Chapter 14 The Cainozoic igneous rocks (continued)

The Central Ring Complex

Introduction

The great discovery by W. Gunn in 1900<ref>Summary of Progress for 1899, *Mem. Geol. Surv.,* 1900, p. 133. Fuller descriptions are to be found in Summary of Progress for 1900, *Mem. Geol. Surv.,* 1901, pp. 123–126; *Quart. Joun. Geol. Soc.*, vol. lvii., 1901, pp. 226–243; and Geology of North Arran, South Bute, and the Cumbraes, (Explanation of Sheet 21), *Mem. Geol.* Surv., 1903, p. 79.</ref> of a large and complicated oval area consisting of fragmental rocks with numerous igneous masses, in the central part of the island, caused a notable advance in the interpretation of Arran geology. The included masses of Liassic, and Cretaceous strata within this area (Chapter 10), provided confirmation of the Triassic age of some of the associated rocks in the southern half of the island, and demonstrated for the first time the Cainozoic age of the large granite masses of Arran. Gunn's description of this area as a volcanic vent ' is undoubtedly too simple to explain all the facts; but unquestionably a volcanic pile rose over part of the area, and tremendous explosive activity accompanied the intrusion of the acid rocks. Following upon the demonstration of ring complexes in Mul1,<ref>*Mull Memoir,* 1924, Chapters XV., XVI.</ref> Ardnamurchan, and Skye, as characteristic features of igneous episodes of the same age as that of Arran, there appears to be no doubt that, in this 'volcanic vent,' we really have to deal with a ring complex which, while less perfectly preserved than those of the above-mentioned centres, had as long and as complicated a history.

Prof. J. W. Gregory has recently advanced in brief outline a new theory of the origin of the central complex.<ref>*Proc. Geol. Assoc.*, vol.xxxv., part iv., 1924, p. 410.</ref> He regards the 'agglomerate' as consisting of (1) sedimentary conglomerates and breccias containing igneous fragments, some of which have been derived from Palaeozoic lavas; (2) intrusive breccia, due sometimes to flow-brecciation, but usually to the intrusive rock having enclosed quartz and fragments of sedimentary and igneous rocks, these breccias resembling those of the Loch BA. region of Mull; and (3) normal tuffs and agglomerates. His reading of the history of the central complex is as follows: the granite forming the base of the Ard Bheinn group was intruded into the Old Red Sandstone, upon which rested some Mesozoic strata. All these beds were upheaved into a dome, which was then eroded so deeply that the granite was ultimately exposed. The sedimentary breccias and conglomerates formed by the denudation of the dome had the characters of talus, and were composed of irregular alternations of sandstone and boulder beds. A complicated series of minor intrusions, mostly acid, were at the same time injected into the granite, and fragments of all these rocks were carried into some of the later conglomerates. The granite had been preceded by gabbro on the eastern margin, and was invaded by a horseshoe belt of basic dykes around the western part. These dykes, which were accompanied by volcanic eruption on the western side of the area, caught up quartz-pebbles from the Old Red Sandstone, and fragments of the earlier acid intrusions.

This reading, while requiring correction in some of the details, has been of great service in leading up to what is believed to be the true interpretation of the complex. The chief features which led the writer to believe that in the 'central volcanic vent' of Arran, we are dealing with a ring complex of the Mull type, are:

(1) The arcuate and annular shapes of many of the outcrops.

(2) The recognition of the fact that many of the supposed intrusive masses, especially on the western side of Ard Bheinn, are really pre-breccia in age, and are remanié masses which contribute fragments to the breccia in increasing proportion as their margins are approached.<ref>This line of attack on the problem was first suggested by Mr. E. B. Bailey who, after traversing the area in company with me, entirely concurred in the ring-complex interpretation.</ref>

(3) The induration and epidotization of the breccia, a phenomenon absent from the later granite, but present in the earlier gabbro intrusions and remanié masses. This feature is entirely similar to the 'pneumatolysis' (better termed propylitization) effects around the ring complex of south-eastern Mull, and to the effects already noted around the northern granite (p. 33).

So far, detailed mapping in the light of the ring-complex theory has only been carried out over the eastern part of the area, although many traverses have been made over the whole region. The continuation of the mapping will doubtless afford many new corroborative facts.

A tentative history of events in the central region may now be outlined (Plate 4). Igneous activity is believed to have begun beneath a cover consisting of Old Red Sandstone and Mesozoic rocks, with a magma of basic character giving rise to lava-flows. Remnants of these lavas are preserved in the screen of basaltic rocks entirely similar to the plateau basalts of Skye and. Mull, which forms the elongated, narrow, arcuate outcrop on the western side of Ard Bheinn. These flows proceeded from an undersaturated magma, whose hypabyssal representatives are the crinanite sills of south-eastern Arran. The sedimentary cover was probably uplifted into a dome-shaped form, and its shattering was initiated at this stage of activity.

An over-saturated magma now appears to have been generated, a basic phase of which was intruded as the incomplete rings of gabbro on the eastern margin of the complex. These rings were originally more extensive than they are at present, as is shown by remnants on the northern edge of the complex, and by the presence of dioritic mixture-rocks at various places on the east and north. A long series of acid intrusions was then injected, some of granite, *e.g.* the broad outcrop which forms an almost complete ring around the area, and the central plug (Glen Craigag). Other facies were felsitic in character. The interaction of the granite with the eastern gabbro produced an interesting series of dioritic mixture-rocks (p. 175). Great explosive action accompanied some of the acid intrusions, shattering the cover into large and small fragments, and thus giving rise to the breccia which now occupies a large part of the area. The explosive action was, no doubt, variable in its intensity in different places; large fragments of the cover escaped complete brecciation, and, although fissured and upturned, nevertheless preserved something of their original characters and attitude. Some of the acid magma may have reached the surface, and formed the small rhyolite masses which are found on Ard Bheinn.

The intrusive and explosive actions were concomitant, and both took place along arcuate fissures, which may or may not have been connected with caldera formation at the surface. One well-marked arcuate line of faulting and brecciation traverses the Glen Dubh gabbro, and a multiple dyke of felsite and basalt has risen along the line of weakness, the felsite being accompanied by further explosive action. The continuation of this feature to the north traverses the eastern margin of the granite, and has produced some shattering and mylonization in that rock. The arcuate nature of the faulting is also shown by the occurrence of curved screens of the country-rock, separating adjacent intrusions, as in the Glen Dubh area; or separating agglomerate and felsite, as on the western side of Ard Bheinn (Plate 4).

The sequence of events was completed by the injection of a final series of acid intrusions, definitely later than the breccia. This series includes the north-eastern felsites, the granophyres to the south and south-east of Tarrnacraig, and the felsite and granophyre near Derenenach.

This interpretation differs from Prof. Gregory's in recognizing the priority of basic extrusions and intrusions; in regarding the fragmental materials as due entirely to volcanic explosion; and in the fuller recognition of Cainozoic pre-breccia igneous masses which have contributed material to the breccia.

The writer agrees with Prof. Gregory in deprecating the extended use of the term 'agglomerate' for the fragmental material. If the term 'agglomerate ' means coarse, fragmental material, consisting largely of lavas, formed in and near a volcanic vent, then the fragmental rocks of the central complex are not agglomerates in this sense. The term *explosion-breccia,* indicating the material formed by the shattering of a sedimentary cover (in this case), and by the auto-brecciation of the invading igneous rock that caused the explosive, action, appears best to describe the nature and origin of the material.

The date of the Central Ring Complex seems to be definitely later than the northern granite; for the north-eastern margin of the outer granite ring clearly truncates the strata of the Old Red Sandstone, the Carboniferous, and the New Red Sandstone, which were uptilted by the intrusion of the northern boss.

Field-relations and petrography

The Central Ring Complex occupies an oval area almost exactly in the centre of the island, its northern boundary just touching the String Road which connects Brodick and Machrie Bay (Plate 4). Its greatest extension is about 4 miles in a west-south-west direction from Windmill Hill to Ballymichael Glen; and its greatest width in a north-north-west to south-south-east direction from Glenloig to Beinn Bhreac is about miles. Its area is estimated at 7 square miles; and it embraces the high plateau ground which culminates in Ard Bheinn (1676 feet), Beinn Bhreac (1649 feet),

A' Chruach (1679 feet), and Cnoc Dubh (1341 feet). The Central Ring Complex is geologically very complicated, and forms very rough, craggy ground especially near its margins. The central part contains large areas of peat which unfortunately conceals the relations of the rocks at some critical points. The principal features will be dealt with in the following order, and the petrographical descriptions will be appended for convenience to the sections treating the different rock groups:-

1. Glen Dubh gabbro, and associated rocks
2. Basic remanié masses included within the explosion-breccia, or enveloped in granite
3. The explosion-breccia ('agglomerate'), with the associated felsites and rhyolites
4. The main granite and granophyre, and the associated quartz-diorite and diorite
5. The late acid intrusions

1. The Glen Dubh Gabbro and associated rocks

A. Field-relations

The rocks included within the boundaries of this mass are Lower Old Red Sandstone, gabbro, granite, dioritic mixture-rocks and hybrid rocks, granophyre, and felsite veins (map, (Figure 22), and section, (Figure 23)). Of these, the granite occurs on the western margin of the mass. It is believed to have been injected into incomplete ring intrusions of coarse gabbro, with the formation of dioritic mixture-rocks and hybrid rocks, which now occupy the major part of the area, the gabbro forming large enclosed remnants. Originally the gabbro seems to have been intruded as two large ring dykes (Figure 23), separated by a narrow screen of Lower Old Red Sandstone. Later pulses of acid intrusion have sent veins of granophyre and felsite far and wide through all the rocks of the complex. Accompanying the later granitic intrusions were arcuate faults, one of which occurs between 'Gabbro Knoll' (Figure 22) ring dyke and the adjacent screen of Lower Old Red Sandstone. The fault-plane has been occupied by a multiple dyke of felsite and basalt. Another fault-plane probably accompanies the felsite intrusion on the western side of 'Gabbro Knoll' (Figure 23).

The map, (Figure 22), and the section, (Figure 23), summarize the details of the field-relations of the various rock components of the mass. The best-exposed portion of the complex occupies the corrie at the head of Glen Dubh, and splendid sections are afforded by the Glen Dubh Water and its northern tributaries. The contact of the intrusion with the baked Old Red Sandstone can be but roughly located in the Glen Dubh Water at the foot of the corrie. The contact is intricate, and there is much veining and interpenetration of the sediments by the igneous rock. The weathering of the two kinds of rock is so closely similar that it is a very laborious task to discriminate the junctions. Much of the Glen Dubh section up to near the 873 feet O.D. is in a dark, fine-grained, dioritic rock, which is profusely veined with aplite and granophyre. Irregular remnants of the Old Red Sandstone country-rocks are also to be found. Under the cliff of Creag na h-Iolaire the igneous rock is mainly of an acidic type. On the south side of the gorge, near the right-angle bend in the burn, a coarse olivine-gabbro is found, and a small fault parallel to the larger arcuate faults to the west can be traced. This mass of gabbro can be followed to the north across the northern tributaries of Glen Dubh. It is especially prominent in a steep scarp between burns A and B (Figure 22), whence the analysed rock was taken (p. 174). The intrusion passes under baked Old Red Sandstone in the prominent unnamed hill immediately north of Burn A, and, just as on the eastern side of Glen Dubh, the contact rock is of a distinctly acid facies.

