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PETROGRAPHY AND PETROLOGY OF ROCK SPECIMENS FROM THE PORT MORESBY-KEMP WELCH AREA, PAPUA.

by

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SUMMARY

Microscopic examination of a suite of gabbro specimens from the Port Moresby-Kemp Welch area, Papua, has indicated two mineralogically and texturally distinct regions of gabbro. Gabbro from the Gea area is fine- to medium-grained, often indistinguishable from basalt in hand specimen, and lacks evidence of appreciable differentiation. Gabbro from the Astrolabe mines area is generally coarser grained and reveals a tholeiitic differentiation sequence from olivine gabbro to quartz diorite. Both the character of the pyroxene and the grainsize of the gabbro suggest rapid crystallisation, especially in the Gea area.

The mineral assemblages of calc-silicate hornfels associated with the gabbro indicate that the highest grade of metamorphism attained was appropriate to the lower regions of the pyroxene-hornfels facies and that the prevailing water vapour pressures were moderate. There is no evidence of associated metasomatism.

Other miscellaneous rock specimens from the area have been individually identified and described.

INTRODUCTION

In 1964 Yates and de Ferranti executed mapping and geochemical sampling of the Port Moresby-Kemp Welch area, Papua, in an attempt to elucidate the mineralisation of the Astrolabe Mineral Field and to seek out possible extensions of the mineralisation. This Record embodies the petrography and petrology of 70 rock samples collected during this programme and is intended to augment the Record compiled by Yates and de Ferranti (1965); the latter Record incorporates the more salient features of this work.

A suite of 28 gabbro specimens have been examined for mineralogical and textural variation over the area. An associated suite of 10 calc-silicate hornfels specimens have been examined to determine the grade of thermal metamorphism produced by the gabbro intrusions and to check for metasomatism. The remaining 32 specimens are miscellaneous rocks, largely sedimentary, submitted for identification and routine examination.

THE GABBRO

Microscopic examination of a suite of 28 rock specimens from the gabbro intrusions of the Port Moresby-Kemp Welch area reveals considerable textural variation and some mineralogical variation. The specimens range from gabbro proper to diorite.

TEXTURES

In hand specimen the rocks can be divided into five broad groups - basaltic, gabbroic, clotted, foliated and porphyritic basaltic. The numbers of specimens allocated to these five broad groups were 9, 8, 7, 2, and 2, respectively.

Basaltic Specimens

These specimens range in grainsize from 0.1 to 2 mm and the microscopic textures displayed are hypidiomorphic granular, allotriomorphic granular, intergranular, and intersertal.

Gabbroic Specimens

These specimens range in grainsize from 0.3 to 4 mm. and the textures displayed are hypidiomorphic granular and hypidiomorphic subophitic.

Clotted Specimens

These specimens are characterised by dark clots of green serpentinous material and, less commonly, chlorite. There is no notable aggregation of the other mafic minerals in the rock and the textures of these specimens on the whole are hypidiomorphic granular, allotriomorphic granular, ophitic, or subophitic. The grainsizes of the various specimens fall in the range 0.1 to 5 mm.

Foliated Specimens

Two specimens show a prominent foliation caused by parallelism of feldspar laths, 2-4 mm long by 0.5 mm wide, and plates of opaque ore, 1-2 mm wide by 0.3 mm thick.

Porphyritic Basaltic Specimens

The two specimens in this category are confirmed in thin section to have a porphyritic basaltic texture. Phenocrysts of plagioclase and of serpentinous pseudomorphs after olivine have a grainsize of about 2 mm and are set in a groundmass of 0.1-1 mm grainsize.

MINERALOGY

The primary minerals present are plagioclase, clinopyroxene, hornblende, olivine, orthopyroxene, quartz, magnetite, ilmenite, pyrite, apatite, and sphene. The secondary minerals present are hornblende, uralite, chlorite, bowlingite, serpentinous minerals, mica, calcite, kaolin, and prehnite.

Plagioclase is ubiquitous. It is generally unaltered but in a few specimens it is kaolinised and in one specimen (R64071622) it is heavily altered to kaolin and calcite. The composition of the plagioclase of the various specimens ranges from bytownite to andesine but middle labradorite is the most frequent composition; the most calcic plagioclase determined is An_{73} and the most sodic is An_{34}. Zoning of individual grains is generally slight.

Clinopyroxene is ubiquitous but varies from about 40% to a few modal percent. The mineral is augite, commonly pale brown and less commonly colourless or greenish.

Hornblende is present as an apparently primary mineral in nearly half the specimens examined. Where present, this hornblende usually predominates over pyroxene. It is a green-brown variety distinct from the secondary pale green uralitic amphibole, red-brown amphibole, and deep green amphibole seen in some sections.

Olivine has crystallised in about one third of the specimens examined but rarely exceeds 5 modal percent. In all specimens except one (R64071616) the olivine has been largely, or wholly, replaced by bowlingite or serpentinous material.

Orthopyroxene is present sparsely in two specimens as discrete grains with pinkish to greenish pleochroism. The grains of one specimen (R64071608) are optically positive, apparently enstatite, and those of the other (R64071615) are optically negative, apparently hypersthene. Very fine exsolution lamellae of orthopyroxene are present in few grains of augite from one specimen (R64071616).

Quartz is present in two specimens, to the extent of about 5 modal percent, both as large anhedral grains and as micrographic intergrowths with andesine.

