Mugearites in the Dunedin District.

By W. N. Benson and F. J. Turner.

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1. Field Occurrence and Petrology.

By W. N. Benson.

Field Relations.

In the course of a detailed geological survey of the Dunedin District made by one of us (W. N. B.) a small group of rocks of basaltic appearance attracted attention. They appeared different both texturally and mineralogically from the normal olivine-basalts with which they are associated, notably in the more sodic character of the plagioclase and dominance of olivine over augite and they possessed a peculiar mode of occurrence, partly intrusive, partly extrusive. They were known for some years before specimens were obtained sufficiently free from secondary minerals (notably carbonates) to yield a trustworthy analysis. Such, however, were collected both by Mr. M. Ongley for the Geological Survey (P. 5569)* and by Benson (246). An analysis of the latter made by Mr. F. T. Seelye (through the courtesy of the Directors of the Geological Survey and of the Dominion Laboratory), revealed the close similarity between its composition and that of the rock of Druim na Crìche near Mugeary, Skye, the type for the rock-species, mugearite, instituted by the late Dr. Harker (1904), and suggested the desirability for a further study here presented.

The mugearites of the Dunedin district appear to be confined to an area of three square miles adjacent to the coast and about eight miles west-south-west of Dunedin, that is, in or on the ridge separating the Taieri Plain from the coast (see Figure 1). The total exposed surface of this rock is less than a quarter of a square mile, barely a fifth of one per cent. of the total area of volcanic rocks in the Dunedin district. The ridge in question is anticlinal, with a core of quartz-albite-sericite-chlorite-schist and a partial cover of sediments of Middle to Upper Cretaceous age according to current views (Ongley, 1939). They comprise a small extent of feldspathic sandstone and conglomerate resting on the planated surface of the schist on the northern flank of the anticline, overlapped near its crest by a

* Rocks denoted by a number following the letter P. were collected by Ongley for the Geological Survey, and were made available for our study by the courtesy of the Director of the Survey. Other rocks noted are in the collection of Otago University Department of Geology.

