

6. *On the IGNEOUS and ASSOCIATED SEDIMENTARY ROCKS of the TOURMAKEADY DISTRICT (COUNTY MAYO).* By CHARLES IRVING GARDINER, M.A., F.G.S., and Prof. SIDNEY HUGH REYNOLDS, M.A., F.G.S.; with a PALÆONTOLOGICAL APPENDIX by FREDERICK RICHARD COWPER REED, M.A., F.G.S. (Read December 16th, 1908.)

[PLATES IV-VI.]

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I. INTRODUCTION.

OUR object in the present paper is to describe a series of igneous rocks associated with beds containing Ordovician fossils, and occupying a tract of country, having a width of about a mile, which extends along the western shore of Lough Mask from the hamlet of Derrindaffderg in the north to the neighbourhood of Tourmakeady in the south, a distance of about $4\frac{1}{2}$ miles.

At the southern end of the area, on its eastern side, this igneous series of rocks is bounded by massive conglomerates; and rocks lithologically similar, though probably of much later date, form the whole of the western boundary. Along most of the eastern border occur conglomerates and sandstones, to which we, following the Survey, shall refer as the basal beds of the Carboniferous, although they may be regarded with equal probability as representing the Old Red Sandstone.

The surface is undulating, but the physical features are not striking—the ground never rising, in the area with which we deal, to a greater height than about 400 feet, or some 350 feet above

Lough Mask. A number of streams traverse the district from west to east, and afford an excellent series of sections; but, apart from these, exposures are almost everywhere numerous, this being partly due to the fact that the district is free from drift.

Considering the interesting and varied character of its geology, it is remarkable that comparatively little has hitherto been written about this area. In 1874, G. H. Kinahan,¹ in a paper on the 'Geology of West Galway & South-West Mayo,' while in the main dealing with districts farther south, incidentally refers to the Tourmakeady district.

By far the fullest account of the district is that by G. H. Kinahan & R. G. Symes, contained in the Explanation of Sheets 73, 74 (in part), 83, & 84 of the Geological Survey map of Ireland, published in 1876. We shall frequently have occasion to refer to this, but will here merely mention that the igneous series, as a whole, is considered to be of Silurian (Upper Silurian) age, the remarkable limestone-masses with Ordovician fossils, to be described later, being regarded as dislocated blocks which had been carried up by later volcanic eruptions.

Nothing appears to have been written about the district for the next 20 years, but the Annual Report of the Geological Survey for 1896² contains an account by Sir Archibald Geikie of Mr. J. R. Kilroe's work, in which the occurrence is mentioned of pre-Bala fossiliferous rocks, and the whole igneous series is considered to be not of Silurian (Upper Silurian) but of Ordovician (Lower Silurian) age. This conclusion is further elaborated in Sir Archibald Geikie's 'Ancient Volcanoes of Great Britain,'³ where a generalized section across the area is given.

Finally, the paper by Mr. Kilroe, 'On the Silurian & Metamorphic Rocks of Mayo & North Galway,' recently published,⁴ contains a number of references to the district with which we are dealing. The most important point in Mr. Kilroe's paper, however, is the conclusion that the coarse grits and conglomerates, which all previous observers had regarded as forming a single group, really include two groups, one of Llandeilo or Arenig, the other of Bala age.

One of the disadvantages, with which a geologist engaged in mapping this district has to contend, is the difficulty of clearly and briefly describing the position of any spot, owing to the small number of names inserted in the 6-inch Ordnance maps, the names of hamlets given being actually fewer than in the 1-inch Geological Survey map. We have, therefore, found it convenient in this paper to distinguish the various streams by the letters B, C, etc.

¹ Geol. Mag. n. s. dec. ii, vol. i (1874) p. 453. A paper on 'Geological Maps & Sections of West Galway & South-West Mayo,' by the same author was read at the British Association Meeting at Belfast (1874), but only the title appears in the Report (Trans. Sect. p. 88).

² Ann. Rep. Geol. Surv. U. K. for 1896 (1897) pp. 49-50.

³ Vol. i (1897) pp. 251 *et seqq.*

⁴ Proc. Royal Irish Acad. vol. xxvi, sect. B, no. 10 (1907) pp. 129-60.

II. THE SEDIMENTARY ROCKS AND THE TUFFS.

As has been already mentioned, thick grits and coarse conglomerates bound the whole district on the west, and play also a prominent part in its southern portion near Tourmakeady; except for them, however, the non-igneous rocks are but poorly exposed. The district is noteworthy for the bad preservation and scanty character of the fossils, a fact which adds greatly to the difficulty of understanding its structure.

(a) The Arenig Rocks (Mount Partry Beds).

Scattered throughout the district, especially near its eastern border, are a number of exposures of conglomerate, coarse grit, radiolarian chert, and slate, sometimes associated with interbedded tuff. The grits and cherts are often mentioned in the Survey Memoir,¹ the cherts, which are referred to as 'jasperized shales or hornstones,' being recognized by the authors of the memoir,² and by Mr. Kilroe & Sir Archibald Geikie,³ as the oldest rocks in the district. The coarse conglomerate was, however, regarded as of much later date than the grits and cherts, being grouped, with that exposed all along the western border of the area, as Llandovery by the authors of the Survey Memoir, and as Bala by Sir Archibald Geikie & Mr. Kilroe. Mr. Kilroe⁴ has, however, recently come to the conclusion that the apparent succession is the true one, and that this eastern conglomerate is of the same general age as the slates and cherts with which it is associated, while that exposed along the western border is of far more recent date (Bala).

The two conglomerates contrast somewhat strongly as regards the nature of their pebbles: in that exposed along the western border the pebbles are mainly of granite and felsite; while in that associated with the cherts and slates in the south-eastern part of the area, though occasional pebbles of felsite and quartz and rather more numerous pebbles of gneiss and mica-schist occur, grit-pebbles vastly preponderate. This is one of the reasons which leads us to accept Mr. Kilroe's conclusion as to the age of the conglomerate associated with the slaty and cherty series. The resemblance of the cherts to those of Arenig age in the Ballantrae district is extremely close.

The general dip of these beds is in a north-westerly or north-north-westerly direction, which is the usual dip of most of the rocks in this district, and there is frequent evidence of disturbance near the exposures of cherts and slates.

¹ Explan. of Sheets 73 & 74 (in part), 83 & 84, Mem. Geol. Surv. Irel. 1876, pp. 21, 61, 62, 65.

² *Ibid.* p. 21.

³ Ann. Rep. Geol. Surv. U. K. for 1896 (1897) p. 49.

⁴ Proc. Roy. Irish Acad., vol. xxvi, sect. B, no. 10 (1907) p. 130 & footnote 1.

Kinahan & Symes,¹ and after them Mr. Kilroe,² detected the presence of graptolites in this series, Mr. Kilroe finding in the stream west of the Monastery, Tourmakeady, 'black shales with Lower Llandeilo, or perhaps even Arenig graptolites.' This observation, it will be seen, we have fully confirmed.

The following are the principal exposures of these rocks :—

(1) In the stream close to Tourmakeady Lodge.—In the lower part of the stream south-east of the Lodge (outside the area of our map) the coarse conglomerates are finely exposed, and are apparently overlain by the fine grits, slates, and cherts. The actual junction is not clearly seen, but there is no evidence that it is a faulted one, and the beds close above the conglomerate have the usual north-westerly dip. Slightly higher up the stream the cherts show a certain amount of disturbance, and north-north-east of the Lodge the series includes a few thin bands of tuff. A small intrusion of felsite separates the Arenig Series from the (?) Bala conglomerate which is seen at the bridge north of Tourmakeady Lodge. A small patch of tuff occurs in a field about 300 yards east-north-east of that house.

No fossils have as yet been found in the slates, despite careful search; but microscopical examination of the cherts reveals the presence of rounded bodies, some of which have an inner ring concentric with the circumference, and these are strongly suggestive of casts of radiolaria. Sponge-spicules are fairly common, and Dr. Hinde suggests that a group of minute claw-shaped bodies is made up of denticles from the radulæ of some gasteropod. This chert is derived rather from the silica of sponge-spicules than from radiolaria.

(2) In the Mount Partry neighbourhood.—This area stretches for a mile in a north-easterly direction, from the road leading westwards from the hotel. By far the best section occurs in the bed of the Treanlaur stream (Stream C); it is, in descending order, as follows :—

[See also fig. 1, p. 108.]

	<i>Thickness in feet.</i>
7. Coarse green grit, very quartzose and felspathic.	
6. Fine grits and cherts	about 20 seen.
5. Fine gritty tuffs	60
4. Coarse tuff	50
3. Fine gritty tuffs	60
2. Fine grits, cherts, and slates, including a black band full of graptolites at about 20 feet above the base.....	50
1. Coarse conglomerate, thickness seen very considerable: assuming the dip to be constant, it would be about	850

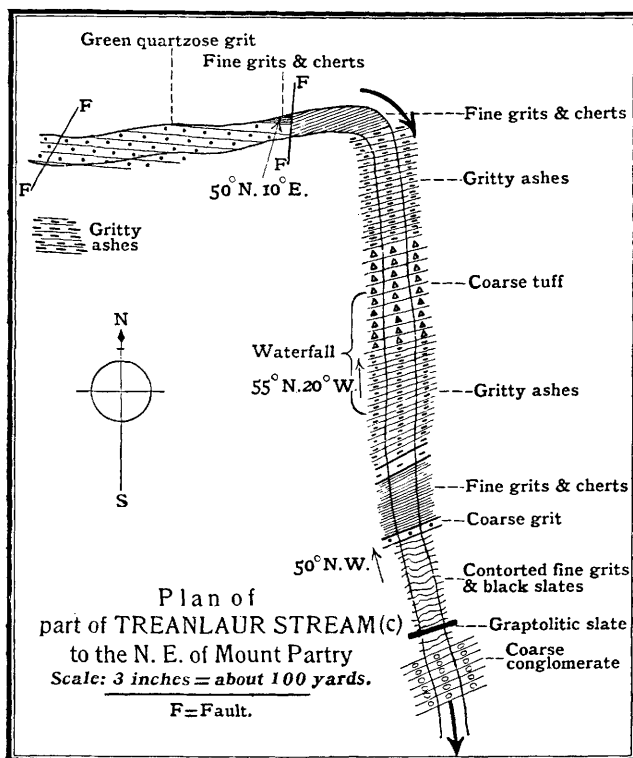
This stream-section is the finest exposure of the Arenig rocks in the district, and differs from that in the Tourmakeady stream

¹ Mem. Geol. Surv. Irel. Sheets 73, 74 (in part), 83 & 84 (1876) pp. 27 *et seqq.*

² Ann. Rep. Geol. Surv. U. K. for 1896 (1897) p. 49.

in the far greater development of tuffs and coarse grits. The conglomerate, which is finely exposed, is identical in character with that in the Tourmakeady stream.

Fig. 1. (For description, see p. 107.)



The graptolites found in Band 2 have been kindly identified by Miss G. L. Elles, D.Sc., to whom we tender our most sincere thanks; they show that the rocks are of Upper Arenig age (about the zone of *Didymograptus hirundo*), and include the following species:—

Didymograptus acutidens, Elles & Wood (common).
Didymograptus bifidus, Hall (common).
Didymograptus extensus, Hall (common).
Didymograptus filiformis, Tullberg.
Didymograptus gracilis, Törnquist (common).

Didymograptus hirundo, Salt.
Tetragraptus bigsbyi, Hall (1 specimen).
Tetragraptus pendens, Elles.
Tetragraptus, sp. nov. (common).
Diplograptus (*Glyptograptus*) *dentatus* (Brongn.).
Clonograptus lapworthi, Rued.
Dendrograptid.

The cherts are exposed, not only in the stream but in a field-drain south of Mount Partry, and in the road north-north-west of St. Mary's Monastery.

The coarse tuff, although only some 50 feet thick in the stream, broadens out on both sides, and forms the hill of Mount Partry and that to the north-west of the Monastery. The bed passes, in places, into a coarse breccia, with large angular blocks of felsite lying in a matrix of an ashy type. This deposit at each locality is suggestive of a vent; but, as it appears to be regularly interbedded among finer tuffs, we hesitate to claim it as such.

The upper band of fine grits and cherts (Band 6) is seen again close to the point where the Mount Partry road branches off, about a third of a mile to the north-west of the hotel; while the coarse grits (Band 7) are well exposed in a road-cutting close by, where they contain small blocks of felsite and chert. The latter rocks are also exposed to the north of the wide strip of coarse ashes east of the Treanlaur stream. Along the whole of its north-western boundary this coarse grit appears to be in contact with felsite, though the junction, even in the Treanlaur stream, is never actually seen.

(3) In the district between Gortanalderg and Drumcoggy Rectory.—The coarse conglomerate occurs in stream D about half a mile south of Drumcoggy Rectory, but no cherts or slates are seen there. Another patch of the conglomerate is seen near the eastern end of the east-and-west road, which crosses the area described in this paper a short distance south of the Rectory. The coarse conglomerate is not met with to the north of this point.

Commencing about half a mile east-north-east of Gortanalderg is a large exposure of the Arenig rocks, forming a roughly triangular area and having a length from south-west to north-east of about 400 yards. The rocks, though considerably disturbed, retain in the main the prevalent north-westerly dip, and appear to be entirely surrounded by felsite, which is faulted against the cherty series on the north-east and south-east sides, and is seen resting upon them along part of the western border.

The lowest beds seen are black slates and cherts, and then, after a gap, comes a considerable exposure of black and red cherts interbedded with coarse quartzose and felspathic grits. All these beds are contorted, and recall most vividly the Arenig cherts of the Ballantrae district.

