 mm. across of argillite, chert, basic and intermediate lavas, slate and sericite schist, with a calcite cement (containing euhedral authigenic ?zeolite).

MT. DAVIDSON VOLCANICS:

G131 Augite-olivine basalt (Angabunga River). Phenocrysts of pale green augite up to 5 mm. long, and smaller olivine (altering to adding-site marginally and in fractures), with scattered small chlorite lined and filled vesicles, in a fine-grained groundmass of plagioclase, interstitial feldspar and some chlorite and granular augite, olivine altered to iddingsite, and opaque oxide.

G132 Pyroxene basalt (Near Bakoiudu). Small phenocrysts of plagioclase with scattered augite and orthopyroxene phenocrysts, in a fine black oxidised groundmass. The rock has small irregular unfilled vesicles.

G120B Olivine-augite basalt (Dilava River). Scattered phenocrysts up to 3 mm. long of pale green augite and olivine altering marginally to iddingsite, and minor plagioclase in a very fine groundmass of generally randomly orientated acicular plagioclase ("flow" round phenocrysts), interstitial feldspar, granular opaque oxide, augite and iddingsite and some brown chloritised glass.

INTRUSIVE ROCKS:

(a) PORPHYRIES:

(i) Aroa River Headwaters:

G13 Hornblende andesite porphyry. Abundant euhedral phenocrysts of plagioclase (to 2 mm. long, often with oscillatory zoning, sometimes altered) and hornblende (to 1½ mm. long, olive green to pale green-brown) and scattered granular opaque oxide, in a clear groundmass of fine plagioclase and anhedral feldspar and quartz, with minor small calcite growths.

G14A Altered plagioclase porphyry. Plagioclase phenocrysts (to 2 mm. long, often partly altered to kaolin, with minor sericite and epidote) aggregates of chlorite and with minor epidote and sphene replacing ferromagnesian phenocrysts and scattered embayed pyrite grains in a cloudy quartzofeldspathic groundmass. The unaltered rock was probably similar to G13.

G18 Andesite porphyry. Plagioclase phenocrysts (up to 2½ mm. long, often with good oscillatory zoning, rarely altered internally) and fewer smaller green hornblende phenocrysts (altering to calcite, with some chlorite), in a quartzofeldspathic groundmass with small patches of calcite and some chlorite, and rare epidote. Accessory opaque oxide.

G19A Slightly altered andesite porphyry. Plagioclase phenocrysts (up to 2 mm. long, some zoned) and smaller pseudomorphs of hornblende in calcite with some chlorite, in a cloudy quartzofeldspathic groundmass with small patches of calcite and some chlorite. Accessory opaque oxide.

G19B Altered andesite porphyry. Phenocrysts up to 2 mm. long of plagioclase completely altered to sericite, colourless chlorite and calcite, and ?hornblende completely altered to calcite, brown chlorite and quartz, in a silicified quartzofeldspathic groundmass with abundant sericite flakes and small patches of calcite. Scattered grains of ilmenite altering to fine sphene occur, and minor pyrite.

G20 Basalt (?related to basic porphyries). Fine plagioclase laths (less than 0.2 mm. long) interstitial feldspar, chlorite, some quartz granular opaque oxide and abundant small patches of calcite.

G26C Highly altered (?andesite) porphyry. Rare phenocrysts of plagioclase (replaced almost entirely by sericite (muscovite) flakes) and scattered phenocrysts of a ferromagnesian mineral (?hornblende) completely replaced by green chlorite, epidote, minor pale green amphibole and abundant pyrite (with minor opaque oxide), in a silicified quartzofeldspathic groundmeass with abundant sericite flakes and scattered epidote grains and fine sphene.

(ii) Auga River headwaters (intrusive into the Owen Stanley Metamorphics).

G48A Altered hornblende andesite porphyry. Phenocrysts, up to 2½ mm. long, of plagioclase (partly or completely altered to aggregates of sericite flakes, with some chlorite and calcite) and pseudomorphs after hornblende (completely altered to chlorite and calcite), in a silicified quartzofeldspathic groundmass (with scattered fine sericite and calcite aggregates) which contains scattered pyrite and opaque oxide.

