35. *On the GEOLOGY of NORTHERN ANGLESEY.* By C. A. MATLEY, Esq., B.Sc., F.G.S. *With an APPENDIX on the MICROSCOPIC STUDY of some of the ROCKS,* by Prof. W. W. WATTS, M.A., Sec.G.S. (Read June 7th, 1899.)

CONTENTS.

	Page
I. Introductory Remarks	635
II. Description of the Rocks	637
(a) The Green Series.	
(b) The Northern Complex.	
(c) The Ordovician Rocks.	
III. Relation of the Green Series to the Ordovician	638
(a) Palæontological Evidence.	
(i) Fossils north of the Green Series.	
(ii) Notes on the Northern Fossils.	
(iii) Fossils south of the Green Series.	
(iv) Conclusions from the Palæontological Evidence.	
(b) Stratigraphical Evidence.	
(i) Nature of the Boundary.	
(ii) Proofs of an Unconformity.	
(c) Conclusion.	
IV. Earth-movements and their Effects	650
(a) Contortions and Folds.	
(b) Dislocations.	
(c) Cleavage.	
(d) Crushing.	
(e) Disruption.	
(f) The Crush-Breccias and Crush-Conglomerates.	
(i) Trwyn Pen-careg.	
(ii) Porth y Corwgl.	
(iii) The Cemaes District.	
(iv) Western part of the North Coast.	
(v) Dykes in the Crush-Zones.	
(vi) Method of Formation.	
(g) Age of the Movements.	
V. The Northern Complex and its Relation to the Ordovician... ..	667
(a) Limestones.	
(b) Quartzites and 'Quartz-Knobs.'	
(c) The Ordovician Rocks.	
(d) Relation of the Northern Complex to the Ordovician.	
VI. Summary	674
VII. Appendix on the Microscopic Study of some of the Rocks ...	675

I. INTRODUCTORY REMARKS.

THE northern part of Anglesey contains a group of rocks regarding the age of which geologists hold divided opinions. As the well-defined district in which they lie occupies the north of the island, the strata taken as a whole are known as the 'Northern District Rocks.' From their frequently twisted and contorted aspect, Prof. Hughes calls them the 'Gnarled Series.' These beds have a

general dip to the north or north-east, and consist mainly of green chloritic schists and grits, and greenish-grey and purple phyllites, slates, and shales. They are everywhere bounded on the south by black slates and shales of acknowledged Ordovician age. This boundary-line forms a curve running from coast to coast from near Carmel Head on the west through Llanfflewin to Porth y Corwgl on the east; it is shown on the 1-inch Survey map, and is considered by several geologists (among others, Ramsay, Hicks, Callaway, and J. F. Blake) as a line of dislocation—an ordinary fault according to Ramsay,¹ or according to later writers as a thrust whereby the Northern District rocks have been pushed over the Ordovician beds. Ramsay² believed this northern area to be mainly altered Cambrian strata, with some Lower Silurian (Ordovician) beds in the northernmost parts near Cemaes,³ though he could not here separate the rocks of the two systems.⁴ Dr. Hicks⁵ considered the beds north of the curved fault to be pre-Cambrian (Pebidian); Dr. Callaway⁶ also classified the beds as pre-Cambrian of the slaty (Pebidian) type. Prof. Blake⁷ concurring in the pre-Cambrian view, grouped the rocks into two sets:—the ‘Sedimentary Series’ and the ‘Disturbed Volcanic Group,’ both of which he assigned to the middle part of his ‘Monian System’; he also separated from them certain conglomerates and black shales in the northernmost part of the district as ‘undoubted Ordovician.’

On the other hand, Prof. Hughes⁸ has long held the opinion that the supposed fault is either non-existent or of little throw, and that the barren green and gnarled strata of the Northern District are intermediate in age, as they are in position, between the black Ordovician slates of the south and those of the north. Dr. Roberts⁹ supported this view, and in 1891 Sir A. Geikie also expressed his opinion¹⁰ that the whole of the Northern District strata were of Bala age. This view finds expression in the recently-published Index Map of England and Wales (Sheet 7).

¹ Mem. Geol. Surv. ‘Geol. N. Wales,’ 2nd ed. (1881) p. 236 & fig. 88.

² *Ibid.* pp. 234 & 242; Geol. Surv. Map, Sheet 78.

³ This is the spelling adopted by the inhabitants and the postal authorities, but the village is called Cemmaes on the Ordnance maps. For all other names I follow the spelling of the 6-inch Ordnance Survey map.

⁴ Geol. Surv. Eng. & Wales, Horiz. Sec. Sheet 40.

⁵ ‘Pre-Cambrian (Dimetian, Arvonian, & Pebidian) in Caernarvonshire & Anglesey,’ Quart. Journ. Geol. Soc. vol. xxxv (1879) p. 295.

⁶ ‘Archæan Geol. of Anglesey,’ *ibid.* vol. xxxvii (1881) p. 210; ‘Archæan & Lower Palæozoic of Anglesey,’ *ibid.* vol. xl (1884) p. 567.

⁷ ‘Monian System of Rocks,’ *ibid.* vol. xlv (1888) p. 514.

⁸ ‘Altered Rocks of Anglesey,’ Proc. Cambr. Phil. Soc. vol. iii (1880) pp. 346-347; ‘Geol. of Anglesey,’ Quart. Journ. Geol. Soc. vol. xxxvi (1880) p. 239.

⁹ Geol. Mag. 1881, p. 573.

¹⁰ Pres. Addr. Quart. Journ. Geol. Soc. vol. xlvii (1891) Proc. p. 132.

II. DESCRIPTION OF THE ROCKS.

By far the greater part of the area is occupied by the set of strata called by Prof. Blake the 'Sedimentary Series,' in contradistinction to a 'Disturbed Volcanic Group' which forms a strip in the northernmost part. As, however, this disturbed group appears to be as sedimentary as the former, I use the term 'Green Series' for the prevailing strata north of the Ordovician boundary, because they are characteristically of a greenish tint, though they have purple and yellowish bands in them. The 'Disturbed Volcanic Group' of Blake will for the present be called merely the 'Northern Complex.'

(a) The Green Series.

A careful and graphic description of these rocks is given by Ramsay in the 'Geology of North Wales,' the principal correction by later writers being to limit his use of the term schist. The strata on the whole dip to the north or, in the western part of the area, to the north-east; but these directions are not constant, especially in the western part. For instance, in the neighbourhood of Pen-yr-orsedd, Caerau, and Nanner the beds have a south-easterly dip, and near Groes-fechan they form a low dome. Various writers have pointed out the characteristic types of rock. The highly contorted Mynydd Mechell Schists occupy the centre of the curve of the boundary-fault; in part they are thoroughly foliated and crystalline, in part they are very quartzose and distinctly gritty, and they appear to be grits and shaly beds in which a crystalline texture and foliated character has been developed, sometimes to the complete obliteration of clastic structure. Dr. Callaway has recently shown that the foliation is more marked and the crystalline structure more complete as we pass southward to the boundary-fault.¹ I am inclined to think that they are in part foliated representatives of the Llanfechell Grits, a set of rather thickly-bedded green grits which succeed the schists to the north.

With the exception of the beds in the extreme north of Anglesey, the country north of the Llanfechell Grits is occupied by green slates with purple zones and numerous coarser gritty layers. The Rhosbeirio Shales of Dr. Callaway—soft greenish, purple, and yellowish-brown shales in the centre of the district, with a constant northerly dip—form part of this series; and similar beds may be followed across the strike as far as Cemaes. To the east of Amlwch they are extremely contorted or 'gnarled.' Grits (of a greyer type) again set in in some force in what appear to be the highest beds, along part of the northern coast, especially in the neighbourhood of Trwyn Cemlyn and Cerig Brith, and they are recognizable among the contorted beds near Point Ælianus.

It is generally considered that these slaty and gritty deposits contain a certain proportion of volcanic dust and ash, and, though

¹ Quart. Journ. Geol. Soc. vol. liv (1898) pp. 374-381.

my microscopic slides have yielded very little evidence of this, I have found a rock containing some volcanic fragments in the series near Taldrws, Cemlyn. The detailed stratigraphy of this Green Series is very complicated, and requires working out; but the succession may be provisionally stated as below, in descending order:—

- (1) Cemlyn Flaggy Grits, Phyllites, and Shales.
(=Llaneilian Beds in part.)
- (2) Rhosbeirio and Cemaes Shales and Slates, with Grit-bands.
(=Llaneilian Gnarled Series in part.)
- (3) Llanfechell Grit and Mynydd Mechell Chloritic Schists.

Numerous dykes and bosses cut through these beds. Some are acid, others basic, and opicalcites and serpentines also occur. Their relationships are interesting, but do not come within the scope of this paper.

(b) The Northern Complex.

This group of rocks lies along the coast, north of a line running almost due east-and-west from Mynydd Wylfa to Bull Bay, passing a little north of Cemaes Pier. Among these rocks are some that correspond with the Green Series farther south, but the bulk have a very different facies. Prof. Blake says that this part of the district may be roughly described as 'full of agglomerates, coarse ashes, quartz-knobs, limestones, and conglomerates.'¹ As some of these rocks owe their clastic appearance to crushing, their description may be more fitly left till the effects of earth-movements have been considered.

(c) The Ordovician Rocks.

These lie in the Northern Complex in strips and patches. They consist of conglomerates and pebbly sandstones, grey sandy shales, and black argillaceous shales with some ironstone. As they are found associated with the last-mentioned group, their fuller consideration will be also deferred to a later part of this paper.

III. RELATION OF THE GREEN SERIES TO THE ORDOVICIAN.

The arguments for and against the Ordovician age of the Green Series fall under two heads—palæontological and stratigraphical.

(a) Palæontological Evidence.

The Ordovician age of the Green Series has been inferred, on palæontological grounds, from certain fossils mentioned as occurring near Craig Wen and in a limestone near Carmel Head. Prof. Hughes discovered *Orthis Bailyana* and other *Orthides* in the beds cut through by the tramway at Craig Wen. These beds are not, however, part of the Green Series; Prof. Blake

¹ Quart. Journ. Geol. Soc. vol. xliv (1888) p. 517.

includes them in his 'Disturbed Volcanic Group,' and claims the fossils as pre-Cambrian (Monian).¹ As I have found abundant examples of *Orthis calligramma* in these beds, they are undoubtedly Ordovician; but the determination of their age does not carry that of the Green Series with it.

Sir A. Geikie mentions² a fossiliferous limestone near Carmel Head as proving the Bala age of the green beds; but it is worthy of note that, though Ramsay recorded that 'a few poor fossils'³ indicated a Bala age, his map shows that he was satisfied that the fossil-bearing bed was distinct from the Green Series. I have collected fossils from this limestone; but, as the relationship of this bed to the Ordovician and the Green Series is rather a question of stratigraphy, this point will be taken up again in dealing with the stratigraphical evidence.

We will now compare the fossils that occur in the rocks north of the barren Green Series with those that are found south of that series, as this should throw some light on the succession. For, if we consider the green rocks to be conformably interbedded between the Ordovician on the south and the fossiliferous beds on the north, we assume a general ascending succession from south to north, and we therefore ought to expect that fossils found along the northern coast will belong to a higher zone than any horizon occurring in the southern rocks.

(i) Fossils north of the Green Series.

Fossils have been known to occur at three localities in Northern Anglesey, namely:—the tramway at Craig Wen, already mentioned; Porth Padrig, near Cemaes; and in a limestone at another Porth Padrig, north-west of Mynachdy; but *Orthis Bailyana* is the only fossil hitherto identified. I have succeeded in finding identifiable specimens in several localities, and append a list.

(α) Porth Padrig. Black Shales.—Most of the forms have been sheared out of recognition, but I have collected the following graptolites:—

Didymograptus superstes, Lapw.
Dicellograptus sextans, Hall.
Climacograptus Scharenbergi, Lapw.
Diplograptus euglyphus, Lapw.

Cœnograptus gracilis, Hall.
Leptograptus sp.
Dicranograptus sp.

(β) In the same beds, in the Vicarage grounds above the Porth, I obtained:—

Paterula balcletchiensis, Dav.
Acrotreta sp.

Siphonotreta (?).

¹ Quart. Journ. Geol. Soc. vol. xlv (1888) pp. 523 & 542; Geol. Mag. 1890, p. 312. [This statement requires some modification, as Prof. Blake pointed out in the discussion, and I willingly make the desired correction. In his paper of 1888 he regarded the Monian age of these beds as only 'probable,' stating at the same time that he was 'quite ready, if possible, to receive the fossils as characteristic' of his Monian system.]

² Pres. Addr. Quart. Journ. Geol. Soc. vol. xlvii (1891) *Proc.* p. 132.

³ Mem. Geol. Surv. 'Geol. N. Wales,' 2nd ed. (1881) p. 229.

