THE GEOLOGY OF THE DISTRICTS AROUND MACHYNLLETH AND ABERYSTWYTH.

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CONTENTS.

I. INTRODUCTION AND PHYSICAL FEATURES.

THE area to be visited includes a portion of Central Wales bordered by the coast from Towyn to the south of Aberystwyth. Two physiographic regions have been distinguished within it; (1) the High Plateau and (2) the Coastal Plateau.

(1) As seen from any high view-point, the surface of the High Plateau forms a remarkably even sky-line. It rises to over 2,000 feet in the northern part of the area, and descends southwards to about 1,800 feet at the southern margin. The plateau is dominated on the west by the mountain masses of Cader Idris (2,927 ft.) and Aran Mawddwy (2,970 ft.), the uneven sky-line of which is in striking contrast to that of the plateau. The Plynlimon mass (2,468 ft.) and a part of the hills east of Devil's Bridge (1,995 ft.) also stand out sharply above the general level, and on a clear day the hill of Drygarn Fawr (2,115 ft.) can be seen far to the south rising like a low mound above the plateau.

(2) South of the Dyfi Estuary the Coastal Plateau forms a strip along the coast widening from about 5 miles to about 8 miles south of the River Ystwyth. Near the coast it stands at an elevation of 400 to 600 feet, and rises gently inland. Its inner margin is not sharply defined; the surface up to about 900 feet clearly belongs to this plateau and above this level the ground rises more sharply to the High Plateau.

Seen in perspective the boundary between the lower and the higher plateaus is usually very marked and often recalls a shore line. When viewed in profile, however, the high ground descends in a fine sweeping concave curve which merges into the general surface of the lower plateau.

The River Systems. The rivers of the area fall into two systems, (1) those flowing in a general westerly direction and draining more or less directly into Cardigan Bay, and (2) those flowing eastwards or south-eastwards into the Severn and

the Wye. In a broad sense the former streams are associated with the Coastal Plateau, and the latter with the High Plateau. The tributaries of the Severn and the Wye which rise near the edge of the High Plateau, flow roughly in the direction of the slope of its surface.

The two rivers Rheidol and Ystwyth, which enter the sea together at the mouth of the harbour at Aberystwyth, have a more complicated history which will be dealt with later. The valleys of the High Plateau are in an advanced stage of maturity with relatively gentle, long slopes and wide, flat floors. Those of the Coastal Plateau are narrow, steep-sided valleys, in a young or sub-mature stage of development. The upper parts, however, of many of these valleys are wide open and of mature aspect.

The river systems and the plateaus lead to the conclusion that this area includes two surfaces in different stages of development. The most mature and possibly the oldest is the High Plateau, and the directions assumed by the rivers that drain it may be regarded as the trend of the earliest drainage of the area. At a later stage the Coastal Plateau was developed by a westerly-flowing system of rivers which attained an advance stage of maturity. Subsequently a general uplift of the whole of Wales caused renewed excavation in those rivers which drained directly towards the coast-line of Cardigan Bay, and this erosion has in some cases removed all traces of the earlier mature stage of these valleys. In other cases portions of them remain as witnesses of the former condition of the surface.

II. STRATIGRAPHY.

ORDOVICIAN.

Llandeilo.

The northern margin of the district is defined by the boundary between the Bala sedimentary and the Llandeilo volcanic rocks. The volcanic rocks form a conspicuous ridge of high mountain country which extends from Cader Idris through Aran Mawddwy, Aran Benllyn and northwards to the Arenigs. This ridge reaches its highest point in Aran Mawddwy (2,970 feet) and dominates all the country to the south and east which consists of the softer Bala and Llandoverian sedimentary rocks.

In the Cader Idris country, these volcanic rocks and their associated sedimentary intercalations have been described by Prof. A. H. Cox.[1] The uppermost division, the Upper Acid Group, is a complex series of acid andesitic tuffs with rhyolitic and possibly some acid andesitic lavas varying from 900 to 1,500 ft. in thickness. The highest rocks are usually well bedded, flaggy, silicified tuffs which like the other rocks of the group weather greyish-white.

[1] *Quart. Journ. Geol. Soc.*, lxxxi. (1925), pp. 539-94.

CLASSIFICATION OF ORDOVICIAN AND SILURIAN ROCKS (see Fig 32).

SILURIAN	LLANDOVERIAN OR VALENTIAN	UPPER	Graptolite Zones of *Monograptus sedgwicki, M. halli, M. turriculatus, M. crispus, M. griestoniensis* and *M. crenulatus.*				
		MIDDLE	Graptolite Zones of *Mesograptus magnus, Monograptus leptotheca* and *M. regularis.*				
		LOWER	Graptolite Zones of *Glyptograptus persculptus, Akidograptus acuminatus, Monograptus atavus, M. acinaces, M. cyphus* and *M. triangulatus.*				
ORDOVICIAN			PLYNLIMON AREA	NORTHERN AREA	BALA AREA	SHELLY FAUNAS	GRAPTOLITE ZONES
	BALA	UPPER	Brynglas and Drosgol Groups	Garnedd-wen Beds (Upper Part)	Hirnant Beds	*Rafinesquina-hirnantensis* fauna	
				Garnedd-wen Beds (Lower Part) Narrow Vein	Foel-y-Ddinas Mudstones	*Phacops-mucronatus* fauna	
			Nant-y-Moch Group	Red Vein	Moelfryn Sandstones		*Dicellograptus-anceps* Zone
			(Not exposed)	Abercwmeiddaw Group	Rhiwlas Mudstones	*Cyclopyge* fauna *Phillipsinella-parabola* fauna	*Dicellograptus-complanatus* Zone
		LOWER	(Not Exposed)	Nod Glas	(Equivalent Doubtful)		*Dicranograptus-clingani* Zone
				Ceiswyn Beds (Upper part)	Gelli-Grin Calcareous Ash Pont-y-Ceunant Ash	*Chasmops* and *Nicolella-actoniæ* fauna	
				Ceiswyn Beds (Lower Part)	Allt-Ddu Mudstones Frondderw Ash	*Asaphus-powisi* and *Heterorthis-alternata* fauna	
					Glyn-Gower Sandstones		
					Nant-hir Shales		*Nemagraptus-gracilis* Zone
	LLANDEILO (?)			Volcanic Rocks	Volcanic Rocks		

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The boundary between the volcanic rocks and the overlying dark slates is well-defined. In many sections there is little or no ashy material above the contact; but in other places bands of ashy mudstone, usually only a few inches thick, may occur a few feet above the main mass of the volcanic rocks. The rocks near the junction with the slates are often veined with quartz and may contain a certain amount of galena. These veins have been worked occasionally, as, for example, at the head of the Cowarch valley, north of Dinas Mawddwy.

Bala.

The Bala rocks may be divided into two parts, the Lower and Upper Bala. The Lower Bala rocks are only found in the northern part of the district where they form a belt of country from one to two miles wide on the southern and eastern flanks of Cader Idris and the Arans. They are succeeded by the Upper Bala rocks which are only fully developed in the northern part of the area. Upper Bala rocks also occur south of the Dyfi and cover considerable areas between the Rivers Ceulan and Llyfnant, around Plynlimon, and between Plynlimon and Llandiloes, but in these areas only the higher beds of the Upper Bala are exposed.

LOWER BALA.

Ceiswyn Beds.

The Llandeilo volcanic rocks are succeeded by the Ceiswyn Beds, which are about 4,000 feet thick. The basal beds consist of very dark blue slates which are often traversed by fine-grained, gritty bands up to an inch or more in thickness. These slates are highly cleaved and the cleavage planes usually possess a silky feel and lustre, and are often puckered and contorted. Occasionally, where the cleavage is not so highly developed, the rocks become somewhat massive, sheared mudstones with smooth, polished surfaces. These slates, which are about 200 to 300 feet thick, maintain their characteristic lithology throughout the area, but their upper limit is rather indefinite because they pass upwards almost imperceptibly into a thick group of grey-blue, slaty mudstones. They have been quarried at various times for roofing-slates, as, for example, at the head of the Llefenni valley (north-west of Aberllefenni), Cloddfa Gwanas (west of Dinas Mawddwy), the Aran Quarries (north-west of Bwlch y Groes) and elsewhere. Various factors such as thin gritty bands, local abundance of pyrite, small-scale jointing and irregular cleavage diminish their economic importance and the quarries are not now working.

These dark slates contain graptolites, but it is difficult to collect well-preserved specimens because the rocks are so highly cleaved. In addition, it seems likely that the graptolites may be restricted to comparatively narrow bands which are difficult

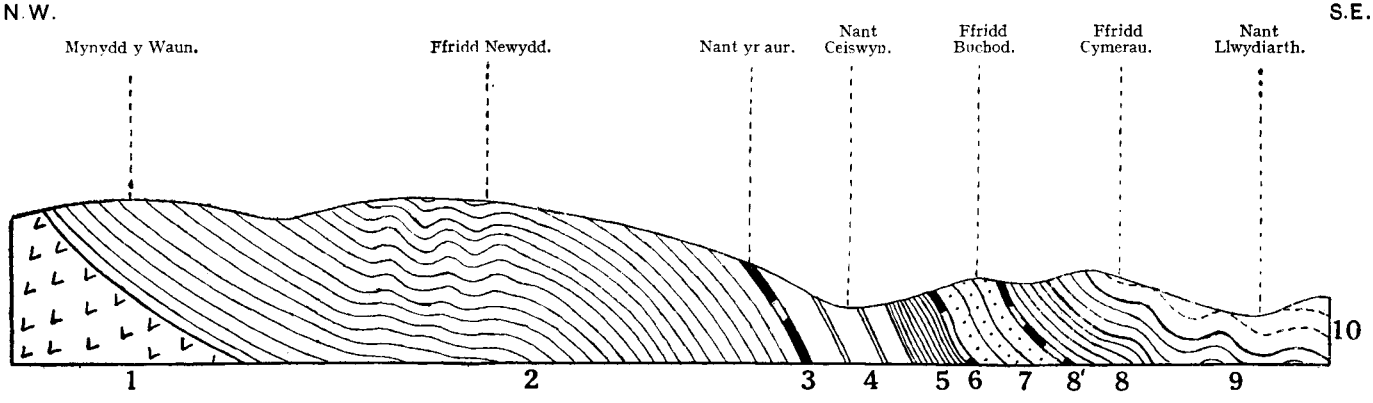

FIG. 32.—GENERAL SECTION FROM MYNYDD Y WAUN TO NANT LLWYDIARTH.
Showing the relations of the rock-groups, on the scale of 3 inches to the mile.

1=Craig y Llam volcanic group. 2=Ceiswyn Beds. 3=Nod Glas. 4=Abercwmeiddaw Group. 5=Red Vein.
6=Narrow Vein. 7=Garnedd-wen Beds. 8=Cwmere Group (with 8′, zone of *Glyptograptus persculptus*).
9=Derwin Group. 10=Ystwyth Stage.

to locate. Prof. A. H. Cox and Dr. A. K. Wells[1] recorded *Amplexograptus arctus* and *Glyptograptus teretiusculus* var. *euglyphus* from Craig Cwm Ammarch, south of Cader Idris, and there is little doubt that they occur in the same dark, slaty beds. Elsewhere between Towyn and Dinas Mawddwy, although a few fragments of graptolites have been found, they are so poorly preserved that they cannot usually be identified. Some of the specimens may be referred tentatively to *Glyptograptus teretiusculus sensu lato*. North of Dinas Mawddwy, graptolites may be collected at the Blaen-Cowarch Lead Mine and the Aran Slate Quarries, but the identifications are given with some reserve owing to the poor state of preservation.

In these localities the rocks appear to contain *Climacograptus brevis* Elles & Wood, *Cl. scharenbergi* Lapworth, *Glyptograptus teretiusculus* (Hisinger), *Dicellograptus* sp., *Dicranograptus rectus* (?) Hopkinson and *D. nicholsoni* (?) Hopkinson. Dr. G. L. Elles[2] has collected the same species of *Climacograptus* together with *Dicellograptus sextans* (Hall) and *Nemagraptus* sp. from the dark slates which overlie the volcanic rocks at Arenig. It seems likely that these dark slates which succeed the volcanic rocks along the flanks of Cader Idris and the Arans belong to the zone of *Nemagraptus gracilis*. It is of interest that no trace of the well-known Derfel Limestone, with its characteristic shelly fauna, has been found south of the Arenig country.

Between Towyn and Dinas Mawddwy, these dark slates are followed by a monotonous group of grey-blue, slaty mudstones which are nearly 4,000 feet thick. Some parts of the group present a banded appearance owing to alternations of paler and darker mudstone layers. The mudstones include gritty bands usually an inch or so in thickness; but the whole group appears to be rather more arenaceous in the Towyn country and there the grit bands may be 3 or 4 feet thick. Pyrite cubes occur commonly along the bedding planes. The greater part of the group exhibits a pale, yellowish brown weathering tint, but some of the darker bands and the highest beds beneath the Nod Glas show well marked rusty-brown weathering colours.

The rocks are not so well cleaved as the dark slates at the base and in some places consist of rather massive mudstones. North-east of Towyn, there are two impersistent ash bands about 500 feet above the base of the Ceiswyn Beds. These ash bands consist of a pale, greenish-grey rock not unlike parts of the Upper Acid Volcanic Group. Each band is about 40 feet thick and they are separated from one another by some 50 feet of sandy mudstone. They can be traced for about a mile, and they are the only ashy bands which have been recognised in the Bala Series south-west of Dinas Mawddwy.

[1] *Rep. Brit. Assoc.* (Manchester, 1915), 1916, p. 425.

[2] *Quart. Journ. Geol. Soc.*, lxxviii. (1922), pp. 144-45.

The Ceiswyn Beds are well exposed and there are several stream and crag sections through the whole group, but the rocks appear to be practically unfossiliferous. Badly preserved graptolites were collected in only one locality, in the Ffridd Newydd crags north of Aberllefenni, about 1,500 feet below the Nod Glas, and they appear to be *Climacograptus scharenbergi* Lapworth. It is thus impossible at present to subdivide this thick group of rocks and the slight lithological differences in the Ceiswyn Beds merge into one another so gradually that subdivisions based on lithology cannot be mapped satisfactorily.

At Dinas Mawddwy, there are important changes in the characters of the highest Ceiswyn Beds where the uppermost 300 feet consist of rusty-weathering shales and mudstones which may be called the UPPER CEISWYN BEDS. These beds can be traced northwards as a distinct lithological and faunal group, becoming calcareous and ashy until eventually they pass laterally into the Gelli-Grin Calcareous Ash Series of the Bala country with the *Orthis* (*Nicolella*)-*actoniae* fauna, but definite limestone bands do not appear until the country immediately south of Bala is reached.

The Upper Ceiswyn Beds are well exposed around and north of Dinas Mawddwy and in the Pumryd and Dyfi valleys at Llanymawddwy, but north of Bwlch y Groes they are usually concealed beneath peat and boulder-clay. Fossils first appear at Bwlch Siglen, about a mile and a half south-west of Dinas Mawddwy, where occasional specimens of *Trinucleus* and *Dalmanella* may be collected. Fossils become more abundant as the rocks are traced northwards, but the fauna in the Dinas Mawddwy-Llanymawddwy area is less varied than that of the Gelli-Grin Series at Bala. Some of the more abundant fossils in the Upper Ceiswyn Beds are :—

Orthis (*Dalmanella*) *elegantula* (Dalman) var.
Orthis (*Dalmanella*) *testudinaria* (Dalman) var.
Triplecia (*Cliftonia*) *spiriferoides* (McCoy).
Leptæna ungula (McCoy).
Chonetoidea cf. *papillosa* (Reed).
Trinucleus (*Cryptolithus*) *caractaci* (Murchison).
Trinucleus (*Cryptolithus*) *gibbifrons* (McCoy).
Phacops (*Acaste*) *apiculata* (Salter).
Homalonotus bisulcatus (Salter).
Asaphus powisi (Salter).
Calymene aff. *caractaci* (Salter).
Holopea striatella (Sowerby).
Beyrichia (*Tetradella*) *complicata* (McCoy).

The rocks beneath the Upper Ceiswyn Beds maintain their monotonous lithology and unfossiliferous character through the Dinas Mawddwy and Llanymawddwy country. They are well exposed in a number of places, but one of the best sections is in that part of the Dyfi valley known as the Llaethnant.

The lower half of the Ceiswyn Beds continues northwards into the Bala country with little or no change in lithology (*Nant-hir Shales* of Dr. Elles). The Nant-hir Shales are probably about 2,000 feet thick in the area north-west of Bwlch y Groes, but like the Ceiswyn Beds, they have not yielded any fossils except certain graptolites in the dark slates at the base to which reference has already been made. North of the Dyfi valley important changes begin to take place in the Ceiswyn Beds below the Upper Ceiswyn group and these rocks have there been divided into the GLYN-GOWER SANDSTONES and the ALLT-DDU MUDSTONES of the Bala country.

At Bala, the GLYN-GOWER SANDSTONES consist of thickly-bedded sandstones and sandy mudstones, the latter often including laminated sandstone bands up to 9 inches in thickness. They become less arenaceous as they are traced southwards from Bala and can no longer be recognised as a separate group on the moorland west of Bwlch y Groes, whilst in the Llaethnant, a little farther south, they have passed into slaty mudstones of the Ceiswyn type. The Glyn-Gower Beds are poorly fossiliferous in the Bala country. Fossils are still more rare farther south and they have only yielded a few poorly preserved specimens at one or two localities north of Bwlch y Groes. In many cases a specific identification cannot be made, and the following only have been recorded :—

Orthis (*Dalmanella*) sp.
Skenidium sp.
Lingula sp.
Trinucleus (*Cryptolithus*) cf. *radiatus* (Murchison).
Asaphus sp.
Beyrichia (*Tetradella*) *complicata* (McCoy).