At the right-angle bend in the burn opposite 'Gabbro Knoll' a broad screen of Lower Old Red Sandstone occurs. On its western edge there is a constant horizon of green quartzitic breccia, which can be traced northward across the northern tributaries. Next to it there is a greenish, silty, quartzitic rock which is so fine grained as to exhibit cleavage like a slate. This sedimentary screen can be traced north across Burn B (Figure 22), but fades out to the north of the burn.

The junction between this screen and the gabbro of 'Gabbro Knoll' is a faulted one. Both gabbro crush-rock and Old Red Sandstone crush-rock can be found along it, and both are highly epidotized, as are also both the adjacent solid rocks. The zone of weakness is occupied by a multiple dyke of felsite and basalt. A good section of the fault-zone, and of the multiple dyke, is afforded by a branch of Burn C, immediately north of the right-angle bend in the Glen Dubh Water. Here the felsite, which carries visible quartz, is 14 feet thick, and the spheroidally-weathering basalt is 8 feet thick. There is some appearance of brecciation within the felsite itself, and this may be due to explosive action attending its intrusion.

Immediately west of the sedimentary screen there comes the prominent scarp of 'Gabbro Knoll', consisting of coarse quartzgabbro. Traced to the north this mass fades out just before Burn B is reached. To the south it passes gradually into the dark, fine-grained, dioritic facies. On the western side of 'Gabbro Knoll' a sharp vertical intrusive junction of felsite against gabbro is seen. The felsite intrusion occupies the valley between 'Gabbro Knoll' and the next scarp to the west. It can be traced northward across the tributaries, and appears ultimately to join up with the fine-grained margin of the main mass of granite (Figure 22). It appears to have been injected along the line of the arcuate fractures, and in Burn A can be seen intruded against the shattered western edge of the gabbro. To the south the outcrop diminishes in width and finally disappears.

To the west of the felsite there is a broad, heterogeneous mass consisting of coarse gabbro, and the fine-grained dioritic facies, intermingled with, and interpenetrated by, large and small masses of granite and granophyre. This zone is well exposed in the headwaters of the Burns A, B, and C (Figure 22). To the south the zone passes gradually into the large area of dioritic rocks which occupies the southern half of the Glen Dubh mass. In the district known as Tir Dubh, the massive rock of the knolls is pierced by many little acid strings and granite veins.<ref>Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv.*, 1903, p. 96.</ref> At the head of Burn C, there are fine exposures of xenolithic and hybrid rocks, showing gabbro and diorite fragments enclosed and partially dissolved in granophyre.

Intervening between the last-mentioned gabbro and diorite zone and the main granite ring, and also occupying the southern half of the basic mass, there is a very heterogeneous region of gabbrogranite mixture-rocks, xenolithic and hybrid types, and also of quartz-diorite and diorite in which no traces of mixture or hybridism can be detected. The finest exposures of xenolithic and hybrid rocks are to be seen on a hill about a quarter of a mile due west of 'Gabbro Knoll', which has been named 'Hybrid Hill' (*see* (Figure 22)). The petrographic evidence renders it probable that the pure, homogeneous diorite and quartz-diorite are the final results of the complete solution of the gabbroidal rocks within the granite magma. All stages in the process can be studied in the field and under the microscope.

Resuming the section in the Glen Dubh Water at the summit of the corrie, we find the junction between the gabbro and the sedimentary screen runs along the stream for some distance. South of the right-angle turn near 'Gabbro Knoll', an intrusive mass of felsite is seen on the eastern side. The composite dyke can be again followed for some distance along the main western headwater of the burn. On the south-east side of this stream, west of 1233 feet O.D., there is a patch of quartz-conglomerate and white sandstone, with some cherty greywacke, entirely surrounded by gabbro. Above this point the gabbro seen in the stream is fine grained with a granulose texture, and has a nearly horizontal sheeted structure which gives it a bedded aspect, and causes a small waterfall. G.W.T.

The alteration effected by these igneous masses on the adjoining sedimentary strata is very great. Along the north side of the oval the actual junction of the igneous rocks with the Old Red Sandstone is not visible, and there is no opportunity of studying the altered rocks, but on the south and east sides the effects are marked. The red sandstones and conglomerates of the Trias and Upper Old Red Sandstone have their colour changed to white and the rocks are converted into quartzites, while the more felspathic sandstones of the Lower Old Red formation are changed from a chocolate to a grey or bluish colour, their bedding sometimes is nearly obliterated, and the rock is very tough and hard. The chocolate mudstones of the same formation are in like manner altered to flinty rocks resembling porcellanite. w.G.

Examples of these baked sediments are represented in the Survey collection (S24352) [NR 985 335]-(S24353) [NR 983 338]. The first of these slices shows angular grains of quartz embedded in an abundant quartzose matrix of silt grade. Numbers of minute, colourless, highly-refracting grains, which appear to be some form of pyroxene, have been developed by the contact metamorphism, along with epidote. Biotite flakes have been formed in argillaceous portions of the matrix, and specks of iron-ores have been segregated into small clouds. Slice (S24353) [NR 983 338] is a baked

argillaceous sediment of quartzo-micaceous composition, which shows remarkable micro-brecciation and faulting, and is epid.otized along some of the crush bands.

B. Petrography

Dr. A. Harker's description of the gabbroid rocks at the head of Glen Dubh is as follows:<ref>Geology of North Arran, etc., (Explanation of Sheet 21), Mem. *Geol.. Surv,* 1903, pp. 111–112.</ref>

'A good example of these normal *quartz-dolerites* comes from the north side of Glen Dubh. It is of quite coarse texture, and, like some other rocks in this collection, might be equally well named gabbro on petrographical grounds. It closely resembles some of the gabbros of Carrock Fell in Cumberland, or the coarsest portion of the Whin Sill of Teesdale. The augite and felspar are very evident, but the quartz is visible only here and there in small spots. The specific gravity of the rock is 2.87. In a thin slice (S2458) [NR 970 330] the felspar is found to be labradorite, with carlsbad and albite twinning and with strong zonary banding in polarised light, this being a constant feature in normal quartz-gabbros and quartz-dolerites. The pale-brown augite shows occasional striation and schiller-structure, parallel sometimes to the orthopinacoid (diallage-structure), sometimes to the basal plane (salite-structure). Needles of apatite and irregular grains of black iron-ore occur as accessories; and there is occasionally a flake of dark biotite intergrown with a fibrous light-green hornblende, which in places has been formed at the expense of the augite. Quartz is fairly abundant, partly in interstitial grains, but chiefly in interstitial patches of micropegmatite. The felspathic element of the latter is probably orthoclase, but is so turbid as to be almost opaque.'

The analysed rock (S24355) [NR 983 335], from the north side of Glen Dubh one-eighth of a mile W.N.W. of 386 feet O.D., is identical with the rock described above. The only point that needs to be added to Dr. Harker's description is that the iron-ore is a beautiful skeletal form of ilmenite which is intergrown with, or grown through, the pyroxenes. The Mull rock which is most closely comparable with the Glen Dubh quartz-gabbro is the lower basic portion of the differentiated ring dyke of Glen More.<ref>*Mull Memoir, 1924*, pp. 325–326, and Figure 56A. This drawing might well represent the Arran rock, with the exception that in the latter, the acid residuum is not so fine grained, and there is more quartz present.</ref> The labradorite felspars of the Arran rock show the same, narrow, ragged, anastomosing veins of albite as are described in the Mull rock.

Olivine-gabbro, and a type rich in iron-ore, are known to occur on the south side of Glen Dubh Water, near the right-angle bend at the head of the corrie, but these rocks are not represented in the Survey collection.

A chemical analysis of the quartz-gabbro of Glen Dubh is set out in (Table 4)., col. 8, and is there compared with two quartz-gabbros from the Glen More ring dyke of Mull.

(Table 4)

	8.	L.	M.
SiO_2	52.43	51.32	50.04
$A1_2O_3$	13.50	13.96	13.32
Fe_2O_3	4.93	2.48	4.71
FeO	7.00	7.10	8.07
MgO	4.61	5.78	5.01
CaO	8.25	11.51	10.02
Na_2O	3.27	3.50	3.28
K_2O	1.08	1.16	1.08
H_2O> 103°	1.64	1.27	1.45
H_2O< 105°	0.28	0.36	0.27
TiO_2	1.91	0.98	2.56
P_2O_3	0.21	0.24	0.28
MnO	0.20	0.34	0.33
CO_2	0.08	0.09	0.08

FeS_2	0.44	nt. fd.	nt. fd.
(Ni, Co)O	—	nt. fd.	nt. fd.
BaO	0.96	nt. fd.	nt. fd.
Li_2O	0.00	nt. fd.	tr.
Cr_2O_3	0.02	—	—
ZrO	0.00	—	—

8. ((S24355) [NR 983 335]. Lab. No. 819). Quartz-gabbro, north side of Glen Dubh, one-eighth of a mile W.N.W. of 386 feet O.D., Arran. *Anal.* B. E. Dixon.

((S18462) [NM 5990 2974]. Lab. No. 441). Quartz-gabbro of the Glen More ring dyke, half a mile S.S.E. of cairn on Cruach Choireadail, Mull. *Anal.* E. G. Radley. Quoted from the *Mull Memoir,* 1924, p. 29.

((S18455) [NM 5654 3251]. Lab. No. 437). Quartz-gabbro, rather more than half a mile W.N.W. of Corra-bheinn, Mull. Part of the Glen More ring dyke. *Anal.* E. G. Radley. Quoted from the *Mull Memoir,* 1924. p. 29.

Inspection of the three analyses reveals very close similarity in every respect save one. The lime in the Mull analyses is distinctly higher than in that of the Arran rock. As shown by the calculation of the norms this greater richness in lime is due to a larger amount of pyroxene in the Mull types, than to the presence of more calcic plagioclase. A tabular comparison of the three rocks is given below:

	%Salic Constituents	% Quartz	% Pyroxenes	% Ab.	% An.
Arran. Anal. 8	59.8	6.7	26.5	27.8	18.6
Mull. Anal. L.	55.5	—	29.5	29.3	18.9
Mull. Anal. M.	54.1	1.6	32.3/7.3 olivine	27.8	18.1

The table shows that the Arran rock is distinctly more acid than those of Mull, being richer in quartz and poorer in pyroxenes. Its mineralogical composition may be taken roughly as: quartz, 6.5; orthoclase, 6.5; plagioclase, Ab_3An_2, 46.5; pyroxenes, 26.5; iron-ores, II; the remainder consisting of apatite, pyrite, and water. The normative plagioclase works out at Ab_3An_2, but the modal plagioclase is described in each case as acid labradorite, near Ab_1An_2. The excess of albite shown by the norm may perhaps be regarded as the measure of the albitization which the felspars have suffered, although allowance must be made for the fact that a little of the soda utilized in the norm for the computation of the amount of albite undoubtedly came from the pyroxenes, which are computed as soda-free.

