Scale of Colours.

- New Red Sandstone
- Mountain Limestone
- Old Red Sandstone
- Ludlow Rocks — Upper Silurian Formation
- Wenlock Rocks — Upper Silurian Formation
- Upper division — Lower Silurian Formation
- Lower division — Lower Silurian Formation
- Cambrian Formation
- Slate beds in various Formations.
- Steatitic Slate & Serpentine.
- Metamorphic Rocks.
- Porphyry & Felstone.
- Greenstone.

CAERNARFON BAY

ISLE OF ANGLESEA

ESTUARY OF THE DEE

FLINTSHIRE

DENBIGHSHIRE

MERIONETHSHIRE

MAP
OF
PART OF NORTH WALES,
to illustrate
Mr D. Sharpe's Memoir.

PROCEEDINGS,

ETC.

POSTPONED PAPERS.

Contributions to the Geology of North Wales. By Daniel Sharpe, Esq., F.G.S.

Plates XII., XIII.

[Read March 6th, 1844.]

The author made a tour in North Wales, having two objects principally in view: the first, to classify the stratified rocks of that country; the second, to ascertain what are the beds that lie below the Silurian rocks of Sir R. Murchison, and whether those beds contain any organic remains.

After first observing the structure of those parts of the country where the order of superposition in the beds was already known, he proceeded to examine other districts where the arrangement of the rocks is more obscure and complicated.

Upper Silurian Rocks.—Llangollen district.

He began by studying the Llangollen district, described by the late Mr. Bowman*. He agrees with that geologist in referring the Upper Silurian rocks in that neighbourhood, partly to the Ludlow and partly to the Wenlock series of Sir R. Murchison.

Ludlow series.—This series, in descending order, consists of

1. Thin, grey, micaceous beds, containing *Terebratula navicula*, *Leptæna lata*, several species of *Cypricardia*, and other fossils.
2. Liver-coloured shales.
3. Blue shale.

The distinction which exists in the English border counties, between the Upper and Lower Ludlow beds, cannot here be made out; nor is there any trace of the Aymestry limestone. There are so few fossils in the greater part of the Ludlow and Wenlock series in North Wales, that it is by differences of colour or mineral composition that one is often obliged to distinguish them. The Ludlow series is of soft texture, is readily decomposed by weathering,

* See Trans. Geol. Soc. Manchester, vol. i. p. 194.

and is rarely affected by cleavage. The Ludlow rocks of Llangollen dip at a low angle, and pass conformably below the mountain limestone of Eglyseg Crags. To the west and south they are bounded unconformably by lofty hills belonging to the Wenlock series, which appear to have been elevated before the deposition of the Ludlow rocks; and the latter, since they were deposited, appear to have been little disturbed.

Outlier of Mountain Limestone at Guerclas, west of Corwen; and district of Ludlow Rocks west of Corwen, and of the Nant Morwynion fault.—On passing from Corwen along the Holyhead-road to the left bank of the Dee, from Lower Silurian rocks, having an eastern strike, and hereafter to be noticed, you enter on a district of more recent origin, where the beds strike N., N.W., or N.E. The gravel which here covers the valley of the Dee conceals one of the principal faults of the country, the continuation of the Nant Morwynion fault, hereafter mentioned.

On the left bank of the Dee, at the north-east end of Cefn Mawr, is a detached outlier of mountain limestone, about half a mile long and a quarter of a mile wide, which is laid down on Mr. Greenough's map. It is a mile and a half west of Corwen.

It is well-exposed in open quarries, and consists of thick beds of light grey limestone, alternating with dark and black argillaceous shale, agreeing in character with the shale that, in the neighbouring districts of mountain limestone, is found in the lower part of that formation. The author obtained from these quarries many well-known fossils of the mountain limestone. The beds of this mass dip north-east, from a low angle up to 45°.

To the west of the limestone, and underlying it, is a rotten grey shale, readily decomposing into mud; which, at Pont Bryn, a mile further west, dips E.N.E. 45°. To the west of the Druid Inn, on the Holyhead-road, is a quarry of the same rocks, dippping E.N.E. 30°. These beds the author was able to connect with well-exposed beds of Ludlow shale, which stretch along the west side of the Nant Morwynion fault towards the head of the vale of Clwyd*. There, at the distance of about six miles from Guerclas, they pass conformably beneath the mountain limestone range of Pwll Naid, near Llanelidan, a range which extends from that point northwards along the western side of the vale of Clwyd. The Ludlow shale therefore is seen to be continuous from the limestone of Guerclas to that of Pwll Naid.

Wenlock series.—The beds of this series, in descending order, are the following:—

1. Thin beds of hard blue siliceous schist.
2. Light blue shales, with grey streaks of a lighter and darker shade. In the lower part the shales alternate with beds of excel-

* At Tyn-y-Celyn, situate in this district of Ludlow shale, two miles north-west of Bryn Eglws, the author found *Orthoceras filosum* (Sil. Syst. pl. 9. fig. 3). The Ludlow rocks dip very irregularly, and they are unconformable to the Wenlock series throughout the whole of this district west of the Nant Morwynion fault.

lent flagstone, the Denbighshire flagstone of Professor Sedgwick. These flagstones are largely quarried, and are worked along the planes of bedding. They are entirely free from cleavage; whereas a true slaty cleavage frequently affects the shale that alternates with the flagstone.

3. Thick beds of liver-coloured indurated shale, distinguishable only by their position from the similar shales (No. 2) of the Ludlow series.

4. Grey slate, the lowest bed of the Wenlock series according to Mr. Bowman. This slate is very largely quarried in the Glyn and Oernant quarries, north of Llangollen, at the southern foot of Cyrn-y-brain. It is worked along the planes of cleavage; but these being strongly marked by transverse lines of bedding, the slates are liable to split across. The dip of the beds at these quarries is south, from 45° to 80°; the dip of the cleavage is north, 45°.

5. Hard, gritty, blue shales, with lighter streaks, several hundred feet thick. This is, according to the author, the lowest bed of the Wenlock series in this district. Mr. Bowman made the aggregate thickness of the four beds which he describes, 3100 feet; and if to these this fifth bed be added, the aggregate thickness of the series will be about 3500 feet.

To the fossils previously noticed as belonging to this series by Mr. Bowman and Professor Sedgwick, the author adds three new species of *Creseis*, viz. *Creseis ventricosa*, *C. obtusa*, *C. gracillima*, a description of which is given in the appendix to this abstract.

The different species of Creseis are the most abundant fossils in the Wenlock series of North Wales. Frequently they quite cover the bedding planes of the large flagstones; and they occur also in beds of other texture and composition in the middle and lower parts of the series. Hence they are of great assistance in distinguishing the beds of the Wenlock period.

The Wenlock beds cover a considerable area round Llangollen: on the east they are bounded by Ludlow shales and mountain limestone. On the north, their boundary runs from Pant-glas, at the foot of the mountain limestone of Cefn-y-fedw, across Moel-y-faen to Bryn-Eglys. Along this line they rest conformably on the dark roofing-slate which is the uppermost of the Lower Silurian beds. Such a conformity between the Upper and Lower Silurian rocks is rarely observed in North Wales.

From Bryn-Eglys a fault runs in a south-eastern direction down Nant Morwynion to the Dee river, about three miles west of Corwen, and cuts off the Wenlock beds*. From that point on the Dee another fault strikes down that river, and for three miles of its course this second fault separates the Wenlock flagstones of Broneinion on the left bank of the Dee from the Lower Silurian beds on the right bank, at the northern extremity of the Berwyns. At Garth-newydd, about six miles east of Corwen, and south of the Dee, Wenlock rocks appear; and from this point their southern

* The same fault may be traced for many miles to the north-east of Bryn-Eglys.

boundary runs south-east through Llansaintfraid glyn Ceiriog to the mountain limestone north of Selattyn. Along this line the Wenlock beds rest unconformably upon the dark roofing-slate which is the uppermost of the Lower Silurian beds*. North of the Dee the Wenlock beds dip exactly south from 40° to 80°, and the cleavage planes usually dip north 45°. South of the Dee the prevailing dip of these beds is north-east from 5° to 10°; and the prevailing dip of the cleavage is north-east 50°. There are also several other faults, the principal of which are noticed by Mr. Bowman.

Recapitulation of the Author's Bala Section.

Since the author, in the sequel of his paper, makes frequent reference to the succession of Lower Silurian and Cambrian rocks near Bala, of which he has given an account in vol. iv. p. 10 of the Proceedings of the Society, it may be as well, for the clear understanding of the present abstract, to recapitulate the members of his Bala section in descending order. Of these he now ranks the first seven amongst the Lower Silurian beds, and the eighth and ninth amongst the Cambrian.

1. Good dark blue roofing-slate and flags, ending downwards in soft worthless argillaceous slate.
2. Dark blue fossiliferous limestone, with calcareous slates and soft brown shales —the Upper Bala limestone of Mr. Sharpe, and the Hirnant limestone of Professor Sedgwick.
3. Light grey, rather argillaceous schist and indurated shale, with few fossils.
4. Dark blue limestone, with calcareous shales and grits full of organic remains —the Bala limestone of Professor Sedgwick.
5. Very hard, grey, slaty grits, streaked occasionally or passing into brown— fossiliferous. The "Bala grits" of the author.
6. Grey impure limestone—fossiliferous. The Rhiwlas limestone of the author and Professor Sedgwick.
7. Slaty grits of Rhiwlas—fossiliferous.
8. Grey rotten clay-slate, weathering brown.
9. Dark blue slate of poor quality.

Mr. Sharpe now considers that he underrated the thickness of these beds in the paper referred to: in other respects he adheres to the views there given.

Lower Silurian Formation.

Lower Silurian Rocks north of the Dee.—The dark grey slate of Moel-y-faen, north of Llangollen, is the uppermost bed of the Lower Silurian formation: it is of good quality and is largely quarried. The beds dip S.W. by S. 70°; and the cleavage dips N.E. by N. 50°. It is continued through Bwlch-uchaf, on the southern flank of Cyrn-y-brain, when it strikes east. This slate is considered

* The main chain of lofty hills which separates the vale of Clwyd from that of the Alyn consists of Wenlock rocks, which are bounded on each side by a range of mountain limestone. At Moel Acre, near the south end of the chain, Creseis occurs in a hard liver-coloured slaty rock. East of Ruthin is a blue flagstone, alternating with shale, belonging to the middle of the Wenlock series. This chain in Mr. Greenough's map is coloured as belonging to the Ludlow series.

identical with the dark roofing-slate worked near Llansaintfraid glyn Ceiriog.

The high ridge of Cyrn-y-brain consists entirely of Lower Silurian rocks. These are bounded on the north, nearly along the line of the road to Wrexham, by the mountain limestone of Llandegla and the millstone grit of Moel Grugog. To the west the beds of Cyrn-y-brain are cut off by the continuation of the Nant Morwynion fault.

Lower Silurian Rocks south of the Dee.—The dark grey roofing-slate, the uppermost of the Lower Silurian beds, is worked in the vale of the Ceiriog, at the east end of Cefn Canol, west of Llansaintfraid. The same bed is worked on the right bank of the Ceiriog, at the northern foot of Fron Frys.

At Cefn Canol and at Fron Frys the planes of bedding and cleavage meet at the same angle, viz. 15°; but if the position of the two planes at Fron Frys be compared with their position at Cefn Canol, it will be found that each of them has been shifted $22\frac{1}{2}°$ in azimuth and 20° in inclination to the horizon; and this disturbance must have taken place since the planes of cleavage were formed.

	Strike.		Difference in Strike.	Inclination to Horizon.		Difference in Inclination.
	Fron Frys.	Cefn Canol.		Fron Frys.	Cefn Canol.	
Cleavage	E. $22\frac{1}{2}°$ S.	E.	$22\frac{1}{2}°$	N.N.E. 45°	N. 25°	+ 20°
Bedding	E. $22\frac{1}{2}°$ S.	E.	$22\frac{1}{2}°$	N.N.E. 30°	N. 10°	+ 20°
Angle at which the planes of bedding and cleavage meet. }	.....	.....	.....	15°	15°	

This bed of dark roofing-slate is continued to the north-west, until it is cut off about half-way between Llangollen and Corwen by the great fault of the Dee. South of the Ceiriog and below the dark roofing-slate of Fron Frys, is a series about 300 feet thick, consisting of rotten schists, full of organic remains; and including two beds of limestone, which have been described by Mr. Bowman and Professor Sedgwick. They dip N.E. 25°.