When the series is followed in the direction of dip, that is, north-westwards, exposures of black chert and fine grit are found to alternate, the whole series being subsequently overlain by coarse quartzose grits closely resembling those of the Mount Partry and St. Mary's Monastery region.

The northern end of the triangle is occupied by a somewhat variable series of grits and tuffs.

Fig. 2.—Section extending west-north-westwards from St. Mary's Monastery. (Horizontal scale : 6 inches = 1 mile.)
[Section 1 on the map, Pl. IV.]

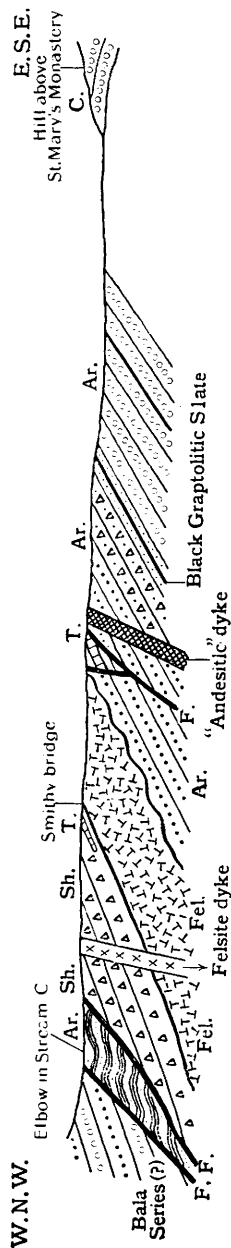
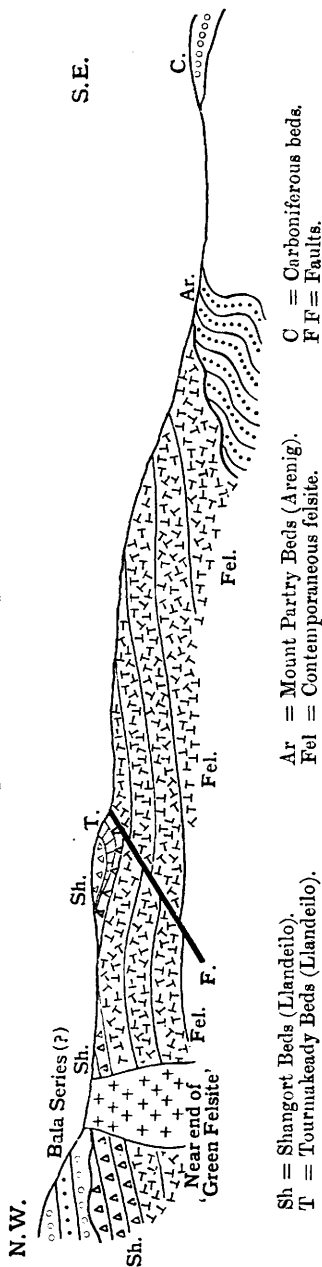


Fig. 3.—Section a quarter of a mile north of Drumcoggy Rectory. (Horizontal scale : 6 inches = 1 mile.)
[Section 2 on the map, Pl. IV.]



Sh = Shangort Beds (Llandeilo).
T = Tournukedy Beds (Llandeilo).
Ar = Mount Partry Beds (Arenig).
Fel = Contemporaneous felsite.
C = Carboniferous beds.
F F = Faults.

(4) In the upper part of Stream C, where to the west of Gortanalderg it follows a north-and-south course.—Here a small thickness of radiolarian cherts, black slates, and fine grits is seen dipping north 25° west, and is overlain by a little quartzose grit. The black slates have yielded *Diplograptus* (*Glyptograptus*) *dentatus*, Brongn., and small brachiopods (*Pholidops* sp. and *Orbiculoidea*!). The cherts from this locality are very pure, black, siliceous rocks, breaking with an excellent conchoidal fracture. It is in them that we have found the best-preserved radiolaria in the district, drawings, of some of these being reproduced in fig. 4, p. 112. Unfortunately, the specimens are too imperfect to allow of proper determination. Nearly all seem to consist of three concentric spheres, and show a single radial spine: but Dr. Hinde thinks it very probable that they were furnished with more spines originally. In one specimen no radial spine is shown, and there are several spokes connecting the different spheres. This specimen Dr. Hinde feels inclined to refer to the genus *Rhodosphæra*, Hæckel, while the form with three concentric spheres bears some resemblance to *Spongosphæra tritestacea*, Rothpletz,¹ from the Silurian of Langenstriegis, in Saxony. Sponge-spicules are present in this chert, but they are few in comparison with the abundant radiolaria, and the rock is a genuine radiolarian chert (see Pl. V, fig. 6).

The grits and cherts show signs of much disturbance, and a little higher up the stream the main mass of (?) Bala grits occurring to the west is faulted against them, the line of crush being well seen in the stream-banks.

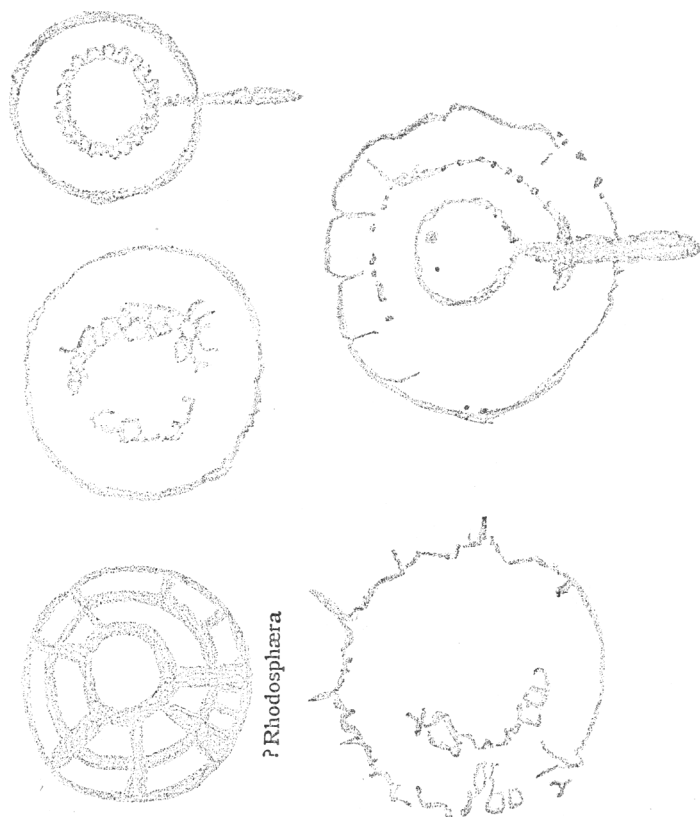
(5) Half a mile west of Drumcoggy Rectory.—Separated from the area No. 3 by red felsite is a small patch of green quartzose grits associated with cherts. The rocks at this spot have the usual strike, and the only point requiring special comment is that coarse grits are here seen underlying the cherts instead of overlying them.

(6) Half a mile north-west of Drumcoggy Rectory.—Here occurs another small area of cherts, having a length of about 300 yards. The cherts are (as usual) red and black, are associated with bands of grit, and though as a rule considerably disturbed, retain the prevalent north-westerly dip. The felsite along the south-western border shows crushing.

(7) Near Gortbunacullin Farm Bridge.—Here in the stream is a rather better section than usual of the cherty series, but the cherts are not so thick or so well-marked as at some places. A considerable thickness of grit is seen both overlying and underlying them. A small patch of tuff, presumably belonging to the Arenig Series, was noted on the eastern border of the felsite about 300 yards north of the bridge.

¹ Zeitschr. Deutsch. Geol. Gesellsch. vol. xxxii (1880) p. 449.

Fig. 4.—Sketches, by Dr. G. J. Hinde, of radiolaria from the cherts of the upper part of Stream C, west of Gortanalderg, Tourmakeady. (Magnified 200 diameters.) See p. 111.



(8) In the area extending from Gortbunacullin to a point south-west of Shangort.—This is by far the most extensive tract of Arenig rocks, the exposures being met with over an area having a length of about a mile and a half, and showing an uninterrupted strike of about a mile.

Along the whole length of this tract the gritty and cherty rocks are cut off on the west by the great green felsite-intrusion, while their whole eastern boundary appears to be faulted, and the continuity of the exposures is further broken up by smaller felsite-intrusions. Coarse grits, sometimes associated with cherts, are seen at many points in the neighbourhood of Gortbunacullin, and at one point become conglomeratic; but the most instructive section of these rocks is seen in the bed of Stream G, which, after cutting its way through the great green felsite-mass, and through the grits and one of the minor felsite-intrusions, turns north-north-eastwards and for some distance follows the fault bounding the grits on the east. In the stream-section the lowest beds are coarse, green, quartzose grits, and these are overlain by fine grits with chert-bands. Grits, slates, and cherts, in this case underlying, not overlying, coarse grits, can be traced more or less continuously northwards from Stream G to a point west of Shangort, that is, for a distance of about three-quarters of a mile. At one point only have we found any fossils in this exposure of the Arenig Series, namely about a third of a mile south-west of Shangort, where the track from the hamlet crosses the stream: here *Diplograptus* (*Glyptograptus*) *dentatus*, Brongn., was found in slate.

The thick series of coarse grits overlying the cherts is finely exposed in a prominent scarp, probably produced in former times by Stream G. The scarp does not follow the outcrop of any particular bed, but, commencing on the south in the green felsite, continues in the coarse grits and a minor felsite-intrusion, ending eventually in more grits at a point west of Shangort. At the southern end of the scarp the coarse grits do not differ in any marked respect from exposures of these rocks elsewhere in the area; but, as one approaches Shangort the beds become much disturbed, the underlying fine grits and slates being broken up and contorted, and blocks of them being embedded in the coarse grit, which farther on becomes conglomeratic, containing well-rounded blocks of felsite, sometimes as much as 2 feet long. These disturbed strata have a thickness of about 30 feet, and pass up into the ordinary quartzose grits. It is probably to this bed that Sir Archibald Geikie refers when he writes¹:—

‘Near Shangort I noticed in one of these breccias one block measuring 12 feet, another 20 feet in length and 3 or 4 feet thick, composed of alternating bands of grit and slate.’

Sir Archibald regards the rock to which he refers as a volcanic

¹ ‘Ancient Volcanoes of Great Britain’ vol. i (1897) p. 253.

Fig. 5.—Section south of Shangort, passing nearly through the middle of the green felsite-mass.
(Section 3 on the map, Pl. IV.)

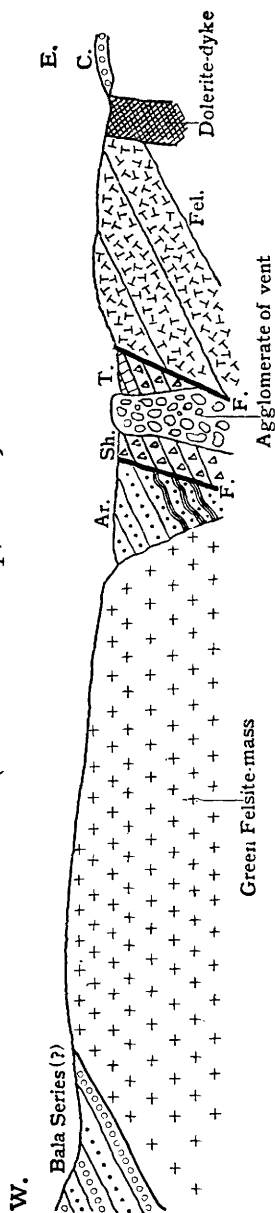
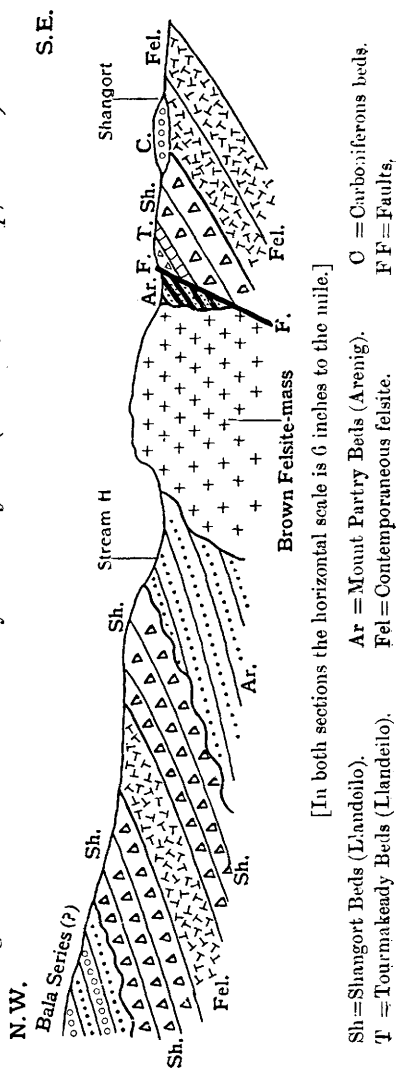


Fig. 6.—Section north-westwards from Shangort. (Section 4 on the map, Pl. IV.)



[In both sections the horizontal scale is 6 inches to the mile.]

breccia. We are inclined to think that the rock which we have just described is a fault-breccia, for the following reasons :—

- (a) It occurs close to the line of fault separating the coarse Arenig grits dipping west 10° south from the Llandeilo tuffs on the east, which dip about north-westwards.
- (b) The underlying fine grits show extensive rupture and displacement just where the breccia is seen, and resemble exactly the masses of grit and slate included in the breccia.
- (c) The matrix of the breccia is quartzose and gritty, closely resembling the grits on the west.

