broad, while on the outer half they are mostly very fine. The carinal portion, instead of being ornamented with slightly flattened longitudinal ridges, has extremely fine longitudinal lines. It differs further in other characters, the most important being that the scutal margin is sinuous, while it is practically straight in *S. dissimile*. *S. dissimile* may also be compared with the tergum from the Cenomanian (Korytzaner Schichten) of Kamajk, Bohemia, represented in the figure given by J. Kafka¹ (1886), and assigned by him to *S. tuberculatum*, Darwin. This tergum agrees in having a number of raised longitudinal ridges radiating from the apex, but disagrees, among other characters, in that the valve is not conspicuously divided into two parts by a prominent ridge, and in the absence of a groove extending from the apex to the scutal margin.

In conclusion I wish to thank the following gentlemen for help in connexion with this paper: Dr. F. A. Bather, Mr. C. P. Chatwin, Dr. A. W. Rowe, and Mr. C. Davies Sherborn.

IV.—THE GEOLOGY OF THE DOLGELLEY GOLD-BELT, NORTH WALES.

By ARTHUR R. ANDREW, M.Sc., F.G.S.

1. Introduction.	6. History and Statistics of Mining.
2. Previous Literature.	7. Lodes of the Dolgelley Gold-belt.
3. Stratigraphy.	8. Summary of the Veins.
4. Structure.	9. Genesis of the Auriferous Veins.
5. Petrology.	10. Bibliography.

INTRODUCTION.

THE town of Dolgelley lies slightly outside the main tract of gold-bearing country of Merionethshire, but it forms a convenient headquarters from which to visit the various gold-mines and auriferous lodes. The Dolgelley Gold-belt lies within the area covered by the quarter-sheets 27 N.E., 27 S.E., 32 S.E., 33 N.W., 33 N.E., 33 S.W., 36 N.W., 36 N.E. of the 6 inch Ordnance Survey maps of Merionethshire. It is on the north side of the estuary of the Mawddach, extending from the sea at Barmouth to the locality of Gwynfynydd on the north-east. The belt forms the south-eastern flank of a range of high ground sloping down to the south and south-east from the mountains of Rhinog, Diphwys, and Garn. It is drained by several tributaries of the Mawddach, of which the principal are the Afons Hirgwm, Cwm-llechen, Cwm-mynach, Wnion, Las, Gamlan, Eden, and Gain.

The rocks of the Gold-belt all belong to the Cambrian System, and are of two main lithological types—

(1) The greywacke set of the Harlech Grits of H.M. Geological Survey.

(2) The shale set of the Lingula Flags of H.M. Geological Survey: the lowest bed of the latter is usually separated out as a distinct zone, the Menevian.

PREVIOUS LITERATURE.

A considerable amount of literature has accumulated, dealing with the stratigraphy, palæontology, petrology, mineralogy, and also the

¹ "Příspevek ku poznání cirripedů českého útvary křídového": Sitz. Ber. k. Böhm. Ges. Wiss., Prag, 1885, p. 565, pl. i, fig. 7.

mining of the district under review. A brief résumé of this literature will now be given, and a full list of references will be found at the end of this paper.

Stratigraphy.—The rocks of the district were first mentioned by Murchison (7) and Sedgwick (3), and formed part of the formations under dispute in the famous Cambro-Silurian controversy. Sedgwick's final classification was as follows, and in so far as it applied to the rocks of the Gold-belt it is that accepted to-day:—

3. Bala Group (Upper Cambrian).	
2. Ffestiniog Group (Middle Cambrian)	(c) Arenig Slates.
	(b) Tremadoc Slates
1. Longmynd and Bangor Group (L. Cambrian)	(a) Lingula Flags
	(c) Harlech Grits
	(b) Llanberis Slates.
	(a) Longmynd Slates.
- } which form
the Dol-
gelley area.

Between 1850 and 1854 the whole of this Merioneth area was mapped by the officers of the Geological Survey, and in 1854 appeared their geological maps (on a scale of 1 mile to 1 inch): these have not yet been revised (11). In 1866 there appeared the first edition of the Geological Survey Memoir of the district (12). A new edition of this memoir, published in 1880 (13), contained some changes in the classification employed. The Tremadoc Slates were separated from the Lingula Flags, with which they had previously been associated, and at the same time the term Menevian was first used by the Survey, for the band of black shales and slates at the base of their former Lingula Flags. The sequence of the Survey became—

4. Tremadoc Slates	Upper Cambrian.
3. Lingula Flags	Upper Cambrian.
2. Menevian Slates	Middle Cambrian.
1. Cambrian Grits and Flags	Lower Cambrian.