The lower bed of limestone is not very continuous, but thins off into numerous alternations of thin semi-calcareous bands. The fossils of these beds are much injured by cleavage. In the escarpment west of Fron Frys the author found the following species, besides others mentioned by Professor Sedgwick:—

Orthis costata.
—— basalis.
—— n. s.
Atrypa globosa.
Turbinolopsis elongata.
—— pluriradialis.
Favosites fibrosa.
Retepora, 2 species.

To the south occurs a great outburst of felspathic rocks, which Mr. Bowman has described; and on this line of section the Bala grits appear to be wanting. On following the line of the strike of the Fron Frys beds to Corwen, where there is no outburst of igneous rocks, one meets to the south of that town with a full development of the lower

part of the Bala series. Corwen stands on the upper part of the hard, dark grey Bala grits, which in this instance are very slaty.

Proceeding from Corwen southwards, the following is the position of the beds in descending order.

	Dip of Bedding.	Dip of Cleavage.
Immediately south of Corwen	N. 25°	
By the road to Bala	N.E. by N. 15°	N. 63°
Near Corwen	N. 10°	
Softer beds as you approach Llandrillo	N. 5°	
Slate of Nant Cwm Dywyll	N. 30°	N. 55°

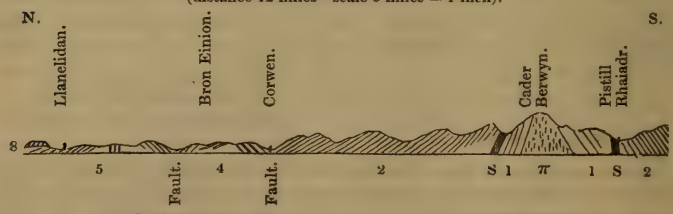
The low dip from near Corwen to Llandrillo accounts for the extent of surface over which the grits are spread. The lower beds, which commence about three miles south of Corwen, become more soft and argillaceous. They extend to about two miles south of Llandrillo, that is, about six miles south of Corwen. There they rest unconformably on a poor roofing-slate, which the author regards as the top of the Cambrian system. The slate is quarried in Nant cwm Dywyll, $2\frac{1}{2}$ miles S.S.E. of Llandrillo, and at the head of Blaen Iwrch, just below and east of Craig Berwyn.

On comparing the Lower Silurian rocks south of the Dee, near Llansaintfraid glyn Ceiriog, with those of the Bala district, the author finds the following points of agreement between them. Taking them in descending order, he finds in both series,—

1. A dark grey roofing-slate.
2. A series of rotten schists containing two beds of dark limestone, and full of Lower Silurian fossils.
3. Grey slaty grits, containing occasionally Lower Silurian fossils.

With this agreement in the mineral character, in the order of superposition, and in the organic contents of the two series of beds, he holds it scarcely possible to doubt of their identity; and especially he regards as fully established the identity of the two limestones of the Ceiriog and of Bala.

Section 1. From Llanelidan to Pistill Rhaiadr
(distance 12 miles—scale 5 miles = 1 inch).



8. Carboniferous limestone.
5. Ludlow series.
4. Wenlock series.
2. Lower Silurian schists.
1. Cambrian schists.
S. Slate.
π. Greenstone.

Cambrian Rocks of the Berwyns.

The Cambrian rocks form an irregular saddle in the middle of the Berwyns, about fifteen miles long from east to west, and three miles wide from north to south. The upper bed is the slate already mentioned of Nant cwm Dywyll and Blaen Iwrch; and a similar bed is found to the south of the axis, in the valley of the Rhaiadr, just below Pistill Rhaiadr. It is there vertical, and strikes east; and the cleavage dips north-east 5°. It is overlaid by Lower Silurian rocks.

Below the slate is a series of rotten schists, of no very definite character. These run to a great height on both flanks of Cader Berwyn. The summit of Cader Berwyn is a mass of greenstone, having somewhat of columnar cleavage. At the head of the Rhaiadr the schists are altered and disturbed by quartzose rocks, which burst out on the north side of the valley.

The author is not aware of the existence, in these Cambrian schists, of any organic remains. The position of the beds is shown in Section 1.

Anticlinal of Lower Silurian and Cambrian rocks south of the Dee.—The Lower Silurian and Cambrian rocks south of the Dee, considered together, are regarded by the author as forming a great anticlinal, whose axis runs due east through Cader Berwyn. The beds usually strike east and west; but near the Ceiriog there is a tendency to a south-east strike. The cleavage usually strikes east, and dips north, but at so variable an angle as to lead to the inference that the beds have been disturbed since the cleavage took place.

The igneous rocks which break through are mostly felspathic; but some peaks consist of greenstone.

On the north the district is bounded by the Wenlock rocks, along a line the course of which has been already defined. On the east it is bounded by mountain limestone and millstone grit; on the west it is cut off by a great fault which runs along the valley of the Dee from Corwen to Llanderfel, four miles from Bala, and which may be traced beyond Llanderfel southwards, across the moors and up the valley of the Calettwr. The southern boundary of this district has not been examined by the author.

Lower Silurian Rocks on the Holyhead road, from near the Druid Inn west of Corwen to the Conway river.

West of the Druid Inn on the Holyhead road, from the point where the Ludlow rocks already described terminate, to the bridge of Maes mawr fechan, is a narrow anticlinal ridge of hard grey Bala grits. On the east side of this ridge the beds dip E.S.E. 40°, on the west side W.N.W. 50°. The cleavage dip on the east side of the ridge is N. 25°.

At the gorge of Glyn Diffwys is a series of rotten schists, full of Lower Silurian fossils; and between the schists is a bed of dark limestone, which the author considers identical with that of Bala: its position is marked on Mr. Greenough's map. Higher in the series he found some calcareous bands which, he thinks, may represent the Upper Bala or Hirnant limestone. The beds dip in one place

S.S.W. 60°, and in another S.S.E. 60°. A greenstone dyke, running north and south, cuts the beds without disturbing them.

Besides some of the fossils of Glyn Diffwys contained in the list given by Professor Sedgwick, the author found *Orthis radians* (Sil. Syst. pl. 22. fig. 1) and *Favosites fibrosa*.

The rotten schists of Glyn Diffwys rest upon hard blue slaty Bala grits, which contain some Lower Silurian fossils. These are continuous westward from near the sixty-first milestone for nearly twelve miles, across the dreary moors of Cernioge and Pentre Voelas.

In the eastern portion of the district the beds undulate, as will appear from the following table.

Distance from Holyhead.	Dip of the Bala Grits.
m	°
60	E.N.E. 20.
58½	N.W. 15
57½	S.E. 30
56½	N.W. 20

In consequence of these undulations they are several times repeated. Their prevailing strike is north-east. They do not extend far to the north of the road, but are covered up, along a line passing nearly east and west, by unconformable Wenlock rocks. The grits found to the east of Cerig-y-druidion split readily along the bedding, and are fossiliferous. The most abundant of the fossils are two unnamed species of *Orthis*, which occur also in the Bala limestone.

Near Yspytty Evan*, a village on the river Conway, the Bala and Hirnant limestones may both be seen, with their attendant upper slate and schists. These beds lie in a sort of trough. About a mile and three-quarters south of the village, on the left bank of the Conway river, the Bala grits are seen, containing an abundance of *Leptæna sericea*. Here they dip N.N.W. 20°. To the north of this point about a quarter of a mile, the Bala limestone appears in a position parallel to that of the grits. Further north, about a quarter of a mile south of the village, the Hirnant limestone, accompanied with fossiliferous schist, crosses the road, its beds dipping north 25°, its cleavage north 60°. North of the village the fossiliferous schist and upper slate abut unconformably against the Bala (?) grits.

Carnarvonshire.

Every traveller on the road to Holyhead, after leaving the forty-seventh milestone, must be struck with the sudden change of scenery. From the dreary moors of Cernioge and Pentre Voelas he passes at once to the picturesque beauty of Bettws-y-Coed, while before him are ranged rugged hills of slate alternating with hornstone and greenstone. This change takes place at a vast dike of greenstone, which forms a high crag on each side of the road. Its course is from S.S.W. to N.N.E. In the latter direction

* In Mr. Greenough's map the occurrence of limestone is marked at Yspytty Evan, and also at Penmachno, a place which the author did not visit.

it passes through Bryn-y-ddinas, and, at the distance of a mile and a half, is lost beneath the Wenlock beds at their junction with the Lower Silurian rocks*. To the S.S.W. it runs along the high hills on the western side of the Penmachno valley, crosses that valley at Moel Machyria, and may be traced in the same direction about two miles further. Throughout the whole of this course, in length about nine miles, it forms a line of abrupt separation between two systems of beds, the system to the east of the dike striking east, the other to the west of it striking north-east.

On the exact line of the direction of the dike, to the further distance of several miles, the beds are in great confusion. The road from Ffestiniog to Bala crosses this line of disturbance at Rhaiadr Cwm, where, at the bottom of the deep and inaccessible chasm formed by the waterfall, the greenstone may perhaps be exposed. On the further prolongation of the same line the greenstone re-appears north of Traws fynydd, and there covers a considerable area. In this, as in the former part of its course, the igneous rock forms the boundary between two systems of beds differing in strike.

The greenstone then bends to the south-west, but its course in that direction cannot be distinctly traced through the intricate number of greenstone rocks belonging to the chain which extends from Barmouth northwards. To the west of this chain the dike is not recovered, but a fault appears, running south-west; and this fault separates the prolongation of the Ffestiniog slates hereafter noticed from the grey slaty flagstones of Harlech. The author endeavoured to connect the bedded rocks of Carnarvonshire with those of Merionethshire, by tracing a section across the line of disturbed beds near Rhaiadr Cwm, where the Bryn-y-ddinas dike does not reach the surface. But he was foiled in this endeavour by a great eruptive mass of felspathic rock, which, a little further to the east, entirely cuts off the beds.

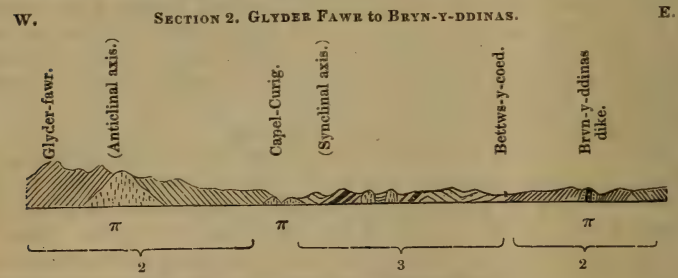
As it appears therefore that Carnarvonshire is completely severed from the rest of Wales, it was from the evidence afforded by the Carnarvonshire rocks themselves, in respect of their position, order of succession, organic remains and internal character, that the author sought to determine their age.

To obtain in the first instance a general section of the position of the beds in Carnarvonshire, he ascertained their dip along two principal lines of section; the first line extending from Bryn-y-ddinas along the course of the Holyhead road to the Menai; the second line passing through Rhaiadr Cwm, Snowdon and Llanberris, to the Menai.

Holyhead Road Section (Section 2).—On approaching the dike of Bryn-y-ddinas from the south-east, the beds of Bala grit are affected by it to the distance of nearly a mile. The dip varies from N.N.E. 15° to N.N.W. 25°, and the cleavage dips N.W. 50°. On the western side of the dike, the beds for $3\frac{1}{2}$ miles dip, at moderate angles rarely exceeding 35°, to the N.W. or N.N.W.: to the north of the Holy-

* The author names it the Bryn-y ddinas dike.

head road the dip is W.N.W. Then for about three miles the dip undergoes frequent changes, owing apparently to the proximity of two dikes of greenstone: then for the distance of more than three

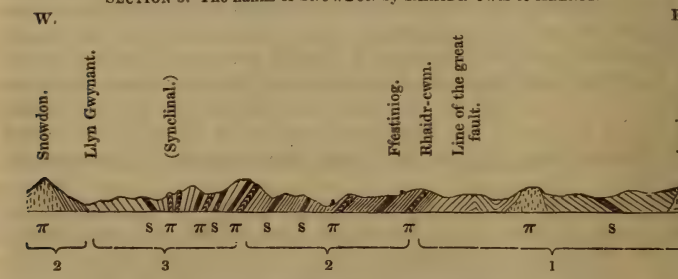


The whole series consists of Lower Silurian rocks.
3. Upper division.
2. Lower division.
π. Greenstone.
This section is the continuation eastward of the section No. 4.

miles the beds dip with great regularity to the N.E., until you arrive at a mass of greenstone in the centre of Glyder-fawr. This greenstone is seen on the Holyhead road in the ridge which separates Cwm Tryfan from Nant-y-gogo. Beyond the greenstone the dip is W., N.W., or N.N.W., for four miles: beyond the thirty-second milestone there are metamorphic rocks and great eruptions of greenstone, and the slates are thrown into great confusion.