The general chemical similarity of the quartz-gabbros to the quartz-dolerites and basic craignurites (*see* (Table 2)), may be noted. The latter group, however, is poorer in lime, but richer in potash, than the former.

Hybrids and mixture-rocks, along with diorite and quartz-diorite, are well displayed in the Glen Dubh complex. There are grounds for the belief that even the homogeneous hornblendic rocks of uncontaminated aspect, are really due to very complete mixing of granitic and gabbroid magmas, or to the complete solution of gabbro xenoliths in granite or granophyre. It also seems probable that, besides mere mixing or solution, there has been, in some cases, a selective mutual interchange of certain constituents between the gabbro and the invading granite. Furthermore, on its eastern margin the gabbro has been modified by the incorporation of Old Red Sandstone material, for the most part a fine-grained, felspathic sandstone, producing results approximately similar in kind and degree to admixture with granite. The Survey material, however, is insufficient for the complete petrographic demonstration of these views, which are based on the study of the collection of the Geological Department of the University of Glasgow.

Amongst the crags on the north side of Glen Dubh material can be gathered showing the isolation and gradual dissolution of gabbro xenoliths within a granitic magma, and the production of hornblende and biotite of identical characters with the minerals of the ' normal ' diorites and quartz-diorites which are obtained from the north side of the complex in positions remote from any occurrence of gabbro. The grain-size at the same time becomes finer. Dr. A. Harker's account<ref>Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv.,* 1903, pp. 105–107.</ref> of these extremely variable rocks cannot be bettered, and is subjoined; the description includes rocks obtained from Glen Dubh and also from other localities.

The ring of plutonic rocks surrounding the volcanic vent consists in part of granite, but in part of more basic rocks which have been termed quartz-diorite, diorite, and gabbro. The granite itself shows by its mineralogical constitution a certain range of variety in chemical composition, the most obvious difference being in the amount of the ferro-magnesian minerals. The increasing amount of hornblende observed in a series of specimens, with other differences developed concurrently, corresponds presumably with the transition noted in the field between normal granite and the type styled *quartz-diorite.* This latter was first described by Zirkel,<ref>*Zeits. deuts. geol. Ges.*, vol. xxiii., 1871, p. 30.</ref> whose account is as follows: "A fine-grained aggregate of white felspar and greenish-black hornblende, which, in spite of the smallness of the individual crystals, stand out clearly from one another, and quartz, which is first seen in the thin slice; plagioclase preponderates, but, as is common in similar rocks, there is some orthoclase present; green epidote borders the hornblende in places; the quartz is very rich in fluid inclusions; except magnetite and apatite needles, often of surprising slenderness with great length (*e.g.,* a needle o•g mm. long and only o•oo8 mm. thick), felsitic matter is not present. Here and there occur roundish dark concretions, in which the constituents are still finer grained and the hornblende predominates strongly, like the concretions rich in dark mica in the granites. The rock is thus a beautiful quartz-diorite, the only one of its kind known from Arran, and essentially different from the augite-bearing diabasic traps".

Some of our specimens answer very well to this description. One from Glen Dubh, north side, for example, has all the characters of a typical quartz-diorite. It has not the fine texture of Zirkel's specimen. A thin slice (S7447) [NR 970 330] shows that it consists principally of plagioclase felspar and abundant idiomorphic crystals of green to greenish-brown pleochroic hornblende. The plagioclase, as in most quartz-diorites, shows strong zonary banding between crossed nicols, indicating a great difference in composition between different coats of the crystal. It can often be verified that the interior and principal part is of labradorite, while towards the margin this passes successively through andesine and oligoclase to albite. Orthoclase is quite subordinate. Quartz too is not abundant, and always occurs interstitially, either by itself or in micropegmatite. The other minerals are magnetite, in fairly plentiful crystals and grains, and apatite, here building rather stout prisms to as much as 0.01 inch (0.25 mm.) in thickness.

'Examining and comparing other specimens, however, we find unmistakable indications that at least part of these rocks are of abnormal nature, in that they have not originated simply by the consolidation of an ordinary rock-magma. Almost all the slices show in the interior of many of the hornblende crystals a core of colourless augite, with a highly irregular and intricate boundary between the two minerals which proves that the hornblende has replaced augite by a process which ate its way inwards into the crystal. Nevertheless it is not a case of the simple conversion of augite crystals into hornblende, which might be a secondary change, for the crystals have always the external forms proper to hornblende. We may infer that the augite was transformed (in great part) to hornblende in a still fluid magma, and the crystals thus transformed, wholly or in their external parts, continued to grow as hornblende, assuming the proper crystal forms. This suggests that the augite was of *foreign derivation,* and other peculiarities leave no doubt that this conclusion is the correct one. The proportion of the ferro-magnesian element in the rocks is variable, and this even in one specimen, a mottled or patchy appearance being often very evident to the eye. Further, there occur in some parts of the mass numerous ovoid dark patches, an inch or less in diameter, of finer texture than their matrix. These are the 'concretions' of Zirkel, but they are to be interpreted as representing the debris of a basic rock almost completely digested by the originally acid magma in which they were enveloped. Thin slices show that these "*xenoliths*", or enclosed foreign fragments, have been totally reconstituted, not merely by metamorphism but by interchange of material between them and the surrounding magma. The mineralogical composition of the dark patches, and especially the occurrence of a noteworthy amount of quartz and alkali-felspars, denotes a certain degree of acidification; and this is the case even when the patches appear quite sharply defined to the eye in a hand-specimen (S7524) [NR 969 354]. The richness of the matrix in ferro-magnesian elements results from the correlated process of basification of the magma, which, however, results also in great part from bodily dissolution of the xenoliths, as proved by their rounded form. The mottled rocks without defined inclusions represent a further stage of intermingling between matrix and xenoliths, and the homogeneous-looking rocks, such as the quartz-diorite first noticed, represent complete amalgamation.'

The conversion of pyroxene into greenish-brown hornblende is well shown in (S24351) [NR 987 335], a specimen taken near the eastern margin of the intrusion on the floor of the Glen Dubh corrie; and in (S7447) [NR 970 330] from the north side of Glen Dubh. A very much more acid type, a quartz-diorite, with abundant interstitial graphic intergrowth between quartz and alkali-felspar, and still retaining some colourless pyroxene, occurs near the head of Burn A, near the junction

with Old Red Sandstone (S24354) [NR 983 339].

The unmodified granophyre of the veins cutting the gabbro at the head of Burn B is represented by the slice (S24372) [NR 979 335]. It is a beautiful coarse granophyre, with quartz and alkali-felspar mainly in fine graphic intergrowth which often fringes idiomorphic crystals of oligoclase. A slice (S24373) [NR 978 335] is cut from a medium-grained quartz-diorite free from graphic intergrowth. The dark patches seen both in the hand-specimen and in the slice are due to the irregular clotting of small anhedral hornblende crystals, which are accompanied by abundant iron-ore, and often contain cores of pyroxene. These crystals are poikilitically enclosed in the matrix of quartz and felspar. Patchy aggregates such as these appear to represent xenoliths of fine-grained gabbro in the last stages of disintegration, dissolution, and alteration. Quartz is distinctly less abundant within their boundaries than in the matrix of the rock. The slice (S7446) [NR 970 320], from Tir Dubh, shows a granite vein intruding a dark rock consisting of a curious foliaceous intergrowth of anhedral green hornblende and plagioclase, which looks as if a fine-grained ophitic dolerite had undergone changes similar to those detailed above.

2. Basic remanié masses included in the Explosion-Breccia, and in the granite

Northward from Glen Dubh a number of masses of gabbroid rocks, badly crushed and sheared, and bounded by arcuate faults, can be recognized. At the head of the central headwater of the Glen Ormidale Burn there is a broad dyke-like mass of brecciated gabbro, bounded by a crushed basalt dyke on the west, which separates it from felsite, and by a thinning tongue of felsite from the Windmill Hill intrusion on the east. The crushed gabbro is mingled with bands of hard quartzite, and is thoroughly shattered, altered, and epidotized. In the hillock south of this exposure the mass widens out, and has an outcrop 80 to go feet wide. Here the rock is comparatively fresh, and is a coarse gabbro consisting essentially of large plates of diallage and labradorite, with a little ilmenite (S24359) [NR 982 344]. The pyroxene is passing to greenish-brown amphibole along its edges. No quartz or alkali-felspar can be detected, but there are small patches of serpentine which may represent altered olivine. The rock is penetrated by thin veins of epidote. To the north of the burn the intrusion can be traced on to the hill called Torr Maol (Plate 4), where it ends before reaching the northern headwater.

Lower down the Ormidale Burn there is a mass of badly crushed and altered basic rock, which may be traced for about 300 yards across the central and southern headwaters (Plate 4). <ref>This mass is mentioned in the Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv.,* 1903, p. 97.</ref> It is apparently interbedded with hard white sandstone, with which it dips at 50° to the south-west. In the southern headwater the basic rock is underlain by a thin felsite intrusion which sends veins into it, and is overlain by steeply-dipping quartzite cut by at least three small masses of felsite.

The slice (S24358) [NR 982 345] is a sample of this rock taken from the central headwater of the Ormidale Burn at a point 250 yards south-east of Torr Maol. The slice shows still recognizable plagioclase laths, but much of the felspar is thoroughly altered to an indeterminable turbid dust, and the ferro-magnesian minerals have broken down to serpentine and chlorite which occupy the interspaces between the felspars. The rock seems originally to have been a coarse dolerite or a fine-grained gabbro. Slice (S24367) [NR 970 340] is a rock of the same type, but has been broken into angular fragments, probably representing a fault-breccia.

In the small crag on the hillside south of the String Road near the third milestone (map, (Plate 4)) there are exposures of crushed, sheared, and hornblendized gabbro.<ref>This mass is mentioned in the Geology of North Arran, etc., (Explanation of Sheet 21),*Mem. Geol. Surv*., 1903, p. 97.</ref> Some types are mottled like some of those at the head of Glen Dubh; all the rocks are much shattered. At the top of the crag the rock is badly sheared, and passes into the condition of a schistose mylonite. Above the crag the gabbro disappears, and granite fragments are found in the peaty soil.

In. a gully to the west the gabbro is seen overlying intensely-baked Old Red Sandstone. The stream gully (see (Plate 4)) shows a vertical junction with a felsitic contact facies of the granite. A dry gully 80 yards west of the stream gives an almost complete section through the basic mass, which is revealed as having an outcrop 150 to 200 feet wide, and intersected by veins and dykes of granophyre and aplite. Only a few fragments of gabbro are found in the next gully, and west of this point the mass disappears abruptly. It is to be interpreted as a remnant of a gabbro ring intensely shattered

by arcuate faulting.

In thin section these rocks (S7536), (S24376) [NR 975 354] show medium-grained aggregates of idiomorphic labradorite ($Ab_i.An_i$), and areas of stronglypleochroic green hornblende, sometimes massive, but often fibrous (S24376) [NR 975 354], which are obviously after pyroxene, as shown by their subophitic relations to the felspars. The felspars are veined by clear albite (S7536). The rocks are broken by numbers of planes of movement along which the amphibole has sometimes migrated. The felspar laths, while bent or broken, are, however, but little altered. The rocks were originally gabbro of the same type as that at the head of the Ormidale Burn (p. 178). G.W.T.