The ALLT-DDU MUDSTONES intervene between the Glyn-Gower Sandstones and the Gelli-Grin Calcareous Ash Series in the Bala country and contain the *Orthis* (*Heterorthis*)-*alternata* fauna. These mudstones may be traced southwards from Bala, although the boundary with the Glyn-Gower Sandstones can only be drawn in a general way where the sandy mudstones gradually give place to the grey-blue Allt-Ddu Mudstones. The Allt-Ddu Mudstones are well exposed and are still fairly fossiliferous in the road section north of Bwlch y Groes. The lowest beds are exposed south of Ty'n-y-fron Farm and the upper part is admirably exposed in the Craig yr Ogof crags. The rocks in these localities have yielded :—

Orthis (*Heterorthis*) cf. *alternata* (Sowerby).
Orthis (*Dalmanella*) *elegantula* (Dalman) vars.
Orthis (*Dalmanella*) *testudinaria* (Dalman) vars.
Orthis (*Dinorthis*) *flabellulum* (Sowerby).
Orthis (*Harknessella*) *vespertilio* (Sowerby).
Sowerbyella sericea (Sowerby) var.
Triplecia (*Cliftonia*) *spiriferoides* (McCoy).

Strophomena (*Rafinesquina*) cf. *bipartita* (Salter).
Strophomena (*Rafinesquina*) *expansa* (Sowerby).
Strophomena (*Rafinesquina*) sp. geniculate type.
Lingula ovata (?) (Sowerby).
Asaphus sp.
Calymene sp.
Trinucleus (*Cryptolithus*) aff. *gibbifrons* (McCoy).
Homalonotus sp.
Beyrichia (*Tetradella*) *complicata* (McCoy).
Monticulipora lens (McCoy).
Ptilodictya fucoides (McCoy).
Numerous crinoid-stems.

These fossiliferous grey-blue mudstones with some rusty-weathering tints pass southwards into the cleaved mudstones of the Ceiswyn type and south of Bwlch y Groes appear to be practically unfossiliferous, a few fossils only having been found at one point in the Llaethnant section.

In the Bala country, the boundary between the Glyn-Gower Sandstones and the Allt-Ddu Mudstones is taken at the Frondderw Ash, while the Pont-y-Ceunant Ash forms the junction between the Allt-Ddu Mudstones and the overlying Gelli-Grin Calcareous Ash Series, but both these ash bands disappear a few miles south of Bala.

Nod Glas.

The Ceiswyn Beds are succeeded by a comparatively thin band of soft, jet-black shales and mudstones which are called locally the Nod Glas. In some places, the rocks consist of highly cleaved, papery shales, but in others they are tough, blocky mudstones. They weather to a pronounced rusty colour, are highly pyritous and are usually traversed by numerous joint planes. Their distinct lithological characters make the band most useful for mapping purposes, and even in the absence of exposures it may be followed without difficulty for, being softer than the adjacent rocks, it forms a well-marked hollow. Owing to its comparatively soft character it is not commonly well-exposed except in certain stream sections. The beds of such streams are often stained reddish-brown, and large blocks of breccia may occur consisting of weathered fragments of black shale cemented into a hard mass by ferruginous material. Between Towyn and Dinas Mawddwy, the band is usually about 70 feet thick and may be examined at Pandy and Dolgoch (south-west of Abergynolwyn), Glyn Iago (south-west of Corris), Nant yr aur in the Ceiswyn valley (north-east of Aberllefenni), Nant-y-Nod (north of Aberangell), and at Bwlch Siglen (west of Dinas Mawddwy). In most places, it is clear that there has been a good deal of movement along this soft, shale-band with much rock-shattering and this is especially well marked between Towyn and Corris. This, together with the intense cleavage, often makes difficult the identification of the abundant

graptolites which the band yields, but the following forms have been recorded :—

Dicellograptus forchammeri Geinitz.
Dicellograptus morrisi Hopkinson.
Dicranograptus clingani Carruthers.
Climacograptus minimus (Carruthers).
Climacograptus scalaris var. *miserabilis* Elles and Wood.
Climacograptus styloideus Lapworth.
Climacograptus tubuliferus Lapworth.
Orthograptus calcaratus var. *basilicus* Lapworth.
Orthograptus truncatus var. *socialis* Lapworth.
Orthograptus truncatus var. *pauperatus* Elles and Wood.
Orthograptus quadrimucronatus (Hall).
Plegmatograptus nebula Elles and Wood.

The most abundant graptolites are the *Dicellograpti* and the *Climacograpti* (especially *Cl. minimus*), and some of the bedding planes are covered with these fossils. It is possible that different levels in this black shale band may be characterised by somewhat different graptolite assemblages ; but this has not yet been investigated, and in many cases the high cleavage makes difficult the extraction of recognisable forms. The general aspect of the fauna suggests the zone of *Dicranograptus clingani*, although there are several forms that suggest the higher horizon of *Pleurograptus linearis*, and it may be that the Nod Glas represents the junction between these two zones.

North of Dinas Mawddwy, the Nod Glas may be traced northwards as far as Bwlch y Groes. It is exposed at Aber-Cowarch, where it consists of the usual jet-black shales and mudstones, but it also contains thin, argillaceous limestone bands, from 2 to 3 feet thick and pyritous like the adjacent mudstones. At the base of the band there are in some places black phosphatic nodules up to 1½ or 2 inches in diameter. These limestone bands were quarried at one time, as, for example, in the Pumryd valley and at Rhiw March Waterfalls in the Dyfi valley, and the remains of the old lime-kilns may still be seen.

Between Aber-Cowarch and Bwlch y Groes graptolites have only been collected at one locality, on the north side of the Llaethnant ; but the rocks are so highly cleaved and sheared that the graptolites appear as white smears on the bedding planes. However, it is clear that where limestone bands are developed in the Nod Glas, graptolites are extremely rare in the adjacent black shales. The limestones may be massive, argillaceous and unfossiliferous, but other parts of the same band may be crowded with small brachiopods. From various localities such as Aber-Cowarch, the Pumryd and Dyfi valleys, the following have been collected :—

Sowerbyella cf. *thraivensis* (Reed).
Chonetoidea cf. *papillosa* (Reed).
Skenidium lewisi var. *craigensis* (?) Reed

Phacops (*Acaste*) *apiculata* (Salter).
Lingula cf. *amabilis* Reed.
Orthis (*Dalmanella*) *testudinaria* (Dalman) var.
Trinucleus sp.

Specimens of *Sowerbyella* and *Chonetoidea* are by far the most abundant and, in some parts, the limestones are largely made up of these small shells. The other forms enumerated occur much more rarely, and only a few specimens have been collected.

At Aber-Cowarch, the thickness of the Nod Glas with its limestone-bands is about 35 to 40 feet as compared with 70 feet in the country to the south-west. Northwards from Aber-Cowarch, the thickness diminishes fairly quickly to 15 or 20 feet. The Nod Glas is exposed in a trial-quarry near Bwlch y Groes, but northwards it must disappear, for no outcrops have been discovered and in the Bala country Dr. Elles does not record it between the Gelli-Grin Series and the Rhiwlas Mudstones. The locality where the Nod Glas disappears cannot be determined owing to lack of exposures on the peat- and drift-covered moorland north-east of Bwlch y Groes.

The Nod Glas with its limestones is set down on the Geological Survey Maps[1] as the Bala Limestone, but the physical and faunal characters of this band differ very much from those limestones which have been mapped as the Bala Limestone in the Bala country. In the latter area, several limestone bands occur in the Gelli-Grin Series, but the highest may be at a rather lower horizon than the Nod Glas. Between Towyn and Bwlch y Groes, there is, so far as is known at present, no evidence of a break between the Upper and Lower Bala rocks. The absence of the Nod Glas north-east of Bwlch y Groes might be interpreted as due to an overstep at the base of the succeeding Abercwmeiddaw (Rhiwlas) Mudstones, but it seems more reasonable to assume that the black graptolitic shales die out as one approaches the arenaceous and calcareous facies which is developed in the Bala district.

UPPER BALA.

It will be convenient to consider first the Upper Bala rocks in the northern area where they are fully developed.

Abercwmeiddaw Beds.

The Nod Glas is succeeded by the Abercwmeiddaw Beds, which consist of pale, greyish-blue, thickly-bedded, massive mudstones rather paler than any other Bala rocks in this district. The mudstones are characterised by a coarse mottling, consisting of dark patches, irregular in pattern and sometimes as much as an inch or more in diameter. The rocks usually weather pale, yellowish-brown and give rise to rough, craggy ground.

[1] Old Series, 1-inch Sheets, 60 N.W. and 74 S.W.

Calcareous nodules are often fairly abundant in the lower part of the group and the rocks as a whole become more calcareous from south-west to north-east. From Dinas Mawddwy northwards, there is a conspicuous band about 6 to 10 feet thick and about 6 feet above the base which contains numerous layers of calcareous nodules separated one from the other by 4 to 6 inch bands of mudstone. The nodules decompose to a brown rottenstone and in many cases have been weathered out, leaving lines of holes. This nodular band usually makes a conspicuous feature and large detached blocks may be found on scree-slopes. The lower part of the Abercwmeiddaw Beds also contains occasional dark, phosphatic nodules.

The Abercwmeiddaw Beds are highly cleaved and, in several places, the cleavage is sufficiently well developed for them to have been quarried for slates or more generally for slabs. These slaty bands, which are usually non-mottled or less conspicuously mottled than the rest of the group, are called locally the Broad Vein (Y Faen lydan). There are large quarries in these mudstones at Bryn-Eglwys (near Abergynolwyn), Abercwmeiddaw (Corris), Cambergi (Aberllefenni) and Maes-y-Gamfa (northwest of Aberangell), whilst there are numerous smaller ones. Most of them are no longer worked, but Abercwmeiddaw has been reopened in recent years. Nearly all of them are situated in the lower part of the group, but the slates are not everywhere on the same horizon. The quality of the slate appears to deteriorate as the rocks are traced north-eastwards, and they have not been so extensively worked at Dinas Mawddwy, while still farther north there are no slate quarries in this group.

Between Corris and Dinas Mawddwy the thickness of the Abercwmeiddaw Beds is about 1,200 to 1,500 feet, but southwestwards towards Towyn it appears to be about 900 to 1,000 feet. North of Dinas Mawddwy the thickness is difficult to determine, partly because the beds are faulted against Llandoverian and partly because of the difficulty in defining the upper limit where neither the overlying Red Vein nor the Narrow Vein can be mapped as separate subdivisions. The rocks are well exposed in streams and crags, but very few fossils have been collected *in situ*. The mudstones are tough and highly cleaved, and fossils are not readily distinguishable in freshly broken pieces. It is only when a considerable amount of loose material can be examined that several specimens may be collected and even then they are often rather poorly preserved. Fossils appear to be present only in the lower part of the group; but it should be remembered that most of the quarries are in the lower part. The upper part is well exposed, but it has not yielded any fossils which can be identified.

Between Towyn and Dinas Mawddwy the rocks about 400 to 600 feet above the base have yielded an interesting fauna :—

Cyclopyge rediviva (Barrande).
Cyclopyge armata (Barrande).
Cyclopyge subarmata Reed.
Trinucleus albidus Reed.
Trinucleus bucklandi Barrande.
Asaphus radiatus Salter.
Phacops brongniarti (?) Portlock.
Christiania tenuicincta (McCoy).
Leptelloidea ? cf. var. *albida* (Reed).
Bellerophon perturbatus (?) Sowerby.

The most abundant fossil is *Trinucleus albidus*; *Asaphus radiatus* is fairly common, but the presence of species of *Cyclopyge* is of special interest. The fauna compares in many respects with that of the *Dionide* Band in the Upper Whitehouse Group at Girvan, which is underlain by the shales of the *Dicellograptus-complanatus* zone, but the graptolites of this zone have not been found in Wales. In one locality, a poorly preserved specimen of a *Climacograptus* was collected along with the *Cyclopyge-Trinucleus albidus* fauna. The discovery of recognisable graptolites at this horizon would be particularly valuable.

The Abercwmeiddaw Beds pass laterally into the Rhiwlas Mudstones of the Bala country. The lower part of the Rhiwlas Mudstones, and particularly the Rhiwlas Limestone, has yielded the *Phillipsinella-parabola* fauna, but this fauna dies out in the overlying beds and disappears at the base of the Moelfryn Sandstones. Apparently the *Phillipsinella-parabola* fauna disappears as the beds are traced southwards, because south of Bwlch y Groes fossils are extremely rare and the *Phillipsinella-parabola* fauna has not been recognised. On the other hand, the *Cyclopyge-Trinucleus albidus* fauna has not been found north of Dinas Mawddwy, but the beds which yield it south-west of Dinas Mawddwy belong to a higher stratigraphical horizon than the typical *Phillipsinella-parabola* beds in the Bala district and the Rhiwlas Limestone is probably several hundred feet below the equivalents of the *Cyclopyge* Beds.

Red Vein.

Between Towyn and Dinas Mawddwy the Abercwmeiddaw Beds are succeeded by dark blue mudstones with well-marked rusty-weathering so that the rocks are called locally the Red Vein (Y Faen goch). They are fairly soft and their outcrop is usually marked by a slight hollow in which occur two or three ill-defined ridges caused by harder bands. These harder bands are usually mottled like the Abercwmeiddaw Mudstones beneath them, but are not so easily recognisable at Dinas Mawddwy. When the Red Vein Mudstones are highly cleaved and weathered,

they often resemble the rusty-weathering Lower Llandoverian shales. The thickness is about 350 feet.

Graptolites may be collected in most exposures, but mention may be made of the quarries in Glyn Iago (south-west of Corris), the Aber-Corris Quarries, the Ceiswyn and Ratgoed Quarries (north-west of Aberllefenni). The most abundant fossil is *Orthograptus truncatus* var. *abbreviatus* Elles & Wood, which is often well-preserved in full relief. It is associated with *Climacograptus scalaris* var. *miserabilis* Elles & Wood, and much more rarely *Dicellograptus anceps* Nicholson, but the latter appears to occur more often at a slightly higher horizon than the beds which yield *Orthograptus* in such abundance. This is clearly the zone of *Dicellograptus anceps*.

For some distance north of Dinas Mawddwy, the beds corresponding to the Red Vein are concealed by strike-faulting; but when the Upper Bala rocks appear once more, as, for example, in the Pumryd valley at Llanymawddwy, it is no longer possible to map either the Red Vein or the overlying Narrow Vein as separate divisions. In this part of the district the corresponding rocks are overlain by the *Phacops-mucronatus* Mudstones; but, in some places, the rocks beneath the *Phacops* Beds may be darker, exhibit rusty-weathering tints and are then indistinguishable from the Red Vein as developed farther south. Around Bwlch y Groes the rocks become more arenaceous and farther north the *Phacops-mucronatus* Beds are underlain by the *Moelfryn Sandstones* which were described by Dr. Elles in the Bala district. These sandstones have not yielded any fossils, but they correspond in position to the Red Vein and possibly the highest part of the Abercwmeiddaw Beds.

Narrow Vein.

The Red Vein is followed by a comparatively thin band, usually 50 to 60 feet thick, of dark blue mudstones which weather to brown tints. These mudstones are well cleaved, and they make the most important slate-band in the Corris country. It is called locally the Narrow Vein (Y Faen gul). This band is a valuable datum-line because it can be mapped accurately, its lower limit being sharply defined by its contact with the rusty-weathering Red Vein mudstones, while overlying it are the ill-cleaved mudstones and grits of the Garnedd-wen Beds.

There are numerous quarries in the Narrow Vein between Towyn and Dinas Mawddwy, of which the most important are at Bryn-Eglwys, Corris and Aberllefenni, but there are many other large quarries temporarily or permanently abandoned. South-west of Bryn-Eglwys towards Towyn, the cleavage generally becomes less regular and is often contorted, due probably to proximity to the line of the great Bala—Tal-y-llyn

fracture belt. North-east of Aberllefenni towards Dinas Mawddwy the quality of the slate appears to deteriorate somewhat, due possibly in part to changes in the character of the sediments, while north of Dinas Mawddwy, the Narrow Vein cannot be recognised as a separate band of slate. But there seems little doubt that the physical characters also vary from point to point, and within comparatively short distances. Although such changes cannot be observed in hand-specimens, they have important effects upon the economic value of the slabs and slates quarried.

Fossils are extremely rare, but the late Mr. G. J. Williams, who visited the quarries for many years, recorded *Orthoceras perannulatum* and *Phacops* sp.

Although the Narrow Vein cannot be recognised north of Dinas Mawddwy as a separate band, it will be seen later that it probably corresponds to the lower part of the *Phacops-mucronatus* Mudstones.

Garnedd-wen Beds.

