

*Two arfvedsonitic rhyolite intrusions from Cloghaneely,
Co. Donegal.*

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INTRODUCTION.

MANY of the Dalradian and 'Moine' rocks of Donegal, and the Caledonian granites associated with them, have been shown to bear structural and petrographic resemblance to the rocks of similar age in Scotland. In Scotland riebeckite-bearing minor intrusions occur at many localities and include Ordovician, Caledonian, Carboniferous, and Tertiary intrusions. There appears to be no record of analogous rocks containing sodic amphiboles occurring in situ in NW. Ireland. The purpose of this paper is to record the existence of two small intrusions of such rocks in western Cloghaneely, Co. Donegal.

The area in which these rocks occur, although rising to over 1400 feet O.D., is thickly mantled by both glacial boulder-sand and peat bog. Consequently exposures are scarce, but sufficient outcrops occur to show that the country-rock comprises a massive lineated quartz-schist of Dalradian age. Both this quartzite and the contained metadolerite sills have sustained the same regional metamorphism. Fig. 1 shows that the Dalradian rocks have been invaded by the Donegal granite which is almost certainly Caledonian. Although numerous microgranitic and rhyolitic dikes cut the granite in various areas, none has been found with strongly sodic affinities, and surprisingly few appear to intrude the quartzitic country-rock. This suite of acid dikes was emplaced shortly after the formation of the main granite. The only later solid rocks in the area comprise a swarm of Tertiary basaltic dikes which cut the granitic, microgranitic, and Dalradian rocks. Considerably to the east McCall (1953) has recorded a suite of lamprophyric dikes, but no members of this suite occur in the present area.

THE SODIC RHYOLITE INTRUSIONS.

On the high plateau linking the summits of Tievealehid and Carntreena, numerous scaly or discoidal porcellaneous erratics are to be found. They

occur on top of the drift immediately under the bog, being seen where the latter has been 'hagged' away, and can only be matched by the rocks occurring in two small dikes. However, the abundance of the small erratics suggests that there are probably further intrusions obscured by

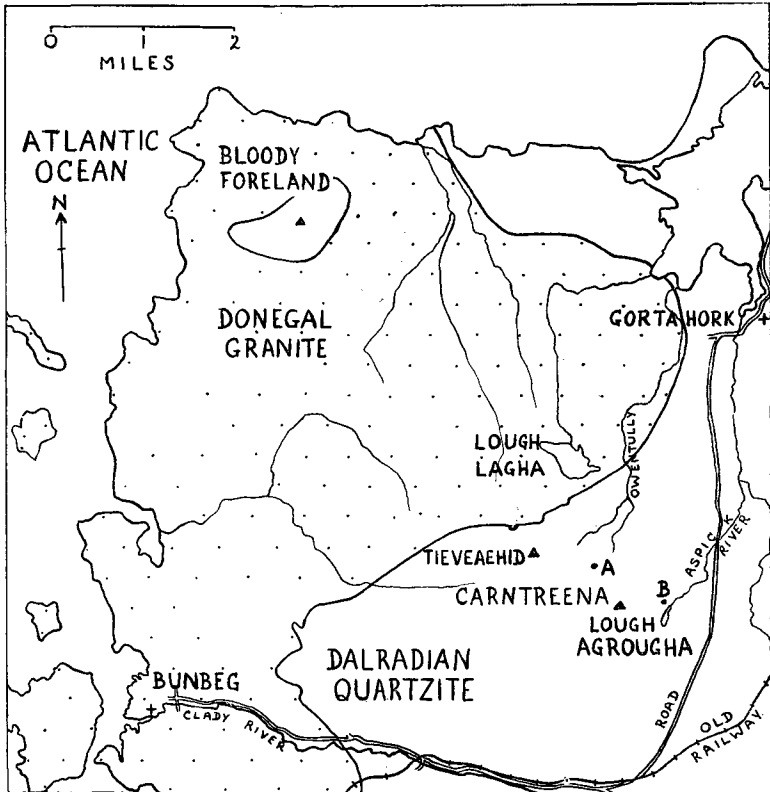


FIG. 1. Sketch-map of the Cloghaneely area, marking exposures A and B.
[For Tieveahid on the map read Tievealehid.]

the drift mantle. The two exposures are too small to determine the exact trend, but the dikes appear to run roughly N.-S.; they are:

- A. NW. of summit of Carntreena, at about 1150 feet above sea level, in a gully draining down into the long eastern tributary of the Owenduff. Occurs on SE. margin of a large metadolerite mass.
- B. East of summit of Carntreena just NW. of Lough Agrougha, the

outcrop being 200 yards up the stream (unmarked on 6-inch map) joining the Aspick river where it leaves the lough.

PETROLOGY OF THE TWO INTRUSIONS.