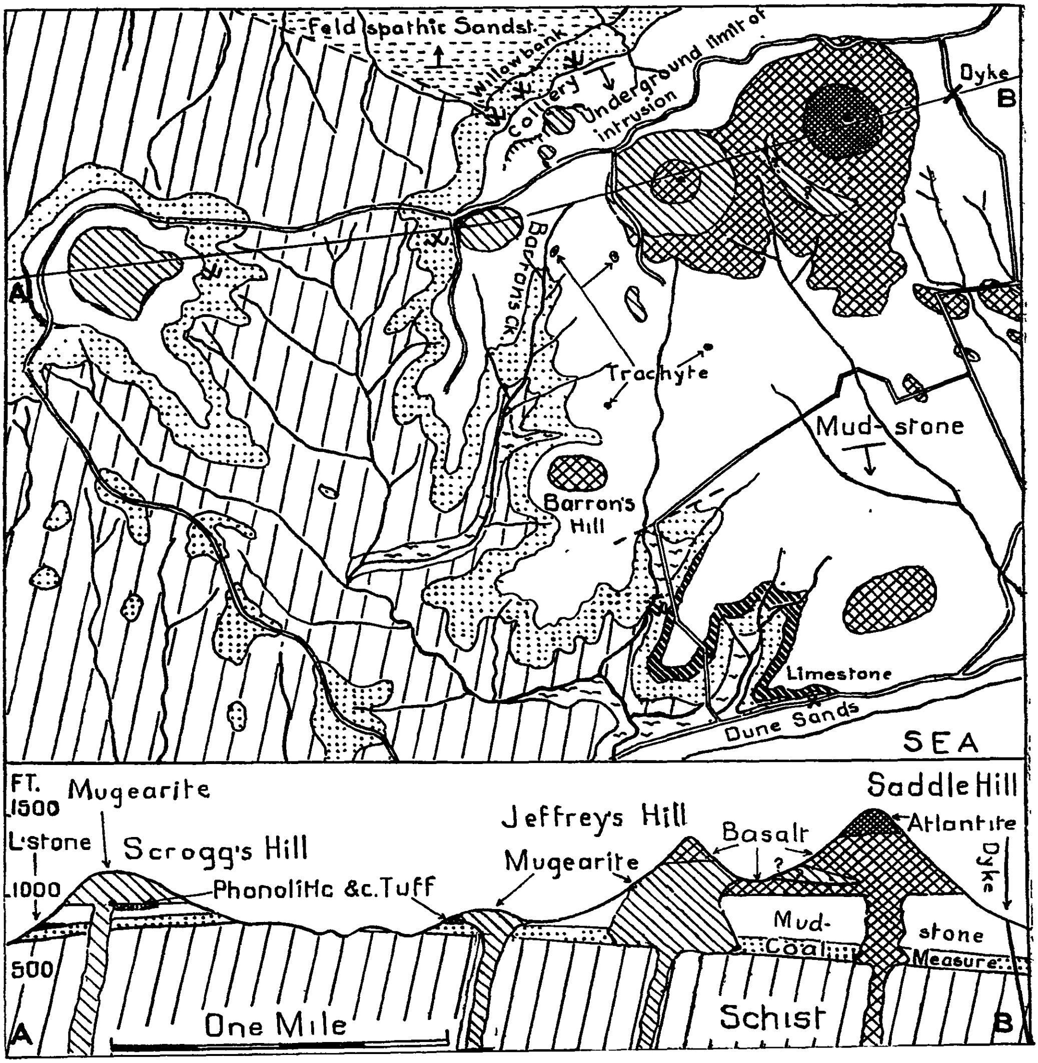

FIG. 1.—Geological Map of the Saddle Hill area south-west of the Dunedin District.

NOTE.—The small patch of lava nearly half a mile S.S.W. of Jeffrey's Hill should have been shown as basalt.

quartz-conglomerate or quartz-sandstone containing lignitic coal-seams extending down the southern flank and locally followed by thin, impure limestone, but in general covered by glauconitic mudstones. Late-Tertiary planation removed the higher members of the Cretaceous-Lower Tertiary series of sediments in this area, leaving above the schists a covering sheet of sediments only fifty to three hundred feet thick, on which the mugearitic and associated basaltic lavas consolidated.

The first volcanic activity was the formation of small plugs of brecciated and vesicular trachyte consisting almost entirely of finely lathy anorthoclase. Two of the four plugs are over twenty yards in diameter and stand in relief above the enclosing mudstone, the third is smaller, and the fourth too brecciated and weak to have topographic expression. These occur west and south of Jeffrey's Hill. After their formation (a time-relation demonstrated by evidence obtained outside this area), a thin extension of a mudflow-sheet, containing pebbles of phonolite basalt, etc., in a tuffaceous feldspathic matrix, flooded onto the region immediately west of Jeffrey's Hill. Subsequently to this, basaltic and mugearitic magma rose through the schist in the vicinity of Saddle Hill, and relatively thin flows spread southwards over the mudstone, remnants of which are scattered over the seaward slopes of the area mapped. The mugearite magma seems to have followed the first basaltic magma near Jeffrey's Hill, spread laterally into the coal-measures, rose dome-like above this into the mudstone, and breaking through it, spread out usually for a short distance over the surface of the earliest basalt, or of the thin layer of phonolitic conglomerate, or of the mudstone itself. These peculiar relations are inferred from the following observations:—The abrupt termination of the coal against "intrusive" mugearite in the old workings of the Willowbank Colliery prove the underground extension of that magma. The hill-slope immediately above this mine exposes two portions of the steep side and flattened top of the irregularly domed igneous mass which rose above the coal-measures into the mudstone. The inward directed radial columnar structure is clearly displayed. Jeffrey's Hill adjacent thereto is a cone rising 400 ft. above a base a quarter of a mile in diameter. It is capped by basalt of the same character as that which forms much of the lower part of Saddle Hill immediately to the east and spreads over the mudstones to the south and south-west. It seems possible, though not probable, that the relatively coarsely granular mugearite which makes the lower portion of Jeffrey's Hill may have risen through the mudstone and spread out beneath a cover of basalt, though its southern portion seems to overlap basalt. A quarter of a mile south-west from Jeffrey's Hill a cap 30—40 ft. thick of mugearite resting directly on mudstone has a very fine-grained groundmass, and is either a marginal extension of that in Jeffrey's Hill or had a separate effusive origin. Here was obtained the analysed specimen. Scrogg's Hill, a mile and a-half to the west of Jeffrey's Hill, is capped by mugearite of the less finely crystalline type. The rock forming the summit of the hill is the most coarsely crystalline of the samples collected. There is here no evidence of the presence of a basaltic cover if any existed above the mugearite. Its relation to the underlying mudstone is usually obscured by drift, but at two places on the southern slope it has been seen to rest on a thin decomposed extension of the sheet of phonolitic mudflow. The mugearite sheet in this hill is about 150 feet thick. The mugearite in the hill between it and Jeffrey's Hill may be seen to rise up through the mudstone at the head of Barron's Creek, while a hundred yards west thereof it seems to rest on the phonolitic mudflow exposed by the side of the main and branch roadway north and west of this hill.

