Chapter 11 The Cainozoic igneous rocks

Introduction and general summary

A rough measurement on the One-inch Geological Map of Arran shows that approximately 70 square miles, or a little less than half the area of the island, are occupied by igneous rocks of Cainozoic age. These rocks form a connected suite, the petrographical characters of which are similar to those of the Cainozoic suites of Skye, Mull, and Ardnamurchan. The age of the Arran rocks cannot be so definitely determined as in the latter cases, as there are no contemporary lava flows, and no Cainozoic sediments, in the island. The great majority of the igneous masses are of intrusive habit, and cut formations ranging from the Dalradian to the Triassic. The remainder are pyroclastic; and it is from the occurrence of Mesozoic fragments in the pyroclastic rocks of the Central Ring Complex that it becomes possible to fix the age of the Arran suite more definitely as post-Cretaceous (Chapter 10). On the other hand, the excavation of the present valleys, probably in Pliocene times, cutting across dyke-filled fissures which would inevitably have flooded the valleys with lava had they been in existence at the time, imposes an upper limit of age for the igneous activity.<ref>*See* J. W. Gregory, The Pre-Glacial Valleys of Arran and Snowdon, *Geol. Mag.*, vol.vii., 1920, pp. 148 *et seq.*</ref> When the time needed to strip off the great dome of metamorphic and sedimentary rocks which must have covered the northern granite boss, and to carve a plane of erosion which was subsequently uplifted in the Pliocene, is added, it becomes necessary to shift the date of the igneous episode back to at least the early middle part of the Cainozoic.

Owing to the intrusive habit of the rocks, and the lack of any contemporaneous stratigraphical datum planes, it is more difficult even than it has been found in Skye and Mull to establish the age-succession of the various igneous groups. But what evidence is available supports a succession which is broadly comparable to those established in the above-mentioned regions. During the short survey of the Cainozoic igneous rocks which was made in preparation for the present Memoir, it was not found possible to deal with them in the detailed manner necessary for the establishment of a complete succession. The succession given below is therefore simpler and more general than it can be in actual fact, and many questions as to the age-relations of certain rock groups have been left over pending more detailed work.

In Mull the Cainozoic succession opens with a regional outpouring of undersaturated 'plateau-basalts', which was followed by the more localized eruption of oversaturated 'central-basalts' from dome or shield volcanoes of Hawaiian and Icelandic type. The main igneous activity subsequent to these volcanic episodes was concerned with the intrusion of great basic plutonic masses, followed by more acid types, accompanied by associated minor intrusions. This succession is also well seen in Skye, but is complicated in Mull by the irregular superposition of two cycles of magmatic change and renewal.

In Arran there are no traces of plateau-basalts, or of central-basalt eruptions, unless certain large basalt, and basalt-tuff, masses, involved in the Central Ring Complex, represent lavas of these phases, which may have existed but have been totally destroyed by erosion, as the Rhaetic, Jurassic, and Cretaceous formations undoubtedly were. But there are numerous large sills of analciteolivine-dolerite, or crinanite, especially in the south-eastern quadrant, which almost certainly are the earliest Cainozoic igneous rocks of the island, and may possibly represent the underground manifestation of a plateau-basalt episode, the products of which have been removed by erosion, or have been faulted beneath the waters of the Firth of Clyde.

This phase of intrusion of undersaturated magma was followed by a great development of oversaturated magma, manifesting itself by the intrusion of plutonic masses in the central and northern parts of the island, and by the intrusion of numerous sills and dykes in the south. The magmatic succession in this phase was, as in all the other centres of Cainozoic igneous activity in the West of Scotland, from basic to acid. Gabbros and quartz-gabbros were injected into the central area, and quartz-dolerite sills of this episode make up many of the extremely numerous tabular igneous masses of the Glen Ashdale region. The development of the acid magma introduced an explosive phase, as in Mull and elsewhere, producing great masses of 'agglomerate' in the Central Ring Complex, and the varied phenomena of composite sills and hybrid mixtures which are so marked a feature of the southern half of Arran.

The third and final phase of igneous activity in Arran was the intrusion of numerous small acid dykes and sills, including the famous pitchstones, and the injection of a great congeries of basaltic dykes — the Arran Swarm — the main direction of which is N.N.W. to S.S.E. Dykes were no doubt intruded in connection with each of the main igneous episodes: some of them may even represent the vanished lavas of the Arran focus; but the evidence is conclusive that the majority of the Arran dykes were injected at a late stage in the igneous history of the island, and indeed appear to have been its final manifestation.