(γ) *Dicranograptus*-beds of Penterfyn.—Near a cottage called Penterfyn, south of Ogof Gynfor, are small quarries in flaggy ironstone interstratified with black, often pyritous, shales, some of the layers of which are crowded with *Dicranograptus* :—

Cænograptus gracilis, Hall.
Cryptograptus tricornis, Hall.
Dicellograptus intortus, Lapw.
Dicellograptus sp.
Climacograptus Scharenbergi, Lapw.
Dicranograptus ramosus, Hall.

Dicranograptus rectus, Hopk.
Diplograptus teretiusculus, Tullb., or
euglyphus, Lapw.
Didymograptus sp.
Lingula brevis, Portl.

(δ) At Ogof Gynfor, in pebbly grits, the following occur :—

Orthis vespertilio, Sow.
— (*Dalmanella*) *testudinaria*, Dal.
— *confinis*, Salter (?).
— *calligramma*, var. *Carausii*,
Salter.
— (?), small species with simple ribs.

Strophomena, cf. *Stropheodonta imbrex*,
var. *semiglobosina*, Dav.
Orthis or *Rhynchonella* (imperfect),
large form with very strong ribs.
Rhynchonella sp.
Crinoid-ring.
Trace of a trilobite.

(ε) At 100 yards east of Ogof Gynfor, in similar beds :—

Orthis vespertilio, Sow.
— (?), small species with simple ribs.

Rhynchonella sp.
Lamellibranchs, cf. *Ctenodonta*.

(ζ) At 120 yards north of Ogof Gynfor, near the boundary-fault. Beds similar to δ and ε yielded *Lingula*, cf. *tenuigranulata*, M'Coy.

(η) Craig Wen tramway. In ashy-looking flaggy beds Prof. Hughes found *Orthis Bailyana*, Dav.

I have also obtained :—

Orthis calligramma, var. *Carausii*,
Salter.

Orthis, cf. *confinis*, Salt.
— sp.

(θ) Limestone-blocks in Ordovician breccia, at the western Porth Padrig, north-west of Mynachdy, yielded :—

Stenopora (*Favosites*) *fibrosa*, Goldf.
Solenopora compacta, Bill. = *Tetradium Peachi*, Nich. & Eth. jun.
Prasopora Graya, Nich. & Eth. jun. ?
Monticulipora sp.
Orthis, perhaps *O. calligramma* or
O. flabellulum ?
? Operculum of a *Maclurea* resembling
M. matutina, Hall.

Operculum of a *Maclurea* like *M. Loganii*, Salt., or *M. Peachi*, Salt.
Large gasteropod, ? *Maclurea*.
Crinoid-stems and ossicles.
Cast of a portion of a trilobite
resembling *Illænus*.

(ii) Notes on the Northern Fossils.

The graptolites which have been identified by Prof. Lapworth and Miss E. M. R. Wood are all typical Glenkiln forms, and the black shales in which they occur may be assigned to the Upper Llandeilo, or the Lower Bala of some authors. The accompanying brachiopods, *Lingula brevis* and *Paterula balclatchiensis*, are also

Llandeilo forms. The latter species has hitherto been recorded, I believe, only in the Scottish Llandeilo.

For stratigraphical reasons it is almost certain that the pebbly sandstones of Ogof Gynfor and the neighbourhood lie below the *Dicranograptus*-beds of Penterfyn. All the species, too, occur as low as the Llandeilo, so that the Ogof Gynfor rocks may be looked upon as Upper Llandeilo. The commonest form in these beds was a small *Orthis* (? *Zygospira*) with simple ribs, which I could not identify. The *Lingula* is large, 1 inch long by nearly $\frac{3}{4}$ inch wide. Its frontal margin is missing, but in contour and size the specimen agrees with *L. tenuigranulata*. The fine granulation is not preserved, owing to the coarseness of the matrix.

It was most interesting to find, associated with these fossils, specimens of the so-called species *Orthis Carausii*, because the occurrence of this form in the *Orthis*-grits of Central Anglesey seems to be the principal reason why Prof. Hughes assigns the basement Palæozoic rocks there to the period of the Tremadoc Slates, though Dr. Callaway has questioned the correctness of this conclusion.¹ It only occurs occasionally at Ogof Gynfor, but one band in the Craig Wen tramway-beds was crowded with casts of the shell, and single individuals are to be found in other parts of the tramway. I have examined a large number of specimens and compared them with Davidson's figures and descriptions, and (by the kindness of Prof. Hughes) with specimens from Central Anglesey in the Woodwardian Museum. The concentric lines of growth are not so well preserved, though this may be due to the nature of the matrix, and a few examples very slightly exceed the dimensions given by Davidson; but the majority of the specimens are within those limits, and all of them, in number of ribs, relative convexity of valves, and internal characters, agree with *Orthis Carausii*. *O. Carausii* was separated as a distinct species from *O. calligramma* as much on account of its occurrence at a lower horizon (namely, Tremadoc and Lower Arenig) as from its smaller dimensions.² But we now see that in Northern Anglesey the *Carausii*-form occurs with *O. testudinaria*, *O. vespertilio*, etc.: that is to say, on the horizon of the ordinary *calligramma*-form; and the last-named is a very variable shell, frequently blending into the *Carausii*-type. There does not therefore seem sufficient justification for their separation into distinct species, and I follow Salter's first identification of this brachiopod as a dwarf variety of *Orthis calligramma*.

It is evident that *Orthis Bailyana* is not pre-Cambrian, and we may with confidence accept Davidson's statement that in Wexford (the only other locality where this species occurs) it is found with *O. calligramma*, *O. bifurcata*, *Leptaena sericea*, and *Favosites fibrosus*. These are taken to indicate a Bala age in Wexford, but the Anglesey beds are more likely to be Upper Llandeilo.

¹ Quart. Journ. Geol. Soc. vol. xxxvi (1880) p. 238 & vol. xl (1884) p. 580.

² Davidson, Monogr. Pal. Soc. (1882-1884) 'Brit. Sil. Brach.' Suppl. p. 183.
Q. J. G. S. No. 219.

Mr. B. N. Peach has examined the fossils from the limestone-blocks of the western Porth Padrig, and sends me notes concerning them. The relationship of these blocks to the breccias in which they lie will be dealt with later (p. 647), but it may be at once mentioned that in Mr. Peach's opinion the limestone cannot be of earlier date than Ordovician, and that it is in all probability of Llandeilo age. He has no knowledge of the occurrence of *Stenopora fibrosa* below the Llandeilo. Opercula of the *Maclurea matutina*-type are very common in the Durness Limestone, both in Sutherland and Skye. *M. magna*, *M. Logani*, and *M. macromphala*, McCoy, are found in the Stinchlar Limestone, Ayrshire, which is either uppermost Llandeilo or at the base of the Caradoc. At Mr. Peach's suggestion, I sent some microscopic sections from this Porth Padrig limestone to Dr. G. J. Hinde, who has very kindly examined them and found that they contain *Solenopora compacta*, *Prasopora Grayæ*?, (both these forms occur in the Craighead Limestones of Gairvan), and a species of *Monticulipora*.

(iii) Fossils south of the Green Series.

In the central area south of the Green Series the fossiliferous beds consist of basal conglomerates which rest unconformably on older rocks or are faulted against them, and pass up through sandstones into black shales. The basal conglomerates and grits are locally rich in the *Orthis* referred by Prof. Hughes and Dr. Davidson to *O. Carausii*. Accompanying this species have been found fragments of trilobites considered by Dr. Woodward and Dr. Callaway to be *Ilænus*, *Asaphus*, and *Ogygia*, but by Prof. Hughes and Dr. Hicks to be *Niobe* and *Neseuretus*.¹ In several localities the black shales have yielded graptolites.² The lowest horizon indicated by them in this central area is at Caemawr, where *Didymograptus Murchisoni* occurs. From Llysdulas *Climacograptus coelatus* has been identified; from Llanbabo *Diplograptus* (probably *D. foliaceus*), *Dicranograptus ramosus*, *Climacograptus Scharenbergi*, *Dicellograptus Morrisi*, and *Leptograptus* sp. From the black slates of Parys Mountain *Monograptus gregarius* and other species belonging to the *M. gregarius*-zone (Lower Birkhill) were obtained. At Treiorwerth Henslow found some fossils, mostly brachiopoda, which Prof. Hughes with some hesitation has also referred to a Llandovery horizon. They appeared to the latter to include such forms as *Atrypa marginalis*, *Strophomena rhomboidalis*, *Meristella angustifrons*, *Orthis* including *O. calligramma* (?) and var. *plicata*, *Petraia elongata* (?), and *Nebulipora* cf. *lens*.

In other parts of Anglesey, cut off from this central area by outcrops of pre-Cambrian rocks, fossiliferous Ordovician strata occur.³ Near Llangwyllog there are graptolites typical of the highest Arenig or lowest Llandeilo. In North-eastern Anglesey Mr. Greenly has found black-shale boulders with *Climacograptus bicornis* (?), and

¹ Quart. Journ. Geol. Soc. vol. xl (1884) pp. 579 & 589.

² *Ibid.* vol. xxxvi (1880) p. 238, vol. xxxviii (1882) p. 26, & vol. xl (1884) p. 580.

³ *Ibid.* vol. xxxvi (1880) p. 238 & vol. lii (1896) p. 628.

recently he has recorded undoubted Arenig fossils (*Didymograptus patulus*, *D. nitidus*, *D. extensus*?, *Climacograptus*?) from the Caernarvonshire side of the Menai Bridge.¹

The sole evidence for assigning the basal Protozoic rocks of Central Anglesey to a Tremadoc horizon is the occurrence of the fragmentary and disputed trilobites mentioned on p. 642, and the presence of *Orthis Carausii*. I have shown that this brachiopod is found a few miles away in Llandeilo Beds. There is a marked absence of typical Arenig graptolites, such as *Tetragraptus* and *Phyllograptus*, and the lowest zonal graptolite, *Didymograptus Murchisoni*, indicates a Lower Llandeilo horizon. The evidence of Tremadoc age should therefore, as Dr. Callaway has already argued, be rejected until further proof be afforded. It is much more likely that the fossil-bearing beach-rocks of Central Anglesey are equivalents of the base of the Llandeilo, or the top of the Arenig, and there is in this area a succession through the Llandeilo and Bala into the Llandovery horizons noted at Treiorwerth and Parys Mountain.

(iv) Conclusions from the Palæontological Evidence.

We see, then, that the southern Ordovician contains fossils from early Llandeilo to the Llandovery. The northern Ordovician commences rather higher in the Llandeilo, and ranges perhaps into the Bala. The palæontological evidence is therefore distinctly opposed to the theory that the Green Series is of Bala age, interbedded between older strata on the south and newer strata on the north. That theory was first suggested by Prof. Hughes, at a time when fossils from the area were almost unknown, because he thought that it afforded a simple and natural explanation of the geological structure. But this simplicity of structure is shown by the fossils to be untenable. We have to imagine an almost complete inversion of the strata, and even then we have to account for the mysterious absence of the Green Series between the Llandovery and the basement-rocks of the central area. On palæontological grounds alone it seems necessary to abandon the theory; if not, we land ourselves in stratigraphical complexities far more improbable than those which the assumption of a Bala age for the Green Beds was intended to remove.

The fossils bring out another point which is worthy of discussion, namely, that the conglomerate in Northern Anglesey seems to be on a higher horizon than the Ordovician base in Central Anglesey; in the latter area it is below the zone of *Didymograptus Murchisoni*, in the north it appears to be well above that zone. This may be explained on the reasonable assumption of an overlap to the north, such as would result from a continuance of the conditions which caused the overlap of the successive horizons of the Cambrian when followed from Merionethshire northward. Anglesey seems to have remained dry land throughout the Cambrian period, and if its more elevated portion lay in the north of the present island when it was slowly submerged in Ordovician times, the old beach creeping up the slopes of the sinking land would there be of later date.

¹ Geol. Mag. 1898, p. 561.

(b) Stratigraphical Evidence.

Not only is the palæontological evidence strongly against the Bala age of the Green Series, but stratigraphical considerations are equally conclusive, although some writers have adduced evidence that part of the boundary cannot be anything but a bedding-plane. That the Green Series is older can be demonstrated in two ways: (i) by an examination of the boundary, and (ii) by proofs of an unconformity.

(i) Nature of the Boundary.

