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THE PETROLOGY OF THE FIVE ISLANDS, PORT KEMBLA, NEW SOUTH WALES.

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(Plate vii and Figures 1–2.)

Introduction.

Petrological notes were supplied to Davis, Day and Waterhouse for use in their paper (1938) on the ecology of the Five Islands. Subsequent work necessitates some modification of the views then expressed.

Islands I and II.

Harper (1915, p. 303) considered that Islands I, II, III, and V are composed of either the Dapto-Saddleback flow (popularly called dolerite) resting on red tuffs, or entirely of tuffs. Islands I and II, however, consist entirely of Dapto dolerite showing a pronounced rusty red colour on the weathered surface.

From examination of this rock in the Port Kembla Government Quarry, Browne and White (1929) enumerated the following types in descending order: A. Dapto-Saddleback trachybasalt. B. Deuterically altered trachybasalt. C. An intrusion from the same magma crystallizing under different conditions, with no completely unaltered type to be seen. D. A rock usually pinkish in colour and heavily impregnated with carbonates. This is type C in an advanced state of alteration. The first two types are seen on Island II and the whole four occur on Island I. The field relations are the same as in the quarry, though not so well exposed. In the following descriptions all numbers prefixed by DR refer to specimens in the Australian Museum collection, while other numbers denote rocks in the Mining Museum. Textural terms are used according to Johannsen (1931).

Field Occurrence.

Type A (*DR 4204*). A black rock with a resinous lustre, showing an abundance of glassy felspar and black augite phenocrysts. On a weathered surface these phenocrysts stand out in marked relief. This type constitutes by far the greatest part of rock exposed on Islands I and II.

Type B (*DR 4203*). This is the trachybasalt that has suffered deuteric alteration. The groundmass is of a dark grey colour and the felspar phenocrysts have lost most of their glassy lustre and are dull greenish white in colour. The augite phenocrysts are unchanged. Exposures of this type are found as scattered masses throughout type A. These exposures are nearly all found below the ten foot contour line and some extend right to sea-level. There is no sharp line of demarcation between them and the surrounding type A. Evidently, as in the quarry, the upward limit of deuteric alteration is quite irregular. In a small ravine on the north coast of Island II some 10 chains east of the isthmus which joins the two islands, a small dome-shaped mass of type B protrudes up into type A. Judging by the comparative scarcity of outcrops and by the comparatively small extent of each outcrop the deuteric solutions had almost reached the limit of their activity.

In the centre of the mass forming the isthmus there occurs a light greyish brown rock (DR 4206) lighter in colour than the usual type B. This type is unrepresented

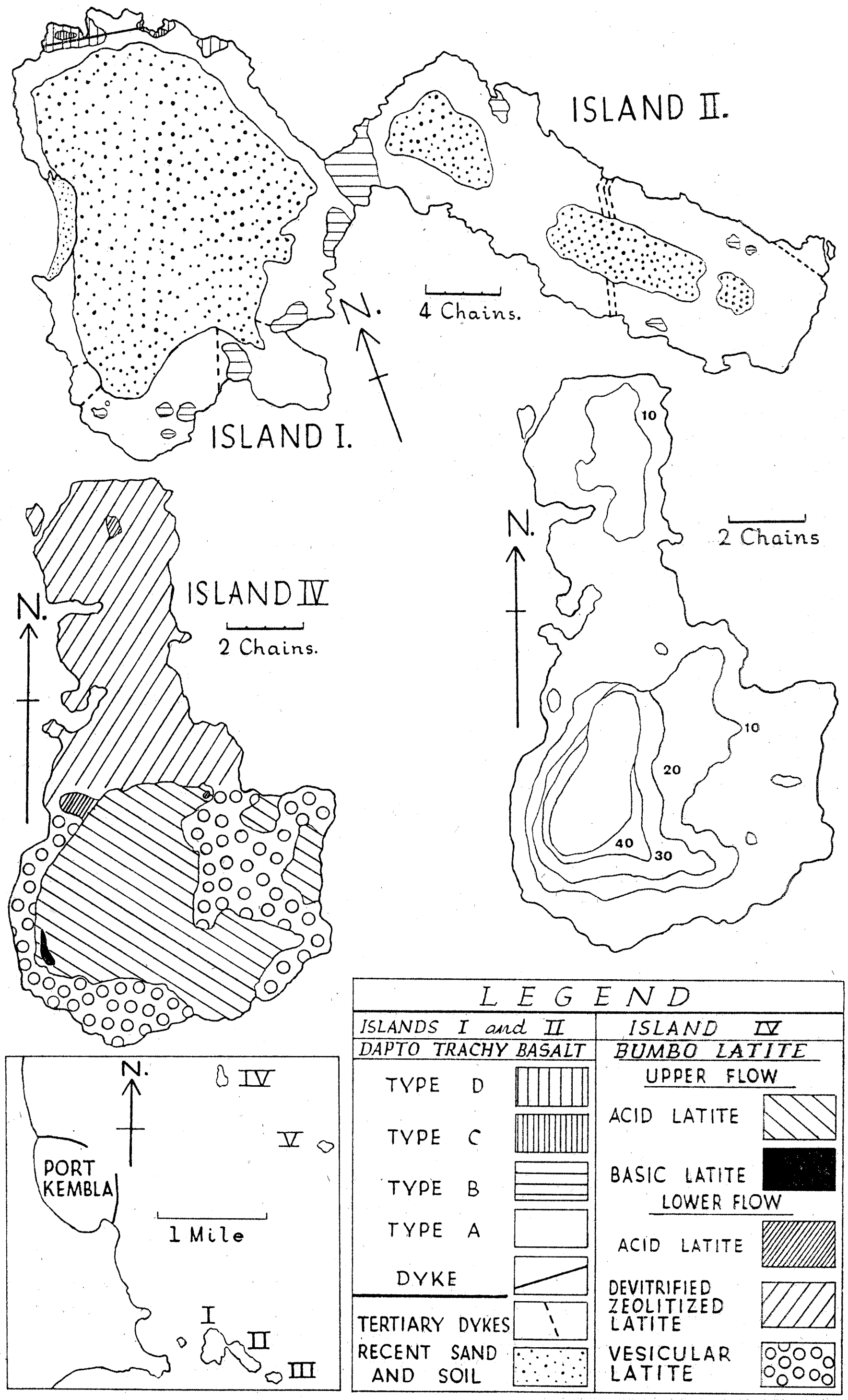

Fig. 1.—Geological map of Islands I, II and IV. Contour map of Island IV (after Davis, Day and Waterhouse), and locality map.

in the quarry. It is crowded with stout phenocrysts of greyish white felspar and black augite that shows tiny veins of chlorite. In the centre of some of the augite phenocrysts chlorite-lined cavities are commencing to form. This supports Browne's view "that in certain cases the cavities may be enlargements of spaces once occupied by olivine or augite, minerals susceptible to attack by deuteric solutions" (Browne and White, 1929, p. 315). Cavities completely filled with chlorite and some few with prehnite are seen. Prehnite has been recorded from this flow at Port Kembla by Card (Harper, 1915, p. 301).

Another rock unrepresented in the quarry is dark in colour with brownish-yellow phenocrysts of felspar resinous in appearance (DR 4201). This occurs on the north coast of Island I about 7·5 chains west of the isthmus, and grades imperceptibly into the trachybasalt. It also appears to grade down into representatives of type C which is not in accord with observations in the quarry where a recognizable boundary was seen between types B and C.

