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THE PETROGRAPHY OF SPECIMENS COLLECTED IN THE MILNE BAY AREA T.P.N.G.

by

W.R. Morgan

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INTRODUCTION

The specimens described in this report were collected by Mr. J.E. Thompson, Resident Geologist, Port Moresby, T.P.N.G., when he examined the Milne Bay area, T.P.N.G. in 1959. The specimens comprise basalts, dolerites, two ultramafic rocks, a pyroclastic, some sedimentary rocks, and a metamorphic rock.

The descriptions of detailed petrography are followed by a short discussion on petrological aspects of the rocks.

LOCALITIES

All the specimens were collected in the Milne Bay District of Papua. The localities are given as latitudes and longitudes.

Specimen	latitude	longitude	Specimen	latitude	longitude
P.336	S10°34'36"	E150°39'54"	P.368	S10°19'36"	E150°36'54"
P.337	S10°42'0"	E150°25'30"	P.369	S10°16'0"	E151°2'0"
P.345	S10°34'42"	E150°8'6"	P.372	S10°24'18"	E150°18'30"
P.348	S10°34'36"	E150°39'0"	P.373	S10°24'42"	E150°18'24"
P.349	S10°28'30"	E150°37'48"	P.374	S10°15'0"	E150°18'32"
P.350	S10°28'54"	E150°33'6"	P.379	S10°25'0"	E150°26'30"
P.351	S10°26'0"	E150°28'30"	P.381	S10°32'18"	E150°25'30"
P.352	S10°26'0"	E150°30'6"	P.384	S10°31'54"	E150°23'30"
P.353	S10°13'24"	E150°52'0"	P.386	S10°36'0"	E150°24'18"
P.354	S10°13'42"	E150°52'24"	P.390	S10°6'6"	E151°7'0"
P.355	S10°24'48"	E150°25'30"	P.392	S10°36'54"	E151°13'0"
P.358	S10°25'30"	E150°25'30"	P.393	S10°38'0"	E151°2'48"
P.359	S10°25'18"	E150°25'0"	P.394	S10°37'18"	E151°18'24"
P.360	S10°15'54"	E150°26'0"	P.395	S10°39'6"	E151°3'36"
P.364	S10°13'2"	E150°26'6"			
P.366	S10°18'0"	E150°36'36"			

PETROGRAPHY

I. Basalts

P.337, slide number 4931

((?) olivine) dolerite

The hand specimen is fine-grained, hypidiomorphic and sparsely porphyritic, and contains lean tabular laths of felspar apparently in ophitic relationship to pyroxene. Small amounts of a micaceous mineral may be seen. Mr. Thompson states that the outcrop from which this specimen was obtained showed pillow-structures, and the rock is hence considered to be extrusive.

The thin section shows the specimen to be fine-grained and sparsely porphyritic, the groundmass mainly being formed of an interlacing network of lean plagioclase laths, whose average length and breadth are 0.4 mm. and 0.05 mm. respectively, and which are ophitically intergrown with anhedral augite grains that measure, roughly, 0.5 mm. The sparse phenocrysts are formed of tabular crystals of plagioclase.

The phenocryst and groundmass plagioclase is bytownite (An75-80) and is sharply zoned at crystal edges to andesine (An40-45). The crystals show only slight alteration to kaolin and sericite, but they commonly have a reticulate meshwork of thin cracks, usually, but not always, coinciding with their cleavages. Along these cracks, a micaceous mineral, pleochroic in brown, may be seen. Augite crystals are colourless although their margins are, in places, a very pale lavender-greenish tint. Probable bowlingite forms anhedral to prismatic grains which appear to ophitically enclose plagioclase, and which, in some places, are partly enclosed by augite. Rarely, serpentine-like veins of (?)xylotile cut across bowlingite (see fig.1). These two minerals are possibly pseudomorphing olivine. Bowlingite also occurs interstitially, commonly highly charged with fine black iron ore. Black iron ore also forms octahedral to irregular grains.

A visual estimate of the percentages of minerals present is: plagioclase:40, augite:38, bowlingite and xylotile:20, black iron ore:2.

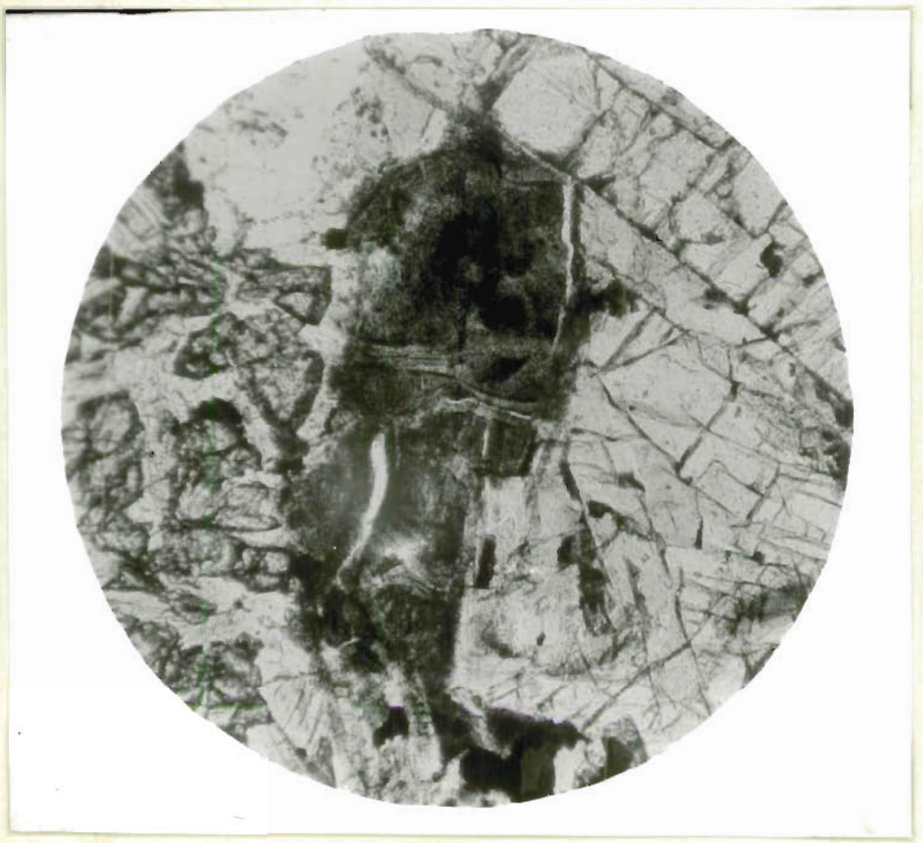

Fig.1. Specimen P.337. ((?) olivine pseudomorphed by bowlingite and a vein of xylotile. Ordinary light, X80.

P.345, slide number 4932

Zeolitized basalt

In hand specimen the basalt is fine-grained, and appears to consist of tabular felspar and pyroxene. Rare amygdales are present.