The crinanite sills

Under this heading will be described the four large sill-like intrusions, and their offshoots, of the Clauchland Hills, Monamore Glen, Kingscross, and Dippin, which occur in the south-eastern quadrant of Arran. No large crinanite intrusions occur in the central or northern parts of the island; nor do they appear in connection with the Central Ring Complex or the northern granite boss. The four above-mentioned masses apparently thin out in a westerly direction, and it is inferred that the focus or foci from which they were derived, must lie to the east under the waters of the Firth of Clyde. These rocks are entirely free from any connection with acid magma, and show none of the composite-sill or hybridism phenomena which characterize many of the presumably later basic intrusions.<ref>The statement made by the writer in 'The Classification and Age of the Analcite-bearing Igneous Rocks of Scotland' (*Geol. Mag.*, vol.lx., 1923, p. 257) to the effect that 'they [the crinanite sills] constitute, in various modifications, the basic members of the composite sills and hybrid rocks, the mélanges of basalt and felsite, dolerite and granophyre, gabbro and granite, which occur so abundantly in the south of Arran ' is now known to be incorrect.</ref> Furthermore they are freely cut by many of the other igneous rock types of Arran. Their petrographical characters are fully consonant with those of the early plateau-basalt lavas of other parts of the Western Isles. For these reasons it is thought that the crinanite sills represent the earliest set of the Cainozoic igneous rocks of Arran. It is possible that some of the larger crinanite dykes, as, for example, the 70-foot north-west dyke near the Free Church Manse at Kildonan, represent the feeders of the sills.

A. Field relations

1. The Clauchland Sill — This mass extends from the fourth milestone on the Brodick–Lamlash road westward to Dun Fionn and Clauchlands Point, a distance of 2½ miles. Its direction of extension is west to east as far as Dun Fionn, but at this point the outcrop makes a sharp turn to the south-east, and reaches the sea at Clauchlands Point. It is last seen in the Hamilton Rock just off Clauchlands Point. The average width of the outcrop is three-eighths of a mile, and its area is about one square mile. This igneous mass has the general form of a thick sill dipping at gentle angles to the S.S.E. or S.E. It has the peculiarity that, while its lower contact is mainly conformable to the New Red Sandstone strata into which the sill is intruded, its upper contact seems everywhere to be transgressive. The escarpment of the sill forms the steep northern face of the Clauchland Hills. Along this escarpment the sill rests quite conformably upon the New Red Sandstones, and only shows irregularities where it enters the sea. Here there is a steep contact with sediments which dip to the S.S.W. at angles of from 30° to 50°.

In places the lower contact is vertical or even overhangs, and the junction here is probably faulted. The shore-section near Clauchlands Point exhibits the entire thickness of the sill. For about a foot from the base it shows irregular banding of rocks of differing colours and textures, mostly fine grained or even basaltic, along with some coarser whitish veins. Above this the rock rapidly assumes a coarser texture; at 20 feet above the base it is already decidedly coarse; and towards the interior of the sill the rock occasionally becomes very coarse grained. Here also it carries pockets of pegmatite in which the lustrous black prisms of titanaugite may reach a length of 3 inches. Associated with these are thin veins and streaks of a whitish aplitic type very rich in zeolites (natrolite and analcite mainly), in which the felspars are highly zeolitized. The best place to see these phenomena is on the shore about 80 yards south of the wire fence at the lower contact. The upper edge of the sill passes under sediments which dip at 45° to the S.S.W., and the contact is complicated by the intrusion of a basalt dyke.

At its western end the Clauchland sill frays out into at least two separate intrusions consisting of fine-grained basaltic rocks, which are to be seen in and about the eastern headwater of the Lag a' Bheith (Birch Burn) on the west side of the Brodick–Lamlash road. Similar fine-grained dolerite is seen a few yards south of the fourth milestone, and in an old quarry a little south of the Standing Stones on the eastern side of the road.

From this point the southern boundary may be traced rather uncertainly eastward across the headwaters of the Blairmore Burn. In the eastern headwater of this burn a smooth slicken-sided scarp of fine-grained dolerite dipping 40° to the south, appears to plunge beneath the adjacent sandstones, and may here form a faulted junction. East of this burn there is a curious projection of sandstone into the heart of the igneous mass. The sandstone occurs in three or four well-marked scarps running approximately W.N.W. to E.S.E., and dipping about 5° to the S.S.W. These scarps are abruptly truncated by dolerite on both the eastern and western sides of the area. On the eastern side a good section is exposed in the burn running by Dunan Mew and Dunan Beag. This section, and adjacent scarps, show plunging contacts of the sill against the sandstones, and a small subsidiary sill is injected into the sandstones under Dunan Mòr.

In the next gully to the east, one-third of a mile north-west of Lochan Ime, there is exposed very coarse pegmatitic rock, and adjacent to it there is fine-grained dolerite with coarse white acid veins. These alternations of coarse-grained and fine-grained rocks are fairly numerous, and are interpreted as *interior contacts; i.e.* the sill is believed to be multiple, and to have been emplaced by a series of intrusive pulses in rapid succession.

