Chapter 12 The Cainozoic igneous rocks

Quartz-dolerite and related craignuritic and felsitic intrusions

A. Introduction

We now deal with a numerous and extensive series of intrusions which consist mainly of a basic or sub-basic rock, quartz-dolerite, and its differentiates in the direction of the intermediate type known as *craignurite,*<ref>See Note 3 p.141.</ref> and finally felsites of related characters. These rocks are to be found mainly in the southern third of the island, and are there widely distributed as sills intruded into the flat-lying or gently-dipping Triassic strata. Dykes, and other masses of transgressive character, are distinctly rare as compared with sills. These sills constitute the main element in the scenery of southern Arran, as they are more resistant to denudation than the soft Triassic strata into which they are intruded, and stand out as scarps with intervening terraces which recall those of the Carboniferous lavas of the mainland. This scarp and terrace topography is particularly well marked in Glen Ashdale (map, (Plate 2)); and the intercalation of sill after sill determines the succession of fine waterfalls which adorn every considerable stream in the southeastern quadrant of the island.

Glen Ashdale and its headwater, the Allt Dhepin, presents a magnificent section of the quartz-dolerite and related sills, and it is therefore proposed to describe this section first as the typical exposure. The sills to the north and south of Glen Ashdale will then be treated. After this will be described in succession the series of large intrusive masses centred about Tighvein, 3.5 miles west of Whiting Bay, and extending northward through Sguiler, The Ross, Cnoc Dubh, and the Sheans, to the Brodick district; and the intrusions of Auchareoch, Auchenhew, Levencorroch, and Kildonan, which are probably southward extensions of the Tighvein masses. Finally, the intrusions in the valley, and at the head, of the Sliddery Water, and a series of western masses, Ballygown, Beinn Tarsuinn, and Tormusk, situated to the east of Blackwaterfoot, will be dealt with.

The intrusions treated in this chapter are remarkable for the abundance of composite sills, and of the phenomena of xenolithic enclosure and hybridization along interior contacts, which they present. In general three petrographic varieties are distinguishable in the field; (1) a dark grey, or bluish-grey, medium-grained to fine-grained dolerite, passing to basaltic types towards their contacts and in the smaller masses — 'blue basalt' was the appropriate field term utilized for these rocks; (2) a light bluish-grey to ash-grey, fine-grained to compact rock, obviously more acid than the 'blue basalts', — this type is identical in composition with the craignurites of Mull; <ref>The Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Qban,' *Mem. Geol. Surv.,* 1924, p. 224. In later footnotes referred to as *Mull Memoir.*</ref> (3) a light grey or yellowish to white rock, granophyric to felsitic in texture, in which minute blebs of quartz can usually be distinguished. These types, while broadly recognizable in the field, are nevertheless connected by many intermediate varieties, and form a continuous petrographic series from dolerite to granophyre, or basalt to felsite (p. 141). In the majority of cases the felsitic rocks are the latest injections, and xenolithic enclosure and hybridization of dark basic fragments included within a matrix of felsitic composition is a common feature. In some cases interior contacts are marked by the xenolithic enclosure of one textural or compositional variety of basaltic or intermediate rock by another.

B. Field-relations

1. The Glen Ashdale–Allt Dhepin Section (Figure 11)

The first and lowermost sill is met with at the large waterfall (p. 4) in Glenashdale Wood, one mile from the sea. The lower contact is well seen in the face of the upper fall, and along the escarpments on both the north and south sides of the gorge. The sill rests on horizontal baked sandstones. The basal rock is a compact, banded, pink and grey quartz-felsite which, 5 feet up, remains substantially the same rock, but becomes a trifle coarser in grain. At 10 to 12 feet above the base the coarse felsite passes rapidly into a fine-grained, vesicular 'blue basalt'; Unfortunately no visible feature marks the change on the weathered surface, and the section becomes very inaccessible at this critical point. The 'blue basalt' becomes coarser as it is traced upward; and at the top of the fall, as well as for some distance above it, the

rock is a medium-grained quartz-dolerite, which is intersected by several thin, irregular, basaltic dykes, and by acid segregation veins.

Farther up the stream the grain-size begins to diminish until, a few yards within the western boundary of the wood, there is encountered a band of dense 'blue basalt,' containing numerous, faintly-defined, darker xenoliths. This rock rapidly becomes coarser to the west, and forms a strong ledge and a waterfall just within the wood. One hundred and fifty yards above the wood the sill is again exposed. The rock is here slabby, and is deeply weathered to a buff colour, but the blocks are blue-hearted. It is a rather more felspathic type of quartz-dolerite than that of other parts of the composite sill. A spherulitic felsite, similar to that at the lower contact, follows, but with no traceable passage. The top of the sill is seen at the bend a twelfth of a mile above Glenashdale Wood, passing under 2 feet of sandstone, above which comes a small felsitic protrusion, not more than 4 feet thick, although the actual junction with the sediments is not exposed. The uppermost 2 inches of this intrusion are composed of a black, banded, pitchstone-like rock (S24874) [NS 028 248]. From this point to the confluence of the Allt Dhepin<ref>The name Allt Dhepin applies to the stream in Glen Ashdale above Glenashdale Wood. Within and below the wood it is called the Glenashdale Burn. See six-inch quarter-sheet, Buteshire, 255 S.W.</ref> with its tributary the Baoileig Burn, the solid rock is concealed beneath a small patch of alluvium.

The Glenashdale sill is thus composite, and consists of four main parts, from above downwards as follows (*see* Section, (Figure 11)):

1. The upper felsite, with intercalation of sediment
2. Felspathic quartz-dolerite or craignurite
3. The main quartz-dolerite
4. The lower felsite

There is a xenolithic band between 2 and 3 indicating an interior contact. The order of injection still requires some further elucidation. It appears probable, however, that the marginal felsite was first intruded, and that after cooling it was split centrally by the main quartz-dolerite injection. While the latter was still hot it was penetrated by a further protrusion of slightly more acid material, which caught up fragments of the basaltic contact rock, and included them in its marginal parts as xenoliths.

The next sill in upward succession first appears at the foot of the Baoileig Burn, and may therefore be referred to as the Baoileig Sill. Its base can be examined in the gorge of the Allt Dhepin extending from the confluence of the Baoileig Burn to a waterfall 200 yards farther west. At the former locality the rock is finely columnar, and rests on horizontal red sandstones and marls. The upper contact is seen at the top of the waterfall. The rock is fine grained throughout, becoming very dense at the contacts, and is in general light grey or blue-grey in colour. It carries sporadic, slender, white, phenocrysts of felspar. The composition is that of a felsite of craignuritic affinities. About the middle of the sill is a band with flow-elongated vesicles. The thickness is estimated at 40 feet.

For 150 yards the bed of the burn is now occupied by horizontal red sandstones and marls. Then begins the outcrop of the great Garbad quartz-dolerite sill (so-called from Cnoc na Garbad to the south), which occupies the burn and its banks for nearly a mile. The Garbad mass contains numerous, thin, lenticular intercalations of sediments; or, in other words, from the focal mass of Cnoc na Garbad, there are thrown off numerous subsidiary offshoots which thin out among the sediments to the east and west.

At the waterfall in the Allt Dhepin (100 yards E.S.E. of the 39 feet O.D.) is seen the easternmost of these offshoots. At the fall it transgresses sharply across the sandstones, which are much disturbed and faulted. This sill clearly thins out to the east amongst the sediments; to the west and north-west it appears to join up with the main mass of the Garbad sill. It can be traced up to the waterfall near 539 feet O.D., where a small patch of sediments is brought in by a fault throwing 6 feet to the north-west.

Above this point there is a more extensive intercalation of sediments in the bed of the burn, with cliffs of 'blue basalt' on either side. The main central part of the Garbad mass is reached in a remarkable dyke-gorge S.E. of 634 feet O.D., east of Cnoc an Fheidh (873 feet O. D.). The rock is here a coarse quartz-dolerite (S24459) [NS 019 252] which has been

selected for analysis (p. 147).

From this point onward the Allt Dhepin section is penetrated by an extraordinary number of dykes which run mostly north-west and north-north-west (Figure 12). A small waterfall at the northwestern end of the dyke-gorge mentioned above is caused by a dyke along a small fault throwing to the west. Above this point there is a fine section in the red sandstones and marls of the upper part of the New Red Sandstone, with the 'blue basalt' seen at the top of the cliff (634 feet O.D.). This condition continues up to and beyond the sharp loop in the burn, south of 739 O.D. No less than six dykes intersect the northern limb of the loop. The 'blue basalt' descends to the bed of the burn and occupies the channel for about no yards at 739 feet O.D. Its base then rises again, leaving the underlying sediments, as before, occupying the bed of the stream.

A section in a tributary flowing east and entering the Allt Dhepin to the north of Cnoc an Fheidh illustrates the multiple character of the Garbad mass (Figure 12).

A small fault running north-west to south-east at the bend in the burn below 786 feet O.D. at length brings in a sill (the Allt Dhepin sill) on a higher horizon than the Garbad mass. This sill is well exposed at the large waterfall near 786 feet O.D., where it is underlain by red sandstones and marls. It consists of an ash-grey felsite of craignuritic affinities; a rock collected from the top of the fall has been analysed ((S24458) [NS 017 265], *see* p. 147). The sill is first seen in a tributary gully entering the Allt Dhepin from the east opposite 739 feet O.D. (Figure 13). This rock occupies the bed of the Allt Dhepin up to the bend near 824 feet O.D., where the lower contact is again seen. The sediments now continue for some distance up the burn, occupying its floor, while grey felsitic rock, probably the same as that of the Allt Dhepin sill, forms the walls of the gorge. A well-marked north-west to south-east fault throwing io feet to the southwest is seen just above the confluence of a tributary from the north; and a dyke, 12 feet wide, of grey felsite with dark xenoliths, occurs at the foot of a waterfall 250 yards E.S.E. of 982 feet O.D. Above this point the top of the sill is seen, with a fine section of overlying sediments. It consists of a flow-banded, yellow or white, felsitic rock. From this point up to 1118 feet O.D., half a mile east of the summit of Tighvein (1497 feet O.D.) exposures of grey felsitic rocks are intermittently seen, which may belong to a sill on a yet higher horizon than the Allt Dhepin sill, and may be identical with the widespread sheet which caps the plateau around Loch na Leirg.

The Allt Dhepin section thus reveals at least five large sills and sill-complexes composed of rocks ranging from quartz-dolerite to felsite of craignuritic type as follows:

	Approximate height of base. Feet	Estimated maximum thickness. Feet
5. Uppermost sill — craignuritic felsite. (Loch na Leirg sill)	1010	100
4. Allt Dhepin sill — craignuritic felsite	770	210
3. Garbad sill — quartz-dolerite	500	250
2. Baoileig sill — felsite and quartz-dolerite of craignuritic affinities	420	40
1. Glenashdale sill — quartz-dolerite and felsite composite sill	190	210

As the strata are nearly horizontal it is comparatively easy to estimate the maximum thicknesses of the respective sills. Still higher in the succession are the intrusions which form part of the Tighvein complex which is described later (p. 133); and in the coastal regions of Whiting Bay and at Largybeg there are one or two sills on a lower horizon than the Glenashdale sill (p. 132).

2. Sections North of Glen Ashdale

A series of five tributaries to the Glenashdale Burn provides the means of tracing the main sills to the north. These burns are the Allt Garbh which drains Loch na Leirg; and then, to the south-west, a series of four unnamed burns which have been designated A, B, C, and D, respectively, from north-east to southwest (*see* (Plate 2)). Burn D, which occupies a gorge on the east side of Cnoc Mòr (867 feet O.D.), loses itself in a bog before reaching the main stream.

The Glenashdale sill forms a massive outcrop following the northern boundary of Glenashdale Wood. There is a fine glaciated exposure where Burn B crosses the moorland track on the north side of the wood. The sill also forms a range of cliffs crossing Burn A. At this point the sill bifurcates; a northern branch, continuously thinning, causes a small waterfall in the Allt Garbh, below Creag Bhan, and then fades out among the sediments. The branching here may be taken as confirmation of the view that the sill is multiple. The main branch, however, crosses the Allt Garbh at the northern corner of Glenashdale Wood (*see* map, (Plate 2)), the exposures here showing dark xenoliths, and then continues to the north across the golf course, following the contours of Borrach (869 feet O.D.). Good sections are exposed in the Allt Ceirde and in a burn to the south. In the Allt Ceirde a felsitic rock appears at both contacts.