Type C is of very limited occurrence, being found as two small outcrops overlying type D on the north coast of Island I. The least altered member of this intrusive type as described by Browne from the quarry (Browne and White, 1929, p. 305) has a dense blue-black groundmass in which are set light coloured semi-opaque plagioclase phenocrysts. This was not seen on the islands. Browne (Browne and White, 1929, p. 313) also mentions that this dark intrusive rock grades into a chocolate coloured type. This, occurring both as a dark coloured (DR 4245) and a light coloured variant (DR 4197), was found on Island I.

Type D. Underlying these chocolate coloured rocks are the heavily calcitized types representing the intermediate and extreme stages of alteration of type C. In the absence of sections it is difficult to say where type C ends and type D begins. A greyish white rock (DR 4200) with milky white felspar phenocrysts represents the intermediate stage of alteration, while the extreme stage is shown by DR 4198, a rock with a dark purplish pink groundmass in which white felspar phenocrysts entirely replaced by calcite stand out. One irregularly shaped cavity, about three inches in greatest length, was filled with clear glassy quartz and calcite. A few smaller cavities were filled with glassy quartz and one with a white pulverulent leptochlorite.

A thin dyke (DR 4196) which has rather a sinuous course intrudes both type D and the normal trachybasalt on the north-west corner of Island I. The weathering of this dyke has produced a well-marked ravine (Davis, Day, and Waterhouse, Plates xv and xvi). It is a dense fine-grained rock and for part of its course is a light greenish grey colour. It suddenly changes to dirty white. It evidently accompanied the intrusion of type C.

Three basalt dykes with slender porphyritic felspars intrude the unaltered trachybasalt on the north side of Island II and pursue parallel courses across to the south side where, however, only two are to be seen. Their strikes are influenced by joint planes. Other dykes, basaltic in appearance, were noted on both islands.

A small block of a dense, black, siliceous, fine-grained sediment was seen included in the normal trachybasalt.

Petrography.

Type A (*DR 4204*). This corresponds exactly with the descriptions given by Card (Harper, 1915, p. 301) and Browne (Browne and White, 1929, p. 308). The chief features are: abundant labradorite phenocrysts, perfectly fresh, with orthoclase rims and up to 5 mm. in length; augite phenocrysts, quite fresh and up to 3 mm. in length; pseudomorphs of yellowish or green iddingsite and chlorite after olivine. Stout labradorite prisms, fresh tabular pieces of augite, interstitial chlorite, magnetite, and an abundance of slender apatite needles constitute the orthophyric groundmass with average grainsize about ·3 mm.

Type B (*DR 4203, 4205, 4212*). This closely resembles the type mentioned by Browne (Browne and White, 1929, p. 310) as showing an intermediate stage of deuteric alteration. The labradorite phenocrysts are albitized and sericitized, but nowhere is there any evidence of the pale green augite having been completely replaced by carbonates as in some of the quarry specimens. In fact calcite is quite scarce in the groundmass. The augite is quite fresh, at most being slightly chloritized. The iddingsite after olivine has remained unaltered except in DR 4212 where the pseudomorphs consist entirely of chlorite.

A type of iron ore in the form of rods, dots or dendrites is present in all these slides, mostly fringing the groundmass augite. This is mentioned by Browne (Browne and White, 1929, p. 312) as occurring in the quarry in a finer grained phase of type B, an accompanying feature being the absence of orthoclase rims surrounding the plagioclase phenocrysts. In the Island slides the grain size is no finer and only in DR 4212 are the orthoclase rims missing.

In DR 4206, the exceptional type showing prehnite in the hand specimen, the felspar phenocrysts are completely albitized and heavily kaolinized, but sericitization, so common in other type B rocks, is completely absent. The prehnite, occurring as radiating masses, partially replaces the albitized felspar phenocrysts (Plate vii, fig. 1). Prehnite has been recorded as replacing felspar in the pegmatitic phase of the Prospect intrusion (Browne, 1925, p. 242). Fresh augite is still to be seen. Browne (1923, p. 282, and 1925, p. 244) records other examples of augite remaining unaltered despite the severe alteration of other minerals. Olivine is completely converted to chlorite. Green pleochroic chlorite is plentiful throughout the groundmass and also forms a partial border to the prehnite masses.

Cavities are present lined with chlorite and aggregates of tiny titanite (?) granules. The filling is an interlacing mass of tiny green pleochroic amphibole laths. This mineral occurs as the main constituent of a hornfels on Island IV; therefore these amphibole filled cavities are regarded as sedimentary inclusions.

In DR 4201, the other exceptional type, a curious feature is shown. The labradorite phenocrysts are perfectly fresh and show no trace of albitization, sericitization or kaolinization, although there are present in minor quantities, chlorite, and veinlets and granules of iron stained calcite. The orthoclase rims to the phenocrysts are missing. The groundmass felspars are wholly or partly replaced by calcite. Fresh augite and olivine are completely replaced by calcite and chlorite. This specimen shows every type of alteration seen in quarry specimens of type B from near the contact with the intrusive type C, with the important exception that the felspar phenocrysts have scarcely suffered any deuteric alteration. Browne (Browne and White, 1929, pp. 331–2) has postulated that after the consolidation of both types A and C, post-magmatic solutions advanced in two waves, an earlier soda-rich and a later carbonate-rich fraction. One can only suggest that the onslaught of the soda-rich fraction was sporadic and that it was missing in this particular place.

Type C (*DR 4245, DR 4197*). These chocolate coloured variants show yellowish pink felspar phenocrysts and chlorite-filled cavities. The phenocrysts are completely albitized. They are also kaolinized and calcitized. Microphenocrysts of felspar stand out in a groundmass heavily pigmented with plumose patches of hematite. The augite and olivine phenocrysts are entirely replaced by calcite and granular quartz. In the lighter coloured chocolate variant there is a decrease in hematite and an increase in calcite, colourless chlorite, and quartz aggregates. Cavities are present lined with calcite and filled with colourless chlorite and/or sericite.

Type D. In the greyish white rocks (DR 4195, 4200) hematite is entirely absent and the felspar phenocrysts much encroached on by calcite stand out in a groundmass consisting almost entirely of colourless chlorite and calcite with few traces of felspar. Some of the cavities are lined with siderite.

In DR 4198, which shows the extreme type of alteration, the phenocrysts of felspar are entirely replaced by calcite, colourless chlorite, and granular quartz. Tiny dots of hematite are abundantly disseminated throughout the calcite-rich groundmass.

One noteworthy feature in all of these type C and D rocks is that sericite is practically absent as a direct alteration product of the felspar. However, the felspars are all heavily kaolinized, most probably due to deuteric action.

The question of the iron ore in types C and D is of interest. Magnetite is practically absent, and hematite is present in the reddish types. A third mineral shows an intergrowth similar in appearance to the Widmanstätten figures shown by some iron meteorites on etching. The laths which fill the octahedral partings in what was once presumably magnetite are dark yellowish or greenish brown in transmitted light and are only semi-translucent. In reflected light they are whitish yellow in colour and are taken to be leucoxenized ilmenite. Magnetite remains occasionally as a filling between the laths or may occur on the edge of the crystal as a dense granular border. Colourless chlorite sometimes with calcite appears as a filling between the laths (Plate vii, fig. 2). In one instance a cubic arrangement of the laths was noted, a hollow square of magnetite remaining set in leucoxene. The shape of some of these crystals suggests that they may originally have been olivine.