In thin section, the specimen is seen to be aphyric and fine-grained, with an average grain-size of 0.07 mm. It is hypidiomorphic-granular, and rare amygdales are present. The basalt contains zeolite, augite, biotite and black iron ore. The zeolites appear to pseudomorph feldspar: (?)stilbite forms tabular, twinned crystals which are partly enclosed by (?)gmelinite. Augite occurs as colourless prismatic, commonly acicular crystals that are colourless. Subhedral flakes of pale brown biotite lie interstitially to augite. Octahedral crystals of black iron ore are present. Rare vesicles are filled by carbonate, and by a chloritic mineral.

An estimation of the percentages of minerals present is: zeolite:50, augite:35, biotite:10, black iron ore:5.

P.348, slide number 4933

Amygdaloidal albite basalt, or spilite

The hand specimen is porphyritic, the phenocrysts being enclosed by a fine-grained amygdaloidal groundmass. The amygdales appear to contain chloritic and zeolitic material. Some flecks of pyrites are present.

In thin section, the rock is seen to be fine-grained, and seriate-porphyritic, the small phenocrysts of albite and augite being enclosed in a hypidiomorphic inequigranular, interstitial amygdaloidal groundmass. Albite phenocrysts form lean, lath-like crystals that measure up to 0.5 mm. long by 0.1 mm. wide. Their margins tend to be irregular, partly enclosing groundmass grains. Albite is partly replaced by (?)quartz, and, in places, zeolites. It shows slight alteration to sericite and kaolin, and contains small inclusions of chlorite. Augite forms colourless euhedral prismatic crystals that rarely show alteration to chlorite.

In the groundmass, partly silicified albite forms tabular to anhedral crystals whose average size is 0.05 mm. Augite occurs as granular-prismatic crystals 0.02 mm. in size. Green chlorite is interstial, and black iron ore forms granular-octahedral crystals.

The amygdales range from small interstitial masses to roughly equidimensional bodies 1.25 mm. in size. They mostly contain green chlorite, but a few contain quartz and nearly isotropic analcite.

A visual estimate of the percentages of minerals present is: albite and (?)quartz:50, augite:30, chlorite:15, black iron ore:5.

P.350, slide number 4935

((?) Olivine) basalt

In hand specimen, the basalt is sparsely porphyritic, and fine-grained.

The thin section shows that the basalt has a fine-grained, hypidiomorphic-inequigranular, and ophitic groundmass.

The rare phenocrysts are formed of slightly sericitized tabular crystals of plagioclase that are zoned from bytownite (An_{78}) to labradorite (An_{56}), and which measure up to 1 mm. in length.

In the groundmass, plagioclase (zoned from An75 to An_{43}) forms randomly oriented laths that range from 0.1 mm. to phenocryst size. Augite forms grains that ophitically enclose plagioclase, and also occurs as granules; it is colourless, but commonly has a thin pale green marginal zone. $2V_z$ of the colourless core is about 55°, and it tends to be smaller in the coloured zone. Bowlingite forms masses of randomly oriented flakes which possibly pseudomorph euhedral, prismatic olivine: it is cut by thin serpentine-like veins of xylotile. Bowlingite also occurs interstitially. Black iron ore is present as anhedral grains. Very small amounts of interstitial zeolite may be seen.

A visual estimate of the percentages of minerals present is: plagioclase:45, augite:25, interstitial bowlingite: 20, pseudomorphed olivine:4, black iron ore:5, and zeolite: less than 1.

P.353. Slide number 4938

Porphyritic and sub-variolitic basalt

In hand specimen the basalt is very fine-grained and sparsely porphyritic, and is cut by thin veins containing chlorite and zeolite.

In thin section, the specimen is fine-grained and sparsely porphyritic; the groundmass is sub-variolitic and sub-ophitic. In the groundmass, turbid labradorite forms variolitic bundles of lean laths; the laths range from 0.08 mm. to 0.5 mm. in length. Labradorite is partly altered to sericite and chlorite, and, in places, to (?)zeolite. Colourless augite forms granular crystals and sub-radial acicular growths, and here and there sub-ophitically encloses labradorite laths. Olive-green chlorite is interstitial, and black iron ore is octahedral to granular. Rarely, interstitial (?)zeolite may be seen: it has negative refringence, and $2V_z$ is small.

The rare phenocrysts, measuring up to 1.75 mm. in length, are formed of labradorite: a few small clustered porphyritic crystals of augite, 0.25 mm. in size, were noted.

An estimation of the percentages of minerals present is: labradorite:45, augite:35, chlorite:15, black iron ore:5, and zeolite:1.

P.364. Slide number 4944

Dolerite

In hand specimen, the dolerite is aphyric and fine-to-medium-grained, and contains pyroxene, tabular felspar, and a micaceous mineral.

The thin section shows the rock to be fine- to medium-grained, and its texture is hypidiomorphic-inequigranular and sub-ophitic. Plagioclase forms very slightly saussuritized laths that range from 0.3 mm. to 1.4 mm. in length. It is zoned from bytownite (An_{73}) at its core to andesine (An_{44}) at the crystal edges. Zoned augite occurs as colourless prismatic to anhedral grains with pale lavender margins. Augite tends to ophitically enclose plagioclase. Anhedral flakes of bowlingite occur interstitially; the mineral is faintly pleochroic in brown. Some of it may represent altered basaltic glass. Black iron ore forms octahedral to anhedral, sometimes skeletal crystals, commonly associated with bowlingite. Accessory fine acicular prisms of apatite is enclosed in plagioclase.

A visual estimate of the percentages of minerals present is:- plagioclase:40, augite:35, bowlingite:14, black iron ore:7.

P.368. Slide number 4946

Variolitic and porphyritic ((?)olivine) basalt

In hand specimen the basalt is fine-grained and porphyritic. Phenocrysts of prismatic pyroxene and lath-like felspar may be seen.

In thin section the basalt is hypidiomorphic, ophitic and seri[illegible] glomeroporphyritic; the groundmass is variolitic The plagioclase phenocrysts are zoned from bytownite (An_{75}) to andesine (An_{48}), and the groundmass plagioclase from labradorite (An_{60}) to calcic andesine. Both phenocryst and groundmass plagioclase form exceedingly lean laths that are commonly radially disposed, and which range in length between 0.04 mm. in the groundmass and 1.2 mm. as phenocrysts. Plagioclase is slightly sericitized in places. Augite phenocrysts are commonly clustered, and form colourless subhedral prismatic crystals that range up to 1.2 mm. in size, and which are often in ophitic relationship to plagioclase phenocrysts. In the groundmass, augite occurs as bundles of small acicular crystals arranged sub-radially, which, in places, have coalesced to form granules having wavy extinction. Groundmass augite ophitically encloses groundmass plagioclase. Hydrated iron oxide, intergrown with minor amounts of green chlorite, form large clots, some of which are tabular in shape; others form rather irregular grains that "ophitically" enclose laths of groundmass felspar: this hydrated iron oxide may represent pseudomorphed olivine crystals. Fine chlorite also occurs interstially, and black iron ore forms fine-grained granular to octahedral crystals. Small clots of hydrated iron oxide are present. The rock is cut by thin veins containing analcite and rare chlorite.

A visual estimate of the percentages of minerals present is:- plagioclase:45, augite:45, chlorite:5, hydrated iron oxide and black iron ore:5.

