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# THE GEOLOGY OF THE TRIAL HARBOUR DISTRICT

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(With 2 plates and 4 text figures.)

## ABSTRACT

A Devonian (?) granite complex intrudes Cambrian (?) volcanics, serpentinised dunite (olivine $Fo_{94}$), and siltstones and quartzites of the Precambrian (?) Oonah Quartzite and Slate and the Silurian Crotty Quartzite and Amber Slate Formations. The general trends of these country rocks are parallel to the granite margins.

The complex is composed of grey, pink and white granites all with the same mineralogical composition (quartz, orthoclase dominant, plagioclase subordinate). The white granite commonly contains tourmaline nodular segregations. Emplacement began with the pink and grey granites, followed closely by the white granite, and finally the intrusion of minor bodies (porphyritic aplite, micro-granite, aplite, pegmatite, quartz-tourmaline dykes, pyroxene dyke). Tourmaline is abundant in the later intrusions and is sometimes accompanied by cassiterite.

## INTRODUCTION

This report describes the results of geological mapping in the Trial Harbour district Western Tasmania, culminating in a laboratory investigation of the rock and mineral types of the area. This involved study of the granite types and their interrelationships, and the metamorphic effect of the granite on the country rocks, and in the course of this study X-ray and optical means were used where possible to indicate the compositions of important minerals. This paper deals with the general geology; the metamorphism will be described in another paper.

The accompanying map of the district (fig. 1) is on a scale of 40 chains to the inch, and extends north-west from Trial Harbour as far as South Gap Creek, inland to the Cumberland Lake and the Mayne's Mine and south to the Little Henty River. The geology was plotted on an enlargement of a contour map of the State Aerial Survey, Zeehan Sheet C (40 chains to the inch) (Topographical Series 1st Edition, reference T 40/50c/1).

As it is situated on the coast, in the path of the westerlies, the district is subjected to boisterous weather, with a high rainfall. Vegetation consists mainly of button grass covering the granite, Precambrian (?) and Silurian rocks, but thick rain forest occurs in sheltered valleys and on the slopes of the Heemskirk Range. The dunite supports an open, stunted scrub flora, but the Cambrian (?) volcanics are covered by a luxuriant rain forest. Consequently inland outcrop of the volcanics is poor except for ridges exposed by bush fire and rocks exposed in Pykes' Creek. Pebble outcrop of weathered Precambrian (?) rocks, dunite, Silurian rocks and rounded granite boulders in situ provide suitable means of mapping boundaries of these rock types inland. Vegetation and soil colour changes often can be used as guides to the rock type (e.g., dark red soil on dunite, red soil on Cambrian (?) volcanics, grey soil on Precambrian (?) rocks and granite).

Outcrop along the coast line strip is about 20-100 yds wide and nearly continuous, apart from occasional sandy or pebble beaches, and except for the dunite, the rocks are usually only slightly weathered.

### Previous Literature

The earliest literature describing the geology of the Trial Harbour area was concerned with the economic aspects of the tin mineralization accompanying the granite intrusion (Twelvetrees 1900, Waller 1902, Waller and Hogg 1903), but Waterhouse (1916) reported in great detail on both the economic geology and the petrology of the granite types and country rocks. He discussed the metamorphic aureole, placing emphasis on the abundance of calc-silicate rocks, which he believed to be of metamorphic origin. Waterhouse also considered that the igneous rocks all formed part of one major phase of activity beginning with the intrusion of the gabbro-dunite suite and concluding with the granite complex.

In 1962 Blissett briefly described the geology of the area, based mainly on Waterhouse's report, but he also revised the age relationships of the rocks and applied recent stratigraphic terminology considered to be in accord with geological data from other parts of Tasmania.

Additional literature related to the Trial Harbour district involves mineralogical description connected with tin or nickel mineralization (Edwards 1953, Williams 1958).

## PHYSIOGRAPHY

The Trial Harbour area consists of two major physiographical units. These are the coastal plain which reaches a width of 1½ miles and follows the north-westerly-south-easterly trend of the coastline and the Heemskirk-Agnew mountain range which forms the north-eastern margin of the area.

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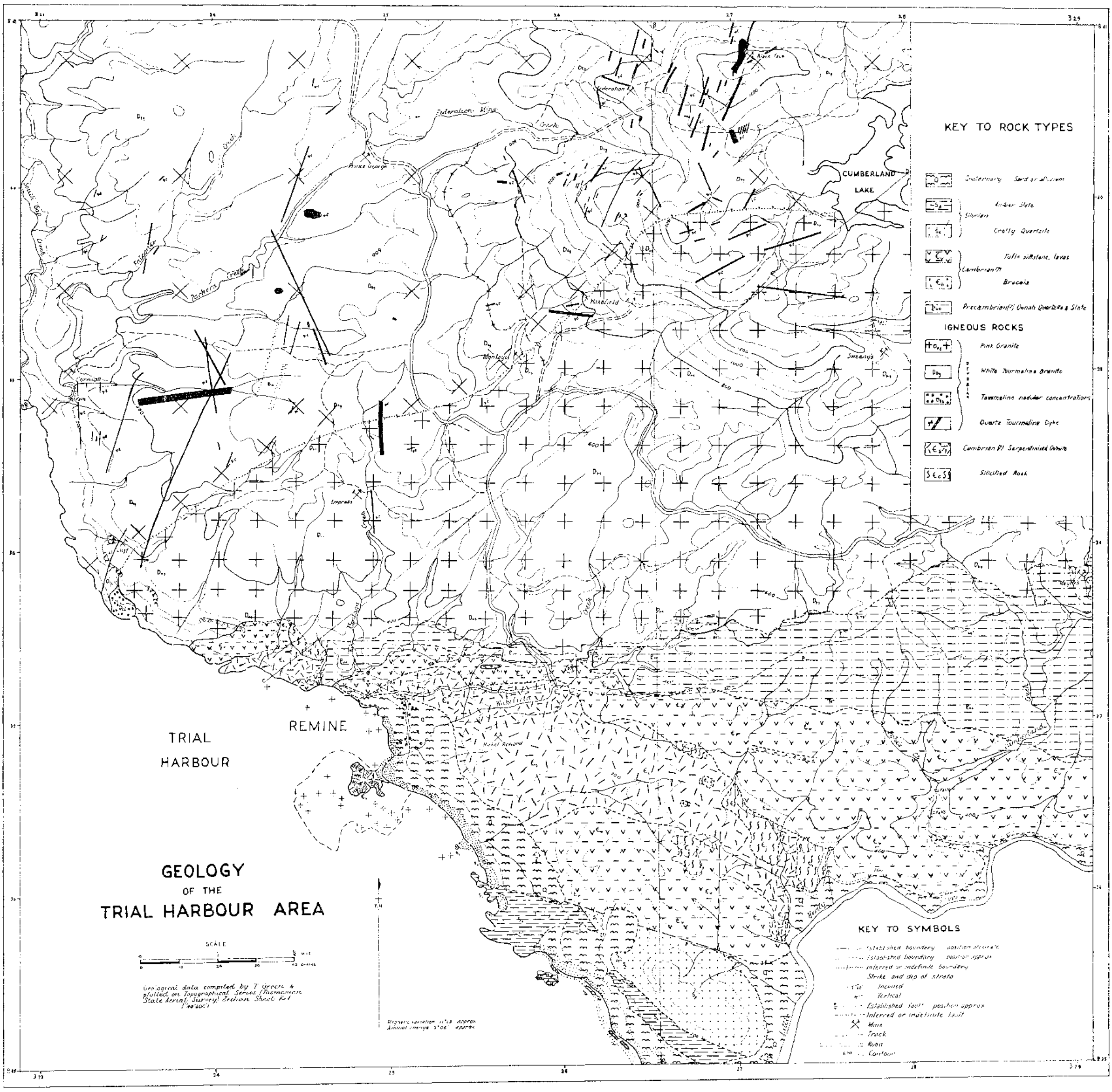


FIG. 1.—Geological Map of the Trial Harbour Area.

The altitude of the coastal plain ranges from about 300′ at the top of the coastline cliffs to 650′ at the base of the Heemskirk Range. This corresponds to the lower coastal surface of Davies (1959). A range of hills between the plain and the main part of the Heemskirk Range has concordant summits 1300′-1600′ high and may be an expression of the higher coastal surface, while the Heemskirk Range (2200′-2500′) possibly reflects the St. Clair surface, with Mt. Agnew (2700′) standing slightly above this level.

Drainage of the area is dominated by the Little Henty River, as its tributaries extend as far north as the Cumberland Dam. The north-western part of the area has a characteristic trellis drainage pattern, governed by jointing in the granite. These streams are short, flowing directly from the Heemskirk Range into the sea. Faulting in the southern part of the area governs the direction of some small streams.

TABLE 1

*Summary of the Stratigraphy in the Trial Harbour Area*

| System | Formation or Rock Type | Thickness (approx.) |
| --- | --- | --- |
| 4. Quaternary | Dunes, alluvium, gravels | |
| 3. Silurian | Amber Slate<br>Crotty Quartzite | 1200′ +<br>1100′ + |
| 2. Cambrian(?) | Siltstones, tuffs or tuffaceous sub-greywackes and tuffaceous siltstones, volcanic breccia lavas | 2500′ + |
| 1. Precambrian(?) | Volcanics(?)<br>Oonah Quartzite and Slate | 2400′ + |

At least two and possibly three old shorelines are evident along the coastline:

(*a*) 12′-18′ above sea level illustrated by concordant topped ridges and benched cliffs 1½ miles north-west of Remine.

(*b*) 25′-30′ above sea level. This is not well developed; slight flattening of seaward slopes occur at this level north-west of Remine and about ⅓ mile south-east of Remine (300 yards inland) a gravel deposit about 30′ above sea level is evident. Pebbles of Owen Conglomerate are present in this gravel.

(*c*) 40′-60′ above sea level reflected by isolated benches north-west of Remine and a possible raised beach dune at the mutton bird rookery one mile north-west of Remine.

Weathering of the granite produces characteristic rounded landforms and frequent isolated tors (e.g., Pulpit Rock).

## STRATIGRAPHY

Owing to the limited occurrence of the stratigraphic horizons never far distant from the granite contact, it is difficult to obtain completely unmetamorphosed rocks for comparison with similar sediments from other areas. However the Cambrian(?) volcanic sediments and the Silurian sediments in the southern part of fig. 1 are only slightly metamorphosed.

The thicknesses given are very approximate and were determined assuming no repetition of beds by folding or unobserved faulting.

### 1. PRECAMBRIAN(?)

**Oonah Quartzite and Slate**

Rocks of this unit crop out between the granite contact and the Cambrian(?) volcanics and extend in a band from the mouth of Montagu Creek inland with an easterly trend to the eastern limit of the area (see fig. 1) and can be traced continuously to the type area (Blissett 1962, Spry 1958).

In the Trial Harbour area it is composed of interbedded sandstones, sub-greywackes and siltstones. The coarser grained beds range from one inch to several feet in thickness but the siltstones are thinly bedded (¼″-2″). Sandstones grade into sub-greywackes with increasing matrix (sericite) component (e.g. specimens 31922*, 31923, 31924 grade from a recrystallized(?) sandstone containing over 90% quartz such as specimen 31922 to a sub-greywacke such as specimen 31924 containing only about 60% quartz). The normal grainsize of the quartz is 0.2-0.5 mm. but it ranges from 0.01 to 1 mm. so that the sorting is poor. The matrix consists of developing shreds of sericite, and these tend to obscure the margin of the quartz grains. Some quartz may be recrystallized but separate grains in the sericitic matrix are probably relict clastic grains and these vary from sub-angular to sub-rounded, with moderate sphericity.

The siltstones frequently show banding in thin section and usually consist of shred-like sericite with a subordinate quartz component. Quartz grains may reach 0.2 mm. in size (specimens 31925, 31926).

Tourmaline, as pale yellow-brown grains, is a common accessory in the Precambrian(?) rocks.

Quartz and black tourmaline veins commonly cut the Precambrian strata.

**Volcanics (?)**

Rocks with the appearance of metamorphosed amygdaloidal lavas or "bile-bean" rocks occur in Montagu Creek about 100 yds from the mouth. These rocks, together with thin pale green basic banded rocks, are interbedded with quartzites and slates similar to the Oonah Quartzite and Slate. They occur to the northern (i.e., Precambrian(?)) side of the suspected irregular contact between the Precambrian(?) and Cambrian(?) rocks exposed at the mouth of Montagu Creek (see page 17). Hence they are considered to be Precambrian(?). Similar pale green basic bands have been observed in about the same stratigraphic position relative to the approximate Precambrian(?)/Cambrian(?) boundary further inland.