From 1846 to 1867 a certain amount of investigation was carried out, chiefly by Sharpe (16), Readwin (29), Salter (20), Plant and Williamson (23), Belt (24). Most of these investigations resulted in proposals of new classifications of the rocks, but on the whole these proposals have not been accepted. The chief of the investigators was Thomas Belt, who introduced the splitting of the Lingula Flags into the Dolgelley, Ffestiniog, and Maentwrog divisions—a grouping which is in use to-day. Belt's sequence consisted of—

10. Tremadoc Slates.
8 and 9. Upper and Lower Dolgelley.
7. Upper Ffestiniog: Tough blue-grey flags.
5 and 6. Lower Ffestiniog: Blue and brownish-grey fine-grained flags, the lower part slightly arenaceous and micaceous.
3 and 4. Upper Maentwrog: Dark-blue slates weathering rusty, the lower part yellowish and bluish-grey fine-grained flags, sometimes a little arenaceous, but not so coarse as the groups still lower.
1 and 2. Lower Maentwrog: Blue-grey and blue-black jointed slates with slightly arenaceous flags, the lower part grey, and yellowish-grey pyritic flags with hard felspathic bands.
0. Lower Cambrian, consisting of—
(c) Menevian with <i>Paradoxides</i> .
(b) Harlech Grits.
(a) Bangor Slates.

From 1867 to the present day, except the second edition of the Survey Memoir, 1881, nothing additional has been published.

Within the last ten years, however, Professor Lapworth and Dr. T. Stacey Wilson have mapped much of the Merionethshire country and determined the sequence and general distribution of the various lithological groups of the Lower Cambrian of the region. Although their work has not yet been published, they permitted me to use their results and showed me through their succession from the Cefn Slate Group to the top of the Vigra Beds. The following is the descending sequence of Lapworth and Wilson as employed and referred to by myself in the present paper:—

Lowest Lingula
Flags of the
Geological
Survey.	{	9. Ffestiniog Beds of Belt.
		8. Pen Rhos Beds (Upper Maentwrog of Belt): Dark-blue slates characteristically weathering to a bright-red or perhaps rusty colour.
		7. Vigra Beds (Lower Maentwrog of Belt): Dark-grey and blue slates, with numerous interstratified hard beds of felspathic and siliceous material, which occur throughout.
Menevian of
Survey.	{	6. Clogau Beds (Menevian of Salter and Belt): Black shales and slates.
		5. Gamlan Shale Group: A succession of grey, greyish-green, and sometimes purple shales, slates, and flags, interbedded with occasional grit bands, which increase in number and thickness on going eastwards; thickness 750 to 1200 feet.
		4. Barmouth Grits: Massive felspathic grits or greywackes with pebble bands; say 600 feet thick.
Harlech Grits
of Survey.	{	3. Hafotty or Manganese Shale Group (with the well-known persistent zone of manganese ore at the base): Grey and green shales and flags; to the west with rare grits; to the east the grits become more frequent and eventually coarse and thick-bedded; total thickness about 1000 feet.
		2. Rhinog Grits: Massive grits forming the Rhinog and other mountains; thickness about 2500 feet.
		1. Cefn or Llanbedr Slate Group: Blue and purple shales, flags, and slates; to the west (Egryn, Llanfair) with occasional grit bands; to east (Cefn Cam, etc.) the grits are more abundant, and the lowest beds (Dolwen) are red felspathic grits and shales.

Paleontology.—The district around Dolgelley had always been considered destitute of fossils until in 1864 Readwin found *Paradoxides Davidis*, which was described by Plant (22). This, together with the discovery of *Anopolenus* and *Theca*, enabled the lower beds in which they occur to be cut off from the higher beds in which are found the *Olenus* and *Lingula* of the Survey. In 1866 Plant discovered a considerable number of fossils (21–3). In 1867 Belt's examination led to the discovery and identification of many additional genera and species (24). Many fossils too had been discovered by the officers of H.M. Geological Survey. The following table contains the names of all fossils that have been discovered in the Dolgelley area and in the immediately neighbouring country. In this list 'P' means that the fossil was reported by Plant, 'B' by Belt, 'S' by the Survey.

From the Ffestiniog Group of Belt; the Hafod Owen of Plant.

B	<i>Conocoryphe micrura</i> (Salt.) (from	B, P, S	<i>Lingulella Davisi</i> (McCoy).
	Upper Ffestiniog).	B	<i>Bellerophon cambrensis</i> (Belt)
P	<i>Conocoryphe</i> sp.		(from Upper Ffestiniog).
B, S	<i>Hymenocaris vermicauda</i> (Salt.).	P	<i>Buthotrepis</i> (?).
P	<i>Olenus</i> sp.		

From the Pen Rhos Beds; the Upper Maentwrog of Belt.