One or two 'blue basalt' sills, on lower horizons than the Glenashdale sill, are exposed in the Cal Burn at North Kiscadale, Whiting Bay.

The Baoileig sill can likewise be traced across Burns C, B, and A, and crosses the Allt Garbh at the lower end of the gorge known as Creag Bhan. Its course between the Glenashdale Burn and Burn D, however, is rather uncertain. In Burn C it encloses a lenticle of sediments, and near Burn B its outcrop is broken by a small north-west to south-east fault. North of the Allt Garbh it throws off at least two branches which die out amongst the sediments.

The Garbad sill can be traced from the Allt Dhepin north-westwards across the moor by means of a series of scattered exposures. Good sections of it are exposed on Cnoc Mòr, and in a gorge at the head of Burn B ((Figure 6), p. 88). The sill ends off bluntly and abruptly against felsite near Creag Bhan. A plan of the exposures in Creag Bhan is given in (Figure 14).

Between the outcrops of the Baoileig and Garbad sills there appears on both sides of Glen Ashdale a series of disconnected masses of spherulitic felsite or granophyre. These are all thick and massive intrusions which have the habit of ending off very abruptly. One is seen in the Creag Bhan section (Figure 14). This mass fades out to the south-west before Burn A is reached. A second intrusion appears below Cnoc Mòr, and is well exposed in the gorge of Burn D. It ends off abruptly to the north as a thin mass of platy felsite at the head of Burn C (Plate 2). To the south it crosses the moor track, and is then lost to sight.

Very little is known as to the extent of the Allt Dhepin sill on the eastern side of the valley. It extends as far south as the gully near 739 feet O.D. (Figure 13), but appears to wedge out farther south. On a higher horizon a thick mass of spherulitic felsite appears. A poor section is exposed in the above-mentioned gully (Figure 13), and the sill can be traced southward by numerous large blocks on the moor surface ((Plate 2), felsite mass on western margin). This intrusion is probably the same as that which caps the plateau around Loch na Leirg, near which there are many exposures. Similar rocks are seen in fragmentary exposures in many places on the moor, notably near 972 feet O.D. (Plate 2), and in the region half a mile south-west of Urie Loch. A columnar sill of felsite is to be seen in the Kingscross Burn at Sloc Ruaridh, half a mile N.N.W. of Loch na Leirg, but this seems to be on a somewhat lower horizon than the Loch na Leirg mass.

3. Sections South of Glen Ashdale

The various sills cause well-defined scarp and terrace topography on both sides of Glen Ashdale, but particularly so on the south side (Plate 2). They can therefore be mapped with considerable facility. The Glen Ashdale sill continues as a well-marked cliff through the southern part of Glenashdale Wood, until it reaches a N.N.W.–S.S.E. fault which passes by Torr an Loisgte (*see* map, Plate 2). It is here offset to the south, and is split by an intercalation of sediments. From this point the outcrop curves round to the south, passes below the cairns known as the Giants' Graves, and exhibits a good section in the Allt Crompucaidh. Both the sill and the adjacent sediments are here much disturbed, and dip at 60° to the west (Figure is). The scarp can now be traced from the Allt Crompucaidh to Largybeg, running in a general south-south-east direction; and, although there are no intervening exposures or features, it is probable that a small sill of

'blue basalt' at Port na Gaillin, a sixth of a mile south-west of Largybeg Point, is its shoreward termination. The sill is here only a few feet thick as compared with over 200 feet in the Glen Ashdale section. It is not only thinning out to the east, but it has also lost the felsitic marginal facies, which are not seen from Glen Ashdale eastwards. This eastward thinning, which appears to be general in the sills of the quartz-dolerite suite, is in marked contrast to the behaviour of the crinanite sills (p. 113).

The Baoileig sill forms an equally well-marked escarpment and terrace which, on the north flank of Torr na Baoileig, makes a narrow ledge just below the steep escarpment marking the outcrop of the Baoileig felsite. The Baoileig sill is cut off and offset by the Torr an Loisgte fault, and continues as a small ledge and scarp around the base of Torr an Loisgte, where it turns south and passes above the Giants' Graves. A good section is exposed in the southern headwater of the Allt Crompucaidh, where the sill is 15 to 20 feet in thickness, and is dipping along with the adjacent sediments at 30° to the W.S.W. (Figure 16). The scarp fades out below the Stone Circle on Bealach Gaothar, and the sill cannot be traced any farther south. A recent small landslide on the road south of Largybeg shows a 6-foot sill of 'blue basalt' just below the scarp of the Dippin crinanite. This is in all probability the Baoileig sill, which, like the Glenashdale sill, is thinning towards the east.

Between the Baoileig sill and the scarp of the Dippin crinanite there occur two masses of felsite precisely similar to those occurring on the north side of Glen Ashdale along the same horizon. The Torr na Baoileig mass consists of a coarse spherulitic felsite or granophyre, and is well exposed in the Baoileig Burn. To the east it ends off very abruptly about half a mile west of Torr an Loisgte. The second mass forms the hill of Torr an Loisgte, which is a prominent scenic feature in the view from Whiting Bay to the south. The rock is a spherulitic felsite which weathers with a minutely-nodular surface. On the west side the intrusion appears to be bounded by the Torr an Loisgte fault; on the east it rises as a short abrupt scarp above the Baoileig sill (*see* map, (Plate 2)).

The great Garbad sill which, on the south side of the Allt Dhepin, spreads around Loch Garbad as centre, is a very thick mass of coarse quartz-dolerite. It is well exposed in many places, notably around Loch Garbad, along its eastern scarp, and at Cnoc na Garbad (959 feet O.D.). At Loch Garbad the rock carries many xenoliths of fine-grained 'blue basalt', and it may therefore be conjectured that there is an interior contact at this locality.

The most notable feature of the Garbad sill is the extraordinary straight scarp running N.N.W. to S.S.E., which bounds it on the eastern side (*see* One-inch Geological Map, Arran, 1910). This scarp runs from the Allt Dhepin to Cnoc na Garbad, a distance of one mile. It is in line with the upper part of the Allt Dhepin, and it coincides in direction with the majority of the dykes of this region, and with many small faults. The scarp of the Dippin crinanite appears to be cut off abruptly against it (*see* map, (Plate 2)). The feature is interpreted as marking the line of a large fracture, which may or may not have been a fault. This fracture is believed to have served as the focus for the irruption of the Garbad quartz-dolerite, and possibly for the other quartz-dolerite sills of the neighbourhood. According to this view the quartz-dolerite magma rose up along this fissure, and was injected mainly to the west; but several smaller protrusions were thrown off to the east, as, for example, the one that forms a scarp immediately above the Dippin crinanite ((Plate 2), south-west corner), and the one that occurs in the Allt Dhepin immediately west of the Baoileig sill (p. 126).

On the north side of Cnoc na Comhairle (913 feet O.D.), a flat-topped hill three-quarters of a mile south-east of Torr na Baoileig, three sills of 'blue basalt' may be traced above the scarp of the Dippin crinanite. The lowermost is thin and impersistent, and shows a peculiar vitreous facies at a point a quarter of a mile S.S.W. of Torr an Loisgte; the second is rather thicker, but fades out rapidly both to the east and west; the third and highest is much more persistent, extending from the Garbad escarpment round the summit of Cnoc na Comhairle to Torr na Cloiche. The actual summit of the hill is composed of sandstone.

On the south side of Glen Ashdale, as on the north, one or two 'blue basalt' sills are found at horizons lower than that of the Glenashdale sill. One such, for example, is found in the section across Largybeg Point ((Figure 7), p. 90), and is 15 feet thick. A massive dyke of craignuritic felsite hading north-east is found at the northern end of the section.

On a still lower horizon is the sill which forms Creag Dubh, the southern horn of Whiting Bay. The lower contact of this sill is exposed at low tide, and is seen to rest on sandstone dipping W.S.W. at 20°. The thickness of the mass is estimated at

30 feet. The rock consists of an acid quartz-dolerite. On one visit a glomeroporphyritic segregation of yellow felspar, 6 inches in diameter, and elliptical in shape, was seen on the seaward side of the crag.

4. Tighvein, Sguiler, The Ross, Cnoc Dubh, The Sheans, and the Brodick area

Tighvein — The masses of igneous rock occuping these localities form a complex and connected series of intrusions extending northward from Tighvein (1497 feet O.D.), situated about 3 miles west of Whiting Bay, to the neighbourhood of Brodick. On the One-inch Geological Map of Arran (1910) the exposures on Tighvein are mapped in the form of an ellipse with its long axis in a north to south direction, which suggested the possibility of a ring-dyke complex in this neighbourhood. In spite of the fact that the exposures are poor and disconnected, owing to the deep covering of peat on the Tighvein plateau, the writer is inclined to believe that the intrusions are mainly concordant in character, and are sills injected on a higher horizon than those of the Glen Ashdale and Allt Dhepin region. The writer has only so far studied the eastern half of the Tighvein complex, and it may be that the sections on the west and south will provide better evidence as to the disposition of the intrusive masses.

A good section on the south-east side of Tighvein is provided at the head of the Allt nan Clach, one of the headwaters of the Kilmory Burn. A traverse of the little gorge which extends from the Kilmory to Lamlash track to the summit of the plateau gives the section shown in (Figure 17). The lowermost sill is a grey, acid, craignuritic felsite, which rests on Triassic marls and sandstones and has a flow-vesiculated base. It is almost certainly on a higher horizon than the sill occupying the summit of the Loch na Leirg plateau. The sediments are dipping to the south-west, although as this section is along the strike, they are here apparently horizontal. The second sill is a 'blue basalt' or fine-grained quartz-dolerite, and contains xenoliths of quartzite. Its base is well seen, but its upper part is concealed beneath peat. A fragmentary exposure of ' grey basalt' in the peat north-west of the pitchstone dyke, may represent a third sill or the upper part of the second sill. Above the pitchstone the ground rises in an ill-defined scarp, and an exposure of coarse, rotted, gabbroid rock (augite-diorite) is seen. About 300 yards north-north-west of this exposure is a rough rocky knoll composed of the same rock.

From this point to the summit of Tighvein the ground is covered with peat, on the surface of which are strewn numerous blocks of microgranite. This rock occupies the area practically to the summit; but the top of Tighvein itself, and of an isolated knoll to the south-west, consists again of augite-diorite. This rock is cut by numerous irregular veins of an acid rock. A ridge near 1490 feet O.D. provides the best exposure of the microgranite. This rock appears to form the summit of the plateau, and falls to the east in a fairly well defined scarp on to the terrace of the lower augite-diorite. No contacts are seen, and it is therefore difficult to decide whether we are dealing with sills or broad ring dykes. The spreading of the outcrops of the augite-diorite to the north and to the south-west, however, seems to indicate that these masses should be interpreted as sills. The upper part of the section (Figure 17) therefore, is drawn according to this view.

A little western headwater of the Allt Dhepin, descending from 1490 feet O.D. east of the summit of Tighvein, provides a section on the eastern face of the hill (Figure 18). The lowermost sill is a typical 'blue basalt'. On a higher horizon there is a slabby, whitish, acid sill, which may be the same as the lowermost sill of the Allt nan Clach section. Augite-diorite and microgranite are again seen at the summit of the plateau.

Between this point and Urie Loch there are many large blocks and an exposure of a coarse, rotted, gabbroid augite-diorite. The boundary of this rock, marked by small crags, sweeps round the head of the Allt Dhepin immediately south and south-east of Urie Loch; and in a crag on the eastern side of the valley the coarse gabbroid rock contains xenoliths of a dark, fine-grained, ' blue basalt,' and the whole exposure is traversed by irregular veins of granophyric rock.

Xenolithic rocks of the same character, with but slight variations in texture, are to be seen in the exposures around Urie Loch. A little intrusive boss of spherulitic felsite, probably a devitrified pitchstone (p. 215), breaks through the augite-diorite on the south shore of the loch; and a dyke-like mass of the same character borders the loch close by. A dyke of fine-grained quartz-dolerite with angular xenoliths of still more fine-grained basalt, occurs on the north-east shore of the loch.