These rocks could not be obtained unmetamorphosed. They are tentatively considered to be volcanic because of the amygdale-like structures, and the basic composition of the mineral assemblages resulting from metamorphism.

* Numbers refer to the catalogue in the Geology Department, University of Tasmania.

A comparison can be made between these rocks and the Montana Melaphyre Volcanics at Zeehan. Blissett (1962) considers the Montana Volcanics as part of the Oonah Quartzite and Slate. Both these volcanic suites occur near the boundary between Precambrian(?) Oonah Quartzite and Slate and overlying Cambrian(?) formations, but the original definition of the Oonah Formation does not include volcanic rocks (Spry 1958).

2. CAMBRIAN(?)

Volcanic sediments, interbedded lavas and siltstones occur in contact with granite on the coast, are present inland south of the Precambrian(?) rocks and completely surround the serpentinised dunite. In the south-western part of the area Cambrian(?) formations are in faulted contact with Silurian strata.

These formations are termed Cambrian(?) only because of probable similarity with other Tasmanian basic volcanic suites forming part of the Cambrian System (e.g., Waratah, Ulverstone, Smithton and King Island) (Banks 1962). Blissett (1962) records the occurrence of a trilobite on a ridge ½ mile south-east of the Little Henty River and 2 miles south-east of Trial Harbour and correlates the host rock with the Dundas Group. However it is not known whether this trilobite bearing formation is part of the same Cambrian(?) succession as the Trial Harbour volcanic suite and Blissett correlates the Cambrian(?) rocks at Trial Harbour with the Crimson Creek Group. The writer prefers not to attempt such a correlation until more is known about the relative stratigraphic positions of the Oonah Quartzite and Slate, the Crimson Creek Group and the Dundas Group in Western Tasmania and until the nature of the contact between the Oonah Quartzite and Slate and the Cambrian(?) volcanics is resolved (this does not seem possible in the Trial Harbour district) (see p. 17).

*(a) Siltstones and Slates*

Thinly bedded, laminated, pink siltstones crop out in a road cutting half a mile from Trial Harbour and on the shore platform at the mouth of Montagu Creek. The beds vary from ⅛″-1½″ in thickness and are near vertical with a strike of 60°.

Black slates occur near the southern margin of the dunite and in a small cliff above the Little Henty River three-quarters of a mile from the shore-line. They are associated with tuffs and tuffaceous sub-greywackes but form the dominant rock type for about 900′ south of the dunite margin and then become subordinate to the coarser sediments which extend to the fault contact with the Silurian strata. In scattered places abundant quartz veining and silicification of the slates has occurred and several prospect trenches have been dug in these localities. These black rocks are distinguishable from the dark fine grained hornfels near the granite and the diopside rock because of a prominent fissility. It is not known whether some of the hornfelses are metamorphic equivalents of these rocks nor can it be determined (without chemical analyses) whether these rocks have a volcanic component and grade into tuffaceous siltstones.

*(b) Tuffs*

The best outcrops of these rocks in an unmetamorphosed state occur to the south of the Cambrian(?) slates and are in faulted contact with the Crotty Quartzite (fig. 1). Tuffs are also exposed in Pyke's Creek about half a mile from the Little Henty River (specimens 31927, 31928, 31929, 31930, 31931, 31932, 31933).

The rocks vary from dense, dark grey types with occasional white or grey fragments representing chert, quartz or feldspar to pale grey or red-brown (iron stained) types. The fragments range up to 2 cm. in size and are usually sub-angular, but rounded particles are also present (specimen 31931).

An examination of the thin sections shows that these rocks are composed of 60-85% irresolvable matrix and 10-40% clastic quartz, feldspar and rock fragments. Specimen 31928 is slightly metamorphosed and biotite, opaques and actinolite can be identified in the matrix. The matrix of all these rocks is probably volcanic in origin (although without analyses this is uncertain) so that the rocks are termed tuffs, with a subordinate clastic non-volcanic component (non-volcanic quartz and composite quartz fragments). Since specimen 31933 is composed of about 25% lithic fragments it is more accurately termed a lithic tuff. Thin bands of opaques or thin bands of the irresolvable material are frequently visible in the groundmass of the slides (e.g., 31933, 31929).

Quartz varies from 10-30% of the rock and has a grainsize from minute to 1 mm. It occurs as discrete crystals or composite quartz fragments of chert or quartzite, which show microsuturing and undulose extinction of their component grains. The rock fragments have moderate sphericity and are sub-angular-sub-rounded. Two types of single quartz crystals are evident—

(*a*) grains with straight margins apart from marked embayments, sometimes occurring as rhombs or hexagonal prisms (specimen 31928). These represent quartz of volcanic origin, have varying sphericity and are usually angular.

(*b*) grains which are rounded and have moderate-high sphericity. These two types suggest a bimodal origin for the quartz—some from a volcanic region and some derived from a sedimentary or metamorphic source.

Plagioclase is evident as sub-angular grains up to 0.8 mm. in size and it has moderate sphericity. Its composition cannot be determined reliably but it is probably andesine. Since the feldspar is no more rounded than the volcanic quartz, it is probable that transport from the volcanic source to the area of deposition was rapid. This is borne out by the ferromagnesian rock fragments which are also sub-angular to sub-rounded, similar to the more resistant volcanic quartz grains. The rock fragments reach 3 mm in size and are composed of aggregates of either amphibole or chlorite crystals. Some show banded structures produced by alignment of opaque minerals. In specimen 31929 rare crystals of possibly detrital pyroxene(?) are evident.

Accessory minerals present in the tuffs include opaques (magnetite, pyrite and ilmenite), rutile, apatite and tourmaline.

Some suggestions regarding the possible origin of these rocks can be made from the foregoing observations. The volcanic components of the sediments were transported rapidly from the volcanic source area to a nearby depositional environment where they were deposited after little or no reworking. Fine volcanic dust, larger volcanic lithic fragments, feldspar, volcanic quartz and opaque minerals were intermixed with no apparent sorting. Quartz grains and composite quartz fragments derived from a reworked sedimentary or a metamorphic source area were also carried into the depositional environment and mixed with the volcanic components. The flow-type structures of opaques and sometimes the irresolvable matrix may have developed as the result of movement of the fine grained material during consolidation.

*(e) Breccia*

A breccia bed 60′ wide crops out in thick scrub 1¼ miles east of Remine (see fig. 1). It cannot be traced for more than about a quarter of a mile.

It is poorly sorted, consisting of angular-rounded fragments from 1 mm.-5 cm. in size set in a green (actinolitic) matrix (specimen 31934). The matrix comprises 50-60% of the rock. The rock has an open framework and the fragments have a low sphericity. Most of these fragments are quartz or chert but actinolite, and one case granitic, fragments have been observed. The rock has been metamorphosed and the development of the actinolite matrix suggests that the original sediment had a considerable basic volcanic component, so that it could be termed a volcanic breccia, although portions of the bed occur which have a sand or silt-rich matrix. Graded bedding is evident, suggesting that the top of the near vertical breccia bed is to the south. The different proportions of actinolitic and silt matrix probably reflect variations in the amount of volcanic activity in the depositional area.

*(d) Lavas*

Bodies, possibly interbedded lava flows, occur in the Cambrian(?) volcanics on the shoreline near the mouth of Montagu Creek (see p. 6).

3. SILURIAN

Silurian rocks are exposed in the south-western corner of the area, where a hill of Crotty Quartzite occurs and Amber Slate crops out on the shoreline from ½-1½ miles south of Remine.

**Crotty Quartzite** Specimen 31936

This formation is composed mainly of massively bedded pale grey pebbly sandstone but purple sandstones also occur (specimen 31935). This sandstone is very well sorted (quartz grains range from 0.1-0.8 mm. in size). The larger quartz grains tend to be well rounded with a moderate to high sphericity, but the small grains are usually subangular to sub-rounded with a low to moderate sphericity. A few grains are composite with undulose extinction suggesting a metamorphic origin. Minor muscovite and accessory apatite, zircon, tourmaline and opaque minerals are also evident.

The pebbles in the grey pebbly sandstone are usually sub-rounded with a moderate sphericity and may reach 1.5 cm. in size. They are enclosed in a sand grade matrix and have an open framework. Rounded depressions common in the rock possibly represent brachiopod moulds. Coarse cross bedding is also evident in this formation.

This formation passes gradually into a series of thinly bedded siltstones which contain *Tentaculites*. The presence of *Tentaculites* suggests that the siltstones belong to the Amber Slate (Blissett 1962) so that the conformably underlying sandstone is the Crotty Quartzite (from the Eldon Group succession defined by Gill and Banks 1950).

**Amber Slate**

The rocks of this formation strike consistently at 100°-125° and dip steeply both to the north and to the south, although minor folding occurs, especially in the north-western part of the coastline outcrop.

This formation consists of thinly bedded purple brown or grey siltstones, cherty siltstones, calcareous siltstones and more coarsely bedded quartzite. The siltstone beds are usually ½″-3″ thick while the quartzite beds reach 12 feet. The quartzites are pale green or yellow and frequently show well developed cross bedding. Lateral variation between quartzite and siltstone may be rapid so that a quartzite bed may change abruptly in thickness or be split into thinner quartzite beds separated by siltstone horizons. In spite of this variation, the quartzites, especially those with cross bedding, provide useful marker horizons along the coast. Some of the coarser calc-silicate bands can also be used as marker beds.

Metamorphism by the granite has resulted in baking of the siltstones and development of calc-silicate hornfels from the calcareous bands. The preferential weathering of the calcareous bands and lenses has given rise to well developed honeycomb weathering.

Fossils are present, but metamorphism has obscured much of the fossil evidence, destroying the finer detail, but strongly ribbed brachiopods, gastropods and crinoid stems are evident. *Tentaculites* is plentiful on some bedding planes.

*Sedimentary Structures*

Sedimentary structures are common in interbedded coarse and fine siltstones on the coastline outcrop 1 mile south-east of Remine. These structures include scours of coarse siltstone in fine siltstone (plate I, fig. 1), intrastratal flow in coarse siltstone, roll structure of coarse siltstone in fine siltstone, and a "pull-apart" structure.

Two hundred yards north-west of these structures the best developed cross bedding is exposed (plate I, fig. 2) and nearby parallel grooves are evident on the bedding planes of the thinly bedded siltstones. These extend over distances of 50′; the origin of this feature is unknown, but it appears to be a relict lineament accentuated by weathering.

Boudin-like structures consisting of quartzite boudins enclosed in siltstone also occur. It is not certain whether they have a sedimentary or structural origin. The presence of possible tensional cross fractures in the " neck " zone suggests a structural origin.

The truncated current bedding and the scour structures indicate that the beds face to the south-west. Hence the Amber Slate is slightly overturned for the north-western part (about a mile) of the coastal outcrop but swings over to the right-way-up for the south-eastern part (about a third of a mile) of the outcrop. The cross bedding also suggests that the depositional currents giving rise to the cross bedded quartzite came from the south-eastern quadrant.

4. QUATERNARY

The Quaternary System is represented in the area by river alluvium, dunes and gravels. Alluvium ocurs along the margins of the Little Henty River and on marshy flats where small streams flow onto low lying areas behind sand-dunes between Remine and the Little Henty River.

Sand-dunes up to 30′ high occur extensively between Remine and the Little Henty River, attaining their maximum development at the northern end of Ocean Beach where they extend inland for about a quarter of a mile.

Gravels are best exposed on the coastline near the mouth of Montagu Creek where a section 8′ thick of interbedded fine sands, grit and coarse gravels is present. These are probably deposits from Montagu Creek later eroded by the sea. They are unlike any of the beach deposits now forming.

Serpentine conglomerates, pebbles of serpentinite cemented by iron minerals precipitated from iron-rich solutions derived from the serpentinised dunite, are well exposed on the coastline ¼ mile south of Remine after storms have washed away a beach sand covering. Local development of similar conglomerates is common on the surface of the serpentinised dunite further inland.

## IGNEOUS ROCKS

There have been two major phases of igneous activity in the area. These phases and the rocks they produced can be summarised as follows:—

1. Cambrian(?)—
   (*a*) Basic volcanic rocks (extrusions and a minor intrusion)
   (*b*) Basic—ultabasic intrusive complex,
2. Devonian—
   Intrusive granitic complex.