Opaque ores are ubiquitous but generally constitute less than 5 modal percent. Magnetite is the most abundant ore, ilmenite is common, though not abundant, and pyrite is sparse. The grainsize and textures of the ores are variable but tend to vary sympathetically with the average grainsize of the rock: in general, the ores are small and equidimensional in fine grained specimens but large and platy, or skeletal, in coarse specimens.

Accessory Minerals

Small elongate apatite prisms are present sparsely in many specimens, but in greater abundance in the more acid examples. Sphene has been noted in two specimens, one of which (R64071606) contains relatively numerous grains of brown sphene, 0.5-1 mm in size, intergrown with opaque ores.

Secondary Minerals

The most abundant secondary minerals are amphiboles replacing augite. Aggregates of pale green uralite, flecks of red-brown hornblende, and flecks of sea-green hornblende are visible separately or together as replacements of pyroxene in many sections.

Chlorite, in some cases pennine, forms fibrous aggregates in about half the sections examined.

Bowlingite and serpentinous material pseudomorph olivine. Yellow and greenish serpentinous material not directly associated with olivine outline fractures and grain boundaries in some sections.

A few specimens contain aggregates of secondary mica which shows pleochroism in shades of golden brown or bright green; the two varieties occur separately or together.

The amount of kaolin occurring as an alteration product of plagioclase is generally small but one specimen (R64071622) has its plagioclase extensively replaced by kaolin and calcite.

Prehnite is present in some sections as local radiating aggregates and as a vein mineral.

MINERALOGICAL VARIATION

Thin sections reveal a moderate degree of mineralogical variation throughout the gabbro masses. When the mineral assemblages of the individual specimens are examined with their field locations it is found that a mineralogical difference exists between those specimens collected from the large south-eastern gabbro mass, occupying mainly the Gea 1:50,000 map sheet, and those collected from the gabbro outcrops in the Mines area, occupying mainly the Geboria 1:50,000 map sheet. These two areas of gabbro are separated by a definite break in continuity of outcrop.

The mineralogical and grainsize data of the two areas are summarised in Table 1. Gabbro from the Gea area is generally finer grained than that from the mines area.

In the Gea area the mineral assemblages are all very similar, consisting essentially of labradorite, augite, and opaque ores, ± minor olivine. There is little variation in the plagioclase composition, about An_{62} being typical. Hornblende occurs in 4 specimens collected close to country rock contacts but, except in one specimen (R64071602), the composition of the plagioclase is unchanged so that probably variation in water vapour pressure during crystallisation, rather than differentiation, is responsible for the formation of the hornblende.

In the mines area the mineral assemblage is not constant and the specimens can be arranged into a series of increasingly acid examples (see Table 1). In order from basic to acid the progressive assemblages are:-

(1) calcic labradorite-augite-ores-olivine ± orthopyroxene

(2) calcic labradorite-augite-ores-olivine-hornblende ± orthopyroxene

(3) sodic labradorite-augite-ores-hornblende

(4) middle andesine-augite-ores-mica ± hornblende ± quartz

(5) sodic andesine-augite-ores-mica-quartz

These assemblages constitute a normal tholeiitic differentiation series. No pattern can be recognised in the areal distribution of the assemblages but interpretation is complicated by the complex outcrop pattern and by the high relief. Careful 3-dimensional sampling would be required to unravel the regional pattern of differentiation which, from the limited data available, appears to be irregular. Simple gravity differentiation seems unlikely.

TABLE 1

MINERALOGY AND GRAINSIZE OF THE GABBRO

(a) Gabbro from Gea Area

Registered No.	Mineralogy								Plag. Composition*	Grainsize
	Plag.	Cpyx.	Ore	Opyx.	Olivine	Amphib.	Mica	Quartz		
R64071613	x	x	x		x				An_{72}	0.5-2 mm
R64071612	x	x	x		x				An_{61}	0.3-2 mm
R64071623	x	x	x		x					0.1-2 mm
R64071624	x	x	x		x					0.1 mm
R64071626	x	x	x		x				An_{62}	0.1-1 mm
R64071607	x	x	x							0.05 mm
R64071614	x	x	x							0.1-1 mm
R64071620	x	x	x							0.1-2 mm
R64071621	x	x	x						An_{65}	0.1-1 mm
R64071622	x	x	x							0.1-2 mm
R64071606	x	x	x		x	x			An_{61}	1-3 mm
R64071601	x	x	x			x			An_{62}	0.3 mm
R64071611	x	x	x			x			An_{62}	0.1-2 mm
R64071602	x	x	x		x	x	x		An_{54}	0.5-5 mm

(b) Gabbro from Mines Area

Registered No.	Mineralogy								Plag. Composition*	Grainsize
	Plag.	Cpyx.	Ore	Opyx.	Olivine	Amphib.	Mica	Quartz		
R64071615	x	x	x	x	x				An_{62}	0.5-4 mm
R64071608	x	x	x	x						0.5-4 mm
R64071616	x	x	x	x	x	x			An_{70}	0.5-2 mm
R64071625	x	x	x		x	x			An_{71}	0.1-3 mm
R64071609	x	x	x		x	x				1-4 mm
R64071619	x	x	x			x			An_{73}	0.3-1 mm
R64071605	x	x	x			x			An_{63}	0.1 mm
R64071610	x	x	x			x				0.5-1 mm
R64071618	x	x	x			x			An_{55}	0.1 mm
R64071627	x	x	x			x	x			0.3-1 mm
R64071603	x	x	x			x	x	x	An_{40}	1-4 mm
R64071604	x	x	x				x		An_{39}	0.5-4 mm
R64071628	x	x	x				x		An_{40}	0.3-3 mm
R64071617	x	x	x				x	x	An_{34}	0.5-3 mm

* Determined using Michel-Lévy's method and the curve published in Fig. 13-26 of Kerr, 1959.