To the east-south-east of Glenloig, about three-quarters of a mile, there is on the east side of a little tarn a projecting mass of rather coarse black rock. It is somewhat balloon-shaped in outline, and about 250 yards in length. The rock is a hyperite composed of labradorite, diallage, and hypersthene, with some interstitial magnetite and biotite. It is surrounded by a granophyric rock, but no junction is visible.

About a quarter of a mile N.N.W. of this is Creag nam Mult, a prominent object from the road which runs through Gleann an t-Suidhe. The dark rock here forms a long and narrow outcrop with a steep face to the north, and consists of plagioclase, augite, hypersthene, and hornblende, with some interstitial quartz and micro-pegmatite. In the middle of this mass, which is 250 yards in length, is a gully where may be a basalt dyke. The surrounding rock is a granophyre which appears to have penetrated the hyperite in veins. There is a small detached area of a similar rock to that of Creag nam Mult 250 yards to the north-east.

About 500 yards east of Glenloig is a small section where two kinds of rock are seen — a coarse ophitic dolerite, and an augiteporphyrite, which is probably intrusive in the former rock. This section is nearly in contact with the mass of volcanic agglomerate which outcrops to the south. On the other side it is probably bounded by quartz-diorite, but no contact is visible. W.G.

One of the most interesting of the Arran rocks is that which has been designated hyperite. It is a very fresh rock of dark aspect and of moderately coarse texture, the pyroxene and felspar being clearly distinguishable in a hand-specimen. An example from three-quarters of a mile E.S.E. of Glenloig Farm (S7530) [NR 950 340] gave the specific gravity 2.97. In a thin slice it is seen that by far the greater part of the pyroxene is of the rhombic kind, though some augite is also present. The rock might therefore be termed *norite.* The dominant pyroxene is of pale colour, but always decidedly pleochroic, varying from a reddish to a greenish tint. It may therefore be called bronzite. Both this and the augite show schiller structures, parallel to the pinacoidal and basal planes, but not constantly developed. It is especially noticeable that these minerals have the ophitic habit, a circumstance not common in rhombic pyroxenes. The felspars are perfectly fresh, but show, except at the border of each crystal, a dirty appearance due to very minute inclusions. Carlsbad and albite twinning are found, and the extinction-angles in symmetrically-cut sections rise to 33° or 34°, indicating labradorite but not one of the more basic varieties. Grains of black iron-ore occur, moulded on the felspar, and occasionally little scraps of biotite clinging about the iron-ore.

Specimens from Creag nam Mult show many points of resemblance with the preceding, but also certain differences, and they may be termed *quartz-hyperite* (S7531) [NR 950 350], (S7532) [NR 950 350]. Here the accessory iron-ore is idiomorphic, and apatite becomes a noticeable constituent. Augite is abundant as well as bronzite, and there is also a considerable amount of strongly-coloured hornblende, varying from brown to green. The browner kind has proper crystal outlines, and is therefore a primary constituent of the rock, but it often contains a core of pyroxene, about which it has grown with the usual crystallographic relation. The greener hornblende, on the other hand, is evidently formed at the expense of pyroxene, usually if not always of augite, and relics of the latter mineral, of highly irregular form and with intricate boundaries, are often preserved in the interior. Not only the pyroxene, but the felspar also has a well-marked schiller structure, the arrangement following the two pinacoid planes and the basal. Finally, and especially characteristic of this rock, there are interstitial patches consisting of delicate micropegmatite.

It seems possible that the conversion of augite to hornblende in these latter rocks may be an effect of metamorphism due to the neighbouring granophyre, but this is not a necessary supposition. A.H.

A number of basic masses occur in the region west of Glen Craigag, especially on the western side of Ard Bheinn. These have hitherto been regarded as intrusive into the breccia.<ref>Geology of North Arran, etc, (Explanation of Sheet 21), *Mem. Geol. Surv.*, 1903, p. 98.</ref> It is demonstrable, however, by the increasing abundance in the breccia of fragments derived from them as their boundaries are approached, that some of these masses at least are older than the breccia, and are to be regarded as on exactly the same footing as the Mesozoic and Paleozoic remanié masses which are likewise enclosed in, and have contributed material to, the breccia.

Creag an Fheidh, one-third of a mile S.S.E. of Glenloig, consists of a mass of flesh-coloured or purplish quartz-felsite, of which numerous boulders and cobbles are found in the adjacent breccia. Immediately above the felsite is a blue basalt, with an irregular but nearly horizontal base; and between the two rocks there is a soft, black, sheared, serpentinous band. The basalt is amygdaloidal in places, and contributes to the breccia in its vicinity. Its western face is highly brecciated. A little to the west of the basalt is the limestone of the Glenloig cave (p. 109); and the view that the basalt is a remanié mass derives further plausibility from this juxtaposition (*see* further, p. 182). G.W.T.

The most noteworthy of these remanié masses of basalt are found on the western and southern sides of Ard Bheinn. One forms a craggy ridge called Creagan Liatha na Cluain Monaidh between the two branches of the stream near the head of Ballymichael Glen. At its eastern end this dark basic rock is highly magnetic. The largest mass runs from the west side of Ballymichael Glen in a northwest direction to above Derenenach, and then bends towards the north-east. It is altogether one and a half miles in length and more than 200 yards wide where it is broadest, and the rock of which it is composed is similar to that last mentioned and also highly magnetic in places. At a point 550 yards E.S.E. of Derenenach the rock is a natural magnet, possessing polarity. This basic mass is certainly

earlier in date than the granophyre. w. G. For the most part this last-mentioned mass consists of a highly amygdaloidal basalt, which in places is interbedded with basaltic tuff. Just above the Rhaetic exposure in Allt nan Dris, in the crag between the fork of its headwaters, the basic rock is first tuffaceous, and then passes to an amygdaloid. It has contributed unmistakable fragments to the breccia which bounds it on the western side On its eastern margin its boundary is formed by an intrusive granophyre. Examination of the basalt shows it to be a lava indistinguishable from many of the plateau-basalt types of Skye and Mull. The only thin section available (S9434) [NR 935 329], from a specimen taken 550 yards E.S.E. of Derenenach, shows a comparatively coarse ophitic plexus of narrow labradorite laths with purple augite, with some iron-ores, and abundant serpentinous material suggesting original olivine. The rock is traversed by numerous anastomosing lines of crush, along which micro-brecciation has occurred with little or no mineral change, and adjacent to which the felspars are often bent and broken.

The most probable explanation of this mass is that it represents a still upstanding screen of early plateau-basalt, which is bounded by an arcuate fault on the western side, and is intruded by an acid ring dyke on the eastern side. At its north-eastern end specimens of coarse gabbro were obtained by Gunn, at a point 200 yards south-east of Creag Mhòr, or about two-thirds of a mile north-east of Derenenach. The relations of this rock to the basalt are not known, but it is likely to be intrusive. Dr. A. Harker described this rock in the following terms:<ref>Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv.*, 1903, p. 107.</ref>

The rocks (S9435) [NR 930 330], (S9436) [NR 930 330] are of average texture, and consist essentially of felspar, sub-ophitic light-brown augite, and irregular grains of black iron-ore. The felspar is a labradorite, with extinction-angles up to 34° in symmetrically-cut sections. The augite has a strong striation and schiller-structure parallel to the basal plane. Olivine is apparently not present.'

It is worth while noting that the above-described basic remanié masses are associated with four of the Mesozoic fragments, within a comparatively narrow, elongated, arcuate area, extending from Creag nam Mult, by Creag an Fheidh with its limestone mass, to the limestone of the 'Pigeon Cave' on Binnein na h-Uaimh, the Rhaetic exposure in the Allt nan Dris, and thence round the western side of Ard Bheinn to the Lias fragment in Ballymichael Glen (Plate 4). This fact suggests arcuate faulting and fissuring parallel to and concentric with the general ring shape of the complex, and to the outer zone of explosion-breccia, along which the fragments may be supposed to have been let down and preserved. In 1925 the writer found traces of another sedimentary inclusion in the area between A' Chruach and the head of the Allt nan Calaman, where the moor is covered with numerous boulders and slabs of a whitish, round-grained sandstone. This

area lies on the eastward continuation of the annular zone described above, if it be produced in that direction. G.W.T.

3. The explosion-breccia, and the associated felsites and rhyolites

The explosion-breccia of the Central Ring Complex consists of a heterogeneous accumulation of fragments of all sizes, ranging from masses hundreds of yards across, down to microscopic chips. The larger masses are much fissured, broken, and tumbled; and many of the smaller fragments have suffered micro-brecciation which can be seen even in a microscopic section. The fragments are composed of the cover of Old Red Sandstone and Mesozoic rocks which originally spread over the explosive foci, and had already been domed and fissured as the result of the earliest igneous activity of the episode fragments of the basaltic lavas which were erupted at this earliest stage; and fragments of the acid igneous rocks whose intrusion and explosive condition were the prime causes of the general fragmentation.

The distribution of the breccia is significant. It forms a ring of very variable width, the greatest diameter of which is about one and a quarter miles. This ring (Plate 4) extends from A' Chruach, where the annular strip is half a mile wide, north-westward to Glenloig, then south-westward to near Derenenach, and thence southeastward to Ballymichael Glen. The narrowest part of the outcrop, only 70 yards in width according to Gunn's mapping, is at a spot two-thirds of a mile south-east of the summit of Ard Bheinn. In the region about Ard Bheinn, Binnein na h-Uaimh, and Creag Dubh, there is a wide central expansion of the outcrop, where the breccia is intricately intermingled with felsite, rhyolite, and granophyre masses. It is believed that the breccia ring has been built along arcuate fissures connected with the intrusion of the outer granite ring, and that the central mass of Ard Bheinn represents the site of a volcanic focus marked by the intrusion, and possibly the extrusion, of felsitic and rhyolitic rocks. The outer ring of granite and breccia may mark the boundary of a caldera, of which the Ard Bheinn area was the somewhat asymmetrically-placed focus.

The breccia is strongly baked and hornfelsed against the later intrusions; but this will not explain the general induration of the rock in areas remote from intrusive masses. This induration, which is accompanied by extensive epidotization, is believed to be due to the transfusion of residual magmatic gases and liquids through the material. The phenomenon seems to be identical with the induration and epidotization of the Old Red Sandstone at certain points around the margin of the northern granite, at places, too, around the margin of the Central Ring Complex, and with the 'pneumatolysis' of the basaltic lavas around the calderas of Mull.<ref>*Mull Memoir,* 1924, p. 95.</ref>

Glen Craigag provides a good representative section of a part of the breccia ring. The first exposure of fragmental rock occurs about a sixth of a mile south-east of Glenloig Bridge. The contact with the granite ring is not seen. At this point the breccia has a light-coloured felspathic matrix, which includes angular fragments of green schistose grit and dark quartz-felsite. Below the gorge caused by a north-west basalt dyke the breccia contains predominant Old Red Sandstone material, both the rounded quartz and quartzite boulders detached from their matrix, and angular fragments of the conglomerate itself, being present. One of the boulders of conglomerate was 15 inches across; and near it was an angular boulder of a lavender-coloured felsitic rock with pink felspar microphenocrysts, and another of dark quartz-felsite, types which can be easily matched amongst the Cainozoic intrusives. These boulders are embedded in a dark, indurated, epidotized, quartzitic matrix.