Overlooking therefore minor local irregularities, there is a synclinal axis near the forty-first milestone, at the distance of about $5\frac{1}{2}$ miles from the dike, and an anticlinal axis in the centre of Glyder-fawr; and, consequently, the oldest beds in this section will be found on the north-west flank of the Bryn-y-ddinas dike, and also on the sides of the central axis of Glyder-fawr; and the newest beds will be found near the synclinal axis, and again on the north-west flank of Glyder-fawr.

Section 3. The flanks of Snowdon by Rhaidr-cwm to Arenig.



3. Lower Silurian series. Upper division.
2. Do. Lower division.
1. Cambrian series.
s. Slate.
π. Porphyry and Greenstone.
The section is a continuation eastwards of that marked (5).

Rhaidr-cwm Section (Section 3).—From Rhaiadr-cwm to Cynicht, a distance of about seven miles, the beds dip at considerable angles and with great regularity to the N.W. or N.N.W. On the west of Cynicht, for a short space, they are nearly vertical; and thence to the east flank of Snowdon inclusive, a distance of about four miles, they dip south-east. The centre of Snowdon is much disturbed by greenstone dikes and faults, but its western flank is formed of schists and slate dipping north-west: further westward the section is cut off by great masses of igneous rock.

There is consequently a synclinal axis on the west of Cynicht; and an anticlinal axis in the centre of Snowdon, though on the western side of the anticlinal the beds are very irregularly disposed. In this section therefore the oldest beds will be found at Rhaiadr Cwm on the one side, and in the centre of Snowdon on the other; and the newest beds will be found at the synclinal axis west of Cynicht, and again on the north-west flank of Snowdon at some distance from its centre.

The two sections thus examined in detail give similar results, and establish two principal features in the geology of Carnarvonshire; viz. a great anticlinal axis of elevation along the centre of the Snowdon chain, and a great synclinal axis running parallel to that chain at a distance of about five miles east of the anticlinal axis.

Course of the great Synclinal Axis.—The great synclinal axis of the trough which lies between the Bryn-y-ddinas dike on the one side and the Snowdon chain on the other, may be traced from Trefriw on the Conway, in a S.S.W. direction, to the forty-first milestone on the Holyhead road; and thence, in a south-west direction, to the Traeth mawr, two miles below Aberglaslyn bridge. The course of the axis is generally marked by a band of disturbed beds of unequal width, through which greenstones have forced their way to the surface, either in one great mass or in several minor dikes or ridges. To these belong a dike which runs across the east side of Moel Siabod, Craig-y-llyn-llagi and Yr Arddu, one of the most rugged of the Welsh hills.

Age of the Beds near the Synclinal Axis.—The author has found but few fossils in the beds near the axis of the trough. To the east of the axis in the northern portion of the trough, and to the west of the axis in the southern portion of the trough, he found the fossils hereunder specified at the localities respectively annexed to their names. All the known species in these lists are Lower Silurian species; and the absence of any that are peculiar to the Llandeilo flags renders it probable that the beds near the axis belong to the Caradoc, or upper portion of the Lower Silurian system,—a conclusion which harmonizes with the position of the beds at the top of the series of rocks of the east of Carnarvonshire.

Names of Genera and Species.	East of the Axis, Northern part of the Trough.						West of the Axis, South portion of the Trough.
	Holyhead Road.					Dolwyddelan Valley.	Cherty bed of Yr Arddu.
	42½ miles.	43 miles.	Bettws-y-Coed.	Waterloo Bridge.	45½ miles.		
Trinucleus Caractaci		+					
Spirifer plicatus			+?				+
Orthis canalis.....		+	+		+	+	
—— basalis? (*Dalm.*)	+						
—— expansa (or O. pecten)							+ +
—— flabellulum		+					+
Leptæna sericea.....		+		+		+	
Porites pyriformis ...							+

Middle and eastern side of the Carnarvonshire trough.—The beds in the middle and on the eastern side of the Carnarvonshire trough, extending from the synclinal axis to the Bryn-y-ddinas fault, consist of slate and schists, alternating occasionally with hornstone. The author has heard of only two places where limestone has been found; the first to the west of Gwydir Park, on the west side of Nant Gwydir; the other half a mile to the west of Trefriew.

The whole district is intersected by numerous dikes or beds of greenstone, which strike with the beds, and are apparently interstratified with them. They are found however, when minutely examined, to thin out irregularly, and occasionally to cut through the beds: they usually make but little disturbance in the strata; but the greenstones on the lines of the synclinal axis and of the Bryn-y-ddinas fault are exceptions to this rule. The mineral character of the beds however is much altered by these igneous rocks: thus the hornstone is converted, in many instances, into semi-crystalline quartz-rock; and probably the quality of the slates depends very much on the distance or proximity of the greenstones.

The slate-quarries in this district are very numerous, and are only second in importance to those on the western flank of the Snowdon chain; but on the eastern side of that chain scarcely any two quarries are worked on the same bed, and few beds are worked to any great distance: for many a bed, which in one part of its course furnishes excellent slate, in another part, not remote from the former, is found to be so altered in quality as not to be worth working; still, regarded geologically, and without reference to their economical value, the beds of slate are found to be persistent.

Since the direction of the synclinal axis, for the greater part of its course, is north-east and south-west, and that of the Bryn-y-ddinas fault N.N.E. and S.S.W., the breadth of the space included between the axis and the fault increases considerably as you proceed southwards. The prevailing strike of the beds is parallel to the synclinal axis, and consequently, on the eastern side of the trough, the Rhaiadr-cwm section presents a much longer series of beds than the section

along the Holyhead road. The synclinal axis near its southern end is formed of a high ridge of greenstone, flanked on both sides by nearly vertical beds of metamorphic quartz-rock, and these form the rugged hill of Yr Arddu. West of this is metamorphic schist of little thickness; and below the schist lies a very hard grey chert or hornstone, faintly affected by cleavage, dipping to the south-east at an angle of 60°. This is the bed of chert already noticed as containing fossils which belong to the upper part of the Lower Silurian system.

The Rhaiadr-cwm section No. 3 passes to the north of Yr Arddu; and on this line the greenstone is divided into two ridges, which are separated by vertical beds of schist. The western of these greenstone ridges forms the very remarkable crag, Craig-llyn-llagi. From this point in the synclinal axis to Rhaidr-cwm, which lies to the south-east, the beds which here constitute the eastern side of the Carnarvonshire trough are traced by the author in the following descending order:—

Upper schists of the Lower Silurian system.

28 Greenstone of Craig-llyn-llagi. Dip of beds N.W. Dip of cleavage 65° N.W.
27 Schist.
26 Greenstone, forming a narrow ridge.
25 Slate which runs up to Cynicht. This perhaps belongs to the same bed as the slate at Llanrhwchwyn, behind Gwydir Park.
24 Semi-crystalline slaty grit.
23 Greenstone.
22 Hard, blue, slaty flagstone.
21 Dark grey slate.
20 Coarse schist.
19 Greenstone, forming a narrow ridge. Strike of beds N.E. by E.
18 Dark slate, of fair quality, near Bryn-gelinnen. It seems identical with one of the beds worked in the great quarries of Dolwyddelan. Dip 45° north-west, of cleavage 65° W.N.W.—Below this point the slates become lighter in colour, and the beds in general become harder than they are above.

Lower division of the Lower Silurian system.

17 Slaty flagstone. Dip of beds 65° N.W. Dip of cleavage 85° N.W.
16 Hard slaty flagstone. Dip of beds 25° N.W. Dip of cleavage 45° N.W.
15 Blue slaty rock.
14 Semi-crystalline chert or hornstone.
13 Blue slate of Moel Wynn. The same bed is worked in the great quarries of Rhiw Brefder, of which see the description, p. 296.
12 Hard schist. Dip 20° N.W.
11 Greenstone interstratified with the schists. To the south it becomes half a mile wide; at the foot of Moel Wynn it thins off; at Rhiw Brefder it is very narrow.
10 Hard schist. Dip 45° to 50° N.W.
9 Thick series of slaty beds alternating with chert or hornstone, seen in the hill above Tan-y-Bwlch. Dip 20° N.N.W.
8 Semi-crystalline quartz-rock, behind Maentwrog.
7 Coarse schist. Dip 30° N.W.
6 Slate of inferior quality, between Ffestiniog and Pant-llwyd. This is the lowest bed of slate worked in this line of section.

Cambrian system.

5 Coarse schist.
4 Greenstone, interstratified, forming a ridge of low crags. Strike of beds N.E.
3 Hard blue schist. Dip 15° N.E.
2 Schist, which continues to Rhaidr-cwm. Dip 40° north-west.
1 Schist, intersected by quartz veins, at Rhaidr-cwm. The beds and cleavage planes are shattered and in great confusion. Dip 20° N., 30° N., and 40° N.E.

In the foregoing section there is no marked change of character in the rocks at those points of the descending series where the author proposes to draw a line of separation between the upper schists and the lower portion of the Lower Silurian on the one hand, or between the Lower Silurian and the Cambrian systems on the other.

On the eastern side of the Carnarvonshire trough, and near the line of the preceding section, are the great slate-quarries which lie to the north-west of Ffestiniog. As these quarries afford great facilities for a minute examination of the beds, the author made a detailed section of these beds, all of which he refers to the lower division of the Lower Silurian formation. The series of slate beds of which the description follows in detail are included in the preceding general account of the strata (see p. 295), in the beds numbered 13 to 7.

	Descending order of Beds in the Slate Quarries N.W. of Ffestiniog.	Feet.
Mr. Holland's quarry at Rhiw Brefder. The quarry of the Welsh Slate Company is worked in the same beds at a lower part of the same hill.	25 Dark blue slate, not yet worked.	
	24 Blue slate, too hard to work	120
	23 Hard grey chert or hornstone	1
	22 Dark blue slate of good quality	150
	21 Blue slate, too hard to work	120
	20 Hornstone	18
	19 Poor slate	3
	18 Hornstone	6
	17 Dark blue slate, of the best quality	150
	Note. All the above beds dip 30° N.W., the dip of the cleavage being 55° N.W.	
	16 A whinstone dyke, which, on the face of the hill, is interstratified with the beds of slate, but, in the quarry, cuts across them.	
	15 Schists	500
	14 Slate, which is quarried	100
	13 Schists	600
Diffws Upper Quarry.	12 Alternations of hornstone and slate, in beds from one to five feet	30
	11 Poor slate	10
	10 Good blue slate	50
	9 Schists, about	100
	8 Whinstone, thinning away towards the top of the quarry.	
Diffws Lower Quarry.	7 Slate, too hard to work	50
	6 Slate, of middling quality	100
	5 Good slate	60
	4 Schist, with some alternations of hornstone; the beds are curved. Dip 10° to 15° N.W.	500
	3 Semi-crystalline quartz-rock	100
	2 Greenstone, interstratified.	
Manod Mawr Quarry.	1 Light grey slate, of indifferent quality. Dip 15° N.W. Dip of cleavage 35° N.W.	150
	Total thickness, exclusive of igneous rocks	2910

Note. The beds 14 to 2 inclusive dip 25° N.W., the dip of the cleavage being 45° N.W.

In the Rhiw Brefder quarries the beds are merely intersected by irregular veins of quartz. In the Diffws quarries the rock is soft, and readily splits into slate; and the colour of the slate is lighter and of a more decided blue than in the beds above. Below the beds of the Manod Mawr quarry there are some beds of slate, of inferior quality, and of no economical importance. These lowest beds the author refers, not to the Lower Silurian, but to the Cambrian system.