B	<i>Agnostus pisiformis</i> (Linn.).	B	<i>O. truncatus</i> (Angelin).
B	<i>Olenus cataractus</i> (Salt.).	S	<i>O. sp.</i>
S	<i>O. micrurus</i> (Salt.).	S	<i>Lingulella Davisii</i> (McCoy).

From the Vigra Beds; the Lower Maentwrog of Belt; the Cwm Eisen of Plant.

S	<i>Agnostus nodosus</i> (Belt).	S	<i>Hymenocaris vermicanda</i> (Salt.)
B	<i>A. pisiformis</i> (Linn.).	P, S	<i>Olenus cataractus</i> (Salt.).
P, S	<i>A. princeps</i> (Salt.).	S	<i>O. gibbosus</i> (Wahl.).
P	<i>A. trisectus</i> (Salt.).	P	<i>Sao hirsuta</i> .
P	<i>Holocephalina</i> sp.	S	<i>Lingulella Davisii</i> (McCoy).

From the Clogau Beds; the Menevian of Salter and Belt; the Tyddyn-Gwladys of Plant.

P	<i>Protospongia fenestrata</i> (Salt.).	P	<i>Leperditia</i> sp.
P	<i>Dictyonema</i> sp. (?).	P, S	<i>Microdiscus punctatus</i> (Salt.).
P	<i>Agnostus Davidis</i> (Salt.).	P	<i>Paradoxides Davidis</i> (Salt.).
P	<i>A. pisiformis</i> (Linn.).	P	<i>P. Forchhammeri</i> (Angelin).
P	<i>A. princeps</i> (Salt.).	P, S	<i>P. Hicksii</i> (Salt.).
P	<i>A. trisectus</i> (Salt.).	P	<i>Lingulella ferruginea</i> (Salt.).
P	<i>A. rex</i> .	P	<i>Obolella</i> sp.
P	<i>Anopolenus Henrici</i> (Salt.).	P	<i>Obolus</i> sp.
P	<i>A. Salteri</i> (Hicks).	P	<i>Theca corrugata</i> (Salt.).
S	<i>Conocoryphe</i> sp.		

Petrology and Mineralogy.—References to the petrology of the igneous rocks of the district will be found in the writings of Salter (20, p. 2), Forbes (25, 26, 27), and Teall (28).

A large number of minerals have been reported at various times from Merionethshire, chiefly by Readwin (30, 31), Forbes (25, p. 226; 27), and by Huddart (35). A list of these minerals is given below: unless otherwise indicated, the report of the occurrence of the mineral is to be found in one of Readwin's notices.

Native Elements: Gold, Electrum, Silver, Platinum, Platiniridium, Iridosmine, Copper, Lead (*Forbes*), Antimony, Bismuth.

Sulphides, Tellurides, etc.: Orpiment, Stibnite, Bismuthinite, Tetradyomite, Galena, Sphalerite, Erubescite, Pyrrhotite (*Huddart*), Pyrites, Chalcopyrite, Marcasite, Arsenopyrite, Berthierite, Tetrahedrite, Aphthionite, Polytelite (*Forbes*).

Oxides: Quartz, Arsenolite, Senarmontite, Magnetite, Titanoferrite, Rutile.

Carbonates: Calcite, Dolomite (*Forbes*), Ankerite (*Forbes*), Chalybite (*Forbes*), Rhodochrosite, Cerussite, Malachite.

Silicates: Orthoclase, Hornblende, Uralite, Mica, Chlorite (*Forbes*), Ripidolite, Talc.

Phosphates: Pyromorphite, Mimetite.

Sulphates: Barytes (*Forbes*).

Mining.—In 1844 Dean (36) and Roberts (37) published the first notices relating to the discovery of gold in Merionethshire. During the years 1870 to 1880 Readwin published many articles in the *Mining Journal* and elsewhere, giving many details of the mining industry (32, 33). In 1902 Maclaren (38) brought together many interesting facts regarding the Merioneth field. Other references to the mining industry of Merionethshire are to be found in the writings of Forbes (25), Booth (39), Huddart (35).

STRATIGRAPHY.

The divisions and groups which have been adopted in the present paper are those of Lapworth and Wilson for the Lower Cambrian and

those of Belt for the Upper Cambrian, as far as they have been generally accepted. The grouping therefore is—

	Tremadoc Slates	} Upper Cambrian.
	Dolgelley Beds	
	Ffestiniog Beds	
Pen Rhos Beds	Maentwrog Beds	} Middle Cambrian.
Vigra Beds		
Clogau Slates	Menevian	
Gamlan Shales		} Lower Cambrian.
Barmouth Grits	Harlech Grits	
Manganese Shales		
Rhinog Grits		
Cefn Slates		

The order above is in the descending sequence of the beds. Of the formations enumerated, those which are more intimately connected with the occurrence of the auriferous lodes are the Gamlan, the Clogau, the Vigra, the Pen Rhos, and the Ffestiniog. These merit more detailed notice.