P.369. Slide number 4947

Porphyritic basalt

The hand specimen is fine-grained and porphyritic: small phenocrysts of pyroxene are seen to be enclosed in a fine groundmass composed of plagioclase and pyroxene.

In thin section, the sparse phenocrysts, which have an average size of 0.5 mm., are seen to be enclosed in a fine-grained hypidiomorphic and sub-ophitic groundmass.

Augite phenocrysts are colourless or faintly green, and subhedral, their margins sub-ophitically enclosing groundmass plagioclase. In places, augite phenocrysts are clustered, and are ophitically intergrown with plagioclase phenocrysts. Bytownite phenocrysts (An_{80}) are more rare, and form tabular, sometimes strongly sericitized crystals.

In the groundmass, lean laths of slightly sericitized plagioclase, whose average size is 0.3 mm. long by 0.02 mm. broad, form an interlacing network. The plagioclase is zoned from bytownite (An_{75}) to labradorite (An_{56}). Colourless to very pale green augite occurs as granular crystals (0.03 mm. to 0.2 mm. in size), and more rarely as

small fibrous bundles of acicular crystals. The granular crystals sub-ophitically enclose plagioclase. Granular to octahedral black iron ore is present, and finely intergrown flakes of green chlorite are interstitial. Fine accessory acicular crystals of apatite are enclosed in labradorite.

A visual estimate of the percentages of minerals present is:- plagioclase:40, augite:40, chlorite:7, black iron ore:3.

P.381. Slide number 4953

Dolerite

The hand specimen is speckled grey and medium-grained, and is aphyric. It contains tabular felspar and granular pyroxene.

In thin section, the basalt is medium-grained and has a hypidiomorphic-inequigranular, rarely sub-ophitic texture. Plagioclase occurs as fresh intersecting laths, measuring 0.75 mm. long by 0.15 mm. broad. The plagioclase is zoned from bytownite (An_{73}) in crystal cores to andesine (An_{38}) at their edges. Prismatic to granular crystals of augite, whose sizes range from 0.1 mm. to 0.75 mm., are mostly colourless, but commonly have faint lavender-coloured margins: rarely, plagioclase is sub-ophitically enclosed by augite. Black iron ore is octahedral to granular, and bowlingite forms fine green flakes that occur interstitially, or in very thin veins in cracks cutting plagioclase and augite.

A visual estimate of the percentages of minerals present is:- plagioclase:50, augite:40, black iron ore:5, and chlorite:5.

P.386. Slide number 4955.

Porphyritic basalt

The basalt, in hand specimen, is dark grey and porphyritic: the phenocrysts consist of plagioclase, and are enclosed in a fine-grained groundmass.

Thin section shows the rock to be hypidiomorphic, intergranular, and seriate porphyritic; the grain sizes range from 0.05 mm. in the groundmass to phenocrysts of 1.75 mm. length.

Plagioclase phenocrysts are zoned from bytownite (An_{85}) at their cores to labradorite (An_{57}) at their margins. The groundmass plagioclase has labradorite (An_{69}) cores zoned to andesine (An_{46}) edges. Both phenocryst and groundmass laths form an interlacing meshwork of crystals. Plagioclase is slightly saussuritized, and rarely, it is partly replaced by (?)analcite. Colourless to very pale green augite forms granular to prismatic intergranular crystals. Black iron ore is granular to octahedral, and greenish-brown chloritic material occurs as masses of interstitially placed fine flakes, and may represent altered glass.

The rock is cut by a thin, irregular vein of (?)analcite.

A visual estimation of the percentages of minerals present is:- plagioclase:40, augite:45, black iron ore:5, and chlorite:10.

P.392. Slide number 4957

((?)olivine)basalt

The hand specimen is dark speckled-grey, fine- to medium-grained, and aphyric.

In thin section the basalt is hypidiomorphic-inequigranular, the grain sizes ranging from 0.1 mm. to 0.7 mm. Plagioclase forms sub-radially arranged laths that tend to be sub-ophitically enclosed by augite. The slightly saussuritized plagioclase is zoned from bytownite (An_{72}) to andesine (An_{38}). Colourless to very pale green augite is granular. Black iron ore forms octahedral crystals. Brown (?)bowlingite and lesser amounts of green chlorite occur interstitially, and form small amygdales, in one of which a euhedral crystal of quartz was noted, enclosed by bowlingite. Some bowlingite occurs in tabular areas that are veined by thin fibres of (?)xylotile, and may represent pseudomorphs of olivine. Thin veins of a zeolite, possibly analcite, cut the rock.

A visual estimate of the percentages of minerals present in the basalt is:- plagioclase:35, augite:40, (?)bowlingite and chlorite:15, black iron ore:10, (?)olivine: less than 1.

P.394. Slide number 4959

Porphyritic olivine basalt

In hand specimen, subhedral to euhedral phenocrysts, which range up to 4 mm. in size, are enclosed in a dark, aphanitic groundmass. The phenocrysts comprise pyroxene, felspar, and subordinate olivine.

The thin section shows that the phenocrysts are enclosed in a fine-grained hypidiomorphic and intergranular groundmass that shows some flow texture around the phenocrysts. The groundmass grain-sizes range between 0.05 mm. and 0.1 mm.

Phenocryst plagioclase is zoned from anorthite (An_{92}) in the cores to labradorite (An_{57}) at the crystal margins, and it forms clear tabular crystals that range between 0.25 mm. and 1.3 mm. in length. Pale green phenocryst augite occurs as large prismatic crystals that sometimes form mosaic clusters, and which range up to 4 mm. in size. Some of them have minutely corroded margins along which small octahedra of black iron ore have formed. Olivine phenocrysts are much more rare, and form colourless euhedral crystals that are partly replaced by veins of brown bowlingite.

In the groundmass, zoned plagioclase (An_{65} to An_{40}) forms small interlacing tabular crystals. Augite occurs as partly or wholly chloritized prismatic to granular crystals.

Green chlorite is also interstitial, and brown bowlingite pseudomorphs probable olivine. A mesostasis of alkali felspar is present. The rock is cut by rare veins of carbonate, and one or two of the plagioclase phenocrysts are partly replaced by analcite. Some hydrated iron oxide staining of chlorite may be seen.

A visual estimate of the percentages of minerals present is:- plagioclase:45, augite:30, chlorite:15, olivine and bowlingite:5, black iron ore:2, alkali felspar:3.

P.395. Slide number 4960.

Saussuritized and partly chloritized basalt

The hand specimen is grey, fine-grained and inequigranular, and contains felspar, pyroxene and chlorite.

In thin section, the basalt is seen to be hypidiomorphic-inequigranular, the grain-sizes ranging from 0.08 mm. to 0.52 mm. Strongly sericitized and kaolinized, and, in places, somewhat strained tabular crystals of plagioclase are zoned from labradorite (An_{50-66}) at their cores to sodic andesine at their margins. Here and there, plagioclase has been replaced by zeolite. Augite occurs as prismatic to irregular crystals sub-ophitically enclosing plagioclase: some alteration of augite to pale green fibrous chlorite has taken place. Bowlingite and chlorite occur interstitially, together with small amounts of brown bowlingite. Black iron ore forms octahedral to irregular grains.