The epidotization and induration of the breccia can be well studied above the dyke-gorge.

At the confluence of the first western tributary of Glen Craigag the breccia is mainly composed of Old Red Sandstone debris, but also contains large boulders of a fine-grained quartz-dolerite entirely similar to some of the rocks described in Chapter 12. The largest was 15 inches in diameter. At this place the breccia appears to be rudely bedded, and dips about 30° to the north-west.

In the stretch of the burn opposite Creag Dubh the breccia appears to be almost devoid of Old Red Sandstone material, and is made up of basaltic, andesitic, and trachytic fragments in a scanty quartzose matrix. Near the Allt an Chruiteir the breccia contains pebbles of plateau-basalt type, along with quartz-felspar-porphyry of a typical Cainozoic habit; and these predominate greatly over the quartzose debris presumably derived from the Old Red Sandstone.

The contact between the central granite and the breccia is seen near 635 feet O.D. The junction is almost vertical. The granite adjacent to it is greenish and fine grained; and the grain-size noticeably increases away from the contact. The

junction is therefore an intrusive one. G.W.T.

The general character of the breccia is not easy to describe, for it varies much in different places. The matrix of the fragments is very often arenaceous, much like that of an ordinary coarse sandstone, and in this are found pebbles and blocks derived from various sources, igneous rocks of an acid character often predominating.

To the west of Ard Bheinn the rock may be called a brecciated conglomerate, which weathers of a brown colour, and when broken is found to have a fine grey matrix. The included fragments are quartz pebbles (generally small), quartzites, acid igneous rocks such as granite and quartz-felsite, schists, etc., all being rather angular in outline.

In Creag Shocach, to the east of Glenloig, the prominent pebbles and blocks in the rock are grits and sandstones of various kinds, more or less angular, small quartz pebbles, and quartzite pebbles generally well-rounded, like those found in the Lower Old Red conglomerates. In ascending the northern end of this crag we find many pebbles of quartz and quartzite in the coarse breccia, as well as several varieties of acid igneous rocks (but few of basic lavas) set in the ordinary grey paste. In the upper part of the crag is a quite different kind of rock, which is distinctly red in colour, with a sandy matrix containing only pebbles of quartz. All over the crag we find the nature of the rock varying. At one extreme is a breccia made up almost entirely of coarse angular or sub-angular fragments of sandstones, etc., of various shapes and sizes, with little or no matrix; while at the other the rock has a fine-grained appearance externally, and on a fractured surface is seen to consist principally of a hard bluish-grey paste, imbedding small angular fragments. There is every gradation between these two extreme varieties. In no part is there any satisfactory indication of bedding. The rock weathers of the usual brown or rusty-brown colour where the grey matrix exists, but does not appear to be so much altered as in some other places — as in the burn to the west for example.

In several places besides Creag Shocach the rock is a coarse conglomerate, very like the characteristic quartzite-conglomerate of the Lower Old Red formation, and there is no doubt that this formation has contributed a large part of the material which now fills the volcanic vent, though it has in most cases been broken up and mingled largely with fragments of granite, quartz-felsite, etc. It is only in a few places that the brecciated rock assumes the character of a true volcanic tuff or agglomerate made up of igneous fragments alone, and basic lavas are seldom represented in it. On the east side of the Rhaetic patch in Allt nan Dris the rock has generally a fine dark-grey matrix, which in places is calcareous and becomes carious on the brown-coloured weathered surface. It contains pebbles of white quartz (small), and quartzite, always well-rounded. Rarely there are pebbles of quartz-felsite, and the schist fragments are always angular. Occasionally there are no prominent fragments, and the rock then has more the character of a fine tuff. A pebble of amygdaloidal andesite<ref>This rock (S9426) [NR 931 336] appears to me to be comparable with the porphyritic central-basalt type of Mull. G.W.T.</ref> was got out of the rocks about 500 yards north-east of Derenenach, and pebbles of similar character are apparently not uncommon between this locality and Creag Mhor, where, near the edge of the granite, the rock has a chloritic and ferruginous matrix, probably from altered basic tuff-material. At the junction with intrusive basic rock 100 yards south-west of the Derenenach cave, a specimen showed a pebble of crushed and schistose grit (schist), besides the usual quartz grains, chips of andesite, etc. The breccia is much altered about three-quarters of a mile south of Glenloig farm. One of the specimens collected from near the mass of altered shale described in Chapter 10 has a large piece of microgranitic quartz-porphyry in a fine grey matrix much metamorphosed, with abundant new-formed biotite. To the west of this, and near the edge of the granophyre or granite, there is a vein one and a half inches wide of a fine-grained biotitegranite traversing the matrix of metamorphosed tuff, apparently of trachytic composition, with new-formed biotite; there are also fragments of metamorphosed basic lava with much biotite.

Some pebbles collected from the breccia in Allt Ruadh to the east of Derenenach are of felsite, with small isolated spherulites. Others are much decayed, but may have been andesitic in character. A fairly large collection of pebbles was made from the breccia in various localities, and they quite bear out the statement that of the igneous fragments those of a decidedly acid character predominate, though basic material may have entered more largely into the formation of the matrix.

West of Creag Mhòr the breccia comes probably directly into contact with the Lower Old Red formation, and there appears to be a break in the igneous ring.

Between Beinn Bhreac and Cnoc an Biorach a portion of the fragmental rock appears to be surrounded by the later intrusive masses, and in two places we find the breccia outside the igneous ring, or only partly included in it. One of these is at the head of Benlister Glen, to the north of Cnoc na Croise. The extent of this cannot be ascertained, as it only occurs as a small section in the burn. A dark-greenish fragmental rock, apparently of a tuffaceous character, and considerably altered, occurs quite close to the granophyre. The fragments are of quartz and of a felsitic rock, in a greenish matrix containing much hornblende (actinolitic) which has evidently been formed *in situ.* The other locality is at Cnoc an Biorach, on the south side of Ballymichael Glen, where a considerable mass of a dark, fine-grained, almost flinty rock, occurs around the Ordnance Station and to the south-west of it. Some of it is obviously fragmental, and portions which appear massive are found when examined under the microscope to consist of metamorphosed, gritty tuff, with much new biotite. Along the eastern margin of the mass a coarse breccia is visible in two places. This area appears to be bounded by granophyre and quartz-diorite, except on the south-west side, where it adjoins the rocks of the Upper Old Red Sandstone. W.G. Dr. A. Harker's account of the petrography of these rocks is as follows:<ref>Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv.,* 1903, p. 103.</ref>

'A number of specimens have been examined of the volcanic agglomerate of the large vent, and of the various rocks enclosed as fragments in it (S9421) [NR 950 340]-(S9430) [NR 940 310], etc. In general they show a *gritty-looking matrix,* stained of various colours, in which are imbedded pebbles and fragments of quartzite, vein-quartz, and other rocks. The matrix itself consists largely, and often principally, of quartz-grains, angular and subangular; but there is also finely divided interstitial matter, which is probably to be interpreted as representing basic igneous material, too much altered for identification. Often it is largely chloritic; in other cases there is a ferruginous or a ferruginous and calcareous cement (S9423) [NR 950 340] and (S9421) [NR 950 340]. In addition to quartz-grains, we find sometimes little crystals and fragments of felspar (S9424) [NR 939 334], grains of partially epidotized augite, and little chips of fine-textured basalt, and especially of a 'pyroxene-andesite'.

'Among the *larger elements enclosed* in the general matrix we may remark especially fragments and rounded pebbles of quartzite and vein-quartz. Numerous other rocks are represented in fragments of all sizes. One specimen has cavities which probably represent destroyed limestone pebbles (S9423) [NR 950 340]. A piece of crushed and schistose grit occurs, showing films of sericitic mica, strain-shadows in the quartz, and a characteristic mylonitic structure (S9424) [NR 939 334]. Especially noteworthy are the fragments of igneous rocks, including andesites (S9426) [NR 931 336], (S9427) [NR 940 310], microgranitic quartz-porphyry (S9428) [NR 940 340], and biotite- or biotite-hornblende-granite (S9479) [NR 950 340], (S9480) [NR 930 330], (S9481) [NR 930 330].'

'The *metamorphism produced in the agglomerate* by the intrusions is evident in some of the specimens. One, traversed by a granite vein, is apparently a trachytic or rhyolitic tuff, in which biotite has been developed by metamorphism, while denser patches richer in biotite represent enclosed fragments of andesite (S9429) [NR 940 340]. Other specimens, representing the gritty tuff which is the most usual matrix of the agglomerate, show in varying degree the same development of new-formed biotite, resulting presumably from the metamorphism of the chloritic matter mentioned above (S9430) [NR 940 310], (S9428) [NR 940 340]. In another specimen, from the edge of the mass, the chief product of metamorphism is a pale-green fibrous hornblende, often with partial radiate arrangement (S6387) [NR 970 310].'

Slice (S9425) [NR 930 330], from Creag Mhòr, Derenenach, south-west of 829 feet O.D., and therefore close to the large remanié basalt mass of that locality, shows fragments of altered doleritic basalt of plateau type, and debris of the same. Slice (S9437) [NR 930 330] also from Creag is made up largely of the debris of a granophyric granite of a type common in the Central Ring Complex.

The felsites and granophyres of the central focus around Ard Bheinn and Binnein na h-Uaimh belong to both remanié blocks and to intrusive masses, which may both be broadly contemporaneous with the breccia. Felsitic breccia, with large and small angular fragments of quartz-felsite and rhyolite, is abundant on Ard Bheinn. On the other hand, near Leana Cuil, the felsite appears to vein the breccia, and has a distinctly intrusive relation to it. The large granophyre mass which crosses the Allt Bheith and the Allt Dornoch to the east of Creag Mhor is clearly intrusive into the breccia at its northern end. G.W.T.

There remain to be described here some of the more prominent intrusive masses that, together with the breccia, form the intricate patchwork of outcrops around Ard Bheinn. Two of the largest run along the western side of the hill in parallel bands; the outer a basic rock, and the more easterly a quartz-felsite, which becomes in places coarsely porphyritic. The basic rock, the course of which has been given elsewhere, is an ophitic dolerite which, 200 yards south-east of Creag Mhbr, is replaced by gabbro (*see* p. 181).

The quartz-felsite is a light-coloured rock, somewhat coarse textured, and very different in character from most of the acid intrusions that occur between Ard Bheinn top and Glenloig. It covers a considerable area, and has in places a width of outcrop amounting to nearly 400 yards.