Gamlan Beds.—In the north-east part of the district, from the neighbourhood of the Afon Gain to near Blaen-y-cwm in the Wnion Valley, the lithological break between the Clogau and the Gamlan Beds is quite sudden, the black Clogau Slates extending down with all their usual characters to a basement grit (the Cefn Coch Grit), and the grey and grey-green beds of the Gamlan Group coming immediately below. In the western part, from Blaen-y-cwm to Barmouth, there is a more or less marked zone of transition, never more than 20 feet in thickness, in which there is an apparent commingling of the dark shales of the Clogau and the grey, green, and purple bands of the Gamlan. It would seem, therefore, that the grit disappears as such to the westward: almost everywhere, however, the boundary-line between the two types of Gamlan and Clogau Beds can be drawn fairly sharply.

In the north-east country the thickness of the Gamlan Group is 1200 feet, made up of intermingled grits, greywackes, flags, and shales. Following the outcrop of the rocks towards the south-west, the grits and greywackes become thinner and thinner, and the collective thickness of the beds less and less, until in the neighbourhood of the Afon Hirgwm most of the coarse-grained beds have disappeared, and the total thickness of the formation has become 750 feet. In this vicinity there is a grey flaggy bed near the top of the formation, characterized by the occurrence in it of good cubic crystals of pyrites, as much as half an inch along the edge. Traced further still to the south-west, the grits and greywackes become still finer, and near Barmouth the Gamlan Beds are seen to be made up entirely of shales and flags.

The Gamlan Shales contain numerous interbedded sills of greenstone. Towards the west, where the group consists chiefly of shales and flags, the sills are thinner than they are towards the north-east, where the greywackes are more frequent and massive. The massive greywackes would offer greater resistance to the folding forces, and would tend to form mighty buckles with large cavities between. The softer flags and shales would fold and pack more readily, and would not have

rigidity enough to support massive arches. The cavities formed would be smaller and less continuous, and this difference would be represented by the difference in the size of the greenstone sills that we see to-day.

Clogau Slates.—These consist of a thickness of 250 feet of well-cleaved slates, dark-blue and black in colour. The streak obtained by scratching, however, is never really black, and as the beds in many places are greyish blue it seems difficult to justify the epithets 'jet-black' and 'intensely black' applied by nearly all those who have previously referred to them. The slates weather to a dull crumbly ochreous yellow colour on the surface. Their dark internal colouring is due to organic matter and to iron sulphide, both being present in greater abundance than in the correspondingly black slates of the Pen Rhos Beds. On analysis I found that the Clogau Slates contained the following:—

Organic matter	.	.	.	.	.	.	.	5.78
Iron in the form of sulphide	.	.	.	.	.	.	.	21.88
Not determined	.	.	.	.	.	.	.	72.34
								100.00

The Clogau Slates do not give rise to surface features, and are seen to advantage only in the stream courses, especially in the bed of the Afon Gamlan, above its confluence with the River Mawddach. Further up the Mawddach, close to the Tyddyn-Gwladys mine, they cut across the river and are well exhibited. Other good localities are found in the course of the Bontddu stream from the St. David's Gold Mill to the Pont-ty-glan-afon; in the workings of the Clogau lode and on the Clogau Hill; and at Aber-Amffra Harbour close to Barmouth, where the beds are exposed on the roadside.

The Clogau Slates are interleaved with numerous thin pyritous bands, usually about $\frac{1}{2}$ inch in thickness, which are rarely discernible at outcrops on the hillside, but are quite plain in the stream-courses. When fresh these bands are but slightly paler in colour than the dark-blue slates with which they are bedded; but on weathering they turn white and show up very distinctly on the smooth water-worn beds of the streams. The cause of this peculiar weathering is probably the much greater proportion of pyrites contained in the white bands. On weathering, the pyrites sets free ferrous sulphate and sulphuric acid, and the latter may dissolve out some of the coloured constituents of the slate.

The Clogau Slates are interbanded with many sills of intrusive greenstone: a few of these are massive, ranging up to 100 feet in thickness, but the majority are much thinner, often as thin as 2 or 3 feet. The strike of the thinner sills is irregular: they show a tendency to cross a few of the planes of bedding, and then resume their original course.