A visual estimate of the percentages of minerals present is:- plagioclase:40, augite:40, chlorite:18, black iron ore:2.

II. Intrusive Rocks

a. Dolerites and Granophyric Dolerites

P.351. Slide number 4936

Saussuritized and albitized melagabbro

In hand specimen the rock is medium-grained, and contains prismatic black pyroxene crystals partly enclosed by white felspar. The pyroxene crystals tend to be clustered into basic clots.

In thin section the rock is hypidiomorphic-granular, the average grain-size being 1.1 mm. Augite forms fairly euhedral colourless crystals that have pale green margins. Some of the crystals have corroded margins, and almost all have a thin rim of green chlorite, and have chloritic inclusions. Sodic plagioclase forms tabular, mostly untwinned crystals that poikilitically enclose augite. The plagioclase, which has a refractive index lower than that of Canada balsam, is sometimes strongly kaolinized. In places it has been replaced by fibrous prehnite, and, rarely, by large flakes of sericite. Masses of fine flakes of green chlorite occur interstitially to plagioclase, and enclose rare, small rounded grains composed of a fibrous brown

epidote-like mineral, and very small laths of plagioclase. Chlorite also occurs as inclusions and thin veins in the plagioclase. Black iron ore forms subhedral crystals that tend to enclose augite, but which are euhedral against the other minerals.

A visual estimate of the percentages of minerals present is:- augite:63, plagioclase:25, chlorite:7, black iron ore:5.

P.352. Slide number 4937

Chloritized and saussuritized oligoclase granophyre

The hand specimen is dark grey and medium-grained, and is composed of prismatic pyroxene, tabular felspar, and fairly substantial amounts of poikilitic quartz.

In thin section, granophyric intergrowths of alkali felspar in quartz are seen to poikilitically enclose oligoclase, augite and chlorite. Oligoclase (An_{26}) forms tabular crystals that are very commonly strongly kaolinized and saussuritized, and which range between 0.3 mm. and 1.65 mm. in length. Pale green augite occurs as partly or wholly chloritized prismatic to anhedral crystals ranging between 0.4 mm. and 1.75 mm. The chlorite is pleochroic from fawn to green, and forms masses of green flakes. In places, chlorite is interstitial to augite and oligoclase. The granophyric intergrowths of quartz and alkali felspar are commonly seen to radiate from enclosed oligoclase crystals: both augite and oligoclase have somewhat corroded margins where they are enclosed by the granophyric material. Black iron ore forms euhedral to anhedral grains in places associated with chlorite. Large acicular crystals of apatite may be seen, some attaining a length of 1.0 mm.; in places it is partly enclosed by black iron ore and augite.

A visual estimate of the percentages of minerals present is:- oligoclase:30, augite and chlorite:30, quartz and granophyric material:35, black iron ore:2, apatite:1.

P.354. Slide number 4939

Partly uralitized micrographophyric andesine dolerite

The hand specimen is a coarse-grained, dolerite-like rock containing tabular felspar, prismatic augite, and interstitial chlorite and quartz. Some black ore and pyrites may be seen.

In thin section, the rock is seen to be medium-grained and hypidiomorphic-inequigranular, the grain sizes ranging between 0.3 mm. and 2.5 mm. Andesine (An_{46-40}) occurs as somewhat turbid tabular to subhedral crystals that commonly show som alteration to chlorite. Augite forms slightly chloritized prismatic to acicular crystals commonly showing an (001) parting. Rarely, augite is in sub-ophitic relationship to andesine. One or two augite crystals have thin uralitized rims formed of actinolitic hornblende. Chlorite is present as interstitial masses of minute flakes, and commonly forms larger flexed flakes that are pleochroic from fawn to green. Quartz is sub-poikilitic and, in places, forms granophyric intergrowths with alkali felspar around

tabular albitized plagioclase crystals (Fig.ii). Black iron ore occurs as anhedral to subhedral, sometimes highly irregular masses associated with chlorite and augite. Accessory acicular apatite, and some irregular grains of pyrites are present.

A visual estimation of the percentages of minerals present is:- andesine:45, augite:25, chlorite:10, quartz and granophyric intergrowths:10, black iron ore, pyrites, apatite and uralite:10.

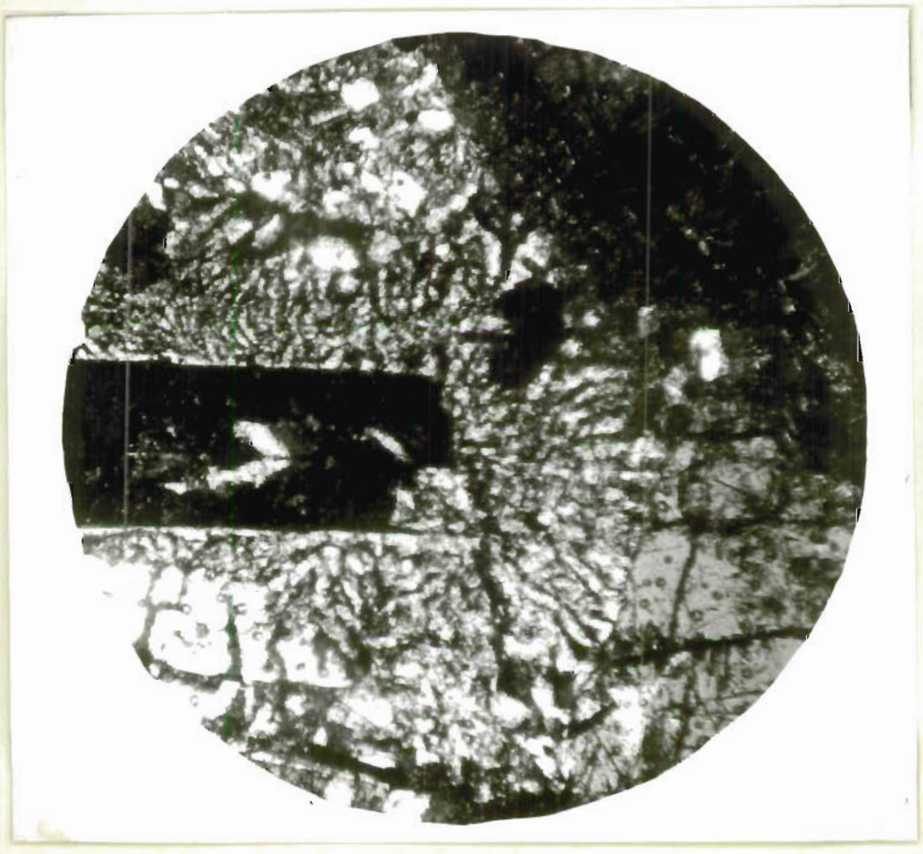

Fig. ii. Specimen P.354. A tabular crystal of plagioclase in the middle left of the photograph is surrounded by a sub-radiating granophyric intergrowth. Crossed nicols, X60.

P.358. Slide number 4941

Partly uralitized porphyritic basalt

The basalt, in hand specimen, is fine-grained and sparsely porphyritic. It is cut by veins composed of quartz and ferro-magnesian minerals. Some flecks of pyrites may be seen.