The dark rock at the summit of Ard Bheinn is magnetic and affects the compass strongly.<ref>The slice shows numerous small ragged masses of magnetite, which may be part cause of the magnetic effect.</ref> It appears to be a felsite with a fine-grained matrix containing whitish felspar crystals (S9432) [NR 944 328]. Around the summit are some bands of a white-weathering rock of a more acid character apparently. Two hundred yards S.S.E. of the summit is a grey rock banded with red (S9439) [NR 945 326]; it is a rhyolite with strong flow structure,<ref>A typical rhyolite in thin section. The slice shows that the rock has suffered some brecciation, and is therefore probably pre-breccia. G. W. T.</ref> and may be connected with the mass of quartz-felsite that runs along the west side of the hill, but there is some doubt whether it is not a portion of a fragmental rock to which it is adjacent, as there are several fragmental masses in the intrusive rocks of this part of the hill.

Spherulitic structure occurs in a granophyric rock 300 yards north-east from the summit of Ard Bheinn. The rock forms here an oval patch about 40 yards long, the relations of which to the surrounding acid and basic rocks are not clear. The colour of it is nearly white on the weathered surface, but when broken it is seen to be a mass of spherules, each averaging half an inch in diameter.

A number of small, basic, intrusive masses occur about the Derenenach cave and around Binnein na h-Uaimh, and others are found near the Glenloig cave, but most of the intrusive rocks of the north side of the hill are of an acid character. Those which occupy the largest area, and which are most regular in their outline, are either granite or granophyre. The masses with such tortuous outlines consist generally of a fine-grained, grey felsitic rock, sometimes almost of a flinty character, minutely jointed and breaking up into splinters. It forms prominent scars at Creag Dhubh overlooking Glen Craigag. Sometimes the rock is of a darker colour and of a bluish cast.<ref>Fragments of felsite of this character are common in the breccias of Glen Craigag. G. W. T.</ref> Quartz in small blebs is generally present in both varieties, and most of the rock is nearly white on the weathered surface. In places the jointing in this rock is beautifully close and parallel, and very striking. Good examples occur 300 yards south of the Glenloig cave and nearly a mile S.S.E. of Glenloig, both near the junction of felsite and breccia. The latter locality is about a quarter of a mile west of the main stream of Glen Craigag.

In several places in this burn about three-quarters of a mile from Glenloig sections occur in a dark, almost black, fine-grained rock, which appears to alternate with masses of undoubted breccia. Some of the fine-grained rock is manifestly banded felsite, but here and elsewhere in this area it is almost impossible without the aid of the microscope to distinguish between the fine-grained massive rocks which are free from quartz and the highly altered matrix of the breccia where it is devoid of fragments. A pitchstone dyke pierces the breccia in a small stream two-thirds of a mile south-east of Glenloig and nearly 300 yards west from the main burn. It is dark coloured, 2 to 3 feet in width, with a hade to the south-west. It runs in a south-east direction, and perhaps has contributed in the formation of the prominent scar of felsite there. W.G.

4. The main granite and granophyre ring, and the associated quartz-diorites and diorites

The main granite mass of the Central Ring Complex has an annular outcrop of variable width, which in general forms the periphery of the complex, and is exterior to the ring of explosion-breccia. It encircles the whole area with the exception of about a mile on the western side at Derenenach. It extends from Cnoc Dubh (*see* map, (Plate 4)) on the north-east, where the radial width of the annulus is greatest (about a mile), south-westward to Beinn Bhreac, and thence westward to Ballymichael Glen. It ends abruptly a quarter of a mile north of Ballymichael Glen against the breccias and younger

felsites and granophyres. On the north the granite extends westward from Cnoc Dubh along the String Road by Glenloig to Tarrnacraig, and then appears to traverse southward across the outcrop of the breccia, ending at Creag Mhòr. There is a small mass of granite exposed in and near the Allt nan Dris, north of Derenenach, which may be a detached portion of the ring.

Another granite mass appears to form a plug which is placed almost centrally in the ring complex. It is roughly triangular in shape, about a mile in greatest width, and occupies most of the upper part of Glen Craigag (*see* p. 184).

At the external contacts, mainly against Old Red Sandstone and Triassic sediments, the granite passes into a fine-grained granophyre or even felsite, as may be well seen in the headwaters of the Glen Ormidale Burn. It may be that the large mass of felsite mapped around 1296 feet O.D., half a mile west of Windmill Hill, merely represents the chilled margin of the granite. At any rate, there is no definite boundary between it and the granite to the west. At a point nearly half a mile south-west of the top of Beinn Bhreac, the granophyre rock is beautifully spherulitic.<ref>Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv., 1903,* p. 88.</ref>

At the middle part of its eastern boundary the granite is in contact with the gabbroid and dioritic rocks at the head of Glen Dubh (*see* p. 172).

Quartz-dioritic and dioritic rocks of entirely similar character to those of Glen Dubh occur at many places on the north-eastern and northern sides of the granite ring (*see* map, (Plate 4)). G.W.T.

Quartz-diorite is a very prominent rock in Gleann an t-Suidhe and in several of the streams that join it from the south, and it occupies a good deal of the high ground between A' Chruach and Beinn Bhreac, though here the exposures are not good as the hilltops are covered with peat. There is a good exposure in Allt nan Calaman (which is the first stream to the west of Cnoc Dubh), and in the stream at Glenloig. It was probably in one of these streams that it was noticed and described by Zirkel fifty-seven years ago (`Geologische Skizzen von der Westkiiste Schottlands,' 1871, p. 30). The older writers, from Jameson in 1798<ref>R. Jameson, An Outline of the Mineralogy of the Shetland Islands and of the Island of Arran, p. 84.</ref> to Ramsay in 1841,<ref>A. C. Ramsay, The Geology of the Island of Arran from Original Survey, 1841.</ref> have described or included this rock under the head of syenite. It varies much in composition, in colour, and in grain. Sometimes the rock is light-grey, contains little hornblende, is very acid in character, and approaches granite in composition, as in a burn 150 yards north-east of Creag nam Mult, Gleann an t-Suidhe. The specimen described by Zirkel consisted of white felspar and greenish-black hornblende with some quartz, plagioclase and orthoclase felspars being both present. The rock often contains finer and darker patches which are richer in hornblende and appear to be more basic than the general mass of the rock. In fact, the composition of the mass seems to be constantly varying, and occasionally we find that the most basic portions of it are penetrated by acid strings and veins approaching granite in composition, which are probably derived from the same magma that produced the more basic portions. Some attempts were made to map the quartz-diorite separately from the granite and granophyre, but the attempt was given up because the rocks are so intermingled, and because it was evident that there are transitional forms between the quartz-diorite and the granophyre, and practically the rocks seem to be but different stages in the consolidation of one and the same molten mass. At all events, this is the impression one gets after examining the sections in the burns on the south side of Gleann an t-Suidhe. W. G.

At the String Road bridge across the Allt nan Calaman a small quarry has been reopened for road-mending operations. It discloses a good section of the fine-grained dioritic types, varying from a light acid type, through evenly and coarsely mottled varieties, to very dark rocks. Xenoliths of the dark fine-grained variety are found within the light variety. There are also irregular mottlings of dark minerals in the light variety, passing gradually into the dark variety, and presenting evidence of thorough mixing and digestion of a basic rock within an acid magma. The acid rock is also found veining the darker rocks in sharply-bounded dykes and strings. Three-eighths of a mile from the road the stream section shows a fine junction between a white quartz-diorite or granite, and a dark diorite, with considerable enclosure of the latter. The whole section up the Allt nan Calaman shows similar phenomena. The dark diorite decidedly predominates, and the light rocks intersect it as dykes and veins of varying widths. There are very similar appearances in the quarry in Glen Craigag, a few yards from the String Road. G.W.T.

One of the most instructive sections occurs in Ballymichael Glen, rather more than half a mile above the road, where we come on to the mass of igneous rock. After passing over several yards of yellowish, crushed, felsitic rock, which probably represents a dyke, we approach a massive, dark-grey, basic-looking rock, probably a variety of diorite. Higher up this rock appears more distinctly acid, a quartz-diorite in fact; and just below the next sharp bend in the stream an irregular, yellow granitic band, 4 to 5 yards wide, which is intrusive in the diorite, crosses the burn. Some thin and still more acid veins penetrate both rocks alike. At the next bend above is a more basic-looking rock which may be a dyke, into which coarse granite intrudes, as also into granite or granophyre of the finer variety, while a thin acid vein or elvan runs along the burn in the darker and more basic rock. At the next bend to the north the rock is more decidedly an acid-variety of quartz-diorite. Just above this is another intrusion of granite, and then the rock in the stream assumes a very massive character, weathering into large rounded masses, with marked joints inclined across the burn northward. This is a dark and coarse quartz-diorite. At the next bend to the north we come upon the main mass of light-yellowish acid granite, much jointed. The junction appears to be an intrusive one, the granite being the more recent rock of the two. W.G.

The field and petrographic evidence certainly suggests that the dioritic areas within the granite represent the profoundly altered and partially-digested remnants of a ring of basic rock, which may have been continuous with the masses of Glen Dubh on the east, and with those east of Glenloig. In the north-eastern part of the area the digested material seems to have transformed the granite to a more or less general quartz-diorite facies.

The interior contact of the granite against the breccia ring is unfortunately almost everywhere concealed beneath peat. The mapping, however (*see* map, (Plate 4)), suggests that the granite is mainly intrusive (*see,* for example. the area near Creagan Leana Muic, and west of Creag Mhòr). Furthermore, fine-grained, chilled varieties of the granitic magma are found near the contacts, as, for example, a quartz-porphyry, 60 yards north-west of summit of A' Chruach (S9440) [NR 974 340]. Nevertheless, in places, the breccia contains numerous boulders and pebbles of granite and granophyre indistinguishable from those of the outer ring, and it is therefore certain that some of the granite had solidified before some of the breccia had been formed.

Petrography

Dr. A. Harker's description of the granitic rocks of the Central Ring Complex is as follows:<ref>.Geology of North Arran, etc., (Explanation of Sheet 21), *Mem. Geol. Surv.,* 1903, p. 105.</ref>

'The *granitic rocks of the more southerly area,* forming part of the ring surrounding the volcanic vent, have many points in common with the northern granite, and especially with the finer-grained variety of that area; but there are also points of difference which are probably significant. There is the same tendency to rude micrographic intergrowths and sometimes a frankly granophyric structure, the same abundance of quartz, and sometimes very clear indications of microperthitic intergrowth in the untwinned part of the felspar. There is, however, a somewhat larger proportion of the coloured silicates, and these embrace not only biotite, often as before of allotriomorphic habit, but also green hornblende accompanying it, or even almost excluding it. Granules of sphene come in occasionally, and in some slices there are conspicuous little crystals of zircon, in addition to the minute ones enclosed here and there in the mica. This description applies not only to the rocks intrusive in the volcanic agglomerate, but also to granite pebbles contained in the agglomerate itself and therefore derived from an older rock. It is interesting to find that here, as in the Isle of Skye, the fragments in the agglomerate preserve evidence of the existence of older plutonic rocks which are not elsewhere exposed, and that these concealed rocks were of closely the same type as those subsequently intruded in the immediate neighbourhood.'