### Cambrian (?) Igneous Rocks

*(a) Volcanic Suite*

Dense, black or dark green, crystalline rocks thought to be basic lava flows occur interbedded with thinly bedded siltstones on the shoreline near the mouth of Montagu Creek. The lavas are considered to be Cambrian(?) in age because the host rocks may be correlated on lithological grounds with similar rocks of Cambrian age (page 4).

The basic masses vary from 1′ to 6′ in thickness. No minerals can be identified in the hand specimen (31980) but a thin section shows that it consists mainly of lath-like feldspar crystals 0.2-0.5 mm. in size and granoblastic pryoxene crystals 0.05-0.1 mm. in size. The presence of lath-like feldspar crystals, in contrast to the usual development of granoblastic feldspar in the metamorphic aureole, suggests an igneous origin for the rock.

Another possible basic mass of igneous origin within the Cambrian sediments occurs on the shoreline near the granite contact north of Remine; it is about 6′ wide and traceable for 50′. However, it is entirely recrystallised by thermal metamorphism (except perhaps for a small olivine lens) to basic and ultrabasic hornfelses and no relict igneous textures have been observed, either macro- or microscopically. It appears to cut across banding which is possibly relict bedding in the surrounding hornfels.

A small basic dyke 4″ wide is exposed on the shore platform only about 40′ from the granite contact. It is not visibly connected with the granite mass and is cut by pyroxene veins. The dyke rock weathers to a red-brown colour but is grey on fresh surfaces. White phenocrysts of plagioclase ($Ab_{45}$) laths up to 3 mm. in size are present in a metamorphic groundmass mosaic of biotite, hypersthene and opaques (plate I, fig. 3).

*(b) Intrusive Suite*

This suite is composed of a serpentinised dunite and a hornblende gabbro. The main gabbro mass does not occur within the area mapped (fig. 1) but a brief description is given because of its probable close relationship with the dunite. This gabbro-serpentinised dunite association is similar to basic-ultrabasic complexes described from Bald Hill, Beaconsfield, and Melba Flat-Ring River areas (Twelvetrees 1913, Reid 1923, Taylor 1955, Green 1959 and Blissett 1962).

Because of the similarity in petrology and composition, the basic-ultrabasic associations of intrusive rocks in Tasmania are considered to have originated initially during the same period of igneous activity. Serpentinite-pebble conglomerates in Upper Cambrian rocks at Adamsfield (Carey and Banks 1954) and chromite grains in Lower Ordovician rocks at Queenstown (Wade and Solomon 1958) and Beaconsfield (Green 1959) suggest that the complexes are pre-Ordovician intrusions; and since also they all occur in rocks of Precambrian or Cambrian age (Taylor 1955), the accepted date of intrusion of the ultrabasic-basic rocks of Tasmania is Cambrian. Banks (1962) proposes a Dresbachian age. Tectonic reintrusion of serpentinite acting as a rheid during orogeny could have occurred during the Devonian Tabberabberan Orogeny, subsequent to the initial intrusion, so that ultrabasic intrusives in post-Cambrian rocks are possible. However the dunite at Trial Harbour only occurs in rocks of Cambrian(?) age and does not intrude younger rocks (e.g., Silurian Crotty Quartzite and Amber Slate) so that it is considered to be Cambrian in age.

*Serpentinised Dunite*

This crops out as low lying reefs backed by small cliffs around Trial Harbour and extends southwards along the coast for half a mile. It occurs intermittently with Cambrian(?) hornfelses for about half a mile north-west of Remine along the coast, and reaches up to three-quarters of a mile inland. The eastern contact extends as far south as the Little Henty River, following a general south-easterly trend. The northern and part of the southern boundaries follow an east to east-south-east trend inland. Thus the overall shape of the mass, as indicated by the observable margins, is lenticular. The western portion is covered by the sea. Since the length of the body is over four times greater than its width and since the northern and southern contracts are roughly parallel to the strike of the country rocks, while the eastern boundary is discordant, the mass is termed a slightly transgressive sheet.

A diopside rock invariably occurs between the Cambrian(?) hornfelses and the dunite along the northern contact. The southern boundary is poorly exposed but there is no evidence of intervening diopside rock. A direct contact between Cambrian(?) hornfels and dunite was not observed. The southern margins of the dunite show some evidence of shearing, in the form of fine fracturing, but this could not definitely be shown to follow the contact. Some shatter zones probably related to minor faulting are present within the mass, and in one case (spec. 31870) a brecciated serpentine has been cemented by carbonate material. No marginal chilling of the dunite as recorded by Blissett (1962) was observed. The diopside rock obscures possible contact effects of the dunite on the Cambrian(?) rocks; but along the northern contact these Cambrian(?) rocks in contact with the diopside rock are baked and, partially at least, reconstituted. To the south there is some evidence of baking of Cambrian(?) sediments near the serpentinite on the shoreline, but this feature may equally well be attributed to the granite because Silurian sediments to the south are also baked.

The dunite is massive and dark blue when fresh, but weathers to a soft, pale green-brown rock, often with irregular, characteristic resistant crusts, representing magnetite rich patches. Much of the inland surface of the serpentinised dunite is covered by an iron rich gangue, resulting from weathering of abundant magnetite in the mass. Silicified rocks are also common within the dunite.

Small pale-green crystals of olivine with vitreous lustre are occasionally visible with a hand lens in a serpentine-magnetite groundmass. Other minerals visible in the dunite mass are irregular segregations and nodules of magnetite, pholgopite, chlorite, aragonite and antigorite. Veins of fibrous serpentine (chrysotile), magnetite, aragonite, brucite and chalcedony varying from 1 mm. to 10 cm. in size are present. These minerals are probably related to later metamorphism and will be described in detail in another paper. Magnetite is possibly both a primary and secondary mineral. Nickel mineralisation is evident near Remine and heazlewoodite has been identified by X-ray.

*Petrography*

In thin section the dunite is seen to vary in composition from a rock consisting almost entirely of magnetite and olivine with minor serpentine to one with serpentine, olivine and magnetite, or with serpentine and magnetite or to one of almost pure serpentine. No section was observed which showed any evidence of relict pyroxene, so that the term peridotite cannot be used in the sense that infers the presence of pyroxene (Waterhouse 1916, Blissett 1962, Spry 1962). Since olivine is the only relict mineral observed, the rock is referred to as dunite. The most common serpentine texture is a mesh structure (cf. spec. 31868, 31869) which consists of varying proportions of lizardite, ortho- and clino-chrysotile.

In specimen 31871 olivine occurs as interlocking, anhedral crystals. The larger crystals are extensively fractured and are traversed by irregular magnetite and serpentine veins. In the serpentinised examples (31873, 31874, 31875) olivine consistently has a rounded core-like form, frequently replaced or surrounded by magnetite and a carbonate mineral (probably magnesite). These cores reach 1 mm. in size but several grains separated by serpentine mesh texture are often in optical continuity, indicating that they were once part of a larger crystal. The serpentine mesh consists of ribbons of chrysotile of slightly higher relief and stronger birefringence surrounding and traversing central regions of lizardite, which have lower relief and birefringence than the chrysotile.

Talc, chromite, chlorite are minor minerals present.

A tentative paragenetic sequence for the minerals present in the serpentinised dunite can be given as follows:—

(i) Olivine, magnetite, chromite and primary nickel bearing phases.
(ii) Magnetite veins, serpentine, talc and carbonate minerals.
(iii) Carbonate veins, antigorite, chlorite and minor late-forming lizardite-chrysotile.

The compositions of six olivines from the dunite have been determined in terms of the forsterite-fayalite end members (see table 2, specs. 31871, -74, -75, -78, -79, -73).

TABLE 2

*X-ray Determined Composition of Olivines (using Yoder and Sahama's* 1957 *curve)*

| Specimen No. | Olivine $d_{130}$ | Composition | Error |
|---|---|---|---|
| 31871 | 2.768 | $Fo_{97}$ $Fa_3$ | ± 4% |
| 31873 | 2.769 | $Fo_{95}$ $Fa_5$ | ± 4% |
| 31874 | 2.770 | $Fo_{94}$ $Fa_4$ | ± 4% |
| 31875 | 2.788 | $Fo_{70}$ $Fa_{30}$ | ± 4% |
| 31878 | 2.778 | $Fo_{82}$ $Fa_{18}$ | ± 4% |
| 31879 | 2.769 | $Fo_{95}$ $Fa_5$ | ± 4% |

Four of these olivines have a uniformly very high forsterite content indicating that this ultrabasic mass would be classed as an orogenic or alpine type body (cf. Hess 1938, Thayer 1960). However the other two (spec. 31875, 31878) have an anomalously low forsterite content. These anomalous values do not appear to be related to metamorphism by the granite causing possible regeneration of lower temperature more iron-rich olivines, since specimens 31878, 31879 were both obtained near each other and near to the granite contact while specimen 31785 was obtained ½ mile from the granite. In addition to these X-ray determined compositions, a composition of

$Fo_{95}$ $Fa_5$ was obtained for specimen 31871 from refractive index determinations ($\alpha = 1.650 \pm .004$, $\beta = 1.671 \pm .006$, $\gamma = 1.693 \pm .004$). In this case Deer, Howie and Zussman's (1962) determinative curves were used. Finally, as a further check, analyses of 5 relict olivine cores in specimen 13254 (obtained from a locality close to specimen 31875) were carried out using an ARL electron microprobe. The composition of these grains ranged from $Fo_{92}$ $Fa_8$ to $Fo_{99}$ $Fa_1$, with an average composition of $Fo_{95}$ $Fa_5$. Hence the most probable composition of the olivine in the serpentinised dunite is $Fo_{95}$ $Fa_5$.

*The Origin of the Magnetite*

Assuming the primary olivine of the dunite was not zoned with iron rich outer rims surrounding magnesium rich cores, the generally low fayalite content of the relict olivine bears out the proposed occurrence of primary magnetite, since release of iron on serpentinisation of the forsterite rich dunite could not give rise to all the abundant magnetite now present within the ultrabasic mass. This explanation does not agree with results obtained by Bowen and Schairer (1935) for crystallization within the system $MgO$-$FeO$-$SiO_2$. If equilibrium had been maintained throughout, the iron present should have been taken up by crystallization of forsterite-fayalite, rather than crystallization of nearly pure forsterite accompanied by magnetite. If equilibrium was not maintained, then primary crystallization could result in the formation of zoned olivines with forsteritic cores and fayalitic margins. Zoned olivines are frequent in basic volcanic and hypabyssal rocks (Deer, Howie and Zussman 1962, Vol. I p. 23) but the writer has seen no reference to such olivines in dunites.

A second possible alternative if equilibrium was not maintained during the crystallization, is that magmatic segregations of magnetite occurred within the dunitic magma. Later metamorphism by the granite could have then given rise to the present veins and large disseminations of magnetite while the minute disseminated grains may have resulted from the serpentinisation of the olivine. This last suggestion provides the most satisfactory explanation of the observed features of the magnetite and olivine in the serpentinised dunite. Hughes (1958, 1959) has indicated a somewhat similar origin for magnetite deposits in the Tenth Legion and Savage River areas, since he regards these deposits as Cambrian magmatic segregations, but in the case of the Savage River deposits in basic dykes Solomon (1962) favours pre-intrusion concentration and Spry (1962) suggests that the dykes may be older Precambrian.

*Origin of the Dunite*

The high forsterite content of the olivine indicates that the dunite could be classed as an orogenic-type ultrabasic mass. The contact relationship between the Cambrian(?) country rocks and the dunite are confused by the later metamorphic effects of the granite, so that no statement concerning the origin of the dunite can be made.

*Hornblende Gabbro*

Hornblende gabbro crops out on the Zeehan-Trial Harbour Road at McIvor Hill about 6 miles from Zeehan. It varies from pale to dark green and from a fine grained interlocking texture of crystals of hornblende and feldspar less than 1 mm. in size, to a coarse grained gabbroic texture with hornblende and feldspar crystals up to 20 mm. in size. Magnetite is present in irregular aggregates up to 10 mm. across.

Plagioclase feldspar laths observed in thin section reach 2 mm. and are subhedral. The maximum symmetrical extinction of 37° measured indicates a composition of $Ab_{34}$ (i.e., basic labradorite). Hornblende occurs as anhedral crystals 1 mm. in size. It is pleochroic from pale green-bluish green-olive green. Small crystals of hornblende enclosed within larger crystals having a different optical orientation, are common, No evidence of relict pyroxene or of hornblende pseudomorphs after pyroxene were observed. Minor amphibole veins cut across the rocks (31886).