MODAL VARIATION

The mines area gabbro varies between the extremes of about 5% mafics and 50% mafics; the typical mode is about 40% mafics. Hornblende does not occur in all specimens of the mines area gabbro but overall it is the most abundant mafic mineral.

The Gea area gabbro varies between about 20% and 50% mafics with a typical mode of about 40% mafics. Hornblende is not abundant in the Gea area gabbro and clinopyroxene is definitely the dominant mafic mineral.

No pattern of modal variation can be recognised in either area but more adequate and objective sampling, preferably using grid collection, would be needed before any definite conclusions could be reached on the presence or absence of any regularity.

CONCLUSIONS

The gabbro varies widely in texture and grainsize, and is best considered in terms of two physically distinct areas referred to as the Gea area and the mines area, respectively. The rocks of the Gea area, though showing moderate modal variation, have a fairly constant mineral assemblage and lack evidence of much differentiation. In contrast, the gabbro of the mines area has a varied mineralogy consistent with a moderately differentiated rock ranging from gabbro proper to diorite. In general, the gabbro of the mines area is coarser grained than that of the Gea area, which in hand specimen is frequently indistinguishable from basalt.

The differences between the gabbros of the two areas may reflect some original chemical differences at the time of intrusion but it is more probable that they reflect slight differences in the cooling histories of the two areas. The coarser grainsize, degree of differentiation, and abundance of hornblende and mica in the mines area gabbro suggests less rapid cooling and a higher volatile content than in the finer grained undifferentiated Gea area gabbro.

The mineralogy and course of differentiation of the Astrolabe gabbro reveals definite tholeiitic affinities. A peculiarity of the rock is the paucity of orthopyroxene and absence of pigeonite: the rock typically contains augite as the sole pyroxene. Basic rocks of tholeiitic parentage more typically contain both a lime-poor pyroxene, pigeonite and/or orthopyroxene, and a lime-rich pyroxene, augite. However, Benson (1944) has described some tholeiitic dolerites in north-western Otago, New Zealand, which contain augite as the sole pyroxene. Benson considers that this formation of a single pyroxene phase is the product of rapid crystallisation. This contention appears to be supported indirectly by the works of Hotz (1953) and of Walker, Vincent and Mitchell (1952). Hotz has described differentiated tholeiitic dolerite bodies near Dillsbury, Pennsylvania, which have both augite and hypersthene (or pigeonite) in the "normal" dolerite but only augite in the chilled facies. Walker, Vincent and Mitchell have described the Kinkell tholeiite, Stirlingshire, which is quite chilled (25% glass) and which contains about 27 modal per cent of pyroxene. Of this pyroxene 99 percent is pale brown augite and 1 percent is pigeonite.

These examples, therefore, suggest that the paucity of lime-poor pyroxene phases in the Astrolabe gabbro is a product of rapid crystallisation and that the rock is in all other respects a normal tholeiitic gabbro.

THE CALC-SILICATE HORNFELS

According to the field observations of Yates and de Ferranti (1965) thermal metamorphism associated with the gabbro intrusions is slight and the thermal aureoles are narrow or absent. Specimens from outcrops of locally developed calc-silicate hornfels have been examined microscopically to specify the grade of metamorphism attained.

PETROGRAPHY

R.65071687

In thin section this rock is seen to be largely a dense mass of tiny granules of diopside or epidote, too fine for positive identification. These grains have a dusty appearance over most of the section and it is only near holes in the section, or near the edge of the section, that their true nature can be properly observed.

Minor constituents of the rock are garnet, idocrase wollastonite and calcite. The garnet is present as rare aggregates of tiny grains of the same dimensions as the diopside or epidote forming the bulk of the rock. Idocrase forms sparse porphyroblasts. The calcite occurs as irregular grains 0.5 mm in size packed with poikilitic granules and also veins the rock. Wollastonate forms sparse small aggregates of prisms.

In plain light the section reveals a relict stratification and "ghost" detrital textures. Three distinct bands, half an inch wide, representing relict primary strata, traverse the section. Primary chemical differences in these bands are reflected in their present metamorphic mineral assemblages: one band contains idocrase porphyroblasts, wollastonite aggregates, garnet granules, and small diopside prisms set in a groundmass of fine diopside or epidote; another band contains a dusty mass, nearly opaque, of fine diopside or epidote with aggregates of fine garnet scattered throughout; the remaining band contains abundant calcite, epidote and diopside.

The rock is a banded calcareous shale which has suffered moderate thermal metamorphism. The slight differences in metamorphic mineral assemblages of adjacent bands are the result of differences in the ratio of limestone to shale in the former sedimentary strata.

R.65071688

The rock is a very fine-grained calc-silicate hornfels. Diopside and garnet form about 90% of the rock; they are present in about equal abundance as streaks and patches of very small granules. Minor patches of calcite and very rare sheafs of wollastonite are present. The mineral grains are dusted with opaque material which is white in reflected light.