Saddle Hill has a more complex though rather obscure structure. A drift specimen from its south-western flank suggests, but does not prove, the extension of the mugearite into this, much as is shown tentatively in Figure 1. Apart from this, the lower part of the hill is basalt of the same nature as that capping Jeffrey's Hill and extending southwards and westwards thereof. The highest portion of the hill is composed of a very pyroxenic atlantite, and the same rock occurs in drift-boulders by the roadside half a mile to the north-east.

Petrographical Features.

The normal olivine-augite-basalt, which makes up most of Saddle Hill (971, 972, 974) and extends westward to cap Jeffrey's Hill (969, P. 5564, 5583), the small ridge nearly half a mile S.S.W. of it (958, 970), and Barron's Hill (4838), is very uniform in texture. The rocks have rather poorly developed flow-structure shown by the short tabulae of labradorite, ranging from An_{65} to An_{54} in the zoned phenocrysts up to 0·4 mm. long, and about An_{45} in the shorter (0·1 mm.) laths in the groundmass. These and subsequent determinations involving the use of universal stage methods were made by Dr. F. J. Turner. Small crystals (0·2–0·3 mm.) of olivine showing $2V = (-)\ 82°–90°$ (corresponding with Fa_{35} to Fa_{12}) occur in varying proportion with narrow prisms of diopsidic titanaugite rarely more than 0·2 mm. long. It is usually more abundant than the olivine, and sometimes very much more so (969, 972) especially where granular aggregates of the mineral are present. Magnetite is also abundant in aggregated grains and octahedra ranging in size up to microphenocrysts 0·3 mm. in diameter. Minute needles of apatite are present in small amount.

The higher portions of Saddle Hill consist of atlantite. The more distinct sample (975) has phenocrysts of olivine and titanaugite in a groundmass in which granular titanaugite predominates, associated with labradorite magnetite and occasional irregular patches of more or less zeolitised nepheline and tiny flakes of biotite. Another sample (973) is possibly part of the outer portion of a flow. The olivine phenocrysts are the only readily recognisable minerals and are set in an exceedingly finely granular augitic matrix containing small and almost opaque residual patches of glass. A boulder (P. 5566) by the road junction north-east of Saddle Hill is intermediate in character between the last two rocks, and like (975) contains a resorbed xenocryst (?) of basaltic hornblende. Here, also, a quarried dyke of atlantite with xenocrystic diopside (5021) rises through the mudstone.