This process is due to the unmixing of a solid solution of ilmenite and magnetite (Schwartz, 1930, Fig. 4, and Edwards, 1938, Fig. 8), subsequent deuteric alteration having almost completely removed the magnetite and converted the ilmenite to leucoxene.

The thin dyke which intrudes type D is very much calcitized. No fresh felspar remains, but what traces of texture are seen suggest that it might once have been pilotaxitic. Numerous cavities filled with pale green chlorite and calcite are present. There is an appreciable quantity of opaque material in the form of closely packed laths, slender and up to 1·5 mm. in length. These laths are aggregates of tiny granules whitish in reflected light and in some instances associated with limonite. They are usually concentrated in the vicinity of the chlorite-filled cavities. These cavities may have been formerly phenocrysts and the original material, on being replaced by calcite and chlorite, migrated but a short distance before being redeposited. There is a fair quantity of an opaque mineral scattered here and there as small fragments. This shows a bronze yellow colour in reflected light and resembles pyrrhotite.

The remaining dykes are typical Tertiary basalts consisting mainly of felspar laths and fresh titanaugite. There is an abundance of green interstitial material, some of it chlorite, and some glass set with tiny doubly refracting microlites. DR 4210 from the eastern end of Island II shows excellent pseudomorphs of pale green iddingsite after olivine. These have calcite associated with them.

Island III.

The only rock found on Island III is the normal trachybasalt (DR 4243). In one place was found an inclusion of an entirely black rock in which occasional stains of malachite could be seen. On close inspection with a powerful lens tiny specks of copper could also be distinguished. This inclusion, which is apparently a thermally metamorphosed basic xenolith, consists almost entirely of labradorite and magnetite. Small fragments of the rock are magnetic. The habit of the felspar in the slide varies. There are masses of closely interlocked stout labradorite prisms about ·25 mm. in length, showing the clouding typical of thermally metamorphosed plagioclase felspars. These masses are magnetite-free and interspersed with them are prisms of felspar about 2 mm. long. Some of these have a corroded appearance and are packed with small fragments of magnetite and apatite needles. On a casual glance they give the impression of being made up of a mass of tiny granules. This appearance is actually due to an intergrowth of two felspars, both perfectly fresh and both showing in most cases twin lamellae, the lamellae of the two sets making an angle of about 60°. There is also a small included fragment of the trachybasalt. Examination in reflected light shows numerous fragments and stringers of copper.

Island V.

A specimen from this island is the normal trachybasalt (DR 3655). Consett Davis, who collected the specimen, informs me that no other type is to be seen.

Island IV.

Harper (1915, p. 303) records this as a remnant of a purely local flow which he named the Five Islands Flow and the specimens collected were named "trachyandesite pro tem". This flow was thought to be more or less contemporaneous with the Dapto Flow. It seems as though only a flying visit was made by Harper, and since the sole landing place is on the north-west corner, probably only types in the vicinity were collected, and these are highly altered.

All the rocks on Island IV have been classified by me as latite. The predominant type has been termed in the field acid latite. It is found in various stages of deuteric alteration. There is also a limited occurrence of basic latite. For the sake of clarity those names will be used in the following descriptions.

Field Occurrence.

The northern half of the island is a slightly elevated platform mostly less than ten feet above sea-level. At the northern end there is a small area about ten feet above sea-level. On this is found one of the two freshest types of acid latite on the island. It is a dense dark bluish-grey rock (DR 4235) and occurs as patches in a more altered light greenish-grey rock (DR 4236) which is of frequent occurrence on this northern half. In this occur large masses of dark brownish calcite, irregular in shape and up to eighteen inches in length. Associated with this is the most altered type on the whole island. It is a crumbly, soft green rock (DR 4279) with abundant veins and amygdules of a faint pink to yellowish zeolite pronouncedly red along the edges. In these altered types are numerous cavities lined with massive milky granular quartz and filled with milky calcite, white or with a faint yellowish tinge. Sometimes the cavities are filled with massive quartz alone and occasional small geodes in this massive material are lined with tiny quartz crystals. This altered type of latite varies in its resistance to weathering, producing small hummocks mostly of a light reddish yellow colour (DR 4280).

At no great distance above sea-level along the western side of the cliffs which form the high southern part of the island there is a dense rock (DR 4238, DR 4278, DR 3656) of the same nature as the blue-grey acid latite except that it has a pronounced reddish tinge. This stands out as a hard bar on the softer zeolite-bearing types. Along the northern face of these cliffs at an elevation of eighteen feet there is a band of bole about one foot thick (DR 4239). This is also seen on the western face at the same level in a shallow cave-like shelter just south of the bar of reddish rock. It slopes down rather rapidly until it disappears below ground-level. Beyond the bar of reddish latite there is a reddish purple rock (DR 5868) with numerous cavities, giving place for a short distance to a rock similar in appearance but light greenish in colour (DR 5869). The reddish purple type then continues to the southwestern corner and is found between sea-level and the ten foot contour along most of the southern and eastern sides of the southern half of the island. On the eastern side quite an extensive platform has developed between these levels. In brief the low-lying parts of the island consist almost entirely of a highly altered zeolitized type mostly of a light greenish or yellowish colour in the northern half, and a less altered vesicular type with a prevailing reddish purple tinge in the southern half.

The prevailing type on the flat table-topped part of the island lying between the ten foot and forty foot contours is a dark greenish grey dense acid latite (DR 4237). Chlorite-filled vesicles, mostly small, can be discerned in all these rocks. In some they are larger and are quite a notable feature. This rock forms steep cliffs along the western edge. On the southern edge there is a more gradual descent to the low-lying, reddish, vesicular type. Along the eastern edge the descent is more gradual still. On the eastern side several caves are found in a small cliff between the thirty and forty foot contours. Here the dark green latite has suffered atmospheric weathering and is light brown in colour (DR 4241). In this there is a large block of some altered sediment, dense and olive green in colour, with shallow cavities filled with small quartz crystals (DR 4242). In the neighbourhood small fragments of this altered sediment are included in the light-brown weathered rock. Why the dark green latite should have weathered thus on the eastern side and not on the western is not apparent.

On the south-western corner of the cliffs, about fifteen feet up, is found the sole occurrence of basic latite. It is a sheet-like mass of rock (DR 5870) which on the weathered surface has a yellowish appearance and resembles a typical basalt when fractured. It is both overlain and underlain by the dark green acid latite, and is of no great extent.

It will be seen that on this island we have the remains of two flows. The bottom flow is almost entirely altered, there being but a few remnants of dark blue acid latite. A band of bole, not visible in all parts of the island, separates it from the overlying more resistant flow, most of which is dark greenish grey in colour and comparatively

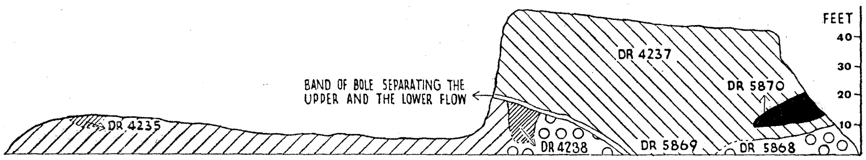

Fig. 2.—Diagrammatic section along western side of Island IV. Length of section about 15 chains. For legend see Fig. 1.

unaltered except for atmospheric weathering on the eastern cliffs and a limited formation of vesicles in DR 5869 low down on the western cliffs (see Fig. 2). In one place on the eastern side at about fifteen feet above sea-level a dark bluish grey acid latite (DR 4276) is found, the same as DR 4235 from the lower flow. This is probably a marked irregularity in the surface of the lower flow protruding through the upper flow. From the evidence shown in the diagrammatic section (Fig. 2) the junction between the flows is quite irregular. The ease with which the highly altered latites have been eroded by marine action, leaving the forty foot high cliffs standing, has caused the peculiar toothbrush shape of the island, seen most clearly from the sea on the western side.

