PETROLOGY OF THE HARTLEY DISTRICT. I.

The Plutonic and Associated Rocks.

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(Seven Text-figures.)

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Introduction and Previous Literature.

The area examined lies in the Cox Valley in the neighbourhood of Hartley and Little Hartley. It is situated some 70 miles to the west of Sydney, and its furthest westerly limit is about 7 miles west-north-west of Mount Victoria.

A small part only of the Kanimbla bathylith is exposed within this area, so the consideration of the Hartley outcrops alone must necessarily be somewhat incomplete, and great caution must be exercised in coming to any very definite conclusions regarding the intrusion as a whole.

Little previous work has been done on this part of the bathylith, the most important and helpful being a geological sketch map made by Messrs. Ball, Curran and Rienits (1898).

Various isolated parts of the intrusion have received attention in connection with the economic minerals, which are associated with the igneous and metamorphic rocks along their contacts.

In his report on the molybdenite deposits at Yetholme, E. C. Andrews (1916, 1917) gives some account of the igneous rocks, and Jones (1924) refers to the granites at Mount Werong in connection with the silver-lead deposits. W. J. Clunies Ross (1894) records a porphyritic granite, a biotite-granite and a quartz-mica-diorite from Bathurst, but reference will be made to these later. W. R. Browne (1929) reports that aplites and pegmatites, porphyritic biotite-granites, hornblende-biotite-granite, quartz-monzonite, granodiorite, quartz-mica-diorite and more basic types have been recorded from various parts of the mass. No systematic petrological investigations, however, appear to have been undertaken.

General Geology.

A. Sedimentary Series.

The sedimentary series consists of altered and tilted Upper Devonian rocks, and unaltered horizontally bedded Permo-Carboniferous and Triassic strata, with occasional patches of alluvium along the creeks. The plutonic rocks are intrusive into the Devonian Series, and are overlain by an Upper Marine conglomerate, which often contains pebbles of the plutonic rock.

The Devonian strata include arenaceous, argillaceous and calcareous types, all of which show contact metamorphism.

A series of Upper Coal Measure Beds overlie the Upper Marine conglomerate but, owing to extensive denudation, these outcrop only to a limited extent—notably in Hartley Vale and on the Victoria Pass. A small outlier of chert occurs on Mr. Cripps' property in the north-east corner of Portion 169, Parish of Hartley.

Triassic sediments belonging to the Narrabeen and Hawkesbury stages cap the higher levels. These form the upper part of the walls of the Cox Valley, and outcrop on a few isolated hills within the valley itself, as on Camel's Back.

Numerous patches of recent alluvium and small bogs occur along the creeks, which are making their way into the entrenched river, and in places clearing of timber has caused gullying and the creeks have begun to cut through their own silts.

B. Igneous Rocks.

Though several types of igneous occurrences are met with in the district, the present work is confined to an examination of the bathylithic rocks, so that several interesting problems can receive but brief mention.

Besides the plutonic rocks, hypabyssal and possibly volcanic types occur, but the relations between these and the bathylith are not as yet known.

Flows (?).—Two outcrops of felsite are met with in the area—a small occurrence on Moyne Farm, and a larger one on Liddleton. Cox's River has cut a deep gorge in the latter.

At Yetholme, quartz-felsites have been found as pre-granite flows (Andrews, 1916) and, as the Liddleton outcrop shows some evidence of having preceded the granite, it is likely that it may represent a Devonian flow.

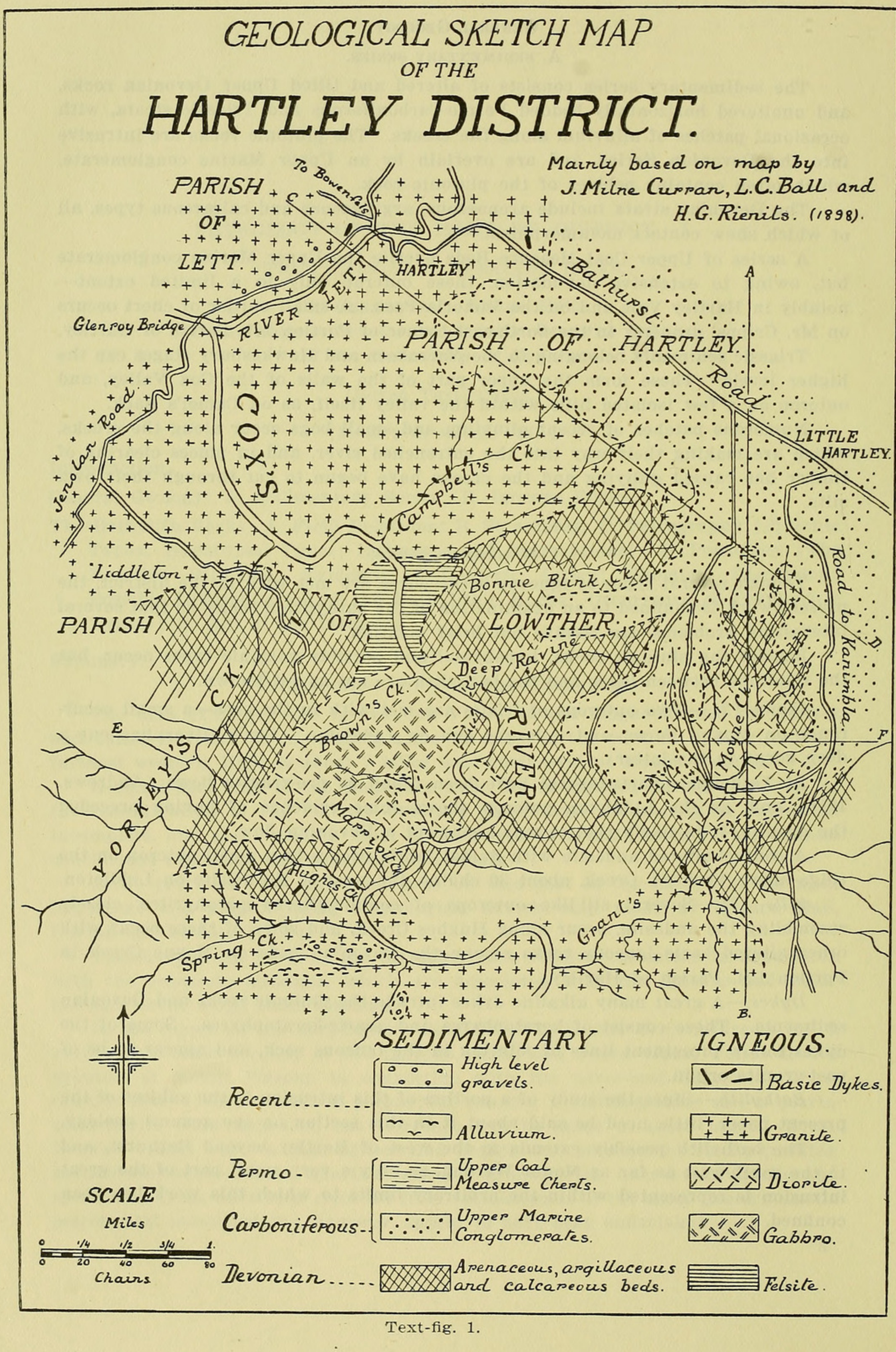
A contact-altered andesite with fluidal fabric occurs in a small outcrop on the ridge above Yorkey's Creek, about 30 chains due west of the felsite on Liddleton.

Sills (?).—Several sill-like outcrops of contact-altered porphyrites, closely resembling the andesite, occur along Hughes Creek, and some of these occur with other altered basic igneous rocks among the Devonian beds on Moyne Creek in Portion 124, Parish of Hartley.

Dykes.—A great many alkaline dykes intrude the plutonic rocks and Devonian sediments. These consist of keratophyres and quartz-keratophyres. Some of the dykes follow prominent lines of jointing in the igneous rock, and appear to be of post-granite origin.

Bathylith.—Since the study of a portion of this intrusion is the subject of the present paper, little need be said about it in this section on the general geology.

The bathylith possibly extends to the west of Hartley beyond Bathurst, and to the south-west as far as Mount Werong, so only a very small part of the great intrusion is represented within the arbitrary limits to which this work has been confined.


GEOLOGICAL SKETCH MAP
OF THE
HARTLEY DISTRICT.
Mainly based on map by J. Milne Curran, L.C. Ball and H.G. Rienits. (1898).
PARISH OF LETT.
To Bowenfels
HARTLEY
Bathurst
PARISH OF HARTLEY
Road
LITTLE HARTLEY
Glenroy Bridge
RIVER LETT
Jenolan Road
COX'S
Campbell's Ck
Liddleton
PARISH OF LOWTHER
Bonnie Blink Ck
Deep Ravine
Brown's Ck
RIVER
Moyne Ck
Road to Kanimbla
YORKEY'S CK
Hughes Ck
Grant's Ck
Spring Ck
E
F
A
B.
SEDIMENTARY
IGNEOUS.
Recent
High level gravels.
Alluvium.
Permo-Carboniferous
Upper Coal Measure Cherts.
Upper Marine Conglomerates.
Devonian
Arenaceous, argillaceous and calcareous beds.
Basic Dykes.
Granite.
Diorite.
Gabbro.
Felsite.
SCALE
Miles
0 1/4 1/2 3/4 1.
0 20 40 60 80
Chains

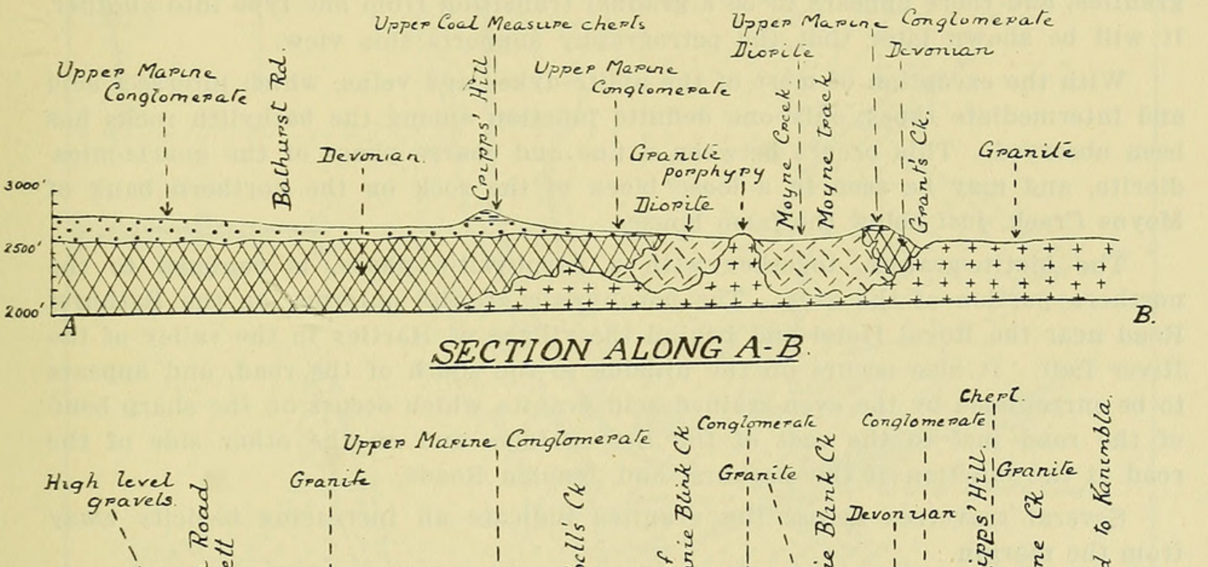
Text-fig. 1.

Bathylithic Types.

A. Field Relations.

The plutonic rocks are intrusive into sediments of Upper Devonian age. Reference to the sketch map (Text-fig. 1) shows granite in the north-west and south-east portions of the area. These two masses are undoubtedly continuous, and represent outcrops of a large bathylith which extends westwards to Bathurst and south-east to Mount Werong.

A large mass of contact-altered Devonian sedimentary rock appears to be included in the granite on Cox's River to the east of Campbell's Creek. This seems to be too large for an inclusion, and may represent a portion of the roof of the bathylith. Furthermore, small inclusions of Devonian rock are very numerous in various parts of the mass, and this also points to the proximity of the roof.



Text-fig. 2.

It will be seen on the sketch map that two masses of basic and intermediate-basic rock occur. The larger of these outcrops on the Cox's River on the properties of Messrs. Chris. Commens and Mitchell. This mass is surrounded by, and is intrusive into, rocks of Devonian age, and in a few instances the beds are seen to dip away from the intrusive rock. The occurrence is probably a stock, and is about one mile by one and a half miles across.

The second smaller intrusion, which also appears to be a stock, is slightly more acid, and occurs on Moyne Farm, the property of Mr. G. Harvey. Though intrusive into Devonian strata, the stock is largely surrounded by overlying beds of Permian age. The intrusion is about one mile in diameter.

The plutonic rocks consist of a series ranging from ultra-basic to acid, and form a complete calcic suite. The series passes from hornblendite and gabbros, through intermediate quartz-mica-diorites, tonalites and granodiorites, into biotite-granites, and there appears to be a gradual transition from one type into another. It will be shown later that the petrography supports this view.

With the exception of most of the aplite dykes and veins, which intersect acid and intermediate types, only one definite junction among the bathylith rocks has been observed. This occurs between a fine and coarse phase of the quartz-mica-diorite, and may be seen in a loose block of the rock on the northern bank of Moyne Creek, just below the farm house.

The biotite-granite, together with a porphyritic phase, is confined to the northern portion of the area. The porphyritic granite outcrops on the Bathurst Road near the Royal Hotel and behind the village of Hartley in the valley of the River Lett. It also occurs on the hillside to the south of the road, and appears to be surrounded by the even-grained acid granite which occurs on the sharp bend of the road just to the east of the Lett Bridge, and on the other side of the road at the junction of the Bathurst and Jenolan Roads.

Several traverses across the granites indicate an increasing basicity away from the margin.

Along the Lett between the bridges the even-grained biotite-granite rapidly passes into a hornblende-biotite-granite, and finally into a rock which stands very close to a granodiorite.

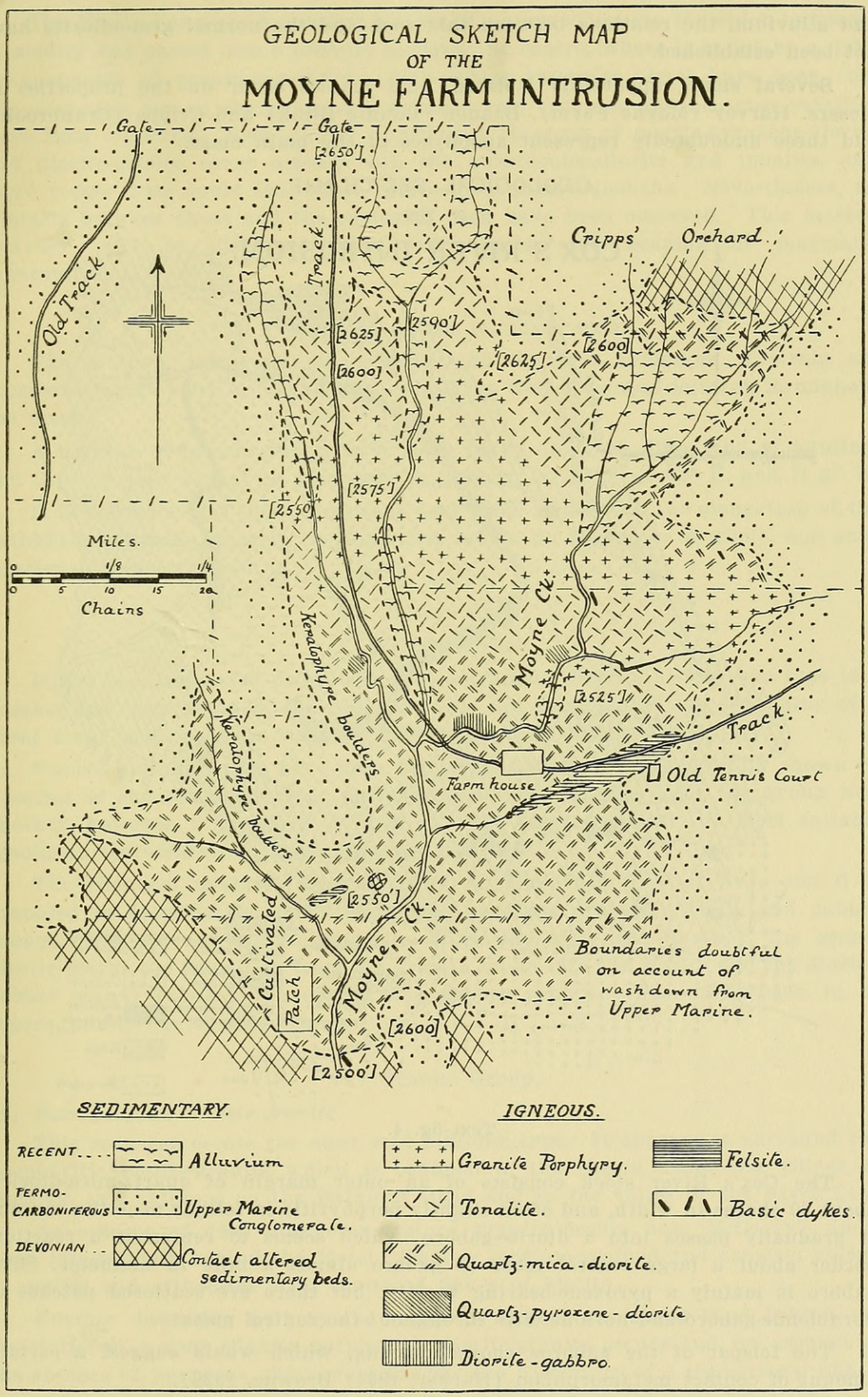
Down Campbell's Creek the same succession is observed, though the most acid phase is not represented in this part of the area.