In plain light the distribution of "dusty" material gives the section a pronounced relict sedimentary texture of former rounded detritus 0.5 to 3 mm in size.

The rock is a calcarenite which has suffered moderate thermal metamorphism.

R.65071689

In hand specimen the rock consists of abundant spheres of a white mineral set in a matrix dominated by a granular green mineral. In thin section the spheres are seen to be scaly aggregates of brucite with minor flecks of a very fine-grained mineral of high relief, too fine to identify. The matrix interstitial to the spheres consists of about equal proportions of idocrase and a mineral of clay dimensions which has aggregate white birefringence and a white colour in reflected light. This mineral is possibly diaspore, an aluminium hydroxide common in metamorphosed clays. Minor areas of tiny diopside granules are present.

The rock is a metamorphosed argillaceous dolomite.

R.65071691

This rock is seen to be a medium-grained calc-silicate hornfels consisting of idocrase, feldspar, tremolite, diopside (or epidote), calcite, and (?)diaspore.

The idocrase occurs as abundant euhedral grains about 2 mm in diameter packed with tiny poikilitic inclusions and fibrous mineral. Untwinned feldspar packed with inclusions forms grains comparable in size with the idocrase. Tremolite is present as sheafs and radiating aggregates irregularly through the rock. Tiny granules of diopside (or peidote) are abundant throughout the rock both as local aggregates and as poikilitic inclusions in the other minerals. Medium-grained calcite is sparsely present. Areas of a birefringent whitish mineral of clay dimensions, possibly diaspore, are moderately abundant.

The rock is a metamorphosed magnesian limestone containing silica and a fairly high aluminous fraction. The high aluminium content is reflected in the formation of plagioclase instead of wollastonite.

R.65071698

In thin section the rock is seen to be a fine-grained metamorphic rock with the relict texture of a medium- to coarse-grained sedimentary rock. The minerals present are diopside, feldspar, quartz, calcite, garnet, idocrase, zoisite, wollastonite. The rock is heterogeneous and consists of areas of -

(1) fine diopside set in quartz and untwinned feldspar, sometimes with sparse garnets 0.5 mm. in size,

(2) very fine diopside and 0.1 mm grains of idocrase,

(3) fine diopside with interstitial calcite,

(4) calcite and untwinned fine feldspar,

(5) slightly coarser feldspar, diopside and calcite,

(6) wollastonite alone.

These areas are related to shadowy outlines inherited from a former detrital texture. Rare grains of twinned andesine are probably relics of the former detrital rock. The rock is a low grade thermally metamorphosed calcareous lithic arenite.

Zoisite is present as a vein mineral.

R.65071699

This rock contains the minerals idocrase, wollastonite, plagioclase, epidote, diopside, calcite. The idocrase occurs as idiomorphic grains about 0.05 mm. in size. Wollastonite occurs as sheafs and aggregates about 2 mm wide. Both medium-grained untwinned plagioclase, filled with poikilitic inclusions, and sparse grains of twinned andesine are present. Diopside forms tiny granules and epidote sparse euhedra about 0.2 mm. long. Calcite occurs frequently interstitially to idocrase and rarely as discrete coarser grains.

The rock is a thermally metamorphosed argillaceous limestone.

R.65071732

In thin section the rock is seen to be a brucite marble. The rock consists of 30% brucite as radiating spheres about 2 mm in diameter set in a mosaic of calcite with an average grainsize of 0.3 mm. Tiny granules of diopside or epidote are present scattered through the brucite, interstitially to the calcite, and enclosed in the margins of calcite grains.

The rock is a brucite marble produced by thermal metamorphism of a dolomitic limestone.

R.65071696

This rock has a metamorphic texture but is too badly weathered to permit a proper examination. Calcite and altered (?)diopside form the bulk of the rock. Some magnetite and much iron staining are visible.

R.65071694

This very fine-grained calc-silicate hornfels is composed of diopside and feldspar with small amounts of tremolite and quartz. Calcite veins the rock and occurs sparsely throughout. There are a few spheres, 3 mm in diameter, of translucent white material with moderate birefringence. This may be altered brucite.

R.65071695

This rock has a relict detrital texture preserved both by a thin veneer of recrystallised chlorite outlining former grain boundaries and by the localised distribution of specific mineral assemblages. The minerals present are abundant calcite and lesser diopside, untwinned feldspar, chlorite, and quartz. Recrystallisation has been incomplete, as evidenced by the local coexistence of calcite and quartz in many places.

The rock is a calcareous lithic arenite which has suffered mild thermal metamorphism. The intensity of the metamorphism has been insufficient to allow attainment of equilibrium; its only effects have been the crystallisation and coarsening of calcite components of the rock, the production of minor diopside, and the recrystallisation of the former chloritic matrix of the arenite.

CONCLUSIONS

The mineral assemblages of the individual specimens have been considered in relation to the facies of contact metamorphism outlined in Turner and Verhoogen (1960), the results being listed in Table 2.