The mugearites differ from the basalts in the greater alkalinity of the feldspar, and complete subordination of the pyroxene to the olivine, which is more ferruginous than that of the basalt, resemblng instead that in the trachybasalts or trachyandesites in the Dunedin district. Associated with these characteristics is a noteworthy abundance of relatively large prisms of grey apatite also resembling those in the trachybasalts. Two facies of this rock may be noted. The less finely granular is also the less markedly porphyritic. It is exposed at the head of Barron's Creek, where it rose through mudstone (968), forms the lower portion of Jeffrey's Hill (234, P. 5563), and the cap of Scrogg's Hill (913, 4889, P. 5564) on the summit of which it reaches its coarsest grainsize. The fluidal structure is well marked by the feldspar tabulae, usually 0·2–0·4 mm. long and 0·005 to 0·1 mm. thick and associated with small zoned phenocrysts which rarely attain twice these dimensions. The composition is that of an andesine ranging from An_{48} to An_{37} both in the phenocrysts and in the groundmass crystals. No trace of sanidine can be recognised among the feldspars, and the suggestion that some of the potash-feldspar molecule in the mugearites may be held in solid solution in the plagioclase may hold good here, for the optical characters of the feldspars in these rocks are not quite normal (see p. 14 and Fig. 2; also Nikitin, *1936*, p. *97*). Olivine forms almost fresh idiomorphic crystals up to 0·3 mm. in diameter. They occur in two habits; some are bounded dominant dome faces, others by pinacoids. The smaller crystals with the latter habit are elongated parallel to the brachy-axis rather than the vertical (as Harker noted in the mugearite of Skye). The composition is about Fa_{40}. The crystals are locally moulded against a titaniferous magnetite forming more or less idiomorphic octahedra and grains up to 0·20 mm. in diameter. Purplish-grey diopsidic augite is very subordinate, forming narrow prisms rarely 0·1 mm. long or smaller irregular grains occurring between the feldspar tabulae. Apatite prisms are abundant and in dimensions up to 0·2 x 0·05 mm., and are often included in the magnetite. A small amount of chlorite, serpentine and carbonates are commonly present.

The more porphyritic mugearites occur most clearly in the margin of the laccolite which has been exposed above the Willowbank Colliery, a quarter of a mile north-west of Jeffrey's Hill (246, P. 5562, 5569). The phenocrysts are plagioclase, olivine and magnetite with grey apatite, and the fine-grained groundmass consists of feldspar laths about 0·05 mm. long, with a little olivine and magnetite of a second generation, and diopsidic augite with $2V = 56°–64°$. The zoned feldspar shows a range of composition from medium andesine An_{42} to a marginal film of sodic oligoclase An_{15}. A smaller unzoned phenocryst was An_{35} and the groundmass feldspar An_{40}. Again the optical properties of the feldspar are rather abnormal and there is no recognisable sign of the presence of sanidine in spite of the potassic character of the rock. The olivine is present in fresh idiomorphic crystals with habits similar to those noted above. Its optical properties show its ferruginous nature—Fa_{30} to Fa_{60}.

A chemical analyis of the freshest example (246) of the fine grained rocks compared with other rock analyses yields the following figures.

	I	II	III	IV	V
SiO_2 ..	48.34	49.24	49.82	49.97	47.39
Al_2O_3 ..	16.14	15.84	15.56	15.30	16.46
Fe_2O_3 ..	3.43	6.09	6.18	2.54	3.75
FeO ..	9.80	7.18	6.42	8.64	8.42
MgO ..	3.16	3.02	3.48	4.57	5.08
CaO ..	6.54	5.26	5.94	7.60	7.37
Na_2O ..	5.24	5.21	4.26	3.64	4.71
K_2O ..	2.01	2.10	1.89	2.32	1.65
H_2O+ ..	0.77	1.61	1.83	1.89	0.28
H_2O- ..	0.30	1.08	1.32	1.10	0.09
CO_2 ..	0.17	—	0.38	0.61	—
TiO_2 ..	2.20	1.84	2.34	1.27	2.83
P_2O_5 ..	1.50	1.47	0.59	0.87	2.22
ZrO_2 ..	0.01	—	—	—	—
MnO ..	0.23	0.29	0.34	0.12	0.09
NiO ..	nt. fd.	—	—	—	—
BaO ..	0.06	0.09	0.04	0.03	0.04
SrO ..	0.06	tr.	—	—	—
Cr_2O_3 ..	nt. fd.	—	—	—	—
V_2O_3 ..	tr.	—	—	—	—
Cl ..	0.11	—	—	0.02	—
F ..	0.05	0.18	—	—	—
S ..	0.04	0.03	—	0.01	—
	100.16	100.46	100.39	100.50	100.38