Another portion of the granite has been examined to the south-east on the properties of Messrs. Hughes, Harvey (Kanimbla Station) and J. S. Commens.

A traverse from the contact of the granite with the Devonian strata down Kanimbla Creek partly reveals the nature of this portion of the intrusion, and a gradual transition from one type into another is apparent here also. A good deal of alluvium and the very deep weathering of the granite, however, prevent the establishment of some of the relations.

On Moyne Creek, apophyses of the granite are fine-grained, and sometimes aplitic, in character. At the junction of this creek with Grant's Creek, a hornblende-biotite-granite occurs, and this rapidly passes into a granodiorite. A few chains above the junction of Kanimbla Creek and Grant's Creek there is a small mass of quartz-mica-diorite, with veins of micropegmatite.

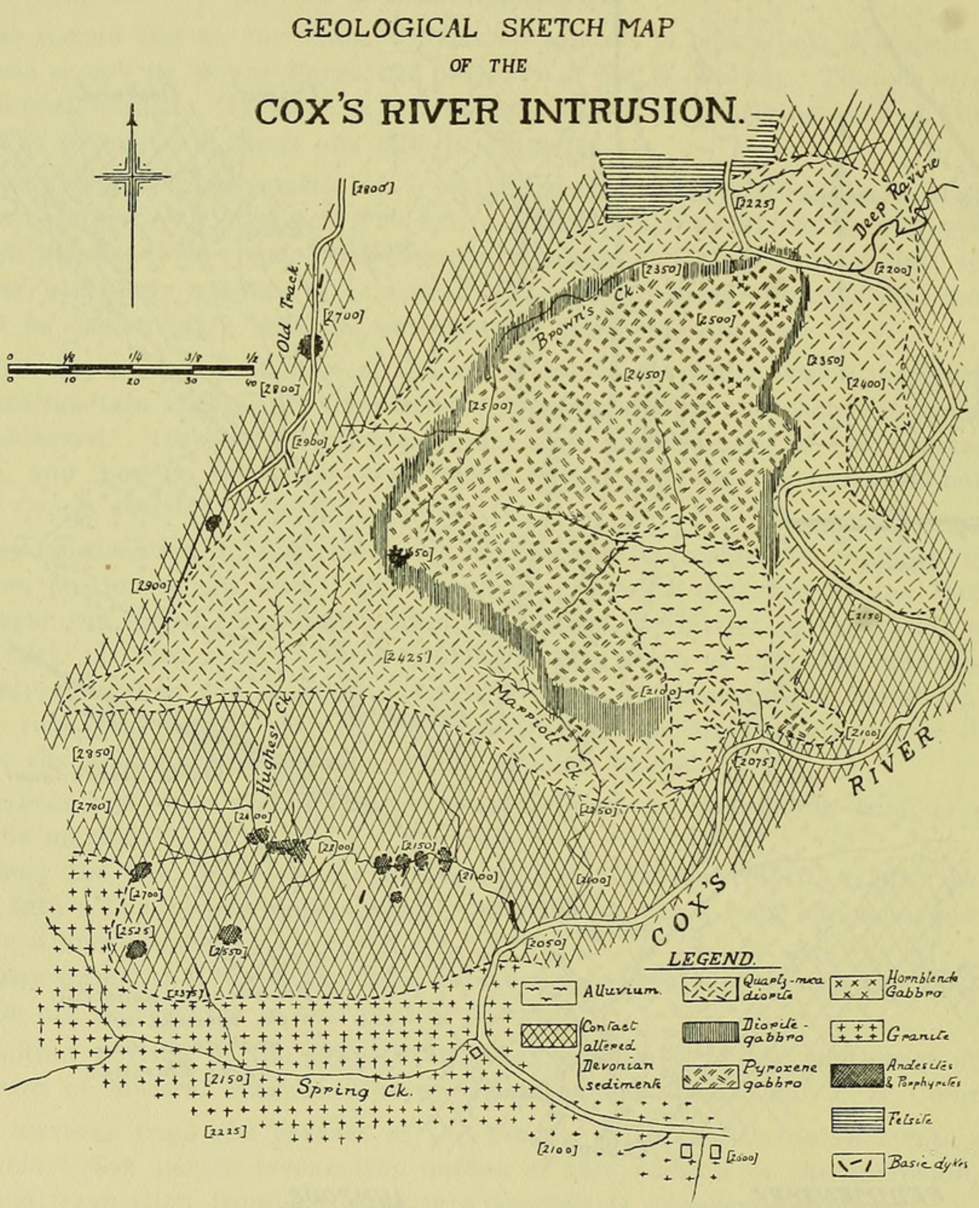
On Kanimbla Station, near the head of the creek, an outcrop of coarse granodiorite, having monzonitic affinities, is met with, but owing to deep weathering


GEOLOGICAL SKETCH MAP
OF THE
MOYNE FARM INTRUSION.
Gate
Gate
[2650']
Old Track
Track
Cripps' Orchard
[2590']
[2625]
[2600]
[2625]
[2600]
[2575']
[2550]
Miles.
0
1/8
1/4
0
5
10
15
20
Chains
Moyne Ck.
[2525']
Track
Old Tennis Court
Farm house
Keratophyre boulders
Keratophyre
[2550']
Cultivated
Patch
Moyne Ck.
[2600]
[2500']
Boundaries doubtful on account of wash down from Upper Marine.
SEDIMENTARY.
RECENT
Alluvium.
PERMO-CARBONIFEROUS
Upper Marine Conglomerate.
DEVONIAN
Contact altered sedimentary beds.
IGNEOUS.
Granite Porphyry.
Tonalite.
Quartz-mica-diorite.
Quartz-pyroxene-diorite.
Diorite-gabbro.
Felsite.
Basic dykes.

Text-fig. 3.

and alluvium, the relations between this rock and the normal granodiorite have not been established.

Several small, apparently isolated, acid masses occur on the properties of Messrs. Harvey (Moyne Farm), Baaner (Bonnie Blink) and Cripps (Cranbrook), and these undoubtedly represent apophyses of the main mass.



Text-fig. 4.

The Cox's River stock consists of an outer margin of quartz-mica-diorite, about 20 chains in width, and often slightly porphyritic in felspar near the contact. It gradually passes into a diorite-gabbro, which seems to represent a reaction-border about a large central mass of gabbro almost a mile in diameter. The gabbro is mainly a pyroxene-bearing variety, but there are scattered patches of hornblende-gabbro and hornblendite throughout the central mass.

The felspar of the gabbros shows clearing, which would suggest a certain amount of contact metamorphism (Harker, 1904; Browne, 1928).

The Moyne Farm stock consists mainly of a quartz-mica-diorite which increases in acidity and passes into a tonalite towards the centre, where it is cut by a dyke or apophysis of granite-porphyry. This latter intrusion must have been contemporaneous, for no sharp contacts between this type and the intruded tonalites have been observed. Sporadically distributed outcrops of quartz-pyroxene-diorite and diorite-gabbro occur among both the quartz-mica-diorite and tonalite, and there seems little doubt that these represent cognate xenoliths. Nevertheless, no contacts between these and the enclosing rock have been observed. This matter, however, will be discussed more fully under the heading of magmatic differentiation.

B. STRUCTURES IN THE PLUTONIC ROCKS.

The plutonic rocks are all massive, and the only evidences of strain are occasional slight bending in the biotites and the well developed jointing throughout the mass.

A number of measurements have been taken on these directions of jointing, and three strikes appear to predominate, namely, N 10° E, N 65° E, and N 2° W.

It is probable that these directions bear some relation to the elongation of the bathylith, but unfortunately the intrusion cannot be viewed as a whole, and such relationships ascertained.

C. PETROGRAPHY.

I. Plutonic Types.

It has been indicated previously that a gradual transition from one type into another has been noted in the field, and this has necessitated the sectioning of a great many specimens in order to confirm the field impressions.

Twelve plutonic types have been identified, and their consanguinity shown by a series of chemical analyses. On account of the passage from one group into another, however, it has been difficult in some cases to select the most suitable specimen, representative of the type, for analysis.

The chemical analyses show a range of more than 35% of SiO_2, and it is proposed to describe the rocks under the headings granite, diorite, and gabbro groups. On account of the gradation from one type into another, the granodiorite marks the transition from the granite group into the diorite and the diorite-gabbro stands between the diorite and gabbro groups. The subdivision is, of course, purely one of convenience.

(a) Granite Group.

(i) *Even-grained Biotite-granite.*

This rock represents the most acid plutonic type. It appears to surround the porphyritic biotite-granite which is confined to the region about the village of Hartley, and outcrops on the Bathurst Road and in the valley of the River Lett.

An outcrop of deep pink even-grained granite occurs near McGarry's duck-pond immediately behind the Hotel. This is medium-grained and consists chiefly of quartz and orthoclase with scattered flakes of biotite.

Further down the Lett on the northern side of the sharp bend behind the Court House, a very slightly porphyritic biotite-granite occurs and, on account of the absence of junctions, this would suggest the possibility of a transitional phase.

At the junction of the Bathurst and Jenolan Roads, and on the road to the east of the Lett Bridge, Portion 4, Parish of Hartley, a very coarse, even-grained type is met with. This is reddish in colour, and consists of quartz, orthoclase and biotite, the latter being a little more prominent in this rock.

Under the microscope, it is allotriomorphic granular and coarse to medium. The average grainsize of the rock outcropping on the Lett is 2–3 mm., whilst the type occurring on the road averages 4 mm. The constituent minerals are quartz, orthoclase, plagioclase, and biotite, with accessory sphene, apatite, magnetite and a little pyrites and topaz. Chlorite, kaolin, sericite, haematite, and a little myrmekite indicate both magmatic alteration and decomposition, and it has not been possible to find any specimen that does not show a certain amount of alteration. This, of course, is to be expected in so acid a type, for it represents one of the end-phases in the consolidation of the magma, in which magmatic solutions must have been very concentrated.

Orthoclase comprises about 39% of the rock and is developed in large allotriomorphic grains, which enclose or partly wrap all the other minerals. The surface is powdered with kaolin and sericite. Quartz forms about 33% of the rock. It occurs in large allotriomorphic grains with sometimes a slight suggestion of graphic intergrowth with orthoclase. Plagioclase (about 21%) forms subidiomorphic tabular crystals, and in the type behind the hotel a slightly porphyritic fabric is suggested by the occurrence of this mineral. The crystals measure up to 2 mm., and are oligoclase ($Ab_{74}An_{26}$). Biotite (roughly 6%) forms tabular flakes measuring up to 3·5 mm., though smaller flakes are more numerous. In one slide a large, partly chloritized biotite appears to be intergrown with smaller, fresher ones. Lenses of chlorite are very numerous, inclusions of apatite, sphene and iron ores are fairly numerous, and topaz has been noted in a few slides.

Though not so fresh as could be desired, the rock on the road occurs in a fairly recent cutting, and it seems likely that this represents the freshest obtainable. On this account it has been analysed, with the following results:

	I.	Ia.	II.	IIa.	III.	IIIa.	IV.	IVa.
SiO_2 ..	73·51	1·225	74·00	1·233	73·98	1·233	73·51	1·225
Al_2O_3 ..	14·03	0·137	14·49	0·142	13·47	0·132	15·53	0·152
Fe_2O_3 ..	0·79	0·005	1·10	0·007	0·72	0·005	2·07	0·013
FeO ..	0·91	0·013	0·45	0·007	0·97	0·014	n.d.	(0·026)
MgO ..	0·38	0·009	0·44	0·011	0·36	0·009	0·39	0·010
CaO ..	1·69	0·030	0·92	0·016	0·90	0·016	1·12	0·020
Na_2O ..	3·03	0·048	3·29	0·053	3·39	0·055	3·01	0·048
K_2O ..	4·58	0·049	4·85	0·052	4·88	0·052	4·93	0·052
H_2O+ ..	0·20	—	0·56	—	0·32	—	0·29	—
H_2O- ..	0·18	—	0·18	—	0·12	—	—	—
TiO_2 ..	0·45	0·006	0·14	0·002	0·54	0·007	—	—
P_2O_5 ..	0·05	—	0·05	—	0·05	—	—	—
MnO ..	0·01	—	0·08	0·001	0·03	—	—	—
Other Const.	—	—	0·06	—	0·10	—	—	—
Total ..	99·81		100·61		99·83		100·85	
Sp. Gr. ..	2·658		2·630		2·639			

The norms have been calculated as follows:

	I.	II.	III.	IV.
Quartz	34·68	33·60	32·88	32·94
Orthoclase	27·24	28·91	28·91	28·91
Albite	25·15	27·77	28·82	25·15
Anorthite	8·34	4·45	4·45	5·56
Corundum	1·33	2·14	0·92	3·26
Hypersthene	1·16	1·10	1·16	4·43
Magnetite	1·16	1·39	1·16	—
Ilmenite	0·91	0·30	1·06	—
Haematite	—	0·16	—	—

I. Even-grained Biotite-granite. Bathurst Road, Hartley. [Toscanose, I, (3)4, 2, 3]. Anal. G. A. Joplin.

II. Aplitic Granite. Tenterfield, New England, N.S.W. [Toscanose, I, (3)4, (1)2, 3]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii, 1907, p. 225. In Washington's Tables, p. 212, No. 360.

III. Granite. Bolivia, New England, N.S.W. [Toscanose, I, (3)4, (1)2, 3]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii, p. 220, 1907. In W.T., p. 212, No. 361.

IV. Granite. Serrerhof, n. Wolfach-Schwarzwald. [Toscanose, I, (3)4, "2, 3]. Anal. H. Schwenkel, in Diss. Tüb., p. 146, 1912. In W.T., p. 199, No. 241.

(ii). *Porphyritic Biotite-granite.*

This occurs along the Bathurst Road in the village of Hartley, and is met with on the hillside above the road to the south, and in the bed of the River Lett to the north.

The rock is of a greyish colour, with large, tabular, pale pink phenocrysts of orthoclase up to an inch in length. Simple twinning is often well developed. The groundmass is fairly coarse, and in the handspecimen can be seen to consist of quartz, plagioclase, biotite and a little orthoclase. Sphene may also be frequently detected macroscopically, and iron pyrites is abundant along joint planes.

Under the microscope the groundmass is seen to be allotriomorphic granular, and to be composed of quartz, plagioclase, orthoclase, and biotite, with accessory sphene, magnetite, and a little muscovite and myrmekite. Small quantities of chlorite, haematite and kaolin occur as alteration products.

The large orthoclase crystals measure up to 20 mm., and show slight microperthitic intergrowth with albite. These phenocrysts contain inclusions of quartz, plagioclase, sphene, biotite, and apatite, and there appears to be a kind of marginal parallel intergrowth with plagioclase. Orthoclase forms about 41% of the rock.

In the groundmass orthoclase is subordinate to quartz and plagioclase, and allotriomorphic grains measure about 1·5 mm. Microperthitic intergrowth is apparent, and where orthoclase is in contact with plagioclase there is an occasional slight development of myrmekite.