This description embraces rocks from Cnoc Dubh (S7521) [NR 977 349], a fine-grained granophyre; from the base of Creag nam Mult (S7526) [NR 950 350], where the granite is clearly intrusive into the hypersthene-gabbro of that locality; from north of Glenloig (S7527) [NR 940 350]; from the quarry in the Allt nan Dris, north of Derenenach (S7525) [NR 931 335]; from the small granite mass immediately east of Derenenach (S9480) [NR 930 330]–(S9481) [NR 930 330]; from Ballymichael Glen (S9477) [NR 930 310]; and from the head' of Benlister Burn, on the south-east side of the ring (6388). Amongst newly-collected material which may be grouped with the above are rocks from the headwaters of Glen Ormidale (S24361) [NR 982 345], (S24365) [NR 970 340], (S24368) [NR 970 340]. A feature of the whole group, which escapes mention above because of the allusive character of the description, is the relative abundance of striated felspar. With a refractive index well below that of quartz or canada balsam, and symmetrical extinction-angles up to 15°, this felspar is

nearly pure albite.

A specimen from the quarry in the Allt nan Dris, near Derenenach (S24454) [NR 931 336], has been analysed by Mr. E. G. Radley, with the result set forth in (Table 5)., 9. This analysis shows the high silica content characteristic of many Cainozoic granites of the Western Isles. It should be compared with the analyses of the northern granite ((Table 3), (Table 7)), and the quartz-felspar-porphyry of Bennan Head ((Table 6)., II). The amount of silica is practically the same in each rock, but the two last-mentioned am richer in potash relatively to soda than that of the Allt nan Dris. This rock compares pretty closely with the granophyre of the Beinn a' Ghraig ring-dyke in Mull ((Table 5)., N), in all respects save the silica, of which it possesses about 2 per cent. more than the Mull rock.

(Table 5)

	9.	N.	10.	8.
SiO_2	75.65	73.12	53.67	52.43
$A1_2O_3$	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	0.15	0.14	4.90	4.61
CaO	0.91	0.88	8.28	8.25
Na_2O	3.44	3.90	2.77	3.27
K_2O	4.26	4.67	0.80	1.08
H_2O>105°	0.40	0.24	0.23	1.64
H_2O>105°°	0.41	0.25	1.73	0.28
TiO_2	0.28	0.39	1.28	1.91
P_2O_5	0.16	0.09	0.21	0.21
MnO	0.26	0.17	0.31	0.20
CO_2	0.09	0.05	0.04	0.08
FeS_2	nt. fd.	nt. fd.	nt. fd.	0.44
(Ni,Co)O	0.02	nt. fd.	0.04	n. d.
BaO	0.03	nt. fd.	0.04	0.06
Li_2O	nt. fd.	nt. fd.	nt. fd.	0.00
Cr_2O_3	—	—	—	0.02
	100.16	100.08	100.26	99.91

9. (S24454) [NR 931 336]. Lab. No. 824. Granophyric granite of Central Ring Complex, quarry in Allt nan Dris, woo feet north of Derenenach, Arran. *Anal.* E. G. Radley.

N. (S14843) [NM 5497 3843]. Lab. No. 372. Granophyre of Beinn a' Ghraig ring-dyke, Benmore Lodge, Loch BA, Mull. *Anal.* E. G. Radley. Quoted from *Mull Memoir,* 1924, p. 20.

10. (S24455) [NR 968 353]. Lab. No. 825. Diorite of Central Ring Complex, quarry at bridge over Allt nan Calaman, at roadside, Gleann an t-Suidhe, Arran. *Anal.* E. G. Radley.

8. Quartz-gabbro of Glen Dubh, Arran. Repeated from (Table 4), p. 174.

The norms of these two rocks supply the following mineralogical comparisons. The composition of the plagioclase is computed on the assumption that all the lime in the analyses, with the exception of trifling amounts in apatite, is in the plagioclase.

	Quartz	Total feldspar	Or.	Plag.	Comp. of Plag.
Granite of Central Ring Complex, Arran	37.4	57.4	25.0	32.4	Ab_{10} An_1

Granophyre of ring-dyke, Mull	30.5	63.3	27.8	35.5	Ab_{13} An_1

The quartz-diorites and diorites involved within the granite ring are entirely similar to those already described from Glen Dubh, and are indeed included in the scope of Dr. A. Harker's account (p. 176). There is, consequently, no need for further description here. The Survey collection includes quartz-diorites and diorites from Gleann an t-Suidhe, mainly from the Allt nan Calaman (S7523) [NR 95 35]-(S7524) [NR 969 354], (S24377) [NR 969 353], (S24378) [NR 969 353] (S24379) [NR 971 351], (S24455) [NR 968 353]; from a quarter of a mile south-west of summit of Cnoc Dubh (S7522) [NR 974 346]; from a burn 500 yards east-north-east of Creag nam Mult (S7535) [NR 962 353]; and from near Glenloig (S7528) [NR 940 350], (S7533) [NR 949 352], (S24383) [NR 947 350]. The analysed rock (S24455) [NR 968 353] was selected from the darkest and most homogeneous material to be found in the Allt nan Calaman exposure. It consists of a uniform, fine-textured mixture of idiomorphic, brownish-green hornblende studded with magnetite, highly-zonal plagioclase laths ranging from labradorite to marginal oligoclase, and some interstitial quartz. A little chlorite and epidote occur as alteration products. Rarely a colourless mineral occurs very patchily in the centres of the hornblende crystals; this may be original pyroxene, but there is insufficient material for determination.

The principal feature of the chemical analysis (Table 5, 10), is its extraordinarily close resemblance to the analysis of the Glen Dubh quartz-gabbro, which is repeated for comparison in (Table 5). The discrepancies between the two analyses are mainly in silica and alumina, which are slightly higher in the diorite; on the other hand, the alkalies are lower, although the relative proportions between soda and potash are preserved. This remarkable correspondence in chemical composition may be taken as additional evidence for the view, clearly foreshadowed by Dr. A. Harker in his account of the petrography of the rocks (p. 177), that the diorites represent portions of an original gabbro ring, which have been transformed into a hornblendic rock by immersion in granite magma; and in places partially digested and assimilated with the production of quartz-diorite.

5. The late acid intrusions

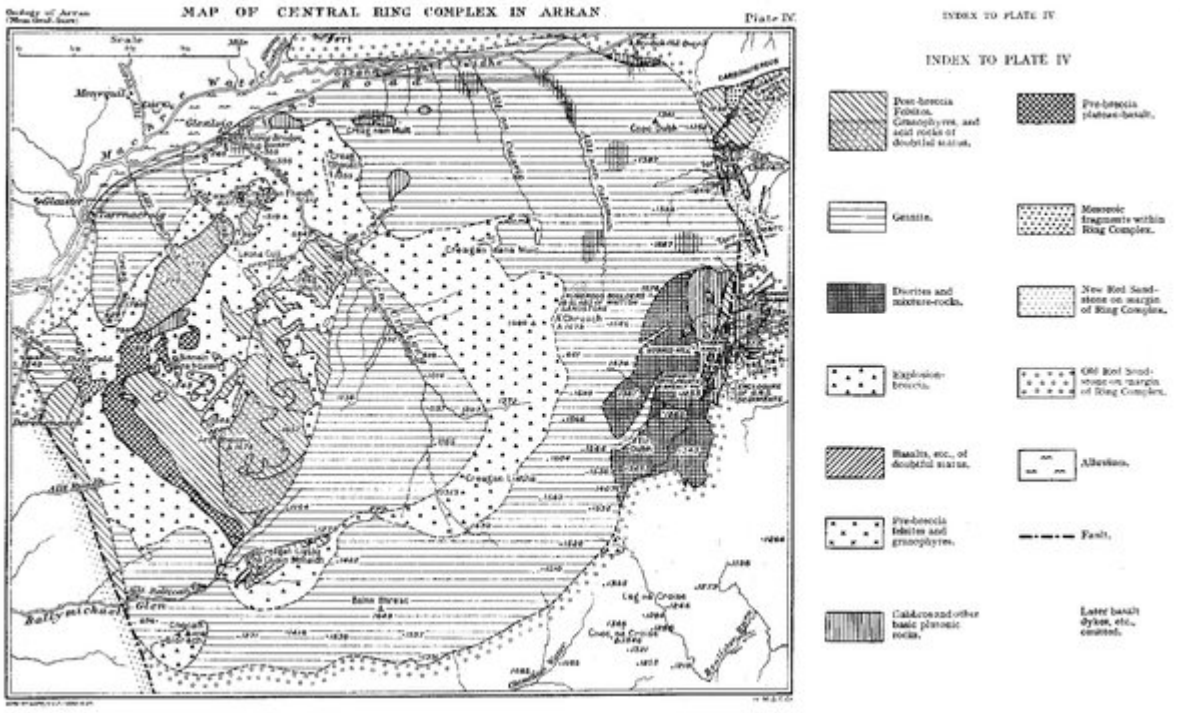
Included in this set, which is believed to represent the latest events in the history of the Central Ring Complex, are the felsite masses in and about the head of Glen Ormidale and Windmill Hill (Muileann Gaoithe), and immediately east of Derenenach,

The Windmill Hill intrusion forms a mass with an elliptical outcrop extended in a north-east to south-westerly direction for about three-eighths of a mile. On its north side it comes into contact with Carboniferous sediments; on the east it ends off bluntly against the New Red Sandstone; and on its southern flank, in the corrie at the head of Glen Ormidale, it has a steeply-dipping contact against the same formation. Its western boundary is against the elongated strip of Mesozoic sediments which extends north-eastward from the head of Glen Ormidale (*see* p. 105). The felsite is distinctly chilled against Triassic marls at this place, and the contact rock is beautifully banded and contorted. The main mass gradually thins out as it crosses the Ormidale corrie; and it is injected into the hardened quartzitic sandstones in large and small veins. In fact, the whole face of the corrie is riddled with felsitic masses, which are often hard to distinguish from the fine-grained white quartzite. A thin section (S24357) [NR 983 345], from the central headwater of the Glen Ormidale burn, 200 yards south-east of Torr Maol, shows an intimate interpenetration of quartzite by flow-banded, glassy, and felsitic veins. A specimen of the intrusion taken from the northern headwater of Glen Ormidale, north of Torr Maol (S24360) [NR 980 348] shows a cryptocrystalline base, with numerous roughly-spherical masses of very fine-grained micropegmatite, in which a number of small phenocrysts of euhedral quartz and alkali-felspar (? albite) are set. The ferro-magnesian element is represented by small moss-like groupings of bluish-green chloritic matter, which resemble some forms of riebeckite and girine.

Little is known concerning the Derenenach felsite masses. One elongated intrusion forms the western boundary of the ring complex for about a mile north-north-west from Ballymichael Glen to Derenenach. It is much crushed, and appears to have been affected by the fault which bounds the complex on this side. Immediately east of Derenenach a small boss-like mass of felsite appears to be intrusive into the above-mentioned marginal mass, and to be later than the

bounding fault (*see* map, (Plate 4)). These masses are not represented in the Survey collection.