In the stream which descends the dip slope west of Clauchlands Farm, a plunging contact between the sill and sandstone is fairly well exposed. From this point to the Dun Fionn path, and thence to the coast, the boundary is uncertain, and can only be approximately fixed.

Along the northern front of the sill the boundary is well marked by a regular escarpment which runs eastward from Dun Fionn for about a mile, but which is lost under peat near the Brodick–Lamlash road.

2. Monamore Glen — On the One-inch Geological Map of Arran (1910) this mass is represented as extending from Sguiler (1332 feet O.D.) in the south, across Monamore Glen, to Cnoc Dubh, and as occupying the whole of The Ross (989 feet O.D.) on the north side of Monamore Glen. From here the outcrop passes north over the Benlister Burn, and extends up to Cnoc Dubh (1003 feet O.D.). It is thus represented as having a north to south extension of 2 miles, and an average width of half a mile. But the upper part of Sguiler consists of quartz-dolerite, and Cnoc Dubh consists of a porphyritic dolerite related to the quartz-dolerite group; the nature of the rock constituting The Ross is doubtful. True crinanite is found only in the Monamore Burn, in one of its southern tributaries, and in the Benlister Burn. Although the area has not been worked over in detail, it appears probable that there are two or three separate masses of igneous rock included under the same colour on the map.

The best section is exposed in the bed of the Monamore Burn west of the Mill Dam, half a mile W.S.W. of Monamore Bridge. The crinanite is here a coarse massive rock with few and irregular divisional planes. Occasionally it shows an extremely coarse pegmatitic facies, and also a fine-grained facies. These occur in irregular patches and streaks which fade gradually into the normal coarse-grained rock. The lower contact is seen a quarter of a mile west of the Mill Dam, and shows the crinanite resting on a felsite-granophyre sill. In the tributary which enters the Mona-more Water a little to the west of this point the felsite sill is separated from the crinanite by a few feet of sandstone.

The upper contact is not well seen. The crinanite is last exposed in the Monamore Burn adjacent to the Mill Dam; and downstream of it, after a blank in the section, come hard-baked conglomerate and quartzite intersected by two basaltic dykes.

Two puzzling felsite exposures occur within the crinanite outcrop: a small one at the footbridge near the Mill Dam, and a larger one 80 yards to the west. This felsite appears to pass nearly horizontally beneath the crinanite, and may therefore be an inlier of the above-mentioned felsite sill at the lower contact. It may possibly be, however, a sill-like sheet injected at a higher horizon within the crinanite. The latter interpretation is favoured, as the crinanite mass appears to be too thick to have been cut through to its base (Fig 8).

The crinanite may also be seen in the tributary which enters the Monamore Burn from the south a little west of the Mill Dam. One-sixth of a mile from the confluence of the two streams the crinanite passes, with a sharp contact, under a sill of fine-grained xenolithic quartz-dolerite.

The crinanite is again exposed in the Benlister Burn, where it shows the same characteristics as in the Monamore section. At this place, however, it cuts transgressively across the edges of the sandstone strata, which dip mainly to the south-west.

As a whole the Monamore crinanite appears to form a sill dipping, as estimated from adjacent exposures of sandstone, about 20° to the south-east.

3. Kingscross — The Kingscross crinanite sill occupies the peninsula of Kingscross between Lamlash and Whiting Bay, and enters the sea at Kingscross Point. It continues into the southern part of Holy Island. From Kingscross Point it extends westward for a distance of one and three-quarter miles, and then frays out into two or more thin intrusions. It is well exposed on the southern shore of Holy Island, and at Kingscross Point. There is a roadside exposure near Kingscross Bridge on the main road between Lamlash and Whiting Bay, and there are several rocky scarps near Auchencairn to the west of the road. The average width of the intrusion is a quarter of a mile, and its area must be about half a square mile.

The lower contact of the Kingscross sill is well seen on the shore, a little south of the Stone Fort at Kingscross Point. The base is fine grained, but within 12 or 18 inches it passes up into a coarse-grained rock threaded with numerous acid veins up to 1½ inches thick. The reddish felspars in these veins have grown from the margins of fissures, and a median line of drusy cavities is often to be seen. The main body of the sill shows considerable variation in texture. In places pegmatitic phases appear in broad stratiform bands and also in irregular veins.

Around Kingscross Point and north of the Stone Fort, the sill plunges down, with a smooth glaciated upper surface dipping at 30° to the west, below sand and shingle. On the far (western) side of the little bay at this point, sandstone appears dipping west and underlying an outcrop of rock identical with that of Kingscross Point. Hence the sill appears to split into two branches, enclosing a sandstone intercalation (Figure 9).