(9) The Shangort and Derrassa area.—We believe that this area is separated by a fault from that just described. The outcrop of the gritty and cherty series widens considerably in the neighbourhood of Derrassa, where the rocks are seen striking up against the green felsite-intrusion, and are almost bisected by a southward-projecting tongue of red felsite. At the north-eastern end of the outcrop in Stream H, the Carboniferous conglomerate is seen resting directly upon the grits.

A strip of chert, having a probable width of only some 30 or 40 yards, can be traced for nearly 500 yards along the south-eastern border of the brown felsite-mass north-west of Shangort.

(b) The Llandeilo Rocks.

It may, perhaps, be desirable to state succinctly at the commencement of our description of the Llandeilo rocks that although, for the sake of convenience, we divide them into two groups, a gritty and ashy series and a calcareous series, and apply the name of Shangort Beds to the former, and of Tourmakeady Beds to the latter, yet the two groups are intimately associated, and we consider them to be of the same general geological age.

(b₁) The main gritty and ashy series (Shangort Beds).

In addition to the tuffs which we have already described when dealing with the Arenig rocks, others are continually met with throughout the whole district. West of the great red felsite-mass they occupy an irregular strip extending from near Tourmakeady Lodge to Shangort, and then, after a break in their continuity, they are again seen in the neighbourhood of Derrindaffderg. While some of these rocks are normal tuffs with little non-igneous matter, the great majority contain a large proportion of gritty material. Every gradation may be traced, from a pure grit through an ashy grit and a gritty tuff, to a tuff almost entirely free from non-igneous matter. They vary, too, greatly in coarseness, some being very fine tuffs, others very coarse breccias, which may contain large or small blocks of limestone.

When unweathered, these gritty tuffs are very hard, and appear to be almost, if not entirely, unfossiliferous. They readily weather,

however, into a crumbly brown rock resembling a soft sandstone, and traces of fossils, generally in a very poor state of preservation, can then nearly always be found in them. At certain localities near Gortbunacullin a considerable series of fossils was obtained, which clearly proved the deposit to be of Llandeilo age.

For descriptive purposes the district may be subdivided as follows:—

(1) The area west of the Tourmakeady - Drumcoggy red felsite.—This area, which has a length of about 2 miles, is bounded on the west by the coarse (?) Bala conglomerate, the boundary being traceable with fair regularity and continuity. On the east it is bounded by the red felsite, and the boundary is most irregular and sinuous. The ashy rocks are not well exposed, and their principal interest lies in their association with the peculiar patches of limestone-breccia which we describe in the sequel. A series of small intrusions of felsite, andesitic rock, and hornblende-lamprophyre pierce the tuffs. Between the Bohaun road and Stream C are several exposures of tuffs, coarse and fine, striking in the normal north-north-easterly direction, but they do not merit a detailed description. The gritty tuffs which are so prevalent farther north at Gortbunacullin are first met with in a low bank by the Smithy bridge, where they have yielded the following fossils in a very poor state of preservation:—*Plectambonites sericea*, Sow., *Pl. quinquecostata*, M'Coy, *Orthis elegantula*, Dalm., *Scenidium* sp., *Cybele connemarica*, sp. nov.

Some 200 yards up the stream an *Illænus* was found in calcareous grit. The Llandeilo grits lie east of the angle made by Stream C, and are separated from the Bala grits and conglomerates on the west by a narrow area of Arenig slates and cherts which show much faulting, the stream for a time following the Arenig band. Gritty tuffs are exposed at various points in the moorland north-east of Gortanalderg, but no section of these rocks is met with until one reaches the east-and-west road which joins the main road south of Drumcoggy Rectory. Here is a fairly good section of tuffs, variable in character, which at a point (293)¹ just south of the road yielded the following fossils:—*Plectambonites sericea*, Sow., *Pl. quinquecostata*, M'Coy, *Orthis* sp., *Illænus* sp., *Cyphaspis* sp., and *Pliomera* cf. *barrandei*, Billings.

(2) The area between Stream F and the southern part of the green felsite-intrusion.—This is an irregular area, having a length of about a mile and a maximum width of about half a mile. Its north-western boundary is not clearly defined, but we believe that the Llandeilo tuffs are here faulted against the Arenig grits, slates, and cherts. On the east the area is bounded by the red felsite, the junction being very sinuous. Along the

¹ These numerals in parentheses throughout the paper indicate localities, shown in the map (Pl. IV), where fossils or rock-specimens were obtained.

eastern border there is a remarkably fine development of the limestone-breccia, and overlying this a series of coarse breccias, consisting of felsite-blocks embedded in a fine ashy matrix, is exposed at several points.

The prevailing rock-type is, however, the calcareous grit or gritty ash, which, as has been already mentioned, is especially characteristic of the Llandeilo of the district. As elsewhere, the rock when fresh is very hard and compact, and fossils could only be detected when it was much weathered. The following fossils were found a quarter of a mile south of Gortbunacullin (212):—

Camerella sp.
Orthisina ascendens, Pander.
Orthis crispa, M'Coy (?).
Orthis testudinaria, Daln.
Orthis sp.
Acidaspis sp.
Cybele connemaria, sp. nov.
Encrinurus sp.

Phacops (*Chasmops*) sp.
Plomera benevolens, Salt. (?).
Plomera pseudoarticulata, Portl. (?).
Helicotoma or *Euomphalus* sp.
Crinoids.
Glyptocystis (?) sp.
Monticuliporoid.

At a spot about a third of a mile south-south-west of Gortbunacullin, and near a little patch of limestone-breccia, the following fossils occurred in calcareous grit (318):—*Plectambonites sericea*, Sow. (?), *Orthis* cf. *intercostata*, Portl., *Orthis* sp., *Triplecia spiriferoides*, Portl., *Orthis* cf. *christianice*, Kjerulf, crinoids, and *Asaphus* sp.

(3) The district lying east of the main part of the green felsite-intrusion.—This district, which is on the line of strike of that just described, and only separated from it by a short space, has a length of rather over half a mile and a width of, as a rule, 200 yards or less.

In the southern part a large series of fossils was obtained from ashy grits of the same type as those found near Gortbunacullin. Mr. Reed has identified those enumerated in the following list from a point (322) about half a mile south-south-west of Shangort. The presence of *Plomera* (= *Amphion*), which occurs in some abundance, definitely fixes the age of the beds as not later than Llandeilo.

Camerella thomsoni, Dav.
Orbiculoidea sp.
Orthisina ascendens, Pander (?).
Orthis cf. *actoniæ*, Sow.
Orthis calligramma, Daln.
Orthis crispa, M'Coy (?).
Orthis cf. *interplicata*, M'Coy.
Orthis testudinaria, Daln.
Orthis sp.
Plectambonites sericea, Sow.
Streptis affinis, sp. nov.
Apatocephalus (?) sp.
Asaphus sp.
Symphysurus (?) sp.

Calymene sp.
Cybele connemaria, sp. nov.
Encrinurus cf. *multisegmentatus*, Portl.
Illænus sp.
Lichas sp.
Plomera benevolens, Salt. (?).
Plomera cf. *pseudoarticulata*, Portl.
Sphærocoryphe sp.
Turrilepas sp.
Eccyliomphalus sp.
Indeterminable gasteropod.
Glyptocystis (?) sp.

Farther north a similar series of ashy grits is met with, in which, at a point (217) about 300 yards south-west of Shangort, the

following fossils were found:—*Cheirurus* sp., *Orthis testudinaria*, Dalm., *Orthis* sp., *Plectambonites sericea*, Sow. (?), *Leptæna* cf. *llandeiloensis*, Dav., and *Acrotreta* (?) *hibernica*, sp. nov.

A patch of limestone-breccia and a mass of compact limestone occur in association with these rocks, the compact limestone being bounded on the west by a mass of coarse breccia which probably represents a vent. To this we shall refer subsequently.

(4) The district lying north-west of Shangort.—A strip of Llandeilo ashy rocks, overlapped on the west by the coarse (?) Bala conglomerate, extends in a north-easterly direction from Stream H to Derrindaffderg, a distance of about three-quarters of a mile; and a second strip, separated from the first (except at the northern end) by a long tongue of red felsite, lies farther east. The ashy series met with in this region does not include examples of the gritty beds which have yielded fossils on the south, but consists entirely of definite tuffs, which sometimes, especially in the southern part near Stream H, are very coarse. The felsite that separates the two strips of tuff sometimes contains xenoliths; and it is by no means easy to discriminate in the field between it and some of the tuffs.

(b.) The Calcareous Series (Tourmakeady Beds).

Along the western side of the area, from a point about 300 yards north-east of Tourmakeady Lodge to Gortbunacullin Farm bridge, are numerous exposures in a very remarkable deposit of a calcareous nature. As will be seen by reference to the map (Pl. IV), the deposit is far from being continuous; at certain places it has obviously been broken up by earth-movements, but there seems no reason to suppose that the bed originally formed a continuous deposit between the various spots where it is now found.

The calcareous rocks show three different lithological types:—

- (1) Compact bedded limestone.—This is rarely seen.
- (2) Limestone brecciated in place.—This is only occasionally met with, the commonest type of calcareous deposit being
- (3) Limestone-breccia; and if this is, as we believe, a deposit produced by volcanic explosions, it is easy to understand how it might be formed in disconnected patches on the floor of the sea near the vent or vents through which it was ejected.

Some further details regarding these three types of calcareous deposit may now be given:—

(1) Compact bedded limestone.—This is red, pink, or grey in colour, and contains in some places quartz-grains which near Shangort become so numerous that the rock passes into a calcareous sandstone.

(2) Limestone brecciated in place.—This is a pink or white rock, which, after being cracked into numberless pieces, has been

recemented by the deposition of material in the cracks. This type of limestone, which has not yielded any fossils, contains, occasionally, scattered angular masses of red or green chert.

(3) Limestone-breccia.—Two main types of these rocks seem to be recognizable:—

(a) A coarse type which contains angular blocks of limestone, red, pink, or grey in colour and horny or crystalline in texture, intermingled with angular blocks of red and green felsite. The matrix in which these blocks are embedded is generally in a very much weathered state, but, when fresh, is found to be a calcareous ashy grit, closely resembling that in which near Gortbunacullin and elsewhere Llandeilo fossils have been found. The blocks measure occasionally as much as 18 inches across, but more usually about 4 or 6 inches. We have found no fossils in the matrix, although some of the included limestone-blocks have yielded a rich harvest of fossils.

(b) A finer type showing often a distinct stratification, and consisting principally of small pieces of limestone of various sizes up to 1 inch across, and of less numerous fragments of felsite and red chert, embedded in a relatively scanty matrix of the nature of a calcareous grit.

Description of the exposures of the Tourmakeady Beds.—(1) The southernmost exposure is about 300 yards north-east of Tourmakeady Lodge. It is in a wood, and the relations of the rock to the surrounding beds are entirely obscured. Both the types of breccia are seen here.

(2) Immediately west of the Smithy bridge are several small exposures of coarse and fine breccia, perhaps parts of a continuous strip.

(3) Some 200 yards east-south-east of the same bridge is a small patch of limestone-breccia, closely associated with a breccia composed of felsite. This is the only exposure of the calcareous series seen on the eastern side of the red felsite.

(4) South of Gortanalderg is a patch of limestone-breccia of the coarse type, and associated with it is a breccia formed of felsite-fragments. The occurrence of crushed material on the north points to the presence of a fault separating it from the felsite.

(5) About 300 yards south-east of the last-described exposure is a small one, showing both coarse and fine types of limestone-breccia, with fine gritty ashes immediately beneath. The limestone fragments are of various sizes up to 4 inches across. Small felsite-fragments are also very numerous.

(6) West of Gortanalderg a strip of limestone, about 400 yards long, extends from the stream through some fields as far as the road coming from the village. The rock here is not a breccia formed of limestone-fragments embedded in a more or less ashy matrix, but a well-bedded grey and pink limestone, which, though often much

Fig. 7.—*Limestone-breccia near (45), upper part of Stream F. See p. 121.*

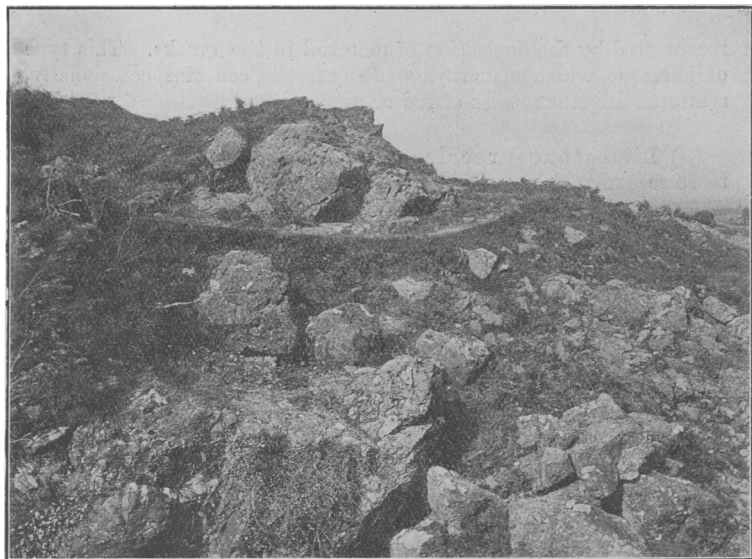
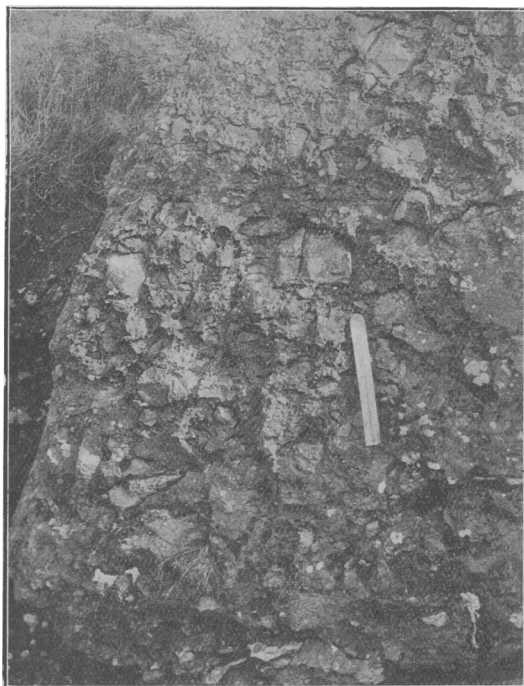


Fig. 8.—*Limestone-breccia near (45), upper part of Stream F. See p. 121.*



brecciated, is entirely free from admixture with ashy material. It dips north 30° west, and has a thickness of at least 30 feet. It appears to be regularly interbedded in grit. The (?) Bala grits and conglomerates are seen faulted against it in the stream.