I. Mugearite (246), a quarter of a mile W. of Jeffrey's Hill; F. T. Seelye, analyst.

II. Mugearite, Drium na Crìche near Mugeary, Skye; W. Pollard, analyst. (Harker, 1904, p. 263); less 0.07 oxygen equivalent for F.

III. Mugearite, average of nine analyses of British mugearites (Cainozoic and Palaeozoic).

IV. Oligoclase-basalt. Average of thirteen analyses of Cainozoic lavas from Victoria (Edwards, 1938).

V. Olivine-oligoclase-andesite, Kohala, Hawaiian Islands; Washington (1923), analyst.

Calculating the normative mineral composition of the Jeffrey's Hill mugearite gives the following figures:—

Feldspar (Or_{13}* Ab_{45} An_{34} Ne_8*)	67.40%
Olivine (Fa_{53})	12:73
Titaniferous magnetite	9.14
Diopside	5.40
Apatite	3.87
Calcite 0.39, Pyrites 0.07, Water 1.07 ..	1.53
	100.07

* The normative orthoclase and nepheline are here assumed to be in solid solution in the modal feldspar (cf. Edwards, 1938, pp. 296–7).

The very close relation between the normative and modal compositions of this rock will be apparent. It is clear also how extremely close is the analysis of the Dunedin mugearite to that of the type rock of Drium na Crìche, closer, it may be added, than is the composition of any other analysed British mugearite or other rock known to us.

On comparing these Dunedin rocks with the published accounts of British mugearites and specimens from Druim na Crìche and Roineval supplied by the late Dr. Harker, it would appear that the chief features of the Dunedin rocks include the absence of the small amounts of brown hornblende and biotite present in many British mugearites, and the more coarse grain-size of several samples, which, however, lie within the limits of Macgregor's (1928) redefinition of the type. Such rocks also have a texture very close to that of the mugearite of Laig in the island of Eigg (Harker, 1908, Plate VII, Fig. 2A). The more finely trachytic of our mugearites, though more porphyritic than the majority of British rocks, are again within the prescribed limits. The plagioclase composition again varies within the limits allowed in the British definition. The crystal habit of the olivine, and its predominance over augite; the rarity of recognisable orthoclase (though the rock contains a noteworthy amount of potash), the habit and abundance of the titaniferous magnetite, and the abundance of apatite, are also features in common with most British mugearites.

Macgregor (1928), reviewing this group of rocks, while recalling Dr. Harker's comment on their affinity with essexite, remarks that many petrologists consider them a variety of trachybasalt. The last point is apposite to the Dunedin mugearites, which resemble the Dunedin trachybasalts in the ferruginous character of the olivine and the abundance and habit of the relatively large apatite prisms. Typically, however, the Dunedin trachybasalts and trachyandesites are richer in both silica and the alkalies and for the most part have more abundant phenocrystic pyroxene as well as xenocrystic amphibole. In view of the variability of the feldspar composition the terms oligoclase-basalt (Wells, 1924) or oligoclase-andesite (Washington, 1923) could not be applied satisfactorily to all rocks grouped under the mugearites.

II. Determinations with Universal Stage.

F. J. Turner.

Plagioclase.