District between the eastern side of the Carnarvonshire Trough and Arenig.—It has been before stated that the author endeavoured to connect the beds on the east side of the Carnarvonshire trough with those in Merionethshire, by prolonging his line of section across the pass of Rhaidr-cwm in a south-eastern direction; and that he was foiled in this endeavour. The following are the rocks that he met with in that line of section.

The schist that is the lowest rock on the west side of the fault of Rhaiadr-cwm, is found also to the east of the pass, dipping first east 25°, then north-east 30°; and further east it forms a poor slate, dipping north 20°, and resting on the eruptive mass of Moel-llech-wydd-gwyn, which wholly cuts off the stratified series. This igneous mass consists of quartzose felspar-rock and porphyry, and belongs in point of date to the porphyry of Cader Idris. Between this mass and the porphyritic chain of Arenig, schistose rocks occur of variable character; and towards the south-east these rocks are found dipping north-east from 30° to 45°: but on the road to Bala two lines of felspathic rock, proceeding to the N.N.W. from Arenig-fawr, intervene to complicate the section. Between these two lines is a hard blue schist dipping north-east 30°. At Tai-hirim, at the south-west foot of Arenig-bach, is a quarry of poor slate, which dips north-east 30°*. Arenig-bach forms the northern extremity of the porphyritic chain of the Arenigs, which is fourteen miles long, and reaches southward nearly to Cader Idris. On the line of section No. 3, the porphyritic mass of this chain is nearly two miles wide. In the centre it consists of grey and black porphyry; on the flanks the porphyry is usually flesh-coloured, passing into an amorphous quartzose felspathic rock. The beds which lie to the west of Arenig were described by the author in a former paper (see Proc. Geol. Soc. vol. iv. p. 10).

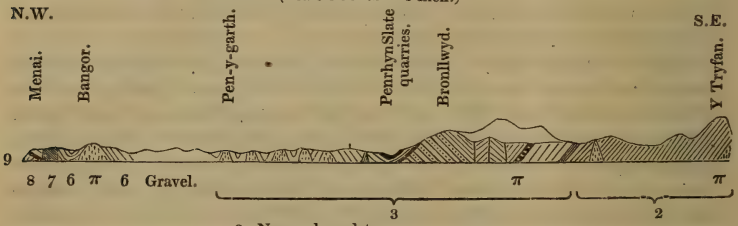
Western side of the Carnarvonshire Trough.—The position of the beds which lie between the synclinal axis and the valley extending from Capel Cerrig to Beddgelert, leads to the inference that these beds are the equivalents of the rotten schists of Merionethshire, which lie above the Bala grits. The beds in question are hard, grey, slaty grits, alternating with slate, grey hornstone or quartz-rock; rocks very different in their mineral character from the schists which they are supposed to represent; but this difference may be attributed to the numerous dikes and interstratified beds of greenstone by which this Carnarvonshire district is traversed; whereas that of Merionethshire is quite free from igneous action. The aggregate thickness of these beds is much greater than that of the rotten schists of Merionethshire.

The valley which reaches from Capel Cerrig to Beddgelert is the line of a considerable fault. To the west of this fault, as far as the eastern sides of Glyder-fawr and Snowdon, are hard grey schists and schistose grits. These the author regards as the equivalents of the

* The bed which is next to the porphyritic rock is so often found to be a true slate, that this character, when it occurs under such circumstances, must be attributed to metamorphic action.

slaty grits of Bala. These are the oldest beds in Glyder-fawr; but the centre of Snowdon consists of older rocks, which are considered by the author to belong partly to the Cambrian system.

Section 4. The Menai to Y Tryfan, the axis of Glyder-fawr.
(Scale 3 miles = 1 inch.)



9. New red sandstone.
8. Carboniferous series.
7. Old red sandstone.
6. Ludlow shale.
3. Lower Silurian. Upper division.
2. Ditto. Lower division.
π. Greenstone.

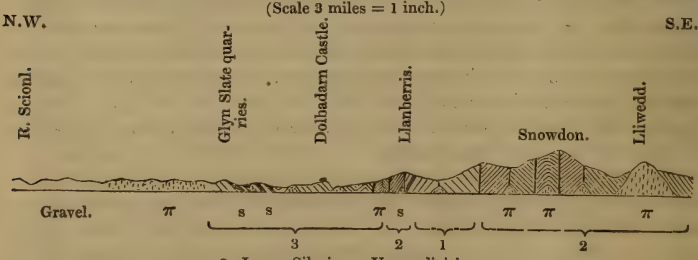
This section is the continuation westward of No. 2.

Western side of the Snowdon Chain (Section 4).--On the line of the Holyhead road the hard slaty grits continue from the central greenstone axis of Glyder-fawr about three miles. At Cwm Perfedd they are overlaid by a series of softer beds, consisting of schists and slate, with occasional alternations of hornstone. These belong to the upper division of the Lower Silurian formation.

Between these beds and the Penhryn slate the section is interrupted by the elevation of the metamorphic rocks of Bronllwyd, which consist of semi-crystalline grits, becoming, in the lower beds, more and more crystalline, until they can hardly be distinguished from greenstone. This grit alternates with thin beds of schist, and the whole mass preserves its bedding and cleavage unaltered. It dips south-east 45°; the cleavage dips north-west 80°.

These rocks are overlaid unconformably by the purple slate of the Penhryn quarry. These slates are of so much importance, that the author describes them under a separate head.

Section 5. From near the Menai to the east flank of Snowdon through Llanberris Pass.
(Scale 3 miles = 1 inch.)



3. Lower Silurian. Upper division.
2. Ditto. Lower division.
1. Cambrian.
s. Slate.
π. Greenstone.

This section is a continuation westward of No. 3.

On the continuation of the line of section passing through Snowdon, the author regards as Cambrian some of the schists which are seen in the pass of Llanberris, and among these he ranks the bed which is quarried for slate opposite Llanberris Church. Owing to the extreme complication of this part of the section and the altered condition of many of the beds when near to the greenstone dikes, he draws the line of separation between the Silurian and Cambrian rocks with great doubt of its correctness.

A little to the west of the church, on the south side of the Llanberris Pass, the Cambrian rocks are cut off by a great fault, which is remarkable for severing in twain an arch of greenstone. In the metamorphic schists above the greenstone a copper-mine is worked. Westward of the fault are metamorphic slates and slaty grits, which probably belong to the Bala grits. These are followed by softer schists and slates, which, when near the greenstone dikes, are altered and disturbed. This series, as was the case on the Holyhead road, is overlaid by the purple slate. Beyond this is a great mass of igneous rocks, which are covered on the west by gravel.

Purple Slate of the Western side of the Snowdon Chain.—The purple slate-bed of the quarries of Penhryn, Llanberris, &c. is, in an economical point of view, the most important bed in North Wales, supplying, as it does, more than half of all the slates which are raised in the Principality.

The slates that are worked on the west of Snowdon are regarded by the author as all belonging to one bed, which, having been much tossed about by the greenstone, is repeated many times in some localities. On the Holyhead road*, its first appearance towards the west is in the Penhryn quarry. It there lies in a trough between the metamorphic rocks of Bronllwyd on the east, and a ridge of greenstone on the west. The bed being equally upheaved on both sides, dips towards the middle of the quarry at an angle of about 45°.

The effect produced by the doubling up of the bed is shown, at the back of the quarry, by a mass of broken and curved slate which fills the middle of the trough, and is there squeezed up together. The axis of the trough strikes north-east, as do the planes of cleavage in all parts of the quarry, including the crushed portion. These planes dip south-east, from 80° to 85°, with great regularity, showing that the elevating forces had ceased to act before the cleavage took place. The peculiar position of the beds has been taken advantage of in working the quarry, which is disposed in terraces that give it nearly the form of a Roman theatre.

The author estimates the thickness of the bed of good slate at not more than 200 feet, though it appears greater, owing to the filling-up of the trough with crushed portions of its upper part. The slate is of a rich purple colour, with green spots and green lines at the junction of the beds.

Below the fine slate lies another bed of slate of the same colour, but too hard for use; and beneath that is a bed of hard, green slate-rock. Then follow coarser schists, which rest on the igneous rocks.

* See Section 4.

These beds are seen on both sides of the quarry. The trough of slate crosses the Holyhead road, but is not worked to the north of it.

To the west of the Penhryn quarries the same purple slate is repeated three times between ridges of greenstone:

1. On the west of Bethesda, where it dips north-west.
2. At Coet-mor and at Tan-y-Bwlch, where it dips south-east 50°, and is underlaid, as at Penrhyn, by green slate. The quarries at these places are of considerable extent.
3. At Pont-y-Coetmor and Bryn, where it dips south-east 30°.

At all these places the planes of cleavage strike, with the beds, north-east, and dip south-east from 80° to 85°.

The purple slate is worked on a large scale near Llanberris, but the beds worked on the opposite sides of the valley are in different positions, as a considerable fault runs along the pass*.

On its northern side are the great Dinorwig quarries, which are worked on three apparently different beds, which may be only one bed repeated owing to local disturbance, all dipping W.S.W. 60°; the cleavage dipping E.S.E. 70°. On the same side of the pass, opposite the middle of Lake Padarn, and again below the middle of that lake, the purple slate is seen lying between great eruptive masses of greenstone.

On the south side of the pass, the slate is first seen at the seventh milestone, dipping west 20°. Here it is separated from the Glyn quarries by a narrow dike of greenstone. These quarries are worked upon two beds, which are separated by some irregular masses of greenstone. The beds dip south-east 55°; and the cleavage is vertical, and strikes, with the bedding, north-east. The slate rests on metamorphic rock; and below that are greenstones and other igneous rocks, forming a band two miles wide, the western edge of which is covered by gravel.

Section 6. Valley of Bettws Garmon.

N.W. (Scale ½ inch = 1 mile.) S.E.

π. Greenstone. s. Slate.

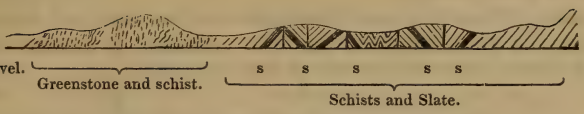
At Bettws Garmon, on the road from Beddgelert to Carnarvon, the purple slate occurs only once; it lies between two beds of greenstone. The beds dip south-east 45°, that is to say, towards the Snowdon chain: the cleavage dips north-west 85°. The slate is of the usual purple colour with green spots, but is of indifferent quality; the workings are on a very trifling scale.

Further south, in the valley of Llanllyfni, the purple slate is thrown up several times, owing to faults and to eruptions of greenstone; in consequence of which it is worked very largely, on no less than six different lines. The colour and quality of the slate are the same as at Penhryn and Llanberris. The beds strike north-east, and dip either north-west or south-east. The cleavage strikes

* See Section 5.

Section 7. Valley of Llanllyfni (north side).

W. E.



south-east, and does not vary more than 10° on one or the other side of the vertical plane. The most easterly part of this slate dips north-west 65°, and it there rests conformably on the schists of the Snowdon chain.

The purple slate extends about two miles to the south of the valley of Llanllyfni, but it is not worked beyond that valley. The slate, where it terminates, is cut off by a system of rocks striking east and west.

Notwithstanding the repetitions shown in sections 4, 5 and 7, the author considers the purple slate as forming only a single bed, which reaches from Aber on the coast above Bangor to Llanllyfni, and overlies, along that line, the schists of the Snowdon chain. The section of Bettws Garmon might lead one to regard the slate as lying below the schists of Snowdon, but that inference would be at variance with all the other sections; and the beds in that locality are so much displaced by the greenstones, that they cannot afford us any sure guidance. The slate is usually unconformable to the Snowdon schists, and the only exception to this is at Llanllyfni. As from the central axis of the Snowdon chain to the purple slate on its west flank there is an ascending series of beds; as the fossils found on that flank of the chain belong to the Caradoc or upper portion of the Lower Silurian system, and as no other Lower Silurian rocks are found above the purple slate, the author concludes that the purple slate is the uppermost of the Lower Silurian rocks.

This purple slate is probably identical with some one of the beds of slate on the east side of the anticlinal of Snowdon, but there is no bed of slate on that side of the ridge which resembles the purple slate in colour. Throughout the greater part of North Wales the top bed of the Lower Silurian formation is a good roofing-slate, but of a dark grey colour. The purple colour ought therefore to be regarded as a local peculiarity*.