Most of the specimens examined have mineral assemblages appropriate to the hornblende-hornfels facies or to a grade transitional between the albite-epidote-hornfels facies and the hornblende-hornfels facies. Only two specimens have equilibrium assemblages appropriate to the pyroxene-hornfels facies, whilst two others have metastable assemblages transitional between the hornblende-hornfels facies and the pyroxene-hornfels facies. Therefore, it is probable that the highest grade of metamorphism attained was confined to the lower regions of the pyroxene-hornfels facies.

It is worthy of note that idocrase is abundant in four specimens of hornfels. The composition of idocrase differs from that of grossular garnet mainly in the presence of an hydroxyl component and its formation in preference to garnet is favoured by higher water pressures. Furthermore, tremolite occurs in another two specimens and this mineral also incorporates an essential hydroxyl component, so it appears that at least moderate water pressures prevailed during crystallisation of the hornfels.

No evidence of metasomatism was afforded by the specimens examined.

TABLE 2

CORRELATION OF THE HORNFELS WITH THE METAMORPHIC FACIES OF TURNER AND VERHOOGEN (1960)

REG. NO.	ASSEMBLAGE	METAMORPHIC FACIES
R65071687	Diopside-garnet-idocrase-wollastonite-calcite	Pyroxene-hornfels
R65071688	Diopside-garnet-wollastonite-calcite	Pyroxene-hornfels
R65071689	Diopside-idocrase-brucite-diaspore	Hornblende-hornfels
R65071691	Diopside-idocrase-calcite-tremolite-diaspore-feldspar	Transitional Albite-epidote-hornfels and hornblende-hornfels
R65071698	Diopside-garnet-idocrase-calcite-wollastonite-feldspar-quartz	Transitional hornblende-hornfels facies and pyroxene-hornfels facies
R65071699	Diopside-idocrase-calcite-epidote-plagioclase-wollastonite	Transitional hornblende-hornfels facies and pyroxene-hornfels facies
R65071732	Diopside-brucite-calcite	Hornblende-hornfels
R65071696	Diopside-calcite-?	Hornblende-hornfels
R65071694	Diopside-calcite-brucite-feldspar-tremolite-quartz	Transitional albite-epidote-hornfels and hornblende-hornfels
R65071695	Diopside-calcite-feldspar-chlorite-quartz	Transitional albite-epidote-hornfels and hornblende-hornfels

MISCELLANEOUS ROCK SAMPLES

Thirty-two miscellaneous rock samples, both from drill holes in the vicinity of the Astrolabe mines and from natural exposures throughout the Port Moresby-Kemp Welch area, have been identified in thin section and briefly described. The individual results are recorded below.

R.64071629

Basalt

In thin section the rock is seen to be a fine-grained basalt with an intergranular texture. Labradorite laths, pyroxene granules, and green serpentinous material are present in nearly equal proportions. Opaque ores account for several modal percent.

The section reveals a small xenolith of slightly coarser basalt.

Several narrow veins of (?)analcime traverse the section; the mineral is slightly birefringent. A few grains of carbonate are present on the edges of the veins in places.

R.64071630

Porcellanite

The rock is seen to be microcrystalline consisting of particles of low birefringence. The section has a dark patchy appearance under crossed nicols as though some areas of the rock are cemented with an isotropic substance.

The refractive indices of the constituent particles, which are neutral to yellowish in colour, are generally less than balsam.

Grains of pyrite, both euhedral and anhedral are scattered through the rock.

Seams resembling stylolites are common.

The rock is probably a porcellanised lutite. Opaline silica in the rock could explain the apparent low refractive index of the constituent grains.

Porcellanised marls, essentially very finely granular calc-silicate hornfels have been described by Benson (1943) at contacts between dolerite and sedimentary rocks in eastern Otago, so a similar origin for this Astrolabe specimen occurring in a very similar environment seems probable. Tomkeieff (1940) has also described thermally metamorphosed finely crystalline rocks, which he calls porcellanite, associated with dolerite plugs.

R.64071631

Variolitic Basalt

In thin section this rock is seen to be an altered variolitic basalt.

Spherulites and sheafs of feldspar altered to kaolin and calcite about 0.5 mm. in diameter are densely packed. Interstitial to these spherulites are fine-grained clinopyroxene, opaque ores, and green serpentinous material.

Veins of calcite and of epidote traverse the section. Rare vesicles are filled with pale green chlorite.

R.64071632

Sheared Argillite

The rock consists of lithic fragments of variable dimensions, generally rounded, set in a matrix of pennine and very yellow epidote.

Some lithic fragments consist of much epidote and indeterminate clay minerals and iron staining. Other fragments are argillite with epidote granules and minute epidote veins distributed through them.

The rock is a sheared argillite.

R.64071633

Gabbro (locally sheared)

The rock is a medium-grained gabbro consisting of augite, plagioclase, serpentinous pseudomorphs after olivine, and opaque ore (decreasing order of abundance).

The augite is colourless; in places it has cores and partial rims of deep red brown hornblende replacing it. Some uralite is present in a few augite grains.

No olivine is present but there are numerous serpentine pseudomorphs.

The opaque ore is in the form of large skeletal grains and is probably ilmenite or ilmeno-magnetite.

Green chlorite is present in the section but its relationship to other minerals is obscure.

Numerous shear planes traverse the section and within these planes the rock has been reduced to serpentinous minerals, chlorites, clays, and other secondary minerals.

R.64071634

Detrital rocks - Siltstones with tuffaceous additions

The thin section reveals two distinct types of rock which in hand specimen are seen to be involved in slump structures.