On the shore a quarter of a mile south of the Stone Fort the sandstones beneath the Kingscross sill are intersected by one or two small irregular basaltic sills, which include numerous interleavings of sandstone. One of these sills carries little groups of porphyritic felspars, and occurs only a few feet below the base of the crinanite. At Kingscross Point the crinanite shows a most striking penetration and veining by a dense black basalt with small white porphyritic felspars, which appears to be the same rock, but of somewhat denser texture, as that of the small sill beneath. The black veins penetrate the whitish-weathering crinanite in more or less regularly parallel bands which range from the merest threads to layers over a foot in thickness. In places there are numerous anastomosing strings of basalt joining up the bands and forming an intricate network (Figure 10). The thicker bands and veins Show distinct chilling against the crinanite. The vein-rock and the underlying thin sills are found, on petrographical examination, to belong to the quartz-dolerite-craignurite group; and this occurrence therefore serves to demonstrate the age priority of the crinanite sills.

The section through the crinanite afforded by the Kingscross Burn is poor, and is much confused by basaltic dykes. The attitude of the sill to the strata is difficult to make out. The southern edge of the outcrop is certainly the lower contact, and the northern edge the upper contact; and this seems to indicate that the sill is dipping gently in a general northerly direction, opposed to the general dip of the New Red Sandstone strata, which is, however, very small. The sill consequently seems to be slightly transgressive.

4. Dippin — The widest spread of the Dippin sill is between the clachan of Dippin and Dippin Head, where the intrusion reaches sea-level. Here the width of the outcrop is about half a mile. From Dippin Head the rise due to the general south-south-east inclination of the mass, causes a narrow outcrop, less than one-eighth of a mile wide, to appear extending in a north-west direction on the east side of Cnoc na Comhairle, reaching a height of 800 feet, and then bending round into Glen Ashdale, where it comes to an abrupt end against the scarp of the Garbad quartz-dolerite. A rapidly-thinning tongue also extends south-west from Dippin Head, and disappears near Kildonan. The total length of the intrusion is therefore about 4 miles, and its outcrop covers about three-quarters of a square mile.

The most complete section occurs on the shore at Dippin Head. A fine range of cliffs runs down by Largybeg, reaching the shore about one-third of a mile north of Dippin Head, where the cliff is about 200 feet in height. The lower contact is exposed at this point. The sill rests on baked purplish shales which dip N.E. at 15°. Several north-west–south-east dykes cut the sill at this place. At the lower contact the sill consists of a fine-grained basaltic rock with sparse microphenocrysts of felspar and olivine. It passes rapidly up into the normal coarse-grained type, with the usual pegmatitic streaks and aplitic veins. As seen in the cliffs the sill has a rude columnar structure, and is divided by massive, widely-spaced, vertical joints. Its upper contact is not seen; but it must run approximately along the main road from Dippin to Kildonan Post Office.

Good sections of the northerly part of the outcrop can be seen in the Allt Crompucaidh near Largymore; in the eastern headwater of a small tributary of Glen Ashdale a quarter of a mile east of Torr na Baoileig; and in the burn immediately west of Torr na Baoileig. At these places the sill rests on shales, marls, and sandstones belonging to the upper division of the New Red Sandstone.

B. Petrography

The greater part of the four large sills described above consists of a coarse, analcite-olivine-dolerite, corresponding to the type named *crinanite* by Sir J. S. Flett.<ref>The Geology of Knapdale, Jura, and North Kintyre, (Explanation of Sheet 28), *Mem. Geol. Surv*., 1911, pp. 116–118.</ref> Considerable masses, however, are richer in analcite and poorer in olivine, than the normal type, and pass over, therefore, to rocks which are better described as *teschenite.*<ref>*G. W. Tyrrell, The Classification and Age of the Analcite-bearing Igneous Rocks of Scotland, Geol. Mag.,* vol. lx., 1923, p. 252.</ref> Further variations are to be found in pegmatitic and aplitic veins, the latter being much richer in analcite and other zeolites than the enclosing rock, whilst the pegmatites differ mainly in their extremely coarse grain. The main type is represented in the Survey collection by specimens from Dippin (S6361) [NS 045 218], (S6884) [NS 047 225], and from the Clauchland Hills (S24356) [NS 056 331], (S24456) [NS 055 331]. The teschenitic type is represented by one comparatively fresh rock (S6883) [NS 017 212] and by two considerably altered rocks (S6881) [NS 050 227], (S6882) [NS 050 227] from Dippin. A gabbroid type poor in analcite is represented by a specimen from the Mona-more Burn (S25053) [NS 00 29]. No. (S24356) [NS 056 331] shows the mode of occurrence of pockets of pegmatite in the rock, and 25069 represents the aplitic veins intersecting the Clauchland sill.