The boundary is mapped by the officers of the Geological Survey as a simple curved line, broken south of Amlwch by a cross-fault. In so crumpled a region as Anglesey the simplicity of the dividing-line is in favour of its being a dislocation. Ramsay¹ inferred the necessity of a fault from the dying-out of the dykes at the junction, and Blake² because the boundary brings together various parts of the two series. As Dr. Callaway³ has already examined this junction, especially with reference to the eastern half, I have contented myself with examining it in that portion at only a few localities, but have devoted more attention to the western part of its course. At its eastern extremity, in the little cove of Porth y Corwgl, it is admitted to be faulted, and the hade seems to be steeply to the north. North of the break are the highly-crumpled or 'gnarled' green rocks; south of it are Ordovician slates, grits, and pebbly slates, which are so broken as to become in part a 'crush-conglomerate.' The movement producing the dislocation is therefore clearly one of compression. Dr. Callaway has pointed out that conglomeratic Ordovician beds fringe the boundary for about 2 miles; he suggests that we are near the base of the Black Slate Series, and that the Ordovician is here inverted. Prof. Blake has examined the two localities farther to the south-west, where Dr. Roberts⁴ states that the Ordovician can be traced quite uninterruptedly into the Green Series, but he does not consider that the exposures justify the latter's conclusions.⁵ Nowhere did I find a passage between the two series. At Bothedd, where a passage has been suggested,⁶ the Ordovician black slates are interbedded with bands of grit and breccia whose green colour at first sight suggests a transition; but these bands are very distinct from the apparently overlying rocks, and owe their colour to the circumstance that they are largely made up of green fragments such as are found in the Green Series. A microscopic section (N.A. 49)⁷ of one of these bands shows it to be a grit almost entirely made up of fragments of fine phyllites, generally sericitic, a few quartz-grains, and some chloritic shales. The clastic structure is not due to crush. The presence of

¹ Mem. Geol. Surv. 'Geol. N. Wales,' 2nd ed. (1881) p. 235.

² Quart. Journ. Geol. Soc. vol. xlii (1888) p. 514. ³ *Ibid.* vol. xl (1884) p. 567.

⁴ Geol. Mag. 1881, p. 573.

⁵ Quart. Journ. Geol. Soc. vol. xlii (1888) pp. 515 & 529.

⁶ *Ibid.* vol. xlvii (1891), Pres. Addr. *Proc.* p. 132.

⁷ The numbers in parentheses are those of the slides in my cabinet.

these bands suggests again that we are near the overturned base of the Ordovician. Beds of very similar character occur in the black shales about $\frac{3}{4}$ mile farther on, and also on the eastern slopes of Mynydd-y-Garn.

It may be remarked that along most of the course of the fault the green beds are generally crumpled and crushed, the neighbouring black shales are frequently similarly affected, and small outcrops of white quartzite, evidently introduced by the movement, occasionally mark its track.

At Caerau the fault splits; the more northerly branch brings in a V-shaped Ordovician outcrop north of Mynachdy, the north-westerly emerges at Porth yr Ebol. The former runs from Caerau through Mynachdy Lodge to Porth Newydd. For the first part of

Fig. 1.—*Eastern side of Porth yr Ebol.*

AB, CD=Intersecting thrusts. 1=Green flaggy slates, much crushed and brecciated. 2=Ordovician blue-black slates.

its course the Green Series, represented here by a purple slate, is brought against the granite and altered rocks of Mynachdy, the characteristic bed along the junction being a white quartzite, but mingled with it are patches of limestone, grit, blue and dark quartzite, and black shale. Farther north the Ordovician comes on, and the junction, though invisible, is unmistakably faulted. The dip and strike of the two series are discordant; on the north side the beds are shattered by hundreds of tiny horizontal faults, and on the south the black shales are highly compressed, and courses of sandstone in them are squeezed into lenticles.

The more westerly branch of the fault can be traced without difficulty from near Mynachdy to Porth yr Ebol, where it may be seen as an irregular synclinal curve in the cliff that forms the eastern side of the Porth (fig. 1). This undulating junction has caused it

to be mistaken for a bedding-plane, but the bands in the two series strike against each other. Its true character can be seen more plainly in a little creek that has been eroded at right angles to the trend of this cliff near its seaward termination, where the thrust AB can be seen rising steadily to the westward at an angle of 20° , and bringing the green beds over the younger Ordovician. This little creek has been eroded along another overthrust CD, which has here a nearly east-and-west course, and again brings up the Green Series. The thrust CD is a somewhat later movement than AB, and its pressure has bent the earlier thrust-plane, thus accounting for its synclinal curve. The green beds are highly crushed and so broken as to be practically crush-breccias, and are much rolled out near the junction. The Ordovician rocks are also much crushed (N.A. 89 & 90).

The later thrust has here an inclination of 60° to the horizontal. Its course can be readily followed in a west-north-westerly direction, first across the shore and then inland in front of the lower

Fig. 2.—Sketch-map of
the North-western corner
of ANGLESEY.

Shaded areas = Ordovician.
Unshaded areas = pre-Llandefllo.

Scale: 2 inches to 1 Mile.

beacon. Its inclination decreases to 30° , and continues to flatten, as shown by the course of its outcrop on the rising ground. It finally passes out to sea in the unnamed Porth south of Porth y Wig, where an almost level platform has been worn along the junction. The underlying beds are the Ordovician slates. The overthrust beds are greenish-grey gritty phyllites, as a rule highly contorted and smashed, and showing microscopically evidences of movement. They are succeeded at Carmel Head by beds with broken limestone and quartzite, where they form almost a 'crush-conglomerate.' In Porth Gron, heading north-west at 45° , can be seen another thrust forcing the Green Series over contorted grey Ordovician slates; but perhaps enough detail has been given to prove that the asserted interstratifications of the two series are the deceptive results of earth-movements. Fig. 2 shows the course of the principal faults and thrusts in this corner of the island.

There still remains the point brought forward by Sir A. Geikie, that a limestone with Bala fossils exists on the shore in the north-western part of the island, and that it forms part of the Green Series. This limestone occurs in the Ordovician tract near Mynachdy, at the base of the Black Slates in a cove called Porth Padrig.¹ It is not found as a bed, but as abundant limestone-blocks, more or less rounded, lying in a thick greyish breccia, below which lies a patch of black shale, and streaks of this shale run up in irregular strings into the limestone-breccia, denoting considerable disturbance. Above this breccia are black shales of the ordinary Ordovician type, with which are interbedded several breccia-bands. These thinner breccias also contain limestone-blocks, some almost as thick as the bands in which they lie. The coarse fragmental deposits in which the limestone-masses occur appear to be the local equivalents of the basal conglomerates of Ogof Gynfor and Porth Llanlliana, and therefore may be considered of Upper Llandeilo age, while the limestone-fossils, according to Mr. Peach, are also Upper Llandeilo. Although, therefore, the limestone-blocks look like pebbles and boulders of ordinary clastic origin, the palæontological evidence is against this view, and we seem to be confronted with the same phenomenon as in beds of about the same horizon in Southern Scotland, where limestone-nodules of contemporaneous age lie in the midst of conglomerates. This confirms Ramsay's conclusions² respecting this limestone, as he speaks of these masses as 'irregular bands,' 'thin irregular bands,' and 'concretionary half-crystalline limestone.' In their lower part they may also have undergone some breaking-up by movement. Mr. Peach adds the following to his notes respecting the fossils from this locality:—'From what I have seen of the limestones in the Southern Uplands of Scotland, I should think that this limestone is of approximately the same date as the conglomerate in which it occurs: that is, that the limestone-masses are not derived pebbles, but that they are in some way formed in place. The manner in which the quartz-pebbles are enclosed in them points to this conclusion. The Stinchar Limestone, where it thins out, is represented as a series of knots or masses in the heart of the Benan Conglomerate with which it is associated. The same is the case with the limestones of Wrae and Glencotho, and also with the fossiliferous conglomerates of Kilbueho and Duntereleuch in the Lead Hills, where the fossils are found in calcareous concretions and masses similar to these limestone-knots.'

These inconstant nodules are therefore Llandeilo limestones lying in Ordovician breccias. They do not form part of the Green Series, nor can we correlate them with the Cemaes limestones. The latter are unfossiliferous, differ in texture, weather in a different way, and retain their characteristic appearance in an exposure at Carmel Head not very far from the outcrop of this Llandeilo rock. The presence of these fossils, therefore, throws no light on the age of the Green Series.

¹ Not to be confounded with the larger Porth of the same name near Cemaes.

² *Mem. Geol. Surv. 'Geol. N. Wales,'* 2nd ed. (1881) pp. 229, 242, & 246.

Fig. 3.—Section at Ogof Gynfor, near Llanbadrig : (length = 200 yards).

(ii) Proofs of an Unconformity.

The evidence detailed in the foregoing pages affords ample proof that the Green Series is older than the recognized Ordovician rocks of the district. It remains to be seen whether the two sets are conformable or unconformable to each other. If unconformable, we may hope to find somewhere the Ordovician (1) lying on the denuded edges of the Green Beds, or (2) containing fragments derived from them. An example of the first kind has been instanced by Prof. Blake at Ogof Gynfor, and of the second by Dr. Callaway in the included fragments of the conglomerates of Pyttiau near Llaneilian.¹

Ogof Gynfor lies on the north coast near Llanbadrig, among the rocks which I have called the Northern Complex. There is a consensus of opinion that the rocks occurring here are an upward continuation of the Green Series: so that, if there is an unconformity of the Ordovician in respect to this northernmost group, there must be a still greater unconformity with regard to the Green Series. I have ventured to produce a figure of the coast-section (fig. 3), partly because it illustrates how very broken even the Ordovician beds are, and partly because it

¹ Quart. Journ. Geol. Soc. vol. xlv (1888) p. 519 & vol. xl (1884) p. 568.

shows some very interesting and unmistakable examples of thrust-planes. The section, which extends farther south than Prof. Blake's figure, differs from his in some respects, but differences may well be expected, for the section has to be constructed piecemeal as it is slowly revealed by scrambles over the rocks. Parts of the section are inaccessible, and some of the details are doubtful, but in its main features it will be found correct.

The Ordovician beds occupy a faulted syncline, overthrust on the north, as Prof. Blake has pointed out, by limestone-beds. That the fault is an overthrust one is rendered unmistakable by the series of small thrust-planes which branch from the main fault, and clearly indicate that the basal conglomerates have been moved in successive steps across the succeeding sandy shales. The uppermost plane represents a travel of about 15 feet, and the curling round of the broken edges of the beds to lie in the plane of movement is well exhibited. These conglomerates are seen in one place to lie on greenish gritty phyllites which contain bands of fine grit and white quartzite. The junction is undulating; there has certainly been some movement along it, and the underlying rocks (N.A. 46 & 47) are highly crushed and have become augen-sericitic schists or phyllites. These changes seem, however, to have taken place to some extent before Ordovician times, as pieces of sericite-schist occur in the conglomerates, and I think that the relationship of the beds really represents an unconformity. Moreover, at the head of the gulf the conglomerate lies against a white quartzite: pebbles in the former appear to be derived from the latter; and the same relation between quartzite and quartz-conglomerate is to be seen at other localities in the neighbourhood, as well as on the headland of Porth Llanlliana. The conglomerates are largely made up of white quartz and quartzite-pebbles, which closely resemble the 'quartz-knobs' of the vicinity, and they contain also occasional identifiable fragments of green slate, limestone, and other rocks that occur *in situ* close by.

Dr. Callaway found a similar assemblage in the conglomerates fringing the boundary-thrust at Pyttiau, but there they contained an abundance of limestone-blocks which corresponded exactly with the Cemaes limestone. The phenomenon of Llandeilo limestone-masses in the basal breccias at the western Porth Padrig must, however, make us very cautious in accepting the presence of calcareous inclusions as proof of an unconformity.

Perhaps, however, the most convincing proof is to be derived from an examination of the geological structure of Mynydd-y-Garn, a faulted inlier, mainly of contorted beds of the Green Series, lying in the midst of Ordovician ground. The summit and the eastern part of the hill are built up of a massive and crushed coarse conglomeratic breccia, which passes up, through slates interbedded with breccia and grit-bands, into the ordinary black shales of the Ordovician. This massive breccia is the result of the denudation of granitic, gneissose, and schistose rocks, granulites, grits, etc.: indeed, such an assemblage as may be found *in situ* on Pen Bryn-yr-Eglwys, 2 miles distant. The southern part of the inlier contains typical beds of the Green

Series, consisting of highly crumpled, green, altered slates, agreeing closely with some seen near Llanfair-y-nghornwy Rectory, about $\frac{3}{4}$ mile away. At the southern boundary the Ordovician black slates can be seen dipping into the hill, and there appears to be an inversion accompanied by a thrust, the emergence of which sweeps round the south of the hill to the western side, where it merges into and may form part of the fault that here too brings the Green Series and the Ordovician ground into juxtaposition. At the south-eastern extremity, in the yard of the cottage called Cefn-du-mawr, the black shales which dip into the hill are interbedded with numerous bands of a green breccia unmistakably made up of fragments of the green altered slates. These fragments, like the parent-rocks, are in the condition of sericitic phyllites, and afford the clearest evidence that the Green Series had not only been exposed to denudation in Middle Ordovician times, but that the green rocks had even at that period undergone considerable alteration.