(7) About 500 yards north-east of Gortanalderg is a strip of limestone-breccia about 100 yards long. This is of the coarse type, and contains many felsite-fragments. It appears to be interbedded with gritty ashes.

We now come to a set of exposures of much more continuous character, seen along the course of Stream F:—

(8) Four patches form a nearly continuous band, which can be traced for 300 yards or more. It clearly follows the strike of the associated tuffs, which at one point dip northwards at 40°. The limestone-breccia is identical in character with the coarse type described above, and consists of blocks of limestone and of felsite embedded in a matrix which weathers very readily into a perfectly rotten rock, but when fresh is seen to be a calcareous ashy grit, practically identical in character with the fossiliferous rock at Gortbunacullin and elsewhere. The limestone-blocks are, as a rule, of a horny type and white or grey, but there are a few red crystalline blocks, including one having a length of 2 feet. From these blocks, and chiefly from the large one just mentioned, we collected the following fossils (45):—

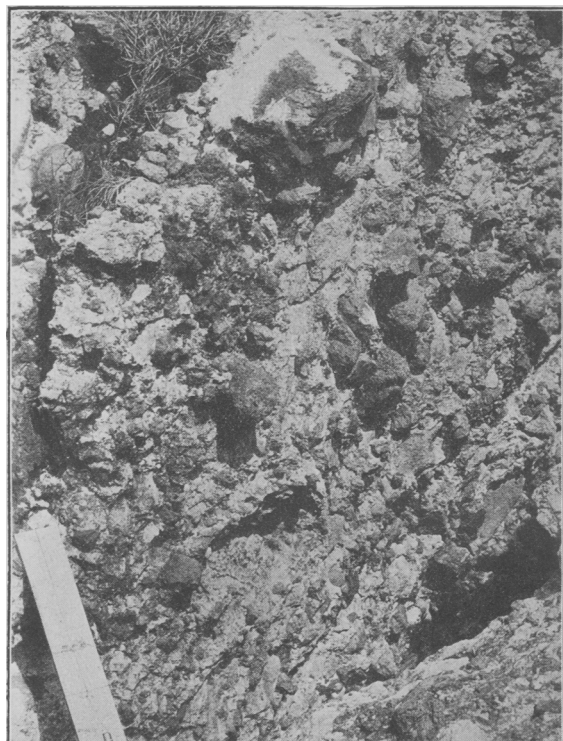
Acrotreta (?) *hibernica*, sp. nov.
Camerella thomsoni, Dav. (?).
Lingula brevis, Portl.
Lingula ovata, M'Coy.
Orthis calligramma, Dalm.
Orthis elegantula, Dalm.
Orthis sp.
Plectambonites sericea, Sow.
Porambonites cf. *intercedens*, Pander.
Porambonites sp.
Strophomena antiquata, Sow.
Strophomena cf. *retroflexa*, Salt.
Acidaspis aff. *bispinosus*, M'Coy.

Agnostus agnostiformis, M'Coy.
Cheirurus sp.
Harpes sp.
Illænus bowmani, Salt. (?).
Illænus sp. aff. *chudeighensis*, Holm.
Illænus sp.
Pliomera pseudoarticulata, Portl.
Pliomera aff. *fischeri*, Eichw.
Sphærocoryphe sp.
Primitia sp.
Turrilepas sp.
 Crinoids.

At one spot on the northern bank is an exposure showing several huge blocks of limestone, one of which measures 10 by 6 feet. This rock is grey and unfossiliferous, but contains numerous quartz-grains. Three other considerable exposures of limestone-breccia are met with before the point where the stream, on meeting the road from Gortbunacullin, bends sharply south-eastwards. They are all of the coarse type, and call for no special description. East of this bend of the stream, however, occurs a narrow strip, trending north by east, which crosses the stream, and can be followed for a distance of nearly 300 yards. It is exposed at several points south of the stream and in the stream-bed itself, but the best exposures are in some small excavations on the north. Here the deposit consists of an upper mass of breccia of the usual coarse type, but

stained in places with copper carbonate, and a lower compact limestone, which sometimes contains quartz-grains and is occasionally much crushed. The limestone-breccia rests regularly, without any sign of break, upon the compact limestone, of which a thickness of about 8 feet is seen.

Fig. 9.—*Limestone-breccia (58), lower part of Stream F.*



The following series of fossils was obtained from blocks in the breccia exposed in the stream, and in a small excavation north of the stream (58):—

Orthis sp.
Plectambonites sericea, Sow.
Lingula brevis, Portl. (?)

Illænus weaveri, sp. nov.
Cheirurus aff. *ingricus*, Schmidt.
Telephus hibernicus, sp. nov.

(9) Completely off the strike of these exposures is a small patch of limestone-breccia, lying about a third of a mile south-west of Gortbunacullin. The breccia is of the coarse type, and presents no unusual features.

(10) The northernmost exposures of the calcareous series are two lying respectively south-west and north-west of Shangort.

South-west of Shangort is a mass of compact limestone, having a probable thickness of not less than 40 feet and a length of about 100 yards. This mass (88), which is exposed in a rather large quarry, is faulted against red felsite on the east. Very small patches of Carboniferous conglomerate are seen in the quarry resting upon both rocks. Lithologically the limestone is hard, compact, and horny, usually grey but sometimes pink. It frequently has small quartz-grains thickly scattered through it, and may be said to pass in places into a calcareous sandstone. Here and there patches of red chert occur in the limestone. Fossils are very scanty; several hours' search yielded only one *Orthis simplex*, M'Coy, a fragment of *Harpes*, and a crinoid-joint.

North-west of Shangort is a strip of limestone-breccia having a length of about 150 yards, and trending in a north-easterly direction along the course of a small tributary of Stream H. The matrix of the breccia is the usual type of gritty ash, and the fragments seem to be exclusively of limestone, no felsite having been found.

As the fossiliferous limestone generally occurs in the form of dislocated blocks, the deposit as a whole was originally regarded by the officers of the Geological Survey as of 'Upper Silurian' age, the blocks being considered derivative: but Sir Archibald Geikie & Mr. Kilroe (Ann. Rep. Geol. Surv. for 1896, p. 49)

'obtained clear evidence that the limestone is truly interstratified in the volcanic series; that the fossils it contains are not derivative, but belong to the time of deposition of the limestone, and that the same organisms occur in the calcareous tuffs associated with the limestone.'

Sir Archibald Geikie writes as follows with regard to the calcareous beds found in the Tourmakeady, Glensaul, and Lough Nafuoey districts ('Anc. Volc. Gr. Brit.' vol. i, 1897, p. 252):—

'The rocks in each of these three areas are similar. One of their distinguishing features is the intercalation among them of a fossiliferous limestone and calcareous fossiliferous tuffs, which contain well-preserved species of organisms characteristic of the Bala division of the Lower Silurian rocks. There cannot be any question that these organisms were living at the time the strata in which their remains occur are found [*sic*].* The most delicate parts of the sculpture on *Ilænus Bowmanni* and *Orthis elegantula* are well preserved. Nor have the limestones been pushed into their present places by volcanic agency, or by faults in the terrestrial crust. They are not only regularly intercalated among the volcanic rocks, but the limestone in some places abounds in volcanic dust, while above it come calcareous tuffs, also containing the same fossils. It is thus clearly established that the volcanic series has its geological age definitely fixed as that of the Bala period.'

[* (?) Misprint for 'were formed.']

With regard to the age of the limestone, Mr. Reed is convinced by the fossil evidence that it is not of Bala, but of Llandeilo age. The reasons for this view are set forth in the appendix to this paper. Further, in the passage quoted above, Sir Archibald Geikie appears to imply that all the limestones lie associated with the tuffs approximately as they were originally deposited. This is no doubt the case with regard to the compact bedded limestones, but it appears to us impossible to maintain this view as regards the rocks which

we have described as limestone-breccias. In the great majority of cases the limestone undoubtedly occurs in the form of disrupted blocks embedded in a calcareous ashy matrix. It seems impossible to avoid the conclusion that, after the deposition of the fossiliferous limestone, it was in some places broken up by volcanic eruptions, and the fragments, accompanied by fragments of felsite, were embedded in a tuff which must thus be of later date than the limestone. It does not, however, follow that there was any very great interval of time between the deposition of the limestone and its disruption, succeeded by the embedding of its fragments in a coarse tuff. The character of the fossils shows that both original deposition and redeposition after disruption took place during Llandeilo times. The view of the explosive origin of the limestone-breccia affords an adequate explanation of its patchy method of occurrence.

(c) List of Fossils from the Llandeilo Beds.	SHANGORT BEDS. (Gritty and Ashy Series.)						TOURMAKEADY BEDS. (Calcareous Series.)	
	Smithy bridge. (5)	1 mile south of Gortbunacullin. (212)	1 mile south-south-west of Shangort. (322)	300 yards south-west of Shangort. (217)	1 mile west of Drumcoggy Rectory. (293)	1 mile south-west of Gortbunacullin. (318)	Upper part of Stream F. 1 mile south-west of Gortbunacullin Farm bridge. (45)	Stream F. 100 yards west of Gortbunacullin Farm. (58)
<i>Acrotreta (?) hibernica</i> , sp. nov.	+	+	+	..
<i>Camerella thomsoni</i> , Dav.	+	+	..
<i>Camerella (?) sp.</i>	+
<i>Cf. Leptæna llandeiloensis</i> , Dav.	+
<i>Lingula brevis</i> , Portl. (?)	+	..
<i>Lingula ovata</i> , M'Coy	+	..
<i>Orbiculoidea sp.</i>	+
<i>Orthis cf. actoniæ</i> , Sow.	+
<i>Orthis calligramma</i> , Dalm.	+	+	..
<i>Orthis cf. christianæ</i> , Kjer.	+
<i>Orthis crispa</i> , M'Coy (?)	+	+
<i>Orthis elegantula</i> , Dalm.	+	+	..
<i>Orthis cf. intercostata</i> , Portl.	+
<i>Orthis cf. interplicata</i> , M'Coy	+
<i>Orthis simplex</i> , M'Coy
<i>Orthis testudinaria</i> , Dalm. (?)	+	+	+	+
<i>Orthis sp. indet.</i>	+	+	+	+	+	+	+	..
<i>Orthisina ascendens</i> , Pander	+	+
<i>Plectambonites quinquecostata</i> , M'Coy	+	+
<i>Plectambonites sericea</i> , Sow.	+	..	+	+	+	+	+	..
<i>Porambonites cf. intercedens</i> , Pander	+
<i>Porambonites sp.</i>	+	+
<i>Scenidium (?) sp.</i>	+
<i>Streptis affinis</i> , sp. nov.	+

List of Fossils (continued).	SHANGORT BEDS. (Gritty and Ashy Series.)						TOURMAKEADY BEDS. (Calcareous Series.)		
	Smithy bridge. (5)	½ mile south of Gortbunacullin. (212)	½ mile south-south-west of Shangort. (322)	300 yards south-west of Shangort. (217)	1 mile west of Drumcoggy Rectory. (293)	½ mile south-west of Gortbunacullin. (318)	Upper part of Stream F. 1 mile south-west of Gortbunacullin Farm bridge. (45)	Stream F., 100 yards west of Gortbunacullin Farm. (58)	300 yards south-south-west of Shangort. (88)
<i>Strophomena antiquata</i> , Sow.	+
<i>Strophomena cf. retroflexa</i> , Salt.	+
<i>Triplecia spiriferoides</i> , Portl.	+
<i>Monticuliporoid</i>	+
<i>Acidaspis aff. bispinosus</i> , M'Coy	+
<i>Acidaspis</i> (?) sp.	+
<i>Agnostus agnostiformis</i> , M'Coy	+
<i>Apatcephalus</i> (?) sp.	+
<i>Asaphus</i> (?) sp.	+	+
<i>Calymene</i> sp.	+
<i>Cheirurus aff. ingricus</i> , Schmidt	+	..
<i>Cheirurus</i> sp.	+	+
<i>Cybele commemorata</i> , sp. nov.	+?	+	+
<i>Cyphaspis</i> (?) sp.	+
<i>Encrinurus aff. multisegmentatus</i> , Portl.	+
<i>Encrinurus</i> sp.	+
<i>Harpes</i> sp.	+	..	+
<i>Illænus bowmani</i> , Salt. (?)	+
<i>Illænus aff. chudleighensis</i> , Holm.	+
<i>Illænus weaveri</i> , sp. nov.	+	..
<i>Illænus</i> sp. indet.	+	..	+	..	+
<i>Lichas</i> sp.	+
<i>Phacops (Chasmops)</i> sp.	+
<i>Pliomera cf. barrandei</i> , Billings	+
<i>Pliomera benevolens</i> , Salt.	+	+
<i>Pliomera aff. fischeri</i> , Eichw.	+
<i>Pliomera pseudoarticulata</i> , Portl. .	..	+	+	+
<i>Sphærocoryphe</i> (?) sp.	+	+
<i>Symphysurus</i> (?) sp.	+
<i>Telephus hibernicus</i> , sp. nov.	+	..
<i>Primitia</i> sp.	+
<i>Terrilepas</i> sp.	+	+
<i>Glyptocystis</i> (?) sp.	+	+
Crinoids	+	+	+	..	+
<i>Helicotoma</i> or <i>Euomphalus</i> sp.	+
<i>Eccyliomphalus</i> (?) sp.	+

(d) The (?) Bala Conglomerate and Grit.