Thin section shows that the groundmass is hypidiomorphic-intergranular and sub-variolitic. The rare phenocrysts are composed of plagioclase and augite. Plagioclase forms clustered, tabular, and somewhat saussuritized crystals of

about 1.75 mm. length: the crystals are zoned from An_{70} to An_{35}. More rare augite occurs as subhedral grains, 0.7 mm. in size, whose margins are in sub-ophitic relationship to groundmass plagioclase.

In the groundmass, plagioclase is zoned from labradorite to andesine, and forms lean laths and stumpy tabular crystals that have a sub-radial disposition, and tend to be somewhat intergrown. The average length of plagioclase crystals is 0.13 mm. Augite occurs as clustered granules, or as fine, sub-fibrous crystallites, and is commonly partly altered to pale green, prismatic to fibrous actinolite. Actinolite also occurs interstitially. Pale green chlorite is interstitial, and black iron ore occurs as granular to octahedral grains. Some irregular grains of pyrites are present. Fine acicular apatite is enclosed in plagioclase.

A visual estimation of the percentages of minerals present is:- plagioclase:45, augite and actinolite:45, chlorite:5, black iron ore and pyrites:5.

The specimen is cut by a vein, approximately 3 mm. wide, composed of finely intergrown quartz enclosing clusters of small crystals of amphibole. The vein is bordered by an amphibole-rich zone.

P.360. Slide number 4943

Partly granulated quartz dolerite

In hand specimen the dolerite is fine- to medium-grained and contains tabular plagioclase and granular pyroxene. Thin veins containing zeolite and quartz cut the rock.

The thin section shows that the dolerite's texture is hypidiomorphic, intergranular, and sub-ophitic. Many of the crystals show straining and micro-fracturing, and, in places, small zones of granulation may be seen.

Plagioclase, zoned from labradorite (An_{67}) to andesine (An_{43}) forms strained laths whose boundaries tend to be intergrown with those of their neighbours. The laths are interlaced, and their lengths range from 0.3 mm. to 1.5 mm. Augite occurs as colourless prismatic to granular crystals that, in places, sub-ophitically enclose plagioclase. Black iron ore is octahedral to granular, and green chlorite is interstitial. Very rare pseudomorphs of bastite after (?)hypersthene were noted. Small amounts of interstitial quartz are present.

A visual estimate of the percentages of minerals present is:- labradorite:50, augite:35, black iron ore:8, chlorite:7, quartz: less than 1.

P.372. Slide number 4949

Partly uralitized and chloritized dolerite

The hand specimen is pale grey, medium-grained and aphyric, and contains plagioclase and ferro-magnesian minerals.

In thin section, the specimen is seen to be fine- to medium-grained and hypidiomorphic-inequigranular, the grain-sizes ranging between 0.05 mm. and 1.5 mm. Plagioclase, zoned from An_{70} to An_{40}, forms somewhat sericitized and kaolinized tabular crystals that are, in places, partly replaced by thin veins of (?)zeolite. Colourless augite occurs as subhedral to anhedral grains that sub-ophitically enclose labradorite. Augite is often partly uralitized and chloritized. The actinolite is pale green and somewhat fibrous, and the chlorite is pleochroic from pale green to pale fawn. Chlorite also occurs interstitially, and commonly has irregular to granular black iron ore associated with it. Some accessory apatite is present.

A visual estimate of the percentages of minerals present is:- labradorite:40, augite:40, actinolite and chlorite:15, black iron ore:5.

P.373. Slide number 4950

Partly granulated and uralitized oligoclase dolerite

In hand specimen the dolerite is medium-grained and apparently granulated: it contains felspar, amphibole and pyroxene.

In thin section, the dolerite is medium-grained, and has strained crystals and zones of granulation. Some remnant sub-ophitic intergrowths were noted. Oligoclase (about An_{25}) forms tabular, commonly untwinned and kaolinized crystals that show patchy, strained extinction. In the granulated zones, plagioclase is broken down to small inequigranular and angular grains. Augite is rare, but where it is present, it forms partly uralitized prismatic to anhedral crystals that sub-ophitically enclose oligoclase. Augite is absent in the granulated zones. The dominant ferro-magnesian mineral present is pale green to green actinolitic hornblende, which forms strained prismatic crystals that are often broken down to masses of small anhedral grains in the zones of granulation. Black iron ore forms anhedral, commonly irregular grains.

A visual estimate of the percentages of minerals present is:- oligoclase:40, actinolitic hornblende and augite: 45, black iron ore:15.

P.374. Slide number 4951

Uralitized oligoclase dolerite

The hand specimen is a pale, speckled grey medium-grained hypidiomorphic-granular rock in which tabular white felspar is seen to be in ophitic intergrowth with a black ferro-magnesian mineral. Fine granular epidote may be seen in association with the ferro-magnesian mineral.

In thin section, the rock is seen to be fine- to medium-grained, the grain sizes ranging between 0.35 mm. and 1.6 mm., although some crystals attain a size of 2.5 mm. Rather strongly sericitized and kaolinized tabular crystals of oligoclase are commonly in sub-ophitic and ophitic intergrowth with partly and wholly uralitized anhedral grains of augite. Pale fawn green to green actinolitic hornblende has, in many cases, completely replaced augite: subordinate epidote and chlorite are associated with the uralitized grains, and, in places, these grains are heavily dusted with fine granular black iron ore and leucoxene. Black iron ore also forms coarse, somewhat irregular grains. Small areas composed of granular epidote are present, and may represent strongly saussuritized plagioclase. Penninite is interstitial, and has small prismatic to fibrous crystals of green to bluish green hornblende associated with it.

A visual estimate of the percentages of minerals present is: oligoclase:50, actinolitic hornblende and augite:35, black iron ore:10, chlorite:5.

P.379. Slide number 4952

Partly uralitized basalt

The basalt, in hand specimen, is dark, fine-grained and apparently aphyric, and is composed of ferro-magnesian minerals and tabular felspar.

In thin section, the basalt is fine-grained, and has an average grain-size of 0.12 mm. In texture the rock is hypidiomorphic and intergranular. Rarely, clusters of small porphyritic crystals ranging up to 0.25 mm. in size may be seen. Plagioclase is zoned from labradorite (An_{67}) to andesine (An_{30}). Plagioclase, which is slightly saussuritized, forms lean, sometimes bent laths that have a vague, sub-variolitic arrangement. Augite occurs as colourless granular to prismatic crystals, many of which are partly uralitized to a pale green to colourless, fibro-prismatic actinolite. Pale green chlorite is interstitial, and black iron ore forms anhedral to octahedral grains. Fine acicular apatite may be seen enclosed in plagioclase. The small porphyritic crystals are composed of prismatic augite. The rock is cut by thin, rather irregular veins containing fine chlorite. Zones of hydrated iron oxide staining in the rock are probably due to weathering.

A visual estimate of the percentages of minerals present in the rock is:- plagioclase:45, augite, actinolite, and chlorite:45, and black iron ore:10.