Sguiler — The xenolithic augite-diorite may be traced at intervals through the peat in the region between Urie Loch and the summit of Sguiler (1332 feet O.D.), which overlooks Monamore Glen. The base of the sill shows an extraordinary development of xenolithic enclosure, the fine-grained basaltic rock having apparently been shattered, and then intimately interpenetrated by a more acid rock. This phenomenon is discussed at greater length in connection with the Sheans (p. 136). On the peat-covered terrace immediately to the south of the summit of Sguiler numerous fragments of felsite are to be seen, which are interpreted as belonging to a sill injected just below the base of the Sguiler mass. From Sguiler the boundary of the basic sill runs south-east to Creag na h'Ennie, and thence to east of Urie Loch.

The Ross — The Ross is the prominent hill (992 feet) which rises on the north side of Monamore Glen, between the Monamore and Benlister valleys. The summit of The Ross consists of a coarse gabbroid rock. On the south side of the hill, the base of the sill, consisting of fine-grained dolerite near the texture of ' blue basalt,' is seen. It is injected by fine-grained veins and thin sills of basalt, with very dense, almost tachylytic, margins. These injections range from a fraction of an inch to about a foot in thickness. Near the western end of the outcrop on the south side of The Ross, intercalations of sandstone, baked to hard white quartzite, make their appearance, and cause the marked banding on the face of the cliff as seen from the Ross Road. This banding is parallel to the general easterly dip of the sill. At the western end of the sill there is also a marked primary banding in light and dark, coarser and finer, more acid and more basic, bands.

The nature of the sill of The Ross is doubtful. The Survey possesses no specimens, and those in the Glasgow University collection are much decomposed. The thin sections are puzzling. There is very little free quartz, and all the ferro-magnesian minerals have gone over to chlorite. Without fresh material it is hard to say whether this mass is really a continuation of the Monamore crinanite (as it is mapped on the One-inch Geological Map), or a member of the quartz-dolerite suite.

A typical 'blue basalt' dyke, 12 feet wide, and running in a north-north-west direction, cuts the base of the Ross sill. This rock is a quartz-basalt obviously belonging to the oversaturated suite. It weathers with a whitish crust, and is mapped as a felsite on the One-inch Geological Map (19I0). It may perhaps be regarded as evidence for the view that the sill of The Ross really represents the Monamore crinanite.

Cnoc Dubh — (1003 feet O.D.) is the summit of the plateau north of the Benlister Burn. It is occupied by an ill-defined and poorly-exposed doleritic intrusion, of which the small detached masses to the east and north-west (including the Sheans) appear to be outliers (*see* One-inch Geological Map). The only specimen collected from this mass (S25048) [NS 000 320], from the western side of the hill, is a quartz-basalt with porphyritic plagioclase felspar and a number of xenocrysts of alkali-felspar.

The Sheans — The Sheans consist of three abrupt rocky hills rising on the edge of the plateau to the south and south-east of Glen Dubh, about 2¾ miles south-west of Brodick Pier. The south-eastern hill shows a compact grey basaltic rock at the foot of the slope. On its summit, however, there is a porphyritic dolerite, intersected by fine-grained acid veins which weather as whitish raised reticulations on the surfaces of the exposures. The central Shean is separated from the above by a deep peat-filled depression. This hill has a long protrusion to the south. At the south-eastern end of the main knoll soft red sandstone, in a horizontal attitude, occurs at the base of the slope, clearly passing beneath the dolerite, and establishing the sill character of the intrusion. The rock is of the same general character as that of the south-eastern hill, but is only sparingly porphyritic. It shows the most extraordinary brecciation, the separated angular or partially-rounded fragments of dark-coloured and rather compact basalt being enveloped in a more acid type which weathers light grey or white. The fragments are mainly between 2 and 6 inches in greatest diameter, and are generally somewhat rounded as if solutional effects had taken place between the xenoliths and the matrix. In freshly-broken material the lines of junction between fragments and matrix are often hard to distinguish, although they are brought out most spectacularly by weathering. The best place to collect specimens is slightly below the summit of the hill on the western side. Occasionally the light acid material forms stratiform bands in the dark rock.

It seems perfectly clear from the exposures that the dark basalt was shattered when solid, and that the acid material then filled up the intervening spaces, and was hot enough to produce some solutional and hybridization effects. The whole thickness of the tabular mass, estimated at 50 feet, appears to have been involved in this shattering and veining process;

and it appears possible to trace increasing grain-size in the xenoliths from the base of the hill to the top, showing that the brecciation occurred within a normally-cooled intrusive mass.

Although there is a peaty depression between the central and northern hills of the Sheans, the exposures show that the sill is really continuous between the two hills. On the north side of the northern hill the same xenolithic rock is seen as on the central hill, but there is apparently a greater quantity of acid matrix. The base of the intrusion is not actually seen, but it is marked by the occurrence of a narrow terrace of hard, white, carious sandstone.

Brodick area — A mile east-north-east of the Sheans, and about 2 miles south-south-west of Brodick, there are many small sills exposed in the headwaters of the Lag a' Bheith. These are mainly of felsitic composition. Their thickness rarely exceeds 20 feet. The best exposure is in a small road-metal quarry situated where the old moor road crosses the easternmost headwater, about a cmarter of a mile west-south-west of the Stone Circle near the fourth milestone on the Brodick–Lamlash road. This is in a fresh-looking, light blue-grey, craignuritic felsite (S25059) [NS 020 340], which contains sparse, coarse-grained segregations (S25076) [NS 020 340]. The main headwater, which descends from a point north of Cnoc Dubh, shows no fewer than six thin sills from where it is crossed by the old moor track, to its confluence with the main burn. The uppermost of these is probably a devitrified pitchstone (S25060) [NS 010 330]–(S25061) [NS 010 330], one of the intermediate or basic types which belong to the quartz-dolerite–craignurite-felsite suite.

The composite sill described by Dr. A. Scott<ref>A Composite Sill in Glen Cloy, Arran, *Trans. Geol. Soc. Glasgow*, vol.xv., part ii., 1915, pp. 140–150.</ref> from Glen Cloy, Brodick, belongs to the series under description. The greater part of it is a dark-grey felsitic rock which has a spherulitic appearance. Towards the top of the sill this rock is overlain by a black, flinty, pitchstone material, with a sharp junction between the two parts. The total thickness of the mass is estimated at 12 feet.

An interesting section of a small composite sill belonging to this suite is seen in the Rosa Water at Rosaburn Bridge, near the Smithy, Brodick. The section is as shown in (Figure 19). Below a fissile banded sandstone dipping 35° to the south-east, there occurs a stratiform quartz-basalt intrusion about 4 feet thick. This is followed downwards by spherulitic felsite, with a sharp junction against the basalt. The felsite is dark at the top for a foot or so; 'then comes a banded layer; and finally, within the lower part of the mass, appears a strongly xenolithic band, with dark, angular to rounded fragments of basaltic composition up to one inch in diameter (S7538) [NS 009 368]. The base of the mass is not seen, but it probably consists of the complementary basalt member of a triple composite sill, whence were doubtless derived the above xenoliths. The visible thickness is 15 feet, and the total thickness is estimated to be 20 feet.

5. Auchareoch, Auchenhew, Levencorroch, and the Kildonan area

The Auchareoch, Auchenhew, and Levencorroch masses appear to represent the horizons of the Tighvein complex in a southward direction. The Kildonan intrusions, however, are injected on a horizon below that of the Dippin crinanite, and are therefore on the same stratigraphic level as the Baoileig and Glenashdale sills of the Whiting Bay district.

Little is known as to the field-relations of the three large masses above mentioned. They all consist of a coarse quartz-dolerite. The Auchareoch sill is well exposed in tributaries of the Kilmory Water near the farm of Auchareoch, but its surface and its boundaries are largely obscured by peat. Auchenhew and Levencorroch Hills are capped by what appears to be the same sill of quartz-dolerite, the outcrop of which has been severed into two parts by the deep gorge of the Levencorroch Burn. The Auchenhew mass is represented by three specimens in the Survey collection (S6885) [NS 007 232], (S6886) [NS 01 21], (S6887) [NS 01 21].

An interesting section of a small 6-foot sill of 'blue basalt' on a lower horizon than the Auchenhew–Levencorroch mass is exposed in the Levencorroch Burn at the small waterfall called Easa Cumhang.<ref>A sketch of this occurrence is given in J. W. Gregory and G. W. Tyrrell, Excursion to Arran, *Proc. Geol. Assoc.*, vol. xxxv., part iv., 1924, p. 418, but the Auchenhew mass is wrongly called crinanite.</ref> The sill is intersected by a 2-foot basalt dyke. It can be traced eastward to the path on the south side of Auchenhew Hill, but apparently does not reach the burn to the east.

A sill on a somewhat lower horizon is exposed in a fine section at the waterfall of Eas Mòr in the Allt Mòr burn running on the eastern side of Auchenhew Hill. The gorge below Eas Mòr heads in an amphitheatral feature caused by the outcrop

of a craignuritic felsite sill, 20 to 30 feet thick, forming the waterfall. The sill rests on nearly horizontal Triassic marls, and on the eastern side of the gorge shows a sedimentary intercalation. Beneath the fall the strata are bent and broken by one or two small faults. Another sill of the same material appears at a small fall one-third of a mile higher up the burn, which is here called the Loch Burn.

The cliff at the back of the 10-ft. raised beach below Kildonan Castle is composed of a sill of craignuritic felsite 15 to 20 feet thick. This is well exposed in the quarry at Lloyd's Signal Station, and there rests on sediments which are seen on the seaward side of the quarry. The rock is a typical 'grey basalt' generally with scattered slender porphyritic felspars (S6358) [NS 03 20], (S6359) [NS 045 218]. The central part of the sill is flow-vesiculated, and the elongated cavities are filled with 'green earth' minerals and calcite (S25057) [NS 033 208]. The rock weathers with a thick greyish crust, but is blue-grey when fresh. The marginal parts of the sill are slightly more basic than the central part, and Dr. Harker therefore regarded it as a composite sill.<ref>Geology of North Arran, etc., *Mem. Geol. Surv.,* 1903, p. 115.</ref>

To the west the sill extends much farther than is shown on the One-inch Geological Map (1910). An exposure is seen in the cliff behind the Schoolhouse at Kildonan, half a mile west of Kildonan Castle. To the east the sill extends along the raised-beach cliff up to the houses at Port a' Leacach, where it suddenly ends off. At this point, however, another sill appears on the foreshore, of exactly the same petrographical character. Its upper surface, with patches of sediments still adhering to it, forms a flat spread on the foreshore for about a quarter of a mile to the northeast of Port a' Leacach. This sill appears to have suffered monoclinal bending at places, and patches and sheets of sediments are included within it. Its relation to the Kildonan Castle intrusion is doubtful. It may be the same mass dropped down to the east along a north-west fault, or it may form a separate sill injected on a slightly lower horizon.

One or two intrusions of quartz-dolerite (S6413) [NS 03 21] occur in the fields between Kildonan Castle and the road, below the horizon of the Dippin crinanite.

The island of Pladda, one mile south of Kildonan, is mainly occupied by a well-marked sill which, judging from the Survey specimen (S6397) [NS 028 189], is a quartz-dolerite belonging to the suite under description.

6. Region west of the Sliddery Valley

A quarter of a mile north-east of the ninth milestone on the Ross Road, and 3 miles W.S.W. of Lamlash, a small quarry gives a section in a thin sill which shows an extraordinarily intimate interpenetration of a dark compact basalt by spherulitic felsite (Figure 20). The basalt occurs in angular or sub-rounded fragments enveloped by a matrix of felsite, and the two rocks appear in approximately equal quantity. The same sill is found intersecting the Carboniferous volcanic rocks in the head of the Sliddery Water, about half a mile south-west of the above-mentioned quarry. The section is poor, and the felsite-basalt sill is cut by a thin N.N.W. basalt dyke.