About 1 mile east of Remine a small outcrop of a gabbro-like rock (specimen 31886A) occurs within the dunite mass, near its eastern margin. The chief component minerals are actinolitic hornblende and irregular, cloudy sericite aggregates, but minor amounts of relict augite and plagioclase are also evident. The plagioclase shows relict lath-like form and relict multiple and simple twinning. The pyroxene has simple twinning. Evidence of ophitic relationship between the pyroxene and feldspar is also preserved. Irregular aggregates of semi-opaque material, frequently with very straight edges probably represent the complete alteration of an iron-rich olivine. Other minor alteration products are talc and chlorite. Hence this rock is an altered gabbro, probably initially an olivine gabbro and is the first recorded occurrence of gabbro actually present in contact with the serpentinised dunite in the Trial Harbour area.

**Devonian Igneous Rocks**

The representative Devonian igneous rocks of the area are the various granite types comprising the Heemskirk Granite Complex. This stock-like complex occupies an area of about 35 square miles extending up to 6 miles inland from Granville Harbour in the north to Trial Harbour in the south. The overall shape is semi-circular with the western margin cut off by the sea. The regional trends in the country rocks surrounding the granite are approximately parallel to the granite margins, but the igneous rock cuts across the bedding of the sediments directly in contact with it, so that on a regional scale the granite is roughly concordant but on a small scale it is markedly discordant. The contact itself is vertical (plate I, fig. 4) or else dips steeply towards the country rocks.

Only the south-western corner of the complex has been mapped, but in this small area several different granite types are distinguishable and these have been mapped separately (figs. 1 and 2). The granite complex has been divided into the following types depending on the texture, composition, colour and form (the two major types are the pink granite and white tourmaline granite)—(*a*) grey granite, (*b*) pink granite, (*c*) white tourmaline granite, (*d*) porphyritic aplite, (*e*) grey micro-granite, (*f*) tourmaline nodular aplite, (*g*) aplite, (*h*) pegmatite, (*i*) tourmaline veins, (*j*) quartz-tourmaline dykes, (*k*) pyroxene dyke and veins.

(*a*) *Grey Granite* (Specs. 31896, 31897, 31898, 31899)

The best outcrops of this rock occur at the granite hornfels contact on the shoreline three-quarters of a mile north of Remine. Wherever an actual igneous/sedimentary boundary has been observed, the granite at the contact is this grey type. Pink granite has never been seen directly in contact with the country rock. The maximum width attained by the grey granite is about 100′ on the coast. Isolated patches of this granite within the pink granite have been mapped along the shoreline and a grey granite zone up to 30′ wide occurs between the porphyritic aplite and the pink granite and between the pyroxene dyke (see p. 12) and the pink granite. Thus the grey granite is a marginal phase of the pink granite, appearing in the contact zones of the pink granite with both the country rocks and other granite types. In the road cutting about a quarter of a mile from Remine grey granite containing disseminated molybdenite crops out in contact with quartzites.

The rock is coarse-grained and the chief component minerals are quartz and orthoclase in crystals up to 1 cm. in size. Subordinate plagioclase and biotite are also present. Tourmaline is very rare. Biotite sometimes occurs in concentrations of up to 20% of the rock so that minor variations of the grey granite grade into biotite granite, but in the immediate contact zone (spec. 31900) there is a biotite free area 1-2 cm. wide. There is no distinct chilling of the granite at the contact but a slight general decrease in grainsize from 10 down to 4 mm. occurs.

Microscopically the contact is very irregular, with many tongues of granitic quartz-rich material extending into the country rock (specimen 31899). The most characteristic feature of the thin section of this specimen is the presence of parallel bands of magnetite grains ending abruptly against the granite, indicating that the latter is discordant to relict lithological banding in the country rock (plate I, fig. 5).

The average size of the crystals in the granite is about 1.6 mm. Graphic and myrmekitic intergrowth between quartz and feldspar is present. Both minerals are usually anhedral but some subhedral crystals do occur. Minor small quartz crystals are commonly poikilitically enclosed in larger orthoclase and plagioclase crystals, which are slightly cloudy. The maximum symmetrical extinction of multiple twinning in plagioclase is 16° and the refractive index is greater than balsam so that the composition is Ab$_{66}$ or acid andesine. Biotite in the granite has two forms—

(*a*) Red brown to pale brown pleochroic flakes (0.2 mm.) occurring poikilitically enclosed in quartz and feldspar crystals in the granite in the immediate vicinity of the contact. This biotite is unaltered and is similar to the biotite in the hornfels.

(*b*) Dark brown to pale brown pleochroic subhedral flakes (0.8 mm.) occurring as crystals interlocking with quartz and feldspar. It is commonly partly altered to chlorite and contains minute zircon inclusions with pleochroic haloes.

Acessory zircon crystals with rhombic section in the granite reach 0.2 mm. in size.

The hornfels is composed of a granoblastic mosaic of xenoblastic quartz, feldspar and red-brown biotite crystals 0.1 mm. in size. Minor magnetite and appatite are also evident. The refractive index of the feldspar is greater than balsam and the maximum symmetrical extinction angle of 17° indicates a composition of Ab$_{65}$.

Other specimens of grey granite (31896, 31897, 31898) characteristically contain sagentic quartz The clusters of irregularly oriented needles responsible for this texture tend to be concentrated near chloritised biotite and sometimes near the margins

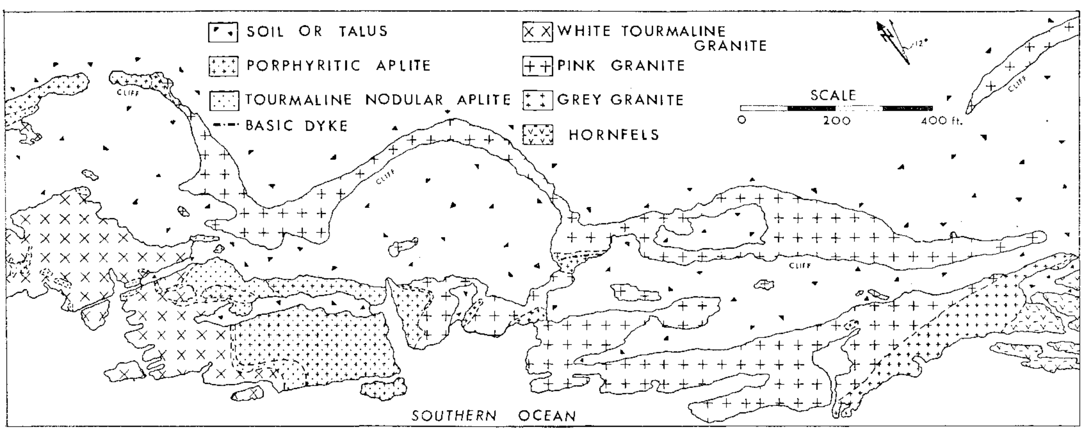


FIG. 2.—Geological Sketch Map of Coastline and Cliff Outcrop 1 mile North-North-West of Trial Harbour, showing Interrelationships of the Granite Types.

of the host quartz crystals. The needles are yellow or dark brown and are probably rutile (or in some cases tourmaline). They sometimes occur in feldspar, tending to be oriented parallel to cleavage directions. The orthoclase is anhedral and usually strongly perthitic, while plagioclase is subhedral-euhedral. The plagioclase is oligoclase in these specimens, contrasting with the andesine in the contact zone. Some of the crystals are zoned and show more strongly sericitized cores surrounded by unaltered rims. Biotite present is pleochroic from dark brown to pale brown. Accessory minerals observed include zircon (often in biotite), apatite, magnetite and sphene.

(*b*) *Pink Granite* (Specs. 31901, 31902, 31903, 31904, 31905)

This rock crops out over the southern part of the granite complex and according to Waterhouse (1916) is the main rock type comprising the Heemskirk Range. It is pink and coarse-grained consisting chiefly of quartz and orthoclase with less important plagioclase and biotite. Black tourmaline is occasionally present.

Biotite occurs in some places concentrated in layers about 1-2 cm. thick and extending up to 100′ with a fairly uniform dip and strike, though sometimes an undulatory effect is supermiposed on the general trend (see plate I, fig. 6). These biotite bands have been observed only within a short distance (440 yds.) of the contact with the porphyritic aplite or the white tourmaline granite.

The best development of the bands occurs within 100 yards of the pink granite margin. The banding present in the porphyritic aplite (see p. 11) is distinct from this biotite banding.

Textural variations range from the normal, granular varieties with a crystal size of 0.5-1.5 cm. (specs. 31901, 31902, 31903) to porphyritic types (specs. 31904, 31905) in which phenocrysts of pink orthoclase up to 1.5 cm. in size occur in an aplitic groundmass with a grainsize of about 0.5 mm. A conspicuous feature of the pink feldspars both in the porphyritic and normal pink granites is a rim of white feldspar commonly surrounding the main part of the crystal. A thin section of specimen 31904 shows that where the orthoclase phenocrysts come into contact with plagioclase a myrmekitic intergrowth between the two develops. The white rims of the orthoclase crystals may thus represent a myrmekitic intergrowth, with white plagioclase developing at the expense of the orthoclase. In specimen 31905 a large lath-like crystal with the form of a subhedral pink orthoclase crystal, is actually seen in the thin section to be composed of interlocking crystals of quartz with minor interstitial orthoclase. This feature suggests that the feldspar is being replaced by quartz. Petrographically the pink granite is identical to the grey granite.

(*c*) *White Tourmaline Granite* (Specs. 31906, 31907, 31908, 31909)

This granite occurs to the north of the pink granite, beginning about one mile north-west of Trial Harbour and extending up the coast to Granville Harbour. It varies from yellow to white and as the name implies tourmaline is an essential accessory mineral (in contrast to the rare tourmaline in the pink and grey granites). This granite type is the host rock for most of the tourmaline and tin bearing bodies in the granite complex (tourmaline nodular intrusions, tourmaline segregations, tourmaline veins, and quartz-tourmaline dykes).

It has a granular texture and the grainsize varies from coarse (spec. 31907) to medium (spec. 31906) but in general it is finer grained than the pink granite since the normal grainsize of the pink granite is 5-15 mm. compared with 1-5 mm. for this granite.

The main component minerals are quartz and orthoclase with minor plagioclase and tourmaline. The tourmaline occurs as disseminated crystals or nodules or as irregular segregations up to two feet in size, in which long tourmaline columns project from the walls into the apparent cavity that the walls surround. Black tourmaline is most common but green, blue and brown varieties have also been observed. Minor accessory minerals also present include biotite, muscovite and fluorite. The two micas occur disseminated throughout the slides examined but the muscovite (and more rarely fluorite) is typically associated with the margins of tourmaline veins and quartz tourmaline dykes since the host granite is usually greisenised by the late intrusions.

In thin section the tourmaline appears interstitial to quartz and feldspar. Frequently the quartz exhibits straight margins against the tourmaline. The pleochroism of the tourmaline is from O = indigo blue to E = pale blue suggesting that it is an iron-bearing tourmaline, schorlite.

(*d*) *Porphyritic Aplite* (Specs. 31910, 31911, 31912, 31913, 31914)

This aplite forms a minor rock type in the granite mass. The best exposure occurs on the shoreline near a mutton bird rookery one mile north-west of Remine. Small outcrops also occur in the Federation Mine area and on the coastal plain, but the exposure is not good enough to map these bodies. The texture and grainsize within the mass is extremely variable ranging from coarse (5-10 mm.) or normal phases of the grey micro-granite (type (*e*) to the normal porphyritic aplite phase in which quartz phenocrysts up to 4 mm. in size occur studded in a medium grain (0.5 mm.) aplitic groundmass.

Macroscopic pegmatitic segregations in the aplite are common and are composed of tourmaline, quartz, feldspar (orthoclase) or biotite. Tourmaline veining is pronounced and greisen zones are associated with these veins (see plate II, fig. 1). Biotite nodules (specs. 31915, 17404) up to six inches across are present, and smaller nodules of a red garnet (spec. 18873), dominantly almandine $Al_{90}$ or $Al_{60}$ $Sp_{40}$), have been identified. Disseminated grains of molybdenite and pyrite also occur in the porphyritic aplite. Tourmaline nodules have developed, but not to the extent observed in the tourmaline nodular aplite.

The porphyritic aplite is light grey when fresh but weathers to a yellow colour. It consists chiefly of quartz and orthoclase with minor amounts of plagioclase, muscovite, tourmaline and biotite.