G59A Altered ?andesite porphyry. Granulated looking rock comprising phenocrysts of plagioclase (often cloudy, altering to sericite (muscovite) and calcite) and a ferromagnesian mineral (?hornblende, completely altered to muscovite, chlorite, calcite and some sphene), with some quartz ?phenocrysts, in a groundmass of ragged quartz and scattered muscovite, chlorite and calcite. Quartz veins have apparently been injected into the rock. Large grains of pyrite (up to 3 mm.) are scattered throughout.

(b) PLUTONIC ROCKS:

(i) Aroa River Headwaters:

G8 ?Augite diorite porphyry. Phenocrysts of euhedral plagioclase (some zoned, with a marginal or internal zone of lateration) up to 1 mm. long, pale green augite, some pale to dark brown biotite, and rare light green amphibole, in a fairly coarse groundmass of plagioclase, quartz, augite, biotite, opaque oxide and some brown chlorite. The porphyry is probably related to the plutonic suite of rocks, rather than the andesite porphyries.

G14B Altered diorite with a granophyre vein.

Altered diorite: Grainsize up to 3½ mm. comprising sodic andesine (altering to calcite, sericite and some epidote) a ferromagnesian mineral (completely altered to chlorite (some pennine), calcite, fine ?sphene epidote and some pale to red-brown biotite), and interstitial quartz (7-10%) with scattered granular epidote and some pyrite and opaque oxide.

Vein: The marginal 6 mm. to 1 cm. of the vein is made up of small (less than 0.25 mm.) anhedral quartz grains (50%) set in larger cloudy orthoclase (kaolinised, minor calcite) with minor cloudy plagioclase. The rest of the vein is granophyric in texture and composition, comprising micrographic quartz and cloudy orthoclase. Irregular quartz veining cuts the granophyre, and has associated with it altered ferromagnesian minerals (altering to chlorite, epidote, ?sphene and minor calcite) and pyrite.

G26A Diorite. Medium-grained (up to 3 mm.) diorite comprising andesine (quite fractured, with sericite in fractures) and 15% green-brown hornblende with minor dark to pale brown biotite (slight alteration to chlorite). Pyrite and opaque oxide are accessories. A crush zone cuts the rock, and is intruded by quartz with minor epidote.

G26B Diorite. The rock is fairly fine-grained (up to 2 mm.) and is made up of plagioclase (in the calcic andesine to sodic labradiorite range, often fractured and altering to sericite), hornblende (15% pale green to pale brown, possibly replacing earlier augite, often cloudy looking and altering to chlorite, calcite, epidote and rare brown biotite) and interstitial cloudy feldspar and quartz. Accessory opaque oxide.

G26D Granodiorite. Medium-grained (up to 2½ mm.) rock comprising euhedral plagioclase (calcic andesine, 60%) interstitial orthoclase and quartz (25%) and euhedral pale green-brown hornblende (15%, some altering to chlorite and epidote). Accessory pyrite and rare opaque oxide.

G26E -- Porphyritic biotite-hornblende granodiorite with a biotite granite vein.

Granodiorite: "Phenocrysts" of oscillatory zoned plagioclase (up to 2 mm. long) in a "groundmass" of fine quartz (small grains and also "platey") and minor orthoclase, with 15% biotite (pale green to dark brown up to 0.5 mm. long) and hornblende (almost colourless, granular) and accessory opaque oxide.

Granite: Equigranular anhedral (1 to 2 mm. grainsize) quartz and cloudy orthoclase, with minor plagioclase and biotite (pale to dark brown altering to green chlorite with concomitant sphene) and accessory opaque oxide.

(ii) Dilava River Headwaters:

G29A Biotite - hornblende (augite) diorite (monzonite). Plagioclase lesser orthoclase and minor quartz, with large crystals of biotite and hornblende (replacing augite), accessory opaque oxide and rare pyrite. Plagioclase forms euhedral grains up to 1 mm. long; orthoclase is interstitial, forming anhedral platey grains. Cloudy looking grains, up to 3 mm. across, of pale green amphibole (?hornblende) replacing fractured augite (with the formation of some granular opaque oxide) make up 15% of the rock. Biotite makes up 10% forming large "ophitic" grains up to 6 mm. long (abundant inclusions cause isolated patches of biotite in optical continuity) which are pale to dark brown, with minor marginal alteration to green chlorite (and minor sphene).