Maentwrog Beds.—These lie above the Clogau Slates and have a thickness of about 2700 feet: they consist of dark-grey, dark-blue, and black slates and flags. There occur throughout them numerous bands of fine-grained siliceous grit. In the upper division of the Maentwrog Group, these are present only as thin wavy white layers,

from $\frac{1}{4}$ up to 2 inches thick. In the lower division, however, they increase in individual thickness to 2 or 3 feet, and occur as hard ribs sufficiently resistant to form surface features, and numerous enough to make up 25 per cent. of the actual thickness of the formation, as it is exposed in the Bontddu Glen and in the bed of the Mawddach River near the Cefn-deuddwr Gold Mine. The very great predominance of these ribs in the Lower Maentwrog is the lithological character which has been utilized by Lapworth and Wilson in separating the Maentwrog Beds into—

(b) Pen Rhos Beds or Upper Maentwrog.

(a) Vigra Beds or Lower Maentwrog.

(a) *Vigra Beds*.—The Vigra Beds are characterized by the large proportion of siliceous grit bands. In hand-specimens these grits are very fine-grained, homogeneous in texture, and light grey in colour; they resemble in appearance a fine-grained quartzite, and the similarity is increased by their extreme hardness.

Under the microscope it is seen that these bands are even and compact grits, the quartz grains of which are about $\frac{3}{16}$ inch in diameter. The visible minerals are quartz, muscovite, and a little feldspar and pyrites. The grains of quartz are but slightly rounded, and a few may show crystalline faces: the quartz constitutes quite 95 per cent. of the total bulk of the rock. The microscopic structure of the flaggy beds in the Vigra Group is similar to that of the grit bands, but the flakes of muscovite are much more numerous and are arranged more or less parallel to the bedding.

The shales, slates, and flags with which the grit bands are interleaved are in the main similar in lithological characters to the shales, etc., in the overlying Pen Rhos Beds, but the harder ribs seem to a great extent to have protected the shales from cleavage, with the result that well-cleaved shales are seldom found. The colour of these interbedded shales and flags is dark grey and dark blue; the proportion of iron in them is somewhat less than in the Pen Rhos Beds, and the characteristic reddish weathering of the latter is generally wanting. Where exposed to atmospheric agencies the shales and flags weather easily from the outstanding grit bands. Many of the flaggy beds and a few of the grit bands weather more readily along certain lines which are not visible in the unweathered specimen, and the weathered surface becomes covered with curling ridges and furrows, which rather resemble tattooing. The type locality for these Vigra Beds is on Vigra Hill, which lies immediately north-west of Bontddu village. Good exposures are seen along the road which leads from Bontddu Post Office to the St. David's Gold Mill, and in the Bontddu stream parallel to this road. Other good exposures are in the bed of the Afon Cwm-Mynach above the Cambrian cottage, and in the bed of the Mawddach River upwards from its junction with the Afon-Eden.

(b) *Pen Rhos Beds*.—The Pen Rhos Beds are 1600 feet thick. They consist of shales and slates, always dark blue or black in colour; they are well cleaved, the cleavage usually being strong enough to efface the planes of bedding. They contain a few bands of siliceous grit,

but compared with the Vigra Beds these are very rare indeed. Owing to the relative softness of the Pen Rhos Beds they do not form prominent surface features, except where hardened by contact with igneous intrusions. The dark colour is due to finely disseminated organic matter and pyrites, the latter of which weathers to iron oxide and gives the slates a characteristic red coloration on exposed surfaces. On fresh specimens of the slates, cubes of pyrites may be seen up to half an inch in size. On analysis these slates gave me the following:—

Organic matter	.	.	.	.	.	.	3.90
Iron in the form of sulphide	.	.	.	.	.	.	12.48
Not determined	.	.	.	.	.	.	83.62

100.00

The Pen Rhos Beds are best seen on the Pen Rhos Hill opposite the Tynygroes Inn, 5 miles up the Mawddach Valley from Dolgelley. Numerous sections are also exposed in the road cuttings along the turnpike road from Llanelltyd to within 2 miles of Barmouth.

Throughout the Maentwrog Group there are numerous igneous intrusions; these belong mostly to the so-called 'greenstone' of H.M. Survey, but some of them are hornblende porphyries. They are mostly sills, with a great extent in strike and dip, but never more than 100 feet in thickness.

Ffestiniog Group.—This group consists of over 3000 feet of grey and grey-green flags, with a few black shales and flags; they are hard and resistant and usually form fairly high ground. Among these grey and grey-green Ffestiniog Flags there are numerous harder ribs from 18 inches down to 1 inch and less in thickness. These are of two types: many of them are greywackes of medium grain; many are compact, fine-grained, and very siliceous grits, similar to those which constitute so large a proportion of the Vigra Beds described above. Where the shales and flags are dark-coloured they contain a large amount of iron, and their weathering causes the rock to assume reddish and dun colours. They are well seen along the road which runs past the mill of the Glasdir Copper Mine up the south bank of the Afon Las as far as Pont Llamyrewig. Good sections also occur in the workings and at the outcrops of the Glasdir Copper Mine, and the gold mine of Ffridd Goch. Many very massive igneous intrusions occur among the Lower Ffestiniog Beds, such as those forming the hills behind Penmaenpool, and also the heights of the Precipice Walk, Ffridd Goch, and Moel Cerniau.