Thin sections of specimens 31910, 31911, 31912 show contacts between porphyritic aplite and grey micro-granite, and for completeness the petrographic descriptions of both granite types will be given in this section. The contact between the two types is sharp, but very irregular. The essential components of both are quartz, orthoclase, plagioclase and accessory chloritised biotite, muscovite and tourmaline, but the quartz content seems to be higher at the expense of the feldspar, in the porphyritic aplite than in the grey micro-granite.

Porphyritic aplite

Quartz occurs in two forms: as anhedral-subhedral phenocrysts and as anhedral grains only about 0.4 mm. in size commonly enclosed in, or forming myrmekitic intergrowth with, orthoclase. Separated crystals of quartz are frequently in optical continuity. These anhedral quartz grains do not contain minute inclusions, but streams of these inclusions occur in the anhedral-subhedral quartz. The "small crystal" type possibly represents quartz replacing orthoclase. Orthoclase is markedly dusty and the crystals are usually anhedral, though some subhedral forms are present. Plagioclase is strongly sericitized, giving a false impression of moderate relief. It occurs as euhedral-subhedral laths. It is albite. Minor chloritised biotite, shredded muscovite and rare brown tourmaline crystals are also present.

The porphyritic aplite in specimen 31912 appears to have developed from the microgranite by superposition of the aplitic texture on the granitic texture, due to the development of anhedral grains and aggregates of quartz forming a myrmekitic texture at the expense of the feldspar.

Grey Micro-granite

The quartz is clear and colourless and commonly contains streams of minute dark inclusions. The crystals range from 0.5-1.5 mm. in size and are anhedral-subhedral. Orthoclase forms interlocking anhedral-subhedral crystals with quartz; the crystal size varies from 0.5-3 mm. It is very dusty in contrast to the clear quartz and, to a lesser extent, the plagioclase. Simple twinning and perthitic texture are common.

Plagioclase occurs in subhedral-euhedral laths, 0.5 mm.-1 mm. in size, strongly altered to muscovite. It is albite as the relief appears to be less than balsam.

Ragged crystals of chloritised biotite and clear, unaltered crystals of muscovite are common accessories. This muscovite occurs in interstitial aggregates in contrast to the muscovite developed by sericitization of plagioclase.

Banded porphyritic aplite (Specimen 31914)

A characteristic banded aplite occurs at the contact zone between the white tourmaline and the porphyritic aplite (see p. 13 and plate II, fig. 4). Similar banded aplites, accentuated by weathering, are exposed nearby, within the borders of the porphyritic aplite mass (see plate II, fig. 2). The rock is pale yellow beneath a white weathered skin. It is granular with a medium grainsize (0.6 mm.). The banding is formed by grey quartz-muscovite bands ranging from 0.5 to 3 mm. thick varying in spacing.

The quartz generally forms coarse myrmekitic intergrowth with orthoclase, but in the quartz-muscovite bands an intricate semi-reticulate intergrowth between the quartz and muscovite is present. The muscovite is very ragged.

Other variations of rock types in the porphyritic aplite include a greisen (spec. 31913), consisting of quartz (phenocrysts with vacuole streams and clear groundmass crystals) and muscovite.

Biotite nodules (31915) are also characteristic. This specimen consists of a central spherical core composed of plagioclase, biotite and quartz with subordinate muscovite, accessory apatite and subrounded zircon, surrounded by a zone 5 mm. wide which is quartz-orthoclase rich and poor in biotite and plagioclase. This zone is succeeded by a grey micro-granite phase extending irregularly into the porphyritic aplite host rock. The biotite of the central core has the typical pleochroism of the biotite from the contact metamorphic zone O = red brown, E = pale brown) which suggests that the nodule may be a xenolith. The plagioclase is albite.

(*e*) *Grey Micro-granite*

This granite is a minor but distinct textural variation occurring within the porphyritic aplite mass, most commonly developed at the margins of this mass with either the grey granite or the white tourmaline granite. Apart from its occurrence, it is distinguishable from the white tourmaline granite by lack of tourmaline and higher percentage of biotite. It is distinct from the grey granite because of its aplitic texture but some variations are coarse and very similar to the grey granite. The contact between the two is however sharp and planar (see plate I, fig. 6). The detailed description has been given on this page with the porphyritic aplite because the two occur in the same specimens (31910, 31911, 31912).

(*f*) *Tourmaline Nodular Aplite* (plate II, fig. 3)

This body is mapped as a separate granite type because of the abundance of tourmaline nodules contained in it and because it occurs as discrete masses within the white tourmaline granite. The best development of the nodular aplite is attained in the boundary zone between the tourmaline granite and the porphyritic aplite.

The tourmaline nodules range from 1 cm. to 15 cm. in diameter. They usually form remarkable spherical bodies, although in some cases adjacent nodules have joined to produce a "dumb-bell" shape. Black tourmaline, quartz and minor feldspar are the most common component minerals, but occasionally blue and green tourmaline, fluorite and cassiterite occur in the nodules. Due to insufficient time, a detailed investigation of the mineral associations in the nodules could not be carried out, but it is probable that definite associations (such as blue tourmaline, fluorite and cassiterite) occur. Another investigation which could lead to profitable results relating to their origin is a study of the textural relations between quartz and tourmaline. In some nodules tourmaline columns appear to project in sheaf-like aggregates from the centre to the walls of the nodule and the space between columns is filled with quartz, while in other nodules (e.g., spec. 32023) the tourmaline is entirely interstitial to quartz.

Microscopically the aplite, host rock (e.g., spec. 32022) to the nodules, is identical to the specimens of porphyritic aplite described previously, and the tourmaline is similar to the schorlite in the white tourmaline granite so that a detailed description is unnecessary.

*(g) Aplite*

Aplite dykes and veins up to ten feet wide though usually only six inches to three feet wide occur throughout the granite in the area; they are best developed in the pink granite (quartz-tourmaline dykes are more common in the white granite). At one locality an intricate network of crossing and merging aplite veins and dykes crops out.

A stereographic plot of the dips and strikes of all aplite bodies observed is discussed later.

The aplites are typically brown or pink coloured and are medium grained and granular. The usual grainsize is about 0.4 mm. The main component minerals are quartz and orthoclase, but plagioclase and biotite are also present. Chalcopyrite has been observed in one dyke. Aplitic segregations in the pink granite are often associated with the biotite banding and irregular biotite rich patches in the coarse pink granite are usually surrounded by aplitic margins.

Aplites also extend from the granite into the country rock, e.g., on the shoreline near the granite contact several irregular aplitic veins intrude the Cambrian(?) hornfelses. One dyke six feet wide and associated smaller intrusions cuts through the serpentinised dunite on the shoreline. This dyke cannot be traced back to the granite but is presumed to originate from the granitic complex (spec. 31892). This dyke contains a minor amount of weekly pleochroic pale green pyroxene, probably aegirine-augite as well as the normal quartz-feldspar component. The plagioclase has a composition of oligoclase-andesine.

Aplites within the main granite mass (31916, 32024, 32025) contain quartz with abundant vacuoles; occasionally it is sagenitic. Orthoclase and quartz form myrmekitic intergrowths. Plagioclase is euhedral and is albite-oligoclase in composition. Biotite present frequently contains zircon inclusions.

*(h) Pegmatite*

Pegmatite bodies are not abundant in the complex but several small dykes, segregations and pipes have been observed. The essential components are large crystals of orthoclase and quartz up to 6 cm. in size. Plagioclase crystals and columnar aggregates of black tourmaline are also usually present. A typical well developed example of a pegmatite pipe occurs on the shoreline three quarters of a mile north-west of Remine. Pegmatite veins also extend from the granite into the country rocks (spec. 31917).

*(i) Tourmaline Veins*

Black tourmaline veins are most common intruding the white tourmaline granite, but also occur in the pink granite and extend into the country rocks especially the Precambrian(?) slates and quartzites at Mayne's Mine). A stereographic plot of measured veins is given in fig. 3. The veins vary from 1 mm. to 20 mm. in width and are usually bounded by altered granite margins containing abundant muscovite. Quartz is a common associate and accessory cassiterite is also present. Where several of these veins are closely spaced so that the granite between them is entirely altered, the rock type produced is very difficult to distinguish from the quartz-tourmaline dykes, and these two types of bodies cannot always be mapped separately where exposure is not good away from the coastline.

Tourmaline veins (and also the quartz-tourmaline dykes) are late stage features of the granite mass, as they cut across all other bodies. Veins have been observed to cut through tourmaline nodules, sometimes causing relative displacement of the two halves of the nodule.

Ward (1909) and Waterhouse (1916) give a discussion of several quartz-tourmaline dyke and vein types related to cassiterite mineralisation. Due to lack of time the writer has not been able to extend this investigation.

*(j) Quartz-Tourmaline Dykes*

These bodies have been mapped and their dips and strikes plotted stereographically (see fig. 3). The dykes vary in thickness from a few inches up to 30 feet and can be traced for up to half a mile. Tin mineralisation is associated with them and most of the mines or prospects in the area are situated on these bodies. The dykes occur in both the white tourmaline and the pink granites, but are commoner in the former. They appear and disappear abruptly with no apparent change in thickness and so it is impossible to map any displacements due to faulting within the granite using these bodies. The essential component minerals of the dykes are quartz and black tourmaline (blue and green tourmaline varieties occur rarely).

*(k) Basic Veins and Dykes*

Within the pink granite, near the contact with the hornfels on the coast several pyroxene veins 1-5 cm. in width extend roughly parallel to each other across the granite contact and can be traced for several hundred feet in both the granite and the hornfels. These veins cut aplite veins in the granite. They are composed mainly of diopside, but minor sericite, amphibole, axinite and sphene may also occur (spec. 31919). The diopside commonly grows on prismatic crystals perpendicular to the margins of the veins, but in some sections a granoblastic pyroxene mosaic is also evident. The composition is 48% diopside, 52% hedenbergite $\pm$ 2% (optical properties: $2V = 60° \pm 1°$, $Z\ C = 39° \pm 1°$, $\alpha = 1.700 \mp .001$, $\beta = 1.708 \pm .003$, $\gamma = 1.728 \pm .001$). All pyroxene composition estimates have been obtained using determinative curves from Deer, Howie and Zussman (1962; Vol. 2, fig. 22 p. 62). The pyroxene near to the sericite aggregates is altered to actinolite ($x =$ very pale green, $y =$ pale green, $z =$ pale blue-green).

The best development of a basic dyke is exposed in the granite cliff nearly one mile north-west of Remine (plate II, fig. 5). It extends up the cliff face varying in width from a few inches to six feet.

It consists of large dark green euhedral-anhedral pyroxene crystals enclosed in an aplitic groundmass, which in turn is in contact with grey granite merging into normal pink granite. On weathered surfaces the aplite surrounding the pyroxene crystals in the dyke shows peculiar intricate "worm-like" patterns, the cause of which is unknown.

Single crystals of pyroxene may reach 10 cm. in size. In thin section it is pale green (31920, 31921). The composition is 34% diopside, 66% hedenbergite $\pm$ 4% (refractive indices: $\alpha = 1.709 \pm .003$, $\beta = 1.718 \pm .005$, $\gamma = 1.735 \pm .003$). Other minerals present include axinite, sometimes showing comb structure, sphene, apatite and calcite.

The aplitic groundmass to the pyroxene phenocrysts is white and medium grained (0.5-2 mm.). The chief component minerals, quartz, plagioclase, and orthoclase, occur in two distinct forms.

(*a*) Specimen 31918. In this specimen the quartz is frequently embayed and contains many streams of minute inclusions. Crystals 2 mm. in size occur. The feldspar is intensely altered and cloudy and cannot be differentiated into feldspar types. The crystals reach 2 mm. in size, varying from anhedral to subhedral. Accessory minerals in this slide are characteristic:—

Sphene occurs as small anhedral aggregates or as discrete wedge-shaped crystals and is brown.

Apatite is evident as anhedral grains (0.05 mm) with irregular fracturing.

Chlorite is pale green with anomalous blue interference colours and moderate relief. It is interstitial to the feldspar and has a shredded form. The interference figure is negative with a low axial angle.

Fibrous mineral aggregates forming a fan structure occur and are similar to chlorite but have a stronger birefringence than is normal for chlorite. Interstitial carbonate (probably calcite) is present, as well as small brown weakly pleochroic crystals of tourmaline. Finally a colourless, interstitial mineral with moderate relief and strong birefringence has been observed. Some slightly anomalous interference colours are evident. It has a biaxial positive interference figure with a moderate axial angle. It typically occurs in acute-angled sections surrounded by a low birefringent rim. It is probably prehnite pseudomorphing axinite, because axinite often occurs as acute-angled crystals, and is present in the basic dyke (spec. 31921).