One type is very fine-grained detrital rock consisting of tiny laths of clay minerals, tiny fragments of pyroxene, rare areas of carbonate, and other indistinguishable constituents. This rock is a siltstone.

The other type of rock consists of detrital euhedral clinopyroxene grains 0.2 mm in size set in a matrix of fine material indistinguishable from the first rock-type described above. This rock-type has been deposited in the same environment as the associated siltstone but has received abundant additions of fresh pyroxene which has undergone very little apparent transport in view of the lack of attrition. Probably the pyroxene has a tuffaceous origin.

Sparse narrow calcite veins traverse the section.

R.64071635

Basalt

The rock is fine-grained basalt now consisting of colourless clinopyroxene, plagioclase, and green serpentinous material. Opaque ore granules are abundant.

There are numerous amygdules which typically possess an outer layer of chlorite and a core of calcite. The chlorite is frequently in the form of microspherulites. Feldspar laths project into some amygdules.

Some serpentinous pseudomorphs after olivine phenocrysts can be seen; some of these pseudomorphs are in part calcite.

Minor calcite veining and zeolite veining is present.

R.64071636

Calcilutite

In thin section the rock is seen to consist of very fine-grained carbonate with very minor clay.

Veins of medium- to fine-grained calcite up to 2 mm in width traverse the rock section.

R.64071637

Calcareous Siltstone

The rock is an extremely fine grained detrital rock. Some stratification is visible both macroscopically and microscopically; this structure is offset by numerous fractures filled by medium- to fine-grained calcite.

The constituents of the rock are mainly too fine for individual identification but can be seen to be predominantly quartz. About 10% of the rock is carbonate in the form of tiny structureless spheres whose grainsize is slightly larger than that of the other constituents.

The rock appears to be a normal type of siltstone which has received additions of carbonate during deposition by chemical and/or biochemical processes.

R.64071638

Basic lithic tuff

In thin section the rock is seen to be a fine- to medium-grained tuff composed of fine grained volcanic fragments and mineral fragments.

The lithic fragments are generally about 1 mm in size and are composed of labradorite and pyroxene laths set in a variety of fine-grained groundmass material which is frequently rich in tiny magnetite granules. The groundmass is frequently altered to secondary minerals or oxidised to opaque iron rich material. Many fragments are markedly trachytic.

The mineral fragments present are mainly labradorite and pale green clinopyroxene, in approximately equal abundance. In addition there is abundant magnetite, some hematite and rare red basaltic hornblende. An orange-yellow micaceous mineral occurs in moderate abundance but it has not been positively identified. The grains showing the micaceous cleavage have parallel extinction and are length fast; the birefringence is similar to that of chlorite but the mineral is only weakly pleochroic. The mineral could be clinochlore.

R64071639

Crystal tuff

In thin section this rock is seen to consist of fine-grained angular crystal fragments and small volcanic lithic fragments set in a matrix of very fine "dusty" material.

The most abundant mineral fragments are fresh well-twinned plagioclase (sodic labradorite). Fresh, pale-green clinopyroxene is moderately abundant. The pyroxene is optically +ve with a 2V estimated at about 60°. Rare grains of green-brown hornblende are present. Magnetite and hematite granules are common.

Lithic fragments up to 0.5 mm in size constitute about 20% of the rock. These are volcanic fragments composed of plagioclase laths and pyroxene set in a fine-grained crystalline groundmass or less frequently in a glassy groundmass.

There are numerous areas of a platy orange-yellow mineral which could not be identified with any certainty. The mineral is possibly a chlorite but any pleochroism is lacking. Iron staining is observed in parts of the section.

The rock is a basic volcanic tuff.

R.64071640

Basalt

The rock is seen to be a fine-grained basalt with an intergranular to variolitic texture. The minerals present are labradorite and brown augite with minor opaque ores and green interstitial serpentinous material.

R.64071641

Basalt

In thin section the rock is seen to be a strongly porphyritic olivine basalt composed of abundant phenocrysts of strongly zoned plagioclase, brown clinopyroxene, and olivine set in a very fine-grained groundmass of plagioclase, clinopyroxene and magnetite. The phenocrysts are 0.5 to 5 mm in grainsize, whilst the groundmass grains are less than 0.05 mm. The rock is free of secondary alteration other than partial alteration of the rims of olivine phenocrysts to bowlingite.

R.64071642

Basalt

This rock is seen to be a porphyritic basalt with a distinctly trachytic texture. Phenocrysts form 50% of the rock and consist mainly of lightly kaolinised strongly zoned plagioclase laths, with lesser amounts of brown augite prisms and olivine partially or completely pseudomorphed by bowlingite. Phenocrysts range from 0.5 to 1 mm and are set in a groundmass of plagioclase, clinopyroxene, and magnetite less than 0.05 mm in size.

R.64071643

Vesicular Basalt

The rock is a medium- to fine-grained porphyritic, vesicular basalt.

The groundmass and phenocrysts are present in about equal proportions. The most abundant phenocrysts are fresh well-twinned plagioclase laths; these are strongly zoned. Slightly less abundant are pale-green euhedral augite grains; these are nearly all zoned, especially the larger crystals which have a colourless core, surrounded by one or more outer zones of green pyroxene. Most grains have small poikilitic inclusions of plagioclase and ores. The pyroxene is pleochroic through shades of green and yellow-green. In lesser, though appreciable, abundance are striking orange iddingsite pseudomorphs after euhedral olivine phenocrysts. No remnants of surviving olivine were detected.