Intrusion A.—Hand-specimens appear to be perfectly homogeneous with a general appearance of impure chalk (despite the superior hardness) due to the off-white colour. In thin section a very strong fluxion structure is revealed in a nearly monomineralic albitic rock. These felspar laths range up to 0.4 mm. long, whilst occasional more stocky microphenocrysts (0.5 mm. wide) of albite occur. These felspars are considerably decomposed. Subhedral and euhedral sodic amphiboles (about 0.1 mm. long) are scattered through the rock with a preferred orientation of the *c*-axes parallel to the fluxion structure. Very rare corroded amphibole phenocrysts up to about 0.9 mm. length have been detected. The extreme rarity of these phenocrysts makes complete optical determination difficult, but they appear to be ordinary common hornblende with α straw-yellow, β straw-yellow, γ rich leaf-green; $\gamma > \beta \geq \alpha$; $\beta = b$; optically negative.

These hornblendes are very highly corroded, giving ragged margins studded with abundant magnetite grains, which to some extent show the original shapes of the grains. One grain also showed the whole central part of the crystal 'scoured' and replaced by ordinary ground-mass constituents. These amphiboles are probably xenocrystic. Yellow-green epidote occurs as very irregular minute prisms, which frequently possess dusky-brown cores. Though much smaller, the epidotes are often numerically as abundant as the sodic amphiboles. Very small amounts of quartz occur interstitially.

Intrusion B.—Hand-specimens are generally similar to those of intrusion A, except for little clusters of black spots. The dominant minerals are albite (Ab_{91-95}) dusted with secondary 'white mica', and quartz, in a volumetric ratio of about 3:1. The grains are more equidimensional and with less marked fluxional texture than in intrusion A. The albite forms larger and more euhedral grains (average length 0.1 mm., and sometimes reaching 0.2 mm.) than the quartz (average size 0.05 mm., rising to 0.1 mm.). The macroscopic black spots prove to be large sodic amphiboles up to 2 mm. across; these are always extraordinarily sieved, giving clusters of apparently isolated fragments which are never more than about 0.25 mm. in diameter. Although in optical continuity, each fragment appears to be interstitial to the quartzo-

felspathic groundmass. Minute grains (up to 0.045 mm.) of interstitial yellow-green epidote occasionally occur.

THE SODIC AMPHIBOLE.

In both rocks the sodic amphibole bears a superficial resemblance to riebeckite, but closer optical examination discloses somewhat complex relationships, and shows that the minerals are closer to arfvedsonite than riebeckite.

In intrusion A the sodic amphibole has been found to possess two different types of optical orientation. The rather less common type (i) shows:

α fairly deep blue-green, β pale orange-yellow, γ dirty bluish- or greenish-yellow; $\alpha > \gamma > \beta$.

and the more abundant orientation-type (ii) shows:

α orange-yellow to pale watery olive-green, β dirty greeny-yellow, γ fairly dense olive-green, slightly blued; $\gamma > \beta > \alpha$.

The other optical characters are as follows:

Type (i).	Type (ii).
2V, negative, very small	2V, positive, very small, almost uniaxial
$\gamma = b$; op. ax. pl. \perp (010)	$\beta = b$; op. ax. pl. \parallel (010)
negative elongation	positive elongation
$\alpha:c =$ about $> 10^\circ$	$\gamma:c =$ about 17°
extremely small birefringence	very small birefringence
strong dispersion, anomalous extinction	
Size: larger prisms about 0.1 mm. long	

Type (i) possesses the standard arfvedsonite orientation, but in the case of type (ii) there is at first sight a considerable discrepancy. A very slight variation in composition would undoubtedly cause minor alteration of the refractive indices, and since the birefringence of type (i) is extremely small, the sign and position of the optic axial plane could easily alter. Since the birefringence is only of the order of 0.002, it would only necessitate, for example, a reduction of γ by 0.003 to give a complete re-orientation in which α , β , and γ of (i) would become γ , α , and β ; and, instead of having $\gamma = b$ and negative sign, would now have $\beta = b$ with positive sign. Since type (ii) bears just this sort of relationship to type (i), it seems reasonable that both should be termed arfvedsonite. It is clear from the absorption formulae given above that, but for the re-orientation, both types show very analogous pleochroism. Microscopically they show similar habits and textural relationships, and it thus seems probable that these two types represent amphibole whose

composition is slightly variable, possibly due to slightly different times of crystallization.

Data on the optical properties of arfvedsonite show quite considerable variation, but Sundius (1946) suggests that the strong absorption colours and low birefringence are characteristic, whilst a review of recently

TABLE I. Optical data for sodic amphiboles.