(*b*) Specimen 31920. In this slide the groundmass quartz and plagioclase form a granular mosaic (grainsize 0.2 mm.). The plagioclase has a composition of $Ab_{66}$ (andesine). It is clear and unaltered in contrast to strongly sericitized orthoclase and has a weak preferred orientation. Accessory sphene and prehnite are also present. The texture of this groundmass is quite distinct from the texture of an aplite type (*g*) but similar to the quartz-feldspar mosaic of the hornfels.

## Stereographic Investigation of Aplite, Tourmaline and Quartz-Tourmaline Veins or Dykes and Biotite Bands in the Granite Complex

### *Biotite Banding*

Twenty poles to biotite banding in the pink granite are plotted in figure 3. A marked concentration occurs, indicating that most bands strike at about 60° and dip to the south at 25°. This maximum is significantly close to the strike and dip of the planar contact between the porphyritic aplite and the pink granite (the pole of this contact is plotted on the same diagram). This substantiates the proposal that the biotite bands are marginal flow phenomena in the pink granite, possibly induced by the later intrusion of porphyritic aplite (see p. 15).

### *Aplite Veins or Dykes*

One hundred poles to aplitic bodies have been plotted in figure 3. There are three marked concentrations, representing aplite veins with a strike of 68° dip 60° N, and 98° dip 75° N, and 50° dip 25° S. The last set has a similar orientation to the biotite bands and represents aplitic veins or bands which commonly accompany the biotite banding. The other two sets are unrelated to jointing in the granite, in contrast to the later forming tourmaline veins and quartz-tourmaline dykes (see below) and so some factor other than jointing must have governed the orientation of the aplitic intrusions. It would be of interest to determine whether these sets of aplite veins are constant in orientation throughout the complex, or whether variations occur, and the pattern obtained for aplite in the south-western corner of the complex is only a local expression of an overall pattern for the whole complex.

### *Tourmaline Veins and Quartz-Tourmaline Dykes*

Figure 3 shows that the tourmaline veins and the quartz-tourmaline dykes have similar girdle concentrations with a strike of 15° and a near vertical dip. The presence of a well developed girdle maximum is probably slightly exaggerated because in many cases the dips of the bodies could not be determined accurately, but appeared to be very steep. Comparing the concentration of these poles with figure 4 showing a stereographic plot of the poles of 500 joints in the granite, it is evident that the dykes and veins correspond with the weaker of the two girdle concentrations of joint poles. It is not known why these late intrusions should be identical in orientation with one set of joints and not the other, more prominent set.

## Interrelationships of the Granite Types and the Origin of the Complex

At a point (1 mile north-west of Remine) on the shoreline near the southern boundary of the white tourmaline granite, a characteristic banded structure is exposed marking the contact between the white tourmaline granite, the tourmaline nodular aplite and the porphyritic aplite (see plate II, fig. 4). The tourmaline granite passes gradually into the tourmaline nodular aplite due to increasing abundance of nodules and decreasing grainsize, but the nodular aplite passes abruptly into a microgranite phase marking the

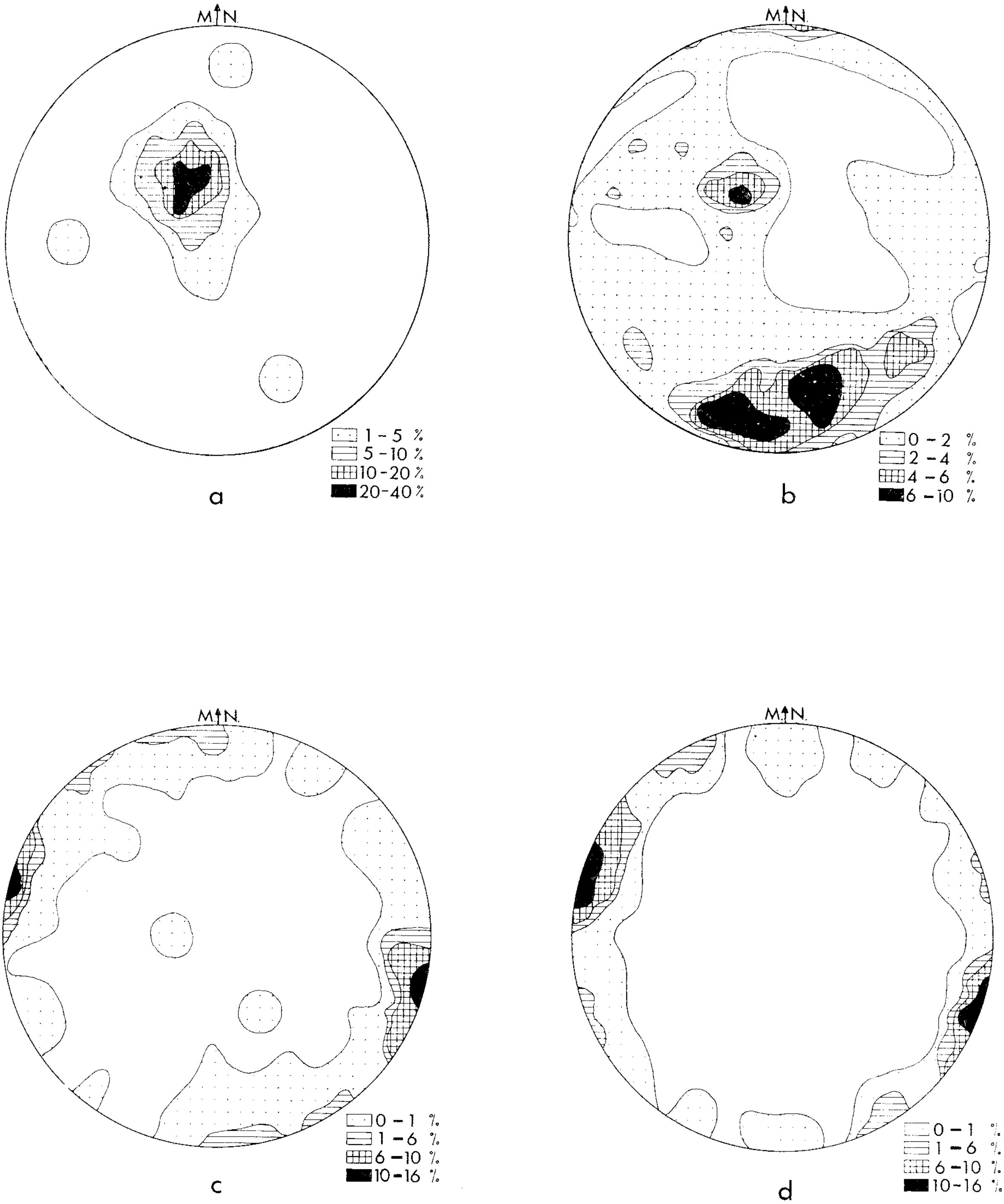


FIG. 3.—Stereographic Plots (lower hemisphere) of—
(*a*) Biotite Banding in the Granite (20 poles).
(*b*) Aplite Veins and Dykes (100 poles).
(*c*) Tourmaline Veins (100 poles).
(*d*) Quartz-tourmaline Dykes (75 poles).

base of the porphyritic aplite. The microgranite passes into a banded aplite and finally into the normal porphyritic aplite.

An actual contact between pink and white granites has not been observed because of poor outcrop. Where rock exposures are good on the shoreline an intervening porphyritic aplite occurs between the two granites. As the aplite cannot be traced away from the coastline, it is not known whether it is merely a local intrusion or if it always occurs as an intermediate rock type between the white and pink granites. The fact that the contact between the porphyritic aplite and the two granites is sharp (e.g., plate II, fig. 1) and not gradational suggests that the aplite is a late intrusion.

There is no definite evidence for chilling at any of the granite/granite contacts. Any grainsize variations that may ocur are also evident in areas away from contact zones and so cannot be considered as contact phenomena. However biotite banding in the pink granite (plate I, fig. 6) and muscovite-quartz bands in the porphyritic aplite are more pronounced in rocks near the contact between these two bodies (plate II, fig 2). The writer considers that this banding is due to flow in the granitic magma during intrusion and is more pronounced near the margins of the intruding bodies where viscous drag in moving magma would be the greatest.

The intrusion of the porphyritic aplite and the white tourmaline granite probably occurred after the intrusion of the pink granite magma, but before the latter mass had cooled, so that no chilling or discordant brecciated structures resulted. The porphyritic aplite and the white granite were separate magmas as the contact between the two is sharp. The banding developed in the aplite is roughly parallel to the contact and suggests relative movement of the two bodies producing flow banding in the still fluid aplite. Thus the writer suggests that the porphyritic aplite magma was later than both the major granite types, and intruded between the white and pink magmas while they were still hot. Volatile-rich segregations in the aplite magma formed tourmaline and quartz patches when the magma crystallized. The quartz phenocrysts possibly represent original quartz crystals suspended in the magma. The presence of almandine or almandine-spessartite nodules in the porphyritic aplite and not in other granite types suggests special conditions existing, at least locally, in the aplite magma allowing the formation of the nodules on crystallization of the magma (Chinner (1962) considers these conditions to be largely compositional). A possible alternative is that these nodules are xenolithic relict fragments of country rock and did not form by igneous crystallization. The xenolithic origin is substantiated by the possible presence of biotite-rich xenoliths in the same mass.

Although the magmas giving rise to the pink and white intrusions had the same bulk composition the later white granite magma had a high content of volatile materials. These volatiles tended to accumulate near the roof of the body, and formed the tourmaline nodular aplite when the mass cooled. This would explain the apparent gradational contact between the tourmaline nodular aplite and the white tourmaline granite described on page 11. Volatile rich segregations throughout the white tourmaline granite magma gave rise to the isolated patches rich in tourmaline nodules and the tourmaline bodies observed.

The last major phase of igneous intrusion in the Heemskirk Complex involved the tourmaline veins and the quartz tourmaline dykes. These were accompanied by greisenization and mineralization. The direction of intrusion of these bodies is related to, and was probably governed by fissuring developed in the granite (fig. 4).

A possible alternative origin for the different granite types in the complex could be argued from a metasomatic viewpoint by attributing the different types to changes taking place in the original pink granite resulting from the activity of volatile rich fluids passing through the granite. The fluids were active just prior to or simultaneously with the intrusion of the tourmaline veins and quartz-tourmaline dykes. However this theory would not explain the sharp contacts observed between the porphyritic aplite and the pink granite shown in plate II, fig. 1, nor could it explain the rarity of tourmaline segregations in pink granite compared with the common occurrence in white granite of disseminated tourmaline segregations free of surrounding alteration of the host rock. This lack of alteration points to actual magmatic crystallization of tourmaline rather than a post-crystallization metasomatic formation of the mineral.

Minor variations within the white tourmaline granite mass are however, explainable by metasomatic activity accompanying the intrusion of tourmaline veins and quartz-tourmaline dykes. The chief result is the replacement of orthoclase by quartz. This is best developed in the porphyritic aplite and the white tourmaline granite where the tourmaline veins are most common.

The grey granite is only a marginal variation of the pink granite and is not a separate intrusion. It is not known why the orthoclase changes colour but two possible explanations are:—

(i) Temperature of formation is governing factor in imparting a pink colour (lower temperature of the margin results in more rapid crystallization and the formation of grey orthoclase).

(ii) Bleaching of the feldspars of the pink granite caused by loss, to the rocks adjoining the margins, of the component imparting the pink colour to the orthoclase.

The clearcut intrusive igneous contact with the country rocks (plate II, fig. 4) indicates that the Heemskirk Complex was a magmatic intrusion, but no marked chilling of the granite margins is evident. Two characteristic features of the country rocks immediately surrounding the granite are the general parallelism of regional trends to the margins of the complex and the fairly consistent dip away from the granite mass. These features provide a possible explanation to the room problem involved in the emplacement of the intrusive magma, since they may reflect a diapiric intrusion of the granite causing an upward bowing of the country rocks and giving rise to the two features described.

An interesting, though very tentative, comparison can be made between the Heemskirk Complex and the Caribou Mountain Pluton, California (Davis 1963). Davis proposed that this pluton was emplaced in the centre of an antiform but that this antiform had developed prior to the granite intrusion. The pluton has a domical form and dominantly concordant contacts; these criteria are consistent with a mesozonal emplacement (Buddington 1959). Davis records no chilling of the granite at the contact.