STRUCTURE.

The Dolgelley Gold-belt lies on the east and south flanks of the well-known Harlech dome of Merionethshire. The great north and south sag between its two main arches, and which Lapworth and Wilson have followed from Moel Gedog, south of Talsarnau in a broken line through the Harlech uplands, continues into this country, and enters the Barmouth estuary close to the Caerdeon Vicarage. From the neighbourhood of Gwynfynydd southwards to near Llanelltyd, the general strike of the beds is about 10° east of north. From

Llanelltyd westwards to Barmouth the general strike is in the main more north-easterly (45° or 50° east of north). This general flanking structure is much complicated by the minor folding to which the strata have been subjected. This folding has given rise to minor anticlines and synclines, often broken by small faults, especially along their axes, where, instead of yielding to the pressure by bending, the strata have snapped.

The faults found in this district may be divided for convenience into two classes—

- (a) Minor faults or fractures.
- (b) Major faults or throw faults.

The minor faults have probably been formed during the upheaval of the dome. They occur along those lines where the beds have been fractured, but where the pressure to which they have been subjected has not been sufficient to produce a relative displacement of the beds on the two sides of the fault. Among the harder beds of the Lower Cambrian they are especially numerous, crossing one another at all angles. In the beds of the Middle and Upper Cambrian they are not so frequent, as the strata there are not so massive, and have been more readily thrown into folds. Each of these fractures forms a noticeable groove along its outcrop.

Of the major faults or dislocations there are two main sets, with a third less important set—

1. East and west faults (practically 70° E. of N.).
2. North-east and south-west faults (30° E. of N.).
3. North and south faults.

1. *East and West Faults.*—These are almost certainly older than the others, for they are sometimes cut and dislocated by them. The most conspicuous one of this east and west set is the Cwm Mynach fault, which cuts out a great amount of the Lower Cambrian rocks. At its western end it is seen in the Maentwrog Beds; going eastwards it increases in throw, and on the Clogau Hill it cuts out fully one-half of the Gamlan Beds. As the fault is traced eastwards, it decreases in amount, and then disappears; it cannot be seen more than 5 miles away from its westerly extremity.

2. *North-east and South-west Faults.*—Instances of this set of faults are seen in the country behind Bontddu, but the displacement they cause is by no means large. They are probably contemporaneous with the north-east and south-west gold-lodes, for at Bwlchcochuchaf and Hafoduchaf there is a close relationship between one of these faults and the lodes which I describe later under these names. The north-east and south-west faults were formed after the east and west ones, as is seen in the country behind Bontddu.

3. *North and South Faults.*—These are the most recent and conspicuous of the faults of the Dolgelley Gold-belt. They are found throughout the district, but are of greatest importance towards the north-east. The chief faults of this set are the following:—

(a) The Llynbodlyn fault of Lapworth and Wilson extends from the estuary at Caerdeon to Llynbodlyn on the west of Diphwys, a distance of about 4 miles. It cuts several lodes and causes a considerable displacement of the sedimentary beds.

(b) The Bryntrion fault is about 2 miles long: it attains its maximum importance on the Clogau Hill, where it intersects the Clogau or St. David's lode.

(c) The Afon Gain fault runs along the course of the Afon Gain, and extends north and south from there. Its effect is greatest in the north, and it dies away to the south in the Maentwrog Beds, faulting the Gwynfynydd lode on the way.

(d) The Beddycoedwr fault passes down the east side of Moel Gwynfynydd. Like its companion, the previous one, it decreases in intensity towards the south, dying out finally in the Ffestiniog Beds. It cuts out all the Pen Rhos Beds, and a small part of the Vigra Beds. The eastern end of the Gwynfynydd lode terminates against it.

Cleavage.—All the finer-grained members of the sedimentary formations of this Dolgelley Gold-belt are traversed by cleavage planes. In very few cases, however, are the resultant slates of sufficiently good quality to be utilized for roofing or similar purposes. The strike of the cleavage planes is northerly; it usually lies between the limits of 5° west and 10° east of the meridian; it exceeds these limits very rarely. The dip of the cleavage planes is always steep, from 70° to 90° , sometimes towards the east, sometimes towards the west. The direction of cleavage in the gold-belt is entirely independent of the geological structure, as expressed in the dip and strike of the beds as a whole, and also of the minor puckerings and contortions into which the slates have at times been thrown. It is quite possible that there has been movement of the country subsequent to the development of the cleavage, but it cannot have been of great importance.