The moor to the north and west of the quarry is strewn with rounded blocks of medium to coarse-grained quartz-dolerite, and there are numerous outcrops of the same rock farther to the west along the Ross Road. This is presumably the elongated sill which is shown on the One-inch Geological Map as extending for about 3 miles on the eastern side of the Sliddery Water.

Nothing is known of the field-relations of the Glenscorrodale mass on the western side of the Sliddery Water. It is represented by two specimens (S6401) [NR 958 282], (S6402) [NR 958 282] in the Survey collection, from which the sill appears to be a dolerite modified by the incorporation of acid material. The intrusion of Tormusk, to the north-west of Glenscorrodale, is also little known. From the Survey specimen (S6407) [NR 948 292] it appears to be a spherulitic felsite of the suite under description.

The complicated ring-shaped outcrop 22 miles east of Blackwaterfoot, which includes Cnoc Ballygown (735 feet O.D.), Beinn Tarsuinn (965 feet O.D.), and Cnoc an Loch (1107 feet O.D.), belongs to a composite sill including coarse quartz-dolerite (S6375) [NR 940 280], Cnoc an Loch; (S6389), Cnoc Ballygown, and various rocks of craignuritic composition (S6377), (S6390), Cnoc Ballygown). On the One-inch Geological Map it is mapped as dolerite and felsite.

The head of the Allt Cul na h'Eilde provides a section in the northern part of the Beinn Tarsuinn mass. The sill rests on practically horizontal Triassic marls and sandstones. Its base consists of spherulitic felsite, which passes into rocks of craignuritic composition higher up the burn. The summit of Cnoc Ballygown consists of a coarse quartz-dolerite of Garbad type, poorly exposed and much decomposed. Lower down on the western slope the rock be comes distinctly more acid.

It is probable that many of the felsites of the Sliddery district, as, for example, at Bennecarrigan, Glenrie, and in the Clauchan Glen, are related to the quartz-dolerite–craignuritic-felsite suite under description.

In a quarry at Pien Bridge, Shiskine, there is a section in a thin composite sill, the exterior member of which is quartz-basalt, and the interior member a felsite.

C. Petrography

The rocks to be described in this section are derived from an oversaturated magma, and in nearly all their varied manifestations show traces of the presence of free silica. Their range of composition varies from basic to acid; their textures from glassy to coarsely holocrystalline. For descriptive purposes we propose to divide them into three groups according to composition, as basic, intermediate, and acid. The basic types are fine-grained quartz-gabbros or quartz-dolerites; the intermediate rocks are augite-diorites and rocks of craignuritic composition; the acid rocks are felsites of distinctive characters belonging to the acid end of the craignurite series.

The nomenclature of these rocks presents a perplexing problem. An attempt has been made in the following descriptions to apply the nomenclature of the similar rocks of Mull.<ref>Mull Memoir, 1924, p. 227.</ref> The chief difficulty has been found in regard to the intermediate types which have been termed craignurite in Mull.

Craignurites are rocks in which the matrix has a characteristically immature type of crystallization, with skeletal crystals of felspars and pyroxenes in an acid crypto- or micro-crystalline base. The larger felspar and pyroxene crystals, too, possess an elongate habit.<ref>Mull Memoir, 1924. </ref> Hence the main features of *craignurite,* as defined in the *Mull Memoir,* appear to be the immature type of crystallization, and the general columnar, acicular, and skeletal development of the minerals.

The compositional range covered by the term craignurite is very wide. It embraces rocks with silica percentages between 55 and 70, the normal and characteristic type, however, containing about 65 per cent. The group, as a whole, should perhaps be referred to as the *craignurite series;* the normal intermediate type as *craignurite* in the narrow sense; the basic end-member as *craignurite-dolerite;* and the acid end-member as *craignurite-felsite.* In Arran, however, rocks which are undoubtedly of craignuritic composition rarely show the characteristic texture and mode of crystallization of the craignurite series. The matrix and mesostasis of many of the rocks certainly show an immature type of crystallization, but it is more of a felsitic and spherulitic character than acicular and skeletal.<ref>Some of the slices were submitted to Dr. H. H. Thomas and Mr. E. B. Bailey, both of whom are of the opinion that the term craignurite should be applied very sparingly to the Arran rocks, as the characteristic texture is quite rare.</ref> Many of the Arran rocks closely resemble the rocks of the Cnoc Carnach group of composite sills in Skye.<ref>A. Harker, The Tertiary Igneous Rocks of Skye, *Mem. Geol. Surv.,* 1904, p. 215.</ref>

The basic members of the suite, represented by the analysed rock (S24459) [NS 019 252], seem to be identical with the quartz-dolerites of Talaidh type in Mull.<ref>Mull Memoir, 924, p. 301 *et seq.*</ref> In the field they are dark, fine-grained, minutely-crystalline rocks usually devoid of porphyritic constituents. The type rock comes from the Garbad sill, where it is exposed in the gorge of the Allt Dhepin, near Cnoc an Fheidh. It consists of well-shaped felspar laths, and colourless augite crystals usually well-developed in the prismatic zone, along with iron-ores and a completely-altered second pyroxene, in an abundant, brown, turbid mesostasis containing irregular blebs of quartz and needles of apatite. The felspars are highly zonal, ranging from acid labradorite to oligoclase. Where they are in contact with the acid mesostasis (as in the vein described later) they are surrounded by a thick investment of turbid alkali-felspar, and show signs of corrosion and reaction. The principal pyroxene is a colourless augite, generally with salite striation and enclosing crystals of magnetite. Occasionally it shows a marginal alteration to a yellow-green amphibole; but more often it is invested by

pseudomorphs in a dark-green, fibrous, pleochroic mineral after a second pyroxene, the alteration of which has disengaged much cloudy iron-ore. This pyroxene forms long columnar crystals, and is never fresh. The alteration product has a fibrous structure parallel to the length of the crystals, and cleaves so perfectly that the laminae are often separated and the interspaces filled with secondary matter. This pyroxene may be the uniaxial enstatite-augite described from Mull rocks of the same suite, or it may be an orthorhombic variety.

The mesostasis is a brownish, turbid, felspathic substance with undulose extinction, in which an occasional irregular area of quartz is set, and which is riddled by needles of apatite. In isolated areas it becomes distinctly spherulitic. Its distribution is rather patchy; and the slice (S24459) [NS 019 252] shows a large irregular area or vein, several millimetres broad, in which the mesostasis has collected. In this area its texture is felsitic or microcrystalline. It contains spongy masses of chloritic material, small well-shaped crystals of magnetite, and the scattered felspars above mentioned which are invested by alkali-felspar.

A specimen from the Glenashdale sill, from below Torr an Loisgte (S24867) [NS 041 251], differs only in inessential particulars from the above. There is little or none of the altered, presumably orthorhombic, pyroxene, and the mesostasis is beautifully spherulitic.

One of the rocks from Auchenhew Hill (S6887) [NS 01 21] is almost identical with that of the Glenashdale sill; but where the mesostasis is particularly abundant it carries long rods of pyroxene, which show parallel intergrowths of the two kinds above described. A fivefold parallelism of a central and two marginal rods of altered enstatite-augite, with two rods of fresh, colourless, monoclinic pyroxene is occasionally seen. Apatite needles and quartz are relatively abundant in this rock.

Another Auchenhew rock (S6886) [NS 01 21] is decidedly more basic than the above. The amount of interstitial quartz and mesostasis, relatively to the pyroxene, plagioclase, and iron-ores, is much less. The rock of the Pladda sill (S6397) [NS 028 189] is generally similar, but is of finer, grain, and shows a tendency towards intergranular texture. From Cnoc Ballygown we have an example of a coarse, almost gabbroidal, type (S6389). The pyroxene here seems to be of the fresh monoclinic variety only, and shows an incipient alteration to yellow-green chlorite. The specimen from east of the Boguille track, west-south-west of Tormusk (S6375) [NR 940 280] is a much altered rock of the same character. Another rock from Cnoc Ballygown (S6377) is almost a replica of the type rock, except that the pyroxene has gone over entirely to green serpentinous material.

Types of intermediate or craignuritic composition are represented in a coarse-grained form, of which a good example is found in the Tighvein complex, near the shepherd's cairn on the northeast side of Urie Loch (S25055) [NS 003 282]. This rock presents a close resemblance to the augite-diorite of the Gaodhail mass in Mull.<ref>*Mull Memoir,* 1924, p. 218.</ref> In hand-specimens it is a light-grey, aphyric rock of medium grain. Under the microscope it shows numerous, euhedral, rectangular, and columnar crystals of zonal plagioclase, with chloritized pyroxene and magnetite, embedded in an abundant mesostasis of turbid alkali-felspar and quartz, which often combine to form a very fine micrographic intergrowth. The felspar is often only singly-twinned and varies from andesine to oligoclase on the margins of the crystals. Where the crystals project into the mesostasis they form the centres of thick investments of micropegmatite, the fibres of which run at right-angles to their margins. Definite crystals of alkali-felspar sometimes occur in the mesostasis, but are invariably intergrown with quartz, and are occasionally moulded by large areas of clear quartz.

A rock from Auchenhew Hill (S6885) [NS 007 232] differs from the above only in its somewhat finer grain, in its abundance of small granules of iron-ores, and the occasional occurrence of a plagioclase phenocryst.

A rock of much the same character, but much finer in grain, and more felspathic than that of Urie Loch, forms the thick veins and patches of light rock which intersect the augite-diorite at the summit of Tighvein (S6409) [NR 998 274]. The pyroxene in this rock is fresh, granular, and subhedral, and is a faintly-coloured greenish augite. The specimen from a crag east of Cnoc Dubh, north-west of Tighvein (S6410) [NR 993 282], is of similar character, but is highly weathered. The light-coloured component of the Cnoc Ballygown mass (S6390) also belongs here. The matrix, however, is very turbid, and is somewhat richer in quartz than usual. The light-coloured matrix of the xenolithic rock which forms the summit of Sguiler (S25054) [NR 998 291] belongs to the same general type (p. 135).

Rocks of intermediate composition, but definitely craignuritic in texture, are rare in Arran, and are very poorly represented in the Survey collection. A rock from near the base of the Glenashdale sill, at the top of the great waterfall in Glen Ashdale, appears to be a craignurite near the basic end of the series (S6382) [NS 010 250]. It consists of numerous small felspar laths, much altered and albitized, in an obscure groundmass composed of felspar microlites, chlorite, iron-ore, turbid matter (alkali-felspar ?), and irregular areas of quartz.

Many of the rocks belong to the acid end of the craignurite series. These types are distinguished in the field by their characteristic compact texture, light bluish-grey colour, and by the presence of small, sporadic phenocrysts of white felspar, which are sometimes aggregated into little stellate groups (S25057) [NS 033 208], (S25059) [NS 020 340]. These rocks tend to have an irregular slabby fracture, and are often characterized, especially near sill contacts, by flow-elongated vesicles, which may be partly or wholly filled with calcite and 'green earths'.

A rock of these characters which has been analysed (Table 2), (Table 5) is that of the Allt Dhepin sill, taken at the waterfall near 786 feet O.D. in the Allt Dhepin (S24458) [NS 017 265]. Under the microscope it shows a few microphenocrysts of alkali-felspar (? soda-orthoclase) set in a groundmass consisting of well-shaped felspar microlites, mostly alkali-felspar but with a few of oligoclase, and a very abundant, turbid, felspathic base with irregular areas and blebs of quartz. This base sometimes shows an obscure intergrowth with quartz. Ferro-magnesian elements are represented by a few small specks of chloritic matter and iron-ores. The norm of this rock gives 38 per cent. of quartz. but as the visible quartz does not nearly amount to this figure, the bulk of the free silica must be occult in the turbid base.