### Age of the Complex and Relation with other Tasmanian Granites

The Heemskirk Complex is similar petrologically and compositionally to other acid bodies occurring on the west coast, the north-eastern and eastern parts of Tasmania; many of these masses are multiple intrusions. The most abundant rock type in these bodies is a coarse grey granodiorite or adamellite (Spry 1962b). The pink granite of the Heemskirk Complex is not a common type, but is similar to the red Coles Bay Granite which is associated with the normal grey granodiorite. No petrographic evidence was observed suggesting that the granites of the Heemskirk Complex could be metasomatized granodiorites, with microcline replacing plagioclase similar to the granites from Coles Bay and the Pieman Heads (Walker 1957, Spry and Ford 1957). However some of the orthoclase crystals which were termed coarsely perthitic in the petrographic descriptions are similar to structures described by Boone (1962, fig. 10). Boone proposed that these orthoclase-plagioclase composite crystals, generally with plagioclase minor in quantity, represented replacement of plagioclase by orthoclase, but the replacement mechanism forming the same textures in the Heemskirk granite is considered unlikely because:—

(i) closely spaced plagioclase crystals enclosed in a single orthoclase crystals are not in optical continuity;

(ii) large euhedral plagioclase laths occur, but orthoclase crystals are anhedral, rarely subhedral and are not lath-like;

(iii) no intermediate stages of replacement between sericitized but only slightly cloudy large euhedral plagioclase crystals, and extremely cloudy, anhedral orthoclase crystals containing small anhedral plagioclase crystals, have been observed.

Solomon (1962) states that the Tasmanian granitic stocks were intruded following the development of the Tabberabberan structures. The intrusions can be limited stratigraphically to post-Silurian and pre-Permian since Silurian sediments are metamorphosed (p. 5) and Permian sediments rest unconformably on granite in North-East Tasmania (Blissett 1959).

From K:Ar isotope ratio work the Heemskirk Granite has been dated at 338 million years (i.e., Lower Carboniferous) (Evernden and Richards 1961) but C. Brooks (1963 pers. comm.) in later K:Ar work has obtained a date of 351 million years. Davis (1962) obtained a minimum age of 375 million years and a probable age of 391 million years (Middle Devonian) for the Coles Bay granite.

## STRUCTURAL GEOLOGY

The general trends of the country rocks in the Trial Harbour district are 90°-120° approximately parallel to the granite intrusion. Carey (1953) proposed that the Heemskirk Granite occurs in an anticlinal zone, extending north-east through the Meredith and Hampshire Hills Granites. No conclusive evidence for this structure was observed in the small area examined, although possible minor drag folds in the Silurian Amber Slate suggest that the steeply dipping strata are the south-western limb of an anticlinal structure to the north-east.

### Folding

The thinly bedded slates of the Oonah Quartzite and Slate frequently show minor intricate fold structures which are probably related to deformation accompanying the granite intrusion. Outcrop is too poor to enable determination of any definite orientation of these folds.

The Cambrian(?) rocks are generally massive, but where thinly bedded strata occur they have near vertical dip and rarely show minor folding.

The thinly bedded Amber Slate strikes consistently at 110°-120° along the coastline and generally dips steeply to the north-east for the northern half-mile of outcrop, but then swings over and dips steeply to the southwest for the remaining exposures to the south. At the northernmost outcrop and in one locality one and a half miles south of Remine minor folding is prominent and varies from isoclinal to recumbent (see plate II, fig. 6). Minor thickening in the cores occurs and it is probably a combined concentric-similar type of folding. Very small amplitude (two inch) kink folds are present on the limbs of the minor folds (these vary up to 5 feet in amplitude and up to 20 feet across). The folds generally plunge at about 20°-30° in a direction 90°-110°, and if they represent minor drag folds on the limbs of a major fold then this major fold is an anticline to the north-east.

### Faulting

The major fault in the district is the fault bringing Cambrian(?) volcanics into contact with Silurian strata. This trends at 110°, and the north-east side is upthrown. It is probably an extension of the Firewood Siding Fault (Blissett 1962). Because of the steep dips of the strata and the lack of knowledge of the thicknesses of Ordovician and Cambrian (?) rocks in the area it is impossible to estimate the movement on the fault. This fault must cut the coastline between a small outcrop of Cambrian(?) volcanics and the Amber Slate but it is not exposed. The rocks which crop out about 50 yards to the south of the volcanics are massive and could not definitely be identified as Silurian as they differ from the normally thinly bedded Amber Slate. If the massive rocks are Cambrian(?) then an extremely complex structure involving both faulting and folding would be needed to explain the relationships of the rocks exposed.

Other faults have also been mapped in the country rocks but they are only minor, with displacements of only a few feet.

### Nature of the Contact between the Precambrian (?) and Cambrian (?) Rocks

There is an unsettled controversy concerning the relation between the younger Precambrian sediments (such as the Oonah Formation) and the Cambrian rocks (Crimson Creek Group and Dundas Group), on the West Coast of Tasmania. It has variously been reported that Crimson Creek Group rocks overly the Oonah Quartzite and Slate either conformably (Spry 1962a) or unconformably (Blissett 1962). At Trial Harbour the Oonah Formation and the Cambrian(?) rocks are conformable but at the mouth of Montagu Creek an irregular contact between the two occurs and strata of both formations end abruptly against this contact. The rocks are too altered and the contact is not well enough exposed to determine whether it represents a fault contact or an unconformable or disconformable contact. Specimens 31924 (Precambrian), 31978 (Cambrian) were collected from either side of the contact. The Precambrian quartzites are strongly quartz-veined, but these veins are rare in the Cambrian siltstones.

### Jointing

*Granite*

Five hundred joints in the granite have been measured and the poles plotted in fig. 4. This figure shows a well defined girdle with two maxima at right angles representing joints striking 10° and 100°. The 10° set is the dominant one. The origin of these joints is unknown. The two sets are probably related and since the tourmaline veins and dykes follow the 10° set the joints probably formed soon after the intrusion of the main part of the complex, but before or at the same time as the last phase of activity involving the intrusion of the tourmaline veins and the quartz-tourmaline dykes.

*Hornfels*

Only 60 poles of joints in the Cambrian hornfels were plotted (fig. 4), but these show 3 maxima representing 3 main sets of joints (2 are close and may not be separate sets). One set strikes 100° and is near vertical so that it is similar to the major joint set in the granite, but the other set (or sets) strikes 84° and dips at 60° N so that it is distinct from the granite joints. The jointing in the hornfels is probably related to the granite intrusion but insufficient poles have been plotted to allow reliable interpretation.

## ECONOMIC GEOLOGY

### History of the Mining Field

Early exploration of the Heemskirk mineral field took place from Waratah. The first party was led by C. P. Sprent and found traces of tin near Mt. Heemskirk in 1876. Following recommendations by Sprent, mining syndicates began sluicing for alluvial tin in the district, but by 1897 vein tin, or tin disseminated in granite host rock was being obtained in small quantities from the Montagu, Cumberland, Empress Victoria, Cornwall and Cliff mines in the area. Early speculation based on the belief that the Heemskirk field would become a "second Mt.

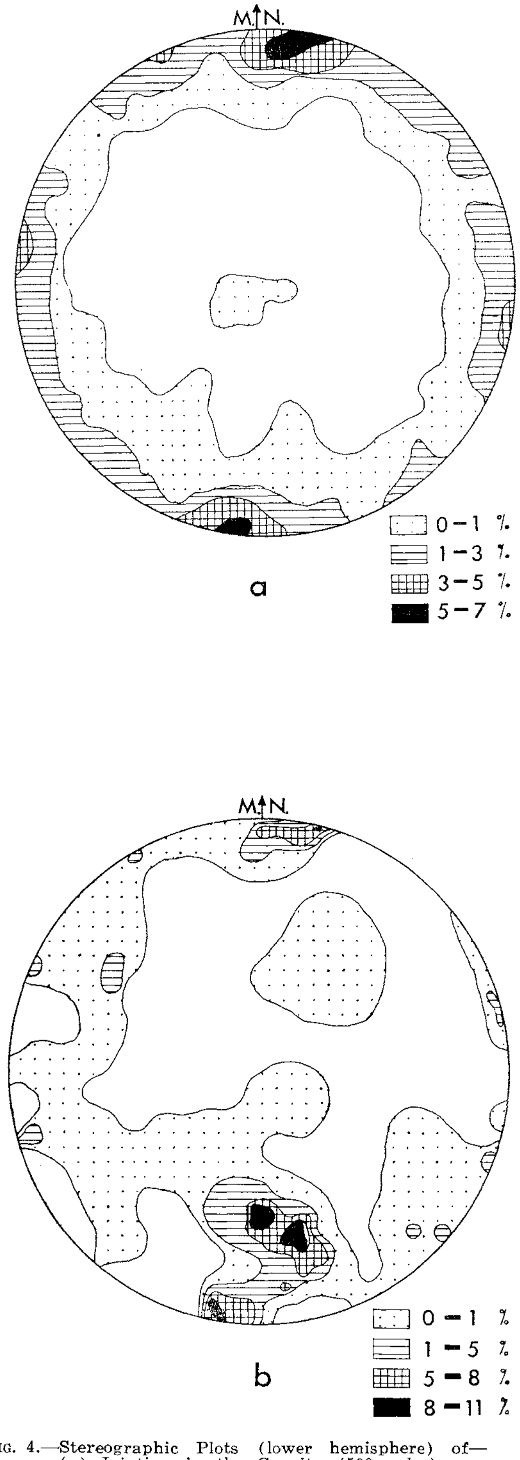


FIG. 4.—Stereographic Plots (lower hemisphere) of—
(*a*) Jointing in the Granite (500 poles).
(*b*) Jointing in the Cambrian(?) hornfels (60 poles).

Bischoff ", resulted in the erection of batteries, driving of adits and sinking of shafts into outcrops which had not been sufficiently well prospected. This latter fact added to the confusing effect of the abundant black tourmaline (frequently mistaken for cassiterite) culminated in the collapse of most of the mining ventures, and gave the field a bad name.

Subsequent mining operations have centred around the Federation area and at Mayne's Mine (where a very rich pocket of tin was discovered). Waterhouse (1916) thoroughly described all the mines and prospects of the area. Since many of these were still in operation or were still accessible at the time of Waterhouse's investigation, his observations were far more complete than any the writer could make. For this reason the description of the economic geology of the area is limited.

Since 1916 adits have been driven in the Black Face area and at Coleman's workings, but these have not resulted in any significant discoveries of tin.

**Mineralisation**

*(a) Associated with the Serpintinised Dunite*

On a ridge a quarter of a mile east-south-east of Remine, three adits and a shaft have been driven into a nickel-bearing dunite. The writer has identified heazlewoodite (see p. 7) and zaratite from the workings (specimens 10532(i), 10532(ii)).

Waterhouse (1916) described the nickel workings fully and Williams (1958) gives a detailed account of the mineralogy. Williams proposed that the nickel accompanied the original intrusion and segregated before serpentinisation. He records the presence of chromite and sphalerite as well as the nickel bearing minerals pentlandite (most abundant), heazlewoodite, shandite ($Ni_3Pb_2S_2$) and millerite (a breakdown product of heazlewoodite). Blissett (1962) records assays of 18.6% and 14.6% nickel from samples from the dumps.

Local segregations and veins of magnetite also occur in the dunite but these are not extensive enough to be economically important.

*(b) Associated with the Granite*

The mineralisation associated with the granite is the only mineralisation of economic significance in the area. The tin is invariably connected with late tourmaline rich intrusions in the granite, and most of the old workings occur in the white tourmaline granite, where it is cut by quartz-tourmaline dykes or tourmaline veins. A few mines are present in the pink granite and are also associated with quartz-tourmaline intrusions, e.g., Empress, Victoria, Sweeney's and Wakefield and in one case (Mayne's Mine) tin mineralisation occurs in the Oonah Quartzite and Slate country rocks, accompanied by extensive tourmaline veining.

*Federation Workings*

Most of the mining operations in the area have been carried out in the Federation Mine Creek, extending from the Western Workings (Geason's, Tributer's, Fowler and Dunn's) through the Central Workings (Black Face, Munro's, Long Tunnel) to the minor Eastern Workings. In between these mines there are many prospect trenches and pits in quartz-tourmaline bodies containing minor cassiterite and pyrite. In one such prospect 200 yards south of the Black Face, cassiterite is associated with well developed cubic pyrite crystals (specimen 12565). In spite of the extent of the Federation Workings, especially in the Black Face area, comparatively little tin has been obtained (less than 800 tons of cassiterite (Blissett 1962)). Large scale mining operations finally ceased in 1938.