Dr. A. Harker's description of the Dippin rocks (*infra*) gives an excellent idea of the chief microscopical features of the crinanitic and teschenitic types. G.W.T.

The rocks of the Dippin sill have been described (under the name olivine-bearing analcime-diabase) by Corstorphine.<ref>*Tscherm. Min. Petr. Mitth.*, vol. xiv., 1895, pp. 463–465.</ref> They are represented in our collection by five specimens from Dippin and Kildonan.

In hand-specimens the rocks appear as ordinary coarse-textured diabases, dark in colour, but with some variation in the relative proportion of black augite and white felspar, etc. A specimen (S6361) [NS 045 218] gave the specific gravity 2.89. Thin slices show a typical ophitic structure. Olivine is abundant in irregular crystal-grains, sometimes fresh (S6361) [NS 045 218], but usually replaced by green or yellow-brown serpentine. Apatite is always abundant in little prisms about one-inch long, or varying from 0.005 to 0.02 inch. Black iron-ore is also rather plentiful in grains and imperfect or skeletal crystal shapes; probably magnetite for the most part, but in some cases with outlines suggestive of ilmenite. The felspar is in crystals which give elongated rectangular sections, with Carlsbad and albite twinning. It is labradorite, but not usually of a very basic variety. The ophitic plates of augite show in thin slices the light purple colour and decided pleochroism often seen in the augite of nepheline-dolerites and other rocks rich in alkali, and probably indicating a certain content of soda and titanic acid in the mineral. Rotating over a Nicol's prism, the colour is often seen to change from a purplish or pale claret tint to pale apple-green or pale brownish-yellow. In natural light the ruddy colour is sometimes seen to pass gradually in one crystal into a pale apple-green, which is also pleochroic. Most of the crystals show, though imperfectly, the hour-glass structure which is so generally associated with augite of this kind. Small flakes of brown mica occur rather rarely in the rock.

In addition to the foregoing minerals there are abundant wedgelike and irregularly-shaped spaces occupying the interstices between the felspar and other crystals, and often enclosing numerous needles of apatite. These spaces consist in general of analcite, clear, colourless, feebly refringent, and isotropic, rarely with obscure traces of cleavage. In other cases we find patches of zeolites partly or wholly taking the place of the analcite, forming a yellowish aggregate<ref>Zirkel seems to have observed, but not identified, this aggregate. He also notes quartz-grains (presumably of foreign origin) in a rock from Dippin Head. *Zeits. deuts. geol. Ges.*, vol. xxiii., 1871, p. 36.</ref> with more or less pronounced radiate-fibrous structure ((S6361) [NS 045 218], etc.) and, if not too fine, showing brilliant interference-colours. Corstorphine identifies natrolite and scolecite: the former might be derived from the analcite, but the latter would have to come from the felspar. In our slices the fibrous zeolites seem clearly to be formed at the expense of the analcite, and are found only in association with other secondary changes in the rock. The analcite itself has all the appearance of an original constituent of the rock. It is most abundant in the freshest specimens, and is there perfectly pellucid and unchanged; in other specimens it is seen in process of conversion to what is probably natrolite. Corstorphine recognizes that the analcite cannot be derived from the felspar, which is often quite fresh, but he supposes it to represent vanished nepheline. While this is possible, there is nothing whatever to indicate the former presence of nepheline, and the supposition seems to be based merely upon reluctance to admit analcite to the rank of an original product from a rock-magma. Various researches on the monchiquites and allied rocks during late years render it difficult to maintain this attitude, and the balance of probability in the case of our rock is decidedly in favour of the view that the analcite is merely the latest product of consolidation of the magma. A.H.

In the analysed rock (S24456) [NS 055 331] the olivine has gone over to serpentine, and the felspars are somewhat zeolitized. It is to be noted that the majority of the rocks are distinctly richer in fresh olivine and poorer in analcite than the typical teschenites of Moravia and the Midland Valley of Scotland. Another mineralogical feature which serves to distinguish the Cainozoic analcite-bearing rocks from both the teschenites and crinanites of Late Palaeozoic age on the adjacent mainland, is the almost complete absence of alkali-felspars, and especially of potassic felspars (*see* p. 122).

A good example of a type extremely rich in olivine and approximating to the rock known as *kylite,*<ref>G. W. Tyrrell, The Late Palaeozoic Alkaline Igneous Rocks of the West of Scotland, *Geol. Mag.,* 1912, pp. 69–80; 120–131.</ref> is found in a specimen from the shore, a quarter of a mile north-north-west of Clauchlands Point (S24356) [NS 056 331]. The augite in this rock is of a stronger purple tint than usual, and has diminished in amount reciprocally with the increase in olivine. The slice is traversed by a thin vein, 2 mm. in width, consisting of analcite and other zeolites (natrolite, scolecite), along with zeolitized felspars, and some red-brown soda-hornblende.