The Garnedd-wen Beds are the uppermost division of the Bala Series in the Corris country and they form a group which can be readily distinguished from all the other sedimentary rocks in the area. They consist of dark blue mudstones which usually weather dull bronze and sometimes rusty brown. They are imperfectly cleaved and appear to possess a rough double cleavage which causes them to split into lenticular or phacoidal pieces with rather sharp edges and polished surfaces. But these mudstones vary quickly in lithology both vertically and laterally. They usually contain a good deal of gritty material and in many places thin bands of grit, whilst in others there are massive grits 100 feet or more in thickness. These grit-bands are impersistent and usually pass rapidly into gritty mudstones indistinguishable from the group as a whole, but sometimes they pass into massive conglomerates in a distance of a few feet. These conglomerates are generally only a few feet thick and consist of well-rounded pebbles in a mudstone or gritty mudstone matrix. The pebbles may be as much as 5 or 6 inches in diameter and are composed mainly of vein-quartz with occasional gritty and quartzitic pebbles. In some places between Towyn and Corris, the Garnedd-wen Mudstones contain large boulder-shaped masses of grit and gritty mudstone, giving the rock a peculiar gnarled or "pillow" structure. This type is more extensively developed south of the Dyfi and will be referred to later. The Garnedd-wen Beds give rise to rough, craggy ground, and, where there are extensive developments of grits, to bold rugged country with boulder-strewn slopes.

North-east of Aberllefenni the amount of arenaceous material diminishes very quickly and the grit bands are never

more than a foot or so thick, occurring as thin, gnarled bands in the mudstones. In this part of the district as far north-east as Dinas Mawddwy, the Narrow Vein is overlain by a characteristic rock called locally the "ribbony rock." It is a dark blue mudstone traversed by numerous thin, irregular siliceous seams, which have a contorted or "curled" bedding and this internal structure is revealed by well-marked concentric weathering tints. It is well displayed at the Ratgoed, Hendre-ddu and Cae-abatty Quarries.

One of the most striking features of the Garnedd-wen Beds as they are traced from Towyn to Dinas Mawddwy is their rapid diminution in thickness, from over 3,000 feet at Towyn to 1,800 feet at Corris, 1,400 feet south-west of Aberllefenni, 500 feet north-east of Aberllefenni and 350 feet at Minllyn. They thus diminish in thickness from over 3,000 feet to 500 feet in about 10 miles along the strike and then the thinning is less rapid, being from 500 to 350 feet in about 7 to 8 miles. The diminution in thickness is accompanied by the gradual disappearance of arenaceous material.

At the Minllyn Slate Quarries, near Dinas Mawddwy, there are important changes in the characters of these beds. The Narrow Vein is succeeded by some 60 feet of dark blue, massive mudstones, weathering snuff-brown, which yield occasional specimens of *Phacops mucronatus* Brongniart. This is the only locality between Towyn and Dinas Mawddwy where fossils have been discovered in the Garnedd-wen Beds and in the country farther south the corresponding rocks are a notoriously barren group. It is of interest, therefore, that *P. mucronatus* first appears near the base of this group above the Narrow Vein and the Red Vein, the latter yielding the fauna of the *Dicellograptus-anceps* zone.

These mudstones are succeeded by rocks which are quite distinct in lithology from the Garnedd-wen Beds to the south-west and consist of fine-grained, dark blue shales, weathering to pronounced rusty colours. These shales might well be confused with the Lower Llandoverian Shales which succeed them, but, unlike the latter, they are never striped with thin, grey, siliceous seams and are apparently devoid of fossils. Moreover, they underlie the *Glyptograptus-persculptus* Mudstones which define the base of the Llandoverian Series. They are rather more than 200 feet thick at Minllyn and may be called the

UPPER GARNEDD-WEN BEDS.

For about 2 miles north of Dinas Mawddwy, the higher Bala rocks are concealed by strike-faulting, but when they reappear in the Pumryd Valley at Llanymawddwy the Upper Garnedd-wen Beds may be recognised and they are underlain by massive, grey-blue mudstones, weathering to pale brown

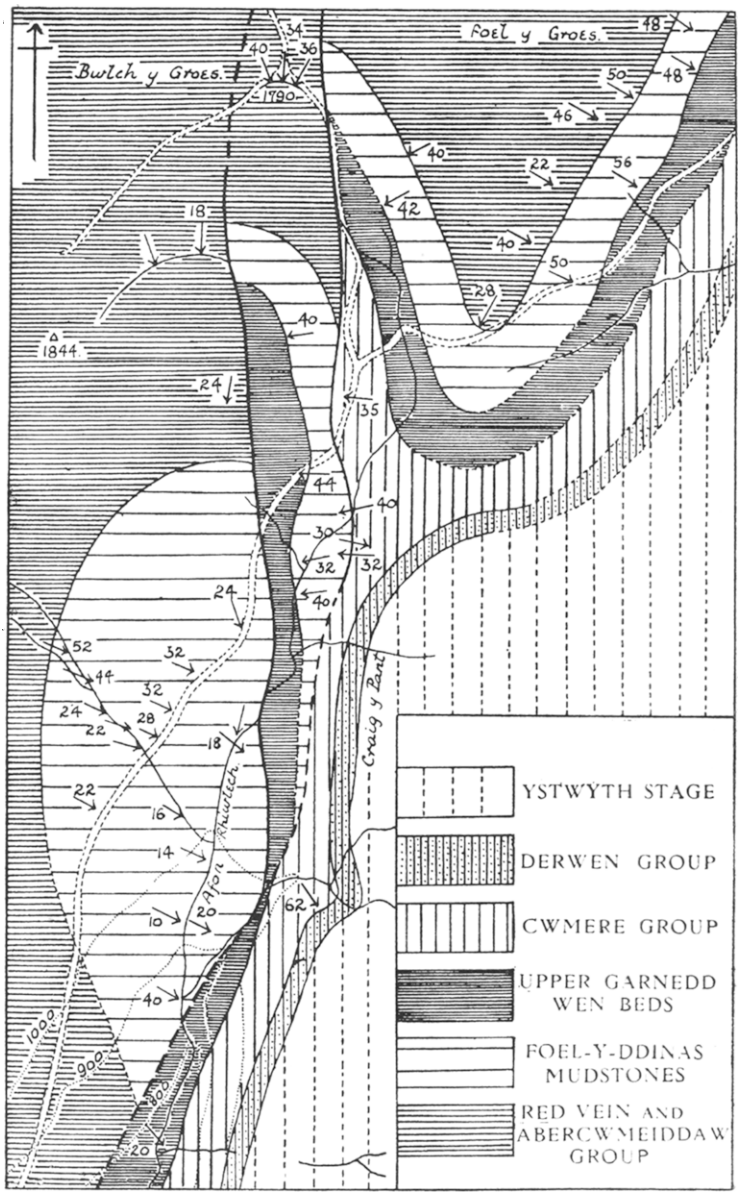

FIG. 33.—MAP OF THE AREA AROUND BWLCH Y GROES.
On the Scale of 6 inches to the mile, or 1 : 10,560.

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tints. These mudstones can be traced northwards as a distinct group into the Bala country, where they are the FOEL-Y-DDINAS or *Phacops-mucronatus* Beds of that district. They maintain their lithological characters with very little variation, although thick beds of sandy mudstone may be developed within them. They usually make a line of crags and a well-marked topographical feature is produced at the contact with the softer Upper Garnedd-wen Beds. There can be little doubt that these beds are the equivalents of the lower parts of the Garnedd-wen Beds and the Narrow Vein at Dinas Mawddwy. They have yielded *Phacops mucronatus* Brongniart at various places and occasional specimens of *Dalmanella* and *Orthoceras*.

The Upper Garnedd-wen Beds show the same lithological characters as at Minllyn. They contain occasional thin bands of gnarled grit and north-east of Bwlch y Groes, a narrow strike ridge about 300 yards long consists of pale, grey-blue mudstones with gritty and siliceous bands from which a single specimen of *Orthis* (*Dalmanella*) *elegantula* (Dalman) var. was collected. The group is again exposed in Nant Eiddew-fawr, where it still consists of rusty weathering shales, but a thin sandy mudstone at the base yielded :—

Strophomena (*Rafinesquina*) *hirnantensis* (McCoy).
Orthis (*Platystrophia*) *biforata* (Schlotheim).
Orthis sagittifera Davidson.
Orthis (*Dalmanella*) *elegantula* (Dalman) var.
Monticulipora fibrosa (McCoy).

The Upper Garnedd-wen Beds are not again satisfactorily exposed for about 2 miles, but at the head of the Hirnant valley they consist of grey-blue sandy and somewhat calcareous mudstones with pale brown weathering tints. These mudstones include numerous calcareous nodules, some as much as three feet in diameter, with irregular layers of pisolitic material about an inch thick. The pisolitic bands are similar to the pisolitic Hirnant Limestone in the type locality farther north in Cwm Hirnant, but there the concretionary masses are wholly pisolitic. The beds yield the *Strophomena-hirnantensis* fauna and in Nant Eiddew-fawr, at the head of Cwm Hirnant and elsewhere are succeeded by shales containing graptolites belonging to the basal beds of the Llandoverian Series. It is clear that the Upper Garnedd-wen Beds pass laterally into the Hirnant Beds with the Hirnant Limestone. These beds overlie the *Phacops-mucronatus* Mudstones, and are themselves overlain by the Llandoverian rocks. They are therefore the highest subdivision of the Bala Series.

South of the Dyfi.

South of the Dyfi valley, Upper Bala rocks cover considerable areas in North Cardiganshire. They occur on certain anti-

clinal axes, as for example, between the rivers Ceulan and Llyfnant in the north-western part of the county, around Plynlimon, and there are smaller tracts between Plynlimon and Llanidloes in the neighbourhood of and to the west of the Van Mines. In all these areas, except Plynlimon, the rocks correspond to the Garnedd-wen Beds farther north.

At Plynlimon, the lowest beds which are exposed have been called the *Nant-y-Moch Flags*, but the base is not seen. The oldest rocks consist of blue, greenish-weathering flags with some thin siliceous seams, and they are succeeded by nearly 300 feet of blue mudstones and dark shales, with greyish-white, siliceous seams an inch or two thick. The shales contain abundant pyrite in cubes and dodecahedra scattered or aggregated along certain bedding planes in bands of an eighth or a quarter of an inch thick. The shales which contain poorly preserved specimens of *Orthograptus truncatus* (*sensu lato*) are succeeded by about 2,000 feet of tough, blue flaggy mudstones with thin seams of rusty-weathering shales. Poor specimens of graptolites occur in the lower part of this division, but about 900 feet above the base, fossils are more abundant, namely :—

Dicellograptus anceps Nicholson.
Orthograptus truncatus (Lapworth).
Orthograptus cf. *mutabilis* Elles and Wood.
Climacograptus scalaris var. *miserabilis* Elles and Wood.

One small specimen of *Remopleurides* and an undetermined gastropod were also found.

The Nant-y-Moch Group has a total thickness of 2,350 feet and is represented in the Corris country by the Red Vein, which contains the same graptolite fauna. There does not appear to be any representative of the grey, mottled Abercwmeiddaw Mudstones at Plynlimon, but had dissection proceeded further, there is little doubt that they would appear, because when older Bala rocks are seen once more farther south, as, for example, on the coast about Cardigan or along the Towy anticlinal axis, the typical, pale grey, coarsely mottled beds may be recognised. The Red Vein is only 350 feet thick, and even if we include with it the Narrow Vein, some 50 to 60 feet thick, there is a very marked diminution in the thickness of these rocks between Plynlimon and the country to the north.

The Nant-y-Moch Group is overlain by the DROSGOL GROUP, the blue flags of the former passing gradually into dark blue mudstones with bands of tough, grey grit, and these are followed by a considerable thickness of coarse-grained deposits consisting of alternations of dark blue mudstones, grey conglomeratic grits and gritty or pebbly mudstone. The gritty beds show a curious gnarled and knotted surface on weathering which is connected with their internal structure, for a fresh fracture shows numerous laminæ twisted and contorted in a remarkable

manner. This structure is common elsewhere in the Aberystwyth district. It may be that these beds represent material which slipped down submarine slopes during deposition and that this accounts for the curiously twisted and contorted internal structure. Some of the mudstones contain well rounded pebbles of vein quartz, giving them a conglomeratic character. In some cases the pebbles are aggregated into definite but impersistent bands, but more usually they are thinly scattered in a haphazard fashion through the softer, relatively fine-grained mudstone. Many of the pebbles are an inch or more in diameter, and the conditions under which these pebbly mudstones were laid down are difficult to understand. Both the grits and mudstones contain numerous scattered cubes of pyrite.

The gritty Drosgol Beds pass upwards into the BRYNGLAS GROUP, which consists of massive blue-black mudstones in which bedding planes are difficult to determine. These mudstones show a rough double cleavage, causing the rock to split into lenticular pieces as has been described above in the Corris country.

The Drosgol and Brynglas Groups are approximately 900 and 1,150 feet thick respectively, that is, a total thickness of 2,050 feet. At Bryn-Eglwys in the Towyn-Abergynolwyn district the corresponding Garnedd-wen Beds are over 3,000 feet thick, Bryn-Eglwys being from 12 to 14 miles north-west of the Plynlimon country. West of Corris the rocks are of much the same thickness, but at Dinas Mawddwy, about 16 miles north of Plynlimon, the Garnedd-wen Beds are only 350 feet thick. The Drosgol and Brynglas Groups have not yielded any fossils, but in the Bala country they are represented by the *Phacops-mucronatus* and *Strophomena-hirnantensis* Mudstones.

Elsewhere in the Aberystwyth district only the highest Bala rocks crop out, and at Machynlleth, for example, they consist as a whole of dark blue, micaceous mudstones, often sandy or gritty and merging into massive grits and gritty mudstones. The thinner bands of grit from 1 to 4 inches thick are often sharply corrugated, while the characteristic gnarled, gritty mudstones are of common occurrence. These rocks are precisely similar to the Garnedd-wen Beds, but no thickness comparisons can be made because the base of the group is not exposed. No fossils have been discovered in the Bala rocks south of the Dyfi except the graptolites in the Nant-y-Moch Group at Plynlimon.

The Bala rocks thus exhibit considerable lateral variations. In general, they become more arenaceous and more calcareous as they are traced into the Bala country, and along the flanks

of Cader Idris and the Arans the transition from a predominantly graptolitic facies in the south-west to a shelly facies at Bala can be followed in considerable detail. One of the striking features is the rapidity with which these changes take place, especially in the neighbourhood of Bwlch y Groes.

The Lower Bala rocks of South Wales consist of fine-grained, black graptolitic shales about 500 to 850 feet thick—the Upper *Dicranograptus* Shales. The Lower Bala rocks also cover considerable areas at, and south of, Cardigan and are known at various places along the line of the Towy Anticline. In this region they are represented by a greater thickness of black and grey graptolitic shales alternating with tough, massive grit bands. This facies of the Lower Bala has been described at Abbey Cwmhir in north-west Radnorshire by Mr. R. O. Roberts,[1] but the Lower Bala rocks are not fully exposed in that area. In the Corris country there is an even greater change, the facies is still a graptolitic one, but there is an expansion in thickness to about 4,000 feet and the greater part of the succession consists of unfossiliferous grey-blue mudstones. At Conway in North Wales a graptolitic black-shale facies occurs again, but there the total thickness does not greatly exceed 300 feet. At Bala, the upper part of the Lower Bala belongs to an exclusively shelly facies, but the lower part, although poorly fossiliferous, has yielded only graptolites.

In South Wales, the Upper Bala rocks are represented by the Slade and Redhill Beds with the impersistent Shoalshook Limestone at the base. Farther north in South Cardiganshire and along the western flank of the Towy Anticline the Upper Bala rocks are on the whole similar to those between Towyn and Corris. They are not very well known, but they have been described at Abbey Cwmhir by Mr. R. O. Roberts[2] and farther south at Abergwesyn by Dr. K. A. Davies.[3] In the latter area they appear to be about 7,000 feet thick. These rocks thus diminish in thickness northwards. At Towyn the equivalent beds are about 4,500 feet thick, at Dinas Mawddwy about 2,000 feet, whilst at Conway, with which area they may be closely compared, they are only 500 feet thick.

SILURIAN.

For many years, there have been two classifications of the Silurian rocks based respectively upon the shelly and graptolitic facies. The term Llandovery was applied to those lower Silurian rocks which contain shelly fossils and was formerly

[1] *Quart. Journ. Geol. Soc.*, vol. lxxxv., pp. 656-58.
[2] *Quart. Journ. Geol. Soc.*, vol. lxxxv. (1929), pp. 651-76.
[3] *Quart. Journ. Geol. Soc.*, vol. lxxxii. (1926), p. 439.