Quartz forms about 25% of the rock, and a few irregular grains, measuring up to 8 mm., occur as phenocrysts, but this mineral is most commonly developed in the groundmass, where grains average 1·5 mm. Some of these sections show a subidiomorphic "arrow-shape", which characterizes graphic intergrowth, though this structure cannot be said to be present. One large rounded equidimensional grain 3 mm. across was noticed, containing radial inclusions of orthoclase, and biotite occasionally forms inclusions in the smaller grains.

Plagioclase ($Ab_{71}An_{29}$) forms subidiomorphic tabular crystals up to 3 mm., and comprises about 20% of the rock. Crystals are often zoned, and sometimes show poorly developed pericline twinning in addition to the well developed albite lamellae.

Biotite is moderately abundant in the groundmass (13%), and small flakes averaging 0·3 mm. are often segregated into masses which measure 2 mm. across. The flakes are mostly idiomorphic and often show cracks and slight bending, whilst the smaller flakes are often much chloritized. Apatite inclusions are very numerous, and are usually oriented in such a way that their longer axes are parallel to the cleavage of the biotite. Inclusions of felspar, magnetite and sphene are also fairly common in the biotite. Sphene is very well developed as an accessory mineral, and is idiomorphic to subidiomorphic. The average grainsize is about 1 mm., though larger crystals have been detected in the handspecimens. A few perfect lozenge-shaped crystals measuring 0·6 mm. are included in an orthoclase phenocryst. Magnetite forms irregular grains, and is included in the felspars and biotites. This usually forms a kind of intergrowth with sphene, but as the latter appears to be primary, there is no justification for assuming the iron ore to be ilmenite, and the appearance is probably due to a simultaneous crystallization of magnetite and sphene. Apatite forms large crystals up to 1 mm., but quite small inclusions in biotite are more common. Primary epidote and allanite have also been found in a slide of this rock.

A chemical analysis has been made of this type, but it has not been possible to compare it with the Bathurst porphyritic biotite-granite, as a complete analysis of this rock has not been obtainable. W. J. Clunies Ross (1894) quotes 68% for SiO_2 and specific gravity 2·75–2·79 for the Bathurst rock.

	I.	Ia.	II.	IIa.	III.	IIIa.	IV.	IVa.
SiO_2 ..	68·60	1·143	68·25	1·138	69·01	1·150	68·20	1·136
Al_2O_3 ..	15·33	0·150	14·41	0·141	15·44	0·151	15·99	0·157
Fe_2O_3 ..	1·92	0·012	2·00	0·013	1·28	0·008	0·89	0·006
FeO ..	1·85	0·026	2·07	0·029	1·28	0·018	2·58	0·036
MgO ..	0·81	0·020	1·08	0·027	0·62	0·016	0·80	0·020
CaO ..	2·78	0·050	3·06	0·055	2·54	0·045	2·61	0·046
Na_2O ..	3·38	0·055	3·19	0·052	3·85	0·062	2·85	0·045
K_2O ..	4·52	0·048	4·74	0·050	4·52	0·048	4·60	0·049
H_2O+ ..	0·50	—	0·35	—	0·56	—	0·64	—
H_2O- ..	0·11	—	0·19	—	0·33	—	0·21	—
TiO_2 ..	0·51	0·006	0·36	0·005	0·49	0·006	0·58	0·008
P_2O_5 ..	0·22	0·001	0·15	0·001	0·24	0·002	0·14	0·001
MnO ..	0·04	—	0·16	0·002	0·01	—	0·04	—
Other Const.	—	—	0·09	—	—	—	0·15	—
Total ..	100·57		100·10		100·17		100·28	
Sp. Gr. ..	2·703		2·698		2·664		2·673	

	I.	II.	III.	IV.
Quartz ..	24·18	23·70	23·64	26·64
Orthoclase	26·69	27·80	26·69	27·80
Albite ..	28·82	27·25	32·49	23·58
Anorthite	13·07	10·84	10·56	11·95
Corundum	—	—	0·31	2·04
Diopside	—	2·94	2·13	—
Hypersthene ..	3·06	2·99	—	4·90
Magnetite	2·78	3·02	1·86	1·39
Ilmenite	0·91	0·76	0·91	1·22
Apatite..	0·34	0·34	0·67	0·34

I. Porphyritic Biotite-granite. Bathurst Road, Por. 14, Parish of Hartley. [Toscanose, I″, 4, 2″, 3]. Anal. G. A. Joplin.

II. Granite. Herding Yard Creek, N.S.W. [Toscanose, I(II), 4, 2, 3]. Anal. W. A. Greig, *Geol. Surv. N.S.W., Min. Res.*, No. 14, 1911, p. 90.

III. Quartz-monzonite. Lone Pine Creek, Mount Whitney Quadrangle, California. [Toscanose, I, 4, 2, 3″]. Anal. R. C. Wells, U.S.G.S. Rec. Lab. In W.T., p. 186, No. 146.

IV. Porphyritic Granite. Granite Island, Encounter Bay, South Australia. [Toscanose, I″, 4, 2″, 3]. Anal. W. R. Browne, *Trans. Roy. Soc. S. Aust.*, 1920.

(iii). *Hornblende-biotite-granite.*

This type is, perhaps, the most abundantly developed in the area examined. It is met with on the River Lett between the bridges, where it grades into a granodiorite to the south, and into a biotite-granite to the north. This rock is a massive, coarse-grained, pinkish-grey type in which quartz, orthoclase, biotite, hornblende and plagioclase may be distinguished in the handspecimen. An almost identical type occurs on Campbell's Creek, and this gradually becomes more basic and passes into a granodiorite at the junction of the creek with Cox's River.

A hornblende-biotite-granite, of slightly finer texture and lighter colour, is met with at the junction of Moyne Creek and Grant's Creek, and this passes into a darker and coarser type towards the south. This latter outcrops near the mouth of Kanimbla Creek, and is found to be very similar to, though slightly darker than, the rock occurring on the River Lett. In this type, the plagioclase is of a yellowish-green colour and, on account of its abundance, and of the darker colour of the rock, it seems that the rock stands very close to a granodiorite.

Under the microscope, the hornblende-biotite-granites are seen to be allotriomorphic-granular with a medium grainsize, averaging 2–3 mm. The minerals present are quartz, orthoclase, plagioclase, hornblende and biotite, with accessory magnetite, sphene and apatite. In addition, the Lett River rock contains a small quantity of epidote, rutile and chlorite.

The quartz forms about 26·5% of the rock and occurs in allotriomorphic grains varying from 1 mm. to 3 mm. in size. Slight granulation and minute inclusions, some of which appear to be liquid, occur in the quartz of the Grant's Creek type; and in the Lett type quartz is both included in, and includes, orthoclase, whilst a parallel development of the hornblende is evinced by a slight graphic intergrowth between that mineral and quartz. Orthoclase forms allotriomorphic grains up to 3 mm., and usually shows microperthitic intergrowth with albite. Orthoclase apparently started to crystallize at the same time as quartz, and continued to grow after the quartz had finished, since some of the larger grains are interstitial. About 35% of the rock is composed of this mineral. The plagioclase is oligoclase ($Ab_{70}An_{30}$). It forms subidiomorphic sections averaging 1-3 mm., and is much less abundant than orthoclase, forming about 25% of the rock. Zoning is often developed, albite twinning is well marked, and some sections show pericline twinning. Rutile needles form schiller inclusions in the Lett type and epidote is present in decomposition zones. Hornblende is well developed (about 10% of the rock). In the Kanimbla type, columnar crystals measure up to 3·25 mm. The average size of hornblende crystals, however, is from 1 to 2 mm., and the mineral usually forms subidiomorphic prisms. Inclusions of apatite, sphene, biotite. felspar and iron ores are numerous and, as has been pointed out, a kind of graphic intergrowth of hornblende with quartz occurs in the Lett type. Some of the hornblende in this rock is rather pale, and may be secondary. Biotite is well developed (some 4·5%) as subidiomorphic flakes, which measure up to 2 mm., and sometimes form aggregates of small shreds averaging about 0·5 mm. Inclusions of iron ore, apatite and sphene are fairly numerous, and chlorite often occurs in lenses parallel to the cleavage. The mineral is strongly pleochroic, and in the more acid type on Grant's Creek, pleochroic haloes are fairly abundant. It is probable that the nuclei are zircons, but this mineral has not been identified.

Magnetite is moderately abundant as an accessory and often forms the centre of a phenocryst, which is bordered by a fringe of biotite, and measures 0·5 mm. across. This is a common feature of the Grant's Creek type. Magnetite forms irregular grains and sometimes is intergrown with sphene, hence some of the iron ore is, perhaps, ilmenite. Sphene occurs both as idiomorphic crystals measuring up to 0·25 mm., and more frequently as allotriomorphic grains wrapping round, and intergrown with, hornblende and iron ores. Occasionally iron ore is included in sphene. Apatite forms small, stumpy prisms and is included in all the other minerals. Topaz has been detected in one slide of the Lett type.

(iv). *Granodiorite.*

This type occurs at the junction of Campbell's Creek and Cox's River, where it has been shown to merge into the hornblende-biotite-granite to the north. Granodiorites are also met with along Kanimbla Creek and Spring Creek. The granodiorite on Campbell's Creek is very similar to the hornblende-biotite-granite to the north, that is, it is a massive, fairly coarse, pinkish-grey rock, consisting of quartz, orthoclase, plagioclase, hornblende and biotite. Though the general body-colour of the rock is almost identical with the more acid type to the north, a close examination reveals the fact that hornblende and plagioclase are a little more plentiful in the granodiorite. This rock is characterized by an abundance of basic segregations averaging about one and a half inches across. One of these has been sectioned and is described later.

Under the microscope, the granodiorite from Campbell's Creek is seen to consist of quartz, plagioclase, orthoclase, hornblende and biotite, with accessory magnetite, sphene, apatite and a little chlorite and kaolin as alteration products.

The rock is hypidiomorphic to allotriomorphic granular with a fairly even grainsize of about 2 mm. Quartz forms about 29% of the rock and occurs in allotriomorphic grains from 1·5 mm. to 3 mm. It contains inclusions of felspar. The plagioclase comprises about 36% of the rock and is andesine ($Ab_{65}An_{35}$). It shows zoning in addition to albite and pericline twinning, and tabular subidiomorphic crystals vary from 3 mm. to 1·5 mm. Orthoclase (about 20·5%) forms allotriomorphic grains varying from 1 mm. to 3 mm., and is slightly microperthitic. Inclusions of hornblende, biotite, sphene, apatite and quartz are fairly numerous. Biotite forms subidiomorphic flakes, a few large ones measuring 2 by 3 mm. It is strongly pleochroic, and shows a slight marginal intergrowth with hornblende. Some smaller flakes show alteration into chlorite which forms lenses parallel to their cleavages. Inclusions of iron ore, felspar, sphene and apatite are fairly abundant. This mineral forms about 11% of the rock.

Hornblende (3%) forms subidiomorphic prisms about 1 mm. in length and, though apparently primary, is of a pale-green colour. A slight intergrowth with biotite is present, and inclusions of sphene, apatite and magnetite are fairly numerous.

Sphene is moderately abundant, and is of a reddish-purple colour. It is associated with iron ore, and included in ferromagnesian minerals and felspars. Magnetite forms grains from 0·5 mm. to 0·1 mm., and is fairly abundant as an accessory. Apatite is present as inclusions.

The rock has been analysed, with the following result:

	I.	Ia.	II.	IIa.	III.	IIIa.	IV.	IVa.
SiO_2 ..	65·33	1·088	65·83	1·097	64·04	1·067	65·36	1·089
Al_2O_3 ..	16·20	0·159	16·44	0·161	15·58	0·153	16·37	0·161
Fe_2O_3 ..	2·43	0·015	1·03	0·006	0·80	0·005	1·80	0·011
FeO ..	2·38	0·033	3·33	0·046	4·47	0·062	2·68	0·038
MgO ..	1·28	0·032	2·00	0·050	2·64	0·066	1·81	0·045
CaO ..	4·02	0·071	4·24	0·076	3·52	0·063	3·82	0·068
Na_2O ..	3·02	0·048	2·25	0·036	2·42	0·039	3·40	0·055
K_2O ..	3·28	0·035	3·40	0·036	2·80	0·030	3·75	0·039
H_2O+ ..	0·58	—	0·67	—	2·25	—	0·33	—
H_2O- ..	0·10	—	0·10	—	0·38	—	0·09	—
TiO_2 ..	0·72	0·009	0·78	0·009	0·80	0·010	0·36	0·005
P_2O_5 ..	0·22	0·001	0·21	0·001	0·18	0·001	0·16	0·001
MnO ..	0·03	—	0·08	0·001	—	—	0·16	0·002
Other Const.	—	—	—	—	—	—	0·33	0·010
Total ..	99·59		100·36		99·88		100·35	
Sp. Gr. ..	2·742		2·741		2·722		2·711	

	I.	II.	III.
Quartz ..	24·78	26·22	25·14
Orthoclase	19·46	20·02	16·68
Albite ..	25·15	18·86	20·44
Anorthite	18·90	20·29	16·68
Corundum	0·82	1·63	2·45
Hypersthene	4·39	9·22	12·94
Magnetite	3·48	1·39	1·16
Ilmenite..	1·37	1·37	1·52
Apatite ..	0·34	0·34	0·34

I. Granodiorite. Junction of Campbell's Ck. and Cox's River, Hartley. [Amiatose, I(II), 4, 3, 3″]. Anal. G. A. Joplin.

II. Granodiorite. Por. 48, Parish of Moruya. [Amiatose, I(II), 4, 3, 3]. Anal. Ida A. Brown, Proc. Linn. Soc. N.S.W., 1928.

III. Granodiorite. Near Braemar House, Mt. Macedon, Victoria. [Harzose, ″II, ″4, 3, 3]. Anal. R. J. Lewis, *Bull. Geol. Surv. Vict.*, 24, 1912, p. 20.

IV. "Blue Granite". Tenterfield, New England, N.S.W. [Amiatose, I(II), 4, (2)3, 3″]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii (3), 1907, p. 203. In W.T., p. 252, No. 54.

(b). Diorite Group.

(v). *Tonalites.*

The tonalites are the most acid members of the diorite group. These outcrop on Moyne Farm, where they form the central, more acid differentiate of the intrusion. The tonalites grade almost imperceptibly into the quartz-mica-diorites by a decrease in orthoclase and quartz and an increase in the ferromagnesian constituents, and in the basicity of the plagioclase.

In the handspecimen, the tonalites appear as fairly fine-grained, massive, grey or pinkish-grey rocks with about equal proportions of light and dark constituents. With the aid of the lens, the light minerals can be distinguished as colourless or smoky quartz, white plagioclase, and pale-pink orthoclase, whilst the dark minerals comprise hornblende and biotite and sometimes fairly large patches of green epidote. Small aplite veins varying from half an inch to mere threads are very abundant, and these have produced a local monzonitic fabric in the contiguous rock.

Under the microscope, the tonalites are found to be holocrystalline and hypidiomorphic to allotriomorphic granular, with a tendency towards subophitic fabric in some cases. The grainsize is even and averages about 2 mm. The rock consists of plagioclase, quartz, biotite, hornblende and orthoclase, with accessory iron ores, sphene, epidote, apatite and occasionally carbonates, sericite, chlorite, kaolin and rutile. Most of the hornblende is due to reaction and a few cores of pyroxene have been detected.

The plagioclase which is andesine ($Ab_{68}An_{32}$) forms subidiomorphic tabular crystals with a lath-like tendency, and varies from 1 mm. to 3 mm. in size. A slight magmatic alteration has caused sericitization and kaolinization of the felspars. Albite twinning and zoning are well developed. About 57% of the rock is plagioclase. The quartz (some 16·5%) is in allotriomorphic grains, and though interstitial, it is not so markedly so as in the quartz-mica-diorites. The consolidation has apparently been in part contemporaneous with that of plagioclase. In several cases a kind of intergrowth between quartz and uralitic hornblende has been observed. On an average the quartz grains in the body of the rock are 1–2 mm., but minute grains are present in quartz veins, which ramify through the tonalites. Hornblende (about 11%) is both primary and uralitic after pyroxene, but the latter type is the more abundant. Simple twinning is often shown and good amphibole cleavage is apparent in some sections. The uralite pseudomorphs are usually fringed with biotite and include secondary magnetite, epidote and sphene.