The district with which we are dealing is bounded along the whole of its western margin by a great series of conglomerates and grits. We have not been immediately concerned with these

rocks, and propose to refer to them very briefly. In the southern part of the area, especially along the steep road over the hill from Tourmakeady to Bohaun, and in the bed of the stream near which the road runs for some distance, the rocks are finely exposed and consist mainly of very coarse conglomerates. The blocks of these conglomerates may reach a length of a foot or more, and are chiefly red granite and quartz-felsite. Subordinate beds of grit are associated with the conglomerates.

A well-marked conglomerate, with pebbles chiefly of quartz-felsite, rests upon the Llandeilo Beds near Gortanalderg and stretches as far as Stream F, where it passes into grit, this forming the prevalent rock all along the remainder of the western margin of the area. The grit becomes pebbly in places, the pebbles being of felsite or quartz.

Between Streams G and H these grits occur in direct relation to the green felsite, the two rocks being seen in juxtaposition in Stream H; and from this point the grits, which are often pebbly, show a fairly continuous series of exposures as far as Derrindaffderg, where they disappear beneath the quartzose conglomerate and red sandstone of the Carboniferous System. As regards the age of these rocks, it is clear that they are newer than the gritty tuffs and limestones with Llandeilo fossils, and they show no lithological resemblance to the sandstones with Llandovery fossils which occur farther south in the neighbourhood of Trean¹ and at the mouth of the Owenbrin river.² We, like all previous observers, have been unable to find any fossils in these rocks in the Tourmakeady district; but Sir Archibald Geikie ('Anc. Volc. Gr. Brit.' vol. i., 1897, p. 253) mentions that in the region farther south-west they include bands with Bala fossils, and we are quite ready to accept his and Mr. Kilroe's conclusions that these conglomerates are of Bala age.

¹ We found here the following fossils in ferruginous grit:—*Favosites hisingeri*, M.-Edw., *Lindstramia* sp., *Palæocyclus* sp., *Leptæna rhomboidalis*, Wilck., *Cælospira hemispherica*, Sow., *Encrinurus punctatus*, Brunn., and *Beyrichia* sp.

² We found the following fossils in blocks of ferruginous sandstone on the shore of Lough Mask, west of Black Rock, and north of the mouth of the Owenbrin River:—

Lindstramia subduplicata, M'Coy.
Lindstramia sp.
Favosites sp.
 Crinoids.
Orthis calligramma var.
 sowerbyana, Dav.
Orthis elegantula, Dalm.
Orthis reversa, Salt.
Orthis sp.
Cælospira hemispherica, Sow.
Rhynchospira baylei, Dav.

Pterinea squamosa, M'Coy.
Trochonema trilineata, M'Coy.
Cyclonema sp.
Holopea sp.
Pleurotomaria sp.
Conularia sp.
Orthoceras subgregarium, M'Coy.
Orthoceras sp.
Encrinurus punctatus, Brunn.
Phacops aff. *downingæ*, Murch.
Illænus cf. *macallumi*, Salt.

III. THE FIELD-RELATIONS OF THE CRYSTALLINE IGNEOUS ROCKS.

The crystalline rocks include :

- (a) a great series of felsites, many certainly intrusive, others contemporaneous ;
- (b) a small development of intrusive andesitic rocks ;
- (c) a number of small but interesting intrusions of hornblende-lamprophyre, and dolerite.

(a) The Felsites.

The rocks which play the most prominent part in the Tourmakeady district are undoubtedly the felsites. They form a number of relatively small intrusions along the western and south-western borders of the district ; but it is in the central part, from near Tourmakeady Lodge to Shangort, that this type of rock is especially prominent, forming nearly all the high ground, and extending with lessening importance as far as the neighbourhood of Derrindaffderg. Lithologically, the rocks belong to three fairly well-marked types :—(α) the green and brown felsite, (β) the red felsite, and (γ) the augite-felsite.

The field-relations of these rocks may now be briefly described.

(α) The green and brown felsite.—This rock-type is characterized partly by the prevailing colour of the ground-mass, but chiefly by the size and prominence of the quartz-phenocrysts. Though it occurs here and there all over the district, its principal development is north-west of a line drawn between Shangort and Gortbunacullin. Here it forms a great oval mass, having a length of about a mile and a maximum width of nearly half a mile, extending from the neighbourhood of Derrassa to Stream G, north-west of Gortbunacullin. South of the stream the mass tapers and becomes more irregular, but extends as far as about half a mile south-west of Gortbunacullin, and therefore the total length of the mass is about a mile and a third. All along its northern and eastern border it truncates the ends of the bedded rocks, tuffs, grits, and cherts, but along its western border its relations to the coarse (?) Bala conglomerate are nowhere visible, owing to the covering of peat, except at certain points in the upper parts of Streams G and H. In the latter stream, however, the felsite shows what appears to be a chilled edge, suggesting that it is an intrusion of later date than the (?) Bala conglomerate. The section is not, however, so clear as could be wished, and can hardly be regarded as conclusive on this point.

North of Gortbunacullin patches of chert are seen caught up by the green felsite, exposed in the bed of Stream G.

The green felsite-mass further gives off, from a point near Gortbunacullin, a long narrow tongue, which stretches north-eastwards through the grits and cherts and can be traced nearly to the western bank of Stream G until cut off by a fault. The total length of this tongue is more than half a mile.

The brown felsite, which is practically identical with the green, the difference of colour being unimportant, forms a patch with a length of about a third of a mile lying north-west of Shangort, and a smaller patch lying east of the green felsite-mass. Brown felsite of similar character to the above also occurs at various points near Tourmakeady and near Gortanalderg.

Intrusive masses of felsite, which agree with the main green felsite as regards both colour and the prominence of the phenocrysts, occur south-west of the district with which this paper deals, only their north-eastern terminations entering it. They form two long narrow tongues, each having a length of over a mile and a width which rarely exceeds 150 yards. The more southerly, commencing near Cappaghduff West, follows the Glensaul river and ends in the Tourmakeady demesne. The more northerly, commencing at a point nearly due west of the termination of the more southerly, extends towards Gortanalderg. It is possible that the two may be parts of the same band shifted by a fault. Neither band makes any prominent surface-feature.

(β) The red felsite.—Though the prevalence of a red colour justifies us in referring to this rock as the red felsite, it is not implied that the redness is an invariable characteristic, the rock often locally becoming brown or green. In the bed of Stream B is seen the southernmost outcrop of the great stretch of red felsite which, except for a brief break in Stream F at Gortbunacullin-Farm bridge, extends continuously to Shangort, a distance of $3\frac{3}{4}$ miles. For the first three-quarters of a mile, from Stream B to Stream C, the red felsite has an outcrop with a fairly uniform width of about 300 yards; but, from Stream C onwards to Stream F, the outcrop becomes very much wider, the maximum width occurring at a point north-west of Drumcoggy Rectory and measuring about 1100 yards. The most remarkable feature about the outcrop is, however, its extraordinarily sinuous character. Along the western margin it repeatedly bends eastward, so that it passes to the east of successive patches of limestone-breccia; while along its eastern border its westward bending, so as to pass to the west of patches of grits and cherts, is almost equally noteworthy. South-west of Drumcoggy Rectory one large patch and several smaller patches of grits, cherts, and tuffs are completely surrounded by it. But, while along this lengthy outcrop it is clearly exposed at many points in the neighbourhood, now of the grits and cherts, now of the coarse tuffs, and now of the limestone-breccia, only at one point have we been able to find it actually in contact with any of these rocks. This point is along the south-western border of the triangular area of

cherts, grits, and tuffs lying about one mile south-west of Drumcoggy Rectory. Here the red felsite is seen resting without any apparent disturbance upon the cherts. Several small isolated patches of felsite occur at intervals west of the main outcrop.

North of Stream F the width of the felsite rapidly narrows. The eastern outcrop from that stream to Shangort follows a fairly straight line, and forms a well-marked scarp overlooking an alluvial area where no exposures except occasional intrusions of dolerite are seen; the western outcrop is more sinuous. At Shangort the felsite is overlapped by the basal Carboniferous conglomerate; but it commences again near Derrassa, and forms an irregular mass extending as far as Derrindaffderg.

(c) *The augite-felsite.*—Although augite has been detected in the felsites at a number of points, only at one spot does this rock form a well-marked and distinctive mass. This is at a point south-south-west of Shangort, where an oval mass of augite-felsite, having a length of about 150 yards, intrudes into the Shangort Beds.

As regards the nature of the various felsites, there can be no doubt that the principal green and brown felsite-masses are intrusive. The massive boss-like character of the green felsite and the way in which it truncates the ends of the coarse Arenig grits south-west of Derrassa clearly point to its intrusive nature. It is, however, noteworthy that little or no sign of metamorphism can be detected round this great mass of felsite, but the type of rock that it penetrates is not one which readily lends itself to metamorphic change.

The two long felsite-tongues south-west of the district described in this paper, and the smaller patches of felsite which occur in the Shangort Beds along the western margin of the main red felsite-mass, are all clearly of an intrusive nature.

It is, however, with regard to the main red felsite-mass, which extends northwards from Tourmakeady stream to near Shangort, that the chief difficulty arises. Its most noteworthy features are :—

- (1) The extraordinarily sinuous outcrop.
- (2) The remarkable variations in the width of the outcrop, from about 250 yards near Tourmakeady to nearly 1200 yards at a point north of Drumcoggy Rectory.

Along its eastern border it is seen at various points in close relation with the Mount Partry beds of Arenig age, and along its western border with the Llandeilo grits and tuffs. Only at two spots, one near Gortbunacullin Farmhouse, and a second at a point near the south-western end of the triangular area of Arenig Beds, 1 mile west-south-west of Drumcoggy Rectory, have we found it in actual contact with any other rock, and at both these spots it rests upon the Arenig cherty series. It is nowhere seen in relation to the coarse (?) Bala conglomerate.

The following are the possibilities with regard to the red felsite :—

1. That it may be intrusive either (*a*) as a boss like the green felsite, forcing its way indifferently through all the pre-Bala sedimentary rocks, or (*b*) as a laccolite or sill between the Arenig rocks on the east and the Llandeilo rocks on the west. The extremely sinuous outcrop tells against both these views, as does the complete absence of any sign of metamorphism in the limestones which are so frequently exposed near the felsite. The 'intrusive' view also affords no explanation either of the frequent juxtaposition of the limestone to the felsite, or of the great abundance of felsite-fragments in the tuffs and limestone-breccias.

2. That it may form one or more flows of Lower Llandeilo age—may, in fact, be the earliest event of Llandeilo time of which the district affords a record. According to this view, which, although not free from difficulties, seems to us to be the most satisfactory one available, the sinuosity of the eastern margin would simply depend on the extent to which the felsite had been removed by denudation from the Arenig rocks, and that of the western margin on the extent to which the Llandeilo tuffs had been denuded from the surface of the felsite. If almost immediately after the outpouring of the felsite the limestones were deposited, and then by explosive outbursts were disrupted, giving rise to the limestone-breccias, their frequent occurrence close to the felsite and their non-metamorphosed condition would be explicable. The abundance of felsite-fragments in the tuffs and limestone-breccias also finds a ready explanation on this hypothesis. The chief difficulty in the way of its acceptance is the great amount of variation in width of outcrop, and hence presumably in thickness, of the felsite, though the difficulty may partly be due to the repetition of the rocks by faulting or folding. Perhaps also the non-vesicular character of the red felsite and the rare occurrence of flow-structure may be taken as objections to this view.

Our conclusions with regard to the felsitic rocks may be summarized as follows :—

1. That the great red felsite (rhyolite)-mass forms a series of lava-flows of Lower Llandeilo age, which are probably penetrated here and there by minor felsite-intrusions.

2. That the remainder of the felsites are intrusions, some certainly, others probably, of post-Bala and pre-Carboniferous date, all belonging to the same general period, and that these intrusions take the form of :—

- (i) bosses, as, for instance, the green and brown felsite-masses ;
- (ii) dykes, as, for instance, the long intrusions which enter the south-western corner of the map, and the small patches scattered along its western border.

(*b*) The Intrusive Andesitic Rocks.

At several points in different parts of the district small intrusions of fine-grained non-porphyrific rocks of intermediate character are met with. Without microscopical examination these rocks are not easily distinguished from certain of the felsites and fine ashes, and it is not unlikely that other small masses may occur.