The composition of the plagioclase was determined by standard universal stage methods as described by Nikitin (1936, pp. 96–103). The positions of the three axes of the indicatrix, α, β and γ, for each of two sub-individuals of a twinned crystal, are plotted upon a stereographic projection. The position of the twinning axis is then given, theoretically by the point of intersection of the three great circles $\alpha_1 \alpha_2$, $\beta_1 \beta_2$ and $\gamma_1 \gamma_2$; actually these arcs usually intersect in a triangle, but unless this is large the results need not be discarded. The mean angles between the twinning axis and α, β and γ respectively are obtained by halving the appropriate angles between α_1 and α_2, β_1 and β_2, γ_1 and γ_2. The approximate position of the pole of the composition-plane is also observed and plotted, and is found in the case of a normal twin to coincide with the pole of the twinning-axis, or in the case of a parallel twin to lie at 90° to the pole of the twinning-axis. For most compositions within the plagioclase series, the composition-plane can at once be distinguished as (010) on the one hand or (001) (or the rhombic section) on the other, by noting its relation to β or γ. If, however, the identity of either twinning-axis or composition-plane is in doubt, a second plane of twinning or cleavage transverse to the original composition-plane is determined and plotted. The angle between the pole of this second plane and the original twinning-axis identifies the latter [see under (4) below].

Nikitin (1936, pl. vii) has given a useful diagram showing the postions of important crystallographic directions in feldspars with relaton to α, β and γ. If the twinning-axis of the measured crystal is now plotted (on tracing paper) on this diagram, the composition of the plagioclase can be read directly from the appropriate curve on the diagram, and the law of twinning can be checked at the same time. In the case of a moderately large crystal not complicated by zonary structure the whole operation takes not more than fifteen minutes.

For slender twinned laths of the groundmass it may not be possible to determine the positions of the axes of the indicatrix in both halves of the crystal. In such cases they are measured in a single broad lamella, and the position of the composition-plane is observed directly; the position of the twinning-axis and the law of twinning cannot be determined without reference to a diagram such as Nikitin's pl. vii, however, and the results obtained are considered a little less accurate than those obtained when the other method is employed.

In the following table data are given for distinguishing the common types of twinning in feldspars.

(1) *Composition-plane (010):—*

Sanidine, β transverse* to composition-plane. Orthoclase, albite-andesine, γ transverse to composition-plane.

Type of Twin.	Twinning-Axis.	Name.
Normal	⊥ (010)	Albite
Parallel	[001]	Carlsbad A
Parallel	[100]	Ala B
Complex	⊥ [100] / (010)	Albite-Ala B
Complex	⊥ [001] / (010)	Albite-Carlsbad A

* When the indicatrix-axis in question makes a high angle (say 70°–90°) with the composition-plane it is said to be transverse to the latter.

(2) *Composition-plane (001):—*

Sanidine, γ transverse to composition-plane. Orthoclase, albite, oligoclase, β transverse to composition-plane.

Type of Twin.	Twinning-Axis.	Name.
Normal	⊥ (001)	Manebach
Parallel	[100]	Ala A
Parallel	[010]	Acline A
Complex	⊥ [100] / (001)	Manebach-Ala A
Complex	⊥ [010] / (001)	Manebach-Acline A
Parallel, composition plane near (001)	[010]	Pericline

(3) *Composition-plane approximately (100):—*

Parallel twin, twinning-axis [001], Carlsbad B.

(3) *Composition-plane (021):—*

Composition-plane is diagonal with reference to other planes of twinning and cleavage.

Normal twin, twinning-axis ⊥ (021), Baveno.

(4) *To check identity of twinning axis:*—

(a) *Composition-plane* (010).

Measure (001) or pericline composition-plane in one of the sub-individuals.

$$\perp (001) \wedge \begin{cases} \perp (010) = 85^\circ\text{–}90^\circ \\ [001] = 26^\circ \pm \\ [100] = 90^\circ \\ \dfrac{\perp [001]}{(010)} = 64^\circ \pm \\ \dfrac{\perp [100]}{(010)} = 0\text{–}5^\circ \end{cases}$$

(b) *Composition-plane* (001).