In one slide a frayed and tufted amphibole occurs in small quantity, and this may be of the nature of actinolite. In another specimen fragments of hornblende, quartz, felspar and chlorite form a kind of groundmass, enwrapping larger mineral individuals. The hornblende contains numerous inclusions of iron ore, apatite and sphene, and is intimately associated with chloritized biotite and epidote.

Biotite is often more abundant than hornblende, but varies in quantity in different parts of the mass. This is probably due to local variations of physical conditions during consolidation, and as a result a certain amount of heterogeneity has been set up. The average amount, like hornblende, is about 11%. The biotite forms subidiomorphic flakes up to 1·5 mm., but most frequently occurs in small flakes which are aggregated together into masses, measuring up to 3 mm. across.

Inclusions of iron ores, apatite and sphene are common, and in one slide granules of secondary sphene and iron ore, evidently ilmenite, are strung out along the biotite cleavages. Where the biotite shows bending, these granular strings are seen to follow it. Small needles of rutile, arranged parallel to the cleavage, are also present in this slide. Lenses of chlorite are numerous, and in some cases the biotite appears to have been entirely chloritized by magmatic solutions. A slight intergrowth with uralitic hornblende is present in a few slides. Both primary and secondary sphene occur, but the latter is the more abundant. It is usually found as inclusions in the ferromagnesian minerals, and also surrounding and associated with ilmenite grains. Epidote is fairly abundant, and much appears to be primary or at least deuteric. Grains measure up to 0·2 mm. and are in association with the ferromagnesian minerals. In one slide subidiomorphic prisms measure up to 0·65 mm. and are grouped. Orthoclase is usually subordinate, but gains prominence in the neighbourhood of aplitic veins. Iron ores appear to comprise both magnetite and ilmenite, and are fairly abundant accessories. Apatite is a constant inclusion mineral and forms prisms up to 0·3 mm.

No specimen has been found entirely free from deuteric alteration, and due allowance must be made for this in the analysis.

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	62·06	1·034	61·61	1·027	61·44	1·024
Al_2O_3	18·25	0·177	17·95	0·176	17·61	0·173
Fe_2O_3	2·91	0·018	3·35	0·021	1·86	0·011
FeO	2·94	0·040	3·38	0·047	3·59	0·050
MgO	1·71	0·043	2·09	0·052	3·09	0·077
CaO	4·90	0·088	4·91	0·088	5·88	0·105
Na_2O	3·12	0·050	3·22	0·052	2·03	0·032
K_2O	1·61	0·017	1·04	0·011	1·03	0·012
H_2O+	1·34	—	1·50	—	1·17	—
H_2O-	0·16	—	—	—	0·10	—
TiO_2	0·60	0·008	0·37	0·005	1·42	0·018
P_2O_5	0·24	0·001	0·19	0·001	0·33	0·002
MnO	0·09	0·001	—	—	0·09	0·001
Total	99·93		99·71		99·64	
Sp. Gr.	2·764		—		2·768	

	I.	II.	III.
Quartz	24·12	24·36	27·72
Orthoclase	9·45	6·12	6·67
Albite	26·20	27·25	16·77
Anorthite	23·63	23·63	27·24
Corundum	2·65	2·86	3·16
Hypersthene	6·28	7·97	10·60
Magnetite	4·18	4·87	2·55
Ilmenite	1·22	0·76	2·74
Apatite	0·34	0·34	0·67

I. Tonalite. Moyne Farm, Little Hartley. [Yellowstonose, near Tonalose, (I)II, 4, 3, 4]. Anal. G. A. Joplin.

II. Andesite (quartzose). Martinique, West Indies. [Tonalose, (I)II, 4, 3″, 4″]. Anal. A. Pisané, A. Lacroix, Mont Pélée, 1904, p. 531. In W.T., p. 384, No. 114.

III. Quartz-diorite (Tonalite). Kelly's Point, 10 miles south-east of Moruya. [Bandose, near Tonalose, 'II, (3)4, '4, 4]. Anal. Ida A. Brown, Proc. Linn. Soc. N.S.W., 1928.

(iv). *Monzonitic Quartz-diorite.*

It has been pointed out that certain of the tonalites might be put down as monzonites from the microscopic examination alone, but field-relations have shown that these rocks occur in the neighbourhood of aplite veins, and that the monzonitic fabric is only of very local occurrence.

On Kanimbla Station, however, a very coarse type of quartz-monzonite occurs, but through the presence of alluvium its field-relations cannot be ascertained. The rock occurs in the bed of Kanimbla Creek and the whole outcrop is only a couple of chains in diameter. On account of its coarse and massive texture, the rock weathers into huge tors, and the outcrop is most distinctive. This rock may be of only local occurrence, but its origin is certainly different from that of the monzonitic tonalites, whose extent is but a matter of centimetres.

Much consideration has been given to the naming of this rock, and it has been decided for the present to call it a monzonitic quartz-diorite, rather than a quartz-monzonite. The latter would imply a distinct group, which some authors (Harker, and Hatch and Wells) place as intermediate between the diorites and syenites, and it will be shown later that the Hartley complex is typical of the granite-granodiorite differentiation as outlined by Bowen (1915).

Though the quartz-monzonites show affinities for this line of descent, other difficulties present themselves. Firstly, the Hartley rock has a silica percentage much lower than the typical quartz-monzonites (Hatch and Wells, 1926). Secondly, the rock may be a local differentiate only, and would hardly warrant the introduction of another group-name. Thirdly, the scheme of classification outlined by Iddings (1909) necessitates exact measurements, either by a Rosiwal analysis, or by calculation from the chemical analysis. It has not been possible to make exact quantitative measurements, and as the composition of the ferromagnesian minerals is unknown, a calculation of the mineral composition is also impossible. Monzonitic affinities, however, are exemplified somewhat by the magmatic name, which is Harzose near Shoshonose. This latter is the subrang of many of the South Coast latites (Card, 1915).

In the handspecimen the rock is holocrystalline, very coarse, and of a greyish-pink colour. It can be seen to consist of white plagioclase showing excellent multiple twinning, large plates of black biotite, colourless quartz grains, pink orthoclase, which often can be seen wrapping plagioclase, and producing a monzonitic fabric, and a little hornblende.

Under the microscope the rock is holocrystalline and hypidiomorphic to allotriomorphic granular, with a distinct tendency to monzonitic fabric. The grainsize is coarse and averages 7 mm. It consists of plagioclase, orthoclase, quartz, biotite, hornblende, iron ores, sphene, apatite, and a little rutile.

Plagioclase forms about 60% of the rock and is present in subidiomorphic, tabular crystals, 2–8 mm. in length. It is andesine of the composition $Ab_{64}An_{36}$. Albite and pericline twinning are both well developed, and the surface is a little kaolinized and sericitized. Inclusions of sphene, biotite, iron ores and apatite are present, and in some cases a slight zoning by inclusions is apparent. Orthoclase forms interstitial allotriomorphic grains up to 6 mm., and comprises some 26% of the rock. This mineral contains inclusions of all the others present in the rock, and is rather kaolinized. A certain amount of intergrowth with albite is present, and kaolinization has been selective in being more abundant in the soda-felspar. Quartz (about 8% of the rock) forms smaller grains than orthoclase, but is more abundantly developed. It too is interstitial, but slightly precedes orthoclase in final consolidation. Grains measure up to 1·5 mm. Biotite (about 2%) is a brown, strongly pleochroic variety, and tabular flakes measure up to 2 mm. across. Inclusions of apatite and felspar are fairly numerous, and there is some intergrowth with hornblende. Peculiar suture-like cracks are developed in some cases, and these must have been produced by strains during consolidation. A little chlorite is found as an alteration-product. Hornblende (about 2·5%) forms subidiomorphic prisms measuring 1·5 mm., and is slightly intergrown with biotite. Inclusions of apatite, felspar, sphene, iron ores and a little rutile are present, and chlorite is often associated as an alteration product. Primary sphene occurs mainly as irregular grain inclusions, but is not abundant. A small quantity of secondary sphene is associated with the iron ores, which apparently consist of both magnetite and ilmenite.

The analysis of this rock is given below:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	58·37	0·973	58·20	0·970	59·94	0·994
Al_2O_3	18·38	0·180	18·35	0·180	15·61	0·153
Fe_2O_3	2·80	0·018	1·44	0·009	1·55	0·010
FeO	4·43	0·061	3·46	0·048	6·25	0·087
MgO	2·79	0·069	3·49	0·087	2·53	0·063
CaO	6·29	0·113	6·20	0·111	6·65	0·119
Na_2O	2·52	0·040	2·63	0·042	2·88	0·047
K_2O	2·56	0·028	2·96	0·032	2·06	0·022
H_2O+	0·56	—	2·05	—	0·57	—
H_2O-	0·16	—	—	—	0·39	—
TiO_2	0·52	0·006	0·87	0·011	1·08	0·014
P_2O_5	0·26	0·002	—	—	0·64	0·004
MnO	0·06	0·001	0·35	0·005	—	—
Total	99·70		100·00		100·15	
Sp. Gr.	2·807					

	I.	II.	III.
Quartz ..	14·76	11·34	15·78
Orthoclase	15·57	17·79	12·23
Albite ..	20·96	20·01	24·63
Anorthite	29·47	29·47	23·35
Corundum	0·20	—	—
Diopside..	—	1·11	5·35
Hypersthene	11·92	12·52	11·93
Magnetite	4·18	2·09	2·32
Ilmenite..	0·91	1·67	2·13
Apatite ..	0·67	—	1·34

I. Monzonitic Quartz-diorite. Kanimbla Station, Little Hartley. [Harzose, ″II, 4″, 3(4), 3″]. Anal. G. A. Joplin.

II. Andesite. St. Paul's, Whangaroa, N.Z. [Harzose, ″II, 4(5), (2)3, 3″]. Anal. J. S. Maclaurin, Bell and Clarke, *Bull. N.Z. Geol. Surv.*, 8, 1909, p. 68. In W.T., p. 368, No. 84.

III. Granodiorite. Glenrock Falls, Marulan. [Bandose]. Anal. G. J. Burrows, Proc. Linn. Soc. N.S.W., xxxiv, 1909.

(vii). *Quartz-mica-diorites.*

Quartz-mica-diorites occur bordering both the Moyne Farm and Cox's River intrusions.

On Moyne Farm, this type merges imperceptibly into the tonalite by a gradual decrease in the ferromagnesian minerals, and an increase in the acidity of the plagioclase. The coming in of orthoclase also marks the transition into the tonalite. At the contact with the Devonian strata, the rock is finer grained and no hornblende has been detected. Masses of alteration-products, however, may represent remnants of this mineral.

On the Cox's River, the quartz-mica-diorites gradually become more basic away from the margin and pass into a diorite-gabbro, which in turn passes into a central mass of gabbro. It seems probable that the quartz-mica-diorites have suffered some contamination and that the diorite-gabbro is a reaction border of the gabbro. The analysis shows that the Cox's River quartz-mica-diorites are a little more basic than the Moyne Farm type, though there is no essential difference in the mineral composition. The rock near the contact with the Devonian strata is usually somewhat porphyritic in plagioclase.

The quartz-mica-diorites have a typical dioritic appearance, light and dark constituents being present in about equal abundance. With the aid of a lens, quartz and biotite may be distinguished in addition to the plagioclase and hornblende.

Under the microscope the rock is hypidiomorphic to panidiomorphic granular, and the fabric is ophitic to subophitic, and sometimes poikilitic. The mineral constituents are plagioclase, biotite, hornblende, quartz and, in some cases, uralitized pyroxene with occasional cores of augite. A little orthoclase is sometimes present in the Moyne type. Accessory minerals are magnetite, ilmenite, apatite and rutile. Epidote, α-zoisite, saussurite, sericite, kaolin, rutile and sphene are deuteric and secondary.

Some of the slides show a mineral that has not been satisfactorily identified, but may possibly be lawsonite. It is found forming lenses in the biotite, and has often caused slight bending in the mica. It appears to be in parallel intergrowth with the biotite, and seems to consist of an aggregate of fibres that are parallel to the biotite cleavage. It has a double refraction about 0·020, and has a medium refractive index, but other optical properties cannot be obtained owing to the fibrous nature of the mineral. Dr. Stillwell has described an apparently similar mineral as lawsonite in an actinolite-schist from Adélie Land, Antarctica, and of this he says: "The colourless mineral is frequently found in parallel intergrowth with biotite. Sometimes it is so developed after this manner that the biotite appears to be merely threaded in along cleavage planes. Its form is usually lobate, and the biotite plates, in consequence, bend round its contour. Its cleavage is well developed parallel to the elongation of the crystal, and the cleavage of the biotite."

It seems likely that the mineral of the Hartley rock is the same, though no evidence of metamorphism has been observed. There is little doubt, however, that the Hartley rocks have suffered deuteric alteration, and it may be possible that lawsonite, like epidote, may be a deuteric as well as a metamorphic mineral.

With regard to the occurrence of lawsonite, Iddings (1911) says: "It has been found in a number of localities in Italy, accompanying albite and saussuritized felspar."

Plagioclase (about 57·5% of the rock) occurs in elongated tabular sections or laths, and varies from 0·75 mm. to 2 mm. It is andesine, which on Moyne Farm ranges from $Ab_{55}An_{45}$, at the margin of the intrusion, to $Ab_{64}An_{36}$ as the quartz mica-diorite passes into the tonalite. On the Cox the range is from $Ab_{58}An_{42}$ to $Ab_{50}An_{50}$ where the rock merges into the diorite-gabbro (see Text-figs. 6 and 7). Albite and pericline twinning are well developed and zoning is fairly common. Some sections show tabular felspars crowded with inclusions of biotite, hornblende, epidote and iron ores. These are concentrated towards the centre of the felspar, and there is an outer border of sericite, kaolin and other alteration products of the felspar. The included biotites are usually oriented in such a way that their longer axes are parallel to that of their host.

One of the Moyne Farm rocks and a great many of the marginal rocks of the Cox intrusion are porphyritic in plagioclase. Tabular, zoned phenocrysts measuring 3 mm. across are set in a typical quartz-mica-diorite groundmass with an average grainsize of 0·15 mm. A somewhat similar type occurs on Kanimbla Creek on the property of Mr. Hughes. All three porphyritic types are somewhat similar to a porphyritic granodiorite (M 127b) described by Miss Ida A. Brown (1928) from Moruya.

As is the case with the tonalites, sometimes biotite, and sometimes hornblende is the more abundant ferromagnesian mineral. Evidently local conditions have favoured the formation of either one or the other. Hornblende (about 16% of the rock) usually forms subidiomorphic plates wrapping plagioclase, and thus producing an ophitic fabric. In some cases almost idiomorphic columnar sections occur, and in one of the Moyne specimens granular aggregates of hornblende are present as well as subidiomorphic individuals. In several slides a kind of poikilitic fabric is produced by optically continuous masses of hornblende up to 3 mm. across, which includes felspars, iron ores, epidote, apatite, biotite and chlorite. Inclusions of the accessory minerals are common in the hornblende of all the specimens. Some sections show an intergrowth of hornblende and biotite, and others masses of secondary amphibole bordered by primary hornblende and biotite, and usually enclosing pyroxene cores. Biotite (averaging about 10·5% of the rock) is sometimes developed in subidiomorphic, tabular flakes up to 3 mm. across, but averages about 1 mm. The larger sheets enclose most of the other minerals, giving a kind of poikilitic fabric, and this structure is sometimes developed to a marked degree. Bending is often present, and lenses of lawsonite (?) are fairly numerous, especially in the Cox's River specimens. Intergrowth of biotite and hornblende is not infrequent, particularly around cores of amphibolized pyroxene.

Inclusions of the accessory minerals are abundant in the biotite, and comprise ilmenite, magnetite and apatite. In one of the Moyne slides a few small reddish-brown haloes are present, and these possibly surround small zircons. Ilmenite and secondary sphene often form little granular strings in the mica. Lenses of chlorite are numerous and in places the biotite appears to have been almost entirely chloritized. Other alteration products of the mica are grains of epidote and secondary magnetite, which appear to be concentrated towards the margin. The original biotite evidently contained a fairly large proportion of titania, since sagenite webs are very well developed in a few slides.