P.393. Slide number 4958

Partly uralitized quartz-chlorite-andesine dolerite

The hand specimen is dark greyish-green and coarse-grained, and has lean, intersecting and sub-radially arranged laths of greenish felspar, and granular pyroxene and flaky chlorite. Subordinate poikilitic quartz is present.

In thin section, the dolerite is doleritic and sub-ophitic. Andesine (An_{40}) forms strongly saussuritized lean laths whose average length and width is 2.0 mm. and 0.15 mm. respectively. The laths are sub-ophitically enclosed by colourless anhedral to prismatic crystals of augite. Pale green actinolite may be found as fibro-prismatic growths around augite, and also, rarely, as prismatic crystals. Quartz is poikilitic about andesine, augite, and chlorite. Abundant pale green to pale fawn chlorite forms rather large, radially arranged flakes that are interstitial to andesine and augite: more rarely, it forms masses of fine, spherulitic flakes. Black iron ore occurs as octahedral, sometimes skeletal crystals.

An estimation of the percentages of minerals present in the specimen is:- andesine:40, chlorite:25, augite and actinolite:20, black iron ore:10, quartz:5.

b. Ultramafic Rocks

P.355. Slide number 4940

Partly serpentinized dunite

The hand specimen is medium-grained, and is composed of granular olivine that is veined by serpentine.

In thin section, the dunite is seen to be xenomorphic-granular, with an average grain-size of 1.25 mm. Rounded olivine grains are colourless, and have $2V_Z = 80^\circ-85^\circ$, showing it to be forsterite. It is, in places, altered to antigorite, and the rock is cut by a meshwork of veins containing fibrous chrysotile and fine granular black iron ore. Black ore also forms octahedral crystals. Commonly, very fine finger-print-like symplectic intergrowths of black ore may be seen in forsterite (Fig.iii).

Although the chrysotile veining forms a meshwork pattern, it does have a strong directional trend, parallel to a series of rather thicker veins more heavily charged with black ore.

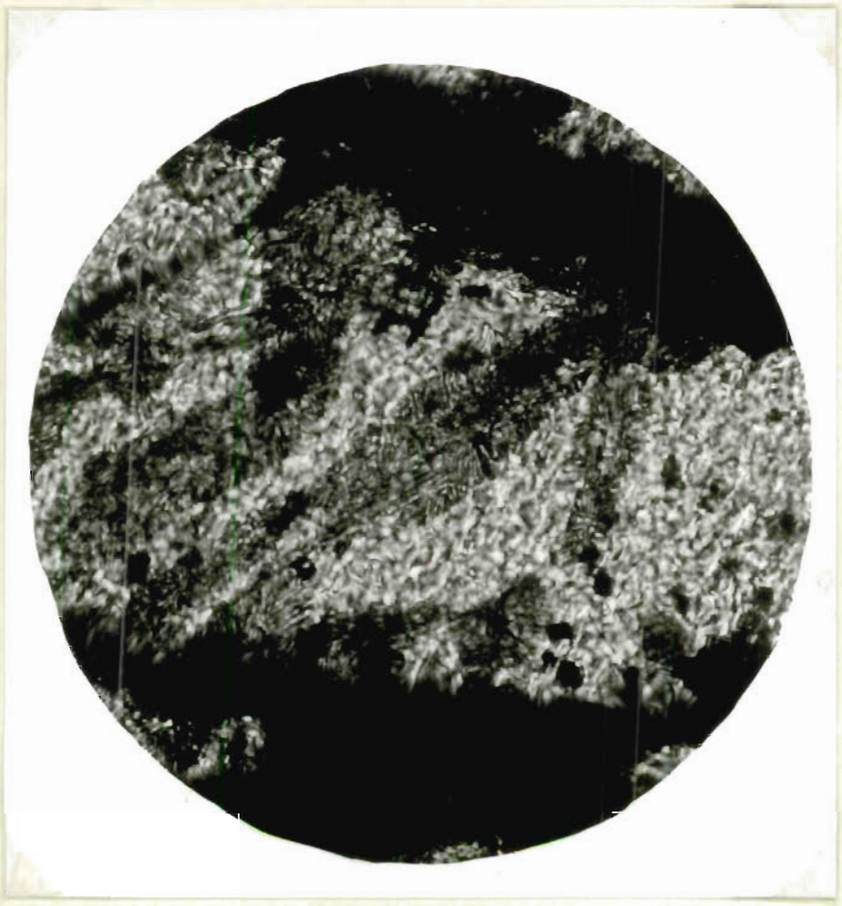

Fig.iii. Specimen P.355. Symplectic intergrowths of black ore in olivine. Ordinary light, X300.

P.359. Slide number 4942

Partly serpentinized and chloritized biotite-olivine pyroxenite

The hand specimen is a coarse-grained ultramafic igneous rock composed of pyroxene with subordinate granular olivine and flakes of biotite.

In thin section the rock is seen to be medium-grained and xenomorphic-granular, with an average grain-size of 1.0 mm., although some grains attain a size of 2.75 mm. Diopside occurs as granular to prismatic, very pale green crystals that are, in places, partly replaced by colourless tremolite. The grains are commonly traversed by thin veins containing serpentinous material. Olivine forms clots of colourless prismatic to rounded grains that are commonly partly altered to green chlorite, and which are cut by a concentrated meshwork of serpentine veins. More rare biotite occurs as anhedral interstitial flakes that are pleochroic from pale to medium fox-brown. Black iron ore is present as octahedral to anhedral grains, and also as fine dust associated with the serpentine veins.

A visual estimate of the percentages of minerals present is: diopside:60, olivine, serpentine and chlorite:27, biotite:4, tremolite:4, black iron ore:5.

III. Pyroclastic, Sedimentary and Metamorphic Rocks

P.336. Slide number 4930

Calcareous chert

In hand specimen, the chert is very fine-grained and is grey, blotched with light grey zones. Dilute HCl effervesces on application, showing the presence of calcite. A smooth surface, etched by the acid, indicates that grains of calcite, 0.25 mm. to 0.5 mm. in size, are fairly regularly distributed through the rock, in both the grey and light grey areas. Calcite grains have, in many places, coalesced to form elongate aggregates that range up to 3 mm. long by 0.5 mm. wide: the aggregates have random orientation, but are confined to the light grey blotches. The rock is cut by some thin, irregular veins of calcite.

The thin section shows that the chert is fine-grained. The light grey, blotchy areas noted in the hand specimen are caused by the presence of very fine-grained, intergranular clay-like material. Twinned calcite forms subhedral to euhedral rhombs whose sizes range from 0.1 to 0.75 mm. The grains in each elongate aggregate are in optical continuity. There seems no doubt that the calcite in this specimen is not of organic origin.

P.349. Slide number 4934

Veined acid ashstone

The hand specimen is a light grey, fine-grained and laminated rock that contains spots of white material. A thin, rather irregular vein cuts the specimen, and the white material causing the spots is absent in a somewhat irregular zone on either side of the vein.