G29B Biotite-hornblende (augite) adamellite. The rock is fairly fine-grained (up to 1½ mm.) and is made up of plagioclase, cloudy orthoclase, quartz and 20% ferromagnesian minerals are brown biotite, pale green amphibole (with opaque oxide) replacing fractured augite, and minor green hornblende (?primary). Several granitic patches (quartzorthoclase) occur in the section.

(iii) Auga River Headwaters:

(a) Schists of the Owen Stanley Metamorphics:

48B Fine-grained hornblende diorite. Zoned euhedral plagioclase (75%, up to 1½ mm. long, generally fresh but some partly kaolinised internally) and pale green to pale brown subhedral to anhedral hornblende, with minor interstitial quartz, rare brown biotite, sphene, chlorite and epidote, and accessory pyrite.

G60A Augite-biotite (monzonite) adamellite. Plagioclase 45% (oligoclase to andesine, euhedral, up to 3 mm. long, some zoned) slightly kaolinised orthoclase 25%, quartz 15% (with common quartz-orthoclase intergrowths), ferromagnesian minerals 15% (comprising augite, some replaced internally by pale green secondary amphibole; pale straw brown to red brown biotite; and pale green and green-brown secondary amphibole) and accessory opaque oxide.

G60B Fine-grained hornblende-biotite-augite-diorite with large augite xenocrysts. The diorite comprises 70% plagioclase (up to 1 mm. long, altering to sericite flakes), 15% interstitial slightly cloudy orthoclase and quartz, 15% very pale green and brown amphibole, pale to dark brown biotite, augite and accessory opaque oxide, interstitial calcite and apatite. The exotic augite phenocrysts (xenocrysts) are quite numerous and are up to 5 mm. long. They are zoned, with thin marginal zones being replaced by fine calcite (?and some fine secondary amphibole), and rims of very pale green secondary amphibole and some calcite. Scattered small grains of opaque oxide are present and minor pyrite. Small grains of plagioclase are rarely included.

(b) Metavolcanics of the Owen Stanley Metamorphics:

G62A Granodiorite porphyry. Indistinct phenocrysts of euhedral plagioclase (poorly twinned and zoned) rounded quartz, some ?orthoclase and green chlorite (with some calcite) replacing ?hornblende, in a quartzofeldspathic groundmass with scattered calcite and chlorite, and accessory opaque oxide. This porphyry is probably related to the plutonic suite of rocks, rather than the andesite porphyries.

G62B Altered gabbro. Grains of augite up to 5 mm. long set in larger grains of completely altered plagioclase (to sericite, kaolir , some zeolite with accessory ?illmenite altering to lucoxene. Irregular veins and patches of pennine chlorite cut the rock.

G63 Gabbro breccia. In the unbrecciated part, the gabbro consists of euhedral to subhedral plagioclase laths (up to 3 mm. long, many completely altered to zeolite or sericite) set in large plates of cloudy augite (up to 8 mm. across). The brecciated portion comprises large fragments of the above composition, and abundant fragments (generally less than 1 mm. across) of cloudy augite and partly zeolitised or sericitised plagioclase in an abundant fine dark indeterminate "matrix": this portion of the rock has the appearance of a volcanic greywacke. Zeolite and pennine chlorite veins cut the rock.

(c) 'e' Stage rocks of the Auga Beds:

G69 Fine-grained granodiorite/adamellite. Equigranular, with grain size up to 1 mm. comprising 50% quartz, 45% highly kaolinised feldspar (plagioclase much in excess of orthoclase) and 5% apple green to pale green chlorite, accessory epidote. Thin calcite filled joints cut the rock.

APPENDIX III

EXTRACT FROM MICROPALAIONTOLOGICAL REPORT BY D.J. BELFORD

Samples P1522 to 1526 collected from the "Mafulu Group" of the Auga Beds, Auga River.

P1522 Foraminifera, algae.

Lepidocyclina spp. (*Eulepidina*; *Nephrolepidina*)

Spiroclypeus sp. (rare)

Gypsina vesicularis (Parker & Jones)

Miogypsinoides? sp.

Indeterminable smaller foraminifera

Discocyclina spp.)

Nummulites sp.) derived.

Halkyardia sp.)

P1523. Foraminifera, bryozoa.

Lepidocyclina spp. (possibly including *Eulepidina*)

Spiroclypeus sp.

Heterostegina sp.

rare planktonic foraminifera (Globigerinidae)

Discocyclina sp.)

Nummulites sp.)