Of almost identical characters is the acid rock which forms the basal member of the Glenashdale sill (S6383) [NS 020 240], and the main rock of the Kildonan Castle sill (S6359) [NS 045 218], which was identified by Dr. Harker as trachyte.<ref>Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv*., 1903, p. 115.</ref> A recently-collected specimen (S25057) [NS 033 208] is slightly coarser in grain, and many of the felspar laths are certainly oligoclase and not alkali-felspar. In these Kildonan rocks there is a tendency for elongation in both felspars and chloritized pyroxenes, and the felspars are often forked and skeletal. Hence there is an approach to the characteristic craignurite texture. At the base of the Kildonan sill a somewhat more basic facies occurs, which has been described by Dr. Harker<ref>Ibid., p. 115</ref> in the following terms:

'A specimen from the lower part [of the sill] is a grey, fine-textured rock, without evident porphyritic crystals, and gives the specific gravity 2.68. In a thin slice (S6358) [NS 03 20] it is found that the felspars, in little "lath-shaped" sections about one-hundredeth inch or less in length, constantly give quite low extinction-angles. Many of the crystals are striated, and the dominant felspar must be near oligoclase in composition, though orthoclase may perhaps be present in addition. The augite preserves its ophitic habit, but is in great part destroyed. In addition there are abundant little crystal-grains of magnetite, and in places a little interstitial quartz. The rock presents the characters of a partially acidified dolerite, the low density being very significant in this respect.'

The rock of the massive dyke at the north end of the Largybeg Point section (Figure 7) is an acid member of the craignurite series, and possesses a highly characteristic craignuritic texture (S25056) [NS 050 230].

The rock of the small quarry in the Lag a' Bheith (p. 137) is somewhat richer in chloritized pyroxene and iron-ores than the type rock of the Allt Dhepin sill (S25059) [NS 020 340]. Another specimen (S25076) [NS 020 340] carries large glomeroporphyritic segregations of altered plagioclase felspar, chloritized pyroxene, and skeletal ilmenite, which collectively make up a rock resembling the above-described augite-diorite.

A cryptocrystalline, spherulitic type (S25060) [NS 010 330], and a flow-banded, spherulitic, glassy facies (S25061) [NS 010 330], come from a 5-foot sill in the main western headwater of Strathwhillan Burn, near Brodick. The black glassy material from Glen Cloy, Brodick, described by Dr. A. Scott, <ref>*Trans. Geol. Soc. Glasgow*, vol. xv., part ii., 1915, p. 242.</ref> is a pitchstone-like rock of similar characters (S24391) [NS 004 352]. The rock which underlies it is a felsite with a typical craignuritic texture (S24390) [NS 004 352].

Allied to the craignuritic felsites are certain other acid intrusions in the southern half of Arran, as, for example, the spherulitic felsite or granophyre which is inserted at intervals between the Baoileig and Garbad sills in the Glen Ashdale

region; other large acid sills, as, for example, those of the Sliddery valley; and the microgranite which is involved in the Tighvein complex. The spherulitic felsite of Glen Ashdale is represented by a specimen from below Cnoc Mòr on the north side of the glen (S24873) [NS 028 253]. This is a light ash-grey rock, rather porous and drusy, with a few small microphenocrysts of felspar. In thin section it shows a large number of curious rounded masses of fine micropegmatite, which are often involved with crystals of quartz and felspar. These masses are apparently reconstituted spherulites. They are set in a dense felsitic groundmass of the usual type. The phenocrystic felspar is largely oligoclase or oligoclase-albite. The original pyroxene (?) has given rise to some disseminated chlorite and epidote. Some of the quartz grains have rounded or embayed shapes which are probably due to a resorption effect. The felsitic granophyre of Torr Beag, from the quarry north of Glenrie, Sliddery valley (S6400) [NR 95 25], shows very similar features, but is richer in the micrographic spherulites, and is devoid of felspar microphenocrysts. The spherulitic rock from Tormusk (S6407) [NR 948 292] is a member of this group.

The large acid intrusion which forms part of the Tighvein complex is treated here, as it is almost certainly closely associated with the augite-diorites of that centre. It may be regarded as the most fully crystallized representative of the partial magma which gave rise to the acid craignurites and craignurite-felsites. It is represented by three slices in the Survey collection (S6384) [NR 99 28], (S6411) [NR 998 275], (S24877) [NR 999 274]. The specimen from a twelfth of a mile north-east of the summit of Tighvein (S24877) [NR 999 274] is a light greyish-yellow rock of minutely-granular aspect, with sporadic rectangular microphenocrysts of felspar. In thin section the three slices mentioned above show a remarkably uniform type of microgranite consisting mainly of anhedral quartz and turbid felspar, with an allotriomorphic or aplitic texture. There is a tendency to imperfect granophyric relations between the two minerals. The felspar is difficult to determine, but appears to be mainly an untwinned alkali-felspar (soda-orthoclase ?). Some lath-shaped sections show simple twinning. The microporphyritic felspars are mainly soda-orthoclase, but a few are albites or oligoclase-albites, with an investment of soda-orthoclase. All the felspars are much weathered. The only mafic constituents are a few specks of iron-ore and shreds of yellow serpentinous material.

Xenolithic and hybrid rocks

In the *Mull Memoir*<ref>*Trans. Geol. Soc. Glasgow*, vol. xv., part ii., 1915, p355.</ref> it is shown that the late acid residues of the intermediate and subacid magmas have reacted with earlier minerals, and that these effects are particularly marked when the residual liquor has migrated within the limits of the individual intrusion. Many of the mineralogical phenomena thus produced are entirely similar to those which are due to hybridization, *i.e.* to the commingling of magmas, or to the assimilation of foreign material within a magma. Since the validity of the reaction principle seems to be unquestionable,<ref>N. L. Bowen, The Reaction Relation in Petrogenesis, *Journ. Geol.,* vol. xxx., 1922, pp. 177–198.</ref> it is clear that assimilation and hybridization effects should only be inferred when there is good evidence of magmatic mingling or the dissolution of xenoliths. Some of the rocks described above have been regarded as acidified basalts and dolerites, or basified felsites and granophyres, but there is no reason to doubt but that many of them are perfectly normal products of differentiation, assuming that reaction between the early-crystallized minerals and the late acid residua has been in progress.

Nevertheless there are many undoubted examples of partial assimilation and hybridization in Arran, in which fragments, generally of basic composition, are enveloped in acid magmas, with reactional or solutional effects. The Sheans and the intrusion at the summit of Sguiler furnish the best examples in the Survey collection of xenolithic rocks within the group described in this chapter; but there are other fine examples between the gabbro and granophyre of the Central Ring Complex (p. 177). The rocks of the Sheans are represented by two slices (S24384) [NR 996 329], (S24385) [NR 996 329]. In (S24385) [NR 996 329] the dark compact xenoliths are seen in thin section to consist of a fresh quartz-basalt with a fine intergranular texture, little granules of augite and magnetite being inserted, often in single rows like strings of beads, between diversely-orientated felspar laths. The composition of the felspar ranges between andesine and oligoclase; the ends of the felspar laths are sometimes embedded in small areas of chlorite which seem to have replaced a pyroxene. A small amount of quartz occurs interstitially.

The light acid rock in which the xenoliths are enveloped differs from the xenoliths in its somewhat coarser grain, the greater relative abundance of felspar, and in the presence of alkali-felspar which forms a scanty mesostasis along with quartz, and which also forms a few phenocrysts mainly of perthitic soda-orthoclase. The boundary between xenoliths and

matrix is quite sharp, and there has been little or no reaction between the two. Little fragments of the xenoliths have, however, been spalled off, and can be found in process of disintegration. The slice (S24384) [NR 996 329] is quite similar except that it is much weathered, as the specimen from which it was cut was collected to show the mode of weathering of the xenolithic rock. The xenoliths in this rock show a few phenocrysts of acid labradorite.

The rock of Cnoc Dubh (S25048) [NS 000 320], of which the Sheans are probably outliers, is similar to the more basic xenoliths of the Sheans. It is a porphyritic quartz-basalt or dolerite with intergranular texture. The phenocrysts range up to 5 mm. in width, and consist of acid labradorite. Some of them are albitized, and others show a narrow rim of alkali-felspar, which appears to be continuous with a scanty mesostasis. In the xenolithic rock of Sguiler (S25054) [NR 998 291] the xenoliths consist of a dense quartz-basalt of character generally similar to that of the Sheans, enveloped in a matrix resembling the more acid type of augite-diorite which is prevalent in the Tighvein complex. There has been some reaction in this case, as skeletal iron-ore has been thickly developed in the xenoliths near the contacts, and specks of iron-ore and shreds of chloritic matter are decidedly more abundant in the acid rock nearer the contacts with xenoliths than in parts remote from them.

A slice from the sill in the Rosa Water, Brodick (S7538) [NS 009 368] shows small, rounded xenoliths of quartz-basalt in a craignuritic matrix. Two slices of rocks from an intrusion 500 yards W.N.W. of Glenscorrodale House, Sliddery valley (S6401) [NR 958 282], (S6402) [NR 958 282], show large xenocrysts of alkali-felspar and quartz in a matrix of craignuritic composition. The quartz has been much corroded, and shows beautiful reaction rims consisting mainly of pyroxene granules.

D. Chemical composition

Analyses of quartz-dolerite or basic craignurite of the Garbad sill, and of craignuritic felsite from the Allt Dhepin sill, both taken from the type section of the Allt Dhepin (p. 126) have been made for this Memoir by Mr. E. G. Radley ((Table 2)-4 and 5). Thus typical specimens of rocks which represent the end-members of the craignurite series have been selected for analysis.

(Table 2)

		4	E	F	5	6	G	H
	SiO_2	54.00	52.16	55.82	71.58	69.26	70.70	71.30
$A1_2O_3$		13.09	11.95	11.47	12.20	11.60	1178	11.24
Fe_2O_3		3.53	4.86	3.68	1.51	1.31	1.32	1.80
FeO		8.45	9.92	7.66	1.77	2.57	3.45	2.84
MgO		3.49	3.77	4.08	0.50	1.10	0.53	0.61
CaO		5.55	7.14	7.88	1.98	2.61	1.30	1.56
Na_2O		3.27	2.36	2.53	2.83	2.08	2.48	3.44
K_2O		1.80	1.74	2.00	3.86	3.88	4.71	4.66
H_2O> 103°		1.71	1.95	1.88	0.76	1.67	1.14	1.04
H_2O< 105°		1.26	0.56	0.66	1.1	1.61	0.50	0.39
TiO_2		2.83	3.25	1.62	0.44	0.45	1.27	0.58
P_2O_3		0.31	0.24	0.23	0.13	0.10	0.26	0.22
MnO		0.37	0.18	0.40	0.31	0.45	0.07	0.31
	CO_2	0.25	0.18	0.08	1.07	1.76	0.51	—
	S	—	0.18	—	—	—	0.08	—
	FeS_2	0.14	—	0.09	nt. fd.	nt. fd.	—	nt. fd.
	(Ni, Co)O	nt. fd.	—	0.04	nt. fd.	nt. fd.	—	nt. fd.
	BaO	0.02	—	0.03	nt. fd.	nt. fd.	—	0.07
	Li_2O	tr.	—	tr.	nt. fd.	nt. fd.	—	? tr.
		100.07	100.44	100.18	100.04	100.45	100.10	100.06

4. (S24459) [NS 019 252]. Lab. No. 828. Quartz-dolerite from the Garbad sill (p. 126) gorge in Allt Dhepin, one-third of a mile E.N.E. of 873 feet O.D., Cnoc an Fheidh, Whiting Bay, Arran. *Anal.* E. G. Radley.

(S18467) [NM 5684 3313]. Lab. No. 444. Quartz-dolerite (Talaidh type), cone sheet, 70 yards south of summit, Cruachan Dearg, Mull. *Anal.* F. R. Ennos. Quoted from the *Mull Memoir,* 1924, p. 17.

(S16800) [NM 6857 3750]. Lab. No. 412. Craignurite (basic), cone sheet, Allt an Dubh Choire, 1220 yards above junction with Scallastle River, Mull. *Anal.* E. G. Radley. Quoted from the *Mull Memoir,* 1924, p. 19.

5. (S24458) [NS 017 265]. Lab. No. 827. Felsitic end-member of the craignurite series, from the Allt Dhepin sill (p. 126), at waterfall in the Allt Dhepin near 786 feet O.D., half a mile S.S.W. of Loch na Leirg, Whiting Bay, Arran. *Anal.* E. G. Radley.