Petrography.

Lower Flow.

Acid Latite (*DR 4235*, *DR 4276*). Dense dark bluish grey rock with a few small phenocrysts of felspar, and numerous small chlorite amygdules.

Holocrystalline, porphyritic; groundmass fine grained (·1–·2 mm.), unoriented. There are a few scattered phenocrysts of orthoclase and plagioclase, 1 or 2 mm. in length. The plagioclase is entirely albitized.

The groundmass felspars are slender prisms of orthoclase and plagioclase, many of them being completely albitized, while others show patchiness due to partial albitization.

Small stumpy prisms of faintly greenish augite are scattered sparsely through the field.

Although small squarish crystals of magnetite are present, this mineral occurs frequently in the form of small rods, dots, and dendritic shapes mostly forming borders to the groundmass felspar (Plate vii, fig. 5). A number of slender colourless needles of apatite are present. There are numerous small granular masses, brown in colour, often cloudy and of high R.I. These are quite a feature of all Island IV rocks and the fresher pieces strongly resemble titanite. Some of the cloudy pieces, difficult to determine, may be carbonates. There are a few small interstitial pieces of quartz.

Cavities filled with aggregates of tiny fibrous rosettes of pale green, very slightly pleochroic chlorite are common. Small interstitial masses of chlorite are plentiful in the groundmass.

Dark reddish acid latite (*DR 4238, DR 4278, DR 3656*). Very similar to the above, except that the small rods and dots of iron ore fringing the groundmass felspars are hematite and not magnetite, thus accounting for the reddish colour of the rock in the hand specimen. The chlorite is much more pleochroic, green to orange yellow; it is presumably iron rich.

In DR 3656 there are numerous cavities filled with closely packed, radiating quartz crystals. There are also cavities filled with epistilbite.

Purplish red vesicular acid latite (*DR 5868*). Somewhat weathered type, breaking with a rough fracture. The vesicular appearance is due to the amygdules having been removed by weathering, leaving only a lining of limonite to the cavities in most cases. A few small glassy patches remain. Allowing for differences due to a somewhat more intense deuteric alteration, this is the same type as DR 4238.

Glassy and devitrified acid latite (*DR 4236, DR 4280*). DR 4236 is a light-grey rock with a faint green tinge. It breaks with a rough fracture. There are quite a number of amygdules of quartz, calcite, and chlorite.

Hypocrystalline, porphyritic; groundmass fine-grained, partly cryptocrystalline, partly hyalopilitic.

There are plagioclase phenocrysts (3·5 cm.), completely albitized, much kaolinized, but with scarcely any sericite, and orthoclase phenocrysts, smaller in size. One phenocryst shows Manebach twinning, and another a combination of Carlsbad, albite and Manebach twinning.

Slender microphenocrysts of both plagioclase and orthoclase (·2 mm.) are set in a groundmass the greater part of which is glassy. There are two patches where the groundmass is cryptocrystalline and highly felspathic. The change is quite sudden, and there is no intermingling of glassy and cryptocrystalline material. There is no indication of this change in the groundmass in the hand specimen.

Cavities filled with chlorite and lined with quartz or calcite are present. One chlorite amygdule is hypautomorphic in shape (Pl. vii, fig. 4). This suggests that these cavities were originally filled with primary ferro-magnesian minerals since dissolved away, their places having been taken by deuteric minerals. One automorphic crystal of augite still remains. Granules of titanite, carbonates, and a minor amount of magnetite are also present.

DR 4280, a light reddish yellow rock, is entirely devitrified, the groundmass being heavily pigmented by tiny plumose masses of hematite and limonite.

Intensely zeolitized acid latite (*DR 4279*). Despite its altered nature, the texture is discernible in parts. The felspar is albitized. The groundmass consists of pale green non-pleochroic material at times isotropic, with small patches of quartz and calcite. Granules of titanite are abundant clustering to form borders round each zeolite amygdule. This zeolite has a (010) cleavage and the axial plane is parallel to (010), consequently no good figure was seen. It is biaxial (—), the maximum R.I. being greater than 1·516 points to epistilbite.

The massive quartz mentioned previously as filling cavities in these altered types is a curious variety. The majority of the individual grains are crowded with tiny indeterminate inclusions of high R.I., strung out in such a way as to give a sheaf-like appearance to the quartz grains. Sometimes the piece of quartz has a thin band free from inclusions running transversely across the middle. The extinction is undulose and commences from opposite sides of the crystal on each side of the band in a peculiar curved manner calling to mind a biaxial interference figure. There is ordinary clear quartz associated with this inclusion-rich variety, in places grading into it quite suddenly.

Upper Flow.

Acid latite (*DR 4237, 4275, etc.*) (Pl. vii, fig. 3). Except for the dark greenish grey colour, this rock resembles the dark blue acid latite of the lower flow. Microscopically the chief differences are that in the green acid latite there is always a fairly well defined border of untwinned felspar fringing the albitized phenocrysts, the groundmass is of somewhat coarser grain, there is a greater abundance of apatite needles, and the dendritic magnetite fringing the groundmass felspars is almost entirely absent. One example each of Baveno, Manebach and pericline twinning was noted in the phenocrysts. Albitization of the groundmass felspar usually takes the form of a patch in the centre of the crystal, leaving a well-marked border. In some cases where the outer shell is of lower R.I. than the central patch, probably orthoclase has been deposited round an already albitized plagioclase crystal. An occasional hypautomorphic chlorite crystal, with thin streaks of a more strongly pleochroic, platy variety amongst the rosetted aggregates, suggests a pseudomorph after olivine.

In some specimens abundant lenticular amygdules occur. Some consist of chlorite associated with quartz and/or calcite. Another cavity is lined with fibrous chlorite immediately followed by a thin layer of opal, and filled with radiating masses of chalcedony associated with quartz grains and calcite. The felspars near this cavity are much kaolinized.

Light greenish grey vesicular acid latite (*DR 5869*). This occurs near the base of the upper flow and has suffered more intense deuteric alteration than usual. Amygdules of chlorite, calcite, and epistilbite still remain, but weathering has removed many of them, leaving only cavities.

Hornfels of sedimentary origin included in the upper flow (*DR 4242*). This is the dense olive green altered sediment which is found as an included block. Traces of the original bedding planes can be seen and a type of minute honeycomb weathering is noticeable along the laminae. The main part of the rock is a dense mass of interlacing slender prismatic laths, pleochroic (grass green to yellow) and averaging about ·1 mm. in length. They show traces of a cleavage. They are very small and difficult to determine, but are probably an amphibole. Irregularly shaped impregnations of granular quartz sometimes intermingled with the tiny green laths are frequent. The rectangular shape of many of these aggregates suggests that the quartz has replaced some original mineral. Prismatic and basal sections of prehnite associated with the quartz impregnations were seen, the basal sections showing the anomalous bluish grey interference colours and the microcline-like gridiron structure mentioned by Iddings (1911, pp. 409–410).