Quartz (some 12% of the rock) forms allotriomorphic grains and is always interstitial. The size of the grains varies with the texture of the rock, ranging from 0·1 mm. to 1·5 mm. Owing to its interstitial occurrence, a kind of poikilitic fabric is produced. In a few slides from both intrusions small plagioclase laths are enclosed in this way, and at first glance it appears to be almost a graphic intergrowth of quartz and plagioclase; the latter, however, are not oriented. Small groups of quartz grains often show mosaic granular aggregates. Inclusions are very numerous in the quartz, but are usually very small. Some of these have been identified as apatite, ilmenite, magnetite and rutile, but the majority are ultra-microscopic. Slight granulation is sometimes present, and in a few cases undulose extinction has been noted. Small quartz veins are fairly numerous. In some cases they merge into the body of the rock, and were evidently injected whilst it was still hot, and only partly solidified. On the other hand, some of these small veins show evidence of having been injected into the cold rock.

Orthoclase is present in a few of the Moyne rocks, but it is not a common constituent, and is developed only in small amount.

The iron ores consist of both ilmenite and magnetite, and are abundant as accessories, and comprise about 4% of the rock. Magnetite usually forms sub-rectangular grains measuring about 0·2 mm., and in one slide grains are bordered by clear, transparent, red haematite. Secondary sphene forms small granules bordering ilmenite, and is abundant in most of the slides. The iron ores occur mainly as inclusions, but in some cases appear to be intergrown with the ferro-magnesian minerals. Small grains of secondary magnetite are commonly associated with biotite and amphibolized pyroxene. Rutile is mostly secondary, but a primary origin must surely be postulated for the needles included in the quartz. Apatite is a constant inclusion mineral, and forms both stumpy prisms and long slender needles. Cross-partings are well developed in the latter.

The occurrence of epidote, α-zoisite, saussurite, sericite, kaolin and secondary sphene, magnetite and rutile would indicate that the rocks have suffered a certain amount of deuteric alteration. Epidote usually occurs in irregular grains associ-ated with biotite or hornblende and occasionally with felspar. In some cases subidiomorphic prisms occur, and these appear to be irrefutable evidence of a deuteric, rather than a secondary origin. A little α-zoisite intergrown with epidote and associated with plagioclase is present in one of the Moyne rocks; and in another it is associated with calcite, epidote, etc., in a mass of saussurite.

Masses of alteration products consisting largely of sericite, carbonates and chlorite are very numerous in the rock from the contact with the Devonian strata on Moyne Creek. These are apparently pseudomorphs after some mineral. Hornblende is conspicuously absent, and some of the pseudomorphs suggest hornblende in form, so this was possibly the original mineral.

Two chemical analyses have been made of the quartz-mica-diorites, one from the Moyne intrusion, and one from Cox's River. In both cases the freshest and most representative specimen has been chosen, but as in the case of the tonalites, due allowance must be made for deuteric alteration. Moreover, on account of the gradations of one type into another, and of the possibility of contamination, single analyses give a poor picture of the true composition of the original magma.

The analysis of the Moyne type is given in column I below:

	I	Ia.	II.	IIa.	III.	IIIa.
SiO_2	54·37	0·900	55·42	0·924	55·16	0·919
Al_2O_3	19·64	0·192	21·35	0·209	17·51	0·174
Fe_2O_3	4·30	0·027	3·37	0·021	2·62	0·016
FeO	4·87	0·068	4·87	0·068	5·83	0·081
MgO	2·94	0·073	3·87	0·097	4·35	0·109
CaO	8·07	0·143	7·51	0·134	8·50	0·145
Na_2O	2·55	0·040	2·94	0·047	1·83	0·029
K_2O	1·01	0·011	0·68	0·007	1·08	0·012
H_2O+	0·96	—	0·37	—	2·01	—
H_2O-	0·11	—	—	—	0·18	—
TiO_2	1·14	0·014	0·33	0·004	0·64	0·008
P_2O_5	0·34	0·002	tr.	—	0·21	0·002
MnO	0·07	0·001	—	—	0·15	0·002
Other Const.	—	—	—	—	0·10	—
Total	100·37		100·71		100·17	
Sp. Gr.	2·861				2·902	

	I.	II.	III.
Quartz	13·14	11·52	13·98
Orthoclase	6·12	3·89	6·67
Albite	20·96	24·63	15·20
Anorthite	38·09	37·25	36·97
Corundum	0·41	2·14	—
Diopside..	—	—	1·36
Hypersthene	11·00	15·38	18·02
Magnetite	6·26	4·87	3·71
Ilmenite..	2·13	0·61	1·22
Apatite	0·67	—	0·67

I. Quartz-mica-diorite. Moyne Farm, Little Hartley. [Bandose, II, 4″, 4, 4]. Anal. G. A. Joplin.

II. Diabase (inclusion in Andesite). Mont Pélée, Martinique, West Indies. [Bandose, II, 4(5), 4, 4(5)]. Anal. A. Pisané, A. Lacroix, Mont Pélée, 1904, p. 543. In W.T., p. 410, No. 36.

III. Quartz-diorite. Octoraro Ck., Cecil County, Maryland, U.S.A. [Bandose, II, 4, 4, 4]. Anal. W. F. Hillebrand, *Am. Geol.*, xxviii, 1901, p. 146. In W.T., p. 406, No. 2.

It is noteworthy that both the Moyne Farm quartz-mica-diorite and tonalite are comparable with Mont Pélée types.

Column I gives the analysis of the Cox's River type of quartz-mica-diorite.

	I.	Ia.	II.	IIa.
SiO_2	52·43	0·874	53·35	0·889
Al_2O_3	20·11	0·197	18·94	0·186
Fe_2O_3	4·18	0·026	3·71	0·023
FeO	5·59	0·078	5·35	0·075
MgO	4·12	0·103	4·15	0·104
CaO	9·06	0·161	8·50	0·152
Na_2O	2·28	0·037	2·56	0·041
K_2O	0·88	0·010	1·19	0·013
H_2O+	0·36	—	1·13	—
H_2O-	0·16	—	—	—
TiO_2	0·78	0·010	0·93	0·012
P_2O_5	0·32	0·002	—	—
MnO	0·19	0·003	—	—
CO_2	tr.	—	—	—
Total	100·46		99·81	
Sp. Gr.	2·836			

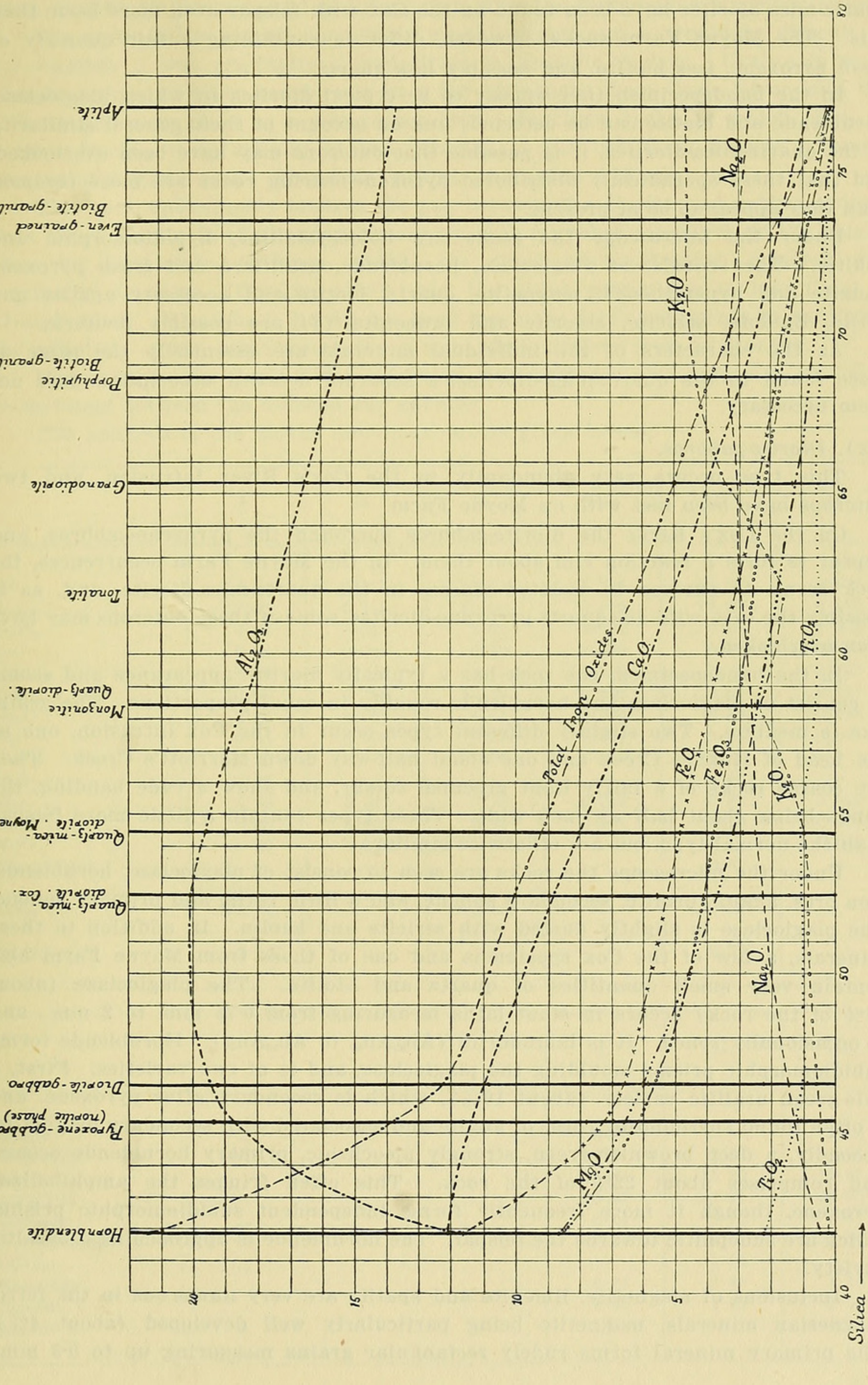
	I.	II.
Quartz	8·34	8·22
Orthoclase	5·56	7·23
Albite	19·39	21·48
Anorthite	41·70	36·70
Diopside	1·11	4·51
Hypersthene	15·71	13·49
Magnetite	6·03	5·34
Ilmenite	1·52	1·82
Apatite	0·67	—

I. Quartz-mica-diorite. Marriott Ck., Cox's River Intrusion, Little Hartley. [Hessose near Bandose, II, (4)5, 4, 4]. Anal. G. A. Joplin.

II. Hypersthene-Basalt. Capo Sperone, San Antioco, Sardinia. [Hessose, II, (4)5, 4, 4]. Anal. A. Johnsen, *Anh. Abh. Pr. Ak. W.*, No. 2, p. 59. In W.T., p. 543, No. 110.

(viii). *Quartz-pyroxene-diorites.*

Three specimens have been collected on Moyne Farm that can be classified neither as quartz-mica-diorites, nor as the more basic diorite-gabbros.



Al_2O_3
Total Iron Oxides
CaO
FeO
Fe_2O_3
K_2O
Na_2O
MgO
TiO_2
Silica

Text-fig. 5.

The plagioclase is basic andesine of the composition $Ab_{52}An_{48}$ to $Ab_{56}An_{44}$, and quartz-mica-diorites have been found on the Cox with felspar even more basic than this. The Moyne Farm rocks, however, differ in containing a fair quantity of fresh pyroxene, less biotite, and possibly less quartz.

In the handspecimen they appear to be typical diorites in which plagioclase, hornblende and biotite can be detected; and on account of their general similarity to the quartz-mica-diorites, it is possible that outcrops may have been overlooked, and that these sporadically distributed pyroxene-bearing rocks are more common than they appear to be at present.

Under the microscope the rocks are holocrystalline, hypidiomorphic and ophitic. They consist of plagioclase, hornblende, uralitized and fresh pyroxene (augite and hypersthene), magnetite, quartz, biotite and accessory apatite and rutile. Epidote, sericite, chlorite and lawsonite (?) are possibly deuteric.

As the characters of the individual minerals are essentially the same as those found in the quartz-mica-diorites, a separate detailed description does not seem necessary.

(ix). *Diorite-gabbros.*

This type occurs very abundantly in the Cox's River intrusion, and two outcrops have been met with on Moyne Farm.

On the Cox's River the diorite-gabbros surround the pyroxene-gabbros, and appear to form a reaction rim about them. In the Moyne Farm occurrences, the rock seems to outcrop in isolated masses in the quartz-mica-diorite, and, as is possibly the case with the quartz-pyroxene-diorites, some of these outcrops may have been overlooked.

In the handspecimen, the rock has a typically dioritic appearance and seems to consist of plagioclase and hornblende roughly in equal proportions. The grain-size is medium. Two slightly different types occur in the Cox intrusion, one at the head of Hughes Creek and one about half-way down Marriott's Creek. They are coarse rocks of a fairly light greenish colour, and show a rude banding, the bands being about half an inch wide. These types contain a little more felspar than the normal type, but are otherwise similar.

Under the microscope the rocks are seen to consist of plagioclase, hornblende, iron ores, augite, uralite, secondary sphene, and a little rutile and primary sphene. The plagioclase is slightly dusted with sericite and kaolin. In addition to these minerals, a few of the Cox specimens and one of those from Moyne Farm also contain very small quantities of quartz and biotite. The plagioclase (about 64% of the rock) occurs in stout laths measuring from 0·75 mm. to 2 mm., and is occasionally zoned. It is labradorite ($Ab_{50}An_{50}$ to $Ab_{43}An_{57}$). Hornblende forms subidiomorphic prisms moulding the plagioclase, and is of two varieties. First, a pale-green uralitic variety (about 10%), which is secondary after pyroxene, and is often found surrounding cores of augite and associated with secondary magnetite. Secondly, a deep brownish-green, strongly pleochroic, primary hornblende occurs, and comprises about 22% of the rock. This often fringes the amphibolized pyroxene, though it more frequently forms independent subidiomorphic prisms, which are subophitic towards the felspar. The hornblende is approaching a basaltic variety.

Inclusions of magnetite, ilmenite and apatite are very numerous in the ferro-magnesian minerals, magnetite being particularly well developed (about 4%). The primary mineral forms rudely rectangular grains measuring up to 0·3 mm., and contains inclusions of apatite. Magnetite was fairly late in crystallizing, and often moulds plagioclase, and is intergrown with the ferromagnesian constituents.

The pyroxene is almost completely amphibolized, and it would be difficult to say whether it was originally a monoclinic or rhombic variety. Uralite is more abundant than primary hornblende in a few specimens from Cox's River, and the rock stands very close to a pyroxene-gabbro. In those rocks in which there is a little biotite, it is usually at the margins of the uralitized masses. Quartz occasionally forms small interstitial grains, averaging 0·15 mm. in size.

This rock undoubtedly bridges the gap between the diorite and gabbro groups. It is like a diorite in the handspecimen, yet it is a gabbro inasmuch as the plagioclase is labradorite (Iddings, 1909), the chief ferromagnesian mineral was originally pyroxene (Harker, 1919), and the silica percentage is less than 52 (Hatch, 1914). Miss Ida A. Brown has used much the same arguments in justifying the adoption of the same name for a somewhat similar rock at Moruya.

Moreover, in the Cox's River intrusion, field-evidence also points to its being transitional between the diorites and gabbros.

The analysis of the Moyne diorite-gabbro is given below:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	46·49	0·775	47·15	0·786	50·04	0·834
Al_2O_3	19·22	0·188	22·30	0·219	18·68	0·183
Fe_2O_3	6·68	0·042	2·22	0·014	0·80	0·005
FeO	6·02	0·083	6·93	0·096	6·91	0·096
MgO	5·89	0·147	5·15	0·129	7·79	0·195
CaO	10·88	0·195	12·30	0·220	9·88	0·177
Na_2O	2·16	0·035	1·81	0·029	2·35	0·038
K_2O	0·65	0·006	0·35	0·004	0·12	0·001
H_2O+	0·96	—	1·00	—	1·74	—
H_2O-	0·17	—	—	—	0·28	—
TiO_2	0·92	0·011	0·90	0·012	0·80	0·010
P_2O_5	0·40	0·003	0·19	0·001	0·16	0·001
MnO	0·20	0·003	—	—	0·14	0·002
Other Const.	—	—	—	—	0·89	—
Total	100·64		100·30		100·58	
Sp. Gr.	2·967		—		2·977	

	I.	II.	III.
Quartz	0·96	—	0·24
Orthoclase	3·34	2·22	0·56
Albite	18·34	15·20	19·91
Anorthite	40·87	51·71	40·03
Diopside	8·64	7·72	6·77
Hypersthene	14·93	14·51	27·17
Olivine	—	2·83	—
Magnetite	9·74	3·25	1·16
Ilmenite	1·67	1·82	1·52
Apatite	1·01	—	0·34

I. Diorite-gabbro. Moyne Farm, Little Hartley. [Hessose, II(III), 5, 4, 4(5)]. Anal. G. A. Joplin.

II. Hornblende-norite. Rivière Clair, Mont Pélée, Martinique, West Indies. [II, 5, 4(5), (4)5]. Anal. A. Pisané, A. Lacroix, Mont Pélée, 1904, p. 543. In W.T., p. 536, No. 64.