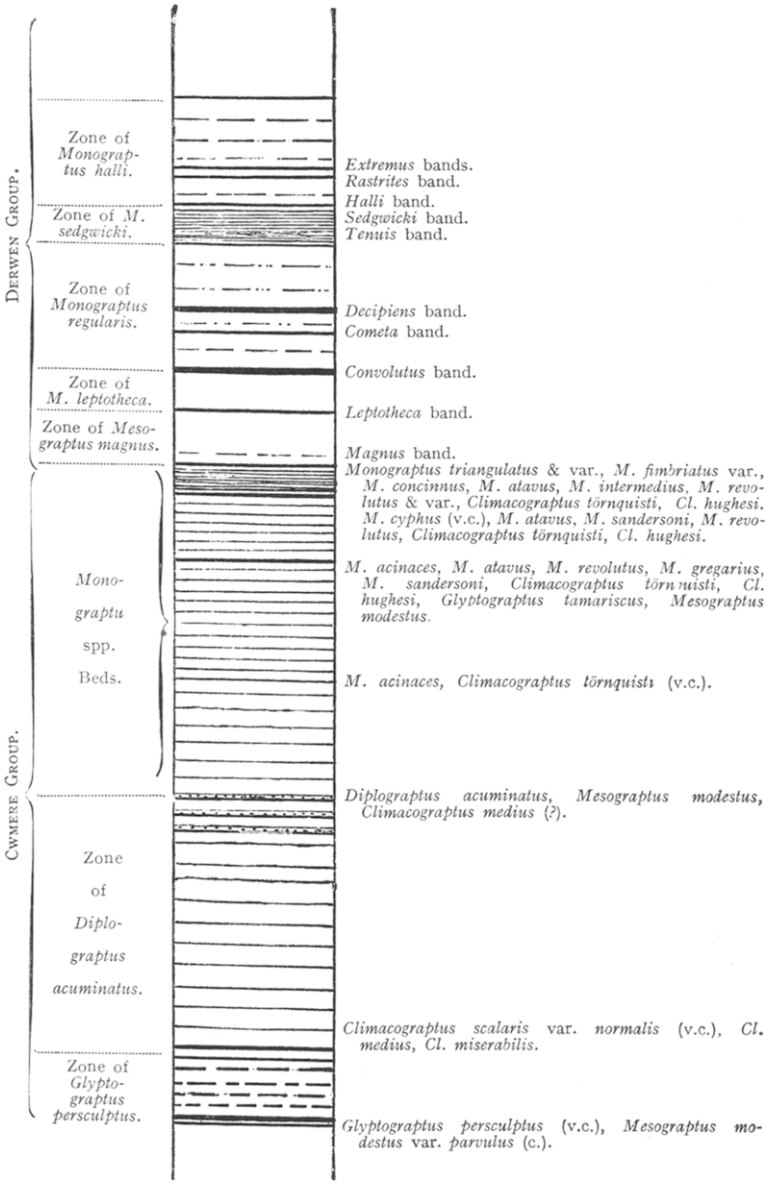

FIG. 34.—VERTICAL SECTION THROUGH THE PONT-ERWYD STAGE SOUTH OF MACHYNLLETH.

On the scale of 100 feet to the inch.

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divided into two stages, Lower and Upper; but a re-examination of these rocks in the classic area round Llandovery[1] has shown that they may be divided into three clearly marked stages separated from one another by unconformities. The term Valentian was applied by Charles Lapworth to the corresponding rocks in the graptolitic facies which he divided into two parts, Birkhill and Gala. The latter sub-division is often referred to as the Tarannon because the rocks are well displayed at Tarannon in Central Wales. The discovery of occasional graptolites in the shelly facies has facilitated correlation between these two developments and it now appears that the Lower Llandoverian is equal approximately to the Lower Birkhill, but also includes the lower part of the Middle Birkhill; the Middle Llandoverian to the Middle Birkhill, while the Upper Llandoverian is represented by the Upper Birkhill and Gala. The Silurian rocks of the Aberystwyth district belong to the Llandoverian or Valentian Series, and they may be subdivided as follows :—

	Zone.		
Upper Llandoverian	*Monograptus*	*crenulatus*	Gala or Tarannon.
	,,	*griestoniensis*	
	,,	*crispus*	
	,,	*turriculatus*	
	,,	*halli*	Upper Birkhill.
	,,	*sedgwicki*	
Middle Llandoverian	,,	*regularis*	Middle Birkhill.
	,,	*leptotheca*	
	Mesograptus	*magnus*	
Lower Llandoverian	*Monograptus*	*triangulatus*	Lower Birkhill.
	,,	*cyphus*	
	,,	*acinaces*	
	,,	*atavus*	
	Akidograptus	*acuminatus*	
	Glyptograptus	*persculptus*	

There is still some uncertainty where the base of the Middle Llandoverian should be drawn on the graptolitic facies. The *Monograptus leptotheca* zone should certainly be included and probably the *Mesograptus magnus* zone. It is noteworthy that there is a marked change in lithology in the Aberystwyth district at the base of the *M. magnus* zone which may possibly correspond to the break between the Lower and Middle Llandoverian at Llandovery, whilst west of Llandovery, where the graptolitic facies is developed, there may be an unconformity at the base of the *M. magnus* zone.[2]

Lower Llandoverian.

Zone of *Glyptograptus persculptus*.

The base of the Lower Llandoverian is clearly defined by

[1] O. T. Jones. *Quart. Journ. Geol. Soc.*, vol. lxxxi. (1925), pp. 344-8.

[2] K. A. Davies, *Quart. Journ. Geol. Soc.*, vol. lxxxix. (1933), pp. 191-92.

a comparatively thin band of blue, compact mudstones, which constitute the zone of *Glyptograptus persculptus*. Within these even-grained mudstones, there are paler bands 2, 3 and sometimes 4 inches thick which are flecked with small, irregular dark blotches. These paler, mottled bands occur at intervals of a few inches up to 1 or 2 feet and the mottling is quite distinct from that which has been previously described in the Bala rocks, namely, in the Abercwmeiddaw Beds and the Red Vein. In the latter rocks, the blotches are much larger and they are not confined to paler bands within the mudstones. The *G. persculptus* mudstones weather, sometimes rather deeply, to a pale, snuff-brown rock, but in other cases greenish or brown metallic tints are more characteristic, especially on cleavage surfaces.

The upper and lower limits of the zone are well-defined, the lower over most of the area by its contact with the ill-cleaved, massive, gritty Upper Bala mudstones and the upper by its contact with the rusty weathering shales of the *Akidograptus acuminatus* and succeeding Lower Llandoverian zones. It is these contrasts coupled with the constant and distinctive lithological characters of the mudstones which make the band such a valuable guide in unravelling the detailed geological structure of the area. The mudstones are more resistant to weathering than the overlying rocks and their outcrop is marked by a characteristic feature separating the smooth ground occupied by the succeeding softer shales from the equally distinctive craggy ground made by the underlying rocks (see Fig. 35).

The junction plane between the Bala rocks and the *G. persculptus* mudstones is always sharply defined, and there is an abrupt change in lithological characters at this level. In many places it is possible to strip off the overlying beds along the junction and the top of the Bala then appears as a smooth, slightly undulating plane; but there is no evidence that this sharp demarcation is caused by movement along the plane. The abrupt change in lithology at this level indicates a change in the physical conditions of sedimentation. There is thus no evidence of a passage between the Bala and Llandoverian rocks. In contrast with the constancy of character which distinguishes the *G. persculptus* beds, the strata upon which they rest exhibit considerable variation; but so far as is known at present, the mudstones do not overstep on to different horizons of the older beds. In the northern part of the area where various subdivisions may be mapped within the Upper Bala rocks, the variation in the characters of the beds underlying the *G. persculptus* mudstones is due to lateral changes in the lithology of those rocks. It would appear therefore that the Llandoverian rocks rest conformably upon the Bala rocks.

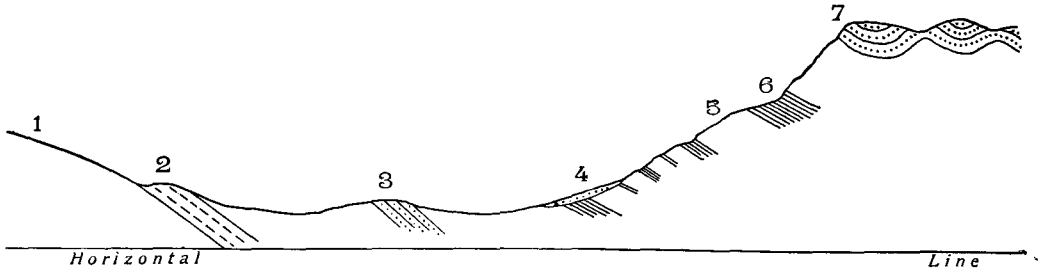

FIG. 35.—DIAGRAMMATIC SECTION ILLUSTRATING THE CHARACTERISTIC FEATURES OF THE OUTCROP OF THE PONT-ERWYD STAGE.

1 = Ty'n-y-maen Group.
2 = Mottled Group.
3 = Group of thin grits near the top of the *acuminatus* Zone.
4 = *Triangulatus* and *magnus* Zones, often scree-covered ; 5 = *Leptotheca* and *regularis* Zones ; 6 = *Sedgwicki* Zone ; 7 = Lowest beds of the Ystwyth Stage.

Like the other Lower Llandoverian rocks, the thickness of the *G. persculptus* mudstones diminishes as they are traced from south to north. At Pont-Erwyd, they are about 50 to 60 feet, whilst at Machynlleth the thickness is about 35 feet. The rocks are usually about 30 to 35 feet thick between Towyn and Dinas Mawddwy, although in some places near Corris they appear to be about 20 feet thick. North of Dinas Mawddwy the mudstones are much thinner and south of Bwlch y Groes are about 5 feet, while at Bwlch y Groes and northwards to Cwm Hirnant, the typical *G. persculptus* mudstones have not been recognised at the base of the Llandoverian and are replaced by dark blue, striped shales, which, however, yield the fauna of the *G. persculptus* zone.

About 2 or 3 feet above the base of these mudstones there is a thin band about an inch or so in thickness which consists of dark, rusty weathering shale crowded with *Glyptograptus persculptus* Salter and *Mesograptus modestus* var. *parvulus* (H. Lapworth), together with *Climacograptus scalaris* var. *miserabilis* Elles & Wood, and *Cl. scalaris* var. *normalis* Lapworth. Many of the specimens of *Glyptograptus persculptus* are preserved in relief in pyrite. This thin band is usually highly weathered and the graptolites may be so decomposed that specific determination is difficult. It invariably contains a good deal of pyrite. Where the *G. persculptus* mudstones become thinner around Llanymawddwy this thin graptolitic band has not been discovered, but the physical characters of the mudstones and their weathering tints are thoroughly characteristic.

Several quarries have been opened in the *G. persculptus* mudstones and they have been frequently used in North Cardiganshire in farm buildings and stone walls. They have also been tried for slabs, but pyrite in the paler bands militates against their use as slates or slabs because of the difficulty experienced in sawing them.

Zone of *Akidograptus acuminatus*.

The rocks which overlie the *G. persculptus* beds usually crop out along a smooth hollow dominated on one side by the scarp, consisting of the harder Middle and Upper Llandoverian rocks, and on the other side by the dip-slopes of the Upper Bala rocks. About the middle of this outcrop, there is often a fairly distinct ridge which may persist for considerable distances and caused by a group of thin, pale, siliceous beds intercalated among dark, rusty-weathering shales. This may be taken as the boundary between the zone of *Akidograptus acuminatus* and the overlying beds (see Fig. 35).

The rocks of the *A. acuminatus* zone consist of flags, mudstones and shales which weather deeply, rusty-red and yellow being the prevailing colours. There are also numerous greyish-

white, siliceous seams, an eighth to a quarter of an inch thick and occasionally a few bands of fine-grained grey grit from 4 to 6 inches thick. Calcareous nodules occur particularly in the lower part of the zone. All the rocks are highly cleaved, so that the soft shales break up into small thin pieces, while the flags divide into rhomboidal prisms. The zone is more shaly in the northern parts of the district and flags are rather less conspicuous. The change in lithology from the *Glyptograptus persculptus* zone to the *Akidograptus acuminatus* zone is very conspicuous and takes place within a thickness of 2 or 3 feet or even less.

Akidograptus acuminatus (Nicholson) is abundant towards the base of the zone and is associated with *Mesograptus modestus* (Lapworth), *Climacograptus medius* Törnquist, *Cl. scalaris* var. *normalis* Lapworth, *Cl. scalaris* var. *miserabilis* Elles & Wood. Most of these graptolites may be found rather more rarely throughout the zone, but in many places fossils are difficult to extract owing to the strong cleavage.

At Pont Erwyd, the zone is about 180 feet thick, at Machynlleth about 130 feet, while north of Machynlleth, the thickness is probably rather less, but there the zone has not been separated from the Lower Llandoverian rocks as a whole.

Zones of *Monograptus atavus, M. acinaces, M. cyphus and M. triangulatus.*

The *Akidograptus acuminatus* zone is succeeded by soft, dark blue, rusty-weathering shales and flags which are striped with numerous pale grey, siliceous seams. The weathering is highly characteristic, externally a deep rusty colour, but in addition the shales may be bleached to a dull greyish-white. The rocks are very pyritous and the surfaces may be pitted owing to the removal of globules of pyrite. There are also occasional layers of calcareous nodules. The rocks are highly cleaved and this, coupled with the readiness with which the shales weather, renders difficult the collection of fossils in many sections. The zones have been worked out in detail at Pont Erwyd, but elsewhere, as, for example, at Machynlleth and to the north where the rocks are thinner, it is often impossible to determine the detailed faunal succession, although the evidence of many different localities shows that the same zones are present and that they succeed one another in the same order.

At Pont-Erwyd, these rocks are splendidly exposed in the Rheidol section. In addition graptolites occur in abundance and are exceptionally well preserved usually in full relief. Although the strata are in several places highly folded and broken, the order of superposition is quite clear. The *Akidograptus-acuminatus* beds are succeeded by more shaly strata in which species of *Monograptus* occur for the first time,

namely, *M. atavus* Jones. The *M. atavus* zone, which is about 150 feet thick, contains in addition to the zone-fossil, *Dimorphograptus erectus* Elles & Wood, *D.* cf. *extenuatus* Elles & Wood, *Orthograptus vesiculosus* (Nicholson), *Climacograptus medius* Törnquist, *Cl. rectangularis* (McCoy), *Cl. scalaris* var. *normalis* Lapworth, and *Cl. törnquisti* Elles & Wood. A line of small calcareous nodules appears to mark the top of the zone, because the succeeding beds, which are rather harder, more sandy, and less shaly, contain a different fauna in which the characteristic fossil is *Monograptus acinaces* Törnquist. The *M. acinaces* zone is 160 feet thick, and in it *M. acinaces* and *M. atavus* occur in considerable abundance together with *M. attenuatus* (Hopkinson) and *M. sandersoni* Lapworth, while *M. incommodus* Törnquist occurs occasionally, especially at the top of the zone. *Climacograptus törnquisti* is even more abundant than the zone fossil, while *Cl. scalaris* var. *normalis* and *Orthograptus mutabilis* Elles & Wood may be found quite commonly. Other fossils found in the *Monograptus acinaces* zone are *Climacograptus rectangularis* (McCoy), *Cl. hughesi* (Nicholson), *Glyptograptus tamariscus* (Nicholson) and *Dimorphograptus confertus* cf. var. *swanstoni* Lapworth.

The top of the *Monograptus acinaces* zone has been taken at a line of calcareous nodules. The succeeding *M. cyphus* zone is about 40 feet thick and the top of this zone is also marked by another layer of calcareous nodules. A characteristic feature of this zone is the presence of sandy flags of a paler colour varying in thickness from mere stripes to about 3 inches in the dark blue shales. The thicker flags occur at fairly regular intervals and the spaces between them are occupied by several of the thinner flags, forming a " pattern " which is well displayed about the middle of the zone and is conspicuous on water-worn surfaces. This zone is remarkably rich in graptolites, and there are several graptolitic horizons, but one about 15 feet above the base and another about 6 feet below the top of the zone may be especially mentioned. *M. cyphus* Lapworth and *M. atavus* are very abundant. *M. gregarius* Lapworth, *M. revolutus* Kurck and *M. revolutus* var. *austerus* Törnquist are common, while *M. attenuatus* (Hopkinson) and *M. sandersoni* Lapworth may also be collected. *Climacograptus törnquisti* and *Orthograptus mutabilis* are still abundant. *Glyptograptus tamariscus* Elles & Wood and *Climacograptus hughesi* also occur frequently together with *Cl. scalaris* var. *normalis* and *Glyptograptus sinuatus* (Nicholson).

The calcareous-nodule band at the top of the *Monograptus cyphus* zone is succeeded by about 6 feet of blue, thickly-bedded mudstones and these by 20 feet of dark blue, rusty-weathering shales with flags of a paler colour. These shales contain abundant graptolites, namely, *M. atavus* (c), *M. attenuatus*, *M.*

communis Lapworth, *M. concinnus* Lapworth (c), *M. fimbriatus* (Nicholson), *M. gregarius, M. revolutus* (c) and var. *austerus, M. sandersoni, M. triangulatus* (Harkness) and var. (c), *Orthograptus* cf. *bellulus* (Törnquist), *Glyptograptus tamariscus, Petalograptus palmeus* (Barrande), *Climacograptus hughesi, Cl. törnquisti* (v.c). The most characteristic form is a variety of *Monograptus triangulatus*, which has shorter and blunter thecæ than is considered typical.

These graptolitic shales are followed by about 3 feet 6 inches of blue mudstones and then another group of graptolitic shales about 4 feet 6 inches thick succeeds with *Rastrites approximatus* Perner, *R. longispinus* Perner, *Monograptus atavus, M. communis* (c), *M. concinnus, M. fimbriatus, M.* cf. *fimbriatus, M. gregarius, M. revolutus* (?), *M. triangulatus* (c) and var., *Orthograptus bellulus, O. insectiformis* (Nicholson), *Glyptograptus sinuatus, Gl. tamariscus, Climacograptus hughesi* and *Cl. törnquisti* (v.c). The genus *Rastrites* makes its first appearance in the ascending sequence. *Monograptus revolutus*, so abundant in lower horizons, has almost if not quite disappeared, while now the typical form of *M. triangulatus* is abundant. These fossiliferous shales are succeeded by some 3 feet of blue flags and mudstones. These 40 feet of shales and mudstones constitute the *M. triangulatus* zone. The graptolites are usually well preserved in full relief.

