

6. *THE ORDOVICIAN and SILURIAN ROCKS of the KILBRIDE PENINSULA* (MAYO). By CHARLES IRVING GARDINER, M.A., F.G.S., and Prof. SIDNEY HUGH REYNOLDS, M.A., F.G.S. (Read December 20th, 1911.)

## [PLATES VI &amp; VII.]

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## I. INTRODUCTION.

THE Kilbride area with which this paper deals lies some 5 miles to the south of the Glensaul area described by us in 1910. Its limits are very sharply defined. It forms a peninsula bounded by two long inlets from the south-western corner of Lough Mask, the northern one being known as Derry Bay or Derrypark Bay, the southern as Kilbride Bay. It has a length from east to west of about  $4\frac{1}{2}$  miles, and a breadth of about a mile and a half. It ends to the west in the alluvial tract through which the Finny River runs. From this low ground the land rises rapidly to a ridge which attains its highest point at Knock Kilbride (1230 feet). Farther east is another eminence (Knocknamuck), and then the ground sinks slowly through Fox Hill to the shore of Lough Mask. The descent from the high ground to Derry Bay on the north is far steeper than that to Kilbride Bay on the south, a fact intimately associated with the geological structure of the country.

Little has been written about the geology of this area. Some

description of it is given in the Memoirs of the Geological Survey.<sup>1</sup> The igneous rocks are referred to as being everywhere felsite; the presence of ash is mentioned; and allusion is made to the finding of Llandovery fossils at several points on the southern side of the peninsula.

In the 'Annual Report of the Geological Survey for 1896' (pp. 49-51) a general account of the igneous and associated rocks of the Tourmakeady, Glensaul, and Lough Nafuoey districts is given; and, in his 'Ancient Volcanoes of Great Britain,' Sir Archibald Geikie (vol. i, 1897, p. 251) briefly alludes to the Lough Nafuoey district, but gives no details. The papers by Mr. J. R. Kilroe<sup>2</sup> 'On the Silurian & Metamorphic Rocks of Mayo & North Galway'; by Messrs. R. G. Carruthers & H. B. Maufe<sup>3</sup> on 'The Lower Palæozoic Rocks around Killary Harbour'; and by the authors of the present communication upon the neighbouring districts of Tourmakeady<sup>4</sup> and Glensaul<sup>5</sup> have some bearing upon the Kilbride district.

At the meeting of the British Association for the Advancement of Science at Dublin in 1908, a Committee was appointed<sup>6</sup> to investigate the igneous and associated rocks of the Glensaul and Lough Nafuoey districts (Galway); and, following a report on the Glensaul district presented at Winnipeg<sup>7</sup> in 1909, a preliminary account of the geology of the Kilbride peninsula was read at the Sheffield<sup>8</sup> meeting of the Association in 1910. The substance of the general account of the structure of the peninsula there given may be repeated in a slightly amplified form here.

The southern and eastern part of the peninsula consists in the main of Llandovery and Wenlock grits and flags, dipping with great regularity in a direction varying from east to south-south-east. These strata are associated with a large intrusion of lime-bostonite, some smaller ones of labradorite-porphryite, and an extensive series of small dolerite sills. Some of the beds are exceedingly fossiliferous, these being on the same horizon—Upper Llandovery—as those to which we referred,<sup>9</sup> in our paper on the Tourmakeady district, as occurring in the neighbourhood of Trean. The northern and western parts of the peninsula consist principally of a great series of igneous rocks—quartz-felsite, pillow-lavas (spilites), and coarse tufts or breccias. These rocks are clearly comparable with the igneous series of the Tourmakeady and Glensaul areas, and a further resemblance lies in their association with cherts and beds

<sup>1</sup> Mem. Geol. Surv. Ireland, Explan. Sheets 93 & 94, with part of Sheets 83, 84, & 103 (1878) pp. 114-16; also Explan. Sheet 95 (1870) pp. 43-45.

<sup>2</sup> Proc. Roy. Irish Acad. vol. xxvi, sect. B, no. 10 (1907) pp. 129-60.

<sup>3</sup> 'Irish Naturalist' vol. xviii (1909) pp. 7-11.

<sup>4</sup> Q. J. G. S. vol. lxxv (1909) pp. 104-53.

<sup>5</sup> *Ibid.* vol. lxxvi (1910) pp. 253-79.

<sup>6</sup> Consisting of Prof. W. W. Watts, Mr. H. B. Maufe, and the authors of the present paper.

<sup>7</sup> Rep. Brit. Assoc. (Winnipeg) 1909, p. 163.

<sup>8</sup> *Ibid.* (Sheffield) 1910, p. 110.

<sup>9</sup> Q. J. G. S. vol. lxxv (1909) p. 126.

containing Arenig graptolites. In the south-eastern corner of the peninsula is an area of gneissic rocks, presumably Archæan, against which the highest member of the Silurian series is faulted. At the north-eastern corner of this gneissic area a second development of the lower members of the Silurian System is met with, the dip here being northerly and easterly.

## II. THE SEDIMENTARY AND VOLCANIC ARENIG ROCKS.

Under this head we group the great series of breccias and spilites, together with a relatively small development of grits, shales, and cherts, these sedimentary beds being confined to the northern part of the district.

Only at one point have Arenig fossils been found; but we consider that we are justified in regarding the whole series of rocks alluded to above, and in addition the intrusive felsites, as of Arenig age, on account of the general resemblance which they bear to those of the Tourmakeady and Glensaul districts. There are, however, many important differences, which will be summarized in the sequel. The most marked feature of the Kilbride series is the immense development of pillow-lavas (spilites).

The general structure of the area north-west of the Silurian outcrop, and west of the great felsite-mass of Glenbeg, is difficult to make out, and there has clearly been much faulting. Throughout a belt stretching westwards along the crest of the ridge from the top of Knock Kilbride to the neighbourhood of Lough Mweelaun, the strike of the Arenig rocks is east-north-easterly, in conformity with that of the neighbouring Silurian rocks; and the same strike is met with in the rocks immediately to the west of the Glenbeg felsite. But two important faults cut these rocks off from those in the western part of our map, occupying the country between Finny and the end of Derry Bay, and throughout this part of the area the strike when ascertainable is found to be south-easterly. Of these faults, one, the exact position of which is not ascertainable, lies to the east of Lough Mweelaun and strikes in a north-north-easterly direction, meeting a second which we propose to call the Oak Island Fault: this latter lies not far west of the great Glenbeg felsite-mass, and strikes the coast to the south of Oak Island.

### (a) The Sedimentary Arenig Rocks.

(1) A small but interesting exposure is seen at a point nearly half a mile north-east of the top of Knock Kilbride. Here thinly-bedded black cherts, with shaly partings, are overlain by quartzose grits. Unfortunately, the exposure is entirely surrounded by peat, and consequently the relations of the rocks are not clear. The strike, however, is east-north-east, in conformity with that of all the Arenig rocks (so far as it is possible to observe this point) east of the Oak Island Fault. The cherts and grits probably form

a band interbedded with the spilites or breccias, patches of which protrude through the peat at various points in the neighbourhood.

In the cherts and shales we found the following graptolites :—

*Didymograptus extensus* Hall.

*Didymograptus protohifidus*=*nanus* Lapw. (common).

*Tetragraptus* sp.

Also a single specimen of what Dr. H. Woodward considers to be a new species of phyllocarid crustacean; this is described in the Appendix (p. 99). The graptolites, which have been kindly examined by Miss G. L. Elles, D.Sc., indicate that the Kilbride beds belong to the same horizon as the graptolite-bearing beds of Lettereen in the Glensaul area, that is, the zone of *Didymograptus extensus*.

Though radiolaria are not so well seen in the cherts from Kilbride as in those from Tourmakeady and Glensaul, they are undoubtedly present in a rock (89)<sup>1</sup> from opposite Oak Island.

(2) A band of grit some 15 feet thick occurs among the spilites south of Oak Island; it is truncated on the east by the Glenbeg felsite, and bisects the more westerly of the two smaller felsitic intrusions.

The narrow sedimentary bands, which occur in places interbedded among spilites or breccias, are best described with the rocks with which they are associated.

### (b) The Breccias.

In the western part of the Kilbride district, as in that of Glensaul, coarse breccias play a prominent part. In the country west of the Glenbeg felsite-mass bands and areas of breccia are associated with the spilites. East of the Oak Island Fault, and to a less-marked extent south-east of Lough Mweelaun (where the strike is west-south-westerly), and north and north-west of Lough Mweelaun (where the strike is south-easterly), the breccias form fairly well-marked bands; while in the district north and west of Finny the breccias occur in more irregular masses. It is possible that certain of these breccia-masses may mark the position of vents, as, for instance, the great mass in the south-western corner of the district; but of this we are not confident. South and west of Lough Mweelaun a very coarse breccia stands up in great ice-worn elevations, in a very striking and characteristic fashion.

The breccias are of two distinct types: in the one, and far the commoner case, the fragments are of felsite, in the other of spilite. As a rule, the two varieties are not intermingled, but sometimes they are. The felsitic type of breccia, though generally distributed, is especially prevalent in the district west of Lough Mweelaun.

In addition to these two types of breccia, both of which are of

<sup>1</sup> These numerals in parentheses indicate the localities marked on the map. (Pl. VI) where specimens were collected.



explosive origin, flow-breccias are not unfrequently met with in the spilites.