III. Diorite. Murgatroyd's Tunnel, New England, N.S.W. [Hessose, II(III), 5, 4, 5]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii (3), 1907, p. 216.

(c). Gabbro Group.

(x). *Pyroxene-gabbros.*

These rocks, which vary among themselves in texture, and in the relative importance of some of the mineral constituents, occur abundantly in the centre of the Cox's River intrusion.

The rocks vary from fine-grained, dark massive types, not unlike basalts, to coarse, dark rocks, which may be seen to consist of pyroxene, plagioclase and often hornblende. By an increase in the latter the rock passes into a hornblende-gabbro, and some of the intermediate types show large "shimmer" plates of amphibole, which enclose numerous inclusions, and give both a porphyritic and poikilitic appearance to the rock.

Under the microscope the rock is seen to be holocrystalline, panidiomorphic granular, subophitic and sometimes glomero-porphyritic. The constituent minerals are plagioclase, hypersthene, brown hornblende, augite, iron ores, uralite, sometimes a little biotite, green hornblende, anthophyllite and rutile, and occasionally a tufted amphibole which may be tremolite.

The plagioclase (about 57% of the rock) occurs in laths measuring 1·5–0·5 mm., and these are frequently moulded by pyroxenes and amphiboles. The composition is labradorite and varies from $Ab_{44}An_{56}$ to $Ab_{37}An_{63}$. Some sections show slight zoning. Inclusions of pyroxene and iron ores are often concentrated towards the centre of the crystal, and the felspars show a remarkable clearing, probably indicative of metamorphism (Harker, 1904, and Browne, 1928). It is hoped that the contact metamorphism of these rocks may be studied in the immediate future. Hypersthene varies in abundance in the several types. It is often the most abundant ferromagnesian mineral (24%), but is sometimes subordinate to augite and sometimes to hornblende. It forms subidiomorphic prisms up to 2 mm. in length, and is strongly pleochroic. Crystals often show a fibrous alteration product surrounding them, and sometimes it is found along cracks. The elongation of the fibres is parallel to the "c" axis of the pyroxene. This mineral is colourless, and may be anthophyllite. Around this, there is an outer, very regular rim of a greenish-blue fibrous mineral, and this appears to be of the nature of hornblende. Fine dust, and sometimes small grains, of magnetite are often associated, and in places this has been haematitized. Patches of uralite sometimes occur in the crystals, and may represent one of two things. Either the rhombic pyroxenes may be altering into uralite; or else the uralite may represent original augite, which is sometimes present in parallel intergrowth with the hypersthene.

Brown hornblende forms irregular sheets up to 3·5 mm., which mould the felspars and enclose most of the other minerals. It is usually found surrounding the pyroxenes or uralite. This mineral varies a good deal in abundance, but averages about 6·5%. It is occasionally present only in minute quantities, whilst it increases in amount and finally establishes itself as the chief ferromagnesian mineral in the hornblende-gabbros. A little green hornblende occurs in some of the more acid types, and this is usually accompanied by biotite. In a few slides the hornblende shows slight zoning as described by Wyllie and Scott (1913), and by Miss Ida A. Brown (1928). Patches of brown hornblende occur in greenish-brown hornblende, and there is a border of a bluish-green variety, which is possibly sodic. Some of the amphibole sections are terminated by small branching tufts, which penetrate the felspar. These may be tremolite. Small veins of amphibole, intersecting all the other minerals, are very numerous.

Augite varies from about 4% to 15% of the rock. In some types it is the main ferromagnesian mineral, whilst in others it is third in order of abundance. It forms subidiomorphic prisms up to 2 mm. across, and groups of these give a glomero-porphyritic fabric in a few sections. Schiller inclusions sometimes occur and the augite is usually somewhat intergrown with hypersthene. Accessory minerals are sometimes present as inclusions. A good deal of the augite is fresh, but those crystals that have suffered alteration have been converted into uralite and secondary magnetite.

Iron ores (about 7%) are usually fresh, and it is difficult to say whether they are ilmenite or magnetite. In consideration of the fact that both occur in other rocks of the series, and that titania is fairly high in the chemical analysis, it is likely that both are present. The crystallization of the primary ore has certainly followed that of plagioclase, and sometimes seems to have been preceded by all except brown hornblende.

The naming of this rock calls for some comment. It has been decided to call the group pyroxene-gabbros for two reasons. Firstly, they all contain both monoclinic and rhombic pyroxene, and this usually exceeds hornblende; secondly, the pyroxenes themselves vary in relative abundance, and many of the types would be classified more correctly as norites. It is desirable, however, that the list of type-names should be kept as low as possible, and as some of the hypersthene may have been produced by contact metamorphism, for the present it seems best to classify both the augite-hypersthene-gabbros, and hypersthene-augite-gabbros as pyroxene-gabbros.

The analysis of the noritic phase is as follows:

SiO_2	45·31	0·755
Al_2O_3	19·39	0·190
Fe_2O_3	5·33	0·033
FeO	7·81	0·108
MgO	6·93	0·173
CaO	11·67	0·209
Na_2O	1·22	0·019
K_2O	0·35	0·003
H_2O+	0·69	—
H_2O-	0·08	—
TiO_2	1·33	0·016
P_2O_5	0·31	0·002
MnO	0·17	0·002
Total	100·59	
Sp. Gr.	3·004	

Quartz	0·96
Orthoclase	1·67
Albite	9·96
Anorthite	46·70
Diopside	7·85
Hypersthene	21·70
Magnetite	7·66
Ilmenite	0·67

Pyroxene-gabbro (Norite). Cox's River, Por. 27, Parish of Lowther. [Kedabekase, III, 5(4), 5, 4(5)]. Anal. G. A. Joplin.

(xi). *Hornblende-gabbros.*

These rocks occur in isolated outcrops among the pyroxene-gabbros, and seem to grade into the pyroxene-bearing types. It is possible that these masses may represent cognate xenoliths, which have been caught up in the pyroxene-gabbro magma whilst they were still hot and only partly consolidated. The hornblende gabbros are usually coarse-grained, dark rocks, which appear to consist of hornblende and plagioclase. In some types the plagioclase is not abundant and the rock stands very close to a hornblendite.

Under the microscope the rock is seen to be holocrystalline, hypidiomorphic-granular and ophitic. The chief constituent minerals are brown hornblende, plagioclase, uralitized pyroxene, iron ore and apatite. In one slide a little green hornblende is present, and the plagioclases are usually dusted with a little sericite and kaolin.

The plagioclase (about 33·5% of the rock) is basic labradorite ($Ab_{32}An_{68}$ to $Ab_{37}An_{63}$), and occurs in stout laths which average 2 mm. in length. Albite, and sometimes pericline, twinning is well developed and a slight alteration is usually evinced by a dusting of sericite and kaolin. Sometimes, however, the plagioclase shows clearing. The plagioclase is moulded by hornblende. Brown hornblende forms large subidiomorphic crystals up to 4 mm. across. These mould the felspars, and partly enclose all the other minerals. A slight zoning is apparent, and veins of green amphibole cut through the rock. The fibres of these veins are parallel, and apparently continuous with the amphiboles that the veins intersect. This mineral comprises about 41% of the rock. A little fresh augite is sometimes present, and uralitized masses of pyroxene quite abundant (about 19%). These pseudomorphs form subidiomorphic columnar sections about 2 mm. in length, and in places tufts or sheaves of pale-green amphibole appear to terminate the pseudomorphs and penetrate adjacent felspars. Secondary magnetite is commonly associated with the uralite. Primary magnetite is moderately well developed in most sections and averages about 6·5%. A little apatite is usually present.

(xii). *Hornblendite.*

This rock appears to occur in irregular small masses in both pyroxene-gabbros and hornblende-gabbros. The masses are sometimes somewhat ovoid and measure a couple of inches across, but at other times they have more the appearance of veins. Some of the inclusions are most irregular in shape, and are possibly basic segregations. They seem to occur more frequently, however, as small cognate xenoliths which have been caught up whilst the magma was still hot. The vein-like appearance is possibly due to a string of these inclusions being drawn out in a certain direction whilst they were still hot and plastic.

In the handspecimen the hornblendites appear to consist of fairly large, black hornblende crystals, but, under the microscope, they are seen to be composed of brown hornblende, iron ores, plagioclase, apatite, uralite and a little quartz, actinolite, calcite, and possibly tremolite.

Brown hornblende (about 54·5% of the rock) forms large subidiomorphic prisms up to 5 mm. across, and wraps the plagioclase. It includes the accessory minerals, and in one place is seen to enclose a mass of calcite, epidote and small grains of felspar and quartz. This mass evidently represents a pseudomorph of some inclusion mineral, but it is impossible to say what the original mineral may have been. The hornblende shows zoning, a bright-green border being present on the outer edges, and also around large inclusions. A good deal of uralite is present (about 5·5%) and sometimes tufts and sheaves of a fibrous amphibole penetrate quartz and felspar. Some of this is pale-green and some colourless, and it would thus seem likely that some has affinities towards actinolite, and some towards tremolite. The iron ores occur in large, somewhat rectangular grains up to 0·75 mm. Some skeleton grains occur, and these may represent ilmenite. These ores comprise some 15% of the rock. Plagioclase (some 12%) is andesine ($Ab_{68}An_{32}$), and most of it is rather altered into kaolin and sericite. Some, however, appears to be quite fresh. A kind of mesostasis is present (about 12%) and this is made up of altered plagioclase, masses of uralitized pyroxene, sheaved and tufted amphiboles, epidote, calcite and some quartz grains.

This rock is certainly an irregular type, but appears to agree fairly closely in mineral composition with one that has been described as a davainite by Wyllie and Scott (1913) from Garabal Hill, Scotland. These workers have noted brown hornblende, much of which is secondary after pyroxene, and andesine as the main constituents of the davainite, but no reference is made to quartz, which appears in the Hartley type. The analysis of the davainite is given for comparison and certain similarities are apparent.

The low specific gravity and the occurrence of relatively acid felspar and quartz would seem to imply that the Hartley rock is a hybrid or has suffered metamorphism.

The analysis of the Hartley rock is given in Column I:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	41·82	0·697	40·2	0·670	43·53	0·726
Al_2O_3	11·79	0·116	9·5	0·093	7·24	0·071
Fe_2O_3	8·64	0·054	9·7	0·060	11·10	0·069
FeO	11·68	0·163	12·2	0·170	8·70	0·121
MgO	8·68	0·217	8·0	0·200	11·51	0·288
CaO	12·14	0·214	13·1	0·234	10·19	0·182
Na_2O	0·53	0·008	0·8	0·013	2·88	0·047
K_2O	0·25	0·003	0·2	0·002	1·39	0·015
H_2O+	0·47	—	0·5	—	1·34	—
H_2O-	0·16	—	—	—	0·43	—
TiO_2	2·26	0·029	4·7	0·059	1·90	0·024
P_2O_5	0·42	0·003	—	—	tr.	—
MnO	0·20	0·003	0·4	0·006	—	—
CO_2	0·53	—	—	—	abs.	—
FeS_2	—	—	0·4	—	—	—
Total	99·55		99·7		100·21	
Sp. Gr.	3·000		3·36			

	I.	II.	III.
Quartz	1·26	0·66	—
Orthoclase	1·67	1·11	8·34
Albite	4·19	6·81	13·62
Anorthite	29·19	21·68	3·06
Nepheline	—	—	5·96
Diopside	22·50	34·79	37·42
Hypersthene	21·76	10·84	—
Olivine	—	—	10·57
Magnetite	12·53	13·92	16·01
Ilmenite	4·41	8·97	3·65
Apatite	1·01	—	—

I. Hornblendite. Cox's River, Por. 27, Parish of Lowther. ["IV, 2, 1, 2, "3]. Anal. G. A. Joplin.

II. Gabbro. Druin an Eidhne, Skye, Scotland. [IV, 2", 1, 2, 3]. Anal. J. H. Player, *Q.J.G.S.*, l, 1894, p. 653. In W.T., p. 716, No. 1.

III. Davainite (Hornblendite). Garabal Hill, nr. Loch Lomond, Scotland. [Montrealose, "IV, 2, 2, 2, 2]. Wyllie and Scott, *Geol. Mag.*, (v) x, 1913, p. 502. In W.T., p. 718, No. 5.

II. *Hypabyssal Types.*

(1). Pegmatites and Aplites.

(i). *Pegmatites and Micropegmatites.*

A dyke of coarse, decomposed pegmatite occurs on the Jenolan Road to the north of the Glenroy Bridge. It is creamy-white in colour, and its structure is somewhat suggestive of the Cooma pegmatites, a graphic intergrowth of orthoclase and quartz forming the outer portion of the dyke, and a quartz vein the centre. A somewhat similar occurrence is met with on Williams' property at the head of Moyne Creek. The exposure is only a small one, but it is possibly continuous with a pegmatite and acid granite on Bonnie Blink. These are probably outcrops of an apophysis from the granite to the west.

Small veins of pink pegmatite and micropegmatite are numerous among the acid granites around the village of Hartley, and quite a striking set of micro-pegmatite veins is found cutting through an outcrop of quartz-mica-diorite near the mouth of Kanimbla Creek. This rock has been sectioned and found to consist of quartz, orthoclase, microperthite, a little plagioclase ($Ab_{75}An_{25}$), and a small amount of biotite, magnetite and lawsonite (?). A micrographic fabric is perfectly developed and the grainsize is 1–3 mm.

(ii). *Aplites.*

Granite-aplites occur abundantly, both as dykes several feet in width and as veins and veinlets that are often mere threads and can only be distinguished under the microscope. Aplites intrude both acid and intermediate types, but none has been observed in association with any rock more basic than the quartz-mica-diorites, and it appears that the intermediate types are affected only by the smaller vein intrusions.

On the Jenolan Road, about midway between the bridges, a dyke of aplite about 2 feet in width follows a prominent line of jointing in the granite, and strikes N 10° W. Several such dykes are found to follow major joint-directions on the northern bank of the River Lett, behind the Court House. A fairly large outcrop of aplite occurs among the granites on Campbell's Creek, and though its mode of occurrence has not been ascertained, it is possibly a large dyke.

On Moyne Farm the tonalites are often threaded by small aplite veins, which rarely exceed half an inch in width. Like the quartz veins, to which reference has been made, there appear to have been two periods of aplitic injection. Some of the veins are well defined, and under the microscope show chilled borders, whilst others have obviously been injected into a hot, and only partly solidified, rock, and the local monzonitic fabric which has already been referred to has been produced.

The aplites vary in grainsize from 1 mm. to 0·1 mm., and in some of the coarser types there is a slight graphic intergrowth of quartz and orthoclase. A kind of monzonitic fabric is sometimes produced by the late consolidation of the orthoclase.

The rocks consist of a mosaic of quartz and orthoclase or microperthite, plagioclase and a little biotite, magnetite and ilmenite. In a few slides apatite and secondary sphene have been noted. The plagioclase is acid oligoclase of the composition $Ab_{89}An_{11}$. Biotite is usually bleached, often chloritized and sometimes contains lenses of lawsonite (?).

Some of the aplites have suffered a certain amount of pneumatolysis, as evidenced by the occurrence of small quantities of molybdenite, cassiterite, fluorspar, and tourmaline. Some of the aplites show greisenization, but these have not been studied in detail.