The thickness of these *Monograpti* Beds in the Rheidol Section is rather less than 300 feet, so that the total thickness of the Lower Llandoverian in the Pont Erwyd country is about 550 feet. At Machynlleth the Lower Llandoverian is about 300 to 350 feet thick, while at Bwlch y Groes the thickness appears to be from 250 to 300 feet. The rocks at Pont Erwyd are thus about twice as thick as their equivalents in the northern part of the district. The faunal succession appears to be the same in all areas and the lithological characters are likewise similar, but the thinner developments are on the whole rather more shaly and include a smaller proportion of flagstone and mudstone.

Middle Llandoverian.

The Middle Llandoverian rocks may be readily distinguished from the underlying rocks by their lithological and faunal characters. The soft, rusty-weathering Lower Llandoverian shales are succeeded by pale grey mudstones with intercalated dark blue, graptolitic, shale bands, but grey mudstones make up the greater part of the group. The change in lithology is particularly valuable in mapping and the base of the Middle Llandoverian may be traced without difficulty throughout the Aberystwyth district. The boundary between the Lower and Middle Llandoverian almost invariably coincides with a well-marked topographical feature, the softer underlying shales

occupying a hollow, while the harder mudstones of the Middle Llandoverian form a scarp overlooking the lower ground. The rocks as a rule are fairly well exposed, but the softer graptolitic bands, which form hollows, are often overgrown with vegetation or covered with the debris from the overlying beds. The position of the different graptolite bands may be inferred from the hollows on the scarp-face (see Fig. 35).

Zone of *Mesograptus magnus*.

The *Monograptus triangulatus* zone is followed by a thin band of black shales and mudstones crowded with well-preserved specimens of *Mesograptus magnus* H. Lapworth. This graptolite has not been found at lower horizons and these rusty-weathering shales, which yield it, may therefore be called the *M. magnus* Band. In the Pont Erwyd country this band appears to be about 6 inches thick, but elsewhere it is usually about an inch. In addition to *M. magnus*, the band also yields *Monograptus fimbriatus* (v.c), *M. concinnus*, *Climacograptus törnquisti* (v.c), *Rastrites approximatus* and *R. longispinus*.

The *magnus* Band is succeeded by greenish blue, thickly-bedded, flaggy mudstones which become progressively paler upwards. The darker beds near the base may be shaly and yield graptolites such as *Monograptus fimbriatus* var. and *M. concinnus*, but the main part of the mudstones are pale, ill-bedded rocks with a sheared appearance due to the development of a phacoidal cleavage. Metallic weathering is a marked feature in contrast with the rusty-weathering of the graptolitic shale bands. These pale mudstones have not yielded any fossils except in the extreme northern part of the area at Bwlch y Groes. The total thickness of the zone at Derwenlas, near Machynlleth, is 26 feet 9 inches, and the thickness appears to be much the same farther south in the Pont Erwyd country; but in the Craig y Pant section at Bwlch y Groes, the zone is only 12 feet 6 inches.

The *magnus* mudstones at Bwlch y Groes present the same lithological characters as elsewhere, but they are calcareous and include well-defined layers of calcareous nodules. These nodules, which are usually 2 or 3 inches in diameter, weather to a brown rotten-stone and the weathered layers make conspicuous bands in the cliff-face of Craig y Pant. There are four main bands of nodules, but thinner calcareous bands also occur, especially towards the top. The mudstones have yielded a few poorly-preserved brachiopods, the majority of which appear to be a small, immature form of *Leptelloidea scissa* (Salter). Some of the others appear to be a species of a small *Meristina*, but the mudstones are so tough that it is difficult to extract complete specimens from these sparingly fossiliferous rocks.

Zone of *Monograptus leptotheca.*

The pale mudstones of the underlying zone are followed by a dark blue, rusty-weathering shale band which may be designated the *Monograptus leptotheca* Band, since the graptolites belong to the *M. leptotheca* zone. In the Rheidol section at Pont Erwyd this band is about 2 feet 6 inches thick, but in the northern part of the district it is never more than 14 inches thick. It is one of the most interesting bands because of the variety of graptolites which it contains and the extraordinary persistence of its characters throughout Central Wales and elsewhere. The graptolites include *Monograptus argutus* Lapworth (c), *M. communis, M. concinnus, M. gregarius, M. leptotheca* Lapworth (c), *M. millepeda* (McCoy), *M. triangulatus* and var. *major, Climacograptus hughesi* (v.c), *Glyptograptus tamariscus* and *Mesograptus magnus* and they are usually well-preserved. About the middle of the band there is a thin green flag, which makes a conspicuous layer about three-quarters or an inch thick in these dark shales. This is the well-known " green streak " which has been recorded from, and maintains a constant position in the *Monograptus leptotheca* Band in, so many localities in Wales and England. This " green streak " maintains its thickness and its relative position in the band throughout the Aberystwyth district, being, for example, about 5 inches below the top of the band when the latter is 14 inches thick. There is usually a thicker green flag overlying the *M. leptotheca* Band, and others occur in the succeeding *M. convolutus* zone.

This graptolitic band is usually succeeded by about 20 feet of pale blue, unbedded mudstones with metallic-weathering similar to but usually rather paler than the *Mesograptus magnus* mudstones. These mudstones are devoid of fossils over practically the whole district, but in the Craig y Pant section at Bwlch y Groes, they are much thinner (about 6 feet), highly calcareous and have yielded a few shelly fossils. In this section, the mudstones include numerous layers of calcareous nodules. The nodule layers are most abundant in the upper part where the group consists mainly of nodule bands with thin, intervening layers of mudstone. The nodules are often completely weathered and replaced by a dark brown earth. The mudstones contain *Phacops elegans* Bœck & Sars, together with fragments of small brachiopods which are not identifiable, but appear to be the same as those recorded from the *Mesograptus magnus* mudstones. In this section and in many others farther south, there is a prominent green flag at the top of the mudstones. The total thickness of the *Monograptus leptotheca* band and mudstones is about 20 feet over most of the district, but at Bwlch y Groes the thickness of the zone is only 7 feet 2 inches.

Zone of *Monograptus regularis*.

This zone consists of alternations of rusty-weathering shale bands with blue mudstones and flagstones. The shale bands yield graptolites, but the mudstones which form the greater part of the zone are unfossiliferous. These rocks are well exposed in various places, and there is an admirable section through them at Derwenlas near Machynlleth.

At Derwenlas, the *M. leptotheca* mudstones are succeeded by dark blue, graptolitic shales 3 feet 7 inches thick, which include bands of grey-green flags some 2 or 3 inches thick. These shales yield *M. convolutus* (Hisinger), *M. decipiens* Törnquist, *M. lobiferus* (McCoy), *M. limatulus* Törnquist, *M. regularis* Törnquist, *Rastrites peregrinus* (Barrande), *Climacograptus hughesi*, *Cl. scalaris* (Hisinger) and other graptolites. Usually *Monograptus convolutus* is abundant throughout the band, while *M. lobiferus* is particularly common towards the top. This may be called the *M. convolutus* Band. It is succeeded by nearly 15 feet of pale, metallic-weathering and dark mudstones and then there is another graptolite band, 18 inches thick, which may be called the *Cephalograptus cometa* Band, which contains in addition to that fossil, *Monograptus regularis* (v.c), *M. decipiens*, *M. limatulus*, *M. convolutus* (v.c), *M. lobiferus*, *M. clingani* (Carruthers), *Orthograptus bellulus*, *Climacograptus scalaris* and *Cl. hughesi*.

This shale band is followed by 10 feet 6 inches of blue mudstones with thin bands and occasional shale laminæ, which are succeeded by a third graptolitic band, 3 feet thick, which yields somewhat sparsely *Monograptus regularis*, *M. decipiens*, *M. limatulus*, *M. convolutus*, *Rastrites hybridus* (Lapworth), *Petalograptus minor* Elles and *Climacograptus hughesi*. In some sections, *Cephalograptus cometa* has also been found in this band which may be designated the *Monograptus decipiens* Band. The rocks above consist of pale mudstones with siliceous seams and frequent striped sandy layers. The mudstones above the *cometa* Band usually stand out rather prominently whether on scarp-slopes or more level ground. They are harder than the *Monograptus sedgwicki* shales, which succeed them, and the shales and mudstones below the *cometa* Band, which underlie them.

The total thickness of the *M. regularis* zone at Derwenlas is 65 feet 5 inches, whilst in the Pont Erwyd country the equivalent rocks are about 80 feet thick. In the latter area the lithological and faunal characters are closely similar, although so far only one shale-band with *Cephalograptus cometa* has been discovered. In the northern part of the district, the zone is much thinner, being only 18 feet 8 inches thick at Bwlch y Groes, but the rocks and fossils are very much the same as at Derwenlas.

Like the Lower Llandoverian, the Middle Llandoverian is thicker in the south than it is in the north, being 135 feet at Pont Erwyd, 115 feet at Machynlleth and less than 40 feet at Bwlch y Groes. The Lower Llandoverian rocks are about twice as thick at Pont Erwyd, as they are at Bwlch y Groes, whilst in the same localities the Middle Llandoverian rocks are about three times as thick. In the Lower Llandoverian the thinning takes place mainly between Pont Erwyd and Machynlleth, while in the Middle Llandoverian it takes place farther north between Machynlleth and Bwlch y Groes.

Upper Llandoverian.

Zones of *Monograptus sedgwicki and Monograptus halli.*

The relatively hard mudstones with siliceous seams which form the upper part of the *Monograptus regularis* zone are succeeded by the dark blue, rusty-weathering shales and flaggy mudstones of the *M. sedgwicki* zone. The shales in the upper part of the zone are usually black and are striped with numerous white seams. *M. tenuis* (Portlock) is especially common in the lower beds, while both *M. tenuis* and *M. sedgwicki* (Portlock) occur rather less frequently at higher levels, but towards the top *M. sedgwicki* becomes abundant and is often well preserved in full relief. Other common fossils in this zone are *M. jaculum* (Lapworth), *M. involutus* Lapworth, *Petalograptus palmeus* var. *tenuis* (Barrande) and *Climacograptus hughesi.* These *Monograptus sedgwicki* shales are usually easy to recognise and follow in the field, and even where they are not exposed, their position may be inferred from the hollow which ordinarily coincides with their outcrop. At Derwenlas, this zone is 20 feet 8 inches thick.

These rusty-weathering shales are followed by a group of mudstones in which there are comparatively thin, graptolitic shale-bands which form the *M. halli* zone. At Machynlleth, a shale-band some 8 inches thick and 2 feet above the base of the zone yields *M. halli* (Barrande) abundantly, together with *M. nudus* (Lapworth), *M. gemmatus* Barrande, *M. involutus* Lapworth, *M. jaculum* Lapworth, *Rastrites linnaei* Barrande and *Climacograptus hughesi.* This may be called the *M. halli* Band. About 14 feet higher in the zone another band, the *Rastrites* Band, yields *R. linnaei*, together with *Monograptus halli* (v.c), *M. gemmatus* and *Glyptograptus tamariscus*, and finally 3 or 4 feet higher there is the *Climacograptus extremus* Band, in which that graptolite commonly occurs with *Monograptus nudus.* Then follow nearly 50 feet of pale blue, thickly-bedded mudstones and towards the top, thin siliceous seams $\frac{1}{8}$ to $\frac{1}{4}$ inch thick appear among the paler mudstones. In the space of a few feet massive grit bands appear which have been taken to mark the upper limit of the zone, although this line

has been chosen principally for convenience in mapping. At Machynlleth, the *M. halli* zone is about 68 feet thick, so that the total thickness of the *M. sedgwicki* and *M. halli* zones in that area is approximately 88 feet. At Pont Erwyd the rocks are much the same, but the *Rastrites* and *Climacograptus extremus* Bands have not been proved. However, the transition from the *Monograptus halli* zone into the overlying beds is the same and the rocks yield the graptolites characteristic of the *M. turriculatus* zone.

These two zones constitute the Upper Birkhill substage and their thickness variations resemble those of the underlying Llandoverian rocks. They are about 105 feet thick at Pont Erwyd, nearly 90 feet at Machynlleth, while at Bwlch y Groes the equivalent rocks appear to be only 7 feet thick.

Zones of *Monograptus turriculatus, M. crispus, M. griestoniensis and M. crenulatus.*

These zones, which constitute the Gala or Tarannon Stage, are fully developed at Tarannon,where they have been described by Mrs. G. A. Shakespear.[1] At Tarannon, these rocks are from 3,000 to 3,500 feet thick. The *M. turriculatus* beds are 900 to 1,000 feet thick and consist of pale to dark grey mudstones and shales with occasional bands of flaggy material. The *M. crispus* beds are 800 to 900 feet and the sediments are rather more arenaceous, but the *M. griestoniensis* beds, 900 to 1,150 feet, contain numerous thick, massive bands of grit, and form the well-known Talerddig Grits. The uppermost *M. crenulatus* beds, 400 to 450 feet, make one of the most striking lithological groups in Central Wales. They consist of pale green mudstones and shales interbedded with a varying number of purple bands. The " purple and green slates " or " Tarannon Shales " which are distinguished on the Geological Survey Maps belong to this zone in Central Wales, but in North Wales they include the whole of the Gala stage.

In the Aberystwyth district these higher Upper Llandoverian rocks cover very large areas due not only to their considerable thickness, but also because they are closely folded so that there is much repetition of the beds. A great deal of work remains to be done upon them and they have not been subdivided and mapped in the same detailed way as the older Llandoverian rocks.

In the Pont Erwyd country the *M. sedgwicki-M. halli* beds are succeeded by the DEVIL'S BRIDGE GROUP, which is about 1,500 feet thick and consists of pale greenish-blue shales and mudstones with regular alternations of thin gritty bands. Some of the grey gritty bands contain black shale laminæ.

[1] *Quart. Journ. Geol. Soc.*, vol. lxii. (1906), pp. 644-701.

M. turriculatus Barrande occurs quite commonly in the lowest beds and is associated with *M. becki* Barrande, *M. runcinatus* Lapworth, *M. variabilis* Perner, as well as occasional dendroid graptolites. The same graptolites are found higher in the group, whilst towards the top *M. exiguus* Nicholson makes its appearance.

The Devil's Bridge Group is succeeded by the MYHERIN GROUP, about 1,000 feet thick, which consists mainly of blue-grey mudstones with occasional bands of shale in the lower part (Dolwen Mudstones) and dark blue mudstones with characteristic concentric weathering tints in which shaly bands are much thicker and more frequent (Blaen Myherin Mudstones). In the Myherin Group, the shaly bands yield *M. exiguus*, *M. galaensis* Lapworth, *M. marri* Perner, *M. becki*, *M. nudus*, *M. planus* Barrande, *M. priodon* Bronn, and *Rastrites linnaei* Barrande. These rocks pass upwards into the RHUDDNANT GROUP, which begins with shales and passes upwards into regular alternations of dark-grey, evenly-bedded grits with smooth blue shales. In these rocks may be found *Monograptus turriculatus*, *M. marri* and *M. priodon*. The Rhuddnant Group is succeeded by grits and shales of great aggregate thickness (the Cwm Ystwyth Grits) and at the head of the Ystwyth valley pale shales overlie them in the Central Wales Syncline.

Similar rocks occupy all the country between Devil's Bridge and Aberystwyth. The Devil's Bridge Group, with occasional graptolites, continues for more than a mile west of Devil's Bridge and may be examined in road and railway-cuttings. It is followed westwards by a great development of blue-grey and dark blue mudstones with frequent shaly bands weathering in bright colours. These rocks are highly folded and disturbed, but it would appear that there is a gradual ascending succession westwards, so that in the neighbourhood of Capel Bangor there are shales which may be the equivalents of the Rhuddnant Group.

Farther west there is a very distinctive group of rocks which may be called the ABERYSTWYTH GRITS, which form a strip along the coast, increasing in width southwards from near Borth. This group consists of smooth, dark, somewhat rusty-weathering shales which are usually highly cleaved, alternating in a very regular fashion with dark grey, speckled grits which vary in thickness from an inch to 12 inches or more. The grit bands which often show graded bedding are distinguished in many cases by curious markings and convolutions on their under surfaces. These rocks are finely exposed both in the cliffs and on the foreshore between Borth and Aberystwyth and in many cases the structures which they exhibit may be examined both in plan and section. Occasionally graptolites may be found in these rocks, namely, *M. priodon*, *M. nudus*,

M. nodifer, *M. turriculatus*, etc. The Aberystwyth Grits and their probable equivalents, the Cwm Ystwyth Grits, with a small succeeding thickness of pale shale, are the highest beds exposed in the Aberystwyth district, if we exclude the Tarannon area.

It is clear that the only lithological representative in the Aberystwyth district of the very distinctive purple and green shales which characterise the *M. crenulatus* zone at Tarannon is the small outcrop of pale green rocks which occurs at the head of the Ystwyth valley on the axis of the Central Wales Syncline. It is doubtful whether there are in the Aberystwyth country any representatives of the *M. griestoniensis* beds (Talerddig Grits). It might be supposed that the Aberystwyth Grits are the local representatives of the Talerddig Grits, but the fossils so far recorded from the Aberystwyth Grits suggest that they belong in the main to a lower stratigraphical level.