6. (S24453) [NR 994 346]. Lab. No. 823. Felsite (devitrified pitchstone ?, *see* p. 211), probably of the craignurite series, 24-foot dyke in Glen Dubh Water, 100 yards above confluence with Glen Ormidale Water, 825 yards W. 37° S. of Kilmichael, Brodick, Arran. *Anal.* E. G. Radley.

Q. (S18464) [NM 5361 2259]. Lab. No. 443. Felsite allied to inninmorite, sill, south of Coire Buidhe, between the Soo-foot and 900-foot contours, about half a mile north of Carsaig, Mull. *Anal.* F. R. Ennos. Quoted from the *Mull Memoir,* 1924, p. 20.

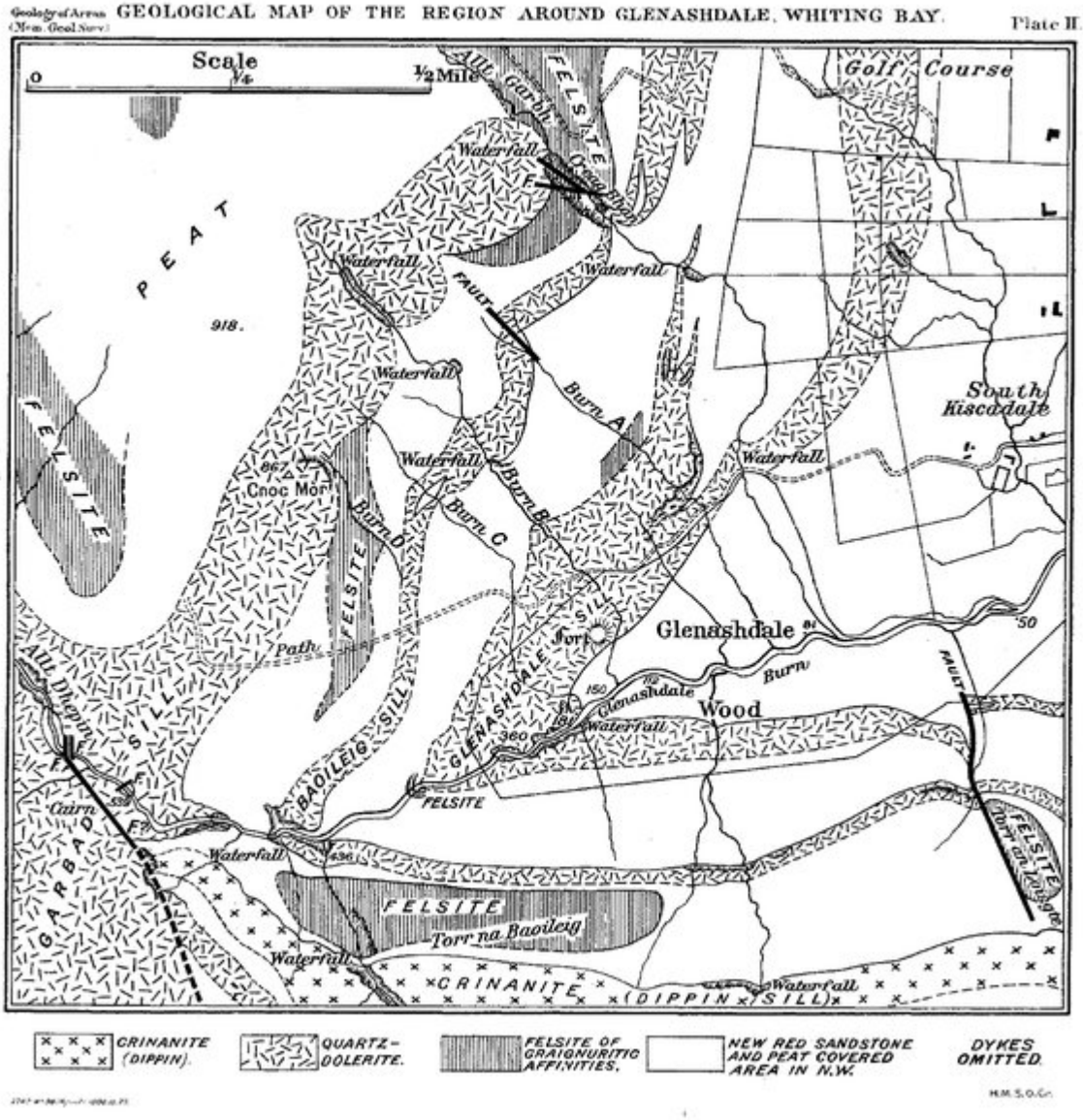
H. (S16803) [NM 7167 3731]. Lab. No. 394). Granophyre allied to craignurite, cone sheet, Craignure Bay, shore 50 yards N.N.W. of U.F.C. Manse. *Anal.* E. G. Radley. Quoted from the *Mull Memoir,* 1924, p. 20.

The closest Mull analogues of the Arran quartz-dolerites are the quartz-dolerite of Talaidh type from Cruachan Dearg (S18467) [NM 5684 3313], and the basic craignurite of a cone sheet in the Allt an Dubh Choire (S16800) [NM 6857 3750], the analyses of which are tabulated for comparison in columns E and F of Table II. Calculation of the norms shows that both the Mull rocks are decidedly more femic than that of Arran, the percentages of salic minerals being 58.4 and 59.2 respectively, as against 64.2 for the Arran example; and they are richer in plagioclase felspar, and poorer in alkali-felspar than the Arran type, as is shown by their higher lime, and lower alkalies and alumina.

The rock from the Allt Dhepin sill, which was selected as typical of the acid end-members of the craignurite series, turns out to be a thoroughly acid type with 38 per cent. quartz as computed from the norm of the analysis (5, (Table 2), and 89.2 per cent. of salic constituents. Along with it are tabulated the analysis of a felsitic dyke rock from Glen Dubh, Brodick (6, (Table 2)), which is dealt with in more detail later (p. 235), and the analyses of two Mull rocks, a felsite allied to inninmorite ' from Carsaig (G, (Table 2)), and a granophyre allied to craignurite from Craignure Bay (H, (Table 2)). Inspection of these four analyses shows their close general similarities. The only notable difference is that the Mull types are somewhat richer in alkalies, and especially in potash, than the Arran rocks. The comparison given below exhibits their variations in the amount of salic constituents and in quartz:-

	% Salic Constituents	% Quartz
Anal. 5	89.2	38.0
Anal. 6	83.6	38.5
Anal. G	87.7	35.2
Anal. H	85.8	27.8

G.W.T.



(Plate 2) Geological map of the region around Glenashdale, Whiting Bay.

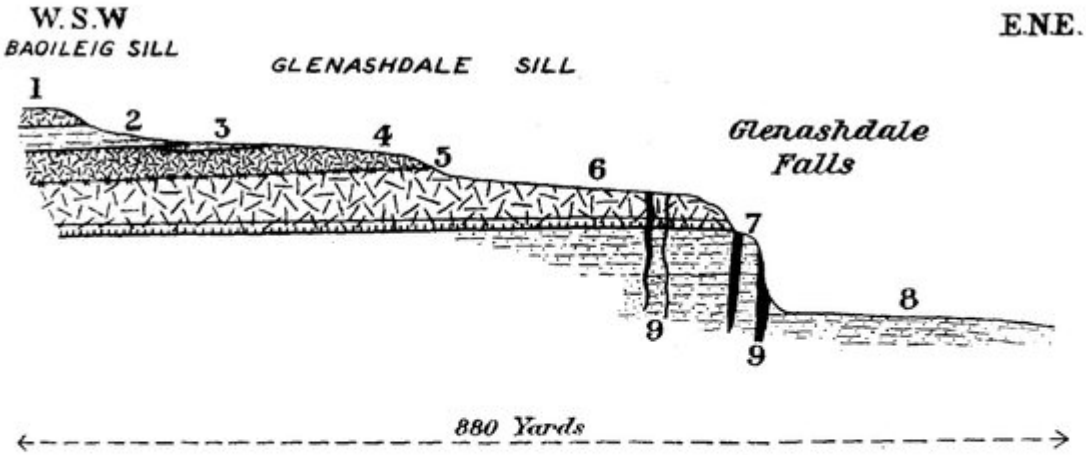


FIG. 11.—*Section along Glen Ashdale from the Falls to confluence with Baoileig Burn.*

1. *Quartz-dolerite ;* 2. *Shales and sandstones ;* 3. *Felsitic margin with intercalation of sandstone ;* 4. *Upper quartz-dolerite ;* 5. *Xenolithic interior contact ;* 6. *Lower quartz-dolerite ;* 7. *Felsitic margin ;* 8. *New Red Sandstone ;* 9. *Basalt dykes.*

(Figure 11) Section along Glen Ashdale from the Falls to confluence with Baoileig Burn. 1. Quartz-dolerite 2. Shales and sandstones 3. Felsitic margin with intercalation of sandstone 4. Upper quartz-dolerite 5. Xenolithic interior contact 6. Lower quartz-dolerite 7. Felsitic margin 8. New Red Sandstone 9. Basalt dykes.

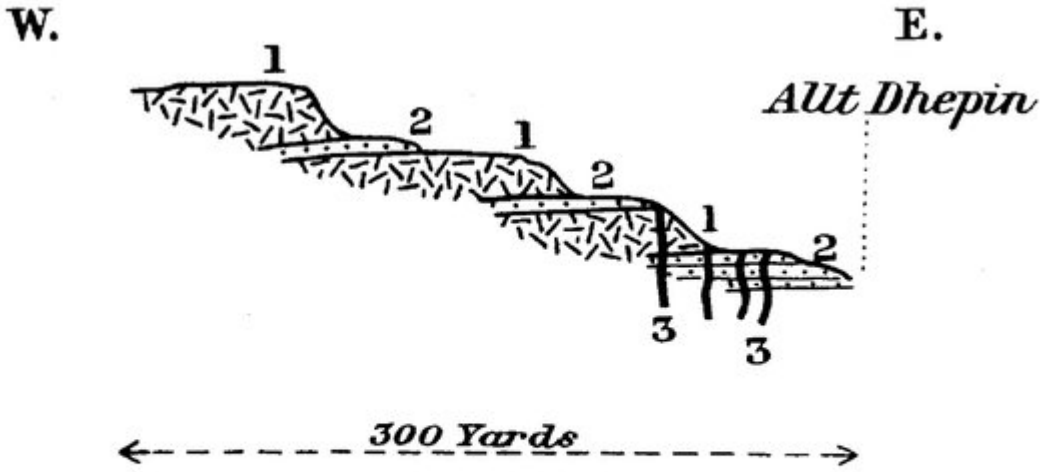


FIG. 12.—*Section along tributary to Allt Dhepin, north of Cnoc an Fheidh, showing intercalations of sandstone (2) within Garbad quartz-dolerite sill (1), and basaltic dykes (3). Vertical scale much exaggerated.*

(Figure 12) Section along tributary to Allt Dhepin, north of Cnoc an Fheidh, showing intercalations of sandstone (2) within Garbad quartz-dolerite sill (1), and basaltic dykes (3). Vertical scale much exaggerated.

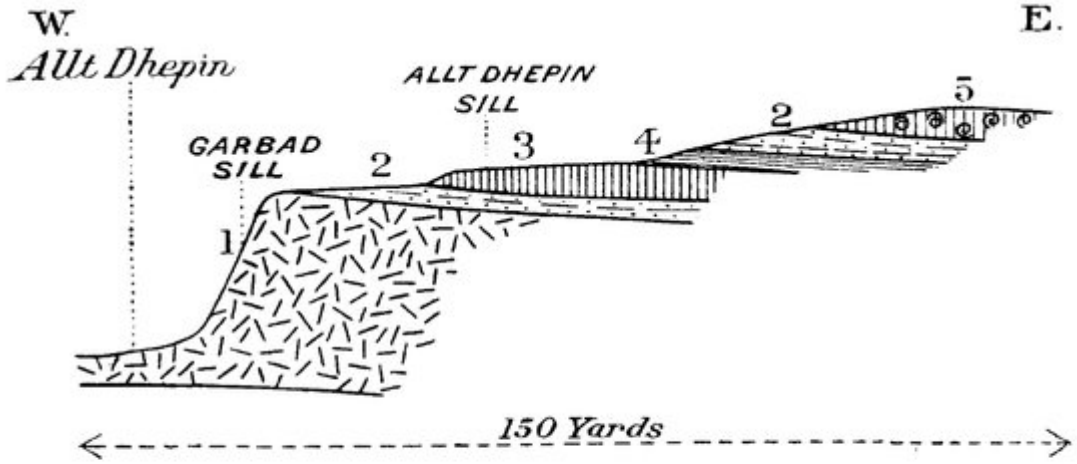


FIG. 13.—*Section in a gully entering the Allt Dhepin from the east, opposite 739 feet O.D.*

1. *Quartz-dolerite ;* 2. *Sandstone ;* 3. *Craignurite-felsite ;* 4. *Marls ;* 5. *Sill of spherulitic felsite. Vertical scale exaggerated.*

(Figure 13) Section in a gully entering the Allt Dhepin from the east, opposite 739 feet O.D. 1 Quartz-dolerite 2. Sandstone 3. Craignurite-felsite 4. Marls 5. Sill of spherulitic felsite. Vertical scale exaggerated.