Measure (010) in one of the sub-individuals.

$$\perp (010) \triangle \begin{cases} [010] = 0^\circ\text{–}5^\circ \\ \dfrac{\perp [100]}{(001)} = 0^\circ\text{–}5^\circ \\ \dfrac{\perp [010]}{(001)} = 85^\circ\text{–}90^\circ \\ [100] = 90^\circ \\ \perp (001) = 85^\circ\text{–}90^\circ \end{cases}$$

The method used in plagioclase determinations has been described somewhat fully, since certain anomalies were observed when the positions of twinning-axes were plotted upon the Nikitin diagram. For most other rocks the writer has usually found that the plotted points lie close to the appropriate curves as given by Nikitin. However, there are often notable discrepancies in the case of plagioclases from Dunedin mugearites (as indicated in Fig. 2) and these may possibly be due to high potash-content of the feldspars in question. The composition of normative plagioclase in the analysed specimen is An_{37} Ab_{49} Or_{14}. Since potash-feldspar was not observed as a separate mineral in this rock, it is safe to assume that it is contained in the plagioclase of the mode. If allowance is made for entry of a small amount of normative anorthite into the modal pyroxene, and for the presence of about 8% of normative nepheline in the modal plagioclase, the composition of the latter should be somewhat more sodic than the An_{37} Ab_{49} Or_{14} indicated by the norm. The values actually determined* (Nos. 246, P. 5569) vary from An_{39-32} in a zoned phenocryst to An_{45} and An_{47} in small phenocrysts and An_{40} in the groundmass, with a mean composition about An_{42} Ab_{58}. C. T. Barber (1936, pp. 234–249) has discussed at length the relative importance of several factors that might contribute to lack of coincidence between the poles of optically measured twinning planes or axes and standard curves such as those of Fig. 2. He concludes (loc. cit. pp. 247–249) that variation in the potash-content has little effect in this connection, but attaches more importance to variation in physical conditions of crystallisation of the feldspar in question.

* Where a plotted lies off the curve in Nikitin's diagram, the composition is obtained by dropping a perpendicular to the appropriate curve.

For comparison, the composition of the plagioclase in Scottish mugearites from type localities was determined by the same method. No orthoclase could be determined with certainty in any case.

Compositions recorded in various slides are as follows:—

Slide.	Large Phenocrysts.	Small Phenocrysts.	Groundmass.
Basalt P. 5561	An_{65}, An_{54}	An_{65}	An_{45}
Mugearites			
(a) *Coarse*			
P. 5564	An_{48}, An_{45}	—	An_{35}
234	An_{46}, An_{42}, An_{37}	An_{47}, An_{40}	An_{45}
(b) *Fine*			
P. 5562	Zoned An_{38-35} to An_{22-15}; Zoned An_{42} to An_{35} to An_{26}	An_{38}	—
P. 5569	—	An_{47}, An_{45}	An_{40}
246	Zoned An_{39} to An_{32}	—	—
(c) *Skye*			
Druim na Criche	—	—	An_{42}, An_{38} An_{30}, An_{28}
Roineval	An_{53}, An_{50}, An_{45}	—	An_{50}, An_{38}

Finally it should be noted that while Carlsbad and albite twins or the two combined in one crystal are the commonest types of twin in Dunedin mugearites, other laws are by no means rare; this applies especially to albite-ala B, Manebach and pericline laws. Similarly the four phenocrysts measured in detail in the rock from Roineval include one instance each of the ála A, ala B, albite and albite-ala B laws.

Olivine and Pyroxene.

Determinations of 2V in phenocrysts of olivine in three different slides of mugearite give a wide range of values:

P. 5562: 68°, 68°, 70°, 75°
P. 5569: 66°, 80°, 82°
234: 74°, 80°

The sign in all cases is negative. These figures are decidedly lower than the average for 2V in olivines from typical Dunedin basalts, but are comparable with values determined in olivines of trachybasalts and trachyandesites from the same district (Benson and Turner, 1939, p. 67). They indicate a relatively ferruginous variety containing 32–66% of fayalite.