The prehnite is interstitial in many places and is partly or wholly replaced by analcite, accompanied by small botryoidal masses of opal stained brown.

Weathered acid latite with included fragments of hornfels (*DR 4241, DR 5867*). A light brownish coloured rock that has suffered atmospheric weathering. There are a number of elongated cavities, but mostly the fillings have been removed, leaving a lining of limonite. Limonite has also been deposited in cracks in the rock. In the groundmass there is an abundance of limonite, and no fresh augite at all. Included fragments of the green hornfels are seen, in which epidote is sometimes present. There has been a small amount of intermingling, for here and there close to the edges of hornfels inclusions there are small groups of the amphibole laths in the latite.

It will be seen that the characteristic feature of all the above described acid latites, whether comparatively fresh or altered, is that the plagioclase shows almost complete albitization. In some cases kaolinization is pronounced and sericitization has been noted particularly in the fresh types belonging to the upper flow, but in no case is it such a marked feature as in the type B rocks from Islands I and II. It is practically absent in the specimens that have been highly altered by deuteric agents.

Basic latite (*DR 5870*) (Pl. vii, fig. 6). This is a black rock, basaltic in appearance, with a few small phenocrysts of augite and greasy-looking felspar.

Holocrystalline, porphyritic; the groundmass is fine-grained (·3 mm.), unoriented and very similar to the acid latite.

Fresh twinned labradorite phenocrysts occur in no great abundance. They are comparatively slender and only one exceeds 1 mm. in length. Some of them have an untwinned border of felspar of lower R.I., presumably orthoclase. Often tiny granules of titanite and needles of apatite are crowded along the untwinned border, while the phenocryst itself is free from inclusions. Both labradorite and orthoclase are present in the groundmass.

There are a couple of stumpy phenocrysts of pale greenish-grey augite about 1 mm. long. Small perfectly fresh crystals are scattered fairly plentifully through the groundmass, some being twinned.

A small amount of dendritic magnetite occurs along the edges of the groundmass felspars, but otherwise it occurs as the usual small fragments. There is a great abundance of slender colourless needles of apatite traversing both the groundmass felspar and the green interstitial chlorite. In a weathered specimen of this rock the interstitial chlorite is yellow in colour, due to oxidation which no doubt accounts for the yellowish appearance of the outside surface of the rock in the hand specimen. There are also small granules of titanite.

In concluding the detailed descriptions it might be repeated that the augite from all the Permian lavas seen on the Five Islands is pale green in colour "characteristic of high alkalic content as opposed to the brownish augites of common basalts" (Ransome, 1898, p. 29).

Comparison with the other South Coast Permian Flows.

A selection of the original slides of the Blowhole, Bumbo, Cambewarra and Berkley Flows described by Card (Harper, 1915; Jaquet, Card and Harper, 1905–09) was kindly lent by the Mining Museum, and comparisons were made.

From the Bumbo Flow are described conspicuously porphyritic types occurring mainly in the Kiama district. Of more significance as regards Island IV is the fact that aphanitic types both basaltic and trachytic in appearance occur in the Jamberoo district. Bearing in mind the occurrence of the two aphanitic types on Island IV, this seemed suggestive. No slides, however, of the Jamberoo basaltic phase were available. It seems likely that this is a type in which the labradorite phenocrysts so typical of the Kiama quarry are smaller and less abundant. This feature has been mentioned by Card (Jaquet, Card and Harper, 1905–09, p. 9). Slides from the Kiama district (5774, 5423, and 5429) and two slides actually from the Kiama quarry were examined. These proved to be exactly the same as the basic latite from Island IV, excepting that some of the Kiama slides had larger and more abundant labradorite phenocrysts. Likewise examination of hand specimens and slides of the Jamberoo trachytic phase (5688, 5689, and 5692) showed them to be exactly the same as the acid latite from Island IV. No slides of zeolitized types or types with abundant cavities were noticed. In 5689 small green amphibole laths as in the Island IV hornfels no doubt represent a sedimentary inclusion. Unfortunately no details of the relation between these two phases of the Bumbo Flow are given.

As regards the other Permian Flows, the Dapto shows such distinctive characters that it could not possibly be confused with either of the Island IV phases. The Cambewarra, although to some extent chemically resembling the Bumbo acid latite, is distinguished from it by its orthophyric texture, the typical occurrence of apatite as stout markedly striated prisms, and by the universal presence of interstitial quartz. The Berkley, which microscopically does resemble the Bumbo acid latite, is of limited extent and thickness. It is a terrestrial flow intercalated with freshwater Upper Coal Measures filling a small drainage channel in the Upper Marine. The nearest occurrence is at Cobbler's Hill on the mainland, some 4¾ miles west of the Island, and there the base of the flow is 320 feet above sea-level. This together with the fact that here the sediments dip west as well as north makes correlation between the two difficult.

It is therefore concluded that Island IV represents an outlying remnant of the Bumbo Flow. It is 9 miles north of the most northerly outcrop of the main mass on the southern shores of Lake Illawarra. There is no evidence to suggest that it was not once joined to the main mass which is most strongly developed in the Kiama-Jamberoo district. A similar instance is found 1½ miles north of the Shoalhaven River, where the most southerly outcrop of the Bumbo on Mount Coolangatta is 6 miles south of the most southerly outcrop of the main mass of the flow. However, since in the region between Wollongong and the Shoalhaven Harper (1915, p. 291) considers that there were two main centres of eruption—one at Kiama and one at Port Kembla—both east of the present coast line, it would be reasonable to suggest that eruption of the magma which consolidated to form the Bumbo Flow proceeded contemporaneously from both centres, that at Port Kembla being on a much smaller scale.

Chemically as well as mineralogically the Island IV acid latite resembles the trachytic phase of the Bumbo at Jamberoo.

	1	1a	2	3
SiO_2	58·21	0·970	55·19	52·42
Al_2O_3	15·45	0·151	16·18	18·05
Fe_2O_3	2·38	0·015	3·52	4·30
FeO	3·82	0·057	3·94	3·60
MgO	2·89	0·072	3·04	3·60
CaO	3·03	0·054	4·68	6·14
Na_2O	5·16[1]	0·083	5·09	3·75
K_2O	4·24	0·045	4·10	4·14
H_2O	2·12		1·75	1·07
H_2O-	0·71		0·99	1·47
CO_2	0·14	0·003	0·28	0·04
TiO_2	0·88	0·011	0·89	1·16
P_2O_5	0·82	0·006	0·59	0·34
V_2O_5	—		0·03	0·05
SO_3	—		0·05	none
Cl	tr.[1]		0·02	tr.
NiO	0·12		none	0·03
CuO	—		0·01	0·05
MnO	0·22		0·18	0·28
BaO	—		0·07	0·11
	100·19		100·60	100·60
Specific gravity	2·70		2·80	2·72

[1] Allowance made for contamination by sea-water.