The movement of the country which gave rise to the cleavage must have been subsequent to the intrusion of the greenstone masses. In several instances we find examples in which a coarse, rude cleavage has been induced in the igneous rocks themselves, in the greenstone above the Precipice Walk, Dolgelley, and further east towards Llanfachreth. Other instances may be seen near the top of Y Garn and elsewhere. In these cases of cleaved greenstone, the direction of cleavage is the same as that of the finer general cleavage which traverses the slates. I have met with one case where the greenstone intrusion has an included band of shale hardened to such an extent that it had resisted the cleaving force and has remained uncleaved. It is possible that it may have been more or less protected by the great thickness of igneous rock in which it is enveloped, but the conclusion remains the same—that the greenstone was there before the cleavage commenced. This example is seen on the Clogau Hill, north of Bontddu, just where the old mine tramway crosses the large sill which runs from Llechfraithisaf up to the top level of the St. David's Gold Mine.

Although the intrusion of the greenstone is previous to the cleavage of the country, I believe that it is subsequent to the folding. In several cases where the rocks are puckered and folded, it is seen that the greenstone sills do not continue uninterruptedly round the folds, but feather out at the actual bend of the folds, the form of the intrusion being here determined by the pre-existing form of the folding.

Again, the intrusion of the greenstone appears to be subsequent to the movement of the country which caused the formation of joint-planes. Some distance up the Bontddu stream, 200 yards above the St. David's Gold Mill, a sill of greenstone is seen to end abruptly at a joint; there is absolutely no trace of movement having taken place along this joint-plane, and of the sill being faulted off. It therefore seems that the joint-plane was there before the greenstone was intruded, and was the determining factor in its abrupt termination.

The general sequence of events in this district after deposition thus appears to have been—(1) folding and jointing, (2) intrusion of igneous rocks, (3) cleavage. In this district there is no evidence to show the actual geological date of origin of these separate phenomena. In the North Wales region generally, however, it is considered certain that the cleavage of the region was effected in the interval between Silurian and Carboniferous times. In the North Wales region, the igneous rocks found among the Ordovician beds are believed to have been intruded in late Ordovician or Silurian times, and the greenstones of the Dolgelley Gold-belt were probably intruded at this time also.

According to Ramsay, the sequence of the movements in North Wales generally was—(1) intrusion, (2) folding, (3) cleavage. I think, however, that in the Dolgelley area the folding preceded the intrusion of the sills, but the point is not of great importance, as it is most probable that the two phenomena were closely associated, and took place at very nearly the same period.

PETROLOGY.

Throughout the district in which the gold-bearing lodes of the Dolgelley Gold-belt occur, there are many intrusions of igneous rock, several of them of considerable magnitude. These intrusions occur in the form of dykes, of sills, and of more massive bosses. Dykes are by no means common and the only clearly defined examples occur in the country at the back of Bontddu. The sills are found most frequently among the soft yielding shales. In the softest formation of all, the Clogau or Menevian, they are very numerous, and have such a considerable aggregate thickness that in places they 'fatten out' the Clogau Beds by fully 50 per cent. The sills constitute far and away the greatest proportion of the igneous rocks of the district; they range in thickness from tiny interbeddings 6 inches wide, such as occur a short distance below the Vigra bridge, Bontddu, up to massive, almost laccolithic intrusions, 200 feet thick, such as form the conspicuous ridge at Llechfraith on the Clogau Hill. The sills continue quite evenly between the bedding planes for considerable distances before they die out. At times, however, they break across the bedding, and their intrusive and subsequent nature is thus clearly demonstrated.

The metamorphic effect of these igneous intrusions upon the rocks with which they come in contact is not very considerable. The shales are baked into hard porcellanites, but only for a short distance (a maximum of a few feet) from the intrusions. On weathering, these

baked shales project from the softer unchanged shales, and also as a rule from the intrusive rocks themselves. The black shales are to a certain extent decolorized by the baking.

I believe that in this district the igneous rocks all belong practically to the same period. There is no great diversity of lithological character among them, and they probably originated in the same common magma. The petrographical character of the igneous rocks is difficult to determine, the metamorphic action to which the rocks have been subjected has been sufficient to destroy and change the characters of many of the minerals of which they are composed. There are two types of igneous rock represented in the district: (1) Diabase (of Harker, Teall, etc.); (2) Porphyry (of Rosenbusch).