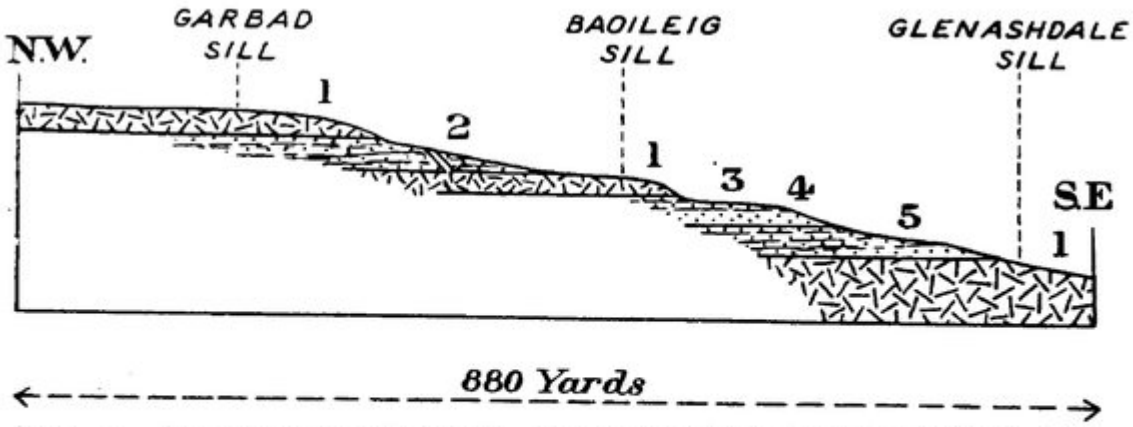


FIG. 6.—*Section along Burn B., one-third of a mile east of Cnoc Mòr, north of Glenashdale Wood.*

1. *Quartz-dolerite and craignurite sills ; 2. Shales and marls ; 3. Quartzitic sandstone ; 4. Chocolate-coloured ferriferous sandstone ; 5. Thin-bedded red sandstone.*

(Figure 6) Section along Burn B., one-third of a mile east of Cnoc Mòr, north of Glenashdale Wood 1. Quartz-dolerite and craignurite sills 2. Shales and marls 3. Quartzitic sandstone 4. Chocolate-coloured ferriferous sandstone 5. Thin-bedded red sandstone.

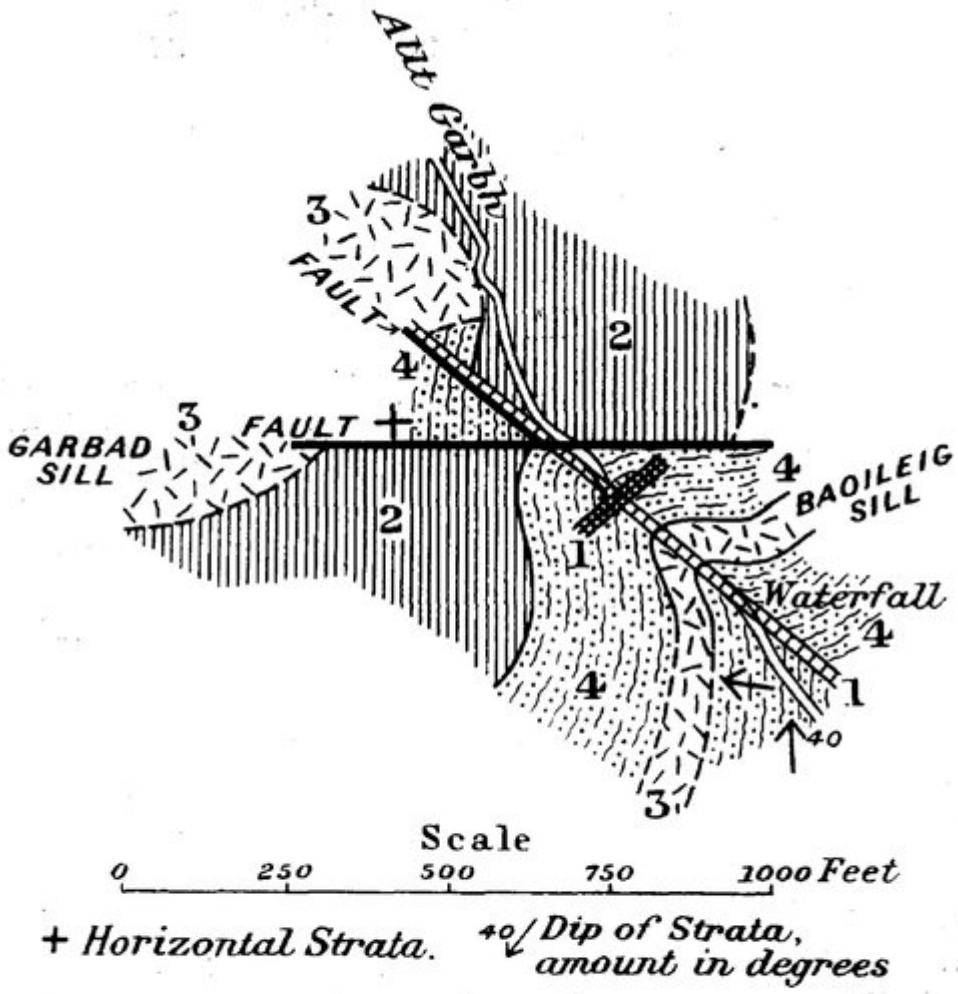


FIG. 14.—*Plan of exposures in Creag Bhan, Allt Garbh, Whiting Bay.*

1. *Basalt dyke ; 2. Felsite sill ; 3. Quartz-dolerite sills ; 4. Triassic sediments.*

(Figure 14) Plan of exposures in Creag Bhan, Allt Garbh, Whiting Bay 1. Basalt dyke 2. Felsite sill 3. Quartz-dolerite sills 4. Triassic sediments.

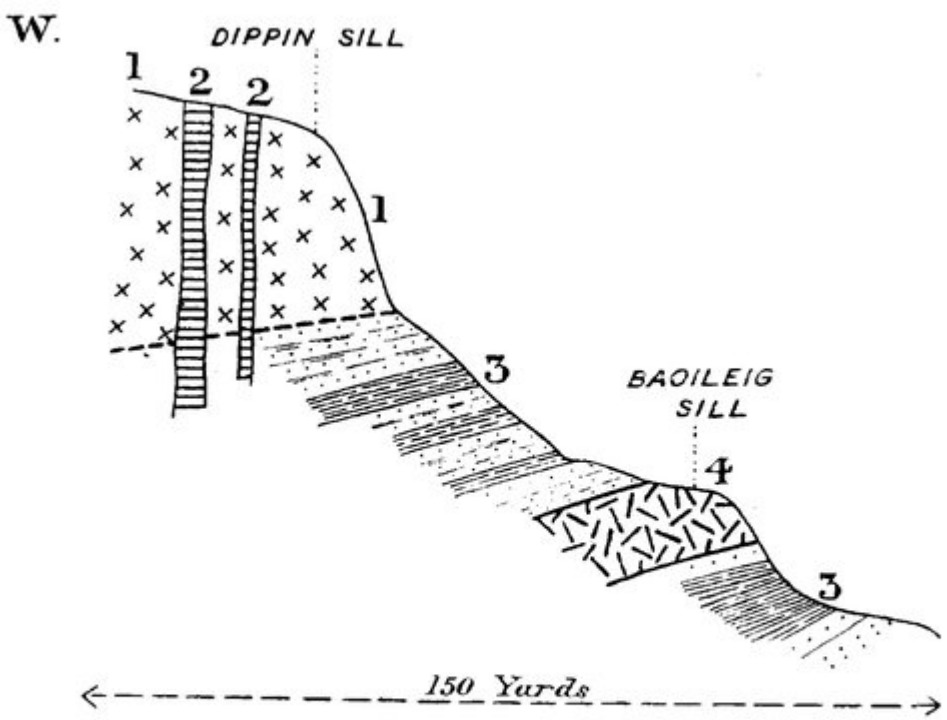


FIG. 16.—*Section in the southern headwater of the Allt Crompucaidh, Largymeanoch, Whiting Bay.*

1. *Dippin crinanite sill ; 2. N.N.W. Basalt dykes ; 3. Red Sandstones and shaly marls (New Red Sandstone) ; 4. Baoileig quartz-dolerite sill. Vertical scale exaggerated.*

(Figure 16) Section in the southern headwater of the Allt Crompucaidh, Largymeanoch, Whiting Bay. I. Dippin crinanite sill 2. N.N.W . Basalt dykes 3. Red Sandstones and shaly marls (New Red Sandstone) 4. Baoileig quartz-dolerite sill. Vertical scale exaggerated.

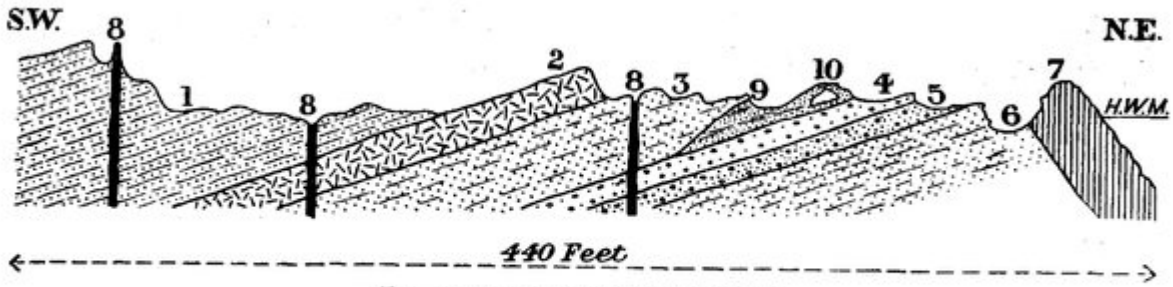


FIG. 7.—*Section across Largybeg Point.*

1. *Thin-bedded red sandstone ; 2. Quartz-dolerite sill ; 3. White sandstone ; 4. Coarse grit with bands of conglomerate ; 5. Conglomerate ; 6. Carious white sandstone ; 7. Thick dyke of craignurite-felsite ; 8. Basalt dykes ; 9. Line of local erosion ; 10. Rock-arch on raised beach.*

(Figure 7) Section across Largybeg Point. 1. Thin-bedded red sandstone 2. Quartz-dolerite sill 3. White sandstone 4. Coarse grit with bands of conglomerate 5. Conglomerate 6. Carious white sandstone 7. Thick dyke of craignurite-felsite , 8. Basalt dykes 9. Line of local erosion o. Rock-arch on raised beach.