Fasciolites sp. (one specimen))

P1524. No foraminifera observed; abundant bryozoal? fragments.

P1525. No foraminifera observed; algae, bryozoa?

P15 26. No foraminifera observed; abundant bryozoa, some uolluscan fragments.

An age can be given only for samples P1522 and P1523: these are regarded as lower 'e' stage (?Lower Miocene) in age, with derived Eocene specimens. The "Mafulu Group" has been considered to be Eocene in age (de Verteuil & Rickwood, 1946; Glaessner, 1946; Australasian Petroleum Company, 1961), on the evidence of Nummulites in one sample. In the present samples derived Eocene specimens are more numerous than those taken to indicate a lower 'e' stage age, and it seems possible that samples containing only Eocene specimens could be collected. It is not possible to give an age to samples P1224 to P1226; a similar fauna was recorded by Glaessner (1946) in samples collected from the "Mafulu Group".

P1527 is float of the Auga Beds, collected in the Dilava River.

P1527 Foraminifera; algae.

Lepidocyclina (Eulepidina) sp.

indeterminable smaller foraminifera.

P1527 is also lower 'e' stage (?Lower Miocene) in age.

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Australasian Petroleum Company, 1961 - Geological Results of petroleum exploration in Western Papua. J. Geol. Soc. Aust., 8 (1), 1 - 133.

de Verteuil, J.P. & Rickwood, F.K., 1946 - Mafulu-Onoge Reconnaissance Australasian Petroleum Company Rept. NB (unpubl).

Glaessner, M.F., 1946 - Report on the palaeontological examination of rock samples, Mafulu-Onoge Reconnaissance. Appendix III in Australasian Petroleum Company Rept. N.E. (unpubl).

PLATE I

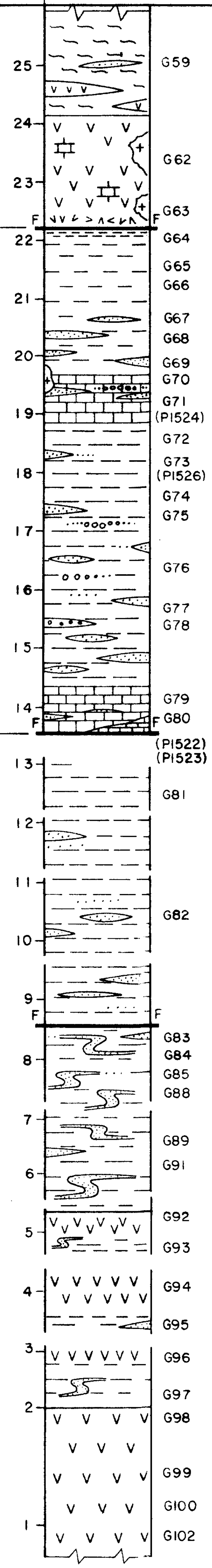
To accompany Record 1969/126

C55/A2/2

PLATE 2

LITHOLOGY — AUGA RIVER SECTOR

NAME	AGE	THICKNESS x 1000



Oven Stanley Metamorphics — **?LOWER CRETACEOUS OR OLDER MESOZOIC**

Crenulated black phyllitic siltstone with small rafted fragments of fine-grained sandstone. Interbedded indurated fine-grained sandstone.

Interbedded metavolcanics.

Hard, green, epidotised, hornfelsic-looking submarine lavas with small deformed lenses of recrystallized grey limestone. Small bodies of andesite porphyry and gabbro.

Auga Beds — **LOWER MIOCENE 'e' stage**

Highly sheared phyllitic black siltstone with sheared-out lenses of fine-grained sandstone.

Phyllitic black siltstone. 20′ bed of argillaceous sandstone.

Thin-bedded shaley black siltstone and fine-grained dark argillaceous sandstone, with sandstone interbeds up to 30′ thick. Very regular bedding.

Fine-grained granodiorite/adamellite.

Grey sandy marble with sandstone, pebbly calcareous sandstone.

Black shaley siltstone, often with fine quartz pebbles, black sandy shale, black pebbly sandstone and beds up to 15′ thick of highly indurated pebble conglomerate. Sandstones grade into orthoquartzites. Clastic material includes strained quartz, plagioclase, chert, argillite, slate and rare intermediate volcanics.