The following are the exposures :—

- (1) A mass, exposed at various spots along a distance of about half a mile, runs in a north-north-easterly direction from a point nearly half a mile north-north-east of Tourmakeady Lodge as far as Stream C. It is a dark-green, generally compact rock,

becoming somewhat amygdaloidal in places. The rocks in its immediate neighbourhood are not well seen, but it is probably intrusive along the line of junction of the Llandeilo Beds with the (?) Bala conglomerates.

- (2) A second band of very similar rock (133), often highly amygdaloidal, is traceable for a distance of about 100 yards through the coarse Arenig grits north of Mount Partry. The rock is exposed in the stream-bed and at spots near the right bank, and can be followed for some distance beyond the left bank. A closely related rock (245), showing numerous small pyroxenes in a hand-specimen, occurs about 300 yards north-west of the Monastery. A further exposure of dark andesitic rock (95) is found on the south-eastern slopes of Mount Partry, intrusive among the coarse felsitic tuffs which make up the bulk of the hill.
- (3) A small intrusion of a somewhat different type of rock (292), full of small amygdules, occurs north of Gortanalderg near the western boundary of the red felsite-mass, and a large mass of a similar nature (294) at a point about 500 yards to the north-east, close by the east-and-west road.
- (4) Several exposures of what are probably two intrusions (140 & 240) are seen south-east of the triangular area of Arenig rocks between Gortanalderg and Drumcoggy Rectory. The rocks are grey-green and very amygdaloidal in places; though occurring close to the Arenig Beds, they are intrusive in the felsite.
- (5) A small patch of a fine-grained rock of andesitic type occurs immediately west of the augite-felsite at Shangort.

(c) The Hornblende-Lamprophyres and Dolerites.

These rocks form a series of small but interesting intrusions, principally distributed round the margin of felsite-masses.

Hornblende-lamprophyres are met with at the following points:—

- (1) About 150 yards north of Gortanalderg (21). The rock here forms a more or less circular intrusion, some 50 yards in diameter, in the Llandeilo tuffs, which appear to be somewhat altered near the junction.
- (2) Half a mile farther north-north-eastwards, near the left bank of Stream F, is a second small, more or less circular intrusion (43), measuring only some 10 yards across. This is also completely surrounded by Llandeilo tuffs.
- (3) Two little patches, each having a visible diameter of only a few yards, are exposed near the upper part of Stream C, west of Gortanalderg. These may be continuous with one another.
- (4) Intrusive in the triangular area of Arenig grits, cherts, and tuffs, nearly a mile west-south-west of Drumcoggy Rectory, is another small patch of similar rock (168).

Dolerites.—The dolerites are more numerous than the hornblende-lamprophyres, and occur at the following spots:—

- (1) In the bed of Stream G, about a quarter of a mile west-north-west of Gortbunacullin, two exposures of dark-green dolerite are seen, one about 110 yards and the other about 60 yards in length. The easternmost mass (78) has felsite exposed all round it, and though felsite is only exposed on one side of the other it seems probable that the two are parts of one and the same intrusion in the felsite. The dolerite, being far more easily eroded than the felsite, has here determined the course of the stream.

- (2) Two exposures (86), no doubt forming parts of one mass of very fresh amygdaloidal olivine-dolerite, occur associated with the basal Carboniferous sandstone in the lower part of Stream G, half a mile north-north-west of Srah Bridge. The dolerite appears to follow the bedding of the sandstone, and may be intruded between it and the underlying red felsite, in which case its age would be post-Carboniferous.

The uppermost 2 inches of the dolerite are not amygdaloidal, and are jointed much as is the associated sandstone. The rest of the rock, however, is very amygdaloidal. A thickness of some 2 feet is seen in a small vertical cliff on the southern side of the stream, and the rock forms the floor of the stream for some 40 yards. Both this and the dolerite-mass previously described are characterized by a rough polygonal jointing on a large scale, which is well seen in both cases in the bed of the stream.

- (3) Very fresh olivine-dolerite (136) occurs in a field, a third of a mile west-north-west of Srah Bridge. Nothing is seen of the neighbouring rocks but the line of junction of the Carboniferous beds, and the red felsite probably passes quite close to this point.

- (4) A similar mass of dolerite (143) is seen, not actually in place, but undoubtedly occurring at the spot, by the side of the road which leaves the main road a quarter of a mile south of Srah Bridge. Very numerous blocks built into the walls occur south-east of this point, between it and the main road, but the rock has not been met with in place.

It is not unlikely that these last three exposures may be a single mass intruded along the line of junction of the Ordovician and the Carboniferous rocks.

- (5) A somewhat different type of doleritic rock (54), which resembles the diabases of North Wales, occurs at the extreme north-eastern limit of the Arenig Series exposed in the Mount Partry and Monastery region, where the mass, which is surrounded by tuff, has a visible length of about 50 yards.

IV. PETROGRAPHICAL DETAILS.

(a) The Felsites.

(1) The main green-felsite intrusion.—This is formed of a pale-green rock, almost always showing in a hand-specimen large and prominent phenocrysts of quartz and sometimes of felspar. The specific gravity in a specimen (71) from near the northern end of the mass is 2·66, while others show 2·70, 2·73, and 2·75.

Sections from different parts of the mass do not exhibit much variation in structure. In each case the ground-mass contains numerous little areas which appear to be imperfect spherules. The quartz-phenocrysts show strong corrosion by the ground-mass (see Pl. V, fig. 1), and the orthoclase is much altered, sometimes showing partial replacement by epidote. A good deal of magnetite is sometimes present (79, 215). Small vesicles generally occur, occupied by calcite (71), or by chalcedony and chlorite (79, 126). A section (194), cut from a specimen taken from the extreme northern end of the long north-eastward projecting tongue, is of a rock-type similar to that of the main green-felsite mass, but contains an exceptional amount of magnetite and much apatite. Another section (214) from near the base of the tongue is of a strongly microspherulitic rock with abundant chlorite, some of which is clearly pseudomorphic after biotite.

(2) The brown-felsite intrusion.—The large felsite-mass between Shangort and Derrassa is composed of the handsomest rock in the district. In a hand-specimen it is brown or sometimes green, showing prominent quartz-crystals and numerous dark-green patches which microscopic sections show to consist of chlorite (perhaps replacing pyroxene) intergrown in some places with the felspar, which includes plagioclase as well as orthoclase. The ground-mass is felsitic, and the specific gravity of one specimen (74) is 2·70 and of another (73) 2·73.

(3) Felsite-intrusions in the Arenig and Bala rocks near Tourmakeady Lodge.—These exposures include the two long intrusions already mentioned, of which only the ends appear in the map, and several smaller intrusions. Microscopically the rock differs from that forming the main green felsite-intrusion, in the absence of any tendency to a spherulitic structure in the ground-mass. No sign of augite was to be seen in any section examined; but biotite in a more or less altered state was observed at several points. The specific gravity of one of these rocks, which contained crystals of orthoclase upwards of an inch long, is 2·68.

(4) Red felsites between Tourmakeady Lodge and Stream C.—These rocks are very variable, but the prevalent types are brown or reddish, and, in hand-specimens, often show dark

patches of chlorite. Three sections were examined: (274) is a normal felsite showing very clearly the imperfectly-spherulitic type of ground-mass, which occurs so frequently in these rocks; (273) is an unusual type, containing a considerable amount of ilmenite. At (4) the ground-mass shows a tendency to be spherulitic, little quartz occurs, and plagioclase is present as well as orthoclase. Magnetite is rather abundant, and there appears to be altered augite.

Several isolated patches of felsite lie west of the main outcrop. A small patch (284), lying south-west of the angle of Stream C, has a coarser ground-mass than is usually noticed, full of little grains of quartz. Apatite is present in some abundance.

The felsite (38) intrusive among the tufts of Mount Partry, which may be mentioned here, contains numerous serpentinous pseudomorphs after pyroxene. Its specific gravity is 2.69.

(5) Felsites between Stream C and the east-and-west road south of Drumcoggy Rectory.—These rocks are very variable: (14) is a red felsite, while (16) and (250), from near the eastern border farther north, and (281) and (288) from near the western border, are green felsites with rather conspicuous quartz-crystals. Their microscopical appearance requires little description. The ground-mass is generally of the imperfectly-spherulitic type. In addition to the usual quartz and orthoclase-phenocrysts, altered biotite (14) is sometimes met with; and (281), a rock from the prominent felsite-crags east of Gortanalderg, contains abundant serpentinous pseudomorphs apparently after pyroxene. Apatite is fairly plentiful in this rock. Another rock (19) from this neighbourhood has a specific gravity of 2.71, and contains numerous pseudomorphs in chlorite apparently after pyroxene.

(6) Felsites between the east-and-west road south of Drumcoggy Rectory and Stream F.—While in the main these rocks are red felsites without prominent quartz-crystals, (146) & (48) are grey, with fairly prominent quartz. The imperfectly-spherulitic type of ground-mass is very well shown by (48), while in (146) bands of quartz and felspar intergrown in an imperfectly granophyric manner traverse the slide.

Along Stream F the felsite shows some modifications exceptional in the district. At (44) the rock is full of thoroughly well-rounded nodules which reach a diameter of a quarter of an inch. They are all solid, and consist entirely of white crystalline quartz.

Another rock (304) from the more easterly of the two felsite-masses on the left bank of Stream F shows strong banding on the weathered surface. In section it does not differ from the majority of the felsites of the district, except for the unusually large proportion of plagioclase present.

(7) Felsite between Stream F and Shangort.—The colour in hand-specimens shows various shades of green, grey, and

red. A rock from immediately north of Gortbunacullin Farm bridge differs from the usual type, showing a felsitic ground-mass much iron-stained and containing no quartz-phenocrysts. Another (187) near the western boundary of the felsite, due west of Srah Bridge, shows a somewhat banded appearance in the field, and in section is seen to contain a considerable amount of augite, mostly represented by pseudomorphs in chlorite.

(8) Felsites between Derrassa and Derrindaffderg.—The rocks here are principally of the red type; quartz is inconspicuous. A felsitic, instead of an imperfectly-spherulitic, type of ground-mass prevails. Flow-structure is sometimes seen (229), and the quartz-crystals are occasionally shattered as well as corroded. The specific gravities are lower than usual, those of five rocks near Stream H being respectively 2·67, 2·69, 2·70, 2·70, and 2·71.

(9) Augite-felsite intrusion of Shangort (279).—In a hand-specimen this is a dark, fresh-looking rock, with a fine-grained ground-mass in which are sparingly distributed a few small quartzes and well-cleaved feldspars. In section the ground-mass is seen to be imperfectly spherulitic, quartz is rather scanty, and the feldspar includes plagioclase as well as orthoclase. The augite is sometimes fresh, sometimes shows replacement partly by epidote, partly by chlorite; there are also pseudomorphs after rhombic pyroxene. The augite-crystals occasionally wrap round and enclose the ends of the smaller feldspars. Magnetite is plentiful, and serpentine occurs filling small irregular vesicles. The specific gravity of (279) is 2·78. This rock might, perhaps, be classed as a quartz-andesite.

Summary of the petrological characters of the felsites.—Three principal types are recognizable, the green and brown felsite, the red felsite, and the augite-felsite. In the green and brown felsite the ground-mass is, as a rule, imperfectly spherulitic; in the red felsite it is frequently felsitic, and sometimes shows flow-structure (229). The principal phenocrysts are quartz and feldspar. Quartz is always prominent in the green and brown felsites and, as a rule, shows strong corrosion by the ground-mass; occasionally, in rocks belonging to the group of red felsites (4, 19, 67) the sections examined do not show quartz-phenocrysts. The quartz-crystals are sometimes shattered (69).

Of the feldspars orthoclase is always present, but it is rarely (48) fresh enough to show good twinning. Plagioclase is sometimes (304 & 279) identifiable by means of the albite twin-lamellæ, and would probably be more often recognizable if the feldspars were less altered. Augite, either fresh (187) or more or less replaced by epidote (279), serpentine (38), or chlorite (19, 90), is not infrequent. Biotite in a more or less chloritized state was noted at three points.

Of accessory minerals, iron-ores are represented with remarkable frequency; ilmenite occurs occasionally (273), a general red stain due to hæmatite is very common, and at a number of points (4, 16, 68, 90) magnetite is present in some abundance. Occasionally apatite is rather plentiful (194, 281, 284). Small irregular vesicles are sometimes present filled with calcite, or with serpentine (187), or with chlorite and chalcidony, the latter mineral being sometimes spherulitic.

(b) The Intrusive Andesitic Rocks.¹

Three types of these rocks are recognizable:—

1. Specimens collected from various points along the dyke west of Mount Partry are all dark compact rocks, showing little in a hand-specimen but occasional small dark amygdulæ. In section the main part of the rock is seen in every case to be composed of needles of plagioclase, which, from the straight or almost straight extinction, are no doubt to be referred to oligoclase. These needles, which are so disposed as to show flow-structure, have interspersed with them a relatively smaller number of larger plagioclase-phenocrysts in a more altered state. One slide (130) shows brown patches, which are probably altered augites, but ferromagnesian minerals are very scanty. Small vesicles are always present, generally occupied by a chloritic mineral. The rock exposed at (3), the point where the dyke is cut by the Bohaun road, contains vesicles the central parts of which are occupied by quartz, then follows a layer of chlorite, while the marginal parts of the vesicle are occupied by epidote and calcite (see Pl. V, fig. 4). A good deal of epidote is scattered throughout this rock. One specimen (283), taken from near the northern end of the dyke, is much more uniformly vesicular than the remainder; and the little patch of andesite (292), near the margin of the red felsite north of Gortanalderg, is of similar type, being crowded with small chlorite-filled vesicles. Very little iron-ore occurs in any of these rocks. In many respects, these rocks seem to be closely allied to those described from the St. David's district by Mr. J. V. Elsdon² as lime-bostonites.