Sign.	Optic axial plane.*	$\alpha:c$	$\gamma-\alpha$	2V.	Pleochroism			
					α .	β .	γ .	
ARFVEDSONITE								
1.	—	—	—	—	—	—	—	
		—14 to 20°	—	—	—	—	—	
2.	—	small	small	—	intense bluish-green to indigo	greyish-violet	light yellowish-green	
3.	neg.	⊥	10	0.005	}	dark bluish-green	brownish-yellow	
4.	neg.	⊥	15	0.005				
5.	neg.	⊥	10	0.005				
6.	pos.		—	0.026	64 to 73°	dark bluish-green	greenish or greyish-brown $\alpha > \beta > \gamma$	yellowish-brown or greyish-yellow
7.	neg.	⊥	8	0.005†	large	—	—	
8.	neg.	⊥	15	0.004†	—	—	—	
9.	—	—	30-35	—	—	—	—	
10.	—	—	8	—	—	blue	indigo-blue $\beta \geq \alpha > \gamma$	yellow-green to brownish-green
11.	neg.	—	44‡	0.009	—	pleochroic in light and dark yellow		
12.	neg.	⊥	> 10	extremely small	very small	see p. 396 $\alpha > \gamma > \beta$		
13.	pos.		~ 17‡	very small	almost uniaxial	see p. 396 $\gamma > \beta > \alpha$		
14.	neg.		> 10	~ 0.013	~ 45°	see p. 397 $\alpha > \beta > \gamma$		
KATAPHORITE								
15.	neg.	—	36	0.007†	—	—	—	
16.	neg.	—	56	0.007†	small	—	—	
ECKERMANNITE								
17.	neg.	—	25-53	0.013	75°	—	—	

* Optic axial plane perpendicular or parallel to (010).

† $\beta-\alpha$ instead of $\gamma-\alpha$.

‡ $\gamma:c$ instead of $\alpha:c$.

1, Johnsen, 1901. 2, De Angelis, 1923. 3-5, Gordon, 1927. 6, Kupletsky, 1927. 7-8, Kunitz, 1930. 9, Sobolev, 1933. 10, Coulson, 1936. 11, Wahlstrom, 1940. 12-14, Whitten, 1954. 15-16, Kunitz, 1930. 17, Sundius, 1946.

described arfvedsonites shows that the pleochroism scheme is usually differentiable from that of riebeckitic types (see table I). The strongly sieved grains from intrusion B give consistent optics, as follows:

α opaque inky prussian-blue, β deep greeny-blue, γ grass-green to yellow-green;
 $\alpha > \beta > \gamma$

2V, negative, about 45°; $\beta = b$ with negative elongation, $\alpha:c > 10^\circ$

$\gamma-\alpha$ appears to be at least 0.013

Practically all sections fail to extinguish, going brown instead

Size: maximum 0.25 mm.

These data also clearly suggest arfvedsonite, except that in this case the optic axial plane is $\parallel(010)$, whilst it is normally $\perp(010)$ in both arfvedsonite and riebeckite. Sundius (1946) postulates a continuous series from arfvedsonite through kataphorite to eckermannite, as follows:

	(Fe,Mn):Mg		
Arfvedsonite ...	100:0 to 70:30	$\gamma = b$	$\alpha:c$ small, say $< 10^\circ$
Kataphorite ...	70:30 to 30:70	$\gamma = b$ (variable)	$\alpha:c$ medium 15-36
Eckermannite ...	30:70 to 0:100	$\beta = b$	$\alpha:c$ large 45-56

Sundius also claims that kataphorite commonly has a normal symmetrical position of the optic axial plane with $\gamma = b$, but that this relationship is not always held. He postulates analogous variations in the refractive indices to those suggested above in accounting for the differences between types (i) and (ii) of intrusion A. Thus he suggests that the variation in the position of the optic axial plane is reasonable in view of the low birefringence, which would allow small modifications of the chemical composition to effect a change in the size of the chief indices. Bearing this in mind, and also the variation noted within the amphiboles of intrusion A, it is suggested that intrusion B contains a mineral of the arfvedsonite-kataphorite range, in which the optic axial plane is perpendicular to the usual direction.

AGE OF INTRUSIONS.

The field relations suggest that these arfvedsonite-rhyolites are dikes, but no direct evidence of age can be deduced, other than that they are younger than the Dalradian metamorphism. J. Plemister (1950, p. 368) has recently pointed out that in the case of the riebeckite-bearing dikes of Scotland '... no conclusion on the question of age can be reached on the basis of mineralogical similarity' with other Scottish rocks. It would seem to be even more dangerous to attempt such a correlation between sodic rocks in Donegal and Scotland.

Reference has been made to the fact that no analogous rocks have been discovered within the main suite of microgranitic dikes cutting the neighbouring Donegal granite. It has been noted in other areas that strongly sodic (particularly riebeckitic) rocks occur in close association with ring-complexes. Particular interest attaches to the present dikes because of the granitic ring-complexes of the Rosses (Pitcher, 1953), Ardara, and possible other foci on the west coast of Co. Donegal. Pitcher (1953, p. 155) describes the Rosses granite as being '... of the same general age as the Caledonian Newer Granites of Scotland'. It is

not impossible that these two phenomena are in fact related, and that the arfvedsonite-rhyolites represent a specialized magma intruded penecontemporaneously with the other varied microgranitic dikes. However, no definite proof of age exists.

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