Along the whole line of the purple slate on the west of Snowdon, the cleavage planes are very constant in their direction; for, with the exception of a slight deviation at Llanberris, they uniformly strike north-east, and do not vary from the vertical plane on either side more than 10°.

Northern continuation of the Snowdon Chain.—The author made only a slight examination of the district north of Glyder-fawr. What he saw of it was analogous in structure to that mountain;

* The purple slates with their green spots have much resemblance to the green slates of Cumberland, which are green with purple spots. These are the only slates in North Wales which have any resemblance to the green slates of the Lakes.

but as you advance towards the north, the igneous rocks become more and more prevalent.

To the north and west of Conway there is an extensive district of metamorphic rocks, of which the most abundant is quartz-rock, in various forms, but usually more or less schistose.

South-west part of Carnarvonshire.

1. *Schistose Rocks.*—The strike of the beds, which, in the Carnarvonshire trough, is from N.E. to N.N.E., changes to east a few miles south of Beddgelert, and a little further to the south becomes perpendicular to the strike prevailing in the trough.

At Porth Treweddyn, 4½ miles south of Beddgelert, in extensive quarries of light grey flagstone, the bedding dips north 20°, the cleavage N.N.E. 30°. About a mile west of Porth Treweddyn, in the high crags north of Tremadoc, a remarkable instance occurs of the interstratification of greenstone with the schist.

The schist on which the village of Tremadoc stands is very much altered and broken. It dips N.N.E. 15°, and passes beneath a thick mass of greenstone, running two miles westward. The same dip prevails in several hillocks south-east of Tremadoc, between that village and Porth-madoc; the rocks consisting of a ferruginous grit alternating with beds, four inches thick, of very rich ironstone. Immediately to the south-west of Porth-madoc, near Morfa Lodge, is a light grey flagstone, dipping N.N.E. 10°.

West of Morfa Lodge is the greenstone ridge of Moel-y-gest, which has raised the schists into an anticlinal ridge, and given them an eastern strike. On the line of the axis of this ridge, three miles west of Morfa Lodge, the beds have a north-east strike; and in a metamorphic rock, which dips south-west 30°, a copper-mine is worked.

From Brongader to the south-west as far as Criccieth, a distance of about two miles, schistose rocks extend. They dip south. To the south of Criccieth the schistose beds are much concealed by great accumulations of gravel.

About seven miles west of Criccieth, and four miles north of Pwllheli, is a quarry beside the road from Pwllheli to Carnarvon, in which the beds strike north and south. Here, in a dark slate of indifferent quality, are found obscure traces of organic remains. The bedding dips west 55°, the cleavage west 70°.

The rest of the south-west part of the county, frequently called the heel of Carnarvonshire, is covered by a brown, very rotten and shivery schist, in which the author did not discover any organic remains. The schists are broken up by various porphyritic masses, and their strike and dip are very irregular.

In the proximity of the felspathic rocks, hereafter noticed, these schists are changed into black shale; the resemblance of which to a coal-shale has, in several places, given rise to borings for coal. One of these trials was made between Criccieth and Pwllheli; and, on a common about 2½ miles west of the latter place, the borings

were continued until the tools were broken by coming in contact with porphyry.

At the extreme point of the south-west promontory of Carnarvonshire, between Aberdaron and Porth-felin, hard gritty schistose flags are found; and these are overlaid by rotten brown schists, striking north-east or N.N.E., and dipping at a very high angle to the south-east; the cleavage here dips south-east 50°.

The schistose rocks of the south-west of Carnarvonshire (with the exception of the steatitic schist hereafter noticed) are referred by the author, though with much hesitation, to the Cambrian series of rocks.

Note, 1846.—From organic remains found in them by Professor Sedgwick, it is now known that they belong to the Lower Silurian series, and they are accordingly coloured as such on the annexed map (see Plate XII.).

2. *Igneous Rocks.*

(*a.*) *Felspathic Porphyry.*—The insulated hill south of Criccieth, a considerable tract round Pwllheli, and the hills which commence on the coast 3½ miles south-west of the latter place, and run north-west from Mynydd-tir-y-Cwmmwd, south of Llanbedrog, through Mynydd-mynytho to Carn Fadryn, consist of an amorphous flesh-coloured rock, composed of compact felspar and quartz, and resembling the rocks of Cader Idris and Arenig. In the ravine of Nant Bodlas, which intersects the last-mentioned felspathic mass, between Mynydd-mynytho and Carn Fadryn, black, grey and flesh-coloured porphyries occur. Felspathic rocks are also found on a line commencing in Mynydd Ystwm north of Aberdaron, and extending, in a north-easterly direction, through Mynydd-cefn-amlwch to the high peaks of Yr Eifls and the hill south of Clynnog-fawr.

These felspathic rocks, when in proximity with the schist, disturb its planes both of bedding and cleavage, and alter its mineral character.

(*b.*) *Greenstone.*—The greenstones of the south-west of Carnarvonshire, not including those of Tremadoc, differ from those of the Snowdon chain in two respects. First, they are of coarser grain; and secondly, they are of posterior date to the cleavage of the schists. Like the felspathic rocks last noticed, they have been upheaved in great masses, causing much confusion in the schistose rocks. Of this description of greenstone consist the hills of Mynydd Rhiw, four miles east of Aberdaron, and of Carn Boduan south of Nevin; also the low rocks of Edeyrn west of Carn Boduan, and of Porthwen on the coast further westward; and to the north-east, the hills of Moel Penllechog and Y-gyrn-ddu, south-west of Clynnog-fawr. To the north of Y-gyrn-ddu, at the points of junction between this greenstone and the porphyry of Y-gyrn-coch, several varieties of igneous rock occur.

(*c.*) *Serpentine and Steatitic Schist.*—Along the western coast of the Carnarvonshire promontory, from the point opposite Bardsey island to Porth Dynllaen, west of Nevin, a band of serpentine and steatitic schists extends.

At Porth-felin, on the south, a narrow ridge of mottled green and red serpentine, associated with green trap, blood-red jasper, and a crystalline flesh-coloured limestone, breaks through between two nearly vertical ridges of greenish-white steatitic schist. The ridge runs N.N.E. and S.S.W. The cleavage of the schist, in the western ridge, dips south-east 50°. At Porth Orion, three miles to the N.N.E., a limestone, similar to that last mentioned, is said to be found.

At Porthwen and at Edeyrn, near Nevin, the serpentine runs between the greenstone, as if ejected at a more recent period. At the northern extremity of the serpentine band, the serpentine is pure, and of a dark green colour.

Merionethshire.

Barmouth chain of Hills.—Barmouth lies at the southern point of a lofty chain, which after running northwards nearly fourteen miles, is cut off by the great Bryn-y-ddinas fault. This chain is chiefly remarkable for the interstratification it exhibits of schistose with igneous rocks.

The axis of the lofty hill immediately north of Barmouth is a mass of compact, highly crystalline, lightish-coloured greenstone. On the west side of the hill are numerous alternations of schist and greenstone. At first the greenstone predominates, and the schistose beds are thin and far apart; but as the distance from the axis increases, they become more frequent, until, at a mile from it, the greenstone wholly disappears.

The schistose beds are of variable thickness; those of greenstone are, many of them, only a few inches thick, and some many feet. The cleavage planes can, in many cases, be traced through the greenstones, but they do not lie close together, and are only faintly marked.

On the east side of the end of the ridge, near Barmouth, the alternations of greenstone are fewer than on the west side. About a quarter of a mile east of Barmouth the greenstone ceases, and the chain is overlaid by a great thickness of hard light blue slaty flagstone, and above this are grey schists.

Towards the southern end of the chain the prevailing strike is north by east. Near Barmouth, on the west side of the chain, the bedding dips south-east 30°, and the cleavage north-west 60°. About a mile north of Barmouth, on the Harlech road, the bedding dips E.N.E. 60°, and the cleavage E.S.E. 80°. East of Hendremynech, which is about a mile north of the town, the cleavage is vertical, and strikes N.N.E. East of Barmouth the bedding dips E.S.E. in a steep arch; the cleavage is vertical, and strikes N.N.E.

Towards the north end of the chain the alternations of igneous with aqueous rocks are on a greater scale. The sides of Cwmmoch, leading from the north-west up to Diphwys, afford a good section of these beds. Greenstone, similar to that of Barmouth, in beds from three to ten feet thick, alternates with thinner beds of sandstone and conglomerate, which are often semi-crystalline, and

with beds of schist. The dip is from N.N.E. to N.N.W., at an angle of 15°.

On the west side of Craig-drwg (a ridge commencing about eleven miles north of Barmouth, and 1½ mile long), on the descent towards Harlech, in a similar series of alternations there are nearly 100 beds of greenstone. The bedding dips from south-west to W.S.W. 10°, and the cleavage north-east 60°.

Between these igneous rocks and the sea is a series of light blue slaty flagstones, with some alternations of shale, and a few thick interstratified masses of greenstone. The lowest beds of the series occur near Harlech.

On the hills behind Llanbedr (seven miles north of Barmouth), and in the ravine of Egryn (three miles north of Barmouth), a bed of slate is worked. The bedding of the flagstone and slate dips east, E.S.E., and north-east by north, on the average east, at an angle of 10°; the cleavage dips east 60°.

Since the beds of the Barmouth chain have not been found to contain any fossils, and since they are cut off by the fault of Bryn-y-ddinas from the beds of the Carnarvonshire trough, the author finds it difficult to determine their age with any precision. In mineral character they much resemble the light grey slaty flagstones of Manod-mawr and Ffestiniog, which are placed by the author near the top of the Cambrian series.

From the Greenstone chain of Barmouth to the Porphyritic chain of Cader Idris and Arenig.—The prevailing dip on the east side of the Barmouth chain near Barmouth led the author to seek for an ascending series of beds in the direction of Dolgelly. The lower beds are hard light grey slaty flagstones, the same probably with those of Harlech; and above these are rusty schists with some beds of tolerable slate. The usual dip of the beds is east at a high angle, but it is subject to great irregularity, and to some alternations to the south-west. The cleavage usually dips from east to south-east, at from 50° to 55°; but the angle also is inconstant. All these rocks the author is inclined to refer to the Cambrian series.

The beds in this line of section are much interrupted by extensive igneous dikes. Near the river Mawdach these dikes strike from E.N.E. to N.N.E.; but further northward they strike due north.

The great eruptive mass of Cader Idris, which crosses the Mawdach at Dolgelly, entirely cuts off the last-described series of beds. Between this porphyritic chain and the parallel and similar chain of Arenig, is a narrow tract of slate and schist, which crosses the road to Bala, about three miles from Dolgelly. Between the porphyritic chains of Arenig and Arran Mowddy, the beds belong wholly or in part to the Lower Silurian series.

West side of Carnarvonshire.

1. *Gravel.*—From Clynnog to Penman-mawr, the whole western side of the Snowdon chain is flanked by igneous rocks, forming

either one broad belt, or several narrower bands broken by intervening beds of slate.

This igneous zone is overlaid on the west by a thick bed of gravel, which, for a space of about three miles broad and twenty-four miles long, entirely conceals the beds lying next to the mountain chain*. On the coast near Clynnog, the gravel forms the entire cliffs, nearly 100 feet high; on the east of Carnarvon and Bangor it passes inland, at some distance from the Menai Straits; it terminates northwards on the coast between Aber† and Penman-mawr. It consists of rolled fragments of all sizes, from mere pebbles up to huge boulders, all apparently derived from the rocks of the Snowdon chain. The valley which contains this great drift deposit is the more remarkable when contrasted with the valleys on the east of the chain, which, comparatively, are exempt from gravel. There is however a similar accumulation of gravel in some of the lower parts of the south-west end of Carnarvonshire.

2. *Upper Silurian and more recent formations.*—It was only at intervals that the author examined the rocks on the Carnarvonshire side of the Menai Straits. The strata on the shore rise for the most part into considerable cliffs.

(*a.*) *Carnarvon.*—The hill to the north-east of Carnarvon consists of a light brown or yellowish felspar porphyry; and this mass runs southward more than a mile. On the west the porphyry is overlaid by a brown or liver-coloured shale, which, near the igneous rock, is much contorted and altered. Carnarvon Castle stands on this shale, which may be seen in an unaltered state in the railroad cuttings south-west of the town. The usual dip of the bedding, when undisturbed, is south-east 45°; the cleavage, which is very decided, dips south 70°. Although the author could not discover any fossils in the shale, yet, from its mineral character, he assigns it without hesitation to the Ludlow series.

