35. *The LOWER PALÆOZOIC ROCKS of the NEIGHBOURHOOD of HAVERFORDWEST.* By J. E. MARR, Esq., M.A., F.G.S., Fellow of St. John's College, Cambridge, and T. ROBERTS, Esq., B.A., F.G.S., St. John's College, Cambridge. (Read June 10, 1885.)

[PLATE XV.]

§ 1. *Introductory.*

THE country around Haverfordwest is of great interest to geologists, first, on account of the evidence furnished therein of the relations of the graptolite-bearing beds to the strata which are characterized by the presence of higher organisms, and secondly, from the nature of the foldings which the rocks of the district have undergone.

We propose, in this communication, to devote our attention to the former of these subjects.

Our work is based upon that which has been done by the Geological Survey, and published in Sheet 40, Horizontal Sections, Nos. 1 & 2, and Mem. Geol. Survey, vol. ii. part i.

Whilst fully acknowledging the great value of these publications, we think it desirable, now that our knowledge of the forms of life occurring in these rocks has been so much increased by the labours of many geologists in recent years, to attempt a more minute classification of the rocks of this district than that adopted by the Government Surveyors. In our opinion, this further description of the beds will throw considerable light upon the character of the movements which the district has undergone.

Our thanks are due to Dr. Hicks for the very kind way in which he placed a series of specimens collected by himself at our disposal. We have also to thank Prof. Lapworth for his kindness in examining our collection of graptolites.

The area which we have chiefly examined is a well-defined tract (see Map, Pl. XV. fig. 1), about eighteen miles in length from east to west, and having an average breadth of five miles, lying to the north of the towns of Haverfordwest and Narberth. It is bounded on the north by a great fault, running from Roch Castle in an easterly direction, along the margin of a mass of rock which Dr. Hicks has claimed as Pre-Cambrian. On the west and south, the Lower Palæozoic rocks of this tract are succeeded by Old Red Sandstone and Carboniferous deposits, and on the east, a considerable extent of Llandeilo limestone is represented on the Geological Survey map.

Within this area is a portion of a wide synclinal, complicated by minor foldings, running from near Clynderwen Station on the east, to the Coal-measures on the west. South of this is a complicated anticlinal in the neighbourhood of Narberth.

§ 2. *Establishment of the Succession.*

1. *Lingula Flags.*—To the north of the great fault alluded to as

running eastward from Roch Castle, north also of the Pre-Cambrian ridges, parallel with this, are black iron-stained slates, weathering olive-grey or yellowish, generally dipping north. They are well seen near Leweston, Trefgarn Bridge, and Spittal Cross. At Leweston Old Mill they have yielded :—

Agnostus pisiformis, Linn.

—, var. *socialis*, Tullb.

Olenus spinulosus, Wahl.

At Trefgarn Bridge the following very important section occurs in a quarry by the roadside, close to the fourth milestone from Haverfordwest (fig. 2).

The shales are considerably disturbed, and contain a fair number of fossils of the same species as those found at Leweston Old Mill.

The conglomerate adheres to an ashy-looking rock of Pre-Cambrian (?) age, with nearly vertical divisional planes, the origin of which we were unable to determine.

The fossils found in these two localities prove that these beds are *Lingula* Flags. Dr. Hicks has recorded the presence of *Lingula* Flags about this spot (Q. J. G. S. vol. xxxv. p. 287), but gives no fossil list; and it is interesting to find that his determination of the age of the beds, based presumably upon lithological characters, is fully borne out by the fossil evidence.

To the south of the great fault, much newer beds occur, so that we are unable to record the occurrence of Tremadoc and Arenig fossils in the area under consideration.

2. *Didymograptus* Shales.—These beds occur in the complicated anticlinal to the east of Narberth, and, next to the *Lingula* Flags, are the oldest beds we have met with in the tract of country we have examined. They consist of black graptolite-shales of the ordinary type, crowded with “tuning-fork” *Didymograpti*, and containing also small horny brachiopods and fragments of trilobites. *Didymograptus Murchisoni* occurs in abundance. That these beds are underneath the Llandeilo limestone is shown by their occurrence in an anticlinal arch between the limestone of Llan Mill and that of Lampeter Velfry. The southern arch of this anticlinal is vertical, and even reversed in places, but it is indicated as an anticlinal in the horizontal section No. 2 of the Geological Survey. The limestone of Lampeter Velfry is a faulted synclinal, and to the north occurs another anticlinal, between Lampeter Velfry and Llandewi Velfry, and here again the *Didymograptus*-shales are found, and have yielded *Didymograpti* by the roadside west of “Ll” in “Llandewi Velfry.”

The same fossils are found in similar shales near Whitland, below the limestone, but at some distance from its outcrop.

Prof. Lapworth (Ann. & Mag. Nat. Hist. Ser. 5. vol. iii. p. 59) also places the *Didymograptus*-shales of this area below the Llandeilo limestone.

3. *Llandeilo Limestone*.—The well-known black limestone of Llan Mill, Lampeter Velfry, Llandewi Velfry, &c., interstratified with black shales. It is frequently crowded with fossils, and the following

are preserved in the Geological Survey Museum from the limestone of this region :—

Monticulipora favulosa, *Phill.*
Beyrichia complicata, *Salt.*
Calymene cambrensis, *Salt.*
Asaphus tyrannus, *Murch.*

Trinucleus favus, *Salt.*
Leptaena sericea, *Sow.*
Orthis striatula, *Conr.*
&c. &c.

The limestone is also seen north of Stoneyford, on the road between Narberth and Clynderwen Station ; and similar limestone, which has, however, not furnished us with any fossils, occurs at Bullhook and Camrose, as marked on the Geological Survey map.

4. *Dicranograptus Shales*.—These beds immediately succeed the Llandeilo limestone of Llandewi Velfry, and are seen above the limestone quarry at “P” in “Parsonage.” They are black shales, with some grit bands, and are usually crowded with graptolites, including *Dicranograptus ramosus*, *Climacograptus bicornis*, &c. We have nowhere seen a section giving the complete series. At Llandewi Velfry there is room for about 50 feet of shales between the Llandeilo limestone and the beds above the shales, but it is very doubtful whether the whole of the shales are now represented here. The uppermost beds of the series certainly occur at this locality. They are well-defined, flaggy and sandy black shales, characterized especially by the abundance of *Orthis argentea*, *His.*, and may therefore be spoken of as the zone of *Orthis argentea*.

Dr. Hicks (Q. J. G. S. vol. xxxi. p. 178) also places the Llandeilo limestone between the *Didymograptus*- and *Dicranograptus*-shales.

Confirmatory sections.—The *Dicranograptus*-shales are exposed to a considerable extent to the north of the complex synclinal.

On the west side of the Western Cleddau, they occur much folded in the neighbourhood of Camrose, and at Camrose Mill the *Dicranograptus* beds are again seen succeeding the Llandeilo limestone. At Wolfsdale they have yielded *Ogygia Buchii*. On the east side of the Western Cleddau the beds set in at Rudbaxton, and we have found graptolites at Green Plain, south of Trefgarn Bridge. At Clarbeston-Road Station also graptolites occur. The beds can then be traced in several sections along the railway as at Pendwr, Longridge Bridge, and Blaen Waen, between Clarbeston-Road and Clynderwen Stations, and they appear to overlie the Llandeilo limestone south of Bullhook, although the two are not in close proximity. These beds are also brought up by folds to the south of this. North of Stoneyford they lie immediately over the Llandeilo limestone. The *Orthis-argentea* zone is seen near Grondre, at Robeston Wathen, and at Prendergast, but no Llandeilo limestone is exposed at these places.

We have then several independent sections showing the *Dicranograptus*-shales immediately succeeding the Llandeilo limestone, and the latter may, indeed, be looked upon as merely a calcareous development of the black shales which occur below, within, and above it.

The fossils, other than graptolites, of the *Dicranograptus*-shales, occur chiefly in the *Orthis-argentea* zone, with the exception of

Ogygia Buchii. In that zone we find *Turrilepas* sp., *Pleurotomaria* and *Orthoceras*. *Siphonotreta micula* also occurs in abundance, as well as in lower zones, and other horny brachiopods are common.

5. *Robeston Wathen Limestone*.—This deposit is best known as occurring at the village of Robeston Wathen, where a quarry to the north of the church contains a black limestone with interbedded black shales, dipping S.S.W. The calcareous bands are crowded with *Halysites catenularius*, and other fossils occur, including *Orthis elegantula*, Dalm. Trilobites are rare and fragmentary.

(It is to be noticed that many of the fossils from this locality in the Jermyn-Street Museum are not from this limestone, but from higher beds, to be described presently.)

As the section here is an important one, a figure of it is added (Pl. XV. fig. 3).

The graptolite-shales are seen by a stream immediately below the quarry, dipping under the limestone. These shales belong, as stated above, to the *Orthis-argentea* zone, and the limestone itself appears to be a calcareous development of the upper part of these shales.

Confirmatory Sections.—Near Grondre, two miles north-west of Robeston Wathen, the same limestone is seen, as represented on the Geological Survey map. It is crowded with *Halysites*, as at Robeston Wathen, and is here nearly vertical. In a quarry, at this place, the black limestone is associated with an ashy-looking limestone which yielded a cystidean, and which is apparently the representative of the lowest stage of the next series; but the relations of the two were not determined. Fossils of the black limestone at Grondre:—

Syringophyllum organum, Linn.
Halysites catenularius, Linn.
Petraia æquisulcata, M^cCoy.

Illænus Bowmanni, Goldf.
Orthis Actoniæ, Sow.

To the north-east of the limestone quarry, in a small quarry in a field close to Grondre farm, the *Orthis-argentea* shales are dipping north. The limestone strikes as though it would pass above the shales. The tract between Grondre and Robeston Wathen is much disturbed, newer beds being faulted and folded in.

At Llandewi Velfry, the *Orthis-argentea* shales, which occur some way above the Llandeilo limestone, pass up into flaggy black limestone like that of Robeston Wathen.

At Fron, $1\frac{3}{4}$ mile north-east of Llandewi Velfry, where the Llandeilo limestone is not seen, the *Orthis-argentea* shales are found in a small roadside exposure, dipping a little north of west; and on the hill-side to the west of this and above it, black limestone is exposed in a quarry, presenting an appearance quite similar to that of Robeston Wathen, also with abundance of *Halysites*, and amongst other fossils the following:—

Heliolites interstinctus, Wahl.
— *dubius*, Schmidt.
Petraia æquisulcata, M^cCoy.
— *elongata*, Phill.
Illænus Bowmanni, Salt.

Glauconome disticha, Goldf.
Orthis Actoniæ, Sow.
— *calligramma*, Dalm.
Leptæna transversalis, Wahl.
Strophomena rhomboidalis, Wilck.

At Prendergast, north of Haverfordwest, the *Orthis-argentea*

shales are seen in a lane north of the church, dipping north, and they are very flaggy and calcareous towards the summit, but limestone bands do not occur as in the above localities.

The section seen in this lane, and in a quarry immediately to the east of it, is shown in Pl. XV. fig. 4.

6. *Trinucleus-seticornis* Beds.—These are subdivided into three stages, viz.:—

- (a) Sholeshook limestone.
- (b) Redhill shales.
- (c) Slade calcareous shales.

The beds succeeding the Robeston Wathen limestone consist mainly of blue-grey shales, weathering olive-green, with a considerable development of calcareous matter at the base and summit.

The form *Trinucleus seticornis*, or its variety *Bucklandi*, occurs throughout, and is very characteristic of these beds, which may therefore be spoken of as the *Trinucleus-seticornis* beds.

(a) *Sholeshook Limestone*.—At Robeston Wathen, the central part of the quarry, as shown in the section (fig. 3), contains the upper portion of these beds immediately succeeding the Robeston Wathen limestone. It differs considerably from that limestone both lithologically and palæontologically. Whereas the black limestone is evidently a calcareous development of the black shales, the calcareous band we are now considering is no less clearly a member of the blue-grey shales; and this is also true of the lower zones which occur in other localities. The following fossils occurred in this calcareous band:—*Heliolites interstinctus*, Wahl., *Glyptocrinus basalis*, M'Coy, *Trinucleus seticornis*, His., *Phacops Brongniarti*, Portl., *P. alifrons*?, *Holopella*, *Orthoceras*.

The actual limestone appears to have been crushed out at this point, the fossils occurring in calcareous shales which are elsewhere seen immediately above the limestone itself.

Confirmatory Sections.—At Prendergast, as seen in fig. 4, the uppermost member of the *Orthis argentea* beds, which is there calcareous, is succeeded by greenish, impure limestone, crowded with fossils, especially trilobites, although the limestone itself is much crushed. The fossils are similar to those of Robeston Wathen, but are much more abundant. The following occur:—

Halysites catenularius, Linn.
Petraia.
 Crinoid and cystoid fragments.
Tentaculites anglicus, Salt.
Phacops mucronatus, Brongn., var.
 — *alifrons*, Salt.?
Cheirurus bimucronatus, Murch.
 — *juvenis*, Salt.
 — *octolobatus*, M'Coy.
Lichas laxatus, M'Coy.
Stygina.
Cybele verrucosa, Dalm.
Ilæus Bowmanni, Salt.

Homalonotus?
Trinucleus seticornis, var. *Bucklandi*, Barr.
Agnostus trinodus, Salt.
Orthis elegantula, Dalm.
Leptæna quinquecostata, M'Coy.
 — *sericea*, Sow.
 — *tenuicincta*, M'Coy.
Strophomena rhomboidalis, Wilek.
Otenodonta?
Bellerophon bilobatus, Sow.
Orthoceras.
Cyrtoceras sonax, Salt.

At Sholeshook a splendid section is exposed in the railway-

cutting. The beds here are of the same nature as at Prendergast, but the calcareous matter is mainly collected into nodules. The general dip is northerly, and the beds which appear to dip under the Sholeshook limestone are probably newer beds brought down by a faulted overfold. To this part we shall refer presently. Although the Sholeshook section does not assist us in determining the relationship of this calcareous band to the older beds, it is important as containing so many fossils, and being a well-known fossil locality. The following list of fossils from this place is compiled from the specimens in the Jermyn-Street Museum, those collected by ourselves, and those noticed by Törnquist (Öfv. af K. V.-A. Förhandl. Stockholm, 1879, No. 2, p. 70).

Favosites fibrosus, Goldf.
Chætetes petropolitana, Pand.
Cystideans (cf. Mem. Geol. Surv. vol. iii.).
Beyrichia strangulata, Salt.
Agnostus trinodus, Salt.
Ampyx tumidus, Forbes.
Trinucleus seticornis, His.
 ———, var. *Bucklandi*, Barr.
Remopleurides longicostatus, Portl.
 ——— *radians*, Barr.
 ——— *dorso-spinifer*, Portl.
Stygina latifrons, Portl.
Illænus Bowmanni, Salt.
Lichas laxatus, M^cCoy.
Calymene fatua, Salt., M^s.
Cyphaspis megalops, M^cCoy.
Phillipsia parabola, Barr.

Cybele verrucosa, Dalm.
 ——— *Loveni*, Linnrs.
Enerinurus sexcostatus, Salt.
Cheirurus bimucronatus, Murch.
 ——— *octolobatus*, M^cCoy.
 ——— *juvenis*, Salt.
Sphærexochus boops, Salt.
 ——— *angustifrons*, Ang.
Phacops aratus, Salt., M^s.
 ——— *Brongniarti*, Portl.
Glauconome, n. sp.
Leptæna sericea, Sow.
 ——— *tenuicincta*, M^cCoy.
Orthis testudinaria, Dalm.
 ——— *calligramma*, Dalm.
Cyrtoceras sonax, Salt.
Trochoceras cornu-arietis, Sow.

At the schoolhouse north of Pelcomb Cross (3 miles north-west of Haverfordwest), the *Orthis-argentea* shales are seen by a small stream to the west of the road, dipping in a southerly direction. South of this, a quarry by the roadside contains beds apparently overlying the *Orthis-argentea* shales. These consist of crushed calcareous shales of a greenish colour, quite like those of Sholeshook and Prendergast. There is room between the *Orthis-argentea* shales and the quarry for the Robeston Wathen limestone, but no exposure is seen. This quarry is probably the place from which Prof. Phillips obtained the fossils mentioned in 'Memoirs of the Geological Survey,' vol. ii. pp. 235 *et seq.* The following occur here:—

Agnostus trinodus, Salt.
Ampyx tumidus, Forbes.
Cybele Loveni, Linnrs.
Enerinurus sexcostatus, Salt.
Illænus (young).
Cheirurus bimucronatus, Murch.

Staurocephalus globiceps, Portl.
Phacops Brongniarti, Portl.
Phillipsia parabola, Barr.
Trinucleus seticornis, var. *Bucklandi*, Barr.

These beds can be traced to the north of West Pelcomb, where similar fossils are found, and *Trinucleus Bucklandi* is specially abundant, and well preserved. *Cheirurus juvenis* also occurred here.

On the north side of the complex synclinal, calcareous beds are seen by the platform on the south side of Clarboston-Road Station, where *Trinucleus Bucklandi* is found in plenty with:—

Phacops Brongniarti, Portl.
Homalonotus?

Leptæna tenuicincta, M^cCoy.

On the north platform, the *Dicranograptus*-shales are seen, dipping as though to pass under the calcareous beds, and a small thickness of these occurs on the south side, just at the east end of the platform. Although the two series are there seen in apposition, a small fault must occur along the line of strike, cutting out the greater part of the calcareous beds; for the summit of the graptolite-shales (the *Orthis-argentea* zone), the Robeston Wathen limestone, and the lower part of the Sholeshook limestone stage are absent.

(b) *Redhill Beds*.—We have named these beds after the farm of Redhill, two miles north of Haverfordwest, where a quarry by the roadside shows a good section of the beds, which are also fairly fossiliferous here. (As a general rule, fossils are somewhat scarce in them.) They consist of blue-grey shales, weathering olive-green. In all cases where the Sholeshook limestone is seen, it is found to pass gradually up into these beds by disappearance of the calcareous material. We have obtained fossils from the Redhill beds, at Redhill, Pelcomb Bridge, and Wolfsdale Well, on the west side of the Western Cleddau; and at Prendergast Mill, Crundale, and Robeston Wathen, on the east side of that river. The list here given shows the principal fossils obtained from these localities:—

	Redhill Quarry.	Pelcomb Bridge.	Wolfsdale Well.	Prendergast Mill.	Crundale.	Robeston Wathen.
<i>Chætetes</i> , sp.					*	
<i>Stenopora</i> , sp.					*	
Crinoid, arms of	*				*	
<i>Phacops mucronatus</i> , <i>Brongn.</i> , var.	*					
— <i>alifrons</i> , <i>Salt.</i> ?	*					
— <i>Brongniarti</i> , <i>Portl.</i>	*	*		*	*	*
<i>Calymene</i> , sp.					*	
<i>Trinucleus Bucklandi</i> , <i>Barr.</i>	*					
<i>Ampyx rostratus</i> , <i>Sars.</i>			*			
<i>Homalonotus bisulcatus</i> , <i>Salt.</i>	*					
<i>Encrinurus</i> , sp.		*				
<i>Lingula</i>		*				
<i>Leptæna sericea</i> , <i>Sow.</i>	*	*				
— <i>tenuicincta</i> , <i>M. Coy.</i>	*					
<i>Strophomena rhomboidalis</i> , <i>Wilck.</i>					*	
<i>Orthis elegantula</i> , <i>Dalm.</i>					*	
— <i>calligramma</i> , <i>Dalm.</i>	*					
<i>Modiolopsis</i> ?				*		
<i>Arca dissimilis</i> , <i>Portl.</i>				*		
— <i>transversa</i> , <i>Portl.</i>				*		
<i>Holopea concinna</i> , <i>M. Coy.</i>	*					
<i>Pleurotomaria</i> , sp.	*					
<i>Bellerophon</i> , sp.				*		
<i>Ecculiomphalus Bucklandi</i> , <i>Portl.</i>			*			
<i>Orthoceras gracile</i> , <i>Portl.</i>	*					
<i>Cyrtoceras</i> , sp.	*					

The large tract of country west of the Western Cleddau occupied by these Redhill beds, is due to frequent repetition by folds, and the

same has taken place, but to a less extent, on the east side of the river.

(c) *Slade beds*.—These succeed the Redhill stage at Lower Slade, immediately north of Haverfordwest, on the west side of the Western Cleddau. They are seen by the roadside, and also in a cutting near the mill. From the latter place, we have examined a number of fossils presented to the Woodwardian Museum by Dr. Hicks. To the south they are faulted against Lower Llandovery beds, the fault being seen in section in the road-cutting.

The beds consist of gritty green shales, with weathered calcareous bands, very similar in lithological character to the well-known Lower Llandovery beds of this district, but the fossils are to a considerable extent different. *Trinucleus seticornis* is fairly common, and has never been found in the Lower Llandovery beds of this area. Many calcareous bands of this stage are crowded with *Phyllopora Hisingeri*, M'Coy. Among the fossils at Slade are :—

Stenopora, sp.
Glyptocrinus basalis, M'Coy.
Tentaculites anglicus, Salt.
Calymene Blumenbachii, Brongn.
Phacops Brongniarti, Portl.
Illænus Murchisoni, Salt. ?
— *Bowmanni*, Salt.
Homalonotus bisulcatus, Salt.
Trinucleus seticornis, His.

Glauconome disticha, Goldf.
Lingula.
Strophomena rhomboidalis, Wilek. ?
— *corrugata*, Dav.
Leptæna sericea, Sow.
Orthis biforata, Schloth.
— *elegantula*, Dalm.
— *testudinaria*, Dalm.

On the east side of the Western Cleddau, these Slade beds occur in a lane north of Crundale, dipping away from the Redhill beds of that locality, which appear to pass under them. They are there very fossiliferous, and have yielded *Trinucleus seticornis* along with :—

Petraia, sp.
Tentaculites anglicus, Salt.
Phyllopora Hisingeri, M'Coy.

Calymene trinucleina, Linnrs.?
Orthis testudinaria, Dalm.
Bellerophon bilobatus, Sow.

These beds are very extensively exposed in this region, being found also in the railway-cuttings at Little Hareshead and Clover Hill, and in a small quarry at Dallaston.

At Robeston Wathen they occur above the blue-grey shales of the Redhill stage ; and on the other side of the Robeston Wathen synclinal, are seen at Benlmond Cottage, where Prof. Phillips found *Trinucleus ornatus*, var. *Caractaci* (Mem. Geol. Survey, vol. ii. p. 240).

Fossils from the north side of the Robeston Wathen synclinal are :—

Climacograptus.
Petraia.
Tentaculites anglicus, Salt.
Ptilodictya costellata, M'Coy.
Calymene trinucleina, Linnrs.?
Trinucleus seticornis, His.
Cheirurus, sp.

Phacops Brongniarti, Portl.
Illænus.
Orthis porcata, M'Coy ?
Leptæna sericea, Sow.
Strophomena.
Bellerophon bilobatus, Sow.

From Benlmond Cottage :—

Tentaculites anglicus, Salt.
Lichas.
Orthis calligramma, Dalm.

Orthis testudinaria, Dalm.
Leptæna sericea, Sow.

North of Stoneyford, the beds of this stage are also seen in the southern limb of a small synclinal, the lower beds of which are apparently absent, owing to a slight dislocation.

To the east of this, the same beds are found occupying the more central part of the synclinal north of Llandewi Velfry.

7. *Conglomerate Series*.—Near the centre of the complex synclinal, and in the centres of the minor synclinals of Robeston Wathen, Penblewin, and to the north of Llandewi Velfry, a coarse conglomerate is found with pebbles of vein quartz, and other materials of distant origin, succeeded by a coarse quartzose grit.

To the west, this grit appears to be first met with in the railway-cutting south of Sholeshook, where it is faulted in against older beds on the north. To the east of this, it is seen near Maryborough, dipping north at a low angle. From here it runs eastward along a ridge to Wiston Wood. In a quarry south-west of Valley Farm, green-banded mudstones, with beds of quartz-grit, possibly belonging to this series, are found. On the north side of the quarry they dip at a very low angle to the north, whilst on the south side they are vertical. This appears to be due to a sudden bend rather than to a fault. To the west of Wiston Wood, the conglomerate is exposed in a quarry in a field. It is here nearly vertical, but dips slightly north, and, according to the strike, would pass beneath the beds of the last-mentioned quarry.

Another ridge of grit runs to the north of this one, also in a general east and west direction. It is seen faulted against *Trinuclaus-seticornis* shales, in the railway-cutting, west of Wiston Mill. Proceeding in an easterly direction, we again find it exposed on the ridge $\frac{1}{2}$ mile S. of "o" in "Dallaston;" it is here much disturbed. It appears to be continued along this ridge to Wiston. In a quarry south of Church Hill, near this village, a very coarse grit is found, dipping south. Wherever exposed, the grit of this ridge appears to overlie or be faulted against beds of the Slade stage.

A third grit-ridge runs parallel to these, and to the south of them. Grit is found, apparently overlying green shales, in a road-cutting west of Slebech New Church. In a quarry south of Clerken Hill, east of the last place, conglomerate is exposed, dipping north.

At Robeston Wathen the conglomerate is many feet thick, and occupies the centre of the synclinal shown in fig. 3. In each limb of the synclinal it rests upon the representatives of the Slade beds, containing *Trinuclaus*.

A patch of grit is seen in a quarry south of "Camp," $1\frac{1}{2}$ mile north-east of Robeston Wathen. The relations of this to the surrounding beds are somewhat obscure, as the tract of country between the limestones of Robeston Wathen and Grondre is, as already stated, much broken.

Another ridge runs from near Penblewin eastward. Here the conglomerate is found in a quarry west of Carmine, dipping north at an angle of 20° and succeeded by coarse grit. It rests upon the representatives of the Slade beds which occur at the cross roads at Penbelwin.

The last appearance of the conglomerate eastward, in the area we have examined, is in a quarry west of Wheelabout, where it is succeeded by sandstone, the beds dipping N.W. It occurs at this place also above beds of the Slade stage, which are well seen at the "k" of "Bank Saison" dipping west.

From the numerous exposures of the beds of this series, where they immediately succeed the Slade beds, there seems little doubt that this is the true position of the conglomerate; and as we have found no evidence of its resting upon any beds lower in the series, it would seem that there is no very great physical discordance at the base of the conglomerate-band, which nevertheless may mark an important physical change in the area.

We have unfortunately been unable to find any exposures showing the conglomerate succeeded, without suspicion of faulting, by still higher beds, as it occurs in most cases on the summits of ridges, and the higher strata have been removed by denudation. In one instance, however, the grit is found between the Bala and the fossiliferous Lower Llandovery beds. This is in a section, previously alluded to, on the railway between Haverfordwest station and Sholeshook. The diagram section (fig. 5) shows the actual exposures, and the fault and folds which we consider necessary to explain the apparent sequence. Between the Sholeshook limestone and the grit only one isolated exposure is seen, in a lane east of the railway, having beds lithologically like those of the Slade stage, and containing fossils which are too imperfect for determination. The beds between the grit and the station are also somewhat unfossiliferous, and though the fossils found, including *Phacops mucronatus*, Ang. (the form which occurs in the Upper Brachiopod beds of Sweden, and not the variety of the Sholeshook and Redhill beds), seem to indicate the Lower Llandovery age of the beds, the determination is doubtful. We can, however, draw no line between these beds and the very fossiliferous beds of the Gas-works, of true Lower Llandovery age.

Another point to be noticed is the absence of the conglomerate, which, however, occurs in connexion with the grit, further east, as above described. Its absence appears to point to the existence of a fault, as well as the inversion represented in the diagram. The relationship of the conglomerate series to the Lower Llandovery further east is obscure, owing to the paucity of sections. From the nature of the ground, we should expect this series to pass continuously round from Wiston to Slebech, thus lying between the Lower Llandovery and the Bala beds which occur further east.

What scanty evidence we have, therefore, certainly points to the conglomerate series being immediately succeeded by the fossiliferous Lower Llandovery beds, and this conclusion is supported by the palæontological evidence; for the fauna of the Slade beds, though differing from that of the Lower Llandovery beds, has several forms in common.

Moreover, the accumulation of the conglomerate series shows only a slight pause in a period during which beds of similar litho-

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logical character were being laid down, as the Lower Llandovery beds closely resemble the Slade beds lithologically.

8. *Lower Llandovery Beds*.—These beds are, as explained above, apparently faulted against the lower beds in the immediate neighbourhood of Haverfordwest. They are usually very highly inclined, and stretch to the south of the town for nearly two miles. The well-known section at the Gas-works shows the general character of the rocks, which consist of gritty green shales, with bands of grit, and weathered calcareous bands crowded with fossils. As the organisms of this deposit are preserved in many museums, it is unnecessary to give a full list. *Nidulites favus*, *Petraia subduplicata* var. *crenulata*, *Tentaculites anglicus*, and brachiopods, lamellibranchs, and gasteropods are all abundant. Amongst the fossils hitherto unrecorded from these beds are *Phacops elegans*, Böeck and Sars (= *elliptifrons*, Esm.), and *Deiphon Forbesi*, Barr. A fine specimen of the latter was presented to the Woodwardian Museum by Mr. H. T. Wills.

§ 3. *Comparison with the Deposits of other Areas.*

The resemblance of many of our stages to those of other areas, whether we take into account their lithological or palæontological characters, is so striking, that it cannot be a mere coincidence, especially as this resemblance does not occur in isolated stages, but in the consecutive stages of some of the series. We propose, therefore, to point out briefly some of these similarities, as they afford assistance in attempting the correlation of deposits of different areas.

i. *Lingula-Flags*.—These beds appear, from the occurrence of *Olenus spinulosus*, to represent the Lower Dolgelly beds of the Lingula-Flags of North Wales, which are correlated by Prof. Brögger (Sil. Et. 2 and 3, p. 144) with his "*Parabolina-spinulosa* niveau" (2b) in the Christiania district, where that fossil is likewise associated with *Agnostus socialis*.

It is desirable, however, that additional species should be obtained; for whilst the fossils already procured leave no doubt as to the Lingula-Flag age of the rocks containing them, it is perhaps dangerous to attempt to assert positively to what portion of the Lingula-Flag series they belong, without further evidence.

ii. *Didymograptus-Shales*.—The "tuning-fork" graptolites of these beds are characteristic of Dr. Hicks's Llanvirn beds in the St.-David's district, as elsewhere. As the horizon is so well known in many places, and contains this particular type of graptolite, it is needless to give a list of deposits of the same age in other areas.

iii. *Llandeilo Limestone*.—The remark just made applies in this case also. The position of the *Asaphus-tyrannus* beds is well established in South Wales. At the same time it is possible that the beds included in the Llandeilo limestone of other regions are partly represented by the lower beds of the succeeding division of the Haverfordwest district; for whereas *Ogygia Buchii* has not been discovered by us in the limestone, and is apparently not recorded

from the limestone of this region, it does occur in the graptolite-shales of the succeeding group.

iv. *Dicranograptus-Shales*.—It has already been stated that several zones must be represented among these beds, and that we have been unable to work these out in the field, owing to the absence of exposures continuous throughout the series. That the beds do represent generally the Glenkiln and lower portions of the Hartfell groups of Scotland appears probable; but as we have submitted a large collection of specimens from this horizon to Professor Lapworth, we leave the fuller determination of the age of the group to him.

The uppermost bands, which are crowded with *Orthis argentea*, may be compared with the *Orthis-argentea* zone of Dr. Linnarsson in Sweden (*cf.* Lapworth, *Geol. Mag.* dec. ii. vol. vii. p. 43).

v. *Robeston-Wathen Limestone*.—The fossils of this limestone are certainly of Middle Bala facies; but trilobites are rare, and the organisms are chiefly corals. The identification of this bed with parts, at any rate, of the Bala and Coniston limestones receives strong support from the evidence furnished by the succeeding deposits.

vi. *Trinucleus-seticornis Beds*.

(a) *Shoeshook Limestone Stage*.—This is comparable both lithologically and palæontologically with the Rhiwlas limestone of Bala, which must certainly be of different age from the true Bala limestone. The bed is so peculiar in character, and maintains its appearance and palæontological characters so uniformly over a wide area, that it is very easy to identify, and forms therefore a very important horizon for purposes of comparison. The Rhiwlas cystideans are similar to those of Shoeshook, and the trilobites are mostly of the same species. *Staurocephalus* is present at Rhiwlas as in Pembroke-shire, and associated with it are the following fossils of the Shoeshook stage :—

Ampyx tumidus, Forbes.
Cheirurus juvenis, Salt.
— *bimucronatus*, Murch.

Trinucleus seticornis, His.
Leptæna tenuicincta, M'Coy.
Cyrtoceras sonax, Salt.

It may be observed that, as Professor Sedgwick made his Upper Bala series to include the beds above the Bala limestone, this stage must be taken as the base of that series, and it forms, as observed, a readily recognized base.

In the Lake-district a bed of quite similar lithological character occurs immediately above the Coniston Limestone. Its fauna has not yet been fully described, but one of us has elsewhere noticed it ('Sedgwick Essay,' 1882, p. 58). *Staurocephalus* is there associated with the same cystideans as at Shoeshook, and a large number of trilobites are common to the two deposits, and do not occur in the underlying Coniston limestone.

The starfish-bed of Prof. Lapworth (*Q. J. G. S.* vol. xxxviii. p. 619) may possibly be the representative of this in the Girvan area; it also contains *Staurocephalus globiceps*.

In Ireland the same group of fossils appears to occur at Desert-

creat, Tyrone, judging from an examination of the specimens preserved in the Museum of Practical Geology. Amongst the fossils common to Sholeshook and Desertcreat are :—

Phacops Brongniarti, *Portl.*
Staurocephalus globiceps, *Portl.*
Remopleurides dorso-spinifer, *Portl.*

Illænus Bowmanni, *Salt.*
Stygina latifrons, *Portl.*
Trinucleus seticornis, *His.*

The absence of cystideans at Desertcreat is noticeable.

A large number of fossils are recorded from this Irish locality, which seem to show that the representatives of the Redhill stage occur there also.

In Sweden the same fauna appears at the same horizon in beds of precisely similar lithological character. Immediately above the beds correlated with the Middle Bala series, in Westrogothia, Dr. Linnarsson's *Staurocephalus*-beds (at the base of the Brachiopod-schists) contain *Staurocephalus clavifrons*, *Ang.*, *Proetus brevifrons*, *Phacops mucronatus*, *Calymene tuberculata*, *Acidaspis centrina*, *Trinucleus Wahlenbergi*, *Agnostus trinodus*, *Phillipsia parabola*, and *Panderia megalophthalma* (Linnarsson, 'Om Västergötlands Cambrika och Siluriska Aflagringar,' p. 51).

In Scania also the same bed occurs. Dr. Tullberg ('Skånes Graptoliter,' i. p. 17) records in his zone with *Staurocephalus clavifrons* :—

Staurocephalus clavifrons, *Ang.*
Phacops mucronata, *Ang.*
Trinucleus Wahlenbergi, *Rouault.*
Illænus, cf. *Salteri*, *Barr.*
Proetus brevifrons, *Ang.*
Cheirurus, sp.

Ampyx tetragonus, *Ang.*
Phillipsia parabola, *Barr.*
Acidaspis, sp.
Calymene Blumenbachii, *Brongn., var.*
Agnostus trinodus, *Salt.*
Dentalium, sp.
Turbo, sp.

From the general occurrence in this zone of *Staurocephalus globiceps*, or a closely allied species, it may be conveniently spoken of as the *Staurocephalus*-zone.

(b) *Redhill Stage*.—This stage is lithologically like the Ashgill shales of the Lake-district, which also immediately overlie the *Staurocephalus*-zone. In Scotland the "soft blue mudstones, homogeneous, thick-bedded, and more or less concretionary in structure," described by Prof. Lapworth as occurring above the Starfish-bed of Lady Burn, in the Girvan area, seem to be likewise similar (Q. J. G. S. xxxviii. p. 619).

In Scandinavia the beds with *Phacops eucentra*, *Ang.* (a variety of *P. mucronatus* ?), which immediately succeed the *Staurocephalus*-zone in Scania and Westrogothia, have elsewhere (Q. J. G. S. xxxviii. p. 321) been compared by one of us with the Ashgill Shales of Britain.

(c) *Slade Beds*.—These are not precisely like any beds known to us as occurring about the same horizon in other areas.

In the Lake-district a mottled grey limestone with many brachiopods occurs immediately above the Ashgill Shales and below the Birkhill beds in Skelgill Beck. Like the Slade beds, it is marked by the occurrence of *Chimacograptus* and the absence of *Monograptus*.

In Scania, Dr. Tullberg ('Skånes Graptoliter,' i. p. 17) finds above his zone with *Phacops mucronatus* (*P. eucentra*) a zone with *Diplograptus* and *Climacograptus scalaris*, and marked by an absence of *Monograptus*. This zone he places at the top of the Upper Cambrian (Sedgwick), and not at the base of the Silurian, where Prof. Lapworth describes a zone marked by the absence of *Monograptus*, viz. at the base of the Birkhill beds (cf. Lapworth, Q. J. G. S. vol. xxxiv. p. 318).

In Westrogothia the gritty beds with *Trinucleus* at Mösseberg may represent our Slade beds.

vii. *The Conglomerate*.—As stated, when describing the apparent position of these beds, they appear to succeed everywhere the Slade beds.

If this be their true position, they form a satisfactory base to the Silurian rocks of this area.

We may compare them with the Mullock-Hill conglomerate of Prof. Lapworth (Q. J. G. S. vol. xxxviii. p. 621), which lies in the Girvan district directly above the *Trinucleus*-shales, just as the conglomerate in the district now described lies above our *Trinucleus*-shales.

viii. *Lower Llandovery Beds*.—We have applied this term to the shelly sandstones immediately south of Haverfordwest town, as they have been constantly spoken of as Lower Llandovery. If they do actually succeed the Conglomerate stage, the latter should also be included in the Lower Llandovery series.

These shelly sandstones are lithologically and palæontologically similar to two well-known deposits, viz. the Mullock-Hill Sandstones of the Girvan district, and stage 5 β in the neighbourhood of Christiania. All these contain *Nidulites* along with *Stricklandinia* and a host of other brachiopods. A comparison of the published lists will show the practical identity of the faunas (cf. Catalogues of Palæozoic Fossils in the Woodwardian Museum, and that of Practical Geology, also Kjerulf's 'Veiviser').

The upper part of the Brachiopod-beds of Westrogothia has a similar fauna, and is placed on this horizon by the Scandinavian geologists.

One of us has in a previous communication (Q