The analysis of the rock from Campbell's Creek is given in Column I:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	76·94	1·282	76·90	1·282	75·67	1·261
Al_2O_3	13·98	0·137	12·53	0·123	13·74	0·134
Fe_2O_3	0·18	0·001	0·99	0·006	0·67	0·004
FeO	0·27	0·004	0·66	0·009	0·72	0·010
MgO	0·06	0·001	0·17	0·004	0·25	0·006
CaO	0·78	0·014	0·86	0·015	0·90	0·016
Na_2O	2·68	0·044	2·36	0·038	2·60	0·042
K_2O	4·67	0·050	4·92	0·052	4·85	0·052
H_2O+	0·39	—	0·43	—	0·64	—
H_2O-	0·11	—	—	—	—	—
TiO_2	0·16	0·003	0·50	0·006	0·29	0·004
P_2O_5	0·02	—	—	—	—	—
MnO	tr.	—	0·08	0·001	none	—
Total	100·24		100·40		100·33	
Sp. Gr.	2·603					

	I.	II.	III.
Quartz	41·34	42·48	39·42
Orthoclase	27·80	28·91	28·91
Albite	23·06	19·91	22·01
Anorthite	3·89	4·17	4·45
Corundum	2·96	1·84	2·55
Hypersthene	0·20	0·40	0·86
Magnetite	0·23	0·93	0·93
Ilmenite	0·46	0·91	0·61
Haematite	—	0·32	—

I. Aplite. Campbell's Creek, Little Hartley. [Tehamose, I, 3″, (1)2, 3]. Anal. G. A. Joplin.

II. Granite. Grafversfors, Stofsjö, Sweden. [Tehamose, I, 3″, (1)2, ″3]. Anal. H. Santesson. P. J. Holmquist, *B. Un. Ups.*, vii, 1906, p. 264. In W.T., p. 82, No. 31.

III. Granite. örnsköldsvik, Angermanland, Sweden. [Tehamose, I, 3″, (1)2, 3]. Anal. H. Santesson. P. J. Holmquist, *B. Un. Ups.*, vii, 1906, p. 260. In W.T., p. 82, No. 34.

(2). Granite Porphyry.

Collinear outcrops of granite-porphyry occur in Portions 172, 173, 175 and 183, Parish of Hartley, and form a small chain of low hills across Moyne Farm. Though no intrusive relations have been observed between this rock and the tonalites and quartz-mica-diorites with which it is associated, the collinear arrangement of the outcrops would suggest a large contemporaneous apophysis of the granite.

The rock is of a pink colour, and there is a decided variation in texture. Though the microscope reveals a porphyritic structure in every case, many of the handspecimens appear to be even-grained, fairly coarse biotite-granites. In the handspecimens of the obviously porphyritic types, phenocrysts of plagioclase, quartz and a little biotite are set in a dull pink lithoidal groundmass. The phenocrysts vary considerably in size and perfection of development. One outcrop on Moyne Creek contains perfect, tabular plagioclases, 20 × 10 mm.

Under the microscope the granite porphyries are seen to consist of plagioclase, quartz, biotite and occasional orthoclase phenocrysts set in a holocrystalline mosaic of quartz, orthoclase and a little biotite. In a few slides a small quantity of plagioclase has also been detected in the groundmass. The grainsize is very variable. The phenocrysts usually average from 3 mm. to 6 mm., and the groundmass, which is always holocrystalline, is fine to medium, and ranges from 0·05 mm. to 0·5 mm.

The plagioclase, forming subidiomorphic tabular phenocrysts, is oligoclase ($Ab_{74}An_{26}$ to $Ab_{69}An_{31}$), and is both kaolinized and sericitized. In one slide bunches of secondary muscovite form small, radiating fans in the felspar. Occasionally zoning is present, and in such cases alteration is selective. Quartz is developed both as subidiomorphic and allotriomorphic phenocrysts, and as irregular grains, which are very abundant in the groundmass. Most of the phenocrysts show corrosion and in some cases pseudo-inclusions are developed. Granulation and undulose extinction are sometimes present. One slide shows a corroded and "nibbled" subidiomorphic phenocryst bordered by smaller quartz grains, which appear to be a graphic intergrowth with the felspar of the groundmass. Harker and Marr (1891), Kemp (1922) and Miss Ida A. Brown (1928) have observed similar structures. Orthoclase (usually microperthite) is very well developed as small grains in the groundmass, but only in a few cases has it been observed as phenocrysts.

A granite-porphyry collected on the Bathurst Road to the east of McGarry's Hotel, however, contains phenocrysts of this mineral. This rock has not been observed *in situ*, but may represent a marginal phase of the biotite-granite. This possibility will be referred to later.

Biotite is developed in tabular flakes as phenocrysts which measure up to 2 mm. across, but is more frequently found as scattered shreds in the groundmass. This mineral has suffered considerable alteration. Apatite often occurs as inclusions, and one large section, measuring 0·3 mm., has been observed. Sphene is also a common accessory. Epidote is abundant as an alteration product, and in one slide a large crystal of allanite has been noted. Iron ores are accessory and comprise both magnetite and ilmenite, and alteration products are represented by chlorite, epidote, haematite and carbonates.

Unfortunately all the specimens that have been sectioned (18) have suffered a certain amount of decomposition by weathering, but in many of the slides the amount of alteration does not warrant the assumption that all has been produced by weathering alone, and there seems little doubt that magmatic solutions have played a part. Quartz phenocrysts are corroded and exhibit pseudo-inclusions, felspars are sericitized and kaolinized, but it is the biotite that produces the strongest evidence of a deuteric period.

In the less altered rocks the biotite is bleached, and secondary magnetite now converted into haematite, possibly by weathering, has been thrown out along cleavage planes. Chlorite and epidote are also present and quartz and felspar grains are associated. In one slide a phenocryst of biotite is entirely replaced by chlorite, in which there are parallel strings of magnetite and haematite grains, and associated granules of epidote.

A further advance in the alteration is shown by masses of chlorite, haematite and epidote up to 3 mm. across. These appear to be pseudomorphs after clusters of biotite flakes. They contain parallel bands of secondary magnetite grains, which indicate the orientation of the original biotites.

Another slide shows a still more advanced stage, but in this case it is likely that surface weathering has played a part. In this rock, "ghosts" of biotite are represented by masses of fairly regularly arranged strings of magnetite and haematite grains with interleaved grains of quartz, felspar, epidote and carbonates.

There appear to have been two main deuteric processes operating upon the biotite: (1) Chloritization, (2) epidotization. It is not possible to trace each whole process through a series of slides, since both operate together, and often interfere with one another. Both processes have caused the throwing out of secondary magnetite, and at times silica has been set free as quartz. Orthoclase is also produced in an advanced stage of the breaking down of the biotite.

From an examination of these slides, it has been inferred that "secondary" minerals have been produced chiefly by deuteric action, but in some of the more altered types weathering has undoubtedly played a part.

Deuteric: (1) Epidotization; (2) chloritization; (3) some oxidation; (4) some carbonation.

Weathering: (1) Most of the oxidation, i.e., haematite, etc.; (2) most of the carbonation.

(3). Hornblende-Lamprophyres.

These rocks have not been found *in situ*, but occur as boulders in the Cox's River in the immediate vicinity of the gabbro intrusion, and it is likely that this is an associated type. The name lamprophyre is applied only tentatively until something of the field occurrence is known. The rocks are not lamprophyres in the strict sense of the word, for felspar is just as abundant as ferromagnesian minerals. In the handspecimen the rocks are light-grey in colour with large phenocrysts of dark blackish-green hornblende up to 10 mm. across.

Under the microscope the phenocrysts are seen to be large idiomorphic or subidiomorphic crystals of amphibolized pyroxene fringed by biotites and iron ore; or groups of these minerals that give a porphyritic effect. The groundmass consists of a plexus of plagioclase laths and interstitial quartz.

III. *Inclusions and Segregations.*

Very little work has been done on these occurrences, and little can be said about them here.

Inclusions are of two classes—those of sedimentary, and those of igneous origin.

The sedimentary type are very numerous near the contact zones, and are often up to a foot across. Some of these occur among the granites on Grant's Creek, and a kind of "swirling" structure shows that the inclusion has been rendered plastic by the great heat of the magma in which it became engulfed.

The igneous inclusions are very common throughout the series, but are most abundant in the intermediate types.

On the property of Mr. J. Commens weathering of the hornblende-biotite-granite has caused the finer-grained inclusion to stand out in small knobs. Small inclusions are also numerous among the porphyritic granites at Hartley, and among the granodiorites at the mouth of Campbell's Creek. One of the latter has been sectioned and certainly appears to be a rather abnormal type. The best name that can be applied to it is a sphene-quartz-diorite.

It has already been indicated that the hornblendite probably occurs as cognate xenoliths, and there is some slight suggestion of their being basic segregations.

D. PETROGENY.

(a). *The "Reaction Principle".*

The foregoing descriptions serve to indicate that there are some striking examples of Bowen's "reaction principle" among the Hartley rocks (Bowen, 1922).

Not only does the series as a whole illustrate this phenomenon, but often much is to be seen within a single specimen.

Some of the basic rocks show an association of hypersthene, augite, brown hornblende and biotite; and thus exemplify an almost complete "discontinuous reaction" series as outlined by Bowen (1922). A "continuous reaction" series is exemplified by the zoning in the hornblende, which in some cases shows a brown centre, a green hornblende zone, and a bluish-green sodic border. The best example of this type of series is shown by the plagioclase. Zoning may be seen in individual slides, but taking the series as a whole there is an increase in the acidity of the felspar from $Ab_{32}An_{68}$ to $Ab_{89}An_{11}$.

Other examples of the operation of the reaction principle amongst New South Wales rocks have been described by Miss Ida A. Brown (1928) from Moruya, and by Dr. W. R. Browne and Mr. W. A. Greig (1923) from Kiandra. Dr. Browne has also described quartz-dolerites from Adélie Land, Antarctica, which exemplify this principle.

Such a mineral association gives some indication of the conditions under which the magma cooled, but this will be discussed later under differentiation.

The mineral content of thirteen of the types described has been tabulated in such a way as to give the same picture as that conveyed by Bowen's diagram (1922).

	Rhombic Pyroxene.	Monoclinic Pyroxene.	Brown Hornblende.	Green Hornblende.	Biotite.	Quartz.	Orthoclase.	Acid Oligoclase.	Basic Oligoclase.	Acid Andesine.	Basic Andesine.	Acid Labradorite.	Basic Labradorite.
Hornblende-gabbro ..	×	×	×	.									×
Pyroxene-gabbro ..	×	×	×	.								×	
Diorite-gabbro		×	×	×								×	
Qtz.-pyrox.-diorite ..		×	×	×	×	×					×		
Qtz.-mica-diorite.. ..			.	×	×	×					×		
Monz.-qtz.-diorite ..				×	×	×	×			×			
Tonalite				×	×	×	.			×			
Granodiorite				×	×	×	×			×			
Hb.-bi.-Granite				×	×	×	×		×				
Porph.-bi.-Granite ..					×	×	×		×				
Biotite-granite					×	×	×		×				
Granite-porphyry ..					×	×	×	×					
Aplite					.	×	×	×					

Diagram to show mineral constituents of the type rocks at Hartley.

(b). *Deuteric Action.*

There seems little doubt that the Hartley rocks have suffered a certain amount of deuteric action. The chief deuteric minerals that have been recognized are lime- and potash-bearing types. Sodic minerals seem to be entirely absent.

No hard and fast line can be drawn between the periods at which the "reaction principle" ceases to operate and deuteric phenomena begin. Both processes are destructive and constructive, and it is possible that the formation of sodic hornblende may be of deuteric origin. Some of the rocks that have been analysed have suffered a certain amount of deuteric alteration, yet there is no marked deviation apparent in the variation diagram, so it is concluded that there has been a re-assemblage of minerals, rather than that additive or subtractive processes have been at work.

A glance at the chemical analyses (p. 53), and at the variation diagram (Text-fig. 5), will show that ferric iron is unusually high. Total iron is certainly high throughout the series, but in normal fresh rocks it is not usual for ferrous and ferric iron to be about equal amount, which is the case with most of the Hartley types. It is concluded from this, that oxidation of ferrous iron has taken place as a result of deuteric action.

(c). *Chemical Discussion.*

Eleven chemical analyses have been made of the chief rock types, and these amply confirm the other evidence of consanguinity. Not only is this close relationship borne out by the analyses, but reference to the norms (p. 53) will show also that there is a gradation in class, order, rang, and subrang.

A variation diagram has been plotted according to Harker's method, and the curves have been somewhat smoothed, though no very wide deviation of the curves has been necessary. In some cases, points actually coincide with the plotted curves. This method of representation has been useful in comparing the rocks of two other series that have been similarly plotted; namely, the Garabal Hill complex, Scotland, and the Moruya complex, N.S.W. The similarity in all three instances is quite striking, and the features of the complexes suggest serial differentiation in a subalkaline or calcic magma. With regard to the Moruya series, Miss Brown says: "the relatively sudden change in the amount of curvature of the oxide-curves between the diorite-gabbro and the more basic gabbro is suggestive of complementary, as opposed to serial differentiation. This idea is supported by the field-occurrence of the hornblende-gabbro."

It is likely that the same explanation might hold for the sudden change of curvature between the pyroxene-gabbro and hornblendite at Hartley. The mode of occurrence here also is suggestive of complementary differentiation.

There is one very marked difference between the Moruya and Garabal Hill complexes on the one hand, and the Hartley series on the other. In the former, magnesia is a very abundant constituent towards the basic end of the series, and greatly exceeds ferrous oxide, with which it is replaceable. At Hartley, however, ferrous oxide is always present in greater quantity, and magnesia does not approach it even in the ultrabasic type.

Another striking feature of the Hartley series is the abundance of ferric oxide, which is usually about equal to ferrous oxide. As already stated, this can possibly be accounted for by deuteric action and "reaction", since many of the slides show a good deal of secondary magnetite, which is evidently due to the oxidation of the ferrous oxide contained in the ferromagnesian minerals.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
SiO_2 ..	41·82	45·31	46·49	52·41	54·37	58·37	62·06	65·33	68·60	73·51	76·94
Al_2O_3 ..	11·79	19·39	19·22	20·11	19·64	18·38	18·25	16·20	15·33	14·03	13·98
Fe_2O_3 ..	8·64	5·33	6·68	4·18	4·30	2·80	2·91	2·43	1·92	0·69	0·18
FeO ..	11·68	7·81	6·02	5·59	4·87	4·43	2·94	2·38	1·85	0·91	0·27
MgO ..	8·68	6·93	5·89	4·12	2·94	2·79	1·71	1·28	0·81	0·38	0·06
CaO ..	12·14	11·67	10·88	9·06	8·07	6·29	4·90	4·02	2·78	1·69	0·78
Na_2O ..	0·53	1·22	2·16	2·28	2·55	2·52	3·12	3·02	3·38	3·03	2·68
K_2O ..	0·25	0·35	0·65	0·88	1·01	2·56	1·61	3·28	4·52	4·58	4·67
H_2O+ ..	0·47	0·69	0·96	0·36	0·96	0·56	1·34	0·58	0·50	0·20	0·39
H_2O- ..	0·16	0·08	0·17	0·16	0·11	0·16	0·16	0·10	0·11	0·18	0·11
TiO_2 ..	2·26	1·33	0·92	0·78	1·14	0·52	0·60	0·72	0·51	0·45	0·16
P_2O_5 ..	0·42	0·31	0·40	0·32	0·34	0·26	0·24	0·22	0·22	0·05	0·02
MnO ..	0·20	0·17	0·20	0·19	0·07	0·06	0·09	0·03	0·04	0·01	tr.
CO_2 ..	0·53	tr.	tr.	tr.	—	—	—	—	—	—	—
Total ..	99·55	100·59	100·64	100·46	100·37	99·70	99·93	99·59	100·57	99·81	100·24
Sp. Gr. ..	3·000	3·004	2·967	2·836	2·861	2·807	2·764	2·742	2·703	2·658	2·603

	I.	II.	III.	IV.	V	VI.	VII.	VIII.	IX.	X.	XI.
Quartz ..	1·26	0·96	0·96	8·34	13·14	14·76	24·12	24·78	24·18	34·68	41·34
Orthoclase ..	1·67	1·67	3·34	5·56	6·12	15·57	9·45	19·46	26·69	27·24	27·80
Albite ..	4·19	9·96	18·34	19·39	20·96	20·96	26·20	25·15	28·82	25·15	23·06
Anorthite ..	29·19	46·70	40·87	41·70	38·09	29·47	23·63	18·90	13·07	8·34	3·89
Corundum ..	—	—	—	—	0·41	0·20	2·65	0·82	—	1·33	2·96
Diopside ..	22·50	7·85	8·64	1·11	—	—	—	—	—	—	—
Hypersthene	21·76	21·70	14·93	15·71	11·00	11·92	6·28	4·39	3·06	1·16	0·20
Magnetite ..	12·53	7·66	9·74	6·03	6·26	4·18	4·18	3·48	2·78	1·16	0·23
Ilmenite ..	4·41	2·43	1·67	1·52	2·13	0·91	1·22	1·37	0·91	0·91	0·46
Apatite ..	1·01	0·67	1·01	0·67	0·67	0·67	0·34	0·34	0·34	—	—
Class ..	"IV	III	II (III)	II	II	"II	I (II)	I (II)	I"	I	I
Order ..	2	5 (4)	5	(4) 5	4"	4"	4	4	4	(3) 4	3"
Section ..	'1	—	—	—	—	—	—	—	—	—	—
Rang ..	2	5	4	4	4	3 (4)	3	3	2"	2	(1) 2
Sub-rang ..	"3	4 (5)	4 (5)	4	4	3"	4	3"	3	3	3
Magmatic Name.	Yamaskase.	Kedabekase.	Hessose.	Hessose near Bandose.	Bandose.	Harzose near Bandose.	Yellowstonose near Tonalose.	Amiatose near Harzose.	Toscanose.	Toscanose near Tehamose.	Tehamose.