To the north-east of the porphyritic hills above mentioned, for the distance of some miles, the beds are covered up by gravel.

(*b.*) *Bangor.*—At the Menai Bridge, mountain limestone forms the base of the cliff. Above the limestone are beds of calcareous sandstone alternating with carbonaceous shale. The sandstone contains large Producti; the shale contains vegetable impressions. These beds are overlaid by alternations of ferruginous sandstone and dark shale belonging to the coal-measures. At the top of the cliff is an impure sandy limestone, mixed up irregularly with calcareous conglomerate, and belonging to the magnesian limestone. These three formations are here conformable, and dip S.S.E. 5°. About one-third of a mile from the bridge they are cut off by a fault, which runs north-east, and comes out on the shore about a mile beyond the bridge.

On the east side of the fault is a narrow ridge, running south-west by south, consisting of thick beds of hard, coarse, siliceous conglo-

* Mr. A. Aikin described this enormous deposit of gravel in his 'Tour in North Wales.'

† Three miles south-west of Penman-mawr.

merate, alternating with beds of grey chert. The bedding dips east. This rock the author refers to the old red sandstone. This conglomerate is cut off by a second fault, which also runs north-east, and comes out on the shore at a hollow in the cliff near Gared-gith, about a quarter of a mile beyond the former fault. Between the two faults there is a good section of the conglomerate.

To the east of the second fault, extending along the cliff about a mile, as far as Garth point, and covering the valley of Bangor, lie various brown and liver-coloured shales, referred by the author to the Ludlow series.

The axis of the hill east of Bangor is a greenstone trap. It runs S.S.E., and has disturbed and twisted about the Ludlow rocks, and has given them a high inclination. They dip between the Straits and Bangor E.S.E. 30°; west of the trap, W.N.W. 60°; east of the trap south-east, at a high angle: further to the east they are lost below the drift already described.

Since the beds on both sides of the two faults agree in having a dip eastward, if the faults were overlooked the Ludlow beds around Bangor would appear to lie above the magnesian limestone; and it is from that circumstance probably that Mr. Greenough in his Geological Maps has been led to colour these Ludlow shales as new red sandstone. Unless the thickness of the Wenlock series has been greatly reduced in this part of North Wales, it is impossible that it should lie concealed under the deposit of drift which skirts the Snowdon chain. It is by no means improbable however that in this part of Carnarvonshire the Wenlock series is entirely wanting; that consequently the igneous rock which flanks that chain is overlaid by the Ludlow shales; and therefore that the stratified formation next above the Lower Silurian slates is the Ludlow rock. This cannot be decided owing to the covering of gravel, which completely conceals the stratification.

At the north-east angle of the county, the Wenlock rocks of Denbighshire cross the river Conway above Caer-hun, four miles and a half south of Conway, and, forming a band about two miles wide, they pass along the left bank of the river to the north of Conway town. Along this line they abut unconformably against the Lower Silurian and igneous rocks of the Snowdon chain.

General Remarks on the Upper and Lower Silurian and Cambrian Formations of North Wales.

The principal points of difference which the author has had occasion to observe between the Silurian and Cambrian rocks of North Wales and those of the English border counties, are arranged by him under the three following heads:—

1st. The greater thickness of each formation in North Wales.

2nd. The paucity of organic remains in North Wales, and that even in beds which in the English border counties are crowded with fossils.

3rd. The prevalence of slaty cleavage in North Wales.

First and second Points of Difference.—From the examination which the author and other geologists have made of the several fossiliferous formations of North Wales, described in his paper, and those of the English border counties, he draws the conclusion, that the same formation contains fewer fossils in the one district than in the other, according as its thickness is greater in the one district than in the other; and this conclusion he supports by several examples.

This seeming correspondence between the paucity of fossils in a formation in any given district, and its thickness in that district, the author conceives to be deducible, as a consequence, from the laws which govern the distribution of marine animals in the sea at different depths, which have been derived by Professor E. Forbes from his dredging operations in the Ægean Sea.

The laws to which he more particularly alludes are, 1st, that the number of species, and of the individuals of every such species inhabiting the sea at any given depth, is the less as that depth is greater, and the greater as that depth is less; and, 2ndly, that the range of depth inhabited by any species is the greater as the depth is greater, and the less as the depth is less. Whence it follows, that were an internal sea to be gradually filled up, and were the solid contents of the basin so filled up to be divided into strata, each stratum being determined by the identity of the species therein preserved, the thicker strata, containing the fewest organic remains, would be found towards the bottom, and each successive stratum in ascending order would be thinner and thinner, and more and more replete with fossils.

Among the examples which he gives of an existing correspondence between the thickness of a formation and its comparative deficiency in fossils, is the Wenlock series, as seen in Worcestershire and in North Wales. This series, near Llangollen, is about 3500 feet thick, and is not known to have afforded more than a dozen different fossil species. Of these the most abundant occur in the middle and lower beds, and belong to the genus *Creseis*. The author states, on the authority of Professor E. Forbes, that the remains of the recent species of this genus are found in great abundance in the Mediterranean, in the sediment at the bottom of the sea at great depths; but that in shallow bottoms such remains are rare. The same series near Dudley does not attain, perhaps, a fourth of the above thickness; and it is crowded with organic remains, among which the stony corals abound; and these are specially indicative of a deposit in shallow water. The same may be remarked of the Lower Silurian formations, which in North Wales are far thicker and contain fewer fossils than in Shropshire and the border counties.

The author has not pointed out any criteria by which to distinguish the Cambrian series from the Lower Silurians, unless it be that the former series lies below the latter, and is almost, if not wholly, destitute of organic remains. The law of diminution in the living animals of the sea as the depth increases, points to a total absence of animal life at about 300 fathoms below the surface. The Cambrian series may therefore be regarded, either as a deposit

formed in the depths of an ocean below the limit of animal life, or as a formation which preceded the appearance of animals in these parts of the northern hemisphere.

Third Point of Difference.—In North Wales, not only in the Cambrian but also in the Lower Silurian rocks, slaty cleavage is universal: it is very common in the Wenlock series; and in many localities it runs, in a marked degree, through the whole thickness of the Ludlow shales; but in other localities these shales are wholly exempt from it. The principal epoch of slaty cleavage, however, preceded the formation of the Ludlow beds; for these beds are in many instances undisturbed by the faults which have broken up the planes of cleavage in the older rocks. The author was assiduous in measuring the position of the planes of bedding and cleavage in various parts of North Wales, in the hope of making out some general laws respecting cleavage. In measuring the angles, however, he does not pretend to have approximated nearer than within 5° of the truth, as the surface of the beds is rarely flat enough to allow of greater accuracy.

One law respecting slaty cleavage was announced in 1831 by Professor Sedgwick*, and is now well known: that law is, that the cleavage planes maintain their parallelism over extensive areas, irrespective of the varying position of the beds which they cut through, or of the mineral character of the beds. Another law respecting slaty cleavage was detected by the author† in the progress of his tour, and is the following: viz. that the strike of the cleavage coincides with the strike of the bedding, whenever the latter continues uninterruptedly the same for a considerable distance; but when the strike of the beds is inconstant, and shifts at short intervals, then the cleavage planes hold their course right on, irrespective of the varying position of the planes of bedding; in other words, that the strike of the cleavage coincides with the prevailing strike of the beds in each district, and does not vary with the subordinate and local irregularities in the strike of the beds. Whence it follows, that the strike of the cleavage in a district is far more constant and regular than the strike of the beds.

In order to present, in a succinct form, the evidence from which the author has deduced this second law respecting slaty cleavage, the observations he made, in various parts of North Wales, of the positions of the planes of bedding and cleavage, are arranged in the table given at p. 315.

From the author's observations it appears, that the district of

* Geol. Trans. 2nd ser. 3rd vol. p. 68.

† While the author was drawing this conclusion from his observations in Wales, a nearly similar law was announced to the British Association at Cork by Professor Phillips, in the following terms:—"The cleavage planes of the slate rocks of North Wales are always parallel to the main direction of the great anticlinal axes, but are not affected by the small undulations or contortions of these lines. In North Wales they maintain the same direction for fifty miles, not varying more than two or three degrees." [See Athenæum, 2nd Sept. 1843.]

North Wales in which the parallelism between the strike of the bedding and cleavage appears in the most marked degree, is all that part of Carnarvonshire which lies north of Tremadoc. Throughout this area, on the south of the Holyhead road, the beds as well as the cleavage planes strike north-east. On the west side of the Snowdon anticlinal the beds are much tossed about, and dip at various angles either north-west or south-east, and the cleavage planes are nearly vertical. On the east side of the anticlinal the beds dip south-east, and the cleavage dips north-west from 60° to 65°. On the eastern side of the Carnarvonshire synclinal the beds dip north-west, as does also the cleavage, but at an angle which gradually diminishes as you recede from the Snowdon chain. Thus at the Rhiw Brefder quarries the angle is 55°; at the Diffwys quarries it is 45°, and at Manodmawr 35°. Towards the northern extremity of the county of Carnarvon the strike of the beds changes from north-east to N.N.E., as does also the strike of the cleavage. To the south of Tremadoc the beds change in strike from north-east to east, and the cleavage changes in strike from north-east to E.S.E.

The parallelism in the strike of the planes of bedding and cleavage prevails also, in a marked degree, in the slaty district north of the Dee, and also in the North Berwyns. The common strike of the two planes approaches to east; but it is subject to many local variations; and in such cases the two planes vary in strike together. The cleavage has a northerly dip, at angles varying from 25° to 65°.

In the Barmouth chain the strike of the cleavage is somewhat irregular; but its mean direction is north and south, and its dip is from east 60° to west 60°.

In the district intersected by the great porphyritic eruption of Arenig, Arran Mowddy, &c., the planes of cleavage have lost their original bearings, and are subject to the greatest irregularity both in respect of direction and dip; and the same observation applies to the district of Lower Silurian rocks extending along the Holyhead road between Bryn-y-ddinas and Corwen.

From the circumstance that the position of the planes of cleavage depends, not on the varying position of the beds at each particular spot, but on their main position, the author infers that slaty cleavage cannot have arisen from any power analogous to that of crystallization; and from the almost mathematical regularity with which those planes are arranged, he concludes that they are not the effect of mechanical force or pressure exerted at the moving or upheaving of the rocks.

The author further concludes from his observations, that in those parts of North Wales where the strata are least disturbed, the planes of bedding and cleavage meet at an angle of from 15° to 30°; and hence he infers, that in those cases where, at the time of cleavage, the beds were horizontal, such was also the angle at which the cleavage intersected the bedding (15° to 30°). The author further observed, that in the quarries of North Wales which afford the slate of the best quality, the bedding and cleavage rarely meet at

an angle less than 25°, and never less than 20°; and that whenever the angle is less than 20°, the slate is of inferior quality. An increase in the angle at which the planes meet has no injurious effect; for in many instances when the slate is of the best quality, the angle of intersection is 45° and upwards.

The Igneous Rocks of North Wales, arranged according to their age.

The oldest igneous rocks in North Wales are the greenstones of the hills north of Barmouth, which are truly interstratified and contemporaneous with the Cambrian schists of these hills. As these schistose beds could not have been deposited in their present inclined position, they must have been elevated since they were deposited.

The next igneous rocks, in point of age, are the parallel dikes of greenstone, striking north-east and N.N.E., which intersect Carnarvonshire. The whole of these had assumed nearly their present position before the Wenlock rocks were deposited, and also before the Cambrian and Lower Silurian slates were affected by cleavage: for these dikes are never continued into the Wenlock series; nor, if any disturbance in the rocks which the dikes traverse can be traced to the proximity of these dikes, is the Wenlock series ever affected by that disturbance; and in the beds which are broken up and tossed about by the eruption of these greenstones, the cleavage planes preserve their parallelism, as was pointed out in describing the purple slates to the west of Snowdon. Some of the dikes of this period have thrown the strata which they traverse into great confusion; and this is especially the case in the centre and to the west of the Snowdon chain. Those on the east of that chain have for the most part the appearance of interstratification with the bedded rocks. It may be doubted, however, whether they are ever really contemporaneous with the beds. On the surface they seem to dip regularly between the beds of schist; but when laid open in the quarries they are found to swell out, and to thin off irregularly, or even to cut through the strata. These dikes are not all of the same age, but they are all of earlier date than the Wenlock rocks*.