Among the diabases are practically all the 'greenstones' of H.M. Geological Survey. (The name 'greenstone' is so convenient for referring to the diabases that I have used it almost invariably throughout this paper.) The structure of the rock is intermediate between the plutonic and the volcanic types, though there is considerable variation and gradation in structure. The minerals that occur in the rock are oligoclase, hornblende, uraltite, pyrrhotite, pyrites, chalcopyrite, calcite, sericite, kaolin, and iron oxides. Plagioclase forms the most conspicuous phenocrysts in the rock; the crystals, rounded in outline, are twinned—chiefly albite twins; the plagioclase is probably a basic oligoclase close to andesine; the felspar phenocrysts are always cloudy, the cloudiness being due to the presence in them of weathering products such as calcite, kaolin, etc., the individuals of felspar range down in size to minute lath-shaped crystals, which make up a large proportion of the ground-mass of the rock. Hornblende is seldom seen to satisfaction, it occurs among the phenocrysts, where it is intensely brown and strongly pleochroic; usually the hornblende is completely decomposed into sericite and chlorite. Pyrites, pyrrhotite, and chalcopyrite are very abundant in the rock, but as far as my examination goes, there is no evidence to determine whether these minerals were originally present in the rock or have been subsequently introduced. Chlorite, sericite, kaolin, and iron oxides are found among the decomposition products of felspar and hornblende, but their characters call for no special mention. The specific gravity of this diabase rock is 2.84; it should be noted that the felspar is oligoclase, which is rather too acid a type of plagioclase to be usually found in a diabase.

The second type of the igneous rocks of this Gold-belt is a porphyry or uraltite porphyry; it is of much more restricted occurrence than the diabase, and I know of only two outcrops where fresh specimens may be obtained; these are at Y Garn and at Cefn-deuddwr. The Y Garn rock is typically porphyritic, the phenocrysts consisting of orthoclase, uraltite, and hornblende, the latter much decomposed; the ground-mass is fine-grained and microcrystalline, and is densely packed with little squares of orthoclase, which, like the phenocrysts, present only the usual characters. The only other minerals in the rock are muscovite, chlorite, and pyrites, produced by the decomposition of the hornblende; the specific gravity of the rock is 2.738.

The Cefn-deuddwr rock differs from that occurring on Y Garn in

the much greater size and abundance of the phenocrysts of uralite, hornblende, and orthoclase, and in its coarser texture; the individuals may be as much as 1 inch in length. The rock is composed of orthoclase, plagioclase, hornblende, uralite, chlorite, magnetite, calcite, and pyrites. Orthoclase is found in large amount both in phenocrysts and in the ground-mass. In the former it often shows a clearly marked arrangement of concentric zones on the external margin of the crystal; the orthoclase is usually cloudy, owing to the presence of calcite. Plagioclase is present sometimes, but never to such an extent as the orthoclase; it is confined to the ground-mass, where it occurs as lath-shaped albite twins, probably andesine. Hornblende, like the orthoclase, occurs in two generations, among the phenocrysts and in the ground-mass; it is brown and strongly pleochroic. The bulk of the coloured constituent of the rock is uralite. Magnetite is a decomposition product of the hornblende, occurring along the cleavage cracks of the smaller hornblende crystals and giving a lattice-like appearance to the mineral. Pyrites may at times be very abundant in the rock, but often it is quite absent: it is perhaps of secondary origin.

It is to be noted that Forbes in 1868 (27) reported and described a uralite porphyry from this neighbourhood.

(To be continued in our next Number.)

V.—ON CORAL ZONES IN THE CARBONIFEROUS LIMESTONE.

By R. G. CARRUTHERS.¹

AMONGST the corals collected by the Geological Survey during the past season, and submitted to me for determination, two specimens call for special remark, since they appear at first sight to occur out of their true zonal position. They were found by Mr. Dixon on the Pembrokeshire coast, to the south and south-west of Castle Martin. In each case Mr. Dixon gives the horizon as C₂-S₁, in the terms of Dr. Vaughan's classification. They are, accordingly, of Lower Viséan age.

One of the specimens (E.D. 1253) is referable to the genus *Dibunophyllum*. In cross section there is a general resemblance to the figure of *Dib.* aff. ψ recently given by Mr. Douglas.² In the Pembrokeshire specimen, however, the mesial plate, although conspicuous, is not thickened in the middle, and the central area is more clearly separated from the septa. In vertical section the central and tabular areas are sharply differentiated, the former being crowded with fine vesicles directed inwards and upwards at a steep angle.

The second specimen (E.D. 1350) is an example of *Cyathaxonia rushiana*, Vaugh. A cross section shows the characteristic columella, relatively large, oval, and with a 'lath' in the centre.

Hitherto, *Dibunophyllum* has not been recorded in the British Isles below the *Dibunophyllum* zone (D), while *Cyathaxonia rushiana* has only been found at a still higher horizon in the uppermost Viséan,

¹ Communicated by permission of the Director of the Geological Survey.

² J. A. Douglas, "The Carboniferous Limestone of County Clare": Q.J.G.S., 1909, vol. lxxv, pl. xxvii, fig. 6.