Characteristically weathering thin-bedded and massive red marble (gritty)
Calcareous sandstone (grit) and calcareous pebble conglomerate.
At the base is dense grey limestone (P1522, 1523) yielding a lower 'e' stage (?Lower Miocene) age.

Auga Beds — **UPPER CRETACEOUS (SENONIAN)**

Black shale, some 20′ interbeds of fine-grained dark sandstone.

Black shaley siltstone with fine-grained sandstone, generally thin-bedded.

Intensely slump deformed thin-bedded black shaley siltstone and fine-grained sandstone, with scattered black calcareous nodules and lenses.

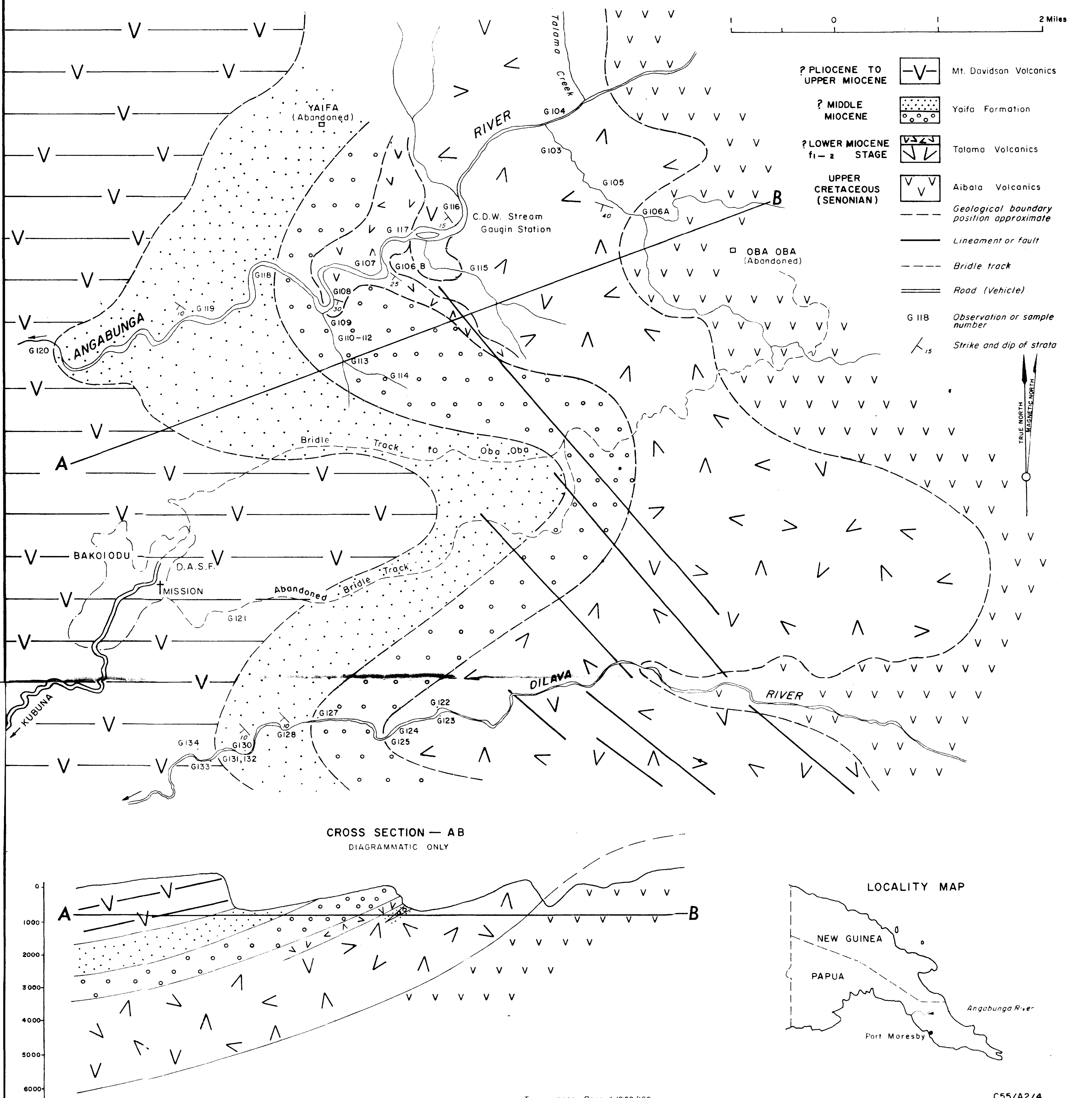
Aibala Volcanics — **UPPER CRETACEOUS**

Soft-weathering, highly sheared, fine-grained volcanics.