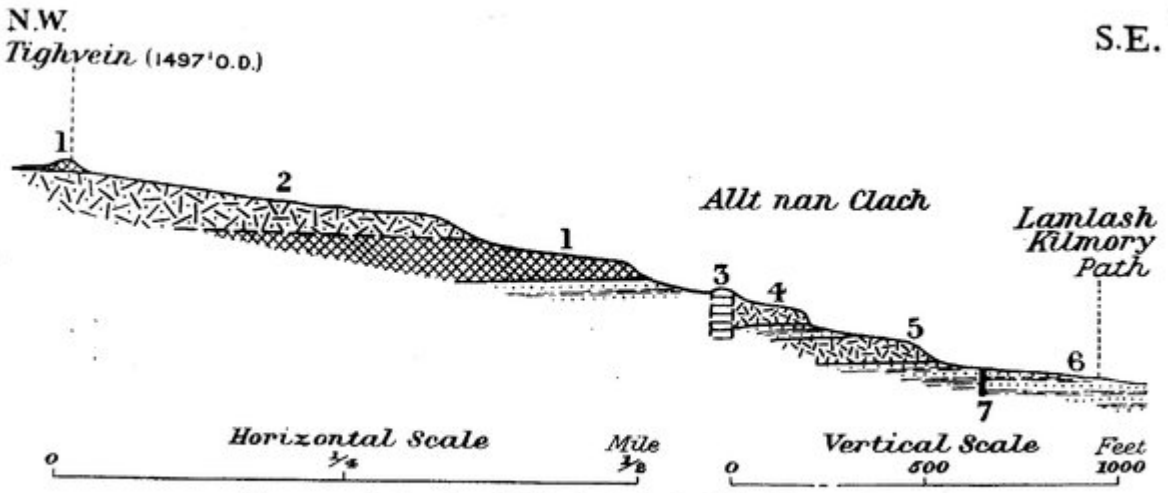


FIG. 17.—*Section from Tighvein to head of the Allt nan Clach.*

1. *Augite-diorite ; 2. Micro-granite ; 3. Pitchstone ; 4. Quartz-dolerite ; 5. Craignurite ; 6. Triassic sediments ; 7. Basaltic dyke.*

(Figure 17) Section from Tighvein to head of the Allt nan Clach. 1. Augite-diorite 2. Micro-granite 3. Pitchstone 4. Quartz-dolerite 5. Craignurite 6. Triassic sediments 7. Basaltic dyke.

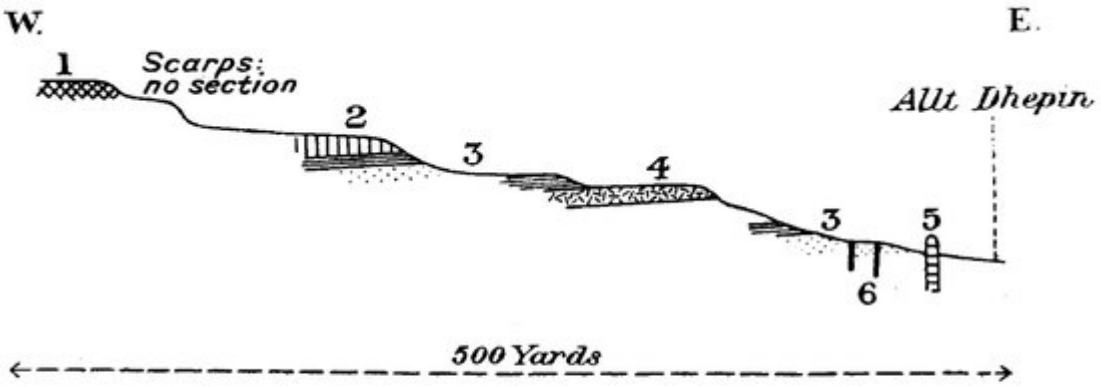


FIG. 18.—*Section in western headwater of the Allt Dhepin, one-third of a mile south of Urie Loch.*

1. *Augite-diorite ; 2. Craignurite-felsite sill ; 3. Red marls and sandstone ; 4. Quartz-dolerite sill ; 5. Quartz-porphyry dyke ; 6. Basaltic dykes. Vertical scale exaggerated.*

(Figure 18) Section in western headwater of the Allt Dhepin, one-third of a mile south of Urie Loch. 1. Augite-diorite 2. Craignurite-felsite sill 3. Red marls and sandstone 4. Quartz-dolerite sill 5. Quartz-porphyry dyke 6. Basaltic dykes. Vertical scale exaggerated.

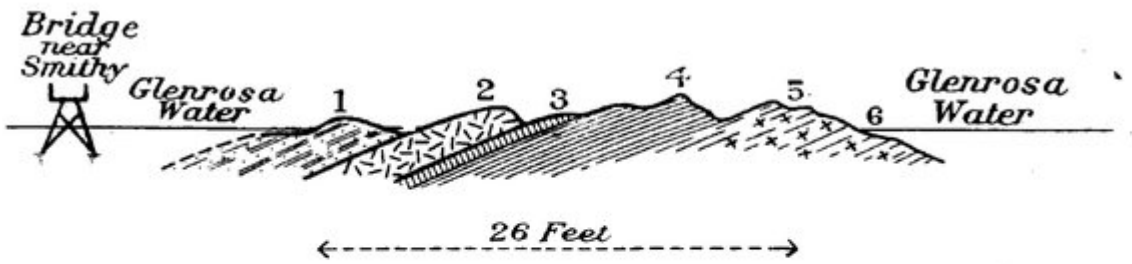


FIG. 19.—*Section across composite sill in the Glenrosa Water at bridge near Smithy, Brodick.*

1. *Fissile sandstone ; 2. Quartz-basalt ; 3. Dark top of felsite ; 4. Banded felsite ; 5. Xenolithic felsite ; 6. Base of sill, concealed.*

(Figure 19) Section across composite sill in the Glenrosa Water at bridge near Smithy, Brodick. 1. Fissile sandstone 2. Quartz-basalt 3. Dark top of felsite 4. Banded felsite 5. Xenolithic felsite 6. Base of sill, concealed.

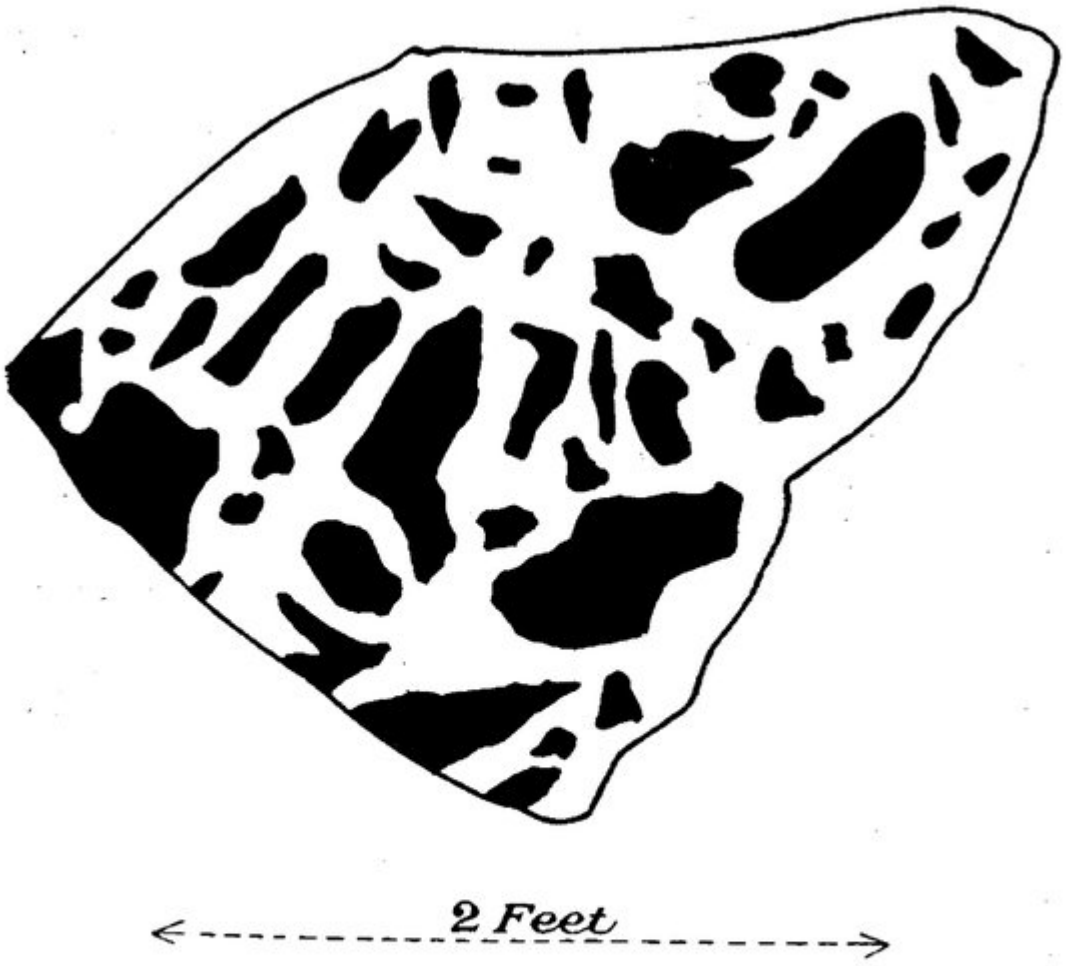


FIG. 20.—*Rock slab showing enclosure of basalt fragments (black) in a matrix of felsite (unshaded). Quarry near summit of Ross road, 3 miles west-south-west of Lamlash.*

(Figure 20) Rock slab showing enclosure of basalt fragments (black) in a matrix of felsite (unshaded). Quarry near summit of Ross road, 3 miles west-south-west of Lamlash.

TABLE II

	4	E	F	5	6	G	H
SiO_2	54·00	52·16	55·82	71·58	69·26	70·70	71·30
Al_2O_3 ..	13·09	11·95	11·47	12·20	11·60	11·78	11·24
Fe_2O_3 ..	3·53	4·86	3·68	1·51	1·31	1·32	1·80
FeO	8·45	9·92	7·66	1·77	2·57	3·45	2·84
MgO	3·49	3·77	4·08	·50	1·10	·53	·61
CaO	5·55	7·14	7·88	1·98	2·61	1·30	1·56
Na_2O ..	3·27	2·36	2·53	2·83	2·08	2·48	3·44
K_2O.. ..	1·80	1·74	2·00	3·86	3·88	4·71	4·66
$H_2O>105°$ ..	1·71	1·95	1·88	·76	1·67	1·14	1·04
$H_2O<105°$ ..	1·26	·56	·66	1·10	1·61	·50	·39
TiO_2	2·83	3·25	1·62	·44	·45	1·27	·58
P_2O_5	·31	·24	·23	·13	·10	·26	·22
MnO	·37	·18	·40	·31	·45	·07	·31
CO_2	·25	·18	·08	1·07	1·76	·51	—
S	—	·18	—	—	—	·08	—
FeS_2	·14	—	·09	nt. fd.	nt. fd.	—	nt. fd.
(Ni, Co)O ..	nt. fd.	—	·04	nt. fd.	nt. fd.	—	nt. fd.
BaO	·02	—	·03	nt. fd.	nt. fd.	—	·07
Li_2O	tr.	—	tr.	tr.	nt. fd.	—	? tr.
	100·07	100·44	100·18	100·04	100·45	100·10	100·06

(Table 2) [no title].

TABLE V

	9.	N.	10.	8.
SiO_2 ..	75·65	73.12	53·67	52·43
Al_2O_3 ..	11·89	12·44	15·47	13·50
Fe_2O_3 ..	1·19	2·09	3·24	4·93
FeO ..	1·02	1·65	7·25	7·00
MgO ..	·15	·14	4·90	4·61
CaO ..	·91	·88	8·28	8·25
Na_2O ..	3·44	3·90	2·77	3·27
K_2O ..	4·26	4·67	·80	1·08
$H_2O>105°$	·40	·24	·23	1·64
$H_2O<105°$	·41	·25	1·73	·28
TiO_2 ..	·28	·39	1·28	1·91
P_2O_5 ..	·16	·09	·21	·21
MnO ..	·26	·17	·31	·20
CO_2 ..	·09	·05	·04	·08
FeS_2 ..	nt. fd.	nt. fd.	nt. fd.	·44
(Ni,Co)O ..	·02	nt. fd.	·04	n. d.
BaO ..	·03	nt. fd.	·04	·06
Li_2O ..	nt. fd.	nt. fd.	nt. fd.	·00
Cr_2O_3 ..	—	—	—	·02
	100·16	100·08	100·26	99·91

(Table 5) [no title].