Over much of North Cardiganshire the rocks belong in general to the Devil's Bridge Group and consist of pale, greenish-blue shales and mudstones with regular alternations of thin grits. The shales and mudstones are usually highly cleaved and in some places have been quarried on a small scale for slates. Fossils are usually very rare in the beds which immediately succeed the *M. halli* zone, but from Dinas Mawddwy northwards fossils become much more abundant and the graptolites characteristic of the *M. turriculatus* zone may be collected without difficulty. Although these rocks have not been examined in detail in the northern part of the district, it is clear that they are very much thinner than farther south and at Bwlch y Groes, which is about 14 miles north of Tarannon, there is comparatively little arenaceous material in them.

The Llandoverian rocks of the Aberystwyth district belong to the graptolitic facies and the different subdivisions may be correlated in great detail in different areas and in almost equal detail with other areas in Wales,the Lake District and the Southern Uplands of Scotland. There is, for example, a close similarity between the Middle Llandoverian at Bwlch y Groes and the Middle Skelgill Beds of the Lake District, both in the character and fauna of the graptolitic shale bands and the intervening mudstones. The graptolitic Llandoverian rocks extend south-eastwards from the Aberystwyth district as far as the Towy Anticline, but in crossing that structure they are replaced by the shelly Llandoverian rocks of Llandovery and Haverfordwest. The rocks are thicker in the south than they are in the north, and this is in keeping with the general diminution in thickness of the Llandoverian rocks in Central Wales, as they are traced from south-east to north-west. The Lower Llandoverian thins more quickly than the Middle Llandoverian, whilst the latter thins more quickly north and north-westwards than the Upper Llandoverian. It would appear that the areas

of thicker sedimentation gradually advanced north-westwards during the Llandoverian period towards the centre of the geosyncline, which lay along the line North Wales-Lake District.

III. STRUCTURE.

The northern part of the area between Dinas Mawddwy and Bwlch y Groes lies on the east flank of the great Merioneth Dome, and a few miles to the east lies the Central Wales syncline, which separates that dome from the Berwyn Dome.

Of these structures represented in North Wales only the Central Wales syncline can be traced southward, where it passes through the Tarannon upland, and thence between the Plynlimon and Llanidloes areas to the head of the Ystwyth Valley a few miles east of Cwmystwyth. From here it has been traced at intervals along the high ground between the Towy and Teifi valleys for a distance of over 50 miles. The area that will be visited during the excursion lies everywhere to the west of the axis of this syncline.

In the southern part of the district the most conspicuous structures are the elongated Plynlimon dome, and the Van dome west of Llanidloes, in each of which the Ordovician rocks reach the surface. These two structures are small scale replicas of the Merioneth and Berwyn domes, and it is interesting to find that the Central Wales syncline passes between them. The Plynlimon dome is a compound structure composed of many subsidiary anticlines and synclines; it is nearly twice as long as it is broad, and is elongated in a direction N.N.E.-S.S.W.; the axes of the component folds range, however, almost due N. and S. The same contrast between the direction of elongation of the dome and the axes of the individual folds composing it can be seen in the Merioneth dome.

The Van dome is roughly circular and like the Berwyn dome it is made up of many smaller folds ranging N. and S. On the line joining the centres of these domes the Ordovician rocks rise higher than elsewhere in the southern district, and even along the axis of the Central Wales syncline the base of the Silurian rocks is only just below the surface. Between Machynlleth and the neighbourhood of Talybont another elongated anticline brings up the Ordovician rocks; some of the details of this anticline will be seen in the Llyfnant valley.

Folds.

The most obvious structures are anticlines and synclines with a strongly developed pitch in the direction of their axes (Fig. 36). These can be seen on almost every scale from folds a few feet across to others in which the distance from the axis of one fold to the next is a mile or more. Good examples will be seen on

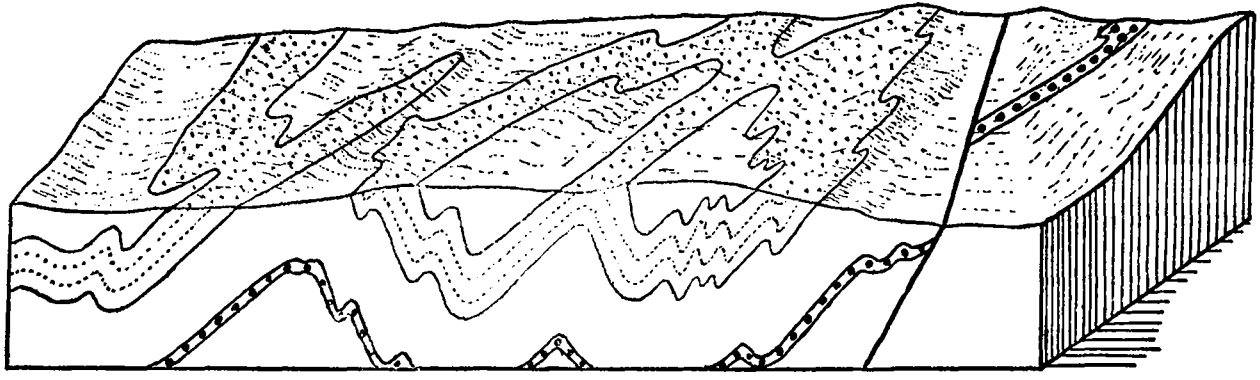

FIG. 36.—BLOCK-SECTION ILLUSTRATING THE RELATION BETWEEN THE FOLDING OF THE STRATA AND THE FORM OF THE OUTCROPS NORTH OF PUMWERN.

On the scale of 6 inches to the mile.

[The Mottled Beds at the base of the Cwmere Group are indicated by heavy dots; other groups colourless].

[Reproduced by permission of the Council of the Geological Society.]

the coast south of Borth. Individual folds cannot be traced far, other folds replacing them usually *en échelon* in the direction of their axes.

From Talybont to Plynlimon the pitch is everywhere southward, but around the Llyfnant valley and thence to Machynlleth a northerly pitch prevails, as is also the case near and to the west of Dylife.

In the Ordovician-Silurian outcrops which extend southwards from Dinas Mawddwy towards Aberdyfi and Towyn the pitch is again southward. This area belongs in fact to the south-eastern flank of the Merioneth dome. The pitch of the folds may in general be detected readily in the form of the more prominent hills. Thus around Pont Erwyd the hill profiles present the appearance of dip slopes and escarpments, the gentle slopes facing south and the steep slopes facing north. Around Machynlleth, where the pitch is north, the gentle slopes face in that direction; again near Aberdyfi the long hill crests slope south in accordance with the pitch of the folds in that area.

The most marked anticlinal axes in the northern region are (1) near Dinas Mawddwy, (2) Maesygamfa west of Aberllefenni, (3) near Corris, and (4) between Pennal and Aberdyfi. It is possible that the Maesygamfa anticline may be the northerly continuation of the Plynlimon uplift, but the direct connection cannot be traced. The Corris anticline is beautifully exhibited in the outcrop of one of the grit bands in the Upper Bala rocks, and in that of the Narrow Vein below. The most instructive feature of these structures is the contrast between the closeness of the folding at different stratigraphical levels of the same fold. There is, for instance, a remarkable contrast between the sinuous outcrops of the Upper Bala and Silurian rocks and the almost straight course of the narrow band of the Nod Glas. This soft shale band is in general characterized by intense shearing, and it is probable that a great deal of differential movement has occurred along it which has allowed of the upper beds to be sharply corrugated, while the beds immediately below the Nod Glas are almost free from minor folding. The line of contact between the volcanic rocks which lie at the base of the sedimentary Bala rocks is, however, affected by some folding, as may be seen on the map north of Corris and north-west of Dinas Mawddwy, where volcanic rocks appear in the core of the anticline west of Aberllefenni.

Faults.

Three marked systems of faults can be distinguished, namely: (1) Strike faults which range roughly between N.-S. and N.N.E.-S.S.W., (2) mineral veins or lode-faults trending between

N.E.-S.W. and E.N.E.-S.S.W., and (3) transverse faults ranging between E. by N. and N.E.

(1) In the southern district strike faults accompany many of the anticlines and synclines, and trend in a direction approximately parallel to the direction of the fold axes. They are not, as a rule, of great importance, and rarely produce any marked topographic features. Perhaps the most striking is that which is followed by the Twymyn valley between Dylife and Llanbrynmair and the one which ranges through the head of the Llyfnant valley to the Dyfi valley east of Machynlleth. These faults are obviously related to the folding movement, and in the outcrop to the west of Minllyn and Dinas Mawddwy many of those which affect the Silurian and Upper Bala rocks die away before reaching the Nod Glas, supplying a further confirmation of the large amount of differential movement in the strata above that level.

In the northern district north of Dinas Mawddwy where the outcrops of the Bala and Silurian rocks form narrow parallel strips almost unaffected by any obvious folds, important strike faults cut out in places a considerable thickness of strata. This is most clearly seen on the Dyfi north of Llanymawddwy, where the Ystwyth stage of the Silurian is thrown against the beds below the Narrow Vein.

Another fault which commences to the east of Bwlchgroes ranges northward into the Hirnant valley, where the *Turriculatus* beds of the Silurian are faulted against the beds at the extreme base of the Silurian.

(2) *The Lode-Faults.*[1] In North Cardiganshire and Western Montgomeryshire a large number of mineral veins have been worked in the past, and the area bears abundant traces of that industry in mine dumps, ruined buildings and an occasional waterwheel. The leets which run for miles along the hillsides to conduct water to the mines are also conspicuous features around Pont Erwyd and elsewhere. The minerals are mainly galena, blende and occasionally copper pyrite; they occur as strings and bands of varying width within the broken ground of faults which range approximately N.E.-S.W. The majority of the faults are of small throw, but three faults in particular are of considerable stratigraphical importance, and have been traced in each case for 12 to 16 miles. The Dylife lode is a downthrow north fault which runs from the Twymyn valley through Craig-y-Pistyll in the direction of Aberystwyth, and is mineralized at intervals to within 5 miles of the coast. The principal mine on it is the Dylife mine. The next lode-belt can be picked up about 1½ miles east of the Van Mine near Llanidloes, and passing a little to the south of Eisteddfa Gurig and Dyffryn Castell

[1] *Mem. Geol. Surv.* The Mining District of North Cardiganshire and West Montgomeryshire, 1922.

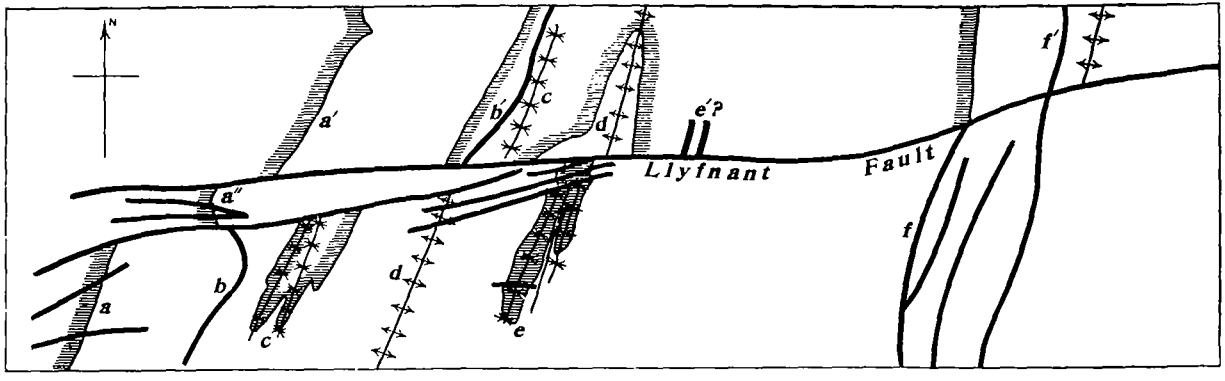

FIG. 37.—DIAGRAM ILLUSTRATING THE DIRECTION OF MOVEMENT AND EFFECT OF THE LLYFNANT FAULT.

On the scale of an inch and a half to the mile.

a=Cwmere outcrop moved to a'' (Caerhedyn outcrop) and to a' (Derwenlas outcrop). b=Brwyno Overthrust moved to b' (Gelli-goch Overthrust). c=Axis of the Alltddu 'Syncline' moved to c' (axis of the Cyfartha Syncline). d=Axis of the Taren Ty'n-y-maen Anticline moved to d' (axis of the Garth Anticline). e=Axis of the Hiraeth 'Syncline' probably moved to e' (small overthrusts in the Glaspwll Syncline). f=Cascade Overthrust moved to f' (Rhiwlwyfan Overthrust).

[The base of the Pont-Erwyd Stage is shaded.]

crosses the Rheidol valley near Parson's Bridge, where it can be seen in the river, and extends to Rheidol Falls. This is a downthrow to the south; near Parson's Bridge its course is indicated by a marked col well seen from the main road. In addition to the Van Mine several smaller mines worked the lode to the westward. Near Pont Erwyd the Castell Mine and Ystum Tuen Mine lie on it, and the Rheidol Mine in the valley is a conspicuous feature on account of the stream of ochreous water which is discharged from one of the drainage adits.

The largest fault is that which runs through Cwmystwyth, and can be traced for about 4 miles to the east of that place; it also is a downthrow south. The same lode system was worked again near Pontrhyd y groes.

The mineralized portions of the lodes seem to bear some relation to the rocks which they traverse. The majority are almost, if not quite, barren where they traverse the Lower Llandoverian rusty shales or where they enter these rocks in depth. Most of the minerals were found either in the Upper Bala or in the Middle Llandoverian and the lower part of the Upper Llandoverian or again in the Grits of Cwmystwyth which occupy a high level in the Upper Llandoverian. Some of the great mines of the past such as Cwm Symlog, Goginan and Frongoch occur on fracture belts which so far as can be determined caused only trifling displacements of the rocks which they traverse.

(3) The fractures of the third system are perhaps the most interesting on account of their influence upon the topographical features of the region. The Talyllyn-Bala fault really lies outside the limits of the area, and the great valley through which it passes will be seen at only one place north-west of Corris. It is in the main a great tear- or wrench-fault with a large horizontal displacement. R. M. Jehu[1] has shown that in all probability this fault has little vertical displacement, but that the south side has moved to the east with respect to the north side, to a distance of about 2 miles.

It is possible that a marked fault-belt which runs through Pennal towards the Dyfi valley at Machynlleth belongs to this system.

Farther south the Llyfnant fault can be traced along the Llyfnant valley and for some three miles to the east. It is probable that the straight north side of the estuary for four miles east of Aberdyfi indicates a continuation of the fault in that direction. The structure of the fault has been worked out in detail.[2] Several well characterized anticlines and synclines and strike-faults can be identified on both sides of the fault-belt, and these prove that whereas the vertical displacement varies between 80 and 618 feet the horizontal displacement

[1] *Quart. Journ. Geol. Soc.*, vol. lxxxii., p. 483.
[2] *Quart. Journ. Geol. Soc.*, vol. lxxi., p. 375.

ranges from 1,700 to 3,200 feet (see Fig. 37). Several small faults which lie between the Llyfnant and Machynlleth are probably accommodation structures related to this fracture, and north-east of Aberdyfi a series of faults can be seen in the coast section which range north-south across the Pennal fault. They are also probably related to the horizontal movements which characterize the Llyfnant fault, and possibly the Pennal fault.

At Cwmystwyth the lodes are cut off on the south by a great fault along which the rocks have been ground down to a clay for a width of 40-50 yards in places. This fracture can be traced along the north side of the Ystwyth valley to beyond Pontrhyd y groes, and it probably runs out to the coast along the Wyrai Valley to Llanrhystyd 10 miles south of Aberystwyth. It has been shown that the Cwmystwyth lode belt reappears on the south side of the fault, and has been extensively worked at Logaulas near Pontrhyd y groes.

From this evidence the displacement of the Ystwyth fault at Cwmystwyth cannot be less than about 3,000 feet. Again at Pontrhyd y groes the Lower Llandoverian rocks have been thrown up on its south side. These rocks disappear beneath the higher Llandoverian rocks near Parson's bridge, 5 miles to the north, and with the southerly pitch of about 10° that prevails in that region the throw of the fault at Pontrhyd y groes may be estimated to lie between 2,500 and 3,000 feet.

This fault can be proved to be of later date than the mineralization of the Logaulas and Cwmystwyth lodes, and at the latter place enormous masses of galena torn off the lodes and incorporated in the soft ground of the fault were worked by the old miners.

Cleavage.

Most of the rocks of the area are cleaved to some extent, but the amount and type of cleavage depend upon the constitution of the rock. The Upper Bala rocks from Corris to Plynlimon have developed a phacoidal structure whereby the rock breaks into sharp-edged flattened pieces with curved surfaces which are often polished as if blackleaded. North of Minllyn, however, rocks of the same age cleave like the overlying Lower Llandoverian shales. These latter are usually well cleaved and split into thin parallel-sided pieces. The strength of cleavage varies from one part to another of the area, and examples may frequently be seen of the variation of cleavage in crossing bands of rock of different texture. Usually the cleavage lines cross the coarse bands at a more acute angle than the finer layers. The cleavage in the Middle and Upper Llandoverian is very variable in its development—and many of the more massive mudstones which occur in these rocks are almost free from its effects.

The direction of cleavage is roughly N.N.E.-S.S.W., and its dip is in general to the W.N.W. at steep angles. It shows no relation to the bedding of the rocks. When the cleavage crosses the bedding at an acute angle, fossils are often difficult to extract but occasionally the cleavage and bedding are nearly coincident, and it is in such rocks that the best graptolites may be obtained.

Jointing.