Massive soft-weathering, strongly jointed, altered submarine doleritic- and basaltic-looking lavas.

PLATE 3

GEOLOGY OF THE MIDDLE ANGABUNGA RIVER AREA



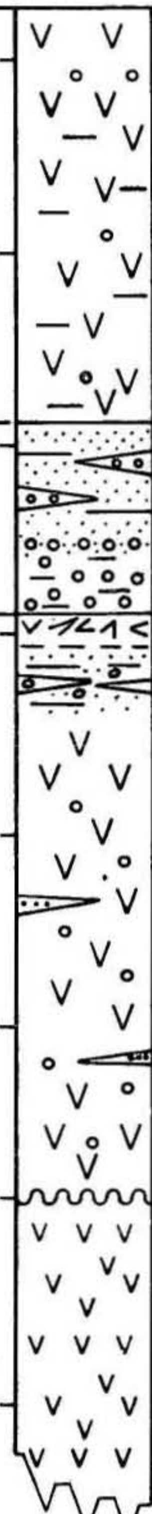
To accompany Record 1969/126

C55/A2/4

PLATE 4

GEOLOGICAL SECTION
MIDDLE ANGABUNGA RIVER AREA

AGE	NAME	FEET	LITHOLOGY
PLIOCENE / UPPER MIOCENE	Mt. Davidson Volcanics	6000 – 5000	Thickly bedded basic pyroclastics and lava flow
? MIDDLE MIOCENE	Yaifa Formation	4000	Tuffaceous sandstones, siltstones, mudstones, claystones, lenses of conglomerate. Boulder Conglomerate
? LOWER MIOCENE f1 — 2 STAGE	Talama Volcanics	3000 – 2000 – 1000	Lava flows, breccias, tuffs. Tuffaceous sandstones and conglomerate. Basic and minor intermidiate agglomerates, lavas and tuffs
		0	Unconformity
UPPER CRETACEOUS (SENONIAN)	Aibala Volcanics	1000	Highly jointed, massive basic submarine lavas