The coarseness of the breccias renders it, as a rule, impossible to ascertain their dip and strike, but occasionally interbedded fine bands give the direction: as, for example, at a point 400 yards north-east of Lough Mweelaun, a band of grit interbedded in the breccia has a north-westerly and south-easterly strike, while 250 yards west-south-west of this point very thin bands of chert and fine ash strike in the same general direction.

The numerous little patches of breccia mapped among the spilites may often be larger than is indicated in the map, the ground being much obscured by peat. An important feature in which the Kilbride district differs from those of Tourmakeady and Glensaul is the complete absence of limestone-breccias—in fact, of calcareous Ordovician rocks of all kinds.

It is noteworthy that the breccias to the south-west of Lough Mweelaun show the introduction of a considerable amount of chert, which has been deposited round the felsite-blocks so as sometimes to enclose them completely. This fact is of importance, in connexion with the method of introduction of chert among the spilites. No chert-fragments were noticed among the tuffs of the Kilbride district, although such fragments are common among the limestone-breccias of the Tourmakeady district.

### (c) The Spilites (Pillow-Lavas).

In our earlier paper on the rocks of the Tourmakeady district, we described as intrusive certain spilites—fine-grained rocks of andesitic character, and quoted (Q. J. G. S. vol. lxxv, 1909, p. 136) Dr. J. S. Flett, who, subsequently to the reading of the paper, kindly examined the rocks, as pointing out their strong resemblance in microscopical structure to certain pillow-lavas. In the Tourmakeady district these rocks, which are very poorly exposed, apparently form small intrusions and show no pillows. But rocks of the same type exhibit a vastly greater development in the Kilbride area, forming its most remarkable feature; and at very numerous points a pillow-structure is finely seen, the diameters of the pillows generally varying from 18 inches to about 3 feet.

Spilites cover a larger area than any other rock in the Kilbride peninsula. Commencing at a point near the top of Knock Kilbride, they extend westwards in a broad band, interrupted in places by patches of breccia, to the Finny River, where their outcrop has a width of half a mile. The rocks between the Oak Island Fault and the felsite-mass of Glenbeg are also predominantly spilites, and are here interbedded with breccia and with a band of grit which bisects the westernmost of the two smaller felsite-masses in this area.

Although, as a rule, there is no clear line of strike to be observed in the spilites, this is commonly obtainable from the interbedded

bands of breccia, and in several cases from the trend of the bands of pillows. Less frequently, information is afforded by the associated bands of sediment, as in the following five cases:—

- (i) The spilites west of the Oak Island Fault are underlain by a narrow band of grit, seen immediately to the west of the more westerly of the two small felsite-intrusions.
- (ii) Half a mile east-north-east of Lough Mweelaun bands of chert occur interbedded with spilites.
- (iii) A band of chert, occurring about 150 yards north-west of Lough Mweelaun, close to the boundary of the lower spilite-band and overlying breccia, strikes parallel to the line of junction between the two rocks and proved, like some of those of the Glensaul area, to be fine silicified tuff.
- (iv) About 350 yards east-north-east of the exposure just mentioned a band of grit is seen.
- (v) Chert and crushed shales occur in the bed of the stream a third of a mile north-north-west of Finny Chapel, along the line of fault between the spilite and the felsite.

In the area west of the Oak Island Fault and west of the Lough Mweelaun Fault there are again large areas of spilite.

The spilites are green or purple rocks, generally dark but sometimes of a light colour. They are very commonly vesicular, often markedly so, and when the pillows are exposed in section they are frequently seen to be more vesicular round the margin than towards the centre, or to have bands of concentrically-arranged vesicles (see Pl. VII, fig. 1). In many cases, however, the vesicles are irregularly scattered throughout. The most readily accessible spot where the pillows are well seen is near where the rough track to Derrypark leaves the Finny road. Fairly good examples occur in the enclosure behind the priest's house at Finny. Pillows are also finely seen at a number of points along the northern outcrop of the broad band of spilite which stretches north-westwards from near Lough Mweelaun, and east and west of the prominent dolerite-dyke which runs up the hillside about a third of a mile south-east of this Lough. Here the pillows are intimately associated with spilite-breccia—a clear case of flow-brecciation. Such brecciation, in this case unaccompanied by pillow-structure, is well seen at a spot on the left bank of the stream a third of a mile north-north-west of Finny Chapel.

An important feature, in which these pillow-lavas resemble those of the Ballantrae district, is their close association with chert, which is very frequently plentiful. The method of occurrence varies: as a rule, the chert forms a series of irregular strings and patches (see Pl. VII, fig. 2). But it may occur filling the spaces between the pillows, or between spheroidal masses of lava isolated by jointing, or else forming a more or less rectangular network around brecciated fragments; while, very rarely, a relatively large mass of chert is found occupying the centre of a spheroid.

A careful examination of the chert-masses described above leads us to the conclusion that they are all the product of deposition

subsequent to the consolidation of the rocks with which they are associated, and that the great majority of them are due to infiltration. One of the best spots for observing these varieties of chert is near the point where the rough track to Derrypark leaves the Finny road.

Allusion may here be made to certain large veins or masses of red chert, or of quartz, which may be observed in various parts of the district. The following are the most important exposures :—

- (i) A band about a quarter of a mile long and some 3 feet thick strikes in a north-westerly direction between the breccia and spilite, a third of a mile south-west of Lough Mweelaun. This runs parallel to the dolerite-dyke (120).
- (ii) A mass appears through the peat, a third of a mile north-east of the top of Knock Kilbride.
- (iii) A patch surrounded by spilite is found half a mile due west of the top of Knock Kilbride.
- (iv) Much red chert occurs to the west of the dolerite dyke (137), where the latter traverses breccia and the basal Silurian conglomerate.

At one point only has a variolitic structure been observed in the spilites: this was at a spot (111) about a quarter of a mile north of Lough Mweelaun, where the spilite rests upon the breccia.

### III. THE SILURIAN ROCKS.

#### (a) The Main Outcrop.

As has been already mentioned, except for an area of gneiss, the whole of the southern and eastern part of the Kilbride Peninsula is formed of Silurian strata and their associated intrusive rocks. Except in the Barnarinnia area, between Bird Hill and St. Bridget's Well, which requires separate treatment, the Silurian strata have a general dip varying from east to south-south-east. At the northern end of the outcrop, east of Knocknamuck, the dip is easterly or east-south-easterly; but, south-west of the Kilbride burial-ground, it becomes south-easterly and then south-south-easterly, this direction being maintained until the area ends at the Finny River.

Although careful mapping shows that the outcrop is shifted by numerous cross-faults, the general succession is perfectly easy to ascertain, and is as follows, in descending order :—

<i>Thickness in feet.</i>		
WENLOCK.....	6. Doon Rock Grits .....	2000 seen.
? TARANNON SHALE	5. Purple sandy shale.....	75
(equivalent)	{ 4. Finny School Beds (calcareous flags).....	600
	{ 3. Annelid-Grits .....	900
LLANDOVERY.....	{ 2. Red sandstone .....	700
	{ 1. Basal conglomerate .....	75

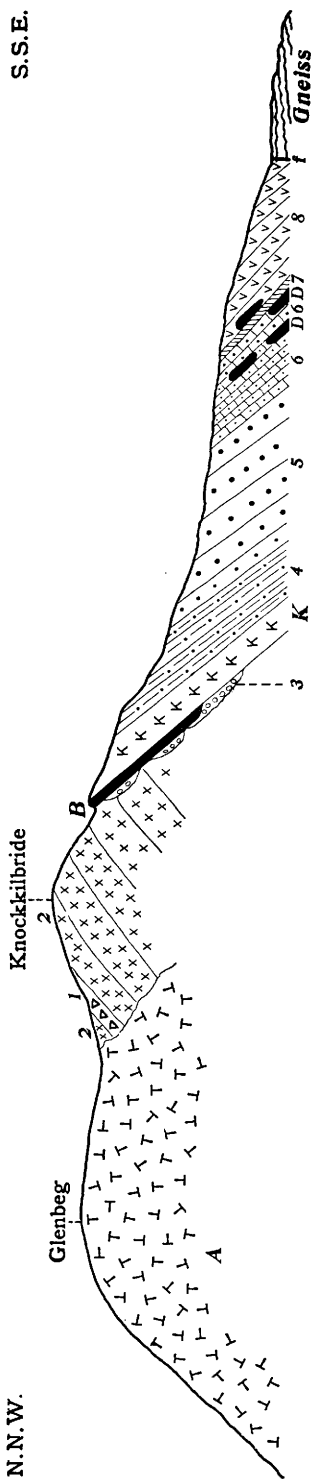
The thicknesses are very variable, and the maximum observed in each case is given.

Fig. 1.—Section through Knock Kilbride. (Scales, horizontal: 4 inches=1 mile; vertical: 1 inch=about 1,000 feet.)

N.N.W.

Knockkilbride

Glenbeg



1 = Breccia } Arenig  
2 = Spilite } Series.