In the Federation area tourmaline nodular aplite, tourmaline veins, and quartz-tourmaline dykes occur in a white tourmaline granite host rock. Crustification texture in quartz may develop along the margins of the tourmaline veins (e.g., specimen 18650). Black tourmaline is the most common tourmaline variety, but green and blue tourmaline are also evident (specimens 18649, 18650, 18651). The cassiterite is usually associated with the latter two varieties. Muscovite and fluorite are also present. The cassiterite either occurs as disseminated grains in the granite host, in veins or in rich segregations and varies from a black to dark-brown colour. Other minerals recorded include bismuthinite and wolframite (Waterhouse 1916).

*Coleman's Workings*

These workings are the only ones at present producing tin in the district. E. Coleman has mined tin on this lease since 1943. It is situated on a 1400′ spur marking the source of Montagu Creek and is about 500 yards south of the Central Workings of the Federation Mine. White tourmaline granite containing some tourmaline nodules is cut by many tourmaline veins and quartz-tourmaline dykes and the tin mined has been obtained from rich segregations, tourmaline nodules and disseminated grains, similar to the occurrence in the Federation Workings. Brown and black cassiterite are present, and minute crystals of native copper or cuprite are occasionally evident (specimens 12566-70, 10023). This deposit is low grade (probably it would bulk about 1% cassiterite) and its possible development is hampered by its location on top of a steep ridge.

Another mine of interest is Sweeney's Mine, which is about half a mile south of Cumberland Lake. The lode occurs in quartz-tourmaline dykes in pink granite and contains sphalerite, cassiterite and stibnite in a gangue of pyrite, siderite, quartz and fluorite (specimens 10491, 13517).

The best cassiterite obtained by the writer came from a dump at a prospect about a quarter of a mile north of the Cliff Mine. This specimen (12572) contains cassiterite crystals up to 0.5 cm in size occurring in a greisen groundmass consisting of muscovite, fluorite, quartz and green tourmaline. The shaft from which the specimens originated is now flooded.

The remaining mines in the district (Prince George, Cornwall, Cliff, Empress Victoria, Montagu, Wakefield and Mayne's) contained cassiterite associated with tourmaline and quartz, and occasionally pyrite and arsenopyrite.

A similar association of tin with tourmaline has been recorded from granites in south-west England (Dewey 1948) and in Malaya (Hutchinson and Leow 1963). Tourmaline nodules and late cutting quartz-tourmaline dykes have also been recorded in the Malayan granites.

## GEOLOGICAL HISTORY

The geological record in the Trial Harbour area began with the deposition of sands and silts in late Precambrian(?) times, with possible volcanic activity towards the end of sedimentation. Folding, uplift and erosion may have occurred before subsequent sedimentation and volcanic activity resulted in deposition of siltstones, tuffaceous siltstones, tuffs and breccia, accompanied by intermittent basic lava flows on the ocean floor. However conformable deposition of Cambrian(?) rocks on Precambrian(?) cannot be ruled out, because of uncertainty of the contact relationship. Emplacement of serpentinised dunite also probably took place in the Cambrian Period.

There is no record of the Ordovician Period in the area, and the next rock type to form was the Silurian Crotty Quartzite, followed concordantly by siltstones, calcareous siltstones and an occasional cross bedded quartzite, all comprising the Amber Slate. These two formations were probably deposited in shallow water.

Folding possibly took place before the next phase of activity, when in Devonian(?) times, a major plutonic igneous complex was intruded, beginning with a pink granite, followed closely by a white tourmaline granite, and finally by minor intrusions of porphyritic aplite, aplite, pegmatite, quartz-tourmaline dykes and tourmaline veins, accompanied by cassiterite mineralisation and local greisenisation of the granite.

No record is preserved of the Carboniferous-Permian Periods. The final events recorded are probably sub-aerial erosion giving rise to prominent topographic levels (e.g., lower coastal surface). Minor Quaternary changes in sea level are also evident.

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PLATE I.

FIG. 1.—Scour of coarse siltstone in fine siltstone.

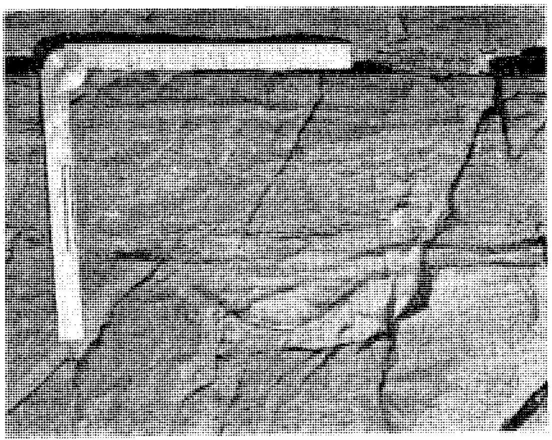
FIG. 2.—Current bedding in quartzite of the Amber Slate.

FIG. 3.—Minor basic intrusion; plagioclase laths set in granoblastic mosaic of hypersthene and biotite (Ord. light; scale mark = 0.5 mms).

FIG. 4.—Granite (right)/country rock (left) contact on the shoreline outcrop. Outcrop about 20' high.

FIG. 5.—Photomicrograph of granite/country rock contact. Banding in the country rock (right) ends abruptly against the granite (left). (Ord. light; scale mark = 0.5 mms).

FIG. 6.—Biotite banding and quartz veining in pink granite. The contact between the grey granite (marginal phase of the pink granite) and the grey microgranite (marginal phase of the porphyritic aplite) occurs near the base of the photograph.



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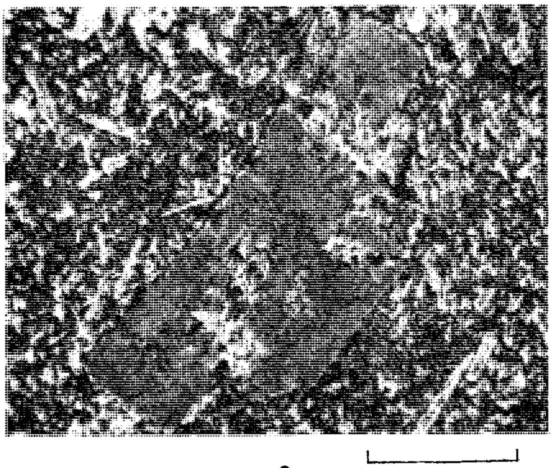

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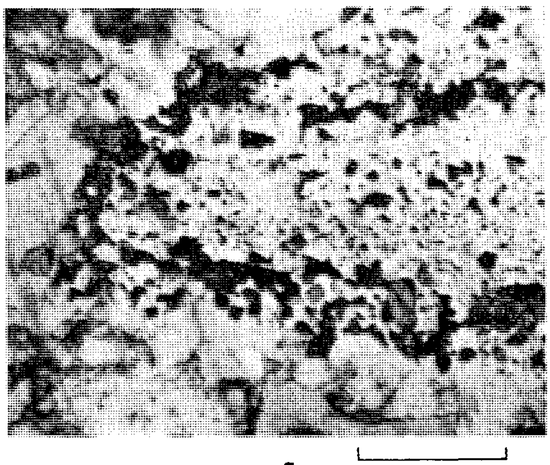

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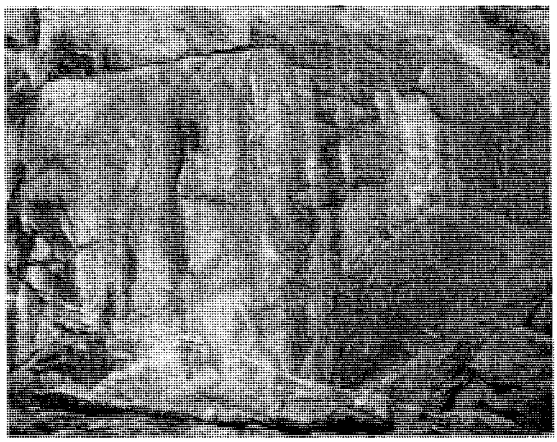

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PLATE II.

FIG. 1.—Prominent tourmaline veining with greisen margins mid-right) and planar contact between biotite banded pink granite and porphyritic aplite.

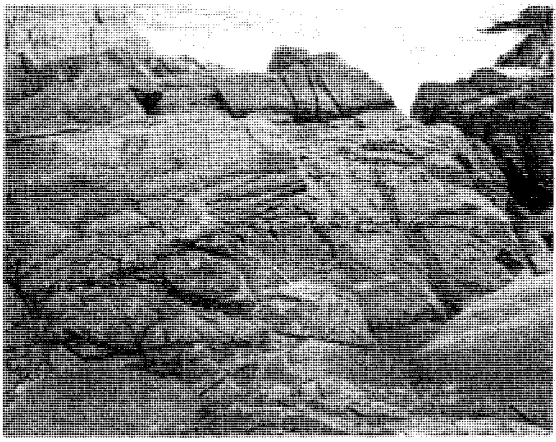
FIG. 2.—Banded porphyritic aplite.

FIG. 3.—Tourmaline nodular aplite and quartz-tourmaline segregation.

FIG. 4.—Contact between white tourmaline granite (below) grading into tourmaline nodular aplite and porphyritic aplite (top). Note banding in porphyritic aplite parallel to the contact.

FIG. 5.—Pyroxene dyke intruding pink granite.

FIG. 6.—Folding in Silurian Amber Slate. Scale 10′ from base to top.



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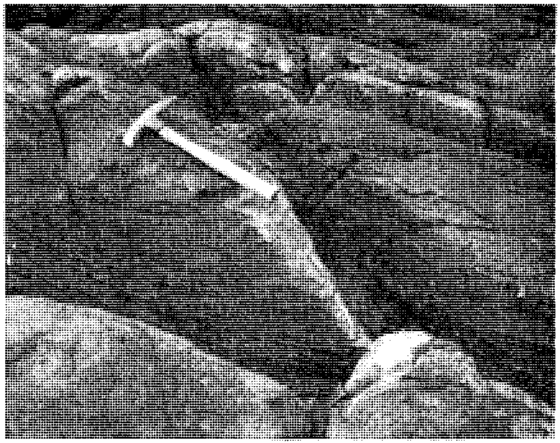

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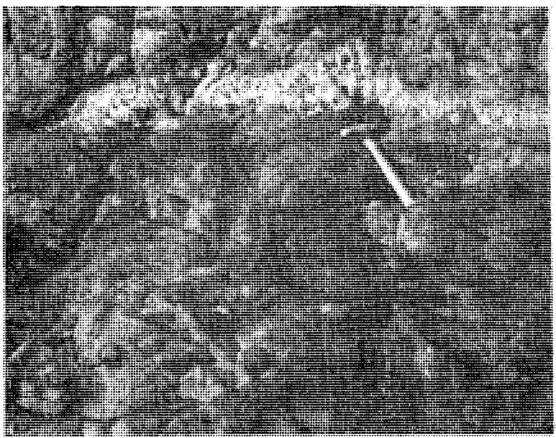

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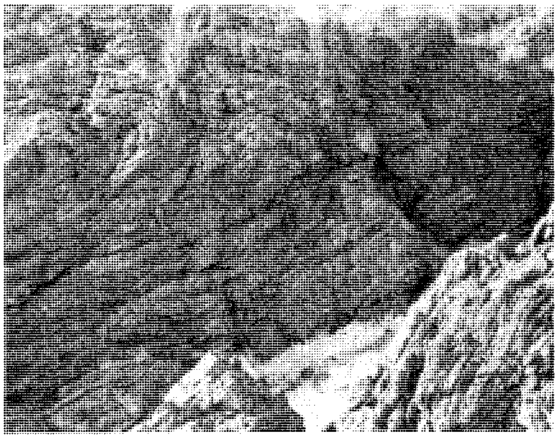

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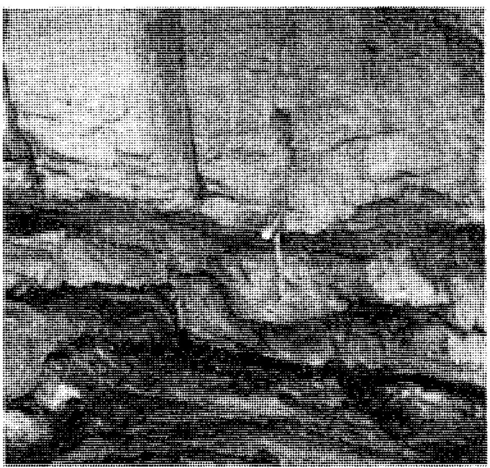

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