	1	2	3
Quartz	2·70		
Orthoclase	25·02	24·46	24·46
Albite	43·49	42·44	31·44
Anorthite	6·39	9·45	20·29
Diopside	1·79	8·25	6·32
Hypersthene	10·43		0·30
Olivine		4·61	4·78
Magnetite	3·48	5·10	6·26
Ilmenite	1·67	1·67	2·28
Apatite	1·86	1·35	0·62
Calcite	0·30		

1. DR 4235. Acid Latite. (Akerose, II, 5, (1)2, (3)4.) Island IV, Five Islands, Port Kembla, N.S.W. Analyst, R.O.C.

1a.—Molecular ratios for 1.

2.—Olivine Latite, aphanitic phase. (Akerose, II, 5, 2″, 4.) 3½ miles north of Jamberoo, N.S.W. Analyst, J. C. H. Mingaye. (Washington, 1917, p. 463; also Harper, 1915, and Jaquet, Card and Harper, 1905-09.)

3. Olivine Latite, phaneric phase. (Shoshonose, II, 5, ″3, 3″.) Average of several specimens, Bumbo Quarry, Kiama, N.S.W. Analyst, H. P. White. (Washington, 1917, p. 479; also Harper, 1915, and Jaquet, Card and Harper, 1905-09.)

In the N.S.W. Geological Survey publications (Harper, 1915; Jaquet, Card and Harper, 1905–09), analysis 2 falls into the sub-rang Monzonose, but in Washington's tables (1917) it is in Akerose. Although analysis 3 falls into Shoshonose in all the above-mentioned publications, there seems to have been some error in working out the norm in Washington's tables. Therefore, the norm has been recalculated, and it is this result that is appended under analysis 3. It does not differ greatly from Card's result.

DR 4235, the bluish grey acid latite of the lower flow, was selected for analysis after the first visit to Island IV, when only a cursory inspection had been made. Although this specimen is the only fresh type on Island IV containing interstitial quartz, it is small in amount and the rock differs only in a minor degree from the greenish grey acid latite DR 4237. The basic latite was not noticed until my last visit to the island, and time has not permitted an analysis to be made; therefore for purposes of comparison the analysis of the very similar type from the Bumbo Quarry is included.

The norm of analysis 1 gives a truer representation of the mode of this particular rock as seen today than do the norms of 2 and 3 because, while olivine appears in their norms, no fresh olivine is to be seen in thin section. However, now and then in the Bumbo rocks, both from Island IV and the mainland, can be seen automorphic masses of chlorite, presumably alterations of iddingsite after olivine. The analysed specimen coming from the lower flow where the most deuterically altered types are found, suggests that the interstitial quartz in it may have been deuterically introduced. It certainly has a higher silica percentage than its counterpart at Jamberoo, and since the norm contains free quartz, olivine is eliminated. However, the fact that there is mostly fresh augite in the Island IV rocks as well as interstitial chlorite, indicates that this is more likely to be an alteration of olivine, especially since the likelihood of the chlorite-filled cavities having been formed as steam holes is largely discounted. On the other hand, as mentioned by Browne (1925, p. 249) when dealing with the Prospect intrusion, some of the chlorite may be the normal crystallization product of the ferro-magnesian constituents.

In all these descriptions of Bumbo latite from Island IV and Jamberoo, the acid latite has been referred to as a fresh type to distinguish it from the zeolitized and devitrified types as well as types with abundant cavities. However, despite its fresh appearance in the hand specimen, the presence of completely albitized felspars showing to a lesser extent sericitization, kaolinization and chloritization stamps it as a rock that has suffered considerable deuteric alteration. The iron ore, both magnetite and hematite in the form of small dots, rods and dendritic shapes fringing the groundmass felspars in some of the acid latites, is of a later generation than the small squarish pieces scattered haphazardly throughout the groundmass. It may have been introduced during the period of late deuteric activity. In the face of all this alteration, the augite has remained fresh, as noted on Islands I and II. The basic latite on the other hand shows perfectly fresh felspars, although interstitial chlorite, probably in part an alteration of olivine, is present.

There is a strong possibility that the acid latite phase of the Bumbo Flow is a product of deuteric alteration of the basic phase. Until one becomes accustomed to the appearance of both types under the microscope, it is often difficult to distinguish them. Actually the main distinguishing feature is the clean, fresh appearance of the felspars and absence of orthoclase phenocrysts in the basic latite. The distinctive unoriented, sometimes markedly criss-cross texture of Johannsen and the presence of small fresh pieces of augite are identical features in both phases. The presence of interstitial chlorite is a common characteristic, as is the occurrence of apatite needles and titanite granules.

It is rather difficult to make a close examination of the relations between the acid and the basic phases on the Island. The amount of the basic latite is small, and it appears to be both underlain and overlain by the dark green acid latite on a vertical cliff section (see Fig. 2), which makes it rather difficult to determine the amount of gradation between the two, if any. Also before a strict chemical comparison could be made by recalculation of analyses on some standard basis, an analysis of the basic latite would be required. However, a rough comparison of the acid latite analyses (1 and 2) with the basic latite analysis (No. 3) shows gains in silica and soda and losses in lime and alumina. Just where the lime of the basic latite has gone since it was replaced may be explained by the presence of large masses of dark brown calcite and frequent smaller masses of white calcite occurring in the highly altered types. The abundance of epistilbite in the highly altered parts of the lower flow accounts for the replaced alumina and some of the lime. Also in the formation of chlorite, whether by alteration of ferro-magnesian minerals or by other means, alumina would be used up. It is noteworthy, too, that sericite which, according to Browne (Browne and White, 1929, p. 320), accounts for the alumina in the altered type B of the Dapto Flow being greater than in the fresh, is not of much importance in the Island IV rocks where, as already stated, there is less alumina in the acid latite than in the basic latite.

The presence of fresh and albitized trachybasalt (types A and B) in the Dapto Flow has been mentioned. In addition there is the pink, heavily calcitized rock (type D) which in the Port Kembla Quarry attained a considerable thickness, as proved by a trial bore (Browne and White, 1929, p. 306). Also, according to Harper (1915, p. 301), towards the southern extremity of the Dapto Flow at Broughton Head, some 20 miles to the south-west of Port Kembla, the resinous fresh trachybasalt gives place to the type with creamy opaque felspar phenocrysts. Although these specimens have not been seen, they appear to be the albitized, sericitized type B seen at the Quarry and on the Islands. Thus it would seem that there is a good deal of deuterically altered material in the Dapto Flow.

Such a widespread incidence of deuteric effects as seen in both the Bumbo and the Dapto Flows cannot be dismissed as a purely local phenomenon. The solutions that have brought about the changes, though they have acted late in the cooling history of the rock, are none the less part of the magma, and there is no reason why the rock types produced should not be regarded as normal rocks and classified as such.

Devitrification.