The groundmass is very fine and consists of plagioclase, opaque ores and clinopyroxene, in that order of abundance.

The section reveals numerous vesicles lined with narrow layers of a radiating fibrous dense-green mineral which has a refractive index less than balsam. Possibly chlorophaeite or montmorillonite. Some vesicles contain a few grains of colourless minerals of low birefringence. These have an RI greater than balsam but cannot be identified with any certainty.

R.64071644

Bauxite

In thin section the rock is seen to consist of brown pisolitic cliachite with gibbsite filling contraction cracks. Very sparse fresh laths of augite and basic plagioclase are present.

R.65071678

Coquinoid Foraminiferal Limestone

In thin section the rock is seen to consist of about 85% foram tests and 10% rounded basalt fragments, set in a little calcite cement. The foram tests are generally unbroken. The basalt fragments are very fine-grained consisting of plagioclase and clinopyroxene with an interstitial yellow-brown mesosfasis. Some fragments consist of sparse phenocrysts of plagioclase set in a groundmass of brownish and greenish devitrification products. The igneous fragments range from 0.5 mm to 4 mm.

Minor components of the rock are siltstone fragments, plagioclase, augite, magnetite and hematite. The siltstone fragments are rounded and range from 0.5 to 1 mm. Very fresh angular plagioclase fragments ranging from 0.1 to 1 mm. and showing strong zoning occur sparsely. Fresh angular augite, hematite and magnetite grains are rare.

R.6507167

Lithic sandstone

This rock is a well sorted lithic sandstone. It is composed of about 50% basalt fragments, 40% pyroxene and plagioclase fragments, and 10% cement. All detrital fragments are rounded to subrounded and their grainsize ranges from 0.1 to 0.5 mm.

The basalt fragments commonly consist of phenocrysts of greenish-yellow augite, plagioclase and magnetite ± iddingsite set in a mesostasis of brown, yellow or reddish material; less commonly they consist of plagioclase and hematite set in a groundmass of fine indeterminate grey material and specks of hematite; rarely they consist of euhedral phenocrysts of red basaltic hornblende set in a groundmass of plagioclase and ores.

The most abundant mineral fragments are fresh yellow-green augite. Slightly less abundant are fresh well-twinned laths of labradorite. Equidimensional grains of magnetite occur commonly, hematite sparsely, and basaltic hornblende rarely.

Some areas of the section have a clear calcite cement with areas as large as 4 mm x 4 mm in optic continuity. A more abundant cement consists of lathlike aggregates of a colourless mineral which has a low relief, low D.R., refractive indices less than balsam, extinction parallel to its one distinct cleavage, and an optically positive figure with a large 2V. These properties are consistent with gypsum.

R.65071680

Calcilutite

In thin section the rock is seen to consist of a brown fine-grained mixture of clay and carbonate. Carbonate predominates. Numerous ovoid and spherical aggregates of clear calcite apparently represent recrystallised foram tests. Several narrow calcite veins traverse the section.

R.65071681

Calcilutite

In thin section the rock is seen to consist dominantly of very finely granular carbonate with a minor amount of clay. Recrystallised calcareous foram (?) tests are distributed sparsely through the rock; these are tiny spheres and ovoid bodies about 0.01 mm in diameter.

R.65071682

Sheared Calcilutite

In thin section the rock is seen to be a fairly pure calcilutite which has undergone shearing and some subsequent recrystallisation to coarse calcite. The rock has abundant iron staining.

R.65071683

Calcilutite

This rock consists of very fine grained carbonate and clays with very minor tiny chips of quartz. Streaks of clay impart a rude stratification to the rock. Calcite veins ranging from 0.005 to 5 mm in width traverse the section.

R.65071685

Calcareous Sandstone

In thin section this rock is seen to consist of well sorted subangular to rounded detrital fragments with a grainsize of about 0.1 mm set in a calcite cement.

Rounded fragments of calcilutite predominate over subangular to subrounded fragments of quartz. Organic carbonate fragments and andesine fragments are the next most abundant constituents. A yellow-green mineral with weak pleochroism is present to the extent of several percent but it is uncertain whether the mineral is a prochlorite or glauconite. The remaining detrital constituents, present in small amounts, are clear granular calcite, siltstone fragments, bleached biotite, muscovite, pale chlorite, and siliceous spherical tests.

A fine-grained calcite cement forms less than 10% of the rock.

R.65071690

Granophyre

The rock consists of micrographic and cryptographic quartz-feldspar intergrowths, feldspar, quartz, serpentinous minerals, calcite, magnetite, and apatite, in decreasing order of abundance.

The feldspar is weathered, rendering difficult the determination of its composition. It appears to consist of both orthoclase and poorly twinned oligoclase but no estimate can be made of the relative proportions of these minerals. In addition to the quartz involved in micrographic intergrowths there are sparse anhedral quartz grains. The other primary minerals present are 1-2% of magnetite and rare small apatite prisms. Streaks of yellow-brown serpentinous minerals occur along fractures and grain boundaries. Local areas of fine-grained clear calcite are disseminated through the rock.

The rock is a medium-grained granophyre.