3 = Conglomerate  
4 = Red Sandstone  
5 = Anneld-Grits  
6 = Calcareous Flags  
7 = Purple sandy shales  
(Finny School Beds)

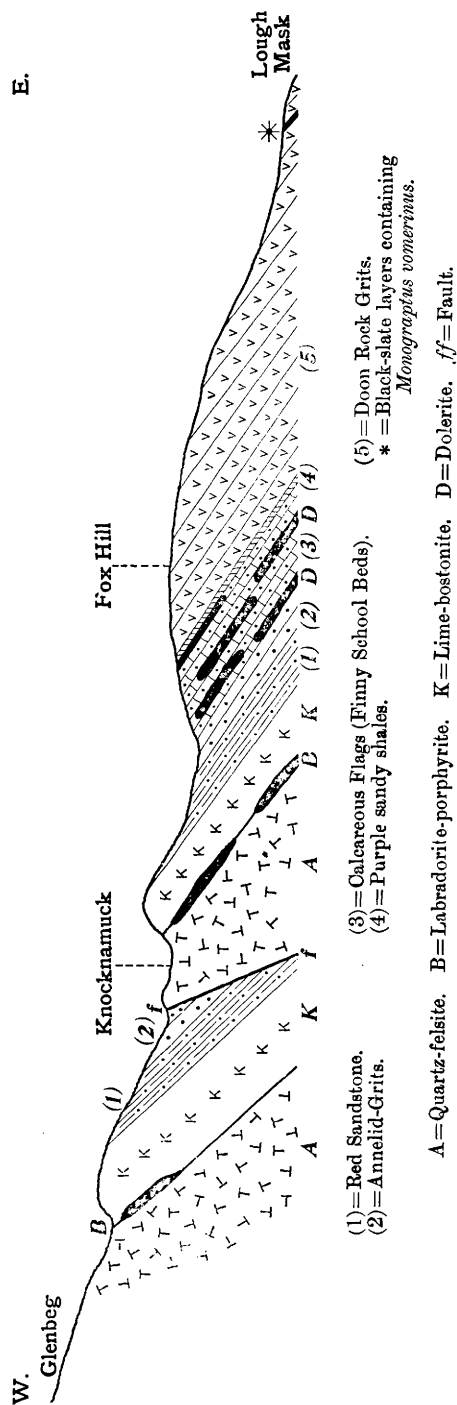
Llandoverly  
Series.

8 = Doon Rock Grits { Wenlock  
Series.

A = Quartz-felsite,  
B = Labradorite-porphryrite,  
K = Lime-bostonite,  
DD = Dolerite sills,  
f = fault.

Gneiss

Fig. 2.—Section through Fox Hill. (Scales, horizontal: 4 inches=1 mile; vertical: 1 inch=about 200 feet.)



### (1) The Basal Conglomerate.

The oldest Silurian rock is a coarse conglomerate, which is very imperisistently exposed. It crops out at several points when it occurs in juxtaposition to specially hard rocks, such as the coarse porphyrite and the dolerite dyke a third of a mile south-east of Lough Mweelaun; but the exposures are relatively few, and the conglomerate frequently gives rise to a narrow tract of smooth grass between the rugged outcrop of the breccias on the north, and of the coarse porphyrite or lime-bostonite on the south. The best locality to observe the conglomerate is in the neighbourhood of the dolerite dyke just mentioned, and for about a quarter of a mile to the east thereof. In the immediate neighbourhood of the dyke the conglomerate is seen in close relationship to the coarse Arenig breccia, and at one point seems to dip below it; the explanation is probably that here the upturned base of the conglomerate rests upon a very uneven surface of breccia. The pebbles of the conglomerate, which are thoroughly well rounded, may reach a length of 10 inches, and consist chiefly of pink quartzite, but include also granite, felsite, quartz, and chert.

### (2) The Red Sandstone.

This is a somewhat current-bedded sandstone, very uniform in character, and with its component quartz-grains cemented together by ferric oxide. It is exposed all along the southern slopes of the Knock Kilbride ridge from near Finny Chapel to the eastern slopes of Knocknamuck. With the exception of an ill-preserved coral, no fossils have been found in it. It occasionally becomes conglomeratic, and may then include well-rounded pebbles of red quartzite rather larger than a hen's egg. In rare cases it includes small patches of red shale. Only at a single point, a spot north of Kilmore, have we found it penetrated by one of the dolerite dykes which are so abundant in some of the overlying rocks. The maximum width of outcrop (about 300 yards) is met with east of the summit of Knock Kilbride; at Kilmore the width of outcrop is reduced to about 100 yards.

### (3) The Annelid-Grits.<sup>1</sup>

The red sandstones are overlain by yellowish or reddish-purple grits, which very frequently have the bedding-planes covered by numerous slight elevations rather less than a quarter of an inch in diameter, which are seen in longitudinal section to be filled-up tubes. The rock closely resembles the Serpulite-Grit of the Durness area. The yellowish and purple grits pass up into a series

<sup>1</sup> The occurrence of these Annelid-Grits is mentioned in the Annual Rep. Geol. Surv. for 1896 (1897) p. 50, where they are stated to resemble the 'pipe-rocks' in the Sutherland quartzite. The age of all these Silurian deposits is stated, however, to be Wenlock.

of very hard white grits, occasionally containing quartz-pebbles. The beds are readily recognized in the field. They are overlain by flaggy sandstones which are sometimes seen, where weathered, to be highly fossiliferous. We obtained the following fossils from exposures north and north-west of the Doon Rock:—

<i>Lindstræmia bina</i> Lonsd.	<i>Chonetes striatella</i> Dalm.
<i>L. subduplicata</i> var. <i>crenulata</i> M'Coy.	<i>Pentamerus oblongus</i> Sow.
<i>Palæocyclus preacutus</i> (?) Lonsd.	<i>Cælospira hemispherica</i> Sow.
<i>Streptelasma elongatum</i> Phill.	<i>Illænus barriensis</i> Murch.
<i>Cyathophyllum</i> (?) sp.	<i>I. maccallumi</i> Salt.
<i>Heliolites interinctus</i> Linn.	<i>Phacops elegans</i> Sars & Beck.
<i>Favosites aspera</i> d'Orb.	<i>Calymene blumenbachi</i> (?) Brongn.
<i>F. forbesi</i> (?) M.-Edw.	<i>Encrinurus punctatus</i> Brunn.
<i>Aulopora</i> sp.	<i>Proetus latifrons</i> (?) M'Coy.
<i>Orthis calligramma</i> Dalm.	<i>Beyrichia klædeni</i> (?) M'Coy.
<i>O. rustica</i> var. Sow.	<i>Tentaculites anglicus</i> Salt.
<i>O. crassa</i> Lindstr.	<i>Ctenodonta anglica</i> d'Orb.
<i>O. elegantula</i> Dalm.	<i>Horiotoma globosum</i> Sow.
<i>O. equivalvis</i> (?) Dav.	<i>Loxonema</i> sp.
<i>Leptæna rhomboidalis</i> Wilck.	<i>Orthoceras</i> (?) sp.
<i>Camarotoechia llandoveriana</i> (?) Dav.	Crinoid stem-joints.
<i>C. stricklandi</i> (?) Sow.	

*Encrinurus punctatus* is locally very abundant.

The grits pass up into the Finny School Beds (4).

#### (4) The Finny School Beds—Calcareous Flags.

These highly fossiliferous beds form one of the most interesting features of the Silurian development, not only in the Kilbride Peninsula, but throughout the country immediately south-west and west of Lough Mask. They are dark-grey fissile flags, much used for building purposes, and are frequently quarried. In the Kilbride Peninsula their outcrop extends in an east-north-easterly direction from near Finny School to a point north of the Doon Rock, and then north-north-eastwards over the shoulder of Fox Hill and down to the shore of Derry Bay. They include two profusely fossiliferous horizons. The lower one is crowded with corals, such as *Favosites*, *Halysites*, *Heliolites*, and *Lindstræmia*, which often cover large slabs of rock and present a remarkable appearance. These beds are well seen at many points, as on the north and west of the Doon Rock, and at a small promontory east of Knocknamuck. In some cases the massive corals are enclosed in calcareous concretions, and this probably was formerly the case with them all; but, as a rule, the rock has been almost completely decalcified. At a somewhat higher level is the second highly-fossiliferous horizon, a bed crowded with brachiopods, chiefly *Orthis calligramma*, which occurs in innumerable large and singularly perfect specimens. This bed is well exposed near the northern shore-line, a short distance east of the outcrop of the coral-bed. The complete list of fossils from the Finny School Beds is as follows:—

*Lindstræmia bina* Lonsd.  
*L. subduplicata* M'Coy.  
*L. subduplicata* var. *crenulata* M'Coy.  
*Palæocyclus* sp.  
*Ptychophyllum patellatum* Schloth.  
*Streptelasma elongatum* Phill.  
*Cyathophyllum* sp.  
*Heliolites megastoma* M'Coy.  
*H. murchisoni* M.-Edw.  
*H. interstinctus* Linn.  
*Propora tubulata* (?) Lonsd.  
*Plasmopora petaliformis* Lonsd.  
*Halysites catenularia* Linn.  
*H. escharoides* Lamk.  
*Favosites gothlandica* Foug.  
*F. forbesi* M.-Edw.  
*F. bowerbanki* (?) M.-Edw.  
*F. aspera* D'Orb.  
*F. cristata* (?) Blum.  
*Favositella* sp.  
*Cænites intertextus* Eichw.  
*Thecia swinderenana* Goldf.  
*Lingula parallela* (?) Phill.  
*Orthis calligramma* Dalm.  
*O. elegantula* Dalm.  
*O. rustica* Sow.  
*Orthotetes pecten* Linn.