The occurrence of a glassy phase of the groundmass described in some of the altered types from the lower flow, sharply changing to a cryptocrystalline groundmass, is of interest when considering the effects of deuteric solutions. Usually the change is ascribed to devitrification. Devitrified latites are described from the Bonanza Mining district, Colorado, by Burbank (1932, pp. 21–30). In all of these devitrified types albitized plagioclase and other deuteric minerals, such as chlorite, quartz, calcite and epidote, are abundant. On the other hand, in associated glassy latites no mention is made of any alteration. Similarly Spock (1928, p. 232), describes a series of trachy-andesites associated with rhyolite, obsidian, andesite and basalt from Colorado, which either show residual glass or else are completely devitrified. These contain amygdules of calcite and various forms of silica. Osborne (1925, p. 117) gives a thorough discussion of devitrification in connection with the occurrence of glassy and lithoidal andesites in the Carboniferous of the Clarencetown-Paterson district, N.S.W. The glassy andesites are quite fresh, but the lithoidal varieties show albitization, chloritization and kaolinization, due to deuteric processes. He considers that the change from a glassy to a lithoidal groundmass might have been brought about by the activity of late-magmatic solutions. The view has been expressed by Hadfield and Whiteside (1936, p. 47), when dealing with some devitrified English andesites, that "so-called devitrification really arises from a primary crystallisation of minute proportions". However, in these very andesites the activity of deuteric solutions is shown by sericitization, calcitization and chloritization of plagioclase phenocrysts, and the presence of calcite cavities which are considered to be a replacement of felspar in situ rather than due to infiltration. This latter is a further resemblance between these and the Five Islands rocks. All this weight of evidence points to the devitrification on Island IV being another sign of deuteric activity.

Nomenclature.

Card (Harper, 1915, p. 284) points out that all these Permian flows are closely related magmatically one with the other and also with the Milton monzonite, some 60 miles to the south. Since they are effusive representatives of a monzonite magma, he gives them the name latite, following Ransome (1898, pp. 59–69). He says, however, that the name has been applied with little regard to mineralogical and textural differences. Browne (Browne and White, 1929, p. 317) in naming the Dapto Flow trachybasalt has evidently also regarded the name latite as having a purely chemical significance.

The Bumbo acid latite chemically resembles some of Ransome's augite latites from the Sierra Nevada (1898, p. 58). Others among the augite latites resemble more the Bumbo basic latite except that silica is about four per cent. higher. These rocks differ texturally from both the phases of the Bumbo in having labradorite and augite phenocrysts with some fresh olivine set in a hyalopilitic groundmass.

Comparing them with the rocks described by Iddings from Yellowstone (1895, p. 933, and 1899, pp. 340, 347), the basic latite has the closest chemical affinity with the banakites and shoshonites. Actually the average analyses of both these types quoted by Daly (1914, p. 34) show close resemblance. The acid latite resembles the quartz banakites. Many of these Yellowstone rocks are holocrystalline and bear a close mineralogical and textural resemblance as well, as mentioned by Card (Jaquet, Card and Harper, 1905–09, p. 14) and Brown (1925, p. 462).

The devitrified latites from the Bonanza mining district, Colorado (Burbank), have a fairly close resemblance both chemically and mineralogically to the Bumbo acid latite excepting that they are lower in alkalis, higher in lime, and contain biotite.

Analyses 1 and 2 of the Bumbo acid type both strongly resemble an analysis of an Italian vulsinite (Washington, 1917, anal. 8, p. 358). Ransome (1898) gives nineteen analyses of rocks that he considers latites, including his Sierra Nevada types and Washington's Italian rocks. Daly (1914, p. 23) has brought Ransome's average latite analysis more up to date, and the Bumbo acid latite bears a very close chemical resemblance to it, excepting that alkalis are higher and lime is lower.

A perusal of Washington's tables (1917) shows that, of the numerous analyses that could be classed as latites, only three fall in a dopotassic sub-rang. Nineteen analyses fall in sodipotassic sub-rangs and ten, many of which are called trachyandesites, in a dosodic sub-rang. Nor are any latite analyses published since 1917, that have come under my notice, dominantly potassic.

The striking predominance of soda over potash in the Bumbo acid latite in conjunction with its other chemical characteristics invites comparison with a series of Cenozoic trachyandesites described from Japan, Korea and Manchuria by Tomita (1935). These constitute a member of an alkaline limburgite-comendite suite. An average of eleven trachyandesite analyses (Tomita, 1935, p. 262) shows a close resemblance to analyses 1 and 2. In this paper is quoted Daly's world average for trachyandesites up to 1933 (see p. 284). The Bumbo acid latite also resembles this very closely. Two analyses of trachyandesites from the Warrumbungles, N.S.W., are given by Jensen (1907, p. 616), in which soda has not the same marked predominance.

In the face of all this, however, the fact remains that Brown (1930, p. 692) has shown the South Coast of New South Wales to have been a monzonitic petrographical province during the late Permian. To quote from another of her papers (1933, p. 351): "During the Upper Marine stage there were vertical adjustments of the adjacent land mass without strong folding and these were accompanied by the deposition of tuffs and flows of latite in the Illawarra district, sill-like intrusions at Milton and by laccolithic intrusion at Mt. Dromedary. These intrusions were monzonitic in character. . . ." She has described latite (banakite) occurring as a marginal phase of the Milton monzonite (1925, p. 456) and also latite forming irregular hypabyssal intrusions in the vicinity of Tilba Tilba Lake, Mount Dromedary (1930, p. 674).

In view of these opinions expressed after much detailed work and following Card's investigations, the name latite will be retained for these Island IV rocks. On looking at Daly's world average for andesite (1914, p. 26) and for trachyte (p. 21), I would suggest that if further distinction were required, the Bumbo basic phase might be called andesitic latite, and the acid phase, trachytic latite.

Summary.

Islands I, II, III and V consist entirely of Dapto-Saddleback trachybasalt, a Permian Flow. On Islands I and II the succession is the same as in the Port Kembla Quarry, where a co-magmatic type intrudes the normal trachybasalt and subsequent attack by alkali and carbonate-rich solutions has produced various altered types. On Island IV two flows of Bumbo latite are found. Both a basic and an acid latite occur, the latter including devitrified and zeolitized types. It was most likely formed by the deuteric alteration of the former by predominantly soda-rich solutions.

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References.

Brown, Ida A., 1925.—The Geology of the Milton District, N.S.W. *Proceedings of the Linnean Society of N. S. Wales,* Vol. l, pp. 448-465.

————, 1930.—The Monzonitic Complex of the Mount Dromedary District. *Proceedings of the Linnean Society of N. S. Wales,* Vol. lv, pp. 637-698.

————, 1933.—The Geology of the South Coast of New South Wales, with special reference to the origin and relationships of the Igneous Rocks. *Proceedings of the Linnean Society of New South Wales,* Vol. lviii, pp. 334-362.

Browne, W. R., 1923.—Notes on the Occurrence of Calcite in a Basalt from the Maitland District, N.S.W. *Journal and Proceedings of the Royal Society of N. S. Wales,* Vol. lvi, pp. 278-284.

————, 1925.—Notes on the Petrology of the Prospect Intrusion. *Journal and Proceedings of the Royal Society of N. S. Wales,* Vol. lviii, pp. 240-254.

Browne, W. R., and White, H. P., 1927.—The Hypersthene Andesite of Blair Duguid, near Allandale, New South Wales. *Journal and Proceedings of the Royal Society of N. S. Wales,* Vol. lx, pp. 372-387.

————, 1929.—Alkalization and other Deuteric Phenomena in the Saddleback Trachybasalt at Port Kembla. *Journal and Proceedings of the Royal Society of N. S. Wales,* Vol. lxi, 303-340.

Burbank, W. S., 1932.—The Geology and Ore Deposits of the Bonanza Mining District, Colorado. *U.S. Geological Survey, Professional Paper* 169.

Daly, R. A., 1914.—Igneous Rocks and their Origin. 8vo, New York and London.