Next in order of time come the eruptive porphyries and felspathic rocks of Cader Idris, Arran Mowddy, the Arenigs, and the igneous plateau of the Ceiriog described by Mr. Bowman. The eruption of these masses, while elevating the rocks in their neighbourhood (including those of the Wenlock series), has broken up the regularity of the planes of cleavage. But the Ludlow rocks lie undisturbed in the hollows between the elevated masses. This eruption must therefore have taken place after the deposition of the Wenlock series, and prior to that of the Ludlow rocks; and to the disturbing forces at work in this interval of time may be attributed the want of conformity between the Wenlock and the Ludlow formations, which is

* The dikes laid down on the accompanying map are such as the author actually observed, but it is probable that there are many more which are still to be discovered.

almost general in North Wales. The great eruptive masses of porphyry in the south-west of Carnarvonshire are probably referable to this period, for they never fail to disturb the regularity of the planes of cleavage.

The greenstones of Rhiw, Boduan, Penllechog, &c. in the south-west of Carnarvonshire, appear to be nearly of the same age with the last-mentioned felspar rocks. The serpentine of Porth-din-llaen seems to be of more modern date than the greenstone in its neighbourhood.

There are some eruptive rocks of less extent and more modern date than any of those before specified. East of Bangor is a mass of trap which has thrown up into a high ridge the Ludlow rocks; and the trap dikes on the shores of the Menai, described by Professor Henslow, are of posterior date to the coal-measures.

The map which accompanies the memoir has been compiled from various sources, with the addition of the author's own observations. The geographical groundwork is copied from Mr. Greenough's Map of England and Wales, and that map and Sir R. I. Murchison's Map of the Silurian district have been freely consulted; Mr. A. Aikin's 'Tour in North Wales,' and his description of Cader Idris in our Transactions, vol. ii. 2nd series, p. 273, supplied some points; but the author is especially desirous of recording his obligations to Mr. William Bowman for the loan of some sheets of the Ordnance Maps, coloured by the late J. E. Bowman, Esq., which were principally used in laying down the boundaries of the Upper Silurian deposits in Denbighshire, as well as for some other points. But the author is the only person who can be considered responsible for any part of the Map, as he has compiled it entirely on his own discretion.

DESCRIPTION OF THE PLATES.

Plate XII.

Map of North Wales *coloured geologically.*

In this map letters of reference have been made use of to denote the different hills and mountains. The following explanation is given of these references arranged according to counties.

Carnarvonshire.

a. Penmaen Mawr.
b. Penmaen Bach.
c. Great Orme's Head.
d. Tal-y-fan.
e. Yr Arrig.
f. Crass.
g. Gyrn Goch.
h. Pen Castell Duon.
i. Y Glelffordd Fawn-Ogder.
j. Benglog.
k. Carnedd Llewelyn.
l. Glyder Fach.
m. Carnedd Ddafydd.
n. Glyder Fawr.
o. Snowdon.
p. Moel Coch.
q. Mynydd Mawr.
r. Yr Arren.
s. Moel Eilio.
t. Craig Goch.
u. Bwlch Mawr.
v. Rivells or Yr Eifls.
w. Carn Boduan.
x. Carn Fadrin.
y. Rhiw.
z. Pen-y-Bryn.

Denbighshire.

a. Moel Morfidd.
b. Pentre Bychan.
c. Bryn Mali.
d. Castell Dinas Bran.
e. Cyrn-y-Brain.
f. Garth Gynnau.
g. Mynydd Llanaermon.
h. Bron Haulog.
i. Bron Banog.
j. Moel Cranaw.
k. Moel Eithin.
l. Cader Danad.
m. Cader Ddimel.
n. Llanellian Mount.
o. Cave Hill.
p. Bryn-y-Pin.
q. Moel-Fre Isa.
r. Moel-Fre Ucha.
s. Moel Fodian.
t. Moel Tywysog.
u. Moel-y-Park.
v. Craig Arthur.
w. Moel Arthur.
x. Moel Fammau.
y. Moel Enlli.
z. Moel Ciw, Cefn Coch.

Flintshire.

a. Gwaunysgaer Down.
b. Garreg Mountain.
c. Pentre Halkin.
d. Moel-y-Gaen.
e. Bryn Yorcin (Fire-Beacon).
f. Fron.

Merionethshire.

a. Llether.
b. Crib-y-Rhiwau.
c. Craig-y-Cae.
d. Llawllech.
e. Rhinog Fawr.
f. Moel-y-Crosau.
g. Moel Llynf Nant.
h. Arenig Fawr.
i. Arenig Fach.
k. Moel-y-fan-y-llan.
l. Rhobell Fawr.
m. Y-Ddualt.
n. Pen-y-Cader.
o. Mynydd Pen-y-Coed.
p. Pen-y-Garn.
q. Craig Coch.
r. Tarren-y-Gessail.
s. Pen-y-Graian.
t. Mynydd Dolgoed.
v. Arran Mowddy.
w. Cader Berwyn.
x. Moel Cerrig Duon.
y. Bwlch-y-Cifno.
z. Moel Ferna.

Plate XIII.

Fossil remains of Pteropodous Shells *from the North Welsh Silurian Rocks.*

Several species belonging to the genus *Creseis* had been confounded with the genus *Orthoceratites*, until Prof. E. Forbes pointed out their true character: these fossils are of great assistance in classifying the middle part of the Silurian system in North Wales, as they are found in rocks otherwise nearly bare of organic remains. The author found the four following species in the Wenlock rocks of Denbighshire and Merionethshire:—

Creseis primæva, E. Forbes, Quarterly Geological Journal, vol. i. p. 146. Plate XIII. fig. 2.—Sheath long and regularly tapering, smooth, with one (or more?) longitudinal grooves. Length two to eight inches; width of the aperture one-twelfth of the length. Very common in the Wenlock rocks of Denbighshire and Merionethshire.

Creseis ventricosa, n.s., Plate XIII. fig. 3.—Sheath straight at the back, slightly ventricose in front, tapering to a point; nearly smooth with faint sloping lines of growth, and a strong longitudinal furrow. Length two and a half inches; width of the aperture half an inch. In Wenlock flagstone, in the Tyn-y-ffridd quarry between Cerrig-y-Druidion and Ruthin.

Creseis obtusa, Plate XIII. fig. 4.—Sheath short and conical, sides slightly curved towards a blunt point, smooth? with a longitudinal furrow. Length two inches; width of the aperture half an inch. Very common in the Wenlock rocks of Denbighshire and Merionethshire.

Creseis gracillima, Plate XIII. fig. 5.—Sheath very long, straight and slender, tapering gently to a point. There is only one broken specimen of this species, four inches long, one-eighth of an inch wide at the upper end. In Wenlock flagstone in Tyn-y-ffridd quarry between Cerrig-y-Druidion and Ruthin.

The following species belonging to the same family is added for the sake of illustration, although found in another district:—

Theca Forbesii, Plate XIII. fig. 1.—Sheath nearly flat behind, rounded in front, conical and tapering to a point; aperture an obtuse-angled triangle, with the angles rounded off; surface covered with fine striæ, arched parallel to the curved edges of the aperture. Length half an inch to one inch; width at the aperture one-third of its length. Common in the middle part of the Ludlow rocks at Underbarrow near Kendal. This species is closely allied to *T. lanceolata* of Morris, found in palæozoic rocks in New South Wales. *a* and *b*, internal casts; the figure above *a* is a section to show the form of the aperture; *c* and *d*, exterior of the sheath. The author names it after Professor E. Forbes, who first pointed out the class of animals to which these fossils belong.

From Nature by C. Schaff

Printed by C. Hullmandel.

1. *Theca Forbesii*
2. *Creseis primæva*
3. *Creseis ventricosa*
4. *Creseis obtusa*
5. *Creseis gracillima*

TABLE of Bedding in different

Di	Dip.			Angle between planes of cleavage and bedding.
	avage.	Bedding.		
	Angle.	Point of compass.	Angle.	
	°		°	°
	80	S 45 E	45	65
	80 to 85	S 45 E	45	35 to 40
	80 to 85	N 45 W	45	55 to 50
	80 to 85	S 45 E	50	30 to 35
	80 to 85	S 45 E	50	30 to 35
West o	80 to 85	S 45 E	30	50 to 55
don A	70	S 68 W	60	65
	90	S 45 E	55	35
	85	S 45 E	45	50
	80	N 45 W	65	15
	80	S 45 E	45	55
	80	N 45 W	65	35
	80	S 45 E	50	30
East				
Snow	60 to 65	S 45 E	40 to 60	55 to 85
ticlin				
	65	N 45 W	45	20
	65	N 45 W	45	28
	85	N 45 W	65	20
East sid	45	N 45 W	25	20
narvo	55	N 45 W	30	25
Syncl	45	N 45 W	25	20
	35	N 45 W	15	20
	50	E 68 N	15	?
East of t				
y-ddi				
Holyh	50	N 22 E	15	125
road				
Ditto ..	50	N 22 W	25	73
Northeri				
mity				
count	variable	?	?	?
narvo				
South-w	50	N 45 W	45	90
of Car	70	W	55	15
shire	30	N	20	13
Menai S	70	S 45 E	45	46
Bala tro	65	N 68 W	35	30
	90	S 45 E	90	63
South o	50	N 45 E	30	20
Lake	55	N 45 E	35	34
	75	S 68 E	40	75

TABLE showing the position of the Plane of Cleavage as compared with the position of the Plane of Bedding in different parts of North Wales.

District.	Locality.	Formation.	Strike.			Dip.				Angle between planes of cleavage and bedding.
						Cleavage.		Bedding.		
			Cleavage.	Bedding.	Difference of strike.	Point of compass.	Angle.	Point of compass.	Angle.	
West of Snowdon Anticlinal	Bron-llwyd	Metamorphic rocks	E 45° N	E 45° N	0°	N 45° W	80°	S 45° E	45°	65°
	Penhryn quarry, west side	Lower Silurian slate	E 45 N	E 45 N	0	S 45 E	80 to 85	S 45 E	45	35 to 40
	Ditto, east side	Ditto	E 45 N	E 45 N	0	S 45 E	80 to 85	N 45 W	45	55 to 50
	West of Bethesda	Ditto	E 45 N	E 45 N	0	S 45 E	80 to 85	S 45 E	50	30 to 35
	Coet-mor and Tan-y-bwlch	Ditto	E 45 N	E 45 N	0	S 45 E	80 to 85	S 45 E	50	30 to 35
	Pont-y-Coetmor and Bryn	Ditto	E 45 N	E 45 N	0	S 45 E	80 to 85	S 45 E	30	50 to 55
	Dinorwig quarries, Llanberris	Ditto	E 68 N	E 68 S	S 136	S 68 E	70	S 68 W	60	65
	Glyn quarries, ditto	Ditto	E 45 N	E 45 N	0	vertical	90	S 45 E	55	35
	Bettws Garmon	Ditto	E 45 N	E 45 N	0	N 45 W	85	S 45 E	45	50
	Llanllyfni	Ditto	E 45 N	E 45 N	0	N 45 W	80	N 45 W	65	15
	Ditto	Ditto	E 45 N	E 45 N	0	N 45 W	80	S 45 E	45	55
	Ditto	Ditto	E 45 N	E 45 N	0	S 45 E	80	N 45 W	65	35
	Ditto	Ditto	E 45 N	E 45 N	0	S 45 E	80	S 45 E	50	30
East side of Snowdon Anticlinal	Sundry localities		E 45 N	E 45 N	0	N 45 W	60 to 65	S 45 E	40 to 60	55 to 85
East side of Carnarvonshire Synclinal	South-east side of Craig-llyn-llagi	Lower Silurian	E 45 N	E 45 N	0	N 45 W	65	N 45 W	45	20
	Near Bryn gelynen	Dark Lower Silurian slate	E 68 N	E 45 N	S 23	N 68 W	65	N 45 W	45	28
	Ditto	Lower Silurian slaty flagstone	E 45 N	E 45 N	0	N 45 W	85	N 45 W	65	20
	Ditto	Hard slaty flagstone	E 45 N	E 45 N	0	N 45 W	45	N 45 W	25	20
	Rhiw Brefder quarries, Mr. Holland's	Lower Silurian slate	E 45 N	E 45 N	0	N 45 W	55	N 45 W	30	25
	Diffwys quarries	Ditto	E 45 N	E 45 N	0	N 45 W	45	N 45 W	25	20
	Manod-mawr quarries	Inferior slate at the base of the Lower Silurian rocks	E 45 N	E 45 N	0	N 45 W	35	N 45 W	15	20
	North of Tremadoc	Light grey Lower Silurian flagstone	E 45 N	N 68 W	N 23	S 45 E	50	E 68 N	15	?
East of the Bryn-y-ddinas fault, Holyhead road	Between the 47th and the 48th milestones	Bala grits, Lower Silurian	E 45 N	E 22 S	S 77	N 45 W	50	N 22 E	15	125
Ditto	Ditto	Ditto	E 45 N	E 22 N	S 23	N 45 W	50	N 22 W	25	73
Northern extremity of the county of Carnarvon			E 68 N	E 68 N	0	?	variable	?	?	?
South-west part of Carnarvonshire	Porth-felin, south of Aberdaron	Schist	E 45 N	E 68 N	N 23	S 45 E	50	N 45 W	45	90
	North of Pwllheli, 3¾ miles	Dark fossiliferous inferior slate	N	N	0	W	70	W	55	15
	Porth Treueddyn, near Tremadoc		E 22 S	E	N 22	N 22 E	30	N	20	13
Menai Straits	North of Carnarvon	Ludlow shale	E	E 45 N	N 45	S	70	S 45 E	45	46
Bala trough	Two miles east of Bala	Good slate, Lower Silurian	E 68 N	E 68 N	0	N 68 W	65	N 68 W	35	30
South of Bala Lake	Between Dinas Mawddy and Mallwyd	Good slate, ditto	E 68 N	E 45 N	S 23	vertical	90	S 45 E	90	63
	Taihirion, west of Arenig fawr	Inferior slate	E 45 S	E 45 S	0	N 45 E	50	N 45 E	30	20
	East flank of Arenig fawr	Roofing slate	E 22 S	E 45 S	S 23	N 68 E	55	N 45 E	35	34
	Nine miles south of Bala, on the Twrch River	Lower Silurian slaty grit	E 68 S	E 68 N	N 136	S 68 W	75	S 68 E	40	75