2. The small andesitic intrusions in the Arenig rocks from the

¹ [Subsequently to the reading of this paper, Dr. J. S. Flett kindly examined our sections of these rocks, and reported on them as follows:—‘Although rocks like these have been described as andesites, andesitic dolerites, etc. in several of our memoirs and elsewhere, they are not good andesites. Their felspars are all albite-oligoclase and oligoclase, and they contain no feldic minerals, only obscure pseudomorphs after pyroxene. I have compared them with the type-slides of monites, and they are not a bit like them. I should call them spilites myself, as their characters, mainly negative I admit, are those of this group. They have the essential features of the Mid-Devonian lavas of the Plymouth area, though they are not exactly like any of the groups of spilites I am familiar with. If they contained more alkali-felspar, they would closely resemble some keratophyres. I cannot get over the belief that they are “pillow-lavas”.’]

² Quart. Journ. Geol. Soc. vol. lxi (1905) pp. 594 *et seqq.*

Mount Partry neighbourhood differ in several respects from those just described and are far more variable. One (133) has many vesicles filled with calcite and chlorite, and contains abundant magnetite very uniformly distributed in small grains. Another from Mount Partry (95) shows abundant highly-altered phenocrysts of both augite and plagioclase, together with numerous chlorite-filled vesicles, embedded in a ground-mass in which little can be recognized with certainty. Another rock (245) from north-west of the Monastery is somewhat similar, showing large highly-altered augite-phenocrysts and little that is recognizable in the ground-mass; but, in addition to the augite, there are numerous pseudomorphs in chlorite after a rhombic pyroxene, this mineral and the augite being often intergrown. No feldspar-phenocrysts and no vesicles occur in this rock.

3. The rocks exposed at several points south-east of the triangular area of Arenig Beds 1 mile west-south-west of Drumcoggy Rectory are somewhat intermediate in character between dolerites and andesites. The low specific gravity, however, 2.75 of (140), shows that they are best classed with the latter rocks. They are fine-grained, rather pale rocks, and as a rule highly vesicular, the vesicles being filled with calcite and chlorite. In section the feldspars are seen to be fairly fresh, but the augites are in the main replaced by epidote and chlorite. Leucoxenized ilmenite is plentiful.

(c) The Hornblende-Lamprophyres and Dolerites.

Hornblende-lamprophyres.—These are all dark, rather coarse-grained rocks, showing, as a rule, little in a hand-specimen except hornblende. Feldspars are, however, to be seen in some varieties of the rock (21) from north of Gortanalderg. This rock has a specific gravity of 2.89. In section hornblende is in each case by far the most prominent mineral, occurring in pale-green, slightly pleochroic crystals, which are often idiomorphic (see Pl. V, fig. 2) and frequently show the normal cleavage. Very little feldspar can be detected, the most prominent minerals next to the hornblende being secondary quartz and a pale-green, almost isotropic, chloritic mineral. Apatite is fairly abundant in (168), the rock from the triangular patch of Arenig Beds west-south-west of Drumcoggy Rectory, and a good deal of epidote and calcite is present.

Dolerites.—Those from the neighbourhood of Srah, and that from a quarter of a mile west-north-west of Gortbunacullin (78) (see Pl. V, fig. 3), are all dark heavy rocks of medium grain, greatly resembling some of those from the English Midlands. In section the freshest of the rocks from near Srah (86 & 136) and that from a quarter of a mile west-north-west of Gortbunacullin are seen to be very similar; they are holocrystalline, and are composed of laths of labradorite, between which are wedged grains of augite, olivine, and magnetite. The specific gravity of one of the rocks (86) from the lower part of Stream G, half a mile north-north-west of Srah Bridge, is 2.92.

The rock (143), seen along the turning which leaves the main road a quarter of a mile south of Srah Bridge, is of the same general character, but somewhat finer grained. A vesicular dolerite, from the lower part of Stream G near (86), differs from the other dolerites of that locality, in having its augite and olivine mainly replaced by serpentine.

In addition to these fresh olivine-dolerites, an allied rock (54) occurs at a point about a quarter of a mile north of the Monastery, differing from the one just described in its weathered condition and in being devoid of olivine. In a hand-specimen the freshest examples of this rock are dark green and show numerous augites and colourless feldspars. In one variety, however, the feldspar-crystals are stained red. In section the rock is seen to be much decomposed. Though some fresh unaltered augite is present, most of the augite is chloritized. The feldspars, which sometimes show twinning, are, as a rule, replaced by secondary quartz and calcite. Ilmenite and apatite are plentiful. The specific gravity of this rock is 2.79.

(d) The Tuffs and Breccias.

Four principal rock-types may be readily recognized:—

- (1) The fine gritty tuffs.
- (2) The fine non-gritty tuffs.
- (3) The limestone-breccias.
- (4) The coarse felsite-breccias or agglomerates.

(1) The fine gritty tuffs.—These rocks, which pass gradually on the one hand into pure grits, and on the other into tuffs free from gritty material, are undoubtedly the type of tuff most prevalent in the district. They are largely developed along the whole of the western outcrop of the red felsite, but are especially well seen in the neighbourhood of Gortbunacullin, where they have yielded many fossils. In hand-specimens they are usually red or brownish rocks of medium to fine grain, showing much quartz and many felsite-fragments. They often effervesce rather strongly with acid. In section the abundant angular quartz-grains are seen to be mingled with closely packed felsite-lapilli of several types, and occasional andesitic fragments, as, for example, in (167), which shows lapilli of a vesicular andesite or basalt containing fairly fresh augites. All these are united by a calcareous cement the proportion of which is variable (see Pl. V, fig. 5). Red iron-oxide is sometimes abundant, forming a stain pervading the section. Magnetite is also rather common. Occasionally a rock is met with (122) in which feldspar-crystals play a prominent part.

(2) The fine non-gritty tuffs.¹—These rocks, some of which are of Llandeilo, others of Arenig age, are principally met with in

¹ It was sometimes very difficult to distinguish between certain of the tuffs and the finer types of felsites. Mr. A. Harker, F.R.S., has kindly helped us, and we desire to tender him our sincere thanks.

the extreme northern part of the area and in the Mount Partry and St. Mary's Monastery district. They consist of closely packed lapilli of felsitic, and occasionally of andesitic rocks, with little or no gritty material. Chlorite tends to be plentiful, sometimes forming irregular patches between the lapilli, sometimes probably representing altered pyroxenes. Unaltered pyroxenes are also present among the constituents of the matrix.

Only rarely, as, for example, at (306) south-east of the brown felsitic intrusion of Shangort, were tuffs free from admixture with gritty material found in other parts of the area.

(3) The limestone-breccias. — Microscopical sections of these rocks show little variation at the various exposures, and consist of a calcareous matrix through which are scattered quartz-grains and ashy particles in varying proportions. The matrix consists principally of limestone, of a horny or not well-cleaved type; but many irregular patches of well-cleaved calcite are also invariably present. The lapilli, while predominantly of quartz-felsite, are sometimes of andesitic rocks (45).

(4) The coarse felsite-breccias or agglomerates. — The matrix of these rocks is the same as in the finer non-calcareous types of tuff.

V. THE VOLCANIC VENT OR NECK.

At a short distance south-west of Shangort occurs an oval mass of coarse breccia having a length of about 100 yards, which Sir Archibald Geikie ('Anc. Volc. Gr. Brit. vol. i, 1897, p. 253) regards as marking a vent, a view with which our own observations are in agreement. This is the only mass which we can claim with confidence as marking the position of a vent or neck.

VI. SUMMARY AND CONCLUSIONS.

We believe the general succession of the Ordovician rocks of the district to be as follows:—

3. (?) Bala Beds.

Coarse conglomerate and sandstone, containing pebbles mainly of granite and felsite.

2. Llandeilo Beds.

(b) Shangort Beds. — Grits and tuffs, coarse and fine—the prevalent type being a calcareous gritty tuff. In this tuff occur bedded limestones and limestone-breccias, the Tourmakeady Beds. The bedded limestones have a maximum thickness of about 30 feet, and the limestone-breccias of about 40 feet. The latter rocks are largely formed of disrupted fragments of limestone corresponding in lithological character to the bedded limestone.

(a) Red felsite or rhyolite. — A series of flows varying much in thickness.

1. Arenig Beds.

Mount Partry Beds.

- (c) Coarse quartzose grits with occasional chert-bands, and, towards the southern half of the area, tuffs.
- (b) Fine grits, graptolitic slates, and cherts.
- (a) Coarse conglomerates.

Owing to the character of the Shangort Beds, there are very few localities where the dip-angle can be obtained, and in consequence their thickness is largely conjectural. The two places where one can obtain an approximate estimate of it are respectively just south-west of Gortbunacullin and west of the Smithy bridge. At both these localities the Shangort Beds seem to be about 1000 feet thick.

The thickness of the red felsite is also a matter of extreme uncertainty. On the assumption that it is dipping at the same angle as the overlying Shangort Beds at the Smithy bridge, its thickness in this region, where it is at its narrowest, is about 300 feet. Farther north, however, there can be no doubt that the thickness is far greater than this, although probably the extra breadth of the outcrop may be partly due to a lower dip-angle, or to repetition by faulting or folding.

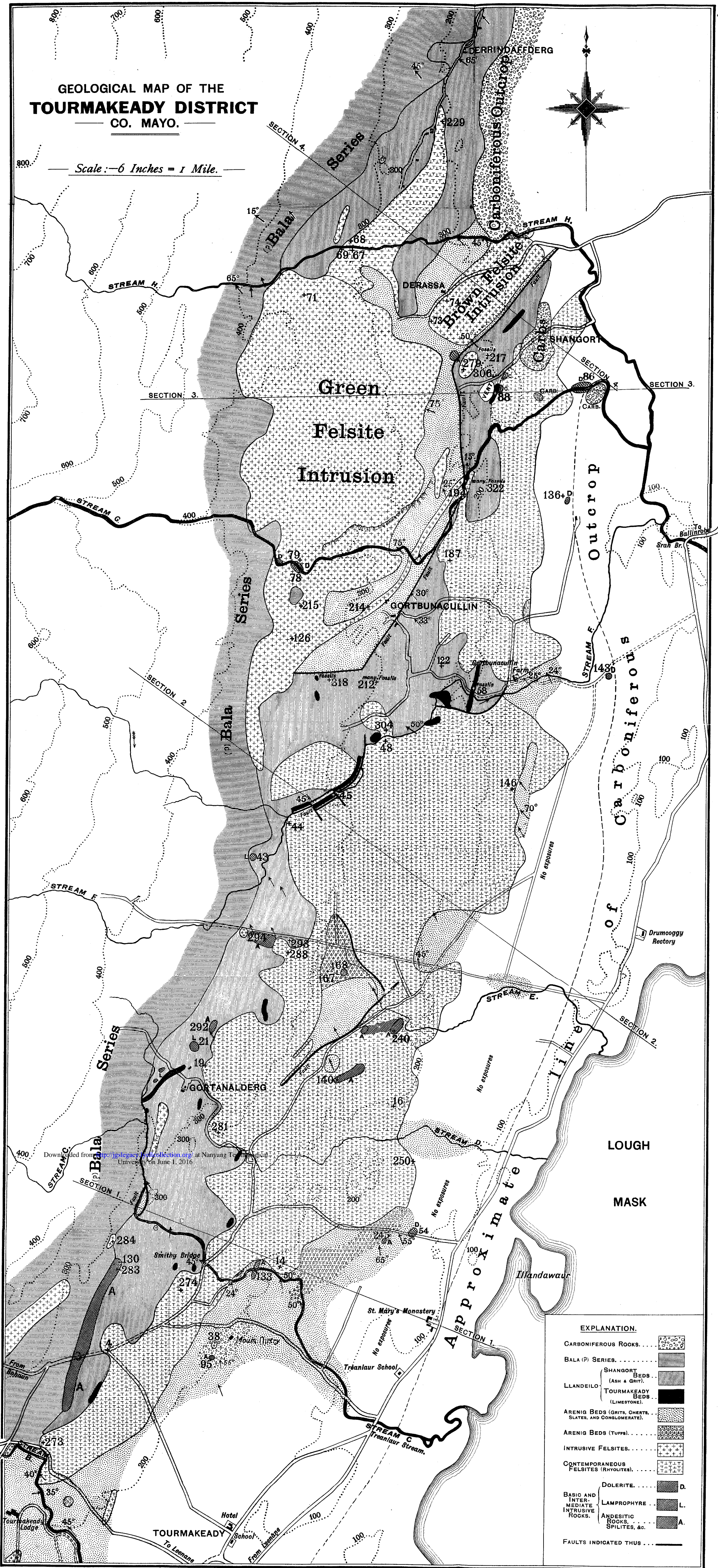
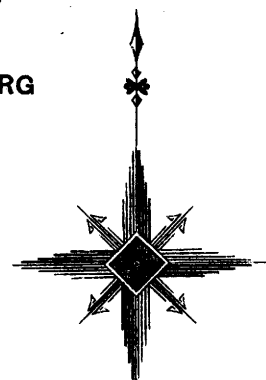
The Mount Partry (Arenig) Beds are well exposed in the Treanlaur stream, and on the supposition that the coarse conglomerate, in which no dips are obtainable, is dipping throughout in conformity with the grits immediately in contact with it, a total thickness of about 1300 feet of Arenig Beds is seen in this section. The coarse quartzose grit, which is comparatively thin near Mount Partry, is probably about 400 feet thick near Gortbunacullin.