(c) Conclusion.

Both palæontology and stratigraphy make it impossible to arrive at any other conclusion than that the Green Series is older than the recognizable Ordovician. The disposition and dip, and even the apparent interstratifications of the rock-groups, are no guide to the true structure of the district, which is comparable in these respects with such regions of powerful earth-movements as the Alps, the Scottish Highlands, and other mountain-ranges. The barren green rocks have been brought up and driven southward over black Ordovician and perhaps even Silurian slates by a great thrust which extends from sea to sea in a sweeping curve. This thrust is steeply inclined at its eastern end; at its western end it shows the low slope characteristic of the thrust-planes of the North-western Highlands. I have instanced other thrusts of varying hade which also bring the Green Series over the Ordovician, while the latter is elsewhere seen to lie with a strong unconformity upon the green beds and to contain fragments derived from them.

As to the actual age of the Green Series, all that Northern Anglesey teaches us at present is that these beds are older than the Llandeilo, and had been subjected to alteration, foliation, and denudation before Upper Llandeilo times. Geologists who have worked over the whole of Anglesey find them to agree so closely with rocks in other parts of the island, which they consider pre-Cambrian, that a similar age for the Northern Anglesey rocks must be provisionally conceded.

IV. EARTH-MOVEMENTS AND THEIR EFFECTS.

The foregoing account will have made it evident that Northern Anglesey is a region affected by powerful earth-movements that have bent, folded, broken, crushed, contorted, and overturned the

strata; in certain parts there is also extensive disruption of the beds, resulting in the phenomena known as 'crush-conglomerates.' These various effects will now be considered.

(a) Contortions and Folds.

In the south of the district the chloritic schists of Mynydd Mechell are thrown into contortions which are everywhere visible in the bare rocky hills which they occupy. The individual folds, though small, are not as a rule sharp, nor do their axes seem confined to one particular direction. In the north-east, stretching for several miles along the coast between Amlwch and Point Ælianus and extending southward to the bounding thrust, is another and more sharply-contorted area, described by Ramsay and other writers. Beds of the same character, and showing similar fine contortions, occur elsewhere, as for example near Llanfair-y'ngornwy Rectory (see fig. 4), where the beds have a beautiful damascened appearance. Here, as in most cases, the axes of the folds slope in the

Fig. 4.—*Contorted green phyllites: part of rock-face in quarry behind Rectory, Llanfair-y'ngornwy.*

same direction as the dip, and the inference from this general southerly to south-westerly tilt of the crests of the anticlines is that the region has been affected by a powerful push acting as a whole from the north: a conclusion which is in harmony with the general structure of the district, as developed in the first part of this paper.

Even where the dip is at first appearance quite steady, a close examination or more favourable exposures will show in some cases that small contortions interfere with the apparent steadiness. An example of this may be seen in the Rhosbeirio Shales of Bodewryd Newydd quarry, and I have noticed a number of other instances, some in the neighbourhood of the crush-conglomerates. Between Trwyn Pen-careg and Cemlyn there is continual over-folding to the south and consequent repetition of the beds; here too are instances of folds in which the axes are almost horizontal.

In the region north of Cemaes the rocks have mostly been smashed instead of forming contorted folds, but in the shaly limestone of Pig y Barcud and elsewhere there are beautiful contortions on a small scale. The intensity of the folding may be well seen in the large limestone-quarry of Trwyn y Parc. This limestone exhibits in the mass no definite dip or strike, and bedding can rarely be made out, except where a coal-black crushed band of shale twists about on the south side of the quarry, or where thin black carbonaceous films make the structure evident. The limestone has the appearance of being built up into vertical prisms, and, save for the colour of the rock, the observer might readily imagine that he was looking at a quarry of basalt exhibiting vertical columns and joints. Though the structure of the massive limestone has been largely masked by jointing, etc., two remarkable folds in the quarry show that it has also been intensely folded. These folds face each other on opposite sides of the quarry. That on the north side shows the junction of the limestone with the overlying beds, which are represented by broken shaly material weathered into a muddy mass. The limestone has been curled up on every side into a basin-like fold with vertical sides, in shape like the bowl of an egg-cup or wine-glass, which would be better seen if the soft shaly stuff in the interior were scooped out. The axis is vertical and the curving-in of the encircling wall of limestone to form the base of the cup can be well seen. The diameter of this fold varies but slightly, say, from 4 to about $4\frac{1}{2}$ yards. The front has been quarried away, and the upward continuation of the fold has also been removed by quarrying or denudation. The second fold, which is similar but not so regular, is to be seen 30 yards to the south on the opposite side of the quarry, and this too is filled in by a weathered mass of broken yellowish-green and black shaly material with less weathered harder pieces that represent the strata succeeding the limestone.

Such folds as these cannot be produced by earth-movements acting in any single direction. We must have a combination of forces acting either simultaneously or consecutively in at least two directions, and these directions, if only two, would have to be at right angles to each other. One of the folding forces may be taken as having acted transversely to the north-and-south line that joins the centres of these two folds, that is, in an easterly or westerly direction. This leaves for the second force the movement from the north to which reference has already been made.

(b) Dislocations.

Faults form so commonly the junctions between the rock-groups as to make the relationship of the various strata to each other a matter of extreme difficulty. The section at Ogof Gynfor (fig. 3, p. 648) affords a good instance of the terribly fractured nature of even the Ordovician rocks of the district. It exhibits normal faults, reversed faults with a more or less curved fracture, and gently sloping thrust-planes. We have already seen instances of dislocations on a larger

scale in investigating the relations of the Green Series to the Ordovician, and similar dislocations of the rocks are common in the Northern Complex of Cemaes and Porth Wen. The older rocks here crop up in strips between newer beds, and are bounded on one side by a normal, on the other by a thrust-fault. I have detected a number of each kind in the cliffs of the north coast, and others are inferred from the stratigraphy. The line of fracture of the reversed faults as exhibited in coast-sections is often not straight, but a more or less sigmoidal curve, and overfolds can be sometimes seen in connexion with them. One such broken overfold is visible in bedded quartzites, south of the graptolitic shale of Porth Padrig, and another example is seen in the 'quartz-knob' at Llanbadrig Point (Trwyn y Buarth); see fig. 5. Of this knob Prof. Blake¹ says

Fig. 5.—Section in quartz-knob, Llanbadrig Point.

[Heavy lines denote shear-planes.]

- 1 = Quartzite.
- 2 = Slaty beds with broken pieces of limestone (= crush-conglomerate).

'the phenomena here are those of ordinary faulting, resulting, not from pressure, but from tension. We cannot get this quartz-knob into its place by folding.' But an examination of the quartz-rock of this small headland shows several polished planes of shear which curve down into the sea and along which the waves have found lines of weakness. Out of these curving shear-surfaces curve other surfaces of shearing. The neighbouring rocks are crush-breccias and the

¹ Quart. Journ. Geol. Soc. vol. xlv (1888) p. 518.

section indicates to my mind not 'ordinary faulting resulting . . . from tension,' but thrust-faulting due to pressure.

In connexion with the overfolding mentioned as occurring around the shores of Cemlyn Bay, there seems to have been plenty of shearing movement on a small scale at an angle agreeing with or only slightly oblique to the bedding. It is often difficult actually to prove this, although some of the planes are unmistakable. Movement gently oblique to the beds is inferred from the curious 'wedging-out' of individual strata when followed either along the dip or the strike. Individual laminae are seen to terminate along some of these planes; this produces an appearance of false or current-bedding, but it is due, I think, to the truncation of the laminae by shear-planes.

There are other horizontal faults which indicate a general shaking and shattering of the beds rather than a movement in a definite direction. Such are the tiny dislocations already mentioned near the Porth Newydd fault, where hundreds of them are revealed by the banding of some nearly vertical beds. A small portion of a rock-face exhibiting twenty-eight of these miniature faults is shown in fig. 6.

Fig. 6.—*Porth Newydd: small horizontal faults in the cliff north of the Ordovician boundary.*

(c) Cleavage.

The phenomena of cleavage have not been closely studied, but a few points may be brought forward. Though the rocks have been subjected over the whole of the area to close compression, yet it is only in a few localities that they are seen to split obliquely to the bedding. The black shales of the Ordovician around Carmel Head are sometimes changed to argillaceous slates, and the coarse, black-banded, grey, sandy shales (also Ordovician) of Llanlliana and the neighbourhood are similarly cleaved, but less perfectly. Along these planes quartz-veins frequently appear. Even the conglomerates have been affected, and new structural planes are seen to cut across the bands of pebbles and determine the splitting of the mass.

The strike of the most evident cleavage is more or less east-and-west, but does not always agree with the strike of the rocks. In

[Distance between bands=about 1 inch.]

the area north of Craig Wen, where folds in the conglomerates and grits are often concealed by cleavage-planes, I noticed a divergence of some 15° between cleavage-strike and bedding-strike. Weathering sometimes brings out other systems of close-jointing, which may be earlier cleavages more or less obliterated by the pressure which produced the principal cleavage. For instance, the limestone and jaspers masses in the 'crush-conglomerates' at Penrhyn, near Cemaes, have such a set of vertical planes at right angles to the already-noticed cleavage-strike. A third set is sometimes noticeable agreeing in strike with the principal cleavage, but dipping northward at a much gentler angle. The facts suggest a series of movements in Anglesey very similar to those that produced the three cleavage-systems noticed by Mr. Lamplugh in the Isle of Man; but the point requires further attention.

(d) Crushing.

In the ordinary parallel cleavage described under the last head there is little or no sliding movement, the particles of the rock retaining as a whole the same position relatively to their neighbours before and after the compression. A further stage in the effects of compression is the differential movement of the molecules of the rock, causing them to slide past each other, and resulting as a rule in a phacoidal structure and a wavy cleavage. This breaking-down of the original structure by shearing movements is usually accompanied by a development of a micaceous mineral, such as sericite, that renders the divisional planes glossy. Hard and resistant fragments included in the rock tend to be pulled out into phacoids, or to be rolled out into strings, or to break up into minor fragments. All stages up to complete mylonization may be observed.

The breaking-up of rocks into phacoids is best known on the minute, but occurs also on the macroscopic scale. A good example is to be seen south of the graptolitic shales of Porth Padrig, in a yellowish-brown sandy rock. Again, a mass of limestone on the coast 250 yards north of Ogof Gynfor is similarly divided by curved joints into lenticles. These are not by any means solitary instances.

On the smaller scale we have an 'augen'-structure developed in fine grits, as, for example, in Porth Padrig (underneath a broken overfold, N.A. 9) and in the older beds of the Ogof Gynfor unconformity (N.A. 46 & 47). Similar structures are common north of Craig Wen, and interbedded with the Craig Wen quartzite are shales which in part are practically mylonites (N.A. 43).

Compression and shearing have had a marked effect on some of the conglomerates of the northern coast, and the results may be studied on both sides of Porth Wen Bay and in some localities inland. The pebbles have been sometimes flattened, sometimes pulled out into long phacoids or even strings of quartz or quartzite, at other times chopped into pieces by parallel planes of movement and thoroughly brecciated.

(e) Disruption.

Instances of the partial breaking-up of bands of rock may be noted outside the bounds of the crush-conglomerates themselves. An excellent example is to be seen in the Ordovician of Porth Newydd, a cove situated north-west of Mynachdy, near the western end of the Northern District boundary-fault. The ordinary black Ordovician shales are here interstratified with courses of grit, and the breaking-up of these grit-bands is shown in the cliff in the clearest manner. The appended sketch (fig. 7) shows that these courses are

Fig. 7.—*Disrupted grit-courses in Ordovician black shales,
Porth Newydd.*

[The two lowest grit-bands are introduced from another part of the section.]

broken into longer or shorter pieces, lying quite dissociated one from the other, and strong transverse cracks indicate the commencement of further disruption. The ends of some of the pieces are pointed, those of others bluntly rounded. One of the bands has become a string of phacoids or lenticles, which a very little more pinching would have separated into distinct pieces. The shales have a general undulating dip to the north, and would not of themselves have suggested that the strata had been subjected to such powerful forces as those to which the disrupted grits testify. A little farther south more

complete disruption is observed, the pinched-out bands being there separated into distinct lenticles. A microscopic slide (N.A. 56) cut from near the surface of one of the bands figured in the sketch shows that the grit is considerably crushed and schistose.