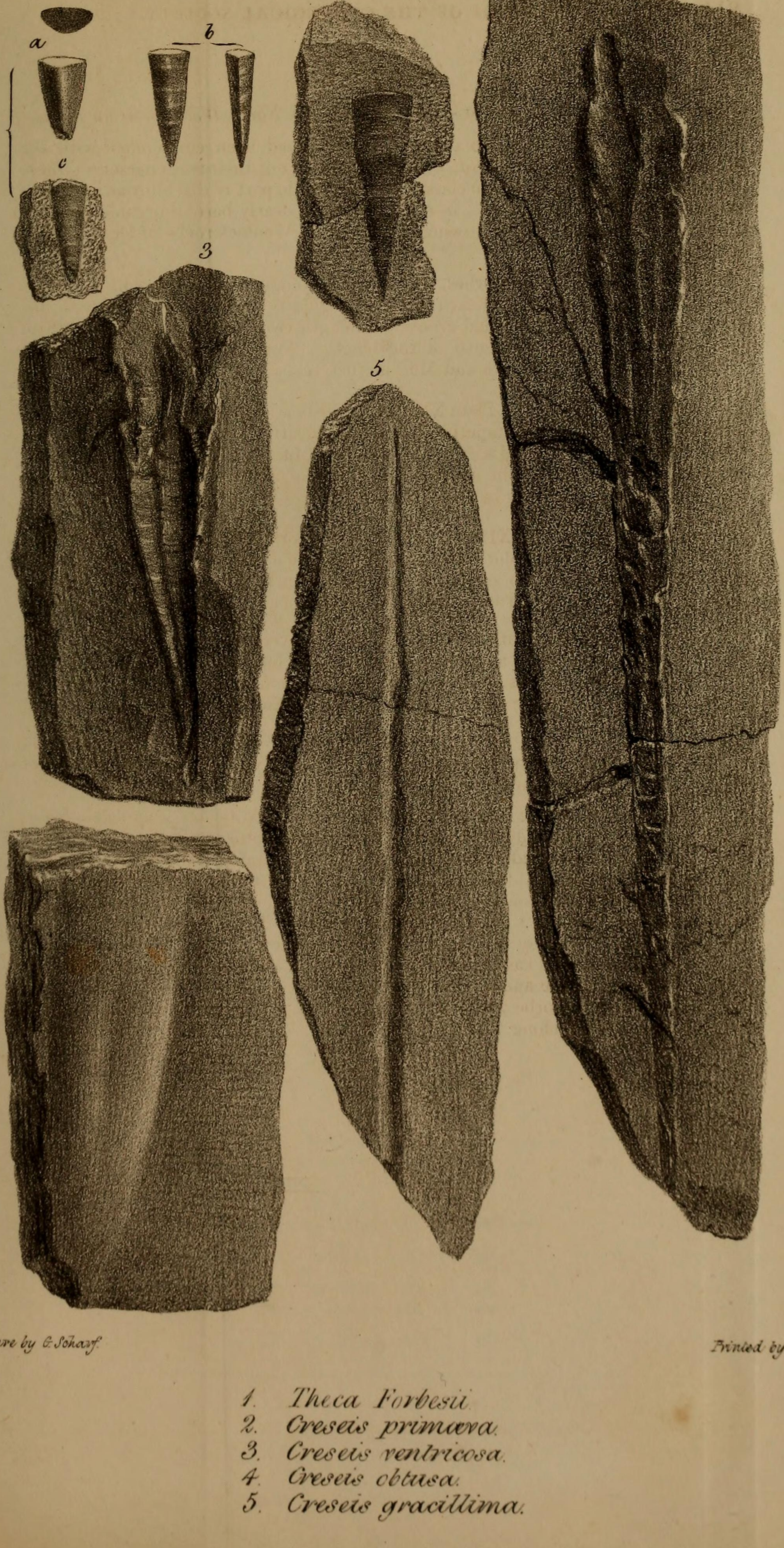
ɔmpared with the position of the Plane of Bedding Wales.

Strike.			Dip.				Angle between planes of cleavage and bedding.
			Cleavage.		Bedding.		
Cleavage.	Bedding.	Difference of strike.	Point of compass.	Angle.	Point of compass.	Angle.	
°	°	°	°	°	°	°	°
E 45 S	E 45 S	0	N 45 E	60	S 45 W	10	110
E 68 S	E 45 S	N 23	?	?	S 68 W	10	?
N	N	0	E	60	E	30	30
N	E 68 N	S 22	E	60	S 68 E	30	34
S	E 56 S	N 34	E	60	N 56 E	30	37
E 68 N	E 68 S	S 136	S 68 E	80	N 68 E	60	59
E 68 N	E 68 N	0	vertical	90	?	?	?
E 45 N	E 45 N	0	N 45 W	60	S 45 E	30	90
E 68 N	E 68 N	0	vertical	90	S 68 E	?	?
E 45 N	N	N 45	S 45 E	50 to 55	E	high	?
N	N	0	E	50 to 55	E	high	?
E	E	0	N	60	N	25	35
E	E 68 N	N 68	N	25	S 68 E	40	139
E	E	0	N	65	S	45	70
E	E	0	N	65	N	15	50
E	E	0	N	65	N	25	40
E	E 34 S	S 34	N	65	N 34 E	15	53
E	E	0	N	55	N	30	25
E 45 S	E	N 45	N 45 E	5	vertical	90	86
E 45 S	E 45 S	0	N 45 E	50	N 45 E	5 to 10	45 to 40
E	E	0	N	25	N	10	15
E 22 S	E 22 S	0	N 22 E	45	N 22 E	30	15
E 45 S	E 45 S	0	N 45 E	30	S 45 W	55	95
E	E	0	N	45	S	80	55
E	E	0	N	45	S	40	95
E	E	0	N	45	S	80	55
E	E	0	N	45	S	45	90
E 34 S	E 34 S	0	N 34 E	50	S 34 W	70	60
E 34 S	E 34 S	0	N 34 E	50	S 34 W	70	60

TABLE (*continued*) showing the position of the Plane of Cleavage as compared with the position of the Plane of Bedding in different parts of North Wales.

District.	Locality.	Formation.	Strike.			Dip.				Angle between planes of cleavage and bedding.
						Cleavage.		Bedding.		
			Cleavage.	Bedding.	Difference of strike.	Point of compass.	Angle.	Point of compass.	Angle.	
Barmouth chain	North of the ridge of Craig drwg	Cambrian	E 45° S	E 45° S	0°	N 45° E	60°	S 45° W	10°	110°
	Ditto	Ditto	E 68 S	E 45 S	N 23	?	?	S 68 W	10	?
	Llanbedr, seven miles north of Barmouth	Ditto	N	N	0	E	60	E	30	30
	Ditto	Ditto	N	E 68 N	S 22	E	60	S 68 E	30	34
	Ditto	Ditto	S	E 56 S	N 34	E	60	N 56 E	30	37
	One mile north of Barmouth	Ditto	E 68 N	E 68 S	S 136	S 68 E	80	N 68 E	60	59
	East of Hendre mynach, one mile north-west of Barmouth	Ditto	E 68 N	E 68 N	0	vertical	90	?	?	?
	Near Barmouth	Ditto	E 45 N	E 45 N	0	N 45 W	60	S 45 E	30	90
	East of the Barmouth ridge	Ditto	E 68 N	E 68 N	0	vertical	90	S 68 E	?	?
East of the Barmouth chain.	Between Barmouth and Dolgelly	Ditto	E 45 N	N	N 45	S 45 E	50 to 55	E	high	?
	Ditto	Ditto	N	N	0	E	50 to 55	E	high	?
East of Bryn-y-ddinas fault.	South of Yspytty Evan, south of Holyhead road	Lower Silurian fossiliferous schist	E	E	0	N	60	N	25	35
	West of Druid Inn, Holyhead road; west of Corwen, north of the Dee	Lower Silurian grits	E	E 68 N	N 68	N	25	S 68 E	40	139
System of the North Berwyns	Corwen	Ditto	E	E	0	N	65	S	45	70
	1½ mile east of Corwen, north of the Dee	Lower Silurian grits	E	E	0	N	65	N	15	50
	South of Corwen	Ditto	E	E	0	N	65	N	25	40
	Ditto	Ditto	E	E 34 S	S 34	N	65	N 34 E	15	53
	Nant-cwm-dywyll, south of Corwen	Cambrian slate	E	E	0	N	55	N	30	25
	Below Pistill Rhaiadr	Ditto	E 45 S	E	N 45	N 45 E	5	vertical	90	86
South of the Dee	South of the Dee from Corwen to Llangollen	Upper Silurian beds	E 45 S	E 45 S	0	N 45 E	50	N 45 E	5 to 10	45 to 40
	Near Llansaintfraid glyn Ceiriog	Dark Lower Silurian roofing slate	E	E	0	N	25	N	10	15
	Fron frys, south of Ceiriog river	Ditto	E 22 S	E 22 S	0	N 22 E	45	N 22 E	30	15
North of the Dee	Llettywyn, south of Cricor Mawr, west of Nant Morwynion fault	Ludlow rocks	E 45 S	E 45 S	0	N 45 E	30	S 45 W	55	95
	From Corwen to Llangollen	Wenlock beds	E	E	0	N	45	S	80	55
	Ditto	Ditto	E	E	0	N	45	S	40	95
	Glyn and Qirnant quarries, south of Cyrn-y-brain	Wenlock slate	E	E	0	N	45	S	80	55
	Ditto	Ditto	E	E	0	N	45	S	45	90
	Moel-y-faen, south of Cyrn-y-brain	Ditto	E 34 S	E 34 S	0	N 34 E	50	S 34 W	70	60
	Ditto	Dark Lower Silurian roofing slate, conformable to the Wenlock beds	E 34 S	E 34 S	0	N 34 E	50	S 34 W	70	60

Fig: 1.



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1. *Theca Forbesii.*
2. *Creseis primæva.*
3. *Creseis ventricosa.*
4. *Creseis obtusa.*
5. *Creseis gracillima.*