Davis, Consett, Day, M. F., and Waterhouse, D. F., 1938.—Notes on the Terrestrial Ecology of the Five Islands. i. *Proceedings of the Linnean Society of N. S. Wales,* Vol. lxiii, 357-388.

Edwards, A. B., 1938.—Some Ilmenite Micro-Structures and their Interpretation. *Proceedings of the Australasian Institute of Mining and Metallurgy,* No. 110, 39-58.

Hadfield, G. S., and Whiteside, H. C. M., 1936.—The Borrowdale Volcanic Series of High Rigg and the adjoining Low Rigg Microgranite. *Proceedings of the Geological Association,* Vol. xlvii, 42-64.

Harper, L. F., 1915.—Geology and Mineral Resources of the Southern Coal-Field. (Petrography by G. W. Card.) *Memoirs of the Geological Survey of N. S. Wales,* No. 7.

Iddings, J. P., 1895.—Absarokite-Shoshonite-Banakite Series. *Journal of Geology,* Vol. iii, 935-959.

————, 1899.—Absarokite-Shoshonite-Banakite Series. *U.S. Geological Survey, Monograph* xxxii, (2), 326-355.

————, 1911.—Rock Minerals. Second edition. 8vo, New York and London.

Jaquet, J. B., Card, G. W., and Harper, L. F., 1905-09.—The Geology of the Kiama-Jamberoo District. *Records of the Geological Survey of N. S. Wales,* viii, 1-66.

Jensen, H. I., 1907.—The Geology of the Warrumbungle Mountains. *Proceedings of the Linnean Society of N. S. Wales,* Vol. xxxii, 557-626.

Johannsen, A., 1931.—A Descriptive Petrography of the Igneous Rocks. i. 8vo, Chicago.

Osborne, G. D., 1925.—The Geology and Petrography of the Clarencetown-Paterson District. iv. Petrography. *Proceedings of the Linnean Society of N. S. Wales,* l, 112-138.

Ransome, F. L., 1898.—Some Lava Flows of the Western Slope of the Sierra Nevada, California. *U.S. Geological Survey, Bulletin* No. 89.

Schwartz, G. M., 1930.—The Relations of Magnetite and Ilmenite in the Magnetite Deposits of the Duluth Gabbro. *American Mineralogist,* Vol. xv, 243-252.

Spock, L. E., 1928.—Geological Reconnaissance of Parts of Grand, Jackson, and Larimer Counties, Colorado. *Annals of the New York Academy of Science,* xxx, 177-261.

Tomita, T., 1935.—On the Chemical Compositions of the Cenozoic Alkaline Suite of the Circum-Japan Sea Region. *Journal of the Shanghai Science Institute,* Section 2, Vol. i, 227-306.

Washington, H. S., 1897.—Italian Petrological Sketches. *Journal of Geology,* Vol. v, 349.

————, 1917.—Chemical Analyses of Igneous Rocks. *U.S. Geological Survey, Professional Paper* 99.

EXPLANATION OF PLATE VII.

Fig. 1.—Deuterically altered Dapto trachybasalt (DR 4206) from Island I. A phenocryst of albitized plagioclase is completely replaced by prehnite. × 25.

Fig. 2.—Deuterically altered Dapto trachybasalt (DR 4200) from Island I. This crystal shows a structure which was originally due to an ex-solution intergrowth of ilmenite and magnetite. The magnetite has been entirely removed, its place being taken by colourless chlorite and the ilmenite laths have been replaced by leucoxene. Outside the border of this crystal, on the left and also at the bottom of the section, the irregularly shaped dark masses consist of carbonates and the light material of felspar. × 100.

Fig. 3.—Acid Bumbo latite (DR 4240) from Island IV. The phenocrysts consist of albitized plagioclase, the one on the right showing partial replacement by chlorite. The dark patches in the groundmass consist of magnetite and interstitial chlorite. × 25.

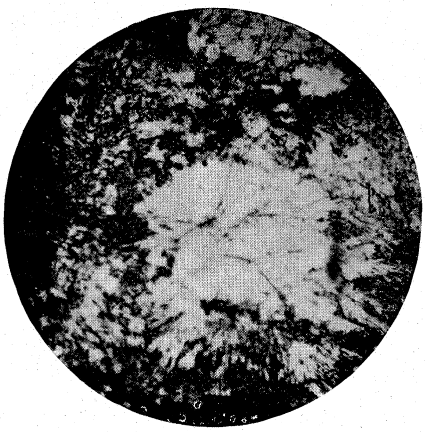
Fig. 4.—Devitrified Bumbo latite (DR 4236) from Island IV. The central mass of chlorite preserves some trace of crystal outline. The outer rim consists of fibrous chlorite and the centre of tiny rosetted masses of chlorite. Microphenocrysts of albitized plagioclase stand out in a cryptocrystalline, devitrified groundmass. The two light coloured, roughly circular masses in the south-west quadrant are holes in the section. × 25.

Fig. 5.—Acid Bumbo latite (DR 4235) from Island IV. Two generations of magnetite can be seen. The earlier appears as irregularly shaped fragments and the later as a border on some of the laths of albitized plagioclase. × 100.

Fig. 6.—Basic Bumbo latite (DR 5870) from Island IV. All the felspar consists of fresh labradorite. Small dark patches in the phenocrysts are replacements by chlorite. Dark patches in the groundmass consist of magnetite and interstitial chlorite. × 25.

All of the above were taken in ordinary light.

Photographs by G. C. Clutton.



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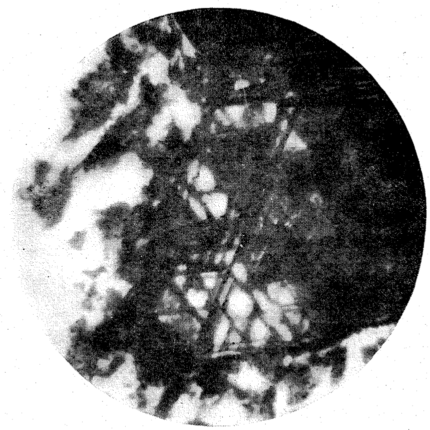

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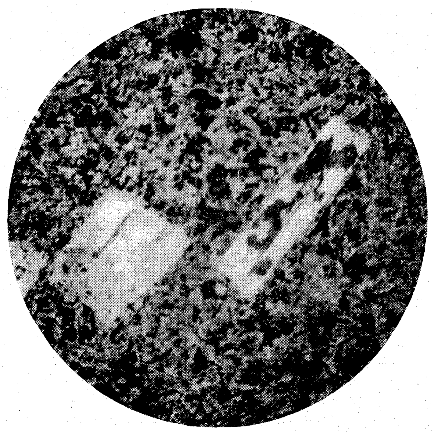

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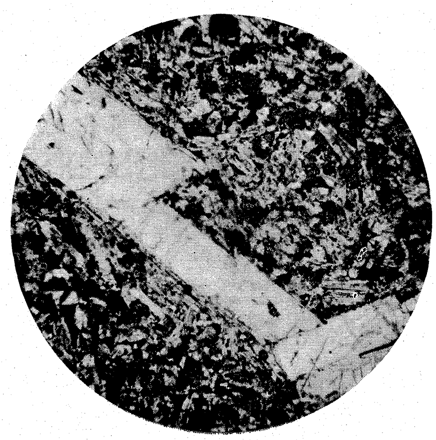

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