*Chonetes striatella* Dalm.  
*Leptæna rhomboidalis* Wilck.  
*Plectambonites transversalis* Wahl.  
*Wilsonia wilsoni* Sow.  
*Camarotæchia llandoveryana* (?) Dav.  
*Pentamerus undatus* Sow.  
*P. oblongus* Sow.  
*Celospira hemispherica* (?) Sow.  
*Spirifer plicatellus* Linn.  
*Atrypa reticularis* Linn.  
*Atrypina barrandei* Dav.  
*Meristella* cf. *angustifrons* M'Coy.  
*Fenestella* sp.  
*Pterinea subfalcata* Conr.  
*Modiolopsis* sp.  
*Ambonychia striata* var.  
*Triblydium* sp. nov.  
*Orthoceras ludense* Sow.  
*Cyrtoceras approximatum* Sow.  
*Gomphoceras æquale* (?) Blake.  
*G. imbricatum* Barr.  
*G.* sp.  
*Beyrichia klædeni* M'Coy.  
*Trinucleus* sp.  
*Proetus latifrons* M'Coy.  
*Encrinurus punctatus* Brunn.  
 Crinoid stems.

The most noteworthy feature in the foregoing list is the occurrence of *Trinucleus* in Llandovery strata. The specimen was not found actually in place, but was collected from a block built into a wall. The matrix is precisely that of the Llandovery rocks of the neighbourhood, and the following fossils were collected from the same block:—*Lindstræmia subduplicata* var. *crenulata*, *Favosites forbesi*, *Spirifer plicatellus*, *Leptæna rhomboidalis*, *Pterinea subfalcata*, and *Encrinurus punctatus*.

#### (5) The Purple Sandy Shale.

This narrow band of shale is remarkably persistent throughout the whole outcrop, from a point north-east of the Doon Rock westwards to the Finny River; and, owing to the readiness with which it could be recognized, it proved of considerable service in mapping. From the neighbourhood of the Kilbride burial-ground northwards no permanent exposure of the shale occurs. It was exposed, however, in 1911, in a trench immediately to the west of the Kilbride burial-ground, and fragments occurring on the beach north of Foxhill indicate that it here strikes the shore-line. No fossils were found in these shales, despite prolonged search.

#### (6) The Doon Rock Grits.

These massive grits attain a greater thickness, and cover a larger area than any other Silurian formation in the district. They are well seen along the southern shore of the peninsula for about a mile to the west of the gneiss, whence they run north-eastwards past the Doon Rock to Kilbride Church. They also form Fox Hill



and the entire eastern and northern shores of the peninsula in the neighbourhood of that hill. Bands of them strike with great persistence through the woods of Barnarinnia. The lower beds are in the main grey quartzose grits; but fine dark grit-bands also occur in the strip of ground that extends from Kilmore to Kilbride Church.

North of Kilbride Church the outcrop of the grit widens greatly; this is due partly to a lower dip, but chiefly to the upper beds being cut out by faulting in the Kilmore-Kilbride exposure. The northern shore-line yields good exposures, and the grit-bands succeed one another with great regularity. Occasionally, however, there is evidence of disturbance in the form of bands of breccia, and about 200 yards short of the extreme point there is some folding. At the point the grit-bands are separated by very thin partings of black shale, in which numerous fragments of badly preserved graptolites have been found. Among these Miss Elles has determined *Monograptus vomerinus* Nich. and *M. vomerinus* var. *gracilis* Elles & Wood. These beds are overlain south of the point by grits, with occasional large calcareous concretions, these being the highest beds in the district.

Doon Rock Grits are also exposed along the eastern coast-line almost as far south as Kilbride Rock, and in various scattered exposures to the west of this line of coast.

### (b) The Barnarinnia Area.

Reference to the map (Pl. VI) will show that the south-eastern portion of the Kilbride peninsula is occupied by gneissic rocks, against which the Silurian strata with a southerly and easterly dip are faulted. From the shore of Kilbride Bay to a point about a third of a mile north-east of the Doon Rock, Doon Rock Grits with a south-easterly dip are faulted against the gneiss; but farther east the other members of the Silurian series, with the exception of the basal conglomerate, are all met with, the lime-bostonite being also present. These rocks, which have in the main a northerly dip, appear to represent part of the southern limb of a big syncline, the northern limb of which is represented by the main Silurian outcrop. They are, however, much faulted, and are swung out of their normal line of strike. The badness of the exposures makes mapping very difficult, and it is uncertain whether the lowest member (the lime-bostonite) rests upon the gneiss or is faulted against it. It appears that four cross-faults traverse these rocks and the adjacent gneiss, dividing the Silurian strata into four blocks. In the two westerly blocks lime-bostonite, Red Sandstone, Annelid-Grits, and Calcareous Flags are all exposed, but the Red and Purple Shales were not detected. In the third block, counting from the west, only the lime-bostonite and the Red Sandstone were seen. In the easternmost band the Red and Purple Shale was exposed at two points (as indicated on the map). In the western exposure the normal northerly dip occurs, but in the

eastern exposure on the small peninsula opposite Kilbride Rock the dip of the exposed rocks is southerly. We regard this as a local inversion.

On Kilbride Rock the Calcareous Flags are seen, and we have thought it best to map them to the south of the red-shale outcrop on the mainland, despite the fact that they have not been detected there, and although certain large blocks doubtfully *in situ* appear to bear a greater resemblance to the Red Sandstone.

The greater part of the area between Bird Hill and Kilbride Rock is occupied by a fine development of the Annelid-Grits, which show the characteristic tubes probably as well as anywhere in the Kilbride Peninsula. The rocks betray signs of disturbance, and discordant dips are noted. In the neighbourhood of Bird Hill the Annelid-Grits are faulted against lime-bostonite and red sandstone, which strike in a north-north-easterly direction.

#### IV. FIELD-RELATIONS OF THE INTRUSIVE IGNEOUS ROCKS.

##### (a) The Felsites.

Felsite is intruded only in the Arenig rocks, for at Knocknamuck (the only place where it is found in contact with the Silurian sediments) the junction is almost certainly a faulted one; and west of Knocknamuck lime-bostonite has been intruded at the base of the Llandovery strata, separating them from the felsite on which they were doubtless originally deposited. Felsite occurs principally in one enormous mass of very coarsely-quartzose rock, which stretches along the southern shores of Derrypark Bay from Knocknamuck to above Red Island. Although it does not form the summit of Knock Kilbride, the highest point in the area, it gives rise to some of the steepest and most rugged country. Two small masses of the same type of felsite, each having a length of some 250 yards, lie to the west of the main mass, the more westerly being bisected by a band of grit and cut off on the west by the Oak Island Fault.

Three very small intrusions of the somewhat coarsely-quartzose felsite penetrate the spilites or breccias near the top of the watershed south-east of Lough Mweelaun; while two other small intrusions occur on the borders of the breccia and spilite a third of a mile south-west of this Lough.

Felsite of a type somewhat different from those just mentioned, and devoid of conspicuous quartz-crystals, forms Red Island and a narrow strip on the shore south and west of it. A mass of felsite, about 300 yards long and 200 yards broad, occurs north of Finny: it is of a type similar to the felsite of Red Island.

### (b) The Lime-Bostonite.<sup>1</sup>

A much-faulted band of this rock extends for nearly 3 miles from the Finny River to Knocknamuck, where it is faulted against felsite. A second band, which appears to be faulted off from the northern end of the main band, extends along the eastern base of Knocknamuck down to the shore of the lake. The southern and western boundaries of this latter band are formed by faults. In the Barnarinnia area four small patches of lime-bostonite occur. Wherever the lime-bostonite occurs throughout the district, it is overlain by red sandstone. The most noteworthy feature of the lime-bostonite is its remarkable variability in width of outcrop. South of the summit of Knock Kilbride the outcrop is only some 25 yards wide; while, in the neighbourhood of the labradorite-porphyrte intrusion south-east of Lough Mweelaun, the width increases to about 275 yards. This remarkable variation in width of outcrop depends mainly on variation in thickness, not on difference of dip. The maximum thickness is about 600 feet. The lime-bostonite is a very resistant rock, and frequently stands up forming steep crags. In view of the marked variation in the thickness of the lime-bostonite, its non-association with tuffs, and the absence of evidence in this or any other Irish area (with the exception of the Clogher-Head district of Kerry) of the existence of volcanic rocks of Silurian age, it seems clear that the lime-bostonite, like the coarse porphyrite, is a sill intruded at the base of the red sandstone. It is noteworthy that the line of least resistance followed by the intrusions was not always that of the unconformity, as the basal Silurian conglomerate, where it is seen, lies beneath the lime-bostonite.

### (c) The Labradorite-Porphyrte.

This rock is entirely unrepresented in the Glensaul and Tourmakeady areas. It forms four intrusive masses, all of which occur in close relation to the lime-bostonite and near the base of the Silurian strata. The principal intrusion is a sill, having a probable thickness of about 100 feet, which occurs immediately south of the top of Knock Kilbride. It strikes north-east and south-west, and can be followed with slight breaks for rather over half a mile. About 300 yards from its south-western end it is interrupted by a fault, which alters its strike from south-west to south-south-west. The north-eastern end is also separated by a fault from the main mass. A second band of porphyrite of about the same thickness, having a length of about a third of a mile, commences about 500 yards to the west of that just described. It resembles the first band in its relations to the other rocks, and in the fact that it is shifted by a fault. It is intersected by a dolerite dyke.

<sup>1</sup> [As British writers seem to confine the term *keratophyre* to lavas, we have thought it advisable to call this rock a *lime-bostonite*, especially as it is so similar both chemically and microscopically to the *Abercastle bostonite*.—*C. I. G. & S. H. R., Feb. 16th, 1912.*]

A third band can be traced for some 250 yards in a north-north-easterly direction along the eastern base of Knocknamuck. All these three bands are clearly sills. A fourth, but much smaller, intrusion occurs at the western end of Knocknamuck. These sills are all on the same horizon.