R.65071692

Lithic Arenite

This lithic arenite is composed of rounded fragments ranging from 0.5-5 mm in size. Mudstone and calcareous mudstone fragments constitute 80% of the rock. Rounded clear calcite fragments, siltstone fragments and volcanic fragments constitute the remainder of the detrital fraction. The volcanic fragments consist of a felt of fine-grained plagioclase, the composition of which cannot be determined.

There is a little interstitial clay and a clear calcite cement. At the time of deposition the mudstone fragments apparently were soft since minor deformation of the fragments has decreased the void space of the rock so that the cement constitutes only about 3% of the total rock.

The section is traversed by fine veins of clear calcite.

R65071693

Lutite

In thin section this rock is seen to consist of a very fine-grained fibrous or platy mineral of low birefringence, presumably a clay mineral. Rare tiny flecks of quartz are present. The rock has fine lamination caused by slight differences in colour of adjacent bands.

The rock is essentially a consolidated pure clay.

R.65071700

Foraminiferal Calcarenite

In thin section this arenite is seen to consist of 50% foram fragments, 20% fine carbonate rock fragments, 5% siltstone fragments, 5% mineral fragments, and 20% fine carbonate matrix.

The foram fragments and carbonate rock fragments are rounded and range from 0.3 - 1 mm in size. The siltstone fragments are rounded and are free of carbonate. The mineral fragments are moderately angular quartz and plagioclase in about equal quantities.

Radiating chlorite is visible filling rare cavities.

R.65071729

Calcilutite

In thin section the rock is seen to be a calcilutite consisting dominantly of fine-grained carbonate with some clay. The rock contains numerous foram (?) tests which are circular or ovoid and 0.01-0.3 mm in size; some are now represented by granular calcite and some by granular or radiating quartz. The rock has fine stratification caused by colour differences in adjacent bands and by differences in the abundance of foram (?) tests.

Irregular veins of calcite traverse the section.

R.65071730

Argillite

In thin section the rock is seen to consist dominantly of very fine grained clay minerals. In addition, there are tiny specks of opaque minerals, sparse calcite rhombs, and some very fine-grained carbonate. The rock is very difficult to scratch and has a hackly fracture so it is correctly termed an argillite.

The rock is traversed by numerous narrow irregular, but subparallel, clear calcite veins.

R.65071731

Calcareous Argillite

In thin section the rock is seen to consist of very fine grained clay and carbonate and abundant calcareous foram(?) tests. The foram(?) tests are now represented by ovoid and spherical tiny areas of granular calcite. There are sparse spheres of even more tiny siliceous tests.

The rock has been sparsely veined with quartz and then with calcite.

The rock is very hard to scratch so the term calcareous argillite seems appropriate.

R.65071733

Foraminiferal Pebble Conglomerate

This rock consists of rounded pebbles of foraminiferal coquinoid limestone and of fine-grained basalt set in a matrix of carbonate-rich mud. The pebbles are generally greater than 3 mm in diameter. The matrix consists of very fine carbonate with lesser amounts of chlorite and indeterminate fine detritus. The proportions of the constituents are about 55% coquinoid limestone, 30% basalt pebbles, and 15% fine calcareous matrix.

Banded Gabbro

The rock is a medium-grained (0.3-3 mm) gabbro with an hypidiomorphic ophitic texture, consisting of about 60% labradorite and 35% pale brown augite arranged in alternating feldspar-rich and pyroxene-rich bands about $\frac{1}{4}$" wide. Both the pyroxene prisms and the feldspar laths have a preferred orientation subparallel to the banding.

Sparse skeletal plates of opaque ore about 1 mm wide by 0.3 mm thick are present. Rare olivine relics occur associated with aggregates of deep green serpentine, chlorite, and secondary magnetite. Flecks of brown hornblende partly replace some pyroxene grains.

Some areas of plagioclase show moderate fracturing and granulation.

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REFERENCES

BENSON, W.N., 1943 - The basic igneous rocks of eastern Otago and their tectonic environment. Part IV. The mid-Tertiary basalts, tholeiites and dolerites of north-eastern Otago. Section A : Distribution and geological occurrence. Trans.Roy.Soc. New Zealand, vol. 73.

_____, 1944 - Idem. Section B. Petrology with special reference to the crystallisation of pyroxene. Trans.Roy.Soc. New Zealand, vol. 74.

HOTZ, P.E., 1953 - Petrology of granophyre in diabase near Dillsburg, Pennsylvania. Geol.Soc.Amer.Bull., 64, p. 636.

KERR, P.F., 1959 - Optical Mineralogy. 3rd Ed. McGraw-Hill. New York.

TOMKEIEFF, S.I., 1940 - The dolerite plugs of Tieveragh and Tievebulliagh near Cushendall, Co. Antrim, with a note on buchite. Geol.Mag., 77, 54-64.

TURNER, F.J., and VERHOOGEN, J., 1960 - Igneous and Metamorphic Petrology. 2nd Ed. McGraw Hill. New York.

WALKER, F., VINCENT, H.C.G., and MITCHELL, R.L., 1952 - The Chemistry and Mineralogy of the Kinkell Tholeiite, Stirlingshire. Min. Mag., 29, 895-908.

YATES, K.R., and de FERRANTI, R.Z., 1965 - Geology and mineral deposits of Port Moresby-Kamp Welch Area, Papua. Bur.Min.Resour.Aust.Rec. 1965/161 (unpubl.)