To accompany Record 1969/126

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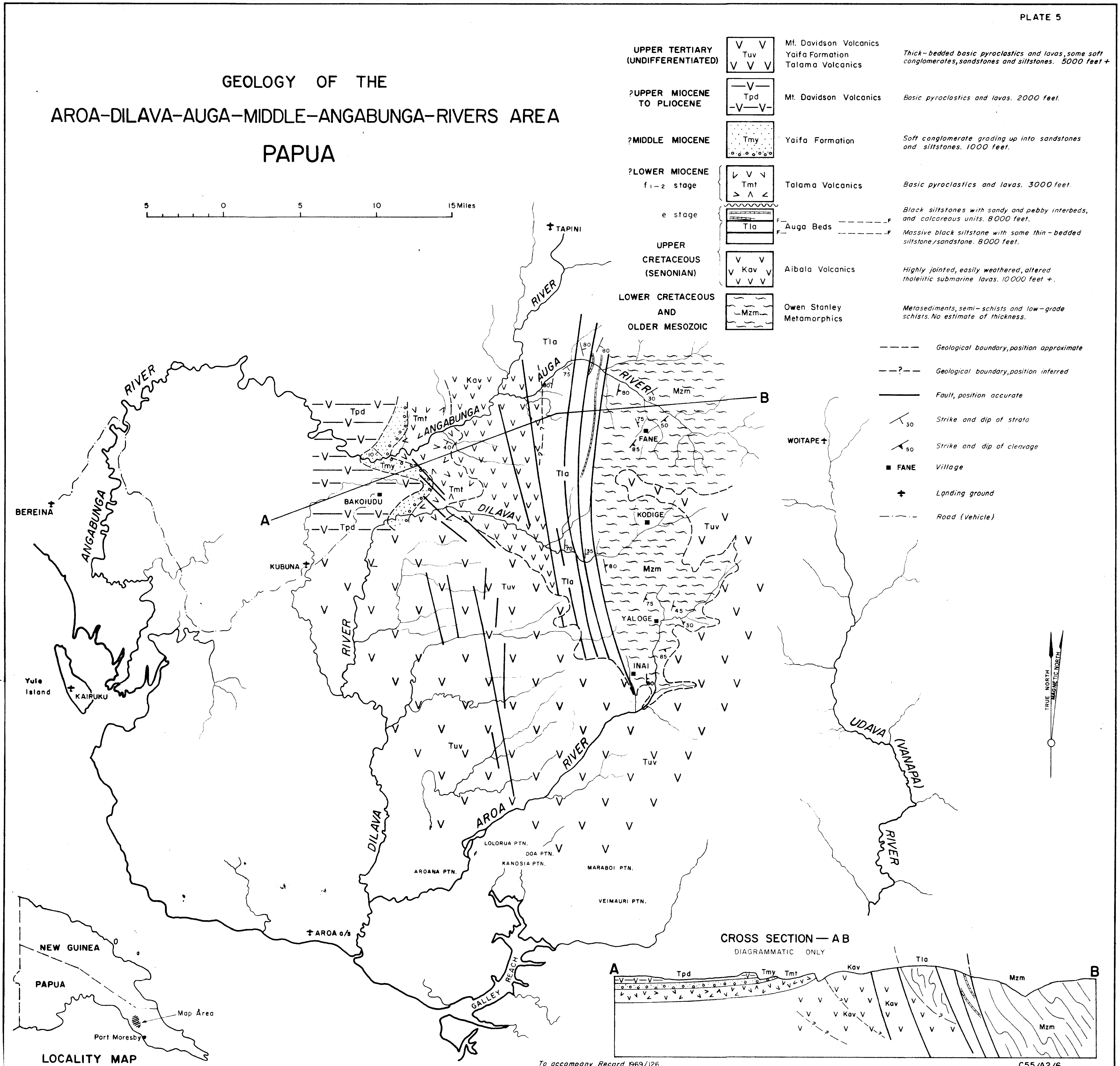
PLATE 5
GEOLOGY OF THE
AROA-DILAVA-AUGA-MIDDLE-ANGABUNGA-RIVERS AREA
PAPUA
5 0 5 10 15 Miles
UPPER TERTIARY (UNDIFFERENTIATED)
Tuv
Mt. Davidson Volcanics
Yaifa Formation
Talama Volcanics
Thick-bedded basic pyroclastics and lavas, some soft conglomerates, sandstones and siltstones. 5000 feet +
?UPPER MIOCENE TO PLIOCENE
Tpd
Mt. Davidson Volcanics
Basic pyroclastics and lavas. 2000 feet.
?MIDDLE MIOCENE
Tmy
Yaifa Formation
Soft conglomerate grading up into sandstones and siltstones. 1000 feet.
?LOWER MIOCENE
f 1-2 stage
Tmt
Talama Volcanics
Basic pyroclastics and lavas. 3000 feet.
e stage
Tla
Auga Beds
Black siltstones with sandy and pebby interbeds, and calcareous units. 8000 feet.
Massive black siltstone with some thin-bedded siltstone/sandstone. 8000 feet.
UPPER CRETACEOUS (SENONIAN)
Kav
Aibala Volcanics
Highly jointed, easily weathered, altered tholeiitic submarine lavas. 10 000 feet +.
LOWER CRETACEOUS AND OLDER MESOZOIC
Mzm
Owen Stanley Metamorphics
Metasediments, semi-schists and low-grade schists. No estimate of thickness.
Geological boundary, position approximate
Geological boundary, position inferred
Fault, position accurate
Strike and dip of strata
Strike and dip of cleavage
FANE Village
Landing ground
Road (Vehicle)
TAPINI
RIVER
AUGA
RIVER
LANGABUNGA
DILAVA
ANGABUNGA
RIVER
BEREINA
BAKOIUDU
KUBUNA
FANE
KODIGE
YALOGE
INAI
WOITAPE
Yule Island
KAIRUKU
RIVER
AROA
RIVER
DILAVA
UDAVA (VANAPA) RIVER
LOLORUA PTN.
DOA PTN.
KANOSIA PTN.
AROANA PTN.
MARABOI PTN.
VEIMAURI PTN.
AROA a/s
GALLEY REACH
TRUE NORTH
MAGNETIC NORTH
A
B
NEW GUINEA
PAPUA
Map Area
Port Moresby
LOCALITY MAP
CROSS SECTION — AB
DIAGRAMMATIC ONLY
To accompany Record 1969/126
C55/A2/6