Some of the rocks exhibit remarkably even jointing. The best example is that seen in the cliffs of the Rheidol Gorge south of Pont Erwyd, where the Middle Llandoverian mudstones are traversed by a series of parallel joints so uniformly spaced as to simulate the appearance of vertical bedding planes. The joints are not obvious in the underlying Lower Llandoverian shales. By contrast, however, the rusty Lower Llandoverian shales of Creigiau Esgair Fochnant, north-west of Dylife, are traversed by a remarkably uniform system of vertical joints which do not pass upward into the Middle and Upper Llandoverian mudstones forming the upper part of the cliff.

IV. GLACIATION.

The effects of glaciation have not been worked out in detail. The area to the north of the Dyfi estuary appears to have been glaciated in the main by ice radiating from the ranges of Cader Idris and the Arans, whereas south of the estuary the ice seems to have come from the high plateau region somewhere near, or to the east of, Plynlimon and coinciding approximately with the axis of the Central Wales syncline. South of Machynlleth the North Wales ice sheet seems to have over-ridden the slopes leading down to the Dyfi estuary and to have spread for several miles inland from the coast nearly as far south as Aberystwyth. This can be shown by striae and by occasional blocks of felsitic rocks from the Aran range. On Foel Fawr near Glandyfi and to the South the striae show that the Central Wales ice at one time flowed westward towards the estuary, while later the same area was over-ridden by southward-moving ice. Towards the end of the period of glaciation there is evidence that the Central Wales ice had begun to withdraw inland, while a belt of ground near the estuary and along the coast to the south was still occupied by North Wales ice. Between Glandyfi and Talybont all the streams draining westward were therefore blocked at their lower ends by ice and consequently in each of these valleys lakes were impounded which escaped southward over various cols, and the final exit to the coast was probably along the Clarach valley north of Aberystwyth. The discharge from these lakes cut a series of overflow channels across the watersheds separating one valley from another (Fig. 38).

The most conspicuous series occurs to the south of Talybont.

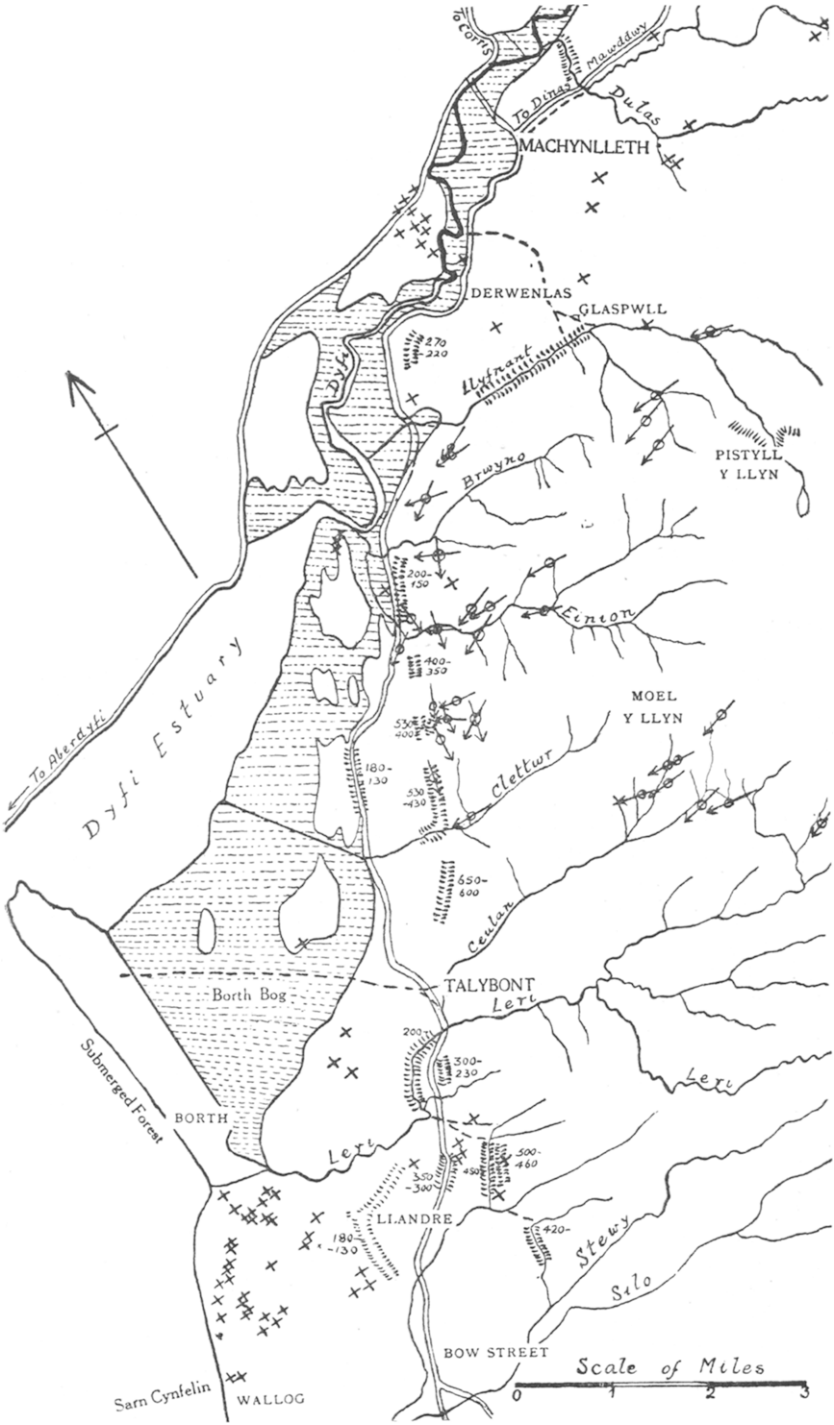

FIG. 38.—GLACIAL OVERFLOW CHANNELS, GLACIAL STRIÆ AND DISTRIBUTION OF FELSITE ERRACTICS IN THE COUNTRY BETWEEN MACHYNLLETH AND BOW STREET.

The ridge between the River Leri and an unnamed stream to the south is cut by three of these notches, the highest of which is just below 500 feet, the next to the west is slightly lower, the lowest is about 290 feet. It is significant that a felsite boulder occurs in the highest notch, proving that the North Wales ice reached at least to that position. It is probable also that a lower channel belonging to the same series may be identified south of Llandre station, where a dry valley having the characteristic features of an overflow channel, has been eroded in a thick deposit of shale-scree, of very late glacial age, and at a level of about 150 feet. While these channels were being cut, the natural exit for the Leri at the north end of Talybont village as well as the present exit at Borth, were blocked by ice. At a later stage in the retreat of the ice the Leri was finally diverted through a pre-existing low col at the south end of the village into its present course through the gorge between Talybont and Borth.

In the Llyfnant valley near Glaspwll the drainage system has been considerably modified as the result of glacial action. Formerly the main Llyfnant stream used to flow northward towards the Dyfi valley north of Derwenlas. About half a mile N.W. of Glaspwll a tributary stream from the south joined the main stream. The abandoned valleys are well-defined, but their floors are partially occupied by drift; a prominent ridge about ¾ mile N.W. of Glaspwll probably marks a halting stage in the retreat of the ice northward. That the northern ice reached well south of this point is shown by the great felsite boulder in the Llyfnant valley about half a mile above Glaspwll. Under these conditions the river was forced to find a new outlet, and it is probable that a low col already existed lower down the present Llyfnant valley due to erosion along the Llyfnant fault, which afforded an escape to the west which has become the permanent course of the river.

Among the more striking topographic effects of glaciation are the great corries which occur both north and south of the Dyfi. They are, of course, best known in the neighbourhood of Cader Idris, where typical corrie lakes occur at the base of the great semi-circular scarp of the corrie. In Plynlimon alone of the corries eroded in the slaty rocks does a corrie lake exist. North of the Dyfi the most conspicuous is Taren y Gesail, though there are smaller ones to the north-east and south-west of it. Farther north great corries occur at the head of the Dyfi tributaries which descend from the Aran range, the best marked of them being that at the head of the Dyfi itself, and is overlooked by the peak of Aran Mawddwy (2,970 ft.). The depth of the corrie is about 1,200 feet, and its width is over a mile. There is another fine corrie facing north about 2 miles west of Dinas Mawddwy.

On the south side of the Dyfi river several of its tributaries head in corrie-like features of an even greater size than Taren y Gesail. The largest of these is Taren Bwlchgwyn, 3 miles west of Dylife. Its depth is over 1,200 feet and its width nearly a mile. Taren Hengwm 3 miles to the west is nearly as deep, though not quite so wide. Another forms the head of the Llyfnant; its most marked feature is the waterfall down the middle of it, called Pistyll-y-Llyn. The source of the Rheidol is a lake lying in the corrie at the foot of Plynlimon. Each of these valleys below the corrie is wide and U-shaped, and suggests intense glacial erosion. At the present time the lower slopes of the corries are cumbered by enormous shale screes, probably representing late glacial erosion. These have probably been stable for very long periods, and it is doubtful if they are being added to at the present time. Shale screes possibly representing intense frost action at the end of the glacial period may be seen in many parts of the district, both in the valleys and on the plateaus.

V. HISTORY OF SOME OF THE RIVER SYSTEMS.

A brief summary of the history of the more important rivers in the area may not be out of place.

The Dyfi drains in the main the region between the Cader Idris range and the Central Wales syncline, and on the whole the system has probably suffered few modifications since its origin. The chief appears to be the capture of the head of one of its tributaries by erosion along the Talyllyn fault, north-west of Corris. The Llyn-y-cau stream rising at the foot of Cader Idris appears to have at one time flowed across the Talyllyn valley towards Corris and thence into the Dyfi. The abandoned valley is now occupied by quite a small stream which flows back towards Talyllyn. The course of the valley between Pennal and Cemmaes Road was probably influenced by the Pennal fault-belt. A very prominent col or bwlch on the line of the fault where it leaves the Dyfi valley may be seen from Machynlleth.

As mentioned earlier, the north side of the estuary east of Aberdyfi may have been defined by the continuation of the Llyfnant fault.

The Coastal Plateau is well defined on each side of the Dyfi, and is especially well seen on the south and east. In that area it abuts against the High Plateau, which rises above it, almost like a sea cliff. The deep incision of the streams into the Coastal Plateau may be attributed to rejuvenation, and in places the head of rejuvenation is well defined as in Afon Pumryd and the Llaethnant (or Dyfi), though now modified somewhat by glacial erosion.

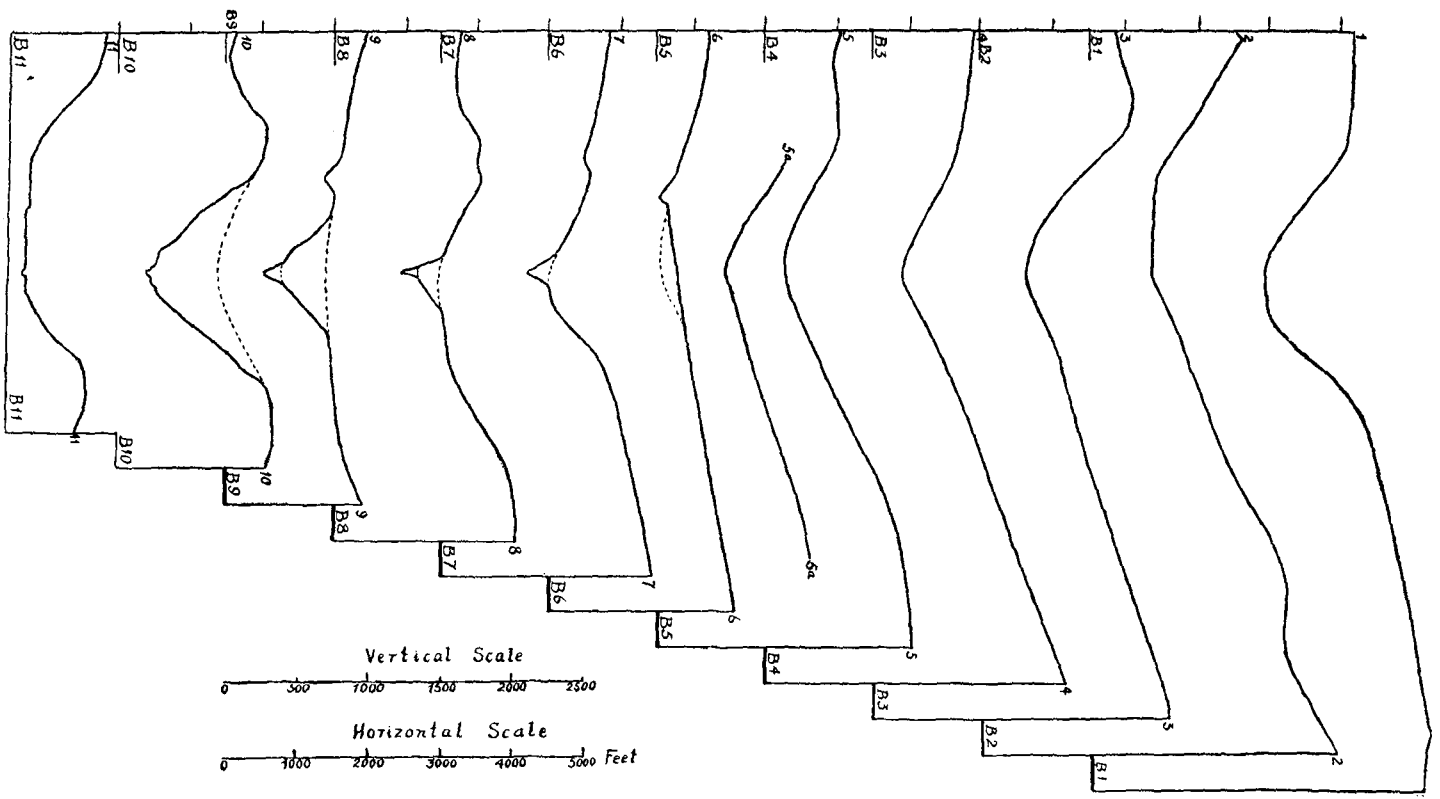

FIG. 39.—SERIAL SECTIONS ACROSS THE RHEIDOL VALLEY FROM NEAR ITS SOURCE TO 1 MILE BELOW DEVIL'S BRIDGE.

The River Rheidol and its tributaries rise on the High Plateau north of Plynlimon. The official source is Llyn Llygad Rheidol, a small corrie-lake situated immediately below the summit of the mountain. Geographically, the stream which comes down from the direction of the head of the Llyfnant, or another which starts near the Hengwm corrie, have a better claim to be regarded as the main stream. Both of these and some of the upper tributaries have been captured by streams working back towards the edge of the Coastal Plateau, and the original limits of the watershed must have been farther north, though its former position cannot be determined.

The Rheidol valley nearly as far as Pont Erwyd is of mature aspect (1 to 5a)[1], but at Craignant, a mile north of that place, it enters a narrow winding rocky gorge (6). It is clear, however, that an older valley lies east of the gorge and is filled with drift. At Pont Erwyd there begins the characteristic gorge which gives the region between that place and Devil's Bridge its great physiographic and scenic interest (7 to 9). At Pont Erwyd the river turns westward through a very narrow deep gorge into which a stream enters at the Hotel over a picturesque waterfall. This gorge also is a recent diversion, since another channel filled with drift can be seen at both ends of the gorge. Less than a mile below is the beautiful gorge which has been so often photographed as an incised meander. Although it is a narrow winding rock-gorge which has been eroded in the floor of an open flat-bottomed valley, thus reproducing the characteristics of an incised meander, this probably does not account for its origin, since an earlier drift-filled gorge pursuing a nearly straight course can be seen at both ends of the "meander" (see Fig. 39).

In all these cases the diversion of the river is due to glacial interference, and in each case the diversion lies to the west of the original course. This may probably be attributed to the ice which pressed down from the high ground of the Plynlimon range on the east against the west side of the valley. These diversions were possibly channels at the edge of the ice during a late stage of the glaciation. At an earlier stage the west side of the valley north of Pont Erwyd was over-ridden almost at right angles by ice from the east.

It is clear, however, that the mature valley had already been incised as far as Pont Erwyd before the glacial period. Below that place the gorge develops rapidly in depth, and at Devil's Bridge 3 miles below, its floor lies some 400 feet below the level of the old mature valley, which is well preserved as a wide shelf more especially on the east side of the gorge (9). From the road between Pont Erwyd and Devil's Bridge the deep gorge is hardly visible; the most striking feature is the old valley floor on which the road runs. At Devil's Bridge the river turns abruptly westward, but the old valley can be traced

[1] The numbers refer to the serial sections in Fig. 39.