A thicker aplitic vein is represented by a specimen from the shore near Clauchlands Point (S25069) [NS 056 331]. Under the microscope this rock shows numerous diversely-arranged labradorite laths, many of which are ophitically enclosed in large plates of pale purplish augite, and the remainder within an abundant groundmass of fresh analcite, There is also some skeletal ilmenite, with which are associated a few scraps of red-brown hornblende, especially where the ore abuts against a crystal of augite. A single crystal of serpentinized olivine is seen enclosed within a plate of augite. The felspars are much corroded by the analcite about their margins and along the cleavage cracks. There are one or two areas of a birefringent zeolite, which is identified as thomsonite, and behaves to the felspars in exactly the same way as the analcite. An analysis of an aplitic vein of this character will be found in (Table 1).

C. Chemical composition

The chemical analysis of an average sample of the Clauchland analcite-olivine-dolerite or crinanite, by Mr. E. G. Radley, is given in (Table 1)., col. 1. The analysis is comparable in general to that of a slightly undersaturated alkaline basalt. The presence of analcite is indicated by the comparatively high values of Na_2O and water. The calculation of the norm shows that about 10 per cent. of olivine, 15 per cent. of pyroxene, and 11 per cent. of iron-ores must be present in this rock; of the remaining 64 per cent., analcite and other zeolites may be estimated at ro per cent., leaving acid labradorite (Ab_1An_1) to the amount of 54 per cent.

TABLE

	1[1]	2	3	A	B	C	D

SiO_2	44.68	46.50	43.95	43.94	44.69	45.57	45.8
$A1_2O_3$	16.37	22.86	17.60	14.03	14.17	14.95	15.0
Fe_2O_3	4.31	3.30	1.43	1.95	3.35	2.82	3.8
FeO	8.11	4.63	11.89	11.65	10.86	7.35	9.5
MgO	6.59	2.52	6.95	10.46	6.41	6.19	8.2
CaO	8.70	9.50	8.54	8.99	10.28	8.27	9.4
Na_2	3.28	4.53	3.66	2.68	3.64	4.33	2.5
K_2	0.21	0.39	0.35	0.33	2.01	2.16	0.5
$H_2O>105°$	1.69	3.25	0.82	2.31	2.53	3.93	1.8
$H_2O<105°$	2.99	0.80	0.94	0.85	1.05	0.97	0.9
TiO_2	2.51	1.30	3.42	2.45	0.46	2.41	2.4
P_2O_5	0.15	0.26	0.11	0.20	0.45	0.67	0.2
MnO	0.32	tr.	0.10	0.32	0.31	0.31	0.3
CO_2	0.06	nt. fd.	nt. fd.	0.16	nt. fd.	0.18	—
S	—	nt. fd.	tr.	—	—	—	—
FeS_2	nt. fd.	—	—	0.04	—	—	—
Fe., S	—	—	—	0.06	—	—	—
(Ni, Co)O	—	—	nt. fd.	—	—	—	—
BaO	0.02	—	—	nt. fd.	tr.	0.07	—
Li_2O	nt. fd.	—	—	—	—	—	—
Cr_2O_3	—	—	—	tr.	—	—	—
	100.04	99.84	99.76	100.42	100.21	100.18	100.3

1 The Arran analyses are indicated by consecutive numerals. Other analyses tabulated for comparison are indicated by capital letters.

(S24456) [NS 055 331], Lab. No. 830)). Analcite-olivine-dolerite (crinanite), sill, shore 340 yards N. 9° W. of Clauchlands Point, Arran. *Anal.* E. G. Radley.

White aplitic vein in analcite-olivine-dolerite (crinanite), shore, three-sixteenths of a mile N. 9° W. of Clauchlands Point, Arran. *Anal.* W. H. Herdsman.

(S26383) [NS 047 267]. Crinanite, dyke on shore near Schoolhouse, Whiting Bay, Arran. *Anal. W.* H. Herdsman.

(S14174) [NR 440 731]. Crinanite or analcite-dolerite, Cainozoic dyke, Slac nan Sgarbh, one mile north of Inver Cottage, Jura. *Anal.* E. G. Radley. Quoted from The Geology of Knapdale, Jura, and North Kintyre,' *Mem. Geol. Surv.*, 1911, p. 118.

Crinanite, sill cutting 'Permian' lavas, Howford Bridge, Mauchline, Ayrshire. *Anal.* A. Scott. Quoted from G. W. Tyrrell, Classification and Age of the Analcite-bearing Igneous Rocks of Scotland,' *Geol. Mag.*, vol. lx., 1923, p. 254.