#### (d) The Dolerites.

Thirty-three dolerite intrusions have been mapped, and it is probable that others may not have been detected. Of these, seventeen are in the Calcareous Flags (Finny School Beds), and seven in the overlying Doon Rock Grits. Five occur in the spilites, two in the breccia, and one in the Red Sandstone; lastly, a dyke starting in the breccias penetrates the basal Silurian conglomerate and one of the labradorite-porphyrite sills ending in the bostonite. The great majority of these intrusions occur in the area north and west of the Doon Rock.

The dolerites are readily divided into two groups: a larger group, the strike of which ranges from west-south-west to south-south-west; and a smaller group striking south-east or south-south-east. All these rocks are dark green or grey on the freshly broken surface, and weather to a rusty brown.

Group (a). Those with a west-south-west to south-south-west strike.—The great majority of these occur in the Calcareous Flags and overlying grits, especially in the region west of the Kilbride burial-ground and north of the Doon Rock; none were met with in the western part of the outcrop of these rocks nearer Finny. These intrusions, which vary in length from a few yards up to some 300 yards, are probably all sills. Their thickness is inconsiderable, 35 feet being probably the maximum, and they have not produced any appreciable alteration in the adjacent strata. In rare cases doleritic intrusions belonging to group (a) are met with in rocks other than the Calcareous Flags and grits. Thus, one occurs in spilite a quarter of a mile south-west of the top of Knock Kilbride; a second in breccia half a mile west-south-west of the same point; and a third in red sandstone half a mile north-east of Finny School.

Group (b). Those with a south-easterly or south-south-easterly trend.—These are in the main dykes, not sills, and occur principally in the spilite. They are far less numerous than group (a). About 300 yards south-east of Lough Mweelaun a dyke 8 feet wide is seen running up the hillside, which is here very steep. Being covered with white lichen, it contrasts strongly with the other rocks and forms a prominent feature. It is intruded into spilite, and shows well-marked chilling at the edges.

On the southern side of the ridge, almost on the line of strike of the dyke just described, occurs another equally well-marked one, which is particularly interesting on account of the variety of rocks

that it intersects. Commencing in breccia, it traverses the basal Silurian conglomerate and a labradorite-porphyrite sill ending in lime-bostonite. This dyke, like that just described, is about 8 feet wide, and shows marginal chilling.

Both dykes strike south-south-eastwards, and may really be part of the same intrusion.

A third intrusion occurs about half a mile north of Finny School, and runs for some 300 yards in a north-westerly direction between spilite and breccia, parallel to a very large red quartzose vein; whether this is a dyke or sill is not clear. Two small intrusions of similar rock are seen near Finny, the one in spilite at the western angle of the wood north of Finny Chapel, the other in coarse breccia a third of a mile north-west of the village. Another small intrusion occurs in spilite, about 800 yards west-north-west of Knock Kilbride.

## V. PETROGRAPHICAL DETAILS.

### (a) The Felsites.

The great quartz-felsite intrusion which extends westwards from Knocknamuck consists of a well-marked rock, much resembling those that form the 'green and brown' felsite-intrusions of the Tourmakeady district and the great sill of the Glensaul district. It is characterized by large crystals of quartz which in hand-specimens often show crystal faces, embedded in a matrix usually of a reddish-purple colour, but becoming yellowish-green near the western border of the mass. Few sections were cut of this rock, but these showed an abundant felsitic ground-mass, through which were scattered crystals of quartz, often strongly corroded, and a few much-weathered feldspars. The last-named include both orthoclase and plagioclase, the plagioclase, as pointed out by Dr. Flett, being often albite. The specific gravity of four specimens of this rock gave an average of 2.65.

West of this great intrusion are two smaller masses of the same rock, which, it can scarcely be doubted, have (or once had) a subterranean connexion with the larger mass. A section taken from the more westerly of these two masses shows a still further resemblance to the intrusive felsites of Glensaul and Tourmakeady, in the presence of numerous pseudomorphs either entirely in a green chloritic mineral, or partly in this, partly in calcite; many of the green pseudomorphs are certainly after rhombic pyroxene. This rock has a specific gravity of 2.74. The feldspars, which are rather less weathered than those in the sections examined from the great intrusion on the east, include both orthoclase and plagioclase. Magnetite is rather plentiful.

A very feldspathic type of felsite, containing much magnetite and abundant green pyroxene-pseudomorphs (72), occurs at Red Island and along the shore to the south and south-west. The small felsite patches which are seen south-east and south-west of Lough Mweelaun show no features of special importance.

Allusion may here be made to an exceptional rock-type seen only at (30), a spot about a quarter of a mile south of Knocknamuck, where it appears to be intruded between the lime-bostonite and the Red Sandstone. In a hand-specimen it is a pinkish rock, with pale-green felspar-phenocrysts and small ill-defined dark patches. Sections show the rock to be principally composed of almost square felspars with simple twinning. Scattered through the ground-mass are larger weathered felspars. Albite is present; but the majority of the felspars, large and small, are orthoclase. The dark patches prove to be chloritized pseudomorphs after hornblende. Epidote and calcite are also present as alteration-products. The rock may be called a hornblende-felsite.

### (b) The Lime-Bostonite.

This retains a very uniform character throughout the whole length of its outcrop. It is a purple or pinkish rock, very compact and fine-grained, and hardly ever showing any phenocrysts. The scarcity or abundance of its amygdules is its sole varying characteristic in the field. As a rule, only a few small scattered amygdules are seen; but sometimes, especially near the base of the sill, as at (134), they are very plentiful. Quartz is by far the commonest mineral forming the amygdules. In thin sections the lime-bostonite is very uniform in character, consisting of a felted mass of small felspar-needles associated with much iron-oxide (sometimes magnetite, sometimes hæmatite), much of which in either case is probably secondary. This is, as a rule, very evenly distributed through the sections in small patches; but it sometimes occurs interstitially, and may, like certain ill-defined patches of calcite which are sometimes (49) seen, represent ferromagnesian minerals, no sign of such minerals in an unaltered state having been observed in these rocks.

The felspar was determined as albite by Dr. Flett, who pointed out that these Kilbride bostonites are more felspathic than the spilites, containing from 60 to 70 per cent. of felspar. Felspar phenocrysts in a much-weathered state are only rarely met with, and no sign is seen of a glassy base. There is little trace of flow-structure. These rocks show a considerable resemblance to the lime-bostonite described by Dr. J. V. Elsdon<sup>1</sup> from the district north-east of St. David's Head and still more to the keratophyre described by Mr. Herbert H. Thomas<sup>2</sup> from Skomer.

We have said that our lime-bostonite resembles microscopically the St. David's rock described by Dr. J. V. Elsdon (*op. cit.* p. 595). The similarity in chemical composition is shown by the analyses of the two rocks:—

<sup>1</sup> Q. J. G. S. vol. lxi (1905) pp. 594-99.

<sup>2</sup> *Ibid.* vol. lxxvii (1911) pp. 193-95.

	I.	II.	III.
SiO <sub>2</sub> .....	54.20	55.38	56.50
Al <sub>2</sub> O <sub>3</sub> .....	21.00	18.34	18.14
Fe <sub>2</sub> O <sub>3</sub> .....	2.60	1.13	3.12
FeO .....	4.32	5.86	2.86
MnO .....	trace	.....	.....
CaO .....	3.80	3.25	3.38
MgO .....	2.02	3.47	1.22
K <sub>2</sub> O .....	0.42	0.22	1.60
Na <sub>2</sub> O .....	6.58	7.12	5.28
TiO <sub>2</sub> .....	2.60	0.90	0.85
P <sub>2</sub> O <sub>5</sub> .....	0.04	trace	.....
CO <sub>2</sub> .....	1.57	2.00	5.11
Water at 110° C. ....	.....	0.48	1.26
Water (combined) .....	1.23	2.39	
Totals .....	100.38	100.54	99.32
Specific gravity =	2.68	2.73	

I. Lime-bostonite from Kilbride (analysed by J. Weintraube).

II. Lime-bostonite from St. David's (analysed by J. V. Elsdén).

III. Lime-bostonite from Mæna, W. C. Brögger, Q. J. G. S. vol. 1 (1894) p. 26.

Calculating the percentages of albite and anorthite from the soda and lime, Dr. Elsdén gets for his felspar:—

Albite .....	60.26
Anorthite .....	16.12,

which amounts to 76.38 per cent. of a plagioclase between Ab<sub>4</sub>An<sub>1</sub> and Ab<sub>3</sub>An<sub>1</sub>.

For the Kilbride rock we get:—

Albite .....	55.61
Anorthite .....	18.86,

which amounts to 74.47 per cent. of a plagioclase corresponding to the formula Ab<sub>3</sub>An<sub>1</sub>.

If we calculate the amounts of silica and alumina needed to form felspars with the lime and alkalies, we arrive at the following result:—

	Ab.	An.	K <sub>2</sub> O, Al <sub>2</sub> O <sub>3</sub> , 6SiO <sub>2</sub> .	Total.	Observed.
SiO <sub>2</sub> .....	38.21	8.14	1.61	49.48	54.20
Al <sub>2</sub> O <sub>3</sub> .....	10.32	6.92	0.46	18.20	21.00
Na <sub>2</sub> O .....	6.58	...	...	6.58	6.58
K <sub>2</sub> O .....	...	...	0.42	0.42	0.42
CaO .....	...	3.8	...	3.8	3.8

It will be observed that the silica and alumina needed for the above suppositions are less than the observed amounts. The excess of these oxides is no doubt due to some of the silica and

alumina being combined with magnesium and iron in the chloritic mineral which is present.