In the example just given the grit-courses do not exceed a few inches in thickness, but disruption of thicker beds of Ordovician grits has taken place at the eastern end of the district, south of the bounding fault at Porth y Corwgl. In the face of the quarries south of the Porth may be seen, lying at intervals in the Black Slates, discontinuous masses of grit; they are evidently parts of bands similar to those seen a little farther north, which are clearly interbedded with the slates. Similarly-shaped isolated bands of conglomerate are shown by Prof. Blake in his figure of Porth Wen, west side.¹

North-west of Cemaes Pier, near Penrhyn, the fine slaty shales contain numerous thin layers of tougher or more indurated material, which, if followed for a few inches, are seen alternately to thicken and thin in a lenticular way and quickly die out. This irregularity of bedding seems best explained as an example, on a smaller scale, of the disruption exhibited in Porth Newydd. Fig. 8 (p. 658) shows this breaking-up in a small overfold.

(f) The Crush-Breccias and Crush-Conglomerates.

The completely disrupted strata known as 'crush-conglomerates' may be looked for, if we take the Manx examples as our guide, along zones of powerful crushing, especially in areas where the soft, fine-grained, slaty rocks alternate with tougher and more brittle strata, such as grits and quartzites. Most of the crush-conglomerates which I am about to describe are indeed formed mainly of lumps of hard quartzose beds in a finer matrix, and in some cases they can be traced into areas where these harder portions form recognizable interbedded bands. The occurrence and significance of such beds in Anglesey seem to have been recognized to some extent so long ago as 1880 by Prof. Hughes (although he does not specify any localities) in his paper 'On the Altered Rocks of Anglesey.' The following extract² has most bearing on the subject:— 'When on a small scale nodules, or on a large scale masses, of hard rock lying in compressible shale are subjected to contortion, the shale is squeezed out over the harder masses, producing a kind of fault all round between the harder and softer rock, and giving rise to slickensides and similar phenomena, and often mineral changes are set up along the parts thus more crushed. In the case of a crumpled and gnarled shale in which there are thin laminæ of harder and softer beds, this unequal yielding must produce similar results, and a kind of slickensides must pervade the whole mass.'

Some of these rocks were described by Prof. Blake in 1888 as volcanic agglomerates, and were included by him in his 'Disturbed

¹ Quart. Journ. Geol. Soc. vol. xlii (1888) p. 521, fig. 23.

² Proc. Cambr. Phil. Soc. vol. iii (1880) p. 344.

Fig. 8.—Section 300 yards north-west of the pier, Cemaes (about $\frac{1}{3}$ nat. size).

Volcanic Group.' He remarks upon their unusual features, in some localities especially, as in Porth Wnol, where 'there is wild confusion in the rocks. The most remarkable feature is the occurrence of great quartz-lumps, which are of all sizes and shapes, and lie promiscuously in agglomerates of slates, grit, and dust. . . . They must have been in existence previous to the formation of the agglomerate, which we cannot here refer to the action of a crush-fault. . . . In the headland of Pen-y-parc we get another agglomerate of quartz-lumps and ash.'

In 1896 Sir A. Geikie, in a short communication to the British Association, announced² that he was convinced, in the light of the Manx examples, that these breccias are crush-conglomerates, produced by the breaking-up of stratified rocks (mainly grits and slates) *in situ*. The limestone-masses he refers to the disruption of some of the limestone-bands of the neighbourhood. He, however, points out that the strata which have been disrupted are largely composed of volcanic detritus, so that the arguments he originally based on the volcanic nature of these beds are not disturbed.

Prof. Blake has expressed his inability to concur in this 'crush-conglomerate' theory, mainly on the ground that the Anglesey agglomerates are composed of 'a variety of rocks not like those of the immediate neighbourhood.'³

(i) Trwyn Pen-careg.—The example of a crush-conglomerate that will be first noticed is to be found on Trwyn Pen-careg, a headland east of Cemlyn Bay, and it is selected for first description as it occurs here in its simplest form and offers an intermediate stage between the broken grit-bands of the Ordovician of Porth Newydd and the more complicated disruption to be seen west of Cemaes. Immediately north of Trwyn Pen-careg lies Cerig Brith, with which the headland is connected by a shingly beach when the tide is low. The promontory of Trwyn Pen-careg itself terminates in a small cliff of crush-conglomerate of a somewhat rudimentary character. It consists of greenish-grey slaty and gritty beds, such as are seen on Cerig Brith, but broken into fragments. Most of the pieces are angular, but some are rounded sufficiently to be considered 'pebbles,' and their surfaces are covered by a glossy sericitic mineral developed by the shearing. The 'pebbles,' or authiclasts as they may be termed, are mostly small, one of the largest noticed measuring 15 × 6 × 9 inches; but much larger masses of almost unbroken beds lie among the brecciated fragments. Some of the purple slaty bands of the locality are included in the crush-zone. Pieces of the purple rock lie among the green fragments, and by the contrast of colour emphasize the fragmental character of the mass, but on the whole the purple 'pebbles' are localized in definite parts of the breccia, thus showing that the amount of relative displacement has been small.

The area of disruption is narrow and short. South of it we find similar, much contorted, and overfolded greenish and purple

¹ Quart. Journ. Geol. Soc. vol. xliv (1888) pp. 517-518.

² Geol. Mag. 1896, p. 481.

³ *Ibid.* p. 570.

Fig. 9.—Coast, Penrhyn, Cemaes : section through the crush-conglomerate, obliquely to the strike, with a semi-diagrammatic suggestion of the overfolds. (Length = about 500 yards.)

Q=Quartzose and jaspery rocks.
[The portion at X is the rock-face shown in fig. 10, p. 662.]

D=Dykes, of later date than the folding.
L=Limestone.

phyllites. The exposure is important in that it is not complicated by limestones and quartzites as in the crush-zones nearer Cemaes, nor has the crushing so completely disintegrated the beds as in that area. We have here a zone of rocks identical in composition with the contorted beds on either side of it, consisting of those beds brecciated and displaced, and with some of the fragments more or less rounded; it is evidently authiclastic in origin.

(ii) Porth y Corwgl.—At the extreme east of the Northern District the thrust between the Ordovician and the Gnarled Series reaches the coast at Porth y Corwgl. Black shales occur immediately south of the junction, but within a few yards they are interstratified with grits of various degrees of coarseness, and some of the shales also take on a pebbly character. The grits are evidently interbedded, but at the southern end of the Porth they are much disrupted and

lie in lenticular patches among the shales. Pieces of these grit-beds form 'pebbles,' often with slickensided surfaces; and angular fragments of the shale, pebbles of quartz and grit, and these 'pseudo-pebbles' are all felted together into a solid rock. Most of the pebbly shales seem to have been, on the whole, formed in the ordinary way by the denudation of older rocks. To the south the slates return to their ordinary character, but bands of grit lie more or less isolated, showing that there is still disruption, though in a less severe form.

This locality (i) introduces us to a crush-conglomerate in Ordovician beds, and hence fixes the age of the movement as post-Ordovician; (ii) shows us a deposit consisting partly of pebbles of earlier date, formed by denudation, and partly of pseudo-pebbles derived from neighbouring beds of contemporaneous age by crushing. Whence we may learn that the test of included fragments to determine the relative age of beds, largely used in unravelling Anglesey geology, must be very cautiously applied.

(iii) The Cemaes District.—The largest and most typical development of the crush-breccias is exposed along the coast in the neighbourhood of Cemaes at Porth Wnol, on Wylfa Head, and along the shores of Cemaes Bay. Immediately south of this remarkable zone lie the green-and-purple slaty beds which occupy the greater part of the Northern District, and compose the crush-zone at Trwyn Pen-careg. As we strike across the green-and-purple beds northward, say from Porth y Pistyll towards Wylfa Head, they are seen to dip a little east of north at a low angle (10° to 20°), increasing to 40° at Porth y Gwartheg. Patches of brecciated rock, agreeing in character with the Trwyn Pen-careg breccia, are visible here and there. Contortions set in, whose axes agree in direction of dip with the bedding, and the bedding becomes irregular, so that thin, harder, and flaggy bands in them appear to die out if followed for a few inches or feet along the strike. On reaching Porth Wnol these beds still form the main mass of the exposures; but in them lie pieces of the gritty beds of the series and great lumps of greenish glassy quartzite that weathers with a white crust; a still larger mass near by forms one of the 'quartz-knobs' of Prof. Blake.

On this headland, and along the shores between Porth yr Ogof and Porth y Wylfa, the slaty rocks are thoroughly broken up, and contain many inclusions of grit and quartzite. A few limestone-masses are folded in among the strata. One of these, of which about 30 feet in length is seen, is of such irregular shape that, had it been, as has been suggested, ejected from a volcano, it would have broken into several pieces in falling.

I may mention here that limestone-'pebbles' in these rocks are not common, and such few as are seen generally occur in the neighbourhood of these limestone-masses.

The great majority of the inclusions are clearly identical with the grits that occur in thin bands to the south, and in thicker beds

Fig. 10.—Rock-face on Penrhyn, near Cemaes, showing relics of stratification in the crush-conglomerate.
(Drawn from a photograph.)

around Cemlyn Bay. The matrix is also comparable with the fine-grained beds of the same series. I consider that the strata are, in the main, the upper beds of the Green-and-Purple Series, the grit-bands of which have been so much broken up that the fragments lie piecemeal in the shaly matrix, though contorted bedding can still be traced in places. As for the quartzites and limestones, some of the former are green, and graduate into the ordinary green grits, and such may, therefore, be considered altered grits of the same series; but others, and the limestones, are in all probability parts of beds occurring higher in the succession, which have been folded in and crushed among the older disrupted strata.

As we pass along the shore, between Porth yr Ogof and Porth y Wylfa, the crush-conglomerates still resemble the Cemlyn beds, and the grit-bands can be traced here in places, though generally they are completely disrupted. At the south-eastern corner of Porth y Wylfa, the greyish-green slates and flaggy grits of Porth y Pistyll and Porth y Gwartheg reappear. Some of the grits are broken to crush-breccias, but the fragments are angular and little displaced. To the north authiclasts again appear in the rocks, and this pseudo-pebbly character obtains along the coast all the way to Cemaes. I have not noticed any of the felsite-fragments which have been stated to occur both here and on Mynydd Wylfa. On Trwyn y Penrhyn (near Cemaes village) the rocky coast exhibits, among the broken-up grits and slates, masses of quartzite and limestone, some over 300 feet long, which follow the general strike of the beds. The limestones are clearly identical with those that occur on the eastern side of Cemaes Bay, where they are more fully exposed. Some of the calcareous shales belonging to them are also disrupted. I give a section (fig. 9, p. 660) along this part of the crush-zone which shows that in general structure the crushed rocks consist of a series of overfolds. This section (taken obliquely to the strike of the beds) gives only a generalized suggestion of what has taken place; the folding is in reality very much more complex, and is complicated by numerous thrusts and faults. In one spot, opposite the house known as Bay View, where the flaggy beds which constitute the bulk of the crush-conglomerate have been less disrupted than usual, the folding is still evident (fig. 10, p. 662).

The eastern shore of Cemaes Bay yields further exposures of crush-conglomerate. Near the rifle-range is seen bedded limestone, passing down into glossy blue-black and greenish shale and beds of quartz-grit and quartzite. The bedding is very irregular; the bands of grit and quartzite are squeezed out among the shales into a succession of somewhat lenticular or rounded pieces, and all gradations from long bands to isolated fragments and lumps may be noticed. Fig. 11 (p. 664) gives an example of two such bands from this locality. These irregular crumpled beds of grit, quartzite, limestone, and shale are to be seen as far as the target which is fixed upon a headland (Pig y Barcud) of highly-contorted limestone and laminated limestone-shale. Occupying a broken and overfolded anticline between this limestone-headland and the large limestone-quarry of Trwyn y Parc is a strip some 100 yards wide

of typical crush-conglomerate, which consists of a dull slaty matrix full of grit-bands more or less broken into fragments. Some of the bands can be followed unbroken along the strike for quite 8 feet, but they are mostly broken up into isolated pieces, the majority of small size. I measured some, however, having the following dimensions:— $5\frac{1}{2}$ by 3 feet; $6\frac{1}{2}$ by 2 feet; 6 by $2\frac{1}{2}$ feet. These larger inclusions were more or less lenticular in outline, and had the longest axis in the direction of the line of strike. They showed very little alteration; but the matrix of this crush-zone displays the typical micro-structures of crush-rocks, corresponding in all essential respects with the Isle of Man examples.

The main limestone-mass,—that of Trwyn y Parc, in which the basin-like-folds noticed earlier in this paper (p. 652) occur—is now reached. It forms a band some 250 yards broad, beyond which is another tract of rocks similar to those on Cemaes shore. Though the beds are still broken up, the cataclastic derivation of the quartzite-lumps may be clearly inferred from their frequent occurrence as series of more or less connected lenticles.

Fig. 11.—*South-eastern corner of Cemaes Bay: parts of broken quartzite-bands.*

[The upper band is $3\frac{1}{2}$ feet, the lower $4\frac{1}{2}$ feet, in length.]