Teschenite. Average of five analyses of the Late Palaeozoic teschenites of the Midland Valley of Scotland. Quoted from G. W. Tyrrell, *op. cit. supra.*

Average plateau-basalt type of the Cainozoic igneous suite in the West of Scotland. Computed from the analyses given in The Tertiary and Post-Tertiary Geology of Mull, etc., *Mem. Geol. Surv.,* 1924, Table II., p. 15.

Along with the typical crinanite (col. 1), analyses of a white aplitic vein in the Clauchland sill (2), and of a later crinanite dyke from Whiting Bay (3), are given. The chemical composition of the aplitic vein is consonant with its augmentation of analcite and other zeolites, and the dwindling of olivine and pyroxene, as compared with the normal rock. Magnesia and ferrous iron-oxide are considerably lower, whilst alkalies and alumina are higher than in the normal rock. The Whiting Bay dyke is clearly a slightly more basic rock than that of Clauchland, as shown by its lower silica, and higher ferrous iron-oxide and magnesia. This rock is dealt with in more detail on another page (p. 255).

For comparison with the Arran crinanites four analyses, namely, the first-described crinanite of Jura (A); the crinanite sill of Howford Bridge, Mauchline (B); the mean of five analyses of Late Paleozoic teschenites of the Midland Valley of Scotland (C); and the mean of the eight analyses representing the Cainozoic plateau-basalt magma type given in the *Mull Memoir* (D), are tabulated. The type crinanite of Jura is clearly a more mafic rock than that of the Clauchland sill, as is shown by its higher ferrous iron-oxide and magnesia, and its lower alkalies; but in their main features the two analyses are closely comparable. The same remark applies to the analysis of the average plateau-basalt; and it is a justifiable inference that the crinanites represent a hypabyssal facies of the plateau-basalt types of the Western Isles.

A chemical feature common to all the Cainozoic crinanites and related rocks is their relative poverty in potash, which, of course, follows from their lack of potassium-rich minerals. This character, however, serves to distinguish them from the otherwise closely similar crinanites and teschenites of the Late Palaeozoic in the Midland Valley of Scotland, as can be seen by comparing the analyses of the Howford Bridge crinanite (B) and the average teschenite (C) with the analyses of the Cainozoic rocks (1, 2, 3, A). G.W.T.

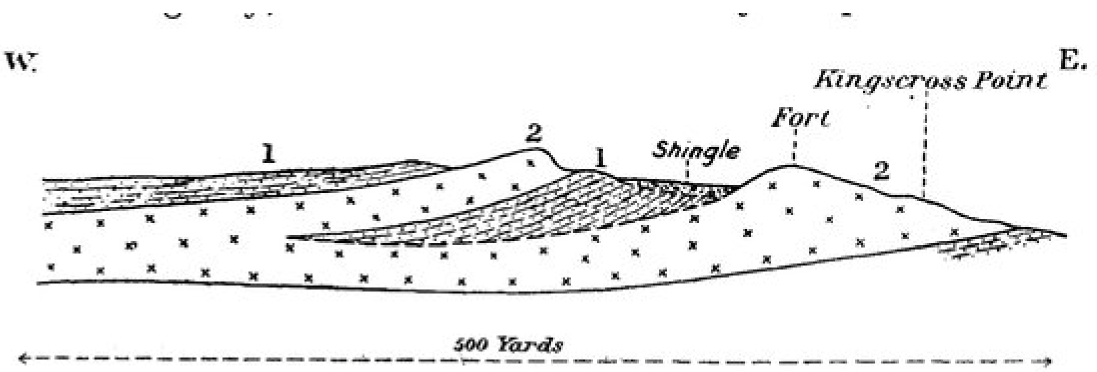

FIG. 9.—*Section across Kingscross Point, showing intercalation of sandstone* (1) *within the Kingscross crinanite sill* (2).

(Figure 9) Section across Kingscross Point showing intercalations of sandstone (1) within the Kingscross crinanite sill (2).