In thin section, the rock is very fine-grained, and has a faint lamination. A finely intergrown felsic groundmass encloses small angular grains of quartz and tabular crystals of (?)albite that have an average size of 0.05 mm. White mica forms small flakes, and spherulitic aggregates of flakes, the spherulites ranging up to 0.15 mm. in size. Rare grains of epidote are present. The rock is cut by a vein composed of coarse, granular calcite. Around the vein, granular aggregates of calcite occur in a narrow, irregular zone. Elsewhere in the rock, calcite is rare. Some of the white spots noted in the hand specimen are composed of calcite, but most are formed of an unidentified mineral that occurs as colourless, sub-radiating fibres that have parallel extinction and a moderate birefringence.

P.366. Slide number 4945

Tuffaceous greywacke

The hand specimen is a fine- to medium-grained, fairly equigranular, dark grey sedimentary rock.

Thin section shows that the rock is composed of sub-angular, rarely sub-rounded, fairly well-sorted grains that range between 0.03 mm. and 0.2 mm. in size. The most

common mineral grains are albite and augite: calcite, glauconite, chlorite and nontronite are also common, and rare grains of quartz and chert are present. Fragments of a very fine-grained variolitic basalt were noted. The grains are embedded in a matrix of haematite.

Many of the albite and augite grains tend to be euhedral, suggesting that the rock is a crystal tuff. However, the rounding of the crystal corners seems to show redistribution by water during or after deposition. The presence of calcite, glauconite and quartz, and the fact that the rock is fairly well sorted support this view.

P.384. Slide number 4954

Deuterically altered tuffaceous greywacke

The hand specimen is a medium- to coarse-grained, fairly equigranular, dark grey detrital rock that contains sub-angular to sub-rounded grains composed of felspar, ferro-magnesian minerals and quartz. The presence of calcite was shown by the application of dilute HCl.

In thin section the greywacke is seen to consist of fairly well-sorted sub-angular to sub-rounded grains, the extremes of grain size being 0.2 mm. and 1.2 mm. The most prominent mineral and rock grains present are of nontronite, intermediate to basic plagioclase, black iron ore, micro-pegmatite, and augite. Calcite, and rarer grains of quartz and intergranular and variolitic basalt are present. Some of the calcite is derived from organic matter, some foraminifera and fragments of algae being noted.

The grains are cemented mostly by calcite: however, some interstitial nontronite is present, and in one place was seen to occupy cavities in a foraminiferal test. Nontronite has also partly replaced some of the augite grains. Small amounts of interstitial analcite are also present, and this mineral has partly and wholly replaced many of the plagioclase grains. Hence, it appears that this rock, subsequent to deposition, has suffered from deuteric action, probably associated with the vulcanicity of the area.

The sub-rounding of the grains, together with the presence of a calcitic matrix, and fragments of organic matter, show that the rock was deposited in water. The greater part of the material was derived from basic igneous rocks, some of it probably tuffaceous: the grains of micropegmatite suggest that part of the source material is from granophyric rocks similar to those represented by P.352 and P.354.

The foraminifera were identified as Elphidium sp. and Amphistegina sp. by D. Belford. He states that they range through the Tertiary. However, he adds that this specimen occurs in the same area as P.382, P.383 and P.385, and fossils in these specimens show a lower Miocene age. Hence, it is probable that the fossils in this specimen are also lower Miocene.

P.390. Slide number 4956

Epidote-albite-tremolite schist

In hand specimen the schist is pale green-grey, and is fine- to medium-grained. The schistocity is wrapped around small augen-like porphyroblasts of epidote and felspar.

The thin section shows that the rock is fine- to medium-grained, schistose and porphyroblastic: the schistosity is affected by a false cleavage. The groundmass is composed mainly of tremolite, albite and epidote. Tremolite forms lineated, colourless and acicular crystals that show some banding and fracturing. Pellucid albite occurs as granular to roughly tabular untwinned grains elongated parallel to the schistocity, and commonly enclosing tremolite. Epidote is granular, and pleochroic in yellow, and, in places, tends to form small aggregates. Rare flakes of pale green, almost isotropic chlorite are present. The minerals have fairly random distribution throughout the rock, although, rarely, small lenticular layers of granular albite, containing relatively rare tremolite, may be seen.

The porphyroblasts, about which the schistocity is wrapped, are composed of epidote and albite. Epidote occurs as prismatic to granular crystals that are sometimes clustered. Rarely, pale green chlorite is intergrown with them. Albite forms tabular to rounded grains, occasionally intergrown with epidote. One albite crystal shows twinning, and is slightly sericitized. This crystal, and some of the epidotes show microfracturing: some porphyroblasts appear to have been rotated.

The specimen is cut by veins containing epidote and pyrites. A visual estimate of the percentages of minerals present is:- tremolite:45, albite:39, epidote:15, and chlorite and pyrites:1.

DISCUSSION

1. General. Mr. Thompson asked for some general comment on the petrology of these rocks; an attempt will be made to do this here. The basalts are fairly straight-forward and will be treated briefly. Some difficulties arise from a study of the rocks that are thought to be intrusive: in dealing with these, the discussion will be more in the nature of suggestions to Mr. Thompson rather than any definite conclusions.

According to Mr. Thompson, the area immediately at the landward end of Milne Bay comprises a suite of dolerites and ultramafic rocks intruded into the volcanics. Mr. Thompson thinks that the dolerites and ultramafics are related. The remainder of the area examined by Mr. Thompson consists of basalt flows interbedded with some pyroclastics and sediments, and intruded by some dolerites.

2. The Basalts. The basalts are a reasonably uniform suite. The texture in some is ophitic and sub-ophitic, and in others it is intergranular or variolitic. Some of the rocks in this suite have been called dolerites on account of their texture and their rather more coarse grain size - however, it is realized that these specimens may well have been taken from thick flows; and Mr. Thompson has obtained field evidence to show that some of these coarser-grained rocks are extrusive.

Mineralogically, most of the basalts have plagioclase that is zoned from bytownite or labradorite to andesine: there are two exceptions - P.345 has its plagioclase replaced by zeolite, and P.348 is albitized. All the basalts have augite, and one (P.394) has phenocrysts composed of fresh or only partly altered olivine. Some other specimens contain bowlingite and xylotile which appear to pseudomorph rare crystals of olivine. No orthopyroxene or pigeonite were observed. Most of the basalts have interstitial bowlingite or chloritic material, and in one or two this may represent altered basaltic glass: some have interstitial zeolite in addition (P.348, P.350 and P.353). One specimen (P.394) has a mesostasis composed of alkali felspar and chlorite. Bowlingite, chlorite and analcite are present in some in veins and amygdales. Quartz was observed only in two specimens: in P.348 partly replacing albite; and in P.392, one crystal was seen in an amygdale. Therefore, apart from the spilite and the zeolitized basalt, the lavas are mineralogically fairly uniform, although the texture, and the presence of fresh phenocrystic olivine in specimen P.394 suggest that this lava may not belong to this province, or that it may belong to a later volcanic episode.

The late stage minerals tend to be alkaline, although the presence of late quartz in one or two specimens, and the occurrence of the acid ashstone (P.349) suggest that the parent magma of the lavas might have produced a rhyolitic differentiate.