Intruded into these rocks are felsites, intermediate rocks of andesitic type, hornblende-lamprophyres, and dolerites. These occur in masses, for the most part, of very small extent; but the felsite-intrusion in the northern part of the area is of very considerable dimensions.

In conclusion, we wish to tender our most hearty thanks to Mr. F. R. Cowper Reed for the large amount of trouble that he has devoted to the examination of our generally very fragmentary Llandeilo fossils. Our sincere thanks are also due to Dr. G. J. Hinde, F.R.S., for examining the radiolaria, and to the Director of the Geological Survey of Ireland for the loan of maps. Other acknowledgments are contained in the body of the paper.

GEOLOGICAL MAP OF THE TOURMAKEADY DISTRICT CO. MAYO.

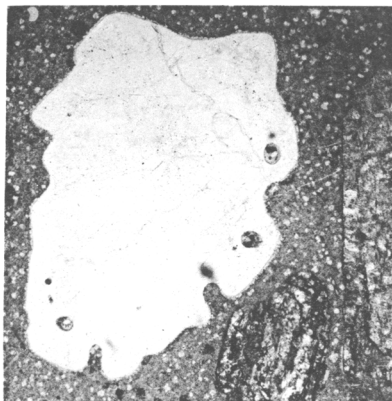
Scale:—6 Inches = 1 Mile.



EXPLANATION.

- CARBONIFEROUS ROCKS.
- BALA (P) SERIES.
- SHANGORT BEDS (ASH & GRIT).
- LLANDEILO TOURMAKEADY BEDS (LIMESTONE).
- ARENIG BEDS (GRITS, CHERTS, SLATES, AND CONGLOMERATE).
- ARENIG BEDS (TUFFS).
- INTRUSIVE FELSITE.
- CONTEMPORANEOUS FELSITE (RHYOLITES).
- DOLERITE. D.
- BASIC AND INTER-MEDIATE INTRUSIVE ROCKS.
- LAMPROPHYRE. L.
- ANDESITIC ROCKS, SPILITES, &c. A.
- FAULTS INDICATED THUS.

1



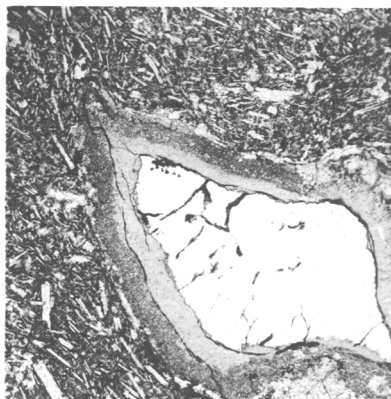
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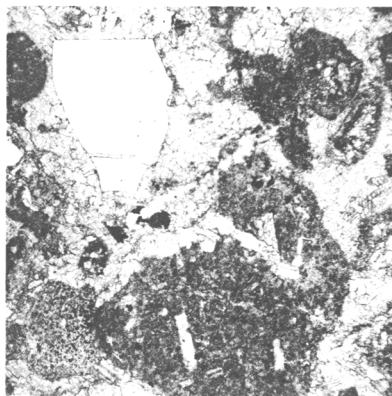
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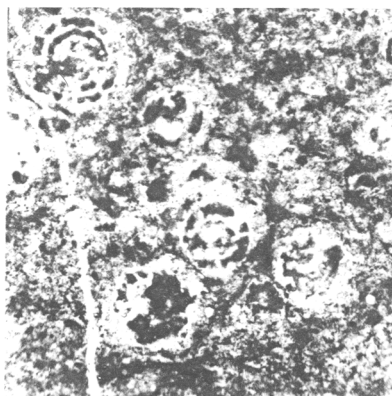


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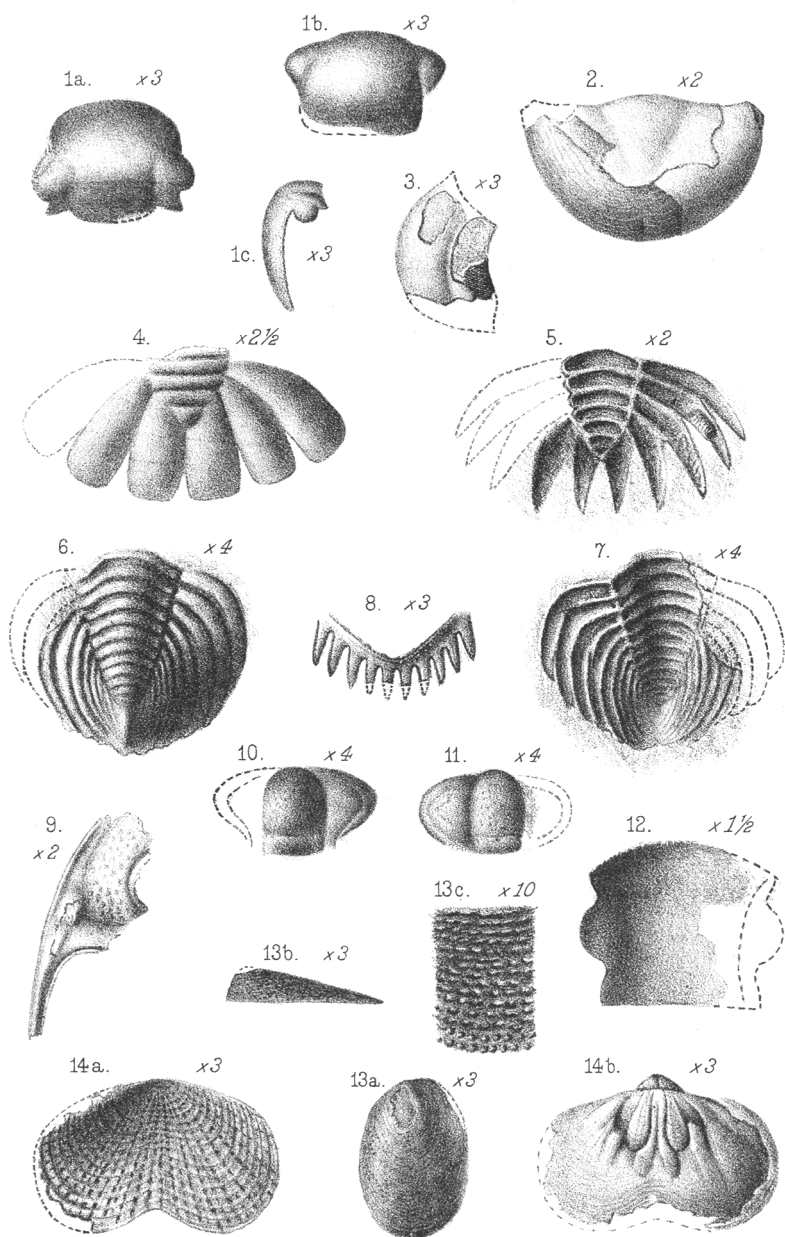
S. H. Reynolds, Photo-micro.

6



Benrose, Collo., Derby

ROCKS FROM TOURMAKEADY.



A.H.Searle del. et lith.

West, Newman imp.

locality and horizon, the gritty ash (322) a third of a mile south-south-west of Shangort. The affinity of this species with *Streptis monilifera* (M'Coy),¹ which occurs in the Upper Bala Limestone of the Chair of Kildare, is obvious; but it differs in the greater number of concentric ridges (25 instead of eight or nine), in the tubercles upon them being widely separated instead of closely placed or contiguous, and in the interspaces between the ridges being narrow impressed lines instead of wide concave grooves. The internal characters of *Streptis* have not been previously described, and we may note in them some resemblance to those of *Mimulus aungloakensis*, Reed,² from the Silurian of Burma, especially in the presence of the umbonal chamber; but there is in this Irish species of *Streptis* no median septum between the diductors. The only other known species of *Streptis* in the British Isles is *Str. grayi*, Dav., from the Wenlock Series, but this is asymmetric, and the concentric ridges are fimbriated.

EXPLANATION OF PLATES IV-VI.

PLATE IV.

Geological map of the Tourmakeady District (County Mayo), on the scale of 6 inches to the mile.

PLATE V.

[All the figures are magnified 28 diameters.]

- Fig. 1. Quartz-felsite (73). Derrassa. The main part of this figure is occupied by a large strongly-corroded quartz-crystal. Parts of two much-weathered feldspars are seen. The little pale spots in the ground-mass are principally quartz. (See p. 133.)
2. Hornblende-lamprophyre (21). Gortanalderg. The figure shows one well-terminated cross-section of a hornblende-crystal, exhibiting the two cleavages. Parts of another large and several smaller hornblendes are seen. The rest of the figure consists principally of quartz. (See p. 137.)
3. Olivine-dolerite (78). West of Gortbunacullin. The most prominent objects are the labradorite-crystals. Between these are small grains of augite, olivine, and magnetite, not clearly differentiated in the figure. (See p. 137.)
4. Spilite (3). Half a mile north of the Lodge, Tourmakeady. The most prominent object in this figure is an amygdale, the main part of which is formed by quartz, while external to this comes a double layer of chlorite, and finally a discontinuous layer consisting partly of calcite, partly of epidote. Surrounding the amygdale are numerous little feldspar-crystals, which extinguish practically straight and are probably oligoclase. (See p. 136.)
5. Calcareous tuff (320). West of Shangort. A quartz-grain and parts of several felsite-lapilli are seen embedded in a calcareous matrix. (See p. 138.)
6. Radiolarian chert (330). West of Gortanalderg. Sections of seven radiolaria are seen wholly or in part. (See p. 111.)

¹ F. M'Coy, 'Silur. Foss. Ireland' 1846, p. 25 & pl. iii, fig. 3; T. Davidson, 'Monogr. Brit. Foss. Brach.' vol. iii, p. 200 & pl. xxv, figs. 3-5, Palæont. Soc. vol. xxii (1868).

² F. R. C. Reed, 'Palæont. Indica' n. s. vol. ii, Mem. 3 (1906) p. 100 & pl. vi, figs. 13-17 a.

PLATE VI.

- Fig. 1 *a.* *Illænus weaveri*, sp. nov. Head-shield, seen from above. $\times 3$.
 1 *b.* Do. Head-shield, seen from the front. $\times 3$.
 1 *c.* Do. Head-shield, seen from the side. $\times 3$.
 2. Do. Pygidium. $\times 2$.
 3. Do. Free cheek. $\times 3$.
 4. *Pliomera* aff. *fischeri*, Eichwald. Pygidium. $\times 2\frac{1}{2}$.
 5. *Pliomera* aff. *barrandei* (Billings). Pygidium. $\times 2$.
 6. *Cybele connemarrica*, sp. nov. Pygidium. $\times 4$.
 7. Do. Pygidium: impression. $\times 4$.
 8. *Acidaspis* (?) sp. Pygidium. $\times 3$.
 9. *Apatocephalus* (?) sp. Free cheek. $\times 2$.
 10. *Telephus hibernicus*, sp. nov. Head-shield. $\times 4$.
 11. Do. Head-shield. $\times 4$.
 12. *Symphysurus* (?) sp. Imperfect head-shield. $\times 1\frac{1}{2}$.
 13 *a.* *Acrotreta* (?) *hibernica*, sp. nov. Pedicle-valve. $\times 3$.
 13 *b.* Do. Pedicle-valve: side view. $\times 3$.
 13 *c.* Do. Pedicle-valve: ornamentation. $\times 10$.
 14 *a.* *Streptis affinis*, sp. nov. Impression of exterior of pedicle-valve. $\times 3$.
 14 *b.* Do. Cast of interior of same valve. $\times 3$.

DISCUSSION.

Prof. WATTS congratulated the Authors in having made a definite correlation between the rocks of this area and of British areas, such as Girvan, in which the succession was well known. He was also pleased to find that it might now be regarded as settled, that the contemporaneous igneous rocks of this area were not of Silurian age.

Mr. H. H. THOMAS, in view of the great thickness of strata between the *Tetragraptus*-Beds and the Llandeilo Flags in Wales, suggested the possibility of the lowest rhyolite being of earlier date than the Llandeilo, especially as there was evidence of volcanic activity in Wales at a low horizon in the *Didymograptus-bifidus* Beds.

Mr. B. SMITH, commenting upon the resemblance between the Tourmakeady Beds and those of the same age in the Girvan district, mentioned by Prof. Watts, pointed out that the rocks of the Pomeroy Inlier in County Tyrone (the Desertcreat Group, of Upper Ordovician age), which lay almost upon the same line of strike, had their nearest equivalents in the Drummuck Beds of Girvan. A link between the Ordovician fauna of Ireland and of parts of Europe was also furnished by the highest Ashgillian Beds (Tirnaskea), in which a trilobitic fauna was associated with a graptolitic one. For example, the recurrent trilobite of Barrande's 'colonies,' *Æglina rediviva*, recognized here for the first time in Ireland, was found together with *Dicellograptus anceps*, the highest zone-fossil of the Southern Uplands.

Mr. O. T. JONES remarked that a number of complicated events appeared to have been crowded into a comparatively limited space of time, if the earliest volcanic activity were referred to the Llandeilo Period. This phase was presumably followed by the deposition and consolidation of the limestone, which was disrupted together with the felsite to form the felsite-breccia; yet the fossils of the higher beds still indicated an horizon of Llandeilo-Flag age. It seemed to the speaker that the conglomerate-beds bounding the area on