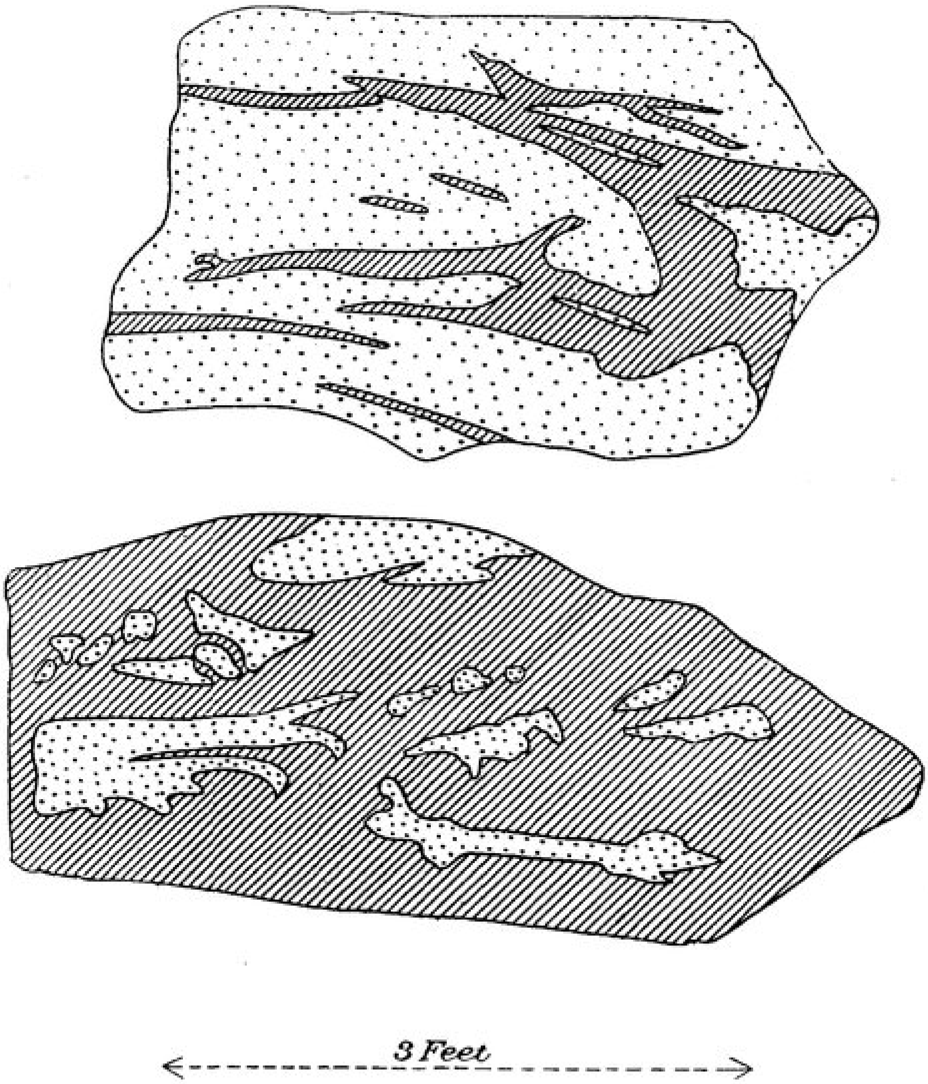

FIG. 10.—*Wave-washed surfaces of the Kingscross crinanite (dotted), showing its interpenetration by tachylytic basalt (line-shaded).*

(Figure 10) Wave-washed surfaces of the Kingscross crinanite sill (dotted), showing its interpenetration by tachylytic basalt (line-shaded).

TABLE I

	1[1]	2	3	A	B	C	D
SiO_2	44·68	46·50	43·95	43·94	44·69	45·57	45·8
Al_2O_3 ..	16·37	22·86	17·60	14·03	14·17	14·95	15·0
Fe_2O_3 ..	4·31	3·30	1·43	1·95	3·35	2·82	3·8
FeO	8·11	4·63	11·89	11·65	10·86	7·35	9·5
MgO	6·59	2·52	6·95	10·46	6·41	6·19	8·2
CaO	8·70	9·50	8·54	8·99	10·28	8·27	9·4
Na_2O ..	3·28	4·53	3·66	2·68	3·64	4·33	2·5
K_2O	·21	·39	·35	·33	2·01	2·16	·5
$H_2O>105°$ ..	1·69	3·25	·82	2·31	2·53	3·93	1·8
$H_2O<105°$ ..	2·99	·80	·94	·85	1·05	·97	·9
TiO_2	2·51	1·30	3·42	2·45	·46	2·41	2·4
P_2O_5	·15	·26	·11	·20	·45	·67	·2
MnO	·32	tr.	·10	·32	·31	·31	·3
CO_2	·06	nt. fd.	nt. fd.	·16	nt. fd.	·18	—
S	—	nt. fd.	tr.	—	—	—	—
FeS_2	nt. fd.	—	—	·04	—	—	—
Fe_7S_8 ..	—	—	—	·06	—	—	—
(Ni, Co)O ..	·05	nt. fd.	nt. fd.	—	—	—	—
BaO	·02	—	—	nt. fd.	tr.	·07	—
Li_2O	nt. fd.	—	—	—	—	—	—
Cr_2O_3 ..	—	—	—	tr.	—	—	—
	100·04	99·84	99·76	100·42	100·21	100·18	100·3

[1] The Arran analyses are indicated by consecutive numerals. Other analyses tabulated for comparison are indicated by capital letters.

(Table 1) [no title].