Finally, it is worth recording that in the three (Kilbride, St. David's, and Mæna) areas, the three similar rocks are all accompanied by a porphyrite. In the Kilbride area there is no direct evidence of transgression to prove which rock was the earlier, but the occurrence in the field suggests that the porphyrite was the later of the two. In the Mæna area Prof. W. C. Brögger finds bostonites and camptonites as complementary rocks, that is, differentiation-products of one and the same magma.<sup>1</sup> Although no camptonites occur in the Kilbride area, it is interesting to note that we have found some intrusions of hornblende-lamprophyre in the Arenig rocks of Tourmakeady.<sup>2</sup>

### (c) The Labradorite-Porphyrite.

This rock is very constant in character. The extensive fine-grained ground-mass is always purplish brown in colour, and is crowded with large fresh, pale-grey, platy crystals of labradorite, having an average length of about 5 millimetres and a breadth of about 1 mm. Their outline is commonly somewhat rounded. The specific gravity of this rock is 2.72. The ground-mass is seen in section to be principally composed of felspar-laths, which are less fresh than the phenocrysts and give a smaller extinction-angle. Fresh augite sometimes (85) occurs, and as a rule chloritic and other pseudomorphs, apparently after rhombic pyroxene, are present. Very small vesicles filled with chlorite and chalcedony are of frequent occurrence.

### (d) The Dolerites.

These include mica-dolerites, in addition to the ordinary augite-dolerites.

(i) The augite-dolerites.—These are dark or nearly black rocks, of medium grain as a rule, the texture in the larger dykes becoming finer towards the margin. In some hand-specimens no crystals are apparent; but in some cases (58, 62) large augites are seen, and in others porphyritic felspars (60, 62). Pyrite is occasionally seen, and small calcite-filled vesicles are not uncommon. The average specific gravity of sixteen specimens was 2.82.

In section, most of the rocks are seen to be normal dolerites—consisting of a felted mass of plagioclase-laths with augite and magnetite. No olivine has been definitely recognized; but pseudomorphs in carbonate, perhaps after olivine, are occasionally met with, as, for instance, in the mica-dolerite (66). The size of the felspar-laths varies a good deal, being generally greater in the dykes in the south-western part of the area with a south-easterly trend, than in the sills associated with the Calcareous Flags. These dykes also tend to be fresher than the sills.

<sup>1</sup> W. C. Brögger, *Q. J. G. S.* vol. I (1894) p. 26.

<sup>2</sup> C. I. Gardiner & S. H. Reynolds, *Q. J. G. S.* vol. lxx (1909) p. 131.



Phenocrysts of felspar are conspicuous in sections of (62); and in (122) the weathered felspar is seen to be bordered by fresh secondary material.

The augite is, as a rule, granulitic in character; but in some cases (58, 62) large well-terminated crystals of augite occur. Less often, as in (136), a specimen taken from the centre of the big dyke south-east of Lough Mweelaun, the augite is ophitic.

As for accessory minerals, magnetite is generally distributed. Chlorite and calcite are common as alteration-products or filling small vesicles, and epidote is occasionally met with (58). A specimen (60) taken from the eastern end of the big dyke north of the Doon Rock has a very fine-grained ground-mass, and its characters in microscopical section are rather those of an augite-porphyrity than of a dolerite. Its specific gravity, however, is 2.81. In addition to the idiomorphic augites, it contains chloritized pseudomorphs, probably after rhombic pyroxene.

(ii) The mica-dolerites occur west of the Kilbride burial-ground and north of the Doon Rock. They differ from the other dolerites only in the presence of numerous flakes of biotite. Dr. Flett points out the presence of albite in these rocks, and that the association of albite-diabases with spilites occurs in Mid Argyll and is universal in Cornwall. Although these two rocks occur in the Kilbride district, they can hardly be said to be associated, since the spilites are of Arenig age, while the mica-dolerites are post-Llandovery intrusions. Apatite is present as an accessory in the rock from (66).

#### (e) The Spilites (Pillow-Lavas).

These are rocks of fine and uniform grain, consisting principally of small lath-shaped felspars which often show fluxion-structure, or are arranged in a divergent sheaf-like manner. Occasionally a subvolcanic structure may be observed. The felspar is practically always albite. Porphyritic felspars are rather rare; they sometimes (29) contain prehnite, and were probably not originally albite but lime-bearing plagioclase. Occasionally pseudomorphs which seem to be after pyroxene are present, but no unaltered ferromagnesian minerals are preserved. Some of the felspars are replaced by carbonate. Iron-ore (sometimes magnetite, sometimes ilmenite) is often present, as small patches uniformly distributed over the section and probably secondary. Vesicles are numerous, and may be filled with carbonates, quartz, chalcedony, or chlorite. Dr. Flett, to whom we are indebted for many of the observations recorded above, alludes to the resemblance which the Kilbride rocks present to the Ordovician pillow-lavas of the South of Scotland, Megavissey and Mullion Island in Cornwall. The resemblance to the Devonian and Carboniferous spilites of Devon and Cornwall is less marked.

We quote below an analysis of one of the Kilbride spilites, and for comparison add two analyses of British spilites as quoted by Mr. Dewey & Dr. Flett in their paper on British pillow-lavas in the 'Geological Magazine'.<sup>1</sup>

	I.	II.	III.
SiO <sub>2</sub> .....	49.80	47.56	51.31
TiO <sub>2</sub> .....	1.70	2.40	1.92
Al <sub>2</sub> O <sub>3</sub> .....	17.94	14.27	12.67
Fe <sub>2</sub> O <sub>3</sub> .....	2.37	1.63	0.54
FeO .....	6.74	6.80	7.99
MnO .....	...	0.30	0.45
CaO .....	9.00	10.95	8.17
MgO .....	4.02	4.90	2.19
Na <sub>2</sub> O .....	4.03	4.61	5.21
K <sub>2</sub> O .....	0.20	0.27	0.54
P <sub>2</sub> O <sub>5</sub> .....	...	0.19	0.90
CO <sub>2</sub> .....	1.28	2.95	6.15
Water at 105° C. ....	0.10	0.42	0.04
Water (combined) .....	3.54	2.65	2.31
Totals .....	<u>100.72</u>	<u>99.90</u>	<u>100.39</u>

I. Spilite from Kilbride, analysed by J. Weintraube.

II. Pillow-lava, Tregedden (South Cornwall): omitting (CoNi)O 0.08, FeS<sub>2</sub> 0.22, Fe<sub>2</sub>S<sub>3</sub> 0.05. Anal. E. G. Radley.

III. Pillow-lava, Argyllshire: omitting FeS<sub>2</sub> 0.30, Fe<sub>2</sub>S<sub>3</sub> 0.17. Anal. E. G. Radley.

A comparison of these analyses shows how similar the Irish spilite is in composition to the Cornish rock.

It is interesting to recall that we found small intrusions of a spilitic rock in the Arenig Series in the Tourmakeady area, which Dr. Flett, after microscopical investigation, stated to have the essential features of the Mid-Devonian lavas of the Plymouth area.<sup>2</sup>

### (f) The Tuffs.

Few sections were cut of these rocks, their interest lying chiefly in features which may be observed in the field. As compared with those of Tourmakeady and Glensaul, the most interesting characters are negative ones, namely the absence of limestone-breccias and the slight development of gritty tuffs. The coarse breccias so extensively developed at Kilbride differ from those of Glensaul, in the fact that the blocks consist of spilite nearly as frequently as of felsite. In many of the fine tuffs, also, the little ashy particles are frequently of spilite. Only at one point (109), a small exposure a third of a mile north-north-east of Lough Mweelaun, occur silicified tuffs similar to those found in the Mount Partry Beds of Glensaul.

<sup>1</sup> Geol. Mag. dec. 5, vol. viii (1911) p. 206.

<sup>2</sup> Q. J. G. S. vol. lxx (1909) p. 136.

# VI. COMPARISON OF THE ROCKS OF THE TOURMAKEADY, GLENSAUL, AND KILBRIDE AREAS.

Arenig Rocks.	Tourmakeady.	Glensaul.	Kilbride.
Shangort and Tourmakeady Beds (Zone of <i>Didymograptus hirundo</i> and perhaps higher beds).	Well-developed, including grits, bedded limestones and limestone-breccias.	Well-developed, including grits, tufts, bedded limestones, and limestone-breccias, also beds containing graptolites of the <i>D.-hirundo</i> Zone.	Unrepresented.
Mount-Partry Beds (Zone of <i>Didymograptus extensus</i> ).	The upper beds are well seen, and include cherts and shale containing <i>Didymograptus extensus</i> and other fossils, quartzose grits, and tufts. Coarse breccias are not prominent. The lower beds (coarse conglomerate) are well seen.	The upper beds are well seen, and include cherts and shales containing <i>Didymograptus extensus</i> and other fossils, tufts, and coarse breccias. Quartzose grits are not very prominent. The lower beds (coarse conglomerate) are well seen.	The upper beds include chert and shale containing <i>Didymograptus extensus</i> and other fossils, but they are not well seen. The same is the case with the gritty tufts, but coarse breccias are very greatly developed. No coarse conglomerates occur.
Igneous rocks.	Two large boss-like masses of intrusive felsite occur, and a great number of small intrusive masses. There is also a great mass of probably contemporaneous rock of similar character (rhyolite) occurring at the base of the Shangort Beds.	A large sill of felsite occurs in the Shangort Beds, but only a very few small intrusions.	A very large mass of felsite penetrates the Mount-Partry Beds, and there are a good many smaller intrusions.
Lime-bostonite.	Unrepresented.	Unrepresented.	Unrepresented.
Labradorite-porphphyrite.	Unrepresented.	Unrepresented.	Unrepresented.
Hornblende-lamprophyre.	Several small dykes occur.	Unrepresented.	A large sill occurs intruded at, or near, the base of the Silurian rocks.
Spilite.	Several small intrusions penetrate the Arenig beds.	Unrepresented.	Several sills of considerable size occur at, or near, the base of the Silurian rocks.
Dolerite.	Several small intrusive masses occur, either in the Arenig beds, or between them and the basal conglomerate of the Carboniferous. Some are olivine-bearing.	Unrepresented.	Unrepresented. Extensive lava-flows of spilite showing well-marked pillow-structure occur in the Mount-Partry Beds. Numerous sills and a few dykes occur intrusive in various rocks, but principally in the Silurian. Some contain biotite, some albite.