The evidence for the age of these masses is as yet rather tenuous. The Windmill Hill felsite appears to abut against the granite ring with an intrusive contact in the headwaters of Glen Ormidale. They may be contemporaneous with the later felsitic intrusions of the Ard Bheinn focus. G.W.T.



(Plate 4) Map of Central Ring Complex in Arran.

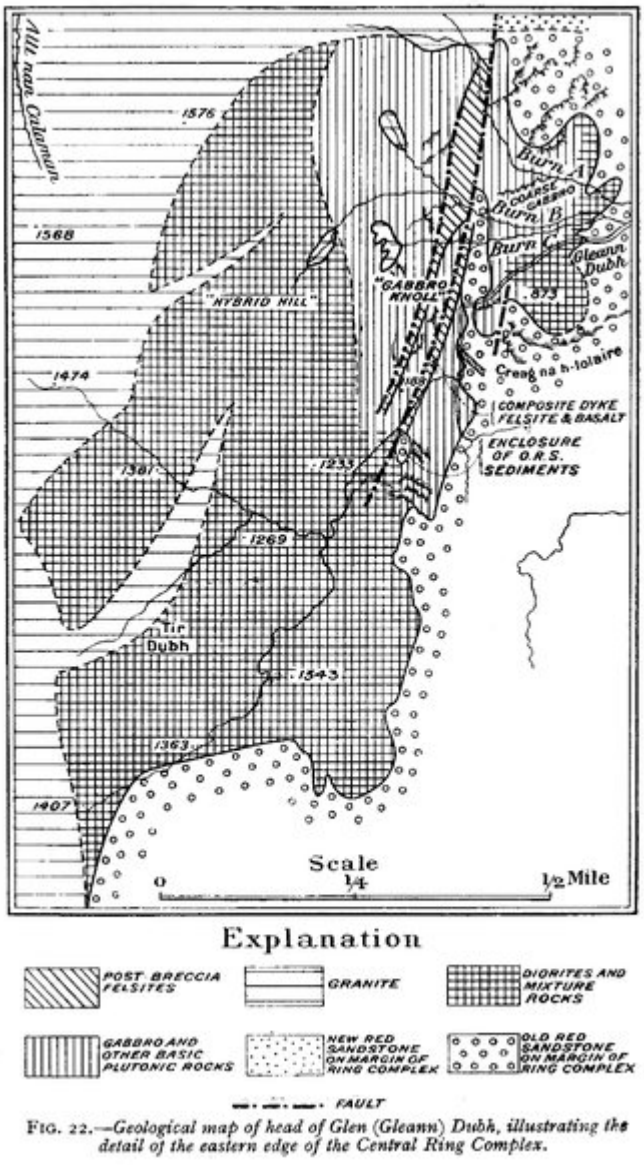


FIG. 22.—*Geological map of head of Glen (Gleann) Dubh, illustrating the detail of the eastern edge of the Central Ring Complex.*

(Figure 22) Geological map of head of Glen (Gleann) Dubh, illustrating the detail of the eastern edge of the Central Ring Complex.

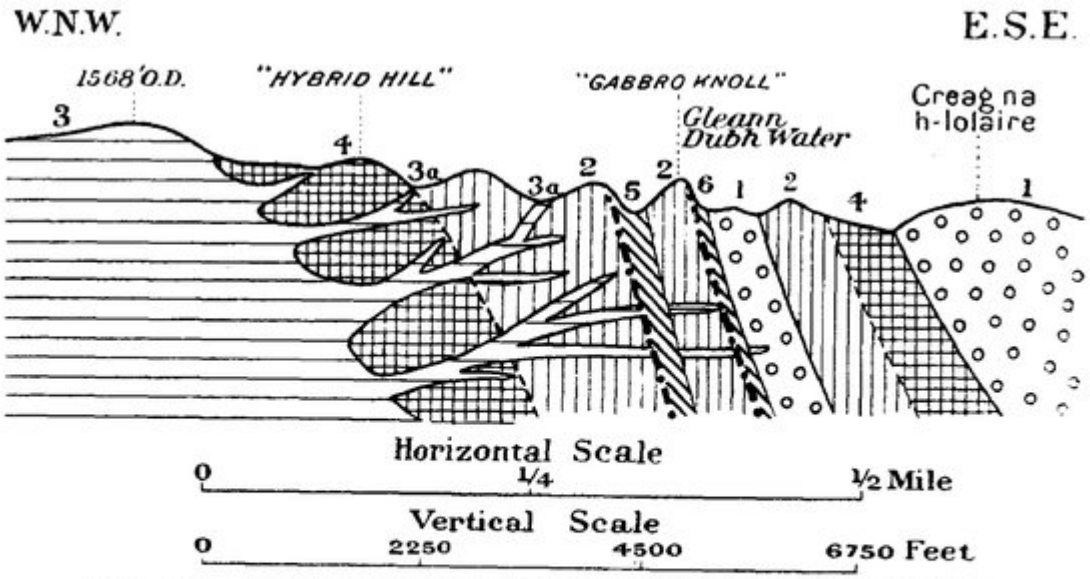


FIG. 23.—*Section across eastern edge of Central Ring Complex.*

1. *Lower Old Red Sandstone ; 2. Gabbro ; 3. Granite and granophyre, with 3a, veins and dykes ; 4. Granite-gabbro mélanges, hybrid rocks, diorite and quartz-diorite ; 5. Felsite intrusion ; 6. Fault, with composite dykes of felsite and basalt.*

(Figure 23) Section across eastern edge of Central Ring Complex. 1. Lower Old Red Sandstone 2. Gabbro 3. Granite and granophyre, with 3a, veins and dykes 4. Granite-gabbro melanges, hybrid rocks, diorite and quartz-diorite 5. Felsite intrusion 6. Fault, with composite dykes of felsite and basalt.

TABLE IV

	8.	L.	M.
SiO_2	52·43	51·32	50·04
Al_2O_3	13·50	13·96	13·32
Fe_2O_3	4·93	2·48	4·71
FeO	7·00	7·10	8·07
MgO	4·61	5·78	5·01
CaO	8·25	11·51	10·02
Na_2O	3·27	3·50	3·28
K_2O	1·08	1·16	1·08
$H_2O > 105°$ ..	1·64	1·27	1·45
$H_2O < 105°$ ..	·28	·36	·27
TiO_2	1·91	·98	2·56
P_2O_5	·21	·24	·28
MnO	·20	·34	·33
CO_2	·08	·09	·08
FeS_2	·44	nt. fd.	nt. fd.
(Ni, Co)O ..	—	nt. fd.	nt. fd.
BaO	·96	nt. fd.	nt. fd.
Li_2O	·00	nt. fd.	tr.
Cr_2O_3	·02	—	—
ZrO_2	·00	—	—
	99·91	100·09	100·50

(Table 4) [no title].

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].

TABLE III

	7	I	J	K
SiO_2 ..	74·87	76·71	72·78	75·00
Al_2O_3 ..	11·24	—	—	13·24
Fe_2O_3 ..	·34	—	—	2·52
FeO ..	1·22	—	—	—
MgO ..	·22	—	—	—
CaO ..	1·30	·47	—	·69
Na_2O ..	3·31	—	4·08	3·07
K_2O ..	5·68	—	5·18	4·33
$H_2O>105°$	·49	—	—	·80
$H_2O<105°$	·29	·22	·34	—
TiO_2 ..	·26	—	—	—
P_2O_5 ..	·09	—	—	—
MnO ..	·05	—	—	—
CO_2 ..	·49	—	—	—
FeS_2 ..	·33	—	—	—
Cr_2O_3 ..	·02	—	—	—
BaO ..	·04	—	—	—
Li_2O ..	·00	—	—	—
F	nt. fd.	—	—	—
	100·24	—	—	99·65

(Table 3) [no title].

TABLE VII

	14.	R.	15.	16.	S.	6.	17.
SiO_2	73·20	73·12	72·33	71·51	71·53	69·26	72·37
Al_2O_3.. ..	10·75	12·44	10·45	10·55	12·00	11·60	11·64
Fe_2O_3.. ..	·95	2·09	1·00	·79	2·90	1·31	1·42
FeO	1·02	1·65	2·14	2·22	2·02	2·57	1·08
MgO	·15	·14	·11	·52	·62	1·10	·52
CaO	·76	·88	1·44	1·52	2·33	2·61	1·30
Na_2O	3·78	3·90	4·09	4·12	4·27	2·08	4·15
K_2O	4·20	4·67	3·49	3·48	3·06	3·88	3·98
$H_2O > 105°$ ..	4·52	·24	4·02	4·07	·36	1·67	ign.
$H_2O < 105°$ ..	·18	·25	·16	·19	·13	1·61	4·86
TiO_2	·16	·39	·30	·33	·64	·45	—
P_2O_5	·19	·09	·16	·24	·17	·10	—
MnO	·37	·17	·50	·42	·36	·45	—
CO_2	—	·05	—	—	nt. fd.	1·76	—
FeS_2	—	nt. fd.	—	—	—	nt. fd.	—
(Ni, Co)O ..	nt. fd.	nt. fd.	nt. fd.	nt. fd.	·02	nt. fd.	—
BaO	·05	nt. fd.	·08	·08	·08	nt. fd.	—
Li_2O	nt. fd.	nt. fd.	tr.	nt. fd.	? tr.	nt. fd.	—
Cr_2O_3.. ..	—	—	—	—	nt. fd.	—	—
S	—	—	—	—	nt. fd.	—	—
V_2O_3	—	—	—	—	nt. fd.	—	—
	100·28	100·08	100·27	100·04	100·49	100·45	101·32

(Table 7) [no title].

TABLE VI

	11.	O.	12.	P.	Q.	13.
SiO_2	75·22	71·98	54·83	53·97	54·11	55·79
Al_2O_3	12·22	13·13	14·10	14·65	11·65	15·97
Fe_2O_3	2·30	1·33	3·57	3·62	2·76	12·50
FeO	·22	1·64	5·87	6·32	7·02	—
MgO	·06	·56	4·88	4·49	5·30	2·22
CaO	·84	1·15	7·90	7·98	8·77	7·06
Na_2O	2·22	2·98	2·32	2·54	2·63	2·21
K_2O	4·94	4·93	1·73	1·52	1·75	1·86
$H_2O > 105°$ ..	·52	1·38	1·23	·94	·81	) Ign.
$H_2O < 105°$ ..	·72	·39	·48	1·92	·68	∫ 2·43
TiO_2	·28	·37	·74	1·24	3·37	—
P_2O_5	·18	·19	·24	·27	·58	—
MnO	·25	·14	·37	·30	·21	—
CO_2	·03	—	1·90	·51	·05	—
FeS_2	nt. fd.	—	nt. fd.	·09	·22	—
(Ni, Co)O ..	nt. fd.	—	·03	nt. fd.	—	—
BaO	nt. fd.	tr.	nt. fd.	·04	·03	—
Li_2O	tr.	nt. fd.	tr.	tr.	nt. fd.	—
Cr_2O_3	—	—	—	—	·03	—
Cl	—	·01	—	—	—	—
S	—	—	—	—	—	·45
	100·00	100·18	100·19	100·40	99·97	100·49

(Table 6) [no title].