I. Hornblendite. Cox's River, Por. 27, Parish of Lowther.
II. Pyroxene-gabbro (Norite). Cox's River, Por. 27, Parish of Lowther.
III. Diorite-gabbro. Moyne Farm, Little Hartley.
IV. Quartz-mica-diorite. Marriott Ck., Cox's River intrusion.
V. Quartz-mica-diorite. Moyne Farm, Little Hartley.
VI. Monzonitic Quartz-diorite. Kanimbla Station, Little Hartley.
VII. Tonalite. Moyne Farm, Little Hartley.
VIII. Granodiorite. Junction of Campbell's Ck. and Cox's River, Hartley.
IX. Porphyritic Biotite-granite. Bathurst Road, Por. 4, Parish of Hartley.
X. Even-grained Biotite-granite. Bathurst Road, Por. 4, Parish of Hartley.
XI. Aplite. Campbell's Creek, Hartley.

Table of Specific Gravities.

Name of Type.	No.	Sp. Gr.	Remarks.
Granite-porphyry..	A.32	2·597	Slightly weathered.
,, ,, ...	A.12	2·657	
Aplite	D.40	2·603	
Even-grained biotite-granite ..	D.22	2·608	Slightly weathered.
,, ,, ,, ,, ..	D.63	2·658	
,, ,, ,, ,, ..	D.25	2·688	
Porphyritic biotite-granite ..	D.20	2·703	
Hornblende-biotite-granite ..	D.30	2·705	
,, ,, ,, ..	D.33	2·706	
,, ,, ,, ..	D.39	2·706	
Granodiorite	D.1	2·742	
Tonalite	A.20	2·742	
,, ...	A.14	2·764	
Monzonitic quartz-diorite ..	D.16	2·807	
Quartz-mica-diorite	A.36	2·750	Rather weathered.
,, ,, ,, ...	A.37	2·754	,, ,,
,, ,, ,, ...	A.53	2·849	
,, ,, ,, ...	A.65	2·854	
,, ,, ,, ...	A.11	2·861	
,, ,, ,, ...	B.102	2·863	
,, ,, ,, ...	B.95	2·883	
,, ,, ,, ...	B.79	2·894	
,, ,, ,, ...	B.90	2·898	
,, ,, ,, ...	B.114	2·900	
,, ,, ,, ...	A.50	2·923	
Quartz-pyroxene-diorite	A.9	2·990	High on account of small segregation.
Diorite-gabbro	B.93	2·917	
,, ,, ...	B.108	2·963	
,, ,, ...	A.33	2·967	
Pyroxene-gabbro	B.25	2·960	
,, ,, ...	B.10	3·004	
,, ,, ...	B.30	3·018	
Hornblende-gabbro	B.40	3·036	
Hornblendite	B.24	3·000	Possibly low on account of small piece used.

The presence of normative quartz, even in the basic types, may possibly be accounted for by this oxidation of the ferrous iron. Free quartz is certainly present in the hornblendite, but the normative figure would exceed the modal. It has been suggested (Browne and White, 1929) that high Fe_2O_3 necessitates the using up of a good deal of FeO for the formation of magnetite in the norm. This leaves a deficiency of FeO for the femic minerals, and the SiO_2, which would have entered into their composition, comes out in the norm as free quartz.

The relatively high alumina content of the Hartley rocks can possibly be explained by the abundance of biotite, which is an essential constituent of all types between the biotite-granite and the quartz-pyroxene-diorite. It has also been found as an accessory in the aplite, and in the more basic types.

Soda is fairly high, particularly towards the more acid end of the series, and this is probably due in part to the presence of albite in the microperthite in the acid and intermediate-acid types.

As in other rocks of comparable age in the State, titania is an important constituent. In the ultrabasic rocks this oxide exceeds the sum of the alkalis, and in the aplite it is comparable in amount to the ferromagnesian constituents.

(d). *Possible Differentiation of the Bathylithic Rocks.*

The fact that the Hartley outcrops represent only small portions of a large intrusion puts many difficulties in the way of a discussion on the differentiation. It is desirable, therefore, to tabulate the following field observations:

(1) A gradation between the types on Moyne Farm.
(2) A gradation between the rocks in the Cox's River intrusion.
(3) An apparent gradation between most of the other types at Hartley.
(4) A normal sequence from basic margin to acid centre on Moyne.
(5) An abnormal sequence from acid margin to basic centre on the Cox's River and River Lett.
(6) Contemporaneous acid dykes, apophyses and veins.
(7) Later dykes and veins that present chilled margins.
(8) The occurrence of basic cognate xenoliths both large and small.

More detailed observations of the stocks have led to the establishment of the following facts:

Cox's River Intrusion.

(1) A margin of quartz-mica-diorite,
(2) which grades into diorite-gabbro,
(3) which surrounds a central mass of pyroxene-gabbro,
(4) which includes sporadically distributed hornblende-gabbros and hornblendite.

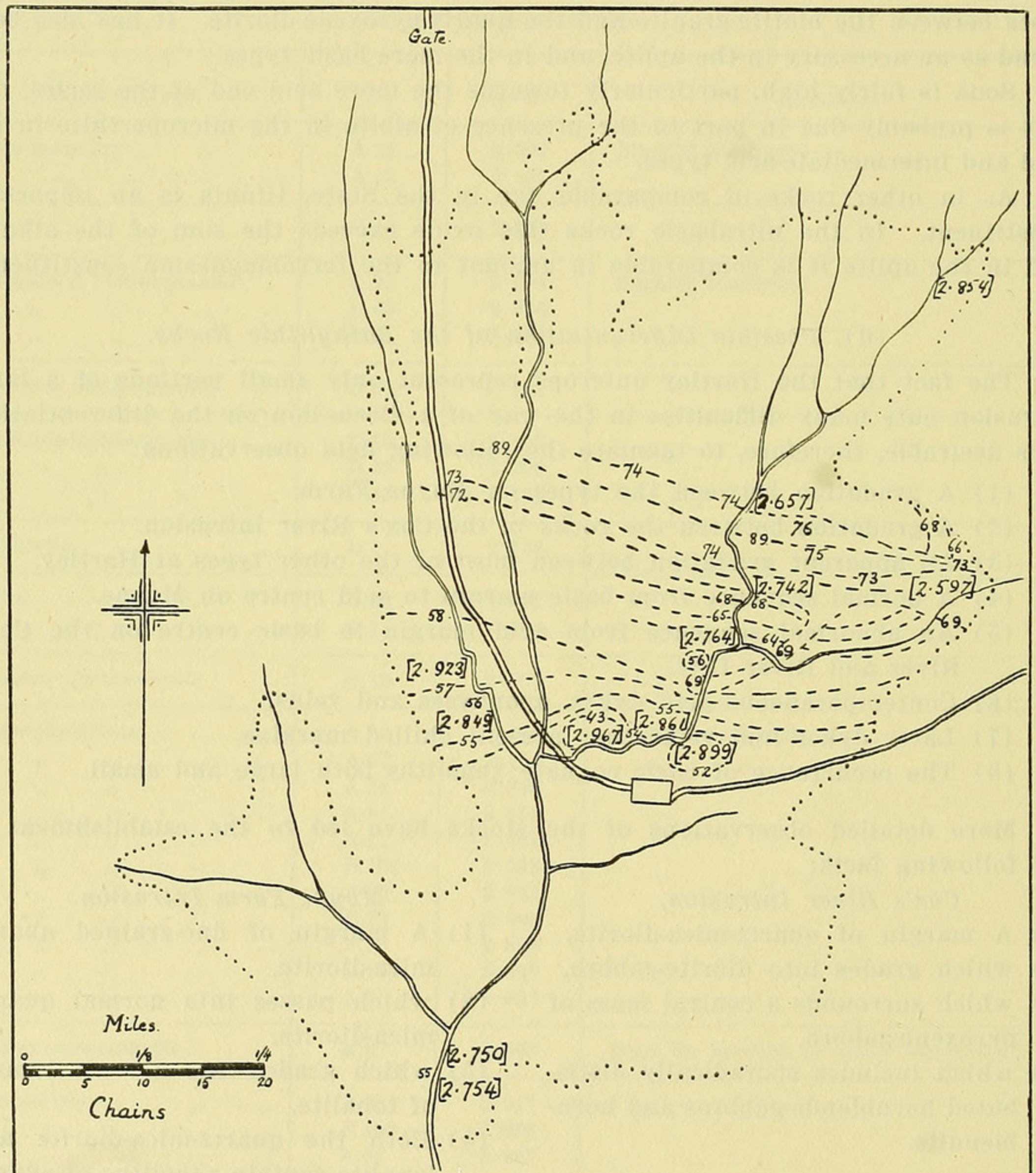
Moyne Farm Intrusion.

(1) A margin of fine-grained quartz-mica-diorite,
(2) which passes into normal quartz-mica-diorite,
(3) which grades into a central mass of tonalite.
(4) Both the quartz-mica-diorite and tonalite contain xenoliths of quartz-pyroxene-diorite and diorite-gabbro.
(5) An apophysis of granite-porphyry and small aplite veins are contemporaneous.
(6) Other veins of aplite and quartz are later.

The chemical and petrographical work points to undoubted consanguinity among the fifteen types that have been described in this paper, and it is evident that all were derived from one original magma.

The Cox's River intrusion appears to be due to two injections of partial magma, (1) a basic one with ultrabasic inclusions, and (2) a quartz-mica-diorite one which reacted with the gabbro to form a diorite-gabbro.

The Moyne Farm intrusion is apparently due to the differentiation in place of a partial dioritic magma, which contained inclusions of gabbros, and reacted with



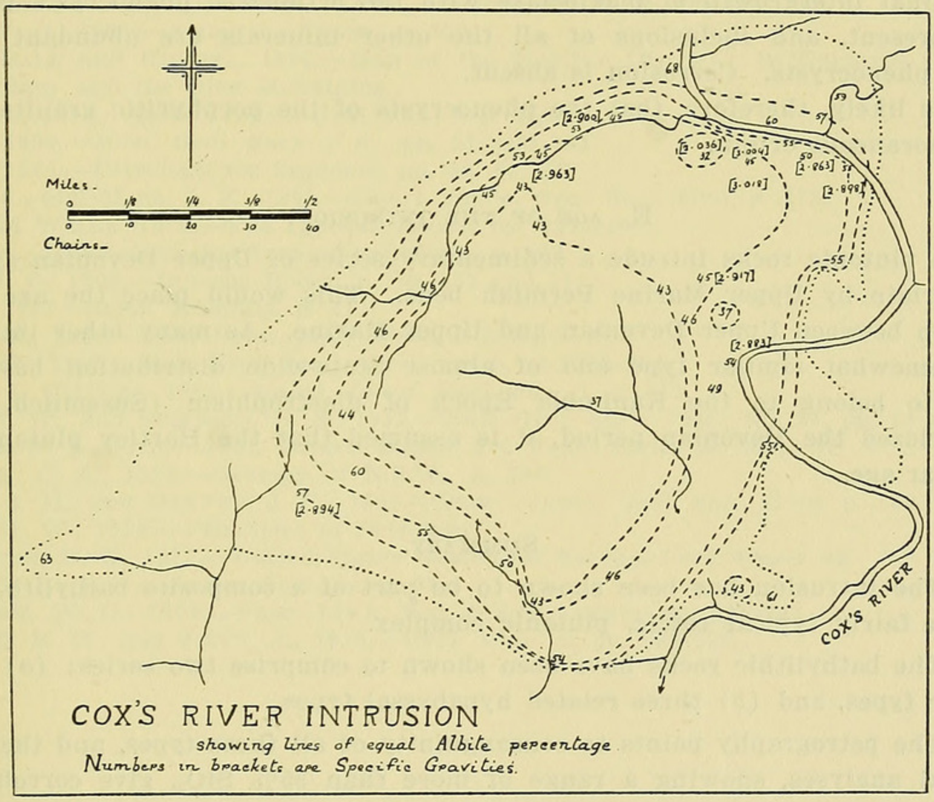
MOYNE FARM INTRUSION
showing lines of equal Albite percentage.
Numbers in brackets are Specific Gravities

Text-fig. 6.

them to form slightly more acid types. The fine-grained phase of the quartz-mica-diorite represents the quickly cooled rock at the contact, and this possibly formed a non-conducting envelope, and differentiation in place thereby proceeded more slowly. The steep temperature gradient would cause convection currents to be set up, and as the more basic constituents consolidated about the margin, the currents would carry the more basic ingredients from the centre, and so cause a gradation into a more acid facies.

Reference to the maps (Text-figs. 6, 7) shows that the specific gravities and the composition of the felspars are in accord with this hypothesis of differentiation.

The injection of the main acid bathylith evidently followed that of the quartz-mica-diorite, before the latter was completely cooled. The granite-porphyry on Moyne Farm is apparently an apophysis of the granite, but is more or less contemporaneous with the diorites.



Text-fig. 7.

The first period of aplitic injection, on Moyne Farm, possibly accompanied this apophysis, and the second most likely represents the end-phase in the consolidation of the granite magma, which was followed by pneumatolysis and the introduction of small quantities of tourmaline, cassiterite, topaz, etc.

As so small a part of the bathylith outcrops at Hartley, little can be said about it here. There appears to be a gradation from one type into another, with the more acid phases situated towards the margin.

Mr. E. C. Andrews (1916) has described marginal acid types in the Yetholme District, and assumes that such are later injections. W. J. Clunies Ross (1894) has observed similarly disposed acid rocks at Bathurst.

(e). *Occurrence of Porphyritic Types.*

Two types of porphyritic rock occur in the Hartley area, (1) a porphyritic granite round and about the village of Hartley, and (2) a granite-porphyry on Moyne Farm and on the Bathurst Road. It is of interest to note that the phenocrysts of these types are possibly of different origin.

The granite-porphyry on Moyne Farm shows a marked contrast in the size and form of phenocrysts and the crystals in the groundmass and, though no orientation has been observed, the quartz crystals are often corroded. It is concluded, therefore, that the phenocrysts of this rock are of intratelluric origin.

On the other hand, it is believed that the even-grained granite borders the porphyritic facies, and several transitional types have been collected. Moreover, a granite-porphyry, not *in situ*, has been found on the Bathurst Road, and this differs from the Moyne Farm type in containing abundant orthoclase phenocrysts. This rock possibly borders the even-grained granite (Watson, 1901; Crosby, 1900). A marginal intergrowth of plagioclase with the orthoclase phenocrysts is sometimes present, and inclusions of all the other minerals are abundant in the tabular phenocrysts. Corrosion is absent.

It is likely, therefore, that the phenocrysts of the porphyritic granite are of contemporaneous origin.

E. AGE OF THE INTRUSION.

The plutonic rocks intrude a sedimentary series of Upper Devonian age, and are overlain by Upper Marine Permian beds. This would place the age of the intrusion between Upper Devonian and Upper Marine. As many other intrusions of a somewhat similar type and of almost State-wide distribution have been shown to belong to the Kanimbla Epoch of diastrophism (Sussmilch, 1914), which closed the Devonian period, it is assumed that the Hartley plutonics are of similar age.

SUMMARY.

1. The intrusion has been shown to be part of a composite bathylith, which forms a fairly typical calcic, plutonic complex.

2. The bathylithic rocks have been shown to comprise two series: (*a*) twelve plutonic types, and (*b*) three related hypabyssal types.

3. The petrography points to consanguinity of all these types, and the eleven chemical analyses, showing a range of more than 35% SiO_2, give corroborative testimony.

4. It has been suggested that three separate intrusions of plutonic rocks have occurred, and that these are all differentiates from a single magma.

5. It has been pointed out also that the two porphyritic types are possibly of different origin, the phenocrysts of one being intratelluric, and of the other contemporaneous.

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