3. The Intrusive Rocks. The intrusive rocks comprise some dolerites and granophyric dolerites, and two ultramafic rocks.

a. The dolerites. With the dolerites I have grouped two partly uralitized basalts (specimens P.358 and P.379), firstly, because they occur in the main area of the intrusive rocks, and secondly, because of their characteristic of uralitization: this characteristic does not appear in the other basalts, whereas it is present in the dolerites. These uralitized basalts, if they are in fact intrusive, may represent either chilled margins of the dolerite intrusions, or may be minor offshoots from them; this point can probably be decided on field evidence.

The five specimens of dolerite are medium-grained and have sub-ophitic textures. The plagioclase in P.360 is labradorite, and in the others (P.372, P.373, P.374, P.375 and P.393) it is more sodic. Augite is present in all, and, except in P.360, it is more or less uralitized. Quartz is accessory in P.360, and in P.393 some is essential and some may be secondary: in the other specimens it is absent.

The two basalts are fine-grained, and contain plagioclase, zoned from labradorite to andesine, and augite,

The granophyric dolerites are medium- to coarse-grained, and contain partly saussuritized sodic plagioclase, and somewhat acicular, partly chloritized (P.352) or uralitized (P.354) augite. These minerals are partly or wholly enclosed by poikilitic quartz or granophyric intergrowths of quartz and alkali felspar.

Most of the dolerites occur in the area immediately south of Milne Bay: P.360 occurs to the north of the Bay, P.354 on the headland on the north-east side of the Bay, and P.393 occurs on the east coast of Basilaki Island.

P.393 is taken as intrusive because of its coarse grain-size; its augite is also partly uralitized. P.354 is a dolerite pegmatite, and is considered to be part of an intrusion. Dolerite pegmatites and granophyric dolerites are known in basic volcanic rocks (Kuno, et al., 1957), but they occur only as schlieren. Mr. Thompson spoke of the outcrop represented by P.354 as being uniform, hence no schlieren appear to be present. Dolerite pegmatites and granophyric dolerites occur more commonly in intrusive rocks, usually sills, as schlieren and irregular patches (Walker, 1940, and 1953), and also as layers in differentiated sills, as at Dillsburg, U.S.A. (Hotz, 1953), and Red Hill, Tasmania (I. McDougal, pers. comm.). It seems probable that P.354 represents part of a differentiated sill of this type. P.352 is a very similar dolerite pegmatite.

These granophyric dolerites are typical acidic differentiates of the tholeiitic magma-type (I. McDougal, pers. comm.). They may be associated with the other dolerites as parts of differentiated sills.

Specimen P.351, a pyroxene-rich melagabbro having clots of prismatic augite crystals poikilitically enclosed in sodic plagioclase, is difficult to place. It may represent a heavy crystal accumulation whose plagioclase has been albitized, or else it may be a different type of pegmatoid dolerite. Some more field information about this specimen would be required in order to decide what it is.

b. The Ultramafic Intrusives. Two specimens, P.355 and P.359, are dunite and olivine pyroxenite respectively. The dunite is a medium-grained, xenomorphic-equigranular rock composed of olivine partly replaced by serpentine. The olivine pyroxenite is a medium-grained rock composed mostly of clinopyroxene, with small amounts of olivine, and minor amounts of biotite, serpentine, tremolite and chlorite.

c. The Relationship Between the Dolerites and the Ultramafics. What follows is merely a summary of the possibilities, and a brief survey of the literature. Many of the references to the literature may be quite irrelevant, but have been put in as possible suggestions.

The ultramafic rocks may represent heavy crystal differentiates of the dolerites: however, this would be unusual, for although tholeiitic magma, on differentiation, often produces olivine in a heavy crystal accumulation, this mineral rarely forms more than 40% of such an accumulative rock - for example, in the Palisades sill, New Jersey, the olivine layer contains a maximum of 25% olivine; this sill is over a 1,000 feet thick, in places (Walker, 1940). Even in differentiated sills of the olivine basalt magma type,

such as the teschenitic sill of the shiant Islands, Scotland (Walker, 1930), no true ultramafics are found in the accumulative layers. From this, therefore, it seems that the dolerites and granophyric dolerites bear no relation to the ultramafics. However, other possibilities will be briefly surveyed.

An association where a basic magma differentiates to produce, on the one hand, ultramafic rocks, and on the other, gabbroic pegmatites, are the great plutonic basic intrusions, such as at Bushveld, South Africa (Daly, Hall, Lombard, quoted in Turner and Verhoogen, 1951), Stillwater, U.S.A. (Howland, Peoples and Sampson, and Hess, quoted op.cit.), and in the Great Dyke of Southern Rhodesia (Worst, 1958). These intrusions are, however, of huge dimensions, e.g., the Bushveld complex covers an area of approximately 20,000 square miles, and in places is as much as 5 miles in vertical thickness. These intrusions are gabbroic and plutonic, whereas the dolerites under consideration have every appearance of being hypabbyssal. Also, Mr. Thompson did not give any indication of any basic plutonic intrusion being present in this area.

It may be argued that differentiation took place at depth, and that the differentiated rocks were subsequently emplaced as a number of smaller intrusions. If this were the case, then I would expect the dolerites and dolerite pegmatites to show pronounced protoclastic textures, as though they were intruded as a crystal mush. In fact they do not. What little granulation that is present in one or two of the dolerites may probably be attributed to tectonic action.

Two more examples of basic pegmatite associated with ultramafic rocks are summarized in the following paragraphs. They may not be directly relevant, but are put in in case the information will be of any use to Mr. Thompson.

Zoned gabbro pegmatite has been described by Lovering and Cordell (1959) as occurring as closed bodies of random distribution and varying size ans shape, enclosed in a pyroxenite in Plumas County, California. These authors consider that the pegmatites are formed from residual liquids of the pyroxenite.

Another occurrence where ultramafics are found in conjunction with basic pegmatites is in the Losberg Complex, Southern Transvaal (Jansen, 1954). Here, rocks such as harzburgite, pyroxenite and norite are associated with a layer of granophyric gabbro and granophyre. The complex intrudes a quartzite, and Jansen considers that the granophyric rocks he describes result from assimmilation of the quartzite by the basic magma.

In conclusion I would say, tentatively, that the dolerite pegmatites are parts of differentiated dolerite sills, and that they bear no relationship to the ultramafics. I have quoted references in an attempt to illustrate this view, but I may be wrong. I have, therefore, quoted and listed references to other types of basic intrusions where basic pegmatites and ultramafics are in association, in an attempt to suggest explanations other than my point of view.

4. Pyroclastic, Sedimentary, and Metamorphic Rocks. Specimen P.336 is a calcareous chert, and need not be enlarged upon. The acid ashstone, specimen P.349, seems somewhat out of place in a suite of basic rocks, but, as mentioned above, it may represent an acid differentiate of the basalts. Specimens P.366 and P.384 are tuffaceous greywackes, and are composed mostly of material derived from the volcanics: P.384 contains grains of micropegmatite, suggesting that they are derived from granophyric dolerites similar to specimens P.352 and P.354. If this is true, then it may show that part of the volcanic sequence is later than the intrusion of the dolerites. Specimen P.390 is an epidote-albite-tremolite schist, and may represent a metamorphosed basic igneous rock, either lava or tuff.

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