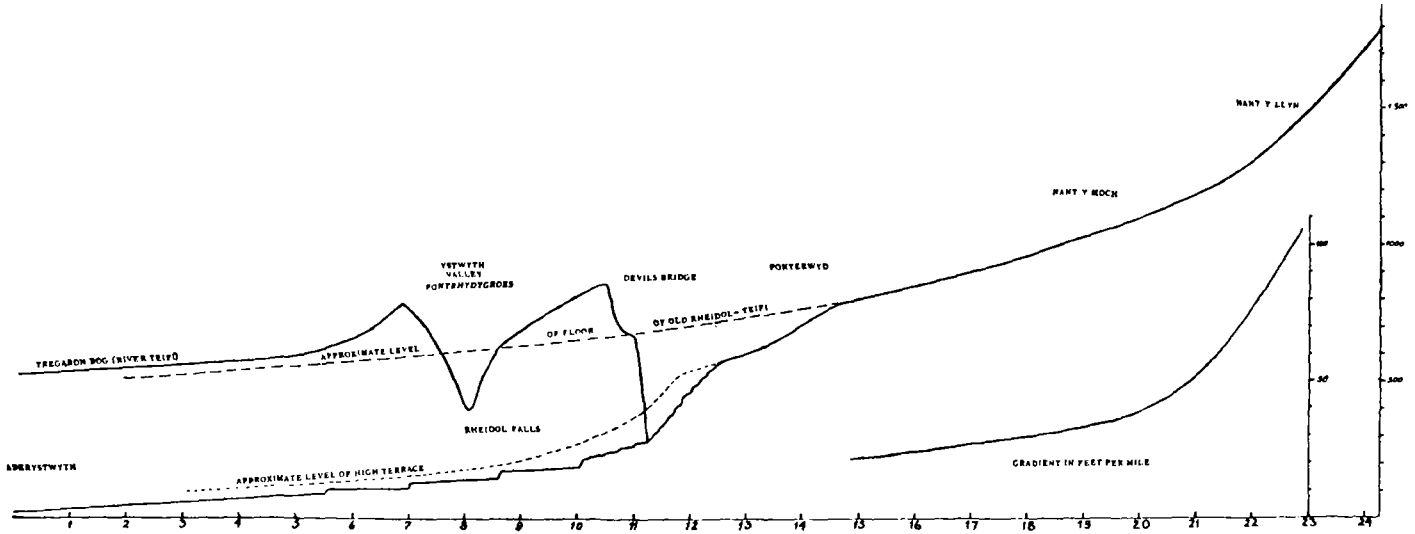

FIG. 40.—LONGITUDINAL PROFILE OF THE RHEIDOL VALLEY AND OF THE OLD RHEIDOL-TEIFI VALLEY SYSTEM PRIOR TO REJUVENATION.

south towards Pontrhyd y groes on the Ystwyth River, although it is now deeply buried under drift (Fig. 40).

The elbow at Devil's Bridge is due to capture by a stream formerly flowing to the west across the Coastal Plateau. The original capture probably occurred about $3\frac{1}{2}$ miles west of Devil's Bridge. Some of the tributaries which enter the Rheidol near that place still flow in from the west; others have been captured farther down the valley; one of them is Nant Bwadrain, which descends into the Rheidol valley over a fine waterfall.

At Pontrhyd y groes the course of the ancient valley is crossed by the River Ystwyth along which passes the great Ystwyth fault. South of that place a well-defined valley leading into the Teify lies in line with the abandoned valley to the north, and there is no doubt that another capture of the old Rheidol has occurred at this point by the River Ystwyth. Headward erosion of an original westerly flowing stream was in this case assisted by the weak ground along the Ystwyth fault. Thus we have an original north-south river captured at two points by westerly flowing streams. Encroachment of the coastal drainage on that of the inland drainage may be seen at numerous points along the line of contact of the Coastal and High Plateau, and it is probable that the original western watershed of the Rheidol valley lay considerably to the west of its present position. The captures and the incision of the streams of the Coastal Plateau occurred as the result of uplift of the area, and the consequent rejuvenation of the rivers, and more particularly of those flowing directly into Cardigan Bay.

On the retreat of the ice from the area most of the larger valleys were occupied by a considerable thickness of drift. In general the drift now remains only in parts of the valleys usually forming a shelf on the side, and it is clear that what was once a continuous cover has been removed from much of the valley floor. In its place one usually finds river gravels and in the Dyfi and Rheidol valleys in particular these deposits form marked terraces on one or both sides of the valley, the highest of these being in some cases over 100 feet above the level of the river. The number of terraces and their relative heights vary from one part of a valley to another, and from one valley to another.

The sequence of events which seem to be recorded in the post-glacial history of these valleys is probably somewhat as follows. While ice still survived on the higher parts of the watershed the lower ends of the valleys were ice-free. The soil in the area was probably frozen to some depth, so that streams fed by rains and melting snows could not readily pick up a load. The rivers were therefore underloaded, and erosion occurred in the lower parts of the valleys. Later when the ground thawed, material could be removed more easily by

running water; further, the stream courses cumbered by glacial debris were not graded. Under these circumstances vigorous erosion of glacial material caused the rivers to become heavily loaded. Their load was largely deposited in the lower reaches of the valleys, which were, therefore, aggraded by river gravels which occupied the place in the central part of the valleys from which the drift had been removed.

As the stream courses in the higher ground approached a more graded condition there was less material available for removal by running water and the load of the rivers diminished. The aggraded plains in the lower reaches of the valleys had too great a slope for a less loaded river, and hence erosion ensued, leading to the reworking of the gravels and the formation of terraces at successively lower levels. It is possible that concurrently there may have been changes in the total rainfall, but it is not necessary to assume such changes in order to account for the terraces of this area. Neither is there any reason to suppose, so far at any rate as the River Rheidol is concerned, that the terraces were due to, or assisted by, progressive uplift of the land area, though this also may have occurred.

The Rheidol Terraces are of considerable interest, because the succession of events is clearly shown. The boulder-clay is only preserved in certain areas, but relics of the highest terrace are abundantly found for a distance of over 5 miles from near Capel Bangor almost to Devil's Bridge. Near the former place it is only 6-7 feet above the river level, but it rises upstream and at its upper end near the Cwm Rheidol Mine it lies between 60 and 80 feet above the river (see Figs. 40 and 41). During the period of its formation it is clear that an enormous amount of material was being brought in to the valley by side streams, large and small. The smaller streams dumped the material on to the high terrace surface, forming very steep alluvial cones. The best of these is about half a mile below the Cwm Rheidol Mine; another occurs at Nant-yr-onen station. The larger tributary entering from Goginan at Capel Bangor has formed an extensive, flattish cone or delta graded to the level of the high terrace. Its slope is from 40-50 feet a mile, whereas that of the delta formed by the smaller streams higher up the valley is at the rate of 800-1,000 feet per mile, and that at Nantyronen is about 300 feet per mile (Fig. 41).

These may be compared with the River Rheidol, which most remarkably has a uniform gradient of about 10 feet per mile measured along the meanders, and probably not more than 15 feet per mile measured along the centre of the valley. There is evidence also that a great deal of shaly scree was being produced on the valley slopes which worked its way down on to the edge of the terrace. The conditions suggest rapid erosion throughout the area.

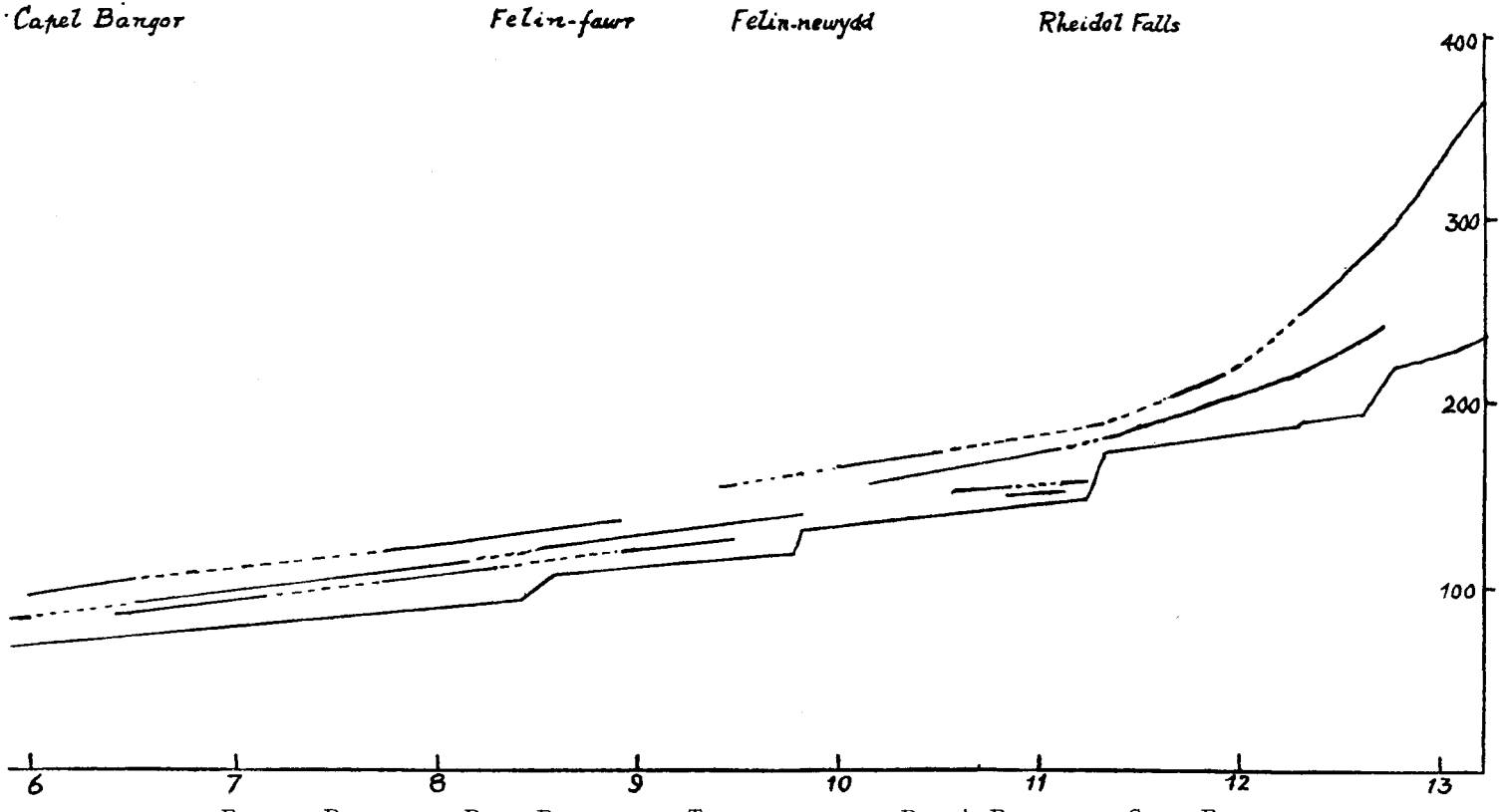

FIG. 41.—PROFILES OF RIVER RHEIDOL AND TERRACES BETWEEN DEVIL'S BRIDGE AND CAPEL BANGOR.

At the maximum development of the high terraces the valley floor was evenly covered by river gravels. During the subsequent period of erosion the river in cutting through the gravel came down in several places onto rock in which it has cut short, narrow gorges usually with a waterfall at the head. There are four of these, the best marked being the one known as Rheidol Falls.

Owing to these accidents, the lower terraces are not as a rule continuous, those below a fall having no necessary relation to those above. In the neighbourhood of these falls the flight of terraces is usually well-preserved owing to the fact that the river is confined in its rocky channel, and cannot meander freely across the valley floor. If this had been possible many of the terrace records would have been lost.

All the terraces slope down stream at a higher angle than the river. If the volume formerly was the same as at present this would argue a greater load than that of the existing river, while, if we assume that the load then was the same as at present, the volume of the river must be assumed to have been less.

Two river captures of late glacial or post-glacial date may be briefly mentioned. The town of Machynlleth lies in the main on an extensive gravel flat, but the river which deposited the gravel was the Dulas which now enters the Dyfi about a mile east of Machynlleth. During the period of aggradation, common to all the rivers of the area, the Dulas raised the surface to such an extent that the river found an exit by way of a low rock col which separated its own valley from that of the Dyfi. The river has remained in this channel, and the gravel plain which was thus abandoned has remained as an example of what such aggradation plains looked like before the rivers eroded them away.

The other case is at the head of the Twymyn valley near Dylife. The stream which descends from the north-west formerly flowed south-eastward into the Clywedog, a tributary of the Severn, and this course appears to have been maintained until late glacial or post-glacial time. Headward erosion by the Twymyn stream appears to have cut into the Clywedog tributary and diverted it northward through Llanbrynmair into the Dyfi. At the present time there is a great delta watershed or corrom near Hirnant farm which has grown across the abandoned valley. The capture appears to have taken place independently of the formation of the corrom.

There may be opportunities for studying and discussing both these interesting types of capture on the ground.

Recent Movements.

The last geological movement that affected the district is

a subsidence shown by the formation of the estuaries in particular the Barmouth and the Dyfi Estuaries. The floors of these estuaries have been proved to extend far below sea-level; the depth of the rock floor in the Dyfi Estuary at Glandyfi is more than 130 feet below ordnance datum, and that of the Barmouth Estuary is more than 120 feet.

It is in connection with this movement that the Borth bog came into existence. In places the rock-floor of the bog is more than 90 feet below the surface. In a late stage of this subsidence an extensive peat bog was developed overlying fine blue clay, a succession which is now familiar in other coastal bogs and marshes, and has been recently investigated in detail in the East Anglian fen region. The peat bog was formerly continued further seaward, and as a result of the encroachment of the storm-beach at Borth, parts of the former bog now appear near the low-tide mark as a submerged forest.

Other features which may be attributed to the subsidence are the great ridges of boulders called sarns which run out at right angles to the coast at intervals from Sarn Badrig to Sarn Cynfelin between Borth and Clarach. These are probably remains of the boulder-clay watersheds which separated the main river systems before subsidence, and after the movement were carried below sea-level and the finer material washed out of them.

It is possible that these events are reflected in some of the Welsh legends.

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GEOLOGICAL MAP

OF THE

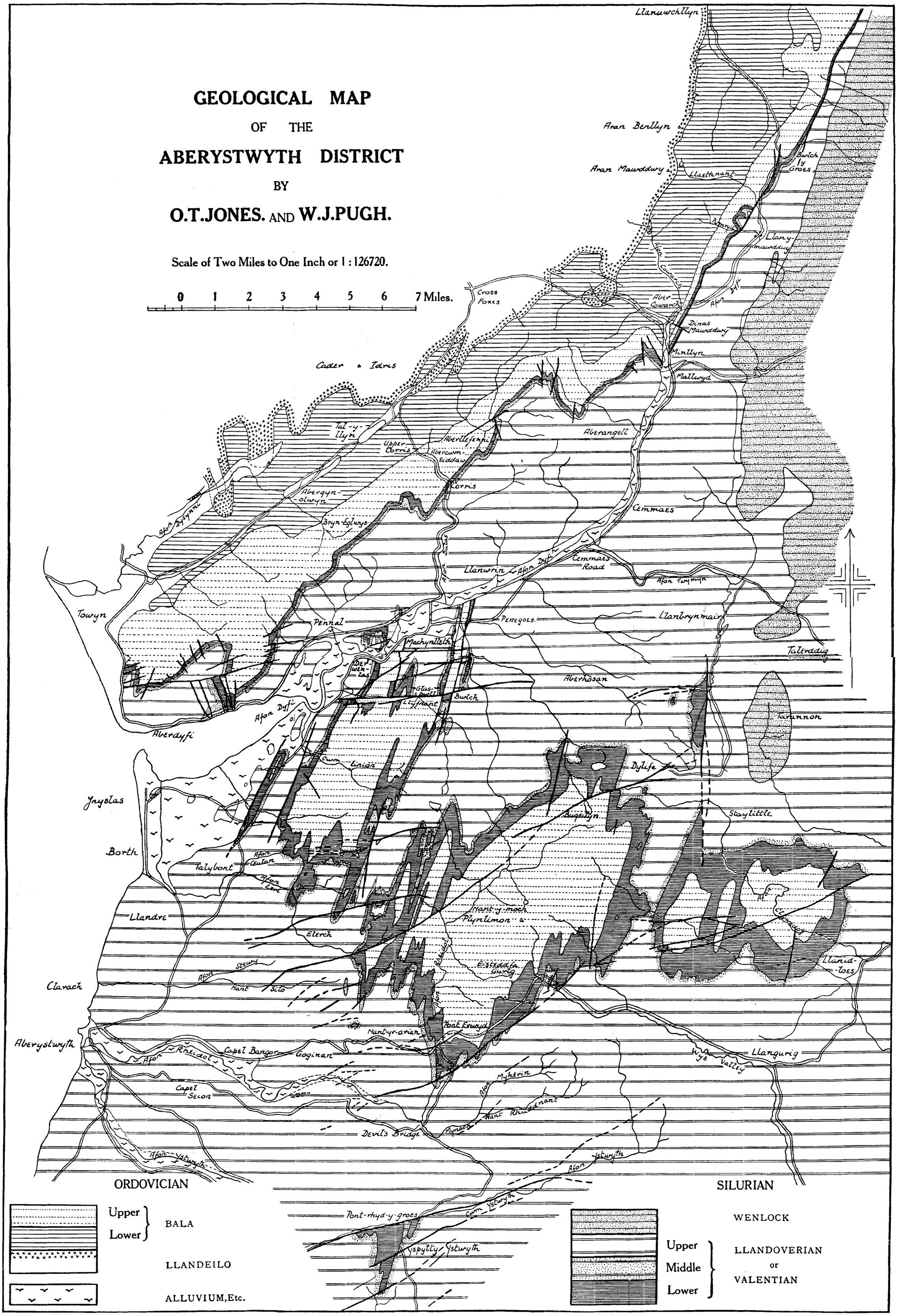
ABERYSTWYTH DISTRICT

BY

O.T.JONES. AND W.J.PUGH.

Scale of Two Miles to One Inch or 1 : 126720.

0 1 2 3 4 5 6 7 Miles.



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