In an earlier paper (Benson and Turner, 1939, p. 64) sharply bounded prismatic microphenocrysts of a colourless highly refractive mineral were described as hypersthene on account of their optic orientation (γ parallel to elongation), axial angle ($2V = 67°–78°$) and negative optic sign. These have now been shown to be olivine with an unusual habit in which the crystals are markedly elongated parallel to the *a* crystallographic axis ($= \gamma$). In such crystals there is usually no trace of cleavage, and determination of birefringence is necessary to distinguish the mineral from hypersthene. Figures obtained for $(\gamma-\alpha)$, using a Berek compensator and assuming a birefringence of 0·007 in the plagioclase, are 0·046 (P. 5569) and 0·041 (P. 5562); these correspond to a range of 2V=64°–78°, and to compositions of 70%–40% fayalite. Axial angles measured indirectly by Dodge's modification of Berek's method (Dodge, 1934) in the crystals on which birefringence was determined were 73° ± 5 and 75° ± 5 respectively, with negative optic sign in each case.

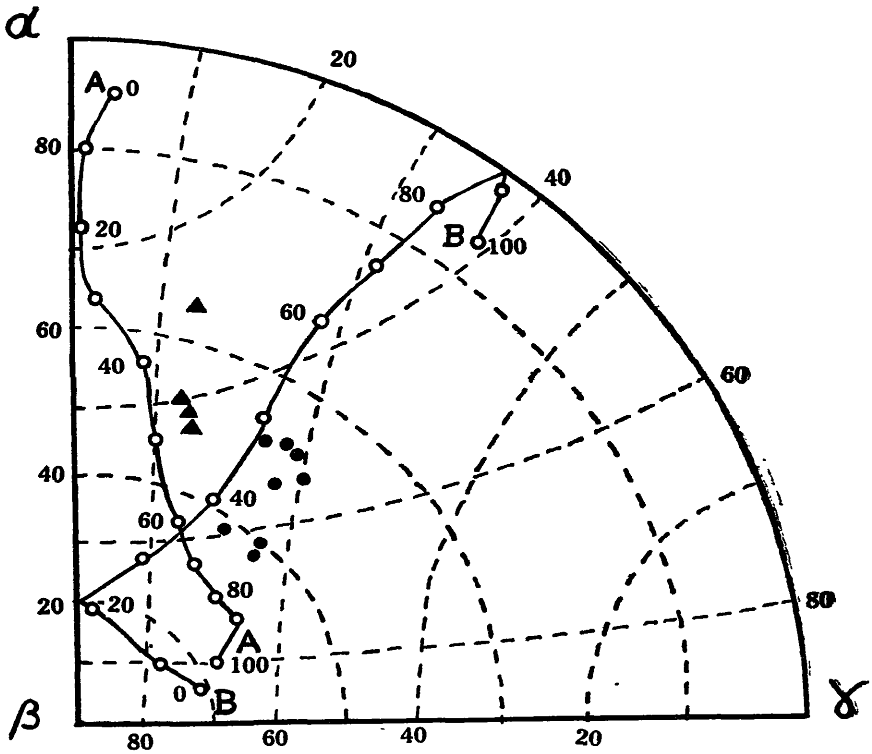

Fig. 2.—Curves (according to Nikitin, 1936, pl. vii) showing variation in the positions of $\frac{\perp[001]}{(010)}$ (curve AA) and [001] (curve BB) in relation to α, β and γ in plagioclase. Broken curves represent angular distances of 20°, 40°, 60° and 80° from α, β and γ respectively. Open circles on AA and BB indicate 10% intervals in increasing anorthite content. Solid circles show determined positions of [001], solid triangles determined positions of $\frac{\perp[001]}{(010)}$ in feldspars from Dunedin mugearites.

Tiny poorly-bounded granules in the groundmass, having 2V = 75°–85° and negative sign might equally well be olivine or orthorhombic pyroxene, but in the light of the determinations cited above, olivine seems the more likely of the two. This conclusion applies, too, to all cases of " orthorhombic pyroxene " reported from the groundmass of Dunedin basalts in the paper cited above.

When pyroxene is definitely present in Dunedin mugearites (e.g. P. 5562) it is a normal diopsidic augite with 2V= 56° to 64°.

In conclusion, the writers desire to express their thanks to Mr. F. T. Seelye for his analysis of the mugearite quoted above.

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