Continuing from this point along the shore of Porth Padrig, we come upon a large development of bedded grit and quartzite interstratified with pale yellow and sage-green, felspathic, shaly, and gritty mudstones, an occasional patch of limestone, and some Llandeilo black graptolitic shales. The thickness of individual beds is often extremely irregular, and the whole of this section has evidently undergone much movement. At Llanbadrig there is another development of limestone and quartzite among grey and reddish slaty beds. The harder rocks are very much crumpled up among the softer ones, and pieces of quartzite and limestone have become detached and lie isolated in the slates. The structure appears to be somewhat similar to that noticed at Penrhyn, though the disruption is not so complete. Many of the bands can be readily traced, others are very irregular, and we find all stages from strings of lenticles to 'pebbles.' The quartzite-masses are much brecciated: some even seem to be made up of cemented fragments.

At the same time the explanation of the presence of the included fragments as due to 'crush' must not be pressed too far, for there are some inclusions, especially near Llanbadrig Point, which appear to be real pebbles; and it seems that some pebbly slates have also been involved in the crush-movement and contributed their contents to the disrupted rocks. In some places irregular beds occur which simulate the crush-conglomerates, but appear to be mainly the result of crushing on pebbly slates. The true pebbles may be almost as much deformed and broken by movement as interbedded grit-bands. In one of these tracts of doubtful origin, north-east of Ogof Gynfor, all doubt as to the ordinary clastic nature of some of the inclusions was removed by finding in the rock a band of conglomerate which ran for quite 20 feet without a break, and by tracing patches of the same or a similar band in other parts of the exposure. It is, however, no easy matter in some cases, especially inland, where exposures are not continuous, to distinguish breccias originally clastic from those only secondarily so: that is, between crushed breccias and crush-breccias; and I have had to suspend judgment as to the real nature of some strata. The existence of one area of crush-conglomerate inland is, however, confirmed by microscopic evidence (N.A. 62). It lies south-west of Rhyd-y-clafdy, a farm east of Cemaes and north of the Amlwch Road, and similar rocks are seen at intervals between this locality and Porth Padrig.

From Ogof Gynfor to Porth Wen the rocks show abundant evidence of great movement and disturbance. Around Porth Wen the disturbance is more pronounced, and the harder masses tend to break up and become surrounded by the softer. In the southern corner of Porth Wen Bay we again have rocks which may be called crush-conglomerates. As at Penrhyn and Llanbadrig, they lie among masses of limestone and quartzite, and they look like disrupted beds of the Cemlyn grits and slates. East of Amlwch again, the folds of the highly-contorted Llanelian rocks are sometimes so broken that the harder grit-bands are shattered and discontinuous; but the disruption is rarely complete.

(iv) Western part of the north coast.—The ragged aspect of the rocks which characterizes the crush-conglomerate coast-scenery around Cemaes and Wylfa reappears between Hen Borth and Carmel Head, and becomes more conspicuous as we pass westward. It has already been seen that Carmel Head is an area of powerful thrust-faults, and we may well expect to find crush-breccias here. The green beds depicted in fig. 1 (p. 645) have this brecciated character. At the extreme west, on Carmel Head itself, a strip of the Cemaes limestone is folded in with the crush-conglomerate, and fragments of it may be found as authiclasts farther east.

It may be inferred from the foregoing evidence that the north coast of Anglesey from end to end has been intensely crushed. Along those portions of the coast where the rocks are fairly homo-

geneous—whether they be soft and slaty, as between Bull Bay and Porth Wen, or whether they be hard and resistant, like the conglomerates and grits of Llanlliana headland and Torllwyn—there is no marked disruption; but whenever there are rapid alternations of the soft and hard types, then disruption becomes more or less pronounced, and on the horizons of such deposits come in extensive zones of crush-breccias and crush-conglomerates.

(v) Dykes in the crush-zones.—A number of subparallel basaltic dykes cut through the crush-conglomerates at Penrhyn, Llanbadrig, Porth Wnol, and Trwyn Pen-careg. They agree, on the whole, in direction with the strike of the crushed beds, and are clearly of later age than the movement; for they keep a straight course through the crush-conglomerate, and pass through it and the associated great limestone-masses uninterruptedly.

There are, however, traces of dykes which, being of earlier date than the movement, have suffered equally with the rocks into which they were intruded. I have found the relics of two of these early intrusions. A few blocks of one of them lie in the slaty crushed matrix at Trwyn y Parc. The other is to be found east of the 'quartz-knob' of Llanbadrig Point. It lies mainly in two lenticles surrounded by a broken quartzite-band and some slaty beds, but other lenticles and pieces of it lie near, folded and faulted among the other rocks. Not only have these dykes been torn to pieces, but their internal nature and arrangement have been altered. Almost all the structures and minerals have been obliterated by the movement, and their original composition and texture can now only with difficulty be recognized. Prof. Watts states respecting them (N.A. 10, Trwyn y Parc; N.A. 11 & 65, Llanbadrig):—'Originally they appear to have been porphyritic basalts with a fine-grained groundmass. Their minerals are now largely calcified, the ilmenite converted into leucoxene, and the porphyritic crystals are mere ghosts, smashed, filled up with chlorite, and converted into aggregates of mica-flakes.'

(vi) Method of formation.—The causes leading to the production of crush-conglomerates have been already discussed by Mr. Lamplugh in connexion with the Isle of Man examples, and Anglesey serves to confirm his conclusion that they are mainly due to the differential yielding of rocks when greatly compressed. The Porth Newydd sketch (fig. 7, p. 656) shows that shale has been capable of accommodating itself to the squeezing by flowing round the harder masses; but the grit-bands, although yielding and stretching to some extent, have commenced to break, and the deficiency in extensibility has been made up by the broken pieces moving away from each other. The same effect has been produced, in the neighbourhood of this section, in the black shale itself; for we find tougher black shale forming lenticles and discontinuous layers in the softer shale. Porth Newydd, too, shows that disruption can go on unaccompanied by folding; but folding has, without doubt, largely aided the dismemberment of these rocks. Especially destructive to the

integrity of the strata would be the results of two systems of movement acting somewhat obliquely to each other, and this may have been the case in Northern Anglesey. Jointing, cleavage, and bedding would all be of service in producing a cataclastic structure.

(g) Age of the Movements.

The thrusting of older beds over the Ordovician rocks and the disruption of the Ordovician in Porth Newydd and Porth y Corwgl determine the age of the last period of great movement in Northern Anglesey as post-Ordovician. This movement is older than the dykes that cut through the crush-conglomerates, but we are not sure whether they are of Carboniferous or of Tertiary age. The Carboniferous rocks of Anglesey being, however, comparatively undisturbed, as also seem to be the underlying deposits mapped as Old Red Sandstone, the period of the movement must lie between Upper Ordovician and Upper Old Red times. This movement may well have been contemporaneous with that of post-Cambrian and pre-Carboniferous date which produced disruption in the Manx slates.¹

The recognizable Ordovician rocks have a less altered and, as a rule, a less disturbed look than most of the older deposits, and the Ordovician conglomerates give evidence that the older rocks had undergone considerable alteration, movement, and upheaval before Llandeilo times.

V. THE NORTHERN COMPLEX AND ITS RELATION TO THE ORDOVICIAN.

We now return to a consideration of the highly-complicated area spoken of as the Northern Complex. Apart from Ramsay's description,² the only account which gives any detail of this area appears to be that of Prof. Blake under the head of 'The Disturbed Volcanic Group.'³ We have seen that the 'agglomerates' of the latter writer's description are crush-conglomerates, and that they are, in the main, disrupted portions of his 'Sedimentary Series' (Green Series). The limestones, or at least some of them, he considered to be the result of 'the action of calcareous springs,'⁴ while the 'quartz-knobs' he looked upon as the product of 'pre-Cambrian geysers.'⁵ This group abounds in other lithological types, and in the complex lie the conglomerates, sandstones, and shales whose age is proved by the fossils recorded above (p. 640) to be Llandeilo. Ramsay⁶ believed that rocks of two systems, namely, Lower Silurian (Ordovician) and 'altered Cambrian,' occurred in this part of the district, but he found it impossible to determine how much of the strata belonged to each system, though he was inclined to consider the Cemaes limestones and all their associated rocks as

¹ Lamplugh, 'Crush-conglomerates of I. of Man,' *Quart. Journ. Geol. Soc.* vol. li (1895) p. 584.

² *Mem. Geol. Surv. 'Geol. N. Wales,'* 2nd ed. (1881) p. 240.

³ *Quart. Journ. Geol. Soc.* vol. xlv (1888) p. 517.

⁴ *Ibid.* p. 519.

⁵ *Ibid.* p. 476.

⁶ *Op. supra cit.* p. 242.

Ordovician. Some writers, as we have seen, have found a way out of the difficulty by lumping all the rocks together as Bala. Prof. Blake first definitely placed in the Ordovician the basal conglomerates and overlying strata of Ogof Gynfor and Porth Llanlliana.

The prosecution of detailed field-work has not yet revealed a full or satisfactory sequence of the rocks in this area, though I am still hopeful of succeeding in this task. Nevertheless, some remarks on two of the principal rock-types and their relationship to the Ordovician may be of interest.

(a) Limestones.

The limestones of the district are of two main types. One is a fairly pure, blue limestone, effervescing freely with acid, and is the only kind that is quarried for lime. Its largest exposures are at Trwyn y Parc near Cemaes, and in the quarries near Llanlliana Farm; but it also occurs at Penrhyn, at Pig y Barcud, between Llanbadrig and Cae-Owen, at the southern end of Porth Wen Bay, at Carmel Head, and in patches at other places. It is sometimes a laminated limestone with filmy black carbonaceous partings, but often so crushed that the partings are almost obliterated and the rock welded into a solid mass.

The other type weathers characteristically as a light grey rock, but is brown or dark bluish and often gritty internally. Though it sometimes effervesces readily with acid, it is usually impure, dolomitic, or siliceous. It is often found with the blue limestone, and the two types appear to pass one into the other. It sometimes weathers to a ferruginous-brown colour. Between Ogof Gynfor and Porth Llanlliana there are strips of this impure limestone running from the coast inland; it occurs again on the south-east side of Porth Wen Bay, in Porth Padrig, on Penrhyn, and at various other localities. I have had none of the limestones analysed, but was told that the analysis of a rock from Porth Gynfor (Hell's Mouth) showed it to be highly magnesian, as it yielded 61·15 per cent. of carbonate of magnesia and only 21·40 per cent. of carbonate of lime. This result, if trustworthy, could have been obtained, I think, only from a quite exceptional piece of rock, the magnesia-percentage being considerably higher than in pure dolomite.

When the limestone retains its lamination the rock-structure is traceable, and it is generally found to be highly crumpled, sometimes also to be imperfectly cleaved, so as to approach an imperfect limestone-slate. Black shales sometimes occur with the limestone and also reveal the bedding, as at Llanlliana Farm quarries, where the dip is seen to be almost vertical. The obliteration of bedding in the Trwyn y Parc quarry has been already noticed (p. 664), and it is most obscure in the solid limestone of other exposures. Much of it seems to be a cataclastic rock recemented by calcite and dolomite or sometimes by quartz-veins.

It was interesting to find 12 yards of limestone in a 'level' driven into Mynydd-y-Garn near Ty'n-y-maen Chapel. This limestone has no outcrop.

Prof. Blake has shown that part of the Llanbadrig limestone is oolitic,¹ with compound grains: that is to say, two or three grains are often enclosed within a larger grain. From this structure, as well as from its intrusive appearance in the mass, he deduces that it is of later date than the rocks among which it occurs and that it was formed by the action of calcareous springs. I did not find an example of this structure at Llanbadrig, though I do not doubt its occurrence there; but there is a band of light-brown limestone on the shore of Cemaes Bay, along the course of the rifle-range, which displays similar structures, except that the oolitic grains are not compound. This oolitic structure shows some breaking-down by veining, recrystallization, and a certain amount of dolomitization (N.A. 87), and may once have been a more common feature of these rocks.² The nuclei show no trace of organisms.

No fossils have yet been discovered in the limestones, though there are some structures in a microscope-slide (N.A. 12) from the Llanbadrig limestone which may possibly be organic. The general absence of fossils fits in with Prof. Blake's chemical theory, but if we consider the reconstruction that these rocks have undergone by shattering, crystallization, veining, dolomitization, etc., we should expect very few organic remains that the limestones may have once contained to escape destruction. The crush-conglomerate explanation of the 'agglomerates' of the north coast should clear away the difficulty experienced by Prof. Blake in accepting the limestones as ordinary bedded rocks. Their irregular, and sometimes even intrusive, appearance is an effect due to these hard resistant masses having been broken and crushed in by complicated movements among thinner strata.

(b) Quartzites and 'Quartz-Knobs.'

The bands and pieces of quartzite which have been mentioned in connexion with the crush-conglomerates are for the most part evidently altered grits and sandstones. There are, however, both in and away from the crush-zones, thicker masses of quartz-rock of which Prof. Blake speaks as presenting 'the most remarkable features of all the Anglesey rocks.'³ He refuses to apply to these the name of quartzite, styling them 'quartz-knobs,' and suggests that they have been produced by hot siliceous springs which may or may not have reached the surface. He distinguishes them by their purity of composition, their internal structure, obscurity of bedding, and form of outcrop, their characteristic mode of occurrence being as isolated hummocks which vary in size from a low mound to a good-sized hill. In composition they are certainly of remarkable purity; for instance, it was stated to me that the Craig Wen rock had yielded on analysis

¹ Quart. Journ. Geol. Soc. vol. xlv (1888) p. 518; 'Microsc. Struct. of Older Rocks of Anglesey,' Brit. Assoc. Rep. 1888 (Bath) p. 389.

² It may be remarked that oolitic limestones are known in the Dalradian of Scotland; see A. Geikie, 'Text-Book of Geol.' 3rd ed. (1893) p. 150, footnote.

³ Quart. Journ. Geol. Soc. vol. xlv (1888) p. 475. See also Brit. Assoc. Rep. 1888 (Bath) pp. 390-392.

99·6 per cent. of silica; but purity is not a *sine quâ non* of a quartz-knob, for Prof. Blake includes among them, on account of their peculiar stratigraphy, some which 'might well pass for grits.'

Leaving Prof. Watts to deal with their microscopic structures, we may notice the manner of occurrence of some of these rocks in the field. The mass at Llanbadrig Point has already been dealt with (p. 653 & fig. 5). It is cut up by thrust-planes, parts of it are well bedded; and it contains abundance of clastic grains. Another quartzite-mass is shown in the Ogof Gynfor section (fig. 3, p. 648). This latter is continued inland, by way of Penterfyn, as a bold, sometimes interrupted ridge, with a branch to Is-allt. Another ridge, overlain by Ordovician conglomerate, occurs between Ogof Gynfor and Porth Llanlliana.

Prof. Blake figures another quartz-knob at Porth Llanlliana,¹ but its structure is not so simple as a general view leads one to suppose. At the base of the cliff it is a bedded and markedly clastic quartzite, the bedding being almost flat. It is separated from the more inclined mass above by a nearly horizontal plane which I take to be a shear-plane, as along it may be found some pieces of impure limestone and crushed shale. This plane is continued as a steep upward curve, and we find a mass of impure limestone forming a kind of sharp anticline in the heart of the knob. Climbing the steep slope to investigate it from the top of the cliff, we find that the quartzite is not a typical 'knob,' but a reef or ridge along which are a number of small disused quarries. The rock is clearly a quartzite with abundant clastic grains, and it is overlain by a purple conglomerate.

The quartzite-ridge crops out again at Hell's Mouth and can be followed with the overlying purple conglomerate almost uninterruptedly to Craig Wen, 'the greatest quartz-knob of the district,'² which is being rapidly removed to make silica-brick. Here the outcrop widens. The north side of this hill gives the impression of a set of thick beds dipping steadily enough, though with a slight undulation, below the conglomerate; but the bedding-planes are full of slickensided surfaces. Along the road on the west side are faint indications of what seem to be southward-tilted anticlines, and small patches and pockets of a pale, highly-crushed, quartzose shale lie in the quartzite. A quarry driven into the eastern side of the hill, in the general direction of the strike, shows that a thick shale is included in the quartzite, and moreover that the rock has undergone such movement that the shale forms a tortuous band around masses of quartzite and has been so crushed in places as to be mylonitic. The north side of this quarry is represented in fig. 12 (p. 671). Purple and green are the prevailing colours of the shale.

Descending into Porth Wen, we find the beds to be much disturbed. By the pier is a conspicuous detached rock of the same quartzite containing some thin crushed shale, and overlain by the same purple conglomerate. The broken and confused rocks south of the pier seem to be a continuation of the Craig Wen mass, and Prof. Blake

¹ Quart. Journ. Geol. Soc. vol. xlii (1888) p. 520, fig. 22.

² *Ibid.* p. 521.

regards the confusion and irregularity as an appearance caused by 'the underground branchings of the quartz-knob.'¹ Considering that all the other rocks in the Bay are shattered and displaced, we may safely assign this effect to disturbance. Its difference from the ordinary crush-conglomerates consists mainly in this, that the latter are derived from soft rocks with subordinate hard layers, while here the predominating rocks are hard, with only subordinate soft layers.

Fig. 12.—Quarry on the east side of Craig Wen, looking north: the section coincides approximately with the strike of the beds.

[The line-shading denotes the shales, crushed into the quartzite, which is indicated by small crosses.]

We see, then, that the 'quartz-knobs' of Porth Llanlliana and Craig Wen are long ridges of a pure quartzite, which is built up—in part, at any rate—of clastic elements, shows bedding, contains bands of shale, and exhibits evidence of crushing and movement by which it has (to some extent) been broken up. Further movement might divide such ridges into a series of detached lenticles or 'knobs.' This is what I consider has taken place between Porth Wen and Bull Bay, and in other parts of this northern area where quartz-rock and limestone form strips or occur as lenticular, elliptical, or rounded masses along a zone which has a rough agreement with the general strike. A series of small 'knobs' of limestone and quartzite is exposed south of Bull Bay village. The farmer who worked the land told me that one of the quartzite-knobs had been entirely removed for road-metal, that it 'did not run deep,' but was surrounded everywhere by the country-rock. This statement strengthens the opinion that these masses are mere lenticles along lines of movement, and is confirmatory of the explanation that Mr. Greenly² has given of the 'quartz-knobs' of Pen y parc, near Beaumaris.

Microscopic sections from the crush-zones reveal all the successive

¹ Quart. Journ. Geol. Soc. vol. xlv (1888) p. 521.

² 'Quartzite-Lenticles in Schists of S.E. Anglesey,' Geol. Mag. 1896, p. 551.

stages in the breaking-up of minute grit-bands to form tiny 'pebbles.' We can pass from the microscopic slide to the hand-specimen, from the hand-specimen to the coast-exposure or quarry, and see the same stages of disruption of the harder rocks among the softer, on an ever-increasing scale. We have even gone farther and found that the isolated quartz-knobs and the detached limestone-masses are separated portions of great rock-sheets, and it is a matter of definition rather than a question of principle whether they should be called the 'pebbles' of a great crush-conglomerate.

(c) The Ordovician Rocks.

Prof. Blake first recognized the Ordovician age of the Ogof Gynfor conglomerates; the fossils recorded on p. 640 confirm his identification and fix the age as Llandeilo. These pass up, as shown in the section (fig. 3, p. 648), into black shales, which are so quartzose as almost to merit the name of grits; their upward continuation seems to be the *Dicranograptus*-shales of Penterfyn, exposed inland, which contain some flaggy bands of oolitic ironstone. The presence of Ordovician ironstones in Anglesey has, *ipso facto*, been considered to suggest an Arenig horizon,¹ but the Penterfyn ironstone is distinctly Llandeilo. The boundaries of this Ordovician tract are the two main faults shown in fig. 3, p. 648, which give a gradually widening outcrop till the series is cut off by an east-and-west fault from Porth Padrig; but these faults enclose much quartzite as well as Ordovician beds. Another tract, of a V-shape, mainly of conglomerates and grits, lies between this area and Porth Llanlliana. Its structure is obscured by cleavage, but the beds appear to be much folded and faulted, as the accompanying sketch (fig. 13, p. 673) indicates.

We pass now to the noble headland of Llanlliana or Dinas Cynfor, whose fine cliffs are mostly composed of Ordovician conglomerates. The uppermost beds are black-banded, grey, quartzose shales, cleaved into rude slates, and we recognize their equivalence with the darker gritty shale which occupies a similar position at Ogof Gynfor. South of these conglomerates and slates is the reddish-purple conglomerate that lies on the quartzite. This is so cut off from the other conglomerates that it is a question whether it should be included in the Ordovician; Blake was doubtful whether it should, and its colour is characteristic of the old rocks. But it seems to be partly derived from the underlying quartzite, its colour is sometimes leached out and then it closely resembles the other conglomerates, and fig. 13 has shown us that the undoubted Ordovician conglomerates contain purple zones. We may, therefore, for the present regard it as the basal bed of the Ordovician, and we can follow it from Hell's Mouth to Porth Wen still lying on the quartzite. The folded and cleaved conglomerates and grits, which lie between the purple rock and the sea, and form the headland of Torllwyn now

¹ Quart. Journ. Geol. Soc. vol. xxxviii (1882) p. 21.

fall into place as Ordovician, and we have no difficulty with the *Orthis Bailyana*-beds which are part of this series, though perhaps faulted against the conglomerate.

The remaining Ordovician outcrops are not extensive. To the east, between Porth Wen and Bull Bay, is a narrow strip, about $\frac{1}{2}$ mile long, of conglomerate forming the ridge of Mynydd Pant-y-gaseg; near it, in Porth Pridd, are the black shales noticed by Prof. Blake. Finally, in Porth Padrig are the shattered black shales which have yielded Glenkiln graptolites; their horizon appears to be near that of the Penterfyn beds.¹ They strike inland a short distance, but are soon faulted out. It will be perhaps needful to add various small exposures of broken-up rocks to this summary of the Ordovician strata.

This Ordovician sequence has a general correspondence with that established in Central Anglesey, where the series commences with conglomerates and passes up through grits and sandstones into black slates, in which ironstone is occasionally present.

(d) Relation of the Northern Complex to the Ordovician.

What, then, is the age of such strata in the Northern Complex as are not included in the Ordovician? Some of them, though shattered to 'crush-conglomerates,' are clearly portions of the Green Series. The more typical members, like the limestones and the quartzites, come in between the Green Series and the Ordovician, and they may be in upward conformable sequence with the green strata. The Ogof Gynfor section shows that the limestone has

¹ I brought away from the seaweed-covered rocks of Porth Padrig, near the black shales, a specimen of oolitic ironstone. It seems to be the equivalent of the Penterfyn ironstone, though my notes do not make it clear whether the specimen came from the black beds or from the neighbouring rocks.

been brought up against the Llandeilo conglomerates by an overthrust-fault. The limestone is therefore older, and there are occasional fragments probably derived from it in these neighbouring conglomerates. Also the conglomerates contain abundance of quartzite-pebbles, and lie on the quartzite, so that the quartzite is older than the conglomerate.

The various lithological types of Northern Anglesey—the purple and pale boulder-conglomerates, the sporadic outcrops of limestone, the shales and flaggy beds of varied colours, the serpentines and other intrusions—have a remarkable resemblance, as Prof. Lapworth pointed out to me, to the general facies of the Girvan and Ballantrae rocks of Southern Scotland. Now the Lower Girvan rocks do correspond in age with the recognized Ordovician of Northern Anglesey, and, like the latter, their basal bed is a purple, red, or white conglomerate which lies on the Ballantrae rocks. The latter, once suggested to be pre-Cambrian, have proved to be no older than the Arenig. It therefore deserves consideration whether the two areas do not correspond in more respects than in lithological similarity, and whether we may not recognize in the Green Beds or in the Northern Complex, or in both sets of strata of Northern Anglesey, a series of rocks not very much older than the Llandeilo. We find, for instance, that black shales typical of the undoubted Ordovician are found among the pre-Llandeilo limestones, and that the purple colour which characterizes certain zones in the Green Series is not wanting in the Llandeilo conglomerates. On the other hand, the included fragments in these conglomerates prove that the Green Series and the quartzites had already undergone much alteration; moreover, the green rocks are correlated by geologists with the pre-Cambrian of other parts of Anglesey, and there is also the general argument (p. 643) that Northern Anglesey remained above water throughout Cambrian and Arenig times. Swayed by these conflicting considerations, we are not in a position to assert unhesitatingly whether the Northern Anglesey rocks below the Llandeilo are of Arenig, Cambrian, or pre-Cambrian age. Though evidences appear to favour the opinion that these rocks, and more especially the Green Series, are very much older than the Ordovician conglomeratic base, it seems better to adopt a cautious attitude, and until the discovery of fossils, or pending the results of further work, to use, in speaking of their age, the general term pre-Llandeilo.

VI. SUMMARY.

The principal conclusions arrived at in the foregoing pages may be summed up in the following statements:—

(1) The barren green strata which form the floor of the greater part of Northern Anglesey are older than the Ordovician rocks to the south, and owe their apparently overlying position to a great overthrust which sweeps in a curve from sea to sea.

(2) In the northernmost part of the island is a complex of rocks of varied lithological character. Among them occurs a group of

strata comprising conglomerates, grits, shales, and ironstone—all or most of which are of Llandeilo age.

(3) The whole region has been extensively affected by powerful earth-movements, mainly acting from the north, which have contorted, overfolded, dislocated, cleaved, crushed, shattered, and altered the strata. Thrust-planes of the Highland type occur, and the north coast exhibits extensive tracts of crush-conglomerates.

(4) The isolated masses of limestone and quartzite that are to be found in the Northern Complex are portions of bedded strata which have been broken up by movement.

(5) The green strata and the rocks of the Northern Complex are older than the Llandeilo, and were metamorphosed to their present extent before Upper Llandeilo times. Whether these rocks are pre-Cambrian, Cambrian, or even Arenig, Northern Anglesey as yet affords no direct proof, but the available evidence points strongly to the view that the bulk of the strata are of pre-Cambrian age.

(6) The strata yield little evidence of contemporaneous volcanic activity.

In conclusion I have to express my indebtedness to Prof. Lapworth and Miss E. M. R. Wood for their examination and determination of the graptolites, and to the former also for various suggestions; also to Mr. B. N. Peach for identifying and forwarding notes on the limestone fossils. Finally, my thanks are due to Prof. Watts for the trouble that he has taken in examining a large number of rock-sections and contributing the following appendix.

VII. APPENDIX.—*On the MICROSCOPIC STUDY of some of the Rocks of NORTHERN ANGLESEY.* By Prof. W. W. WATTS, M.A., Sec.G.S.

The following notes are based on the examination of about 100 slides made from rocks collected by Mr. Matley during his work in Northern Anglesey, and examined by me at his request. These rocks may be classed under the following heads:—

- (1) The Green Series.
- (2) The Ordovician Rocks.
- (3) The Quartzites and 'Quartz-knobs.'
- (4) The Results of Earth-movement; Crush-Conglomerates.

(1) The Green Series.

These rocks usually show their original clastic structure distinctly, although they are often considerably altered. They vary from coarse quartzose grits, through finer grits, to close-grained phyllites. The fragments consist of quartz-grains, clastic mica, and felspar, the first constituent being present in greatest quantity. Secondary chlorite and sericite are usually developed, the latter becoming more abundant as the evidences of earth-movement increase, and certain bands in the fine grits are schists consisting of

little but sericite. More usually the groundmass is made up of fine chlorite-flakes embedded in granulitic quartz. Epidote in veins and isolated crystals is usually present. Secondary chalcidonic silica has often been deposited along planes and lenticles produced by the movement. In the finer-grained rocks strain-slip is present, and not infrequently the rock is brecciated and contains fragments derived from itself; one example (N.A. 43, from the Craig Wen 'quartz-knob') has the structure of a mylonite. One rock (N.A. 18, near Taldwrws, Cemlyn) has been detected in the Green Series which contains, in addition to angular grains of quartz, several fragments of orthophyre, of angular grit, and crushed rock. Another rock (N.A. 70, Hell's Mouth) in this series contains fragments, possibly of volcanic origin. The rock from Porth yr Ysgraff (N.A. 20), found in the neighbourhood of a dyke and of serpentine, exhibits dark spots, probably developed by contact-action subsequently to foliation. A specimen of Llanfechell Grit (N.A. 86, Pen-y-bont) contains fragments of granulite, quartz-schists, micropegmatite, and felspar, all clearly derived from an area of foliated rocks. The bulk of the rocks may be spoken of as chloritic schists, chloritic and sericitic phyllites, and phyllitic grits.

(2) The Ordovician Rocks.

The rocks examined are mostly from the neighbourhood of the junction with the Green Series, collected with the view of obtaining evidence from the contained fragments, or else from the Ordovician beds in the Northern Complex. A typical specimen (N.A. 53, from Cefn-du-mawr, Llanfair-y-nghornwy) contains, among abundant angular fragments of quartz, granulated and non-granulated, the following larger fragments of rocks:—(a) sericitic phyllites consisting mainly of granular quartz with little sericite; (b) well-foliated sericitic phyllites with minute quartz-grains; (c) sericitic phyllites with larger quartz-grains; (d) fine sericitic phyllites consisting almost solely of sericite; (e) green quartz-chlorite-schists; and (f) fine gritty rocks. All these types have been found among the rocks of the Green Series examined, and all are in precisely the same stage of metamorphism as in the fragments. Other examples of the rocks contain fragments of quartzose grits, quartzites, and rocks quite undistinguishable from those of the 'quartz-knobs.' In one specimen there are abundant fragments of a limestone now crystalline. No volcanic fragments have been discovered in any of the specimens examined by me, with the exception of one doubtful instance from the western Porth Padrig. In a few cases, where there has been much movement, the groundmass of these rocks, and of the finer bands within them, becomes a sericitic schist. The state of metamorphism of the rock-fragments indicates that there must be a considerable gap between the Ordovician rocks and those of the Green Series. The rocks from Mynydd-y-Garn (N.A. 74 & 75) contain fragments of granitic, gneissic, and schistose

rocks such as might have been derived from the area (N.A. 82, 83, & 84) near Pen Bryn-yr-Eglwys, 2 miles away, where granites, quartzose gneisses, and biotite-gneisses occur *in situ*.

(3) The Quartzites and 'Quartz-knobs.'

Under the microscope I have not found it possible to draw any line between quartzites and the rocks of Prof. Blake's 'quartz-knobs.' Evidence of rounded quartz-grains can be generally obtained in both types of rock, but is not more easily obtainable in the one type than in the other. The amount of growth of secondary quartz on the grains is not very great, and it is difficult to identify because the old quartz is not much fuller of inclusions than the new, and at times the whole rock is traversed by abundant seams of bubbles which pass from one adjacent grain to another. Still, in most of the slides I have found this secondary growth, and when it is well developed the grains interlock in a way which shows that it is only to be expected that the elastic structure would not be always apparent. In all the slides there is a certain amount of interstitial quartz which takes several forms; it may be granulitic, microcrystalline and interpenetrating, cryptocrystalline, or minutely elastic. In some cases the adjacent well-rounded grains are coated with fringes of bright sericite (N.A. 31, from a 'quartz-knob' at Llanbadrig Point [Trwyn y Buarth]).¹ The grains often exhibit strain, but not often granulitization. Grains of felspar and other minerals are decidedly rare, and the groundmass is usually purely siliceous, but in some cases it is full of sericite, which has a parallel and schistose arrangement. Two specimens were cut from a band of shale included in the 'quartz-knob' of Craig Wen. One of them was a rather fine-grained quartzose grit, very much crushed, with its grains embedded in a groundmass of sericitic schist; the other was a sericite-schist, so much crushed as to be brecciated and to have acquired the structure of a mylonite; lenticles of quartzite are crushed into it.

(4) The Results of Earth-movement; Crush-Conglomerates.

Nearly all the rocks examined have suffered in some way from earth-movement. Either they are cleaved, or they show strain-slip, or they are brecciated and phacoidal; and the amount of crushing may be roughly measured by the amount of sericite developed in the groundmass, as well as by the shearing, granulitization, and eventual fraying-out of the contained fragments of quartz. Most of the stages towards the formation of crush-breccias and crush-conglomerates can be traced in the slides as well as upon the ground, and the best examples are as marked and unmistakable as those discovered in the Isle of Man by Mr. Lamplugh. As a

¹ See Greenly, Trans. Edin. Geol. Soc. vol. vii (1897) p. 256.

rule the coarser rocks form fragments in the finer, but not infrequently 'pebbles' (authiclasts) and matrix are made of the same material. Many of the larger fragments have undergone no mechanical deformation in their interior, but the smaller fragments are kneaded and crushed, and the isolated grains of quartz are granulated. Usually the fragments consist of a single type of rock, but often several distinct types occur together. In the example (N.A. 63) from the west side of Porth y Wylfa various grits, sericitic and chloritic schists, etc., occur in a single rock-slide, as is the case with the thrust-conglomerates described by Gardiner & Reynolds from Portrairie.¹ Sometimes quartzites of the 'quartz-knob' type occur in the conglomerates, but so far no fragments of volcanic rock have been found in them; indeed, in all the rocks examined there is very little volcanic material. Quartzite-bands found in the crush-conglomerates are much crushed.

DISCUSSION.

The Rev. J. F. BLAKE said that the first impression created on him by the paper just read was a sense of his own rashness eleven years ago in attempting to explain the whole of the Monian system in a single evening, whereas the Author that night had been unable to conclude his account of even a very small portion of the rocks. The second impression was one of satisfaction that an independent worker, who had been enabled to devote some time to the subject, practically confirmed all the speaker's contentions (quartz-knobs excepted); which was all the more important, inasmuch as in the new Index-map of the Geological Survey all the Monian rocks of the district had been changed into Ordovician on the strength of some supposed intercalations of black shale, which the Author now rightly interpreted as a result of complex thrusting. He begged that the Author would modify the statement he had made that the speaker had claimed *Orthis Bailyana* as a Monian fossil. He had never come nearer to that than saying that he should like to do so; but, after an examination of the Wexford beds *in situ* and the collection in the hands of the Irish Geological Survey, he could find no encouragement for any such idea. He quite appreciated the statement of Prof. Watts that the northern so-called 'volcanic series' did not contain any fragments of volcanic rocks, or very few, in the shape of lapilli; but the angular scattered fragments of felspars, etc. seemed to suggest some volcanic origin. He did not understand the Author's section [fig. 9, p. 660], as the folds were indicated as having a north-and-south axis, whereas, the pressure being from the north, the axis must be east-and-west.

With regard to the quartz-knobs, the best was seen near Parys Mountain. Not every quartzite in the district was a quartz-knob, and the rounded grains in many of the latter had been recognized

¹ Quart. Journ. Geol. Soc. vol. liii (1897) p. 527.

by the speaker and accounted for. These were not the difficulty; it was the stratigraphical one. If quartz-knobs were fragments of old sandstones separated by earth-movements, where were these sandstones, and what was the cause of the remarkable purity of the material? Some of these knobs were quite white, and perfectly isolated amidst miles of dark schistose slates, etc.

Prof. SOLLAS joined in recognizing the importance of this contribution to our knowledge of an unusually difficult country. As regards the 'quartz-knobs' he was in complete agreement with the Author; and having had, through the kindness of Prof. Blake, the opportunity of studying specimens from a typical quartz-knob of Anglesey, he had found in them the same characters as those that distinguished the quartzites of Howth and Bray, which had clearly originated from true sandstones. The joints and other fissures of these masses were filled with secondary quartz, which had penetrated the adjacent portions of the rock and destroyed in many cases all traces of its original structure; but the great mass of the rock had escaped this influence, and afforded obvious evidence of a clastic origin. The isolation of the quartzite-masses stood in connexion with the earth-movements that had produced 'flow-breccia'; indeed, the whole terrane had been forced into a state of 'flow,' and the 'quartz-knobs' were phacoids of quartzite on a grand scale. The quartzite and green-and-red slates of Howth and Bray would require but slight alteration to acquire characters like those of the Green Series of Anglesey.

Dr. HICKS congratulated the Author on the careful manner in which he had worked out the geology of an important and difficult district in Anglesey. He believed that the interpretation put forward by him was essentially the correct one, and the one to be expected in an area where pre-Cambrian and Lower Palæozoic rocks had been so greatly affected by earth-movements. The *Orthis* exhibited seemed to him to be *Orthis Carausii*, which is found at St. David's in beds of Tremadoc age. There are conglomerates in Anglesey belonging to different horizons—the oldest, he believed, are those near Llanfaelog, which contain not only fragments of green schists but also pebbles of gneiss and granite, and are overlain by a series of greenish and grey sandstones older than the slates of Llandeilo and Arenig age. In so greatly faulted an area it is extremely difficult to make out the natural succession, for series of beds are frequently absent or not exposed, not from want of deposition, but as the result of faults and overthrusts.

Prof. WARRE said that microscopic examination had not enabled him to discern any difference between Prof. Blake's 'true quartz-knobs' and others which that observer disclaimed as quartz-knobs. He had had the pleasure of working with Prof. Sollas in the Howth district, and eagerly awaited the publication of the latter's map. The structure of some crush-conglomerates curiously simulates the geological map of that district—and this extraordinary resemblance extends to the hand-specimens of the rock, even to the very appearance of the quarries. There is no doubt that the origin

of quartzite does still present considerable difficulties. He could not refrain from saying that the kindly spirit in which Prof. Blake had spoken of the present Author's work deserved their warmest thanks.

Prof. LAPWORTH also spoke.

The AUTHOR, in reply to Prof. Blake, stated that he had seen the latter's 'best quartz-knob' near Parys Mountain, but it was outside the area described. Several masses in Northern Anglesey specifically mentioned by Prof. Blake as 'quartz-knobs' were dealt with in some detail in the paper, but time had not permitted the evidence to be given that evening. He thanked all the speakers, especially Dr. Hicks, for the very kind way in which they had received his paper.