## VII. GENERAL SUMMARY AND CONCLUSIONS.

The stratigraphical succession in Arenig times is not nearly so complete in the Kilbride area as at Tourmakeady and Glensaul, neither the coarse conglomerate towards the base of the Arenig deposits nor the Shangort Beds near their summit being seen. The lowest Arenig bed at Kilbride is a spilite-flow with some accompanying breccias, upon which rest quartzose grits, with black cherts and shales containing *Didymograptus extensus*, these being almost the sole representatives of the Arenig sedimentary deposits in the area. A most extensive series of spilite-lavas accompanied by felsite and spilite-breccias follows: the coarseness of the breccias indicating the highly explosive character of the eruptions, and the large blocks of felsite in the breccias proving the presence of an acid magma at no great distance, although no acid lavas have been found in the area and as yet no acid intrusions had taken place.

Later on, but almost certainly in Arenig times, occurred the upwellings of the acid rock which now forms the great felsite-intrusion of Glenbeg and the smaller felsite-masses elsewhere in the area. At what exact period the extensive fracturing of the Arenig beds took place is not evident. It is probable that it occurred in post-Arenig times, and was connected with the uplift which brought these rocks under the influence of the Llandeilo sea.

The Kilbride area contains no Llandeilo rocks; but an enormously thick series of grits, with a coarse basal conglomerate containing blocks of a quartz-felsite exactly like the Glenbeg rock, rests upon the Arenig beds along the western margin of the Kilbride area, and forms the northern shore of Kilbride Bay. These rocks are similar to the grits and conglomerates to which we refer in our Tourmakeady and Glensaul papers as of Bala (?) age, but according to Mr. H. B. Maufe and Mr. R. G. Carruthers they are of Llandeilo age.

If these beds ever extended over the Kilbride Peninsula, they were removed by erosion in pre-Llandovery times, as the Llandovery Beds rest directly upon the Arenig Series.

Llandovery Beds some 2350 feet thick, succeeded by about 2000 feet of Wenlock grits, occur in the area; but no Ludlow Beds are seen, *Monograptus vomerinus* being found in the very highest strata.

Probably at an early post-Silurian date came intrusions of lime-bostonite and of coarse porphyrite. Then followed a period of important earth-movement, connected in all probability with the Caledonian movements of other regions. The whole area was folded into a syncline, the axis of which trended roughly north-east and south-west; and, perhaps owing to the presence of the rigid block of the Glenbeg felsite, the rocks in adjusting themselves were traversed by numerous cross-faults, which shifted the outcrops of the lime-bostonite and coarse-porphyrine intrusions as well as those of the Silurian strata. The important fault bringing the Silurian deposits against the gneiss in the south-eastern part of the area is probably also of this date.

An interval of erosion, perhaps corresponding to the Lower Old-Red-Sandstone Period, followed, and then came the conglomerates of Upper Old-Red-Sandstone or Lower Carboniferous age, which are to be seen towards the eastern end of the peninsula at the lake side,<sup>1</sup> and of which a small remnant containing a block of coarse porphyrite is seen resting on the lime-bostonite west of Fox Hill.<sup>2</sup> If the dolerite intrusions, as seems probable, are of the same period as those of Tourmakeady, we may regard them as of post-Old-Red-Sandstone age. They are clearly later than the cross-faulting which shifted the outcrop of the Silurian rocks.

In conclusion, our sincerest thanks are tendered to Mr. F. R. Cowper Reed, M.A., for naming the great majority of our fossils; to Miss G. L. Elles, D.Sc., for examining the graptolites; to Dr. J. S. Flett, M.A., for much help in the examination of the igneous rocks; to Mr. Herbert H. Thomas, M.A., for the loan of rock-sections; and to Prof. G. A. J. Cole for 6-inch Ordnance Survey maps.

#### APPENDIX.

NOTE on a new SPECIES of *CARYOCARIS* (*C. KILBRIDENSIS*) from the ARENIG ROCKS of the KILBRIDE PENINSULA. By HENRY WOODWARD, LL.D., F.R.S., V.P.Z.S., F.G.S.

EARLY in the present year I received from my friend Prof. S. H. Reynolds a very interesting little phyllopod crustacean obtained in the Arenig rocks of Kilbride (Mayo), with a request to subjoin a note upon it to the paper which Mr. Gardiner and he were reading to the Geological Society.

This form approaches the *Caryocaris wrightii* of Salter, a species which also occurs in shales of Arenig age on the Firth of Clyde and at many localities near Keswick (Cumberland), etc.<sup>3</sup>; but the carapace in *C. wrightii* is narrower in proportion and less arcuate on its ventral margin, while the posterior border is truncated and not produced into a latero-posterior spine as in the Kilbride example.

The Irish phyllocarid has both the impression and counterpart of the carapace preserved (both being marked by the authors as 55) and exposed on the surface of a rather coarse dark-brown shale, exhibiting a good side-view of the carapace and three caudal segments displaced and bent upwards dorsally.

The carapace is 25 millimetres in length, 5 mm. in depth at its anterior end, and increases to 10 mm. in depth near the posterior ventral border. The anterior margin is truncated, and its border is fringed by ten or twelve minute spines about 1 millimetre long directed forwards (resembling in appearance the oral cirri in

<sup>1</sup> These large masses of conglomerate are not demonstrably in place; but it is impossible to doubt that they are almost in position.

<sup>2</sup> This patch is too small to show in the map (Pl. VI).

<sup>3</sup> See T. R. Jones & H. Woodward, Monogr. Pal. Soc. pt. ii (1892) p. 89 & pl. xiv, cf. fig. 15 &c.

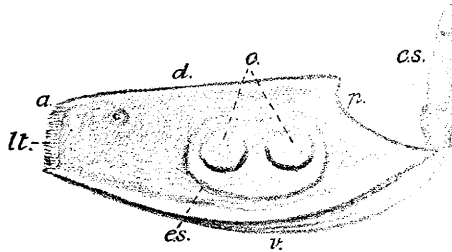
*Amphioxus*)—the longest being next the dorsal line of the carapace.

The dorsal margin is straight, and is 17 mm. long; its posterior margin is strongly incurved or emarginated, but produced backwards where it unites with the ventral border to form a strong projecting spine.

The ventral margin is 25 mm. long, and very arcuate, terminating posteriorly in an acute spine.

The caudal segments measure together about 15 mm. in length and lie close to the posterior margin, being displaced and bent upwards.

Fig. 3.—*Caryocaris kilbridensis*, sp. nov. (Twice the natural size.)



- |  |                                       |
|--|---------------------------------------|
| [ <i>a</i> = Anterior border.            | <i>v</i> = Ventral border.            |
| <i>lt.</i> = Labial tentacles or spines. | <i>p</i> = Posterior border.          |
| <i>o</i> = Ova.                          | <i>e.s.</i> = Ephippial shield.       |
| <i>d</i> = Dorsal border.                | <i>c.s.</i> = Three caudal segments.] |

What appears to me to be of great interest in this specimen, is the presence, near the centre of the carapace, and evidently, as it seems to me, enclosed within it, at its broadest part, of two round bodies (each measuring about  $2\frac{1}{2}$  mm. in diameter) which appear to be eggs, and may possibly be homologous with the pair of ephippial eggs, so often observed in *Daphnia*, especially protected to retain their vitality by their additional covering during the cold of winter—or when the water in which the parent lived had been dried up by evaporation, leaving the mud containing the eggs to solidify, and so remain imprisoned, until, after a more or less protracted period of drought, the arrival of the rainy season again sets them free—when the eggs are duly hatched out.

I may mention that, many years ago, I received by the favour of Mr. Clement Reid, F.R.S., a number of these small ephippia, which he had picked out of the ancient Freshwater Bed at Mundesley on the Norfolk coast, attesting the almost indestructible nature of these minute siliceous envelopes.

I have myself hatched out a number of these ephippial eggs sent to me which had been obtained from the dried-up mud of a stream in the Orange Free State, after some years' imprisonment in a dry box in the British Museum (Natural History).

The late Dr. W. Baird, in a similar manner, brought to life quite a number of Entomostraca from a sample of dried-up mud which

had been sent to him by a friend from the deserted pool of Gihon, near Jerusalem.<sup>1</sup>

I believe this is the first ancient Phyllocarid in which traces of eggs have been observed within the bivalve shell of the parent. Eggs (in clusters) called *Parka decipiens* have been noticed with remains of *Pterygotus* in the Old Red Sandstone of Trimpey, north of Bewdley.<sup>2</sup>

The curious fringe of cirrus-like spines on the anterior (oral) border of the carapace has not, I believe, been before observed in any species of Phyllopod, and deserves especial notice.

I venture to designate this interesting Phyllocarid as *Caryocaris kilbridensis*, after the locality where it was discovered by Mr. Gardiner and Prof. Reynolds, to whose kindness I am indebted for the privilege of examining it.

#### EXPLANATION OF PLATES VI & VII.

##### PLATE VI.

Geological map of the Kilbride Peninsula, on the scale of  
4 inches to the mile or 1 : 15,840.

##### PLATE VII.

Fig. 1. Spilite, showing the concentric arrangement of the vesicles in regard to the margins of the 'pillows.' (See p. 82.)

2. Chert, associated with spilite, in the form of irregular strings and patches. (See p. 82.)

#### DISCUSSION.

The PRESIDENT (Prof. WATTS) congratulated the Authors on this addition to the important series of papers which they had presented on the Palæozoic rocks of the West of Ireland. He enquired whether the *Trinucleus* said to occur in Silurian strata was not a derived form, and cited an analogous occurrence of *Trinucleus* in the Silurian of the Onny-River district of Shropshire, where it was undoubtedly derived.

Dr. A. WADE, after congratulating the Authors upon this further development in their very important work in the West of Ireland, said that the point of special interest to himself was the close parallel which existed between the succession of the beds, from the Llandovery Conglomerate to the base of the Wenlock, in this area and in the Welshpool District. This similarity became more marked when one considered the bostonite-like rocks intruded near the base of the Silurian. Some complex faulting made the position of the Welshpool Dyke somewhat obscure, but the speaker had come to the conclusion that it occupied a position very similar to that held by the keratophyres described by the Authors. The microscope slides and descriptions showed how closely the rocks resembled

<sup>1</sup> See *Annals & Mag. Nat. Hist.* ser. 3, vol. iv (1859) pp. 280-83 & pls. v-vi [*Estheria gihoni*, *Daphnia atkinsoni*, *Cypris celtica*, *C. orientalis*, & *Diaptomus similis*]; and in a second paper, *op. cit.* vol. viii (1861) pp. 209, 210 & pl. xii [*Branchipus eximius*].

<sup>2</sup> See H. Woodward, *Monogr. on Merostomata*, Pal. Soc. 1871, p. 79 & pl. xvi, figs. 10-11.



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C. I. GARDINER AND S. H. REYNOLDS.

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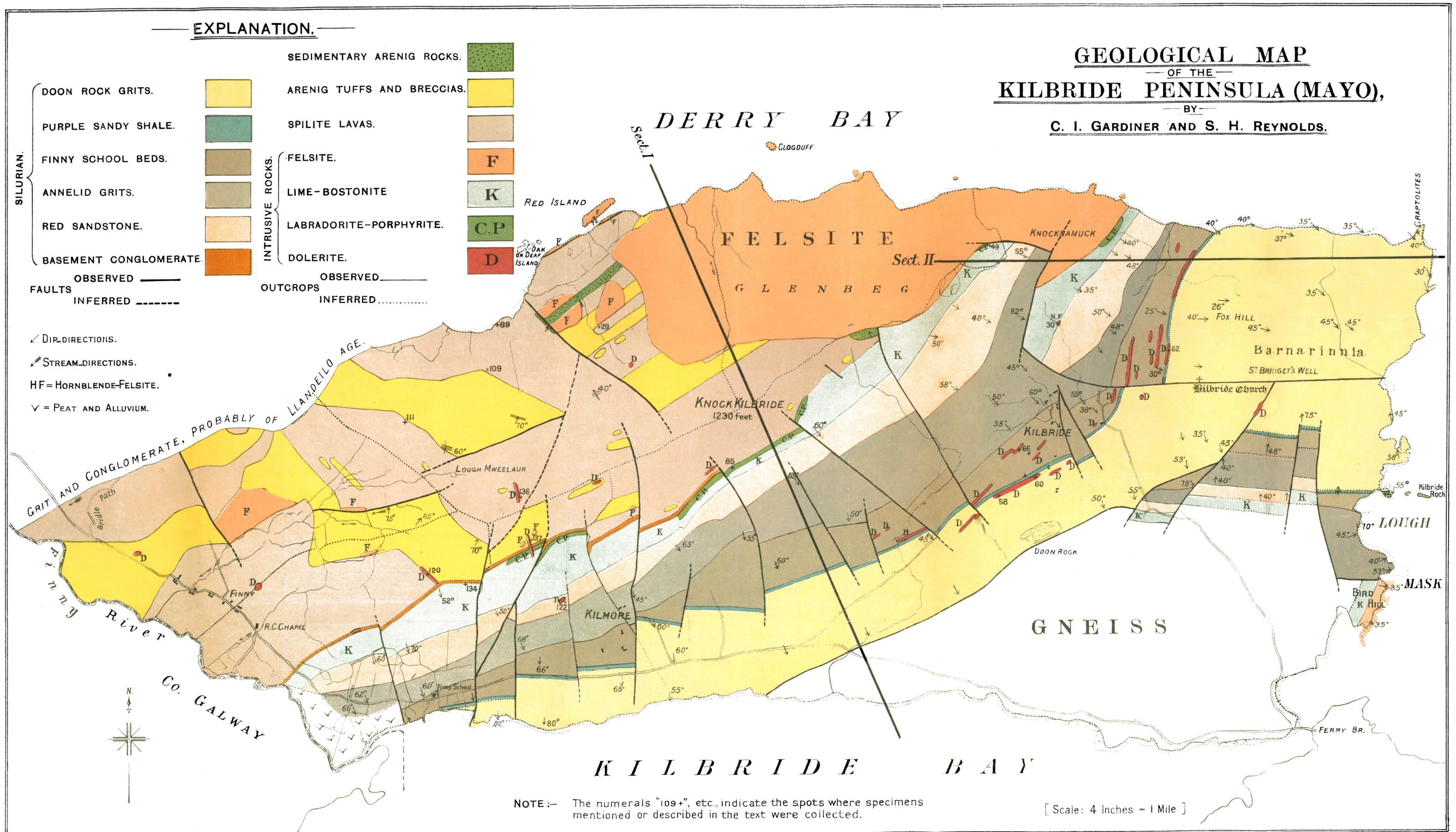




FIG. 1.

SPLITE (PILLOW-LAVA), SHOWING THE CONCENTRIC ARRANGEMENT OF THE VESICLES IN REGARD TO THE MARGIN OF THE PILLOWS.



S.H. Reynolds, Photo.

FIG. 2.

CHERT, ASSOCIATED WITH SPLITE, IN THE FORM OF IRREGULAR STRINGS AND PATCHES.



S.H. Reynolds, Photo.

Bemrose L<sup>th</sup>, Colln., Derby.

one another, the only difference being perhaps a little coarse texture in the case of the Welshpool bostonite.

It was a most unsatisfactory circumstance that, in practically every case where *Trinucleus* had been recorded from Silurian rocks, something was left open to doubt. Here it had turned up in a wall-fragment. It was, however, of such importance that he thought it would be very advisable for the Authors to give a separate list of the fossils associated with it in the fragment.

Dr. H. LAPWORTH said that he was interested in the comparison of the Llandovery rocks in the West with their equivalents in the North-East of Ireland. In the former region they appeared to be of the arenaceous type as developed at Llandovery itself, along the Welsh Borders, and in the Girvan area in Scotland; in the other region they were of the graptolitic-mudstone facies, as found in North-West Wales, the Lake District, and the Southern Scottish Uplands. With further work in Ireland and Wales, it would become possible to trace approximately the limits of the original deep-sea trough.

With reference to the Authors' geological map, he was struck by the amount of detail inserted along the faulted southern margin, and on what he assumed was a 6-inch plan. He would be interested to know whether the exposures were so numerous as to enable the Authors with certainty to develop the detailed structure shown.

Dr. J. V. ELSDEN called attention to the resemblance mentioned in the paper between the Kilbride keratophyre and the lime-bostonite described by him from Abercastle, in Pembrokeshire. From his examination of the specimens exhibited, he thought that, while there seemed to be points of similarity, there were also important differences. He would like to see a chemical analysis of the Kilbride rock. The felspar in this rock was described as albite, while that in the Abercastle variety seemed to be oligoclase. Referring to the general question of the nomenclature of these rocks, he had submitted specimens of the Abercastle rock to Prof. W. C. Brögger, who, while not denying its general mineralogical and chemical resemblance to the typical mænaita or lime-bostonite of the Gran district, was disposed to exclude the Abercastle specimen from that class on account of its associated rocks. In the speaker's opinion, however, the introduction of genetic affinities greatly increased the difficulties of rock-nomenclature.

Mr. C. I. GARDINER thanked the President and Fellows for the way in which they had received this communication. He assured them that the paper would include chemical analyses. As attention had been drawn to the large number of more or less parallel faults, which were seen on the 6-inch map to displace the Silurian strata, he pointed out that, owing to the fact that there was a red sandstone near the base and higher up in the series dark calcareous flags covered by purple shales, it was a comparatively easy matter to map in the faults represented, as the exposures were very numerous. The Authors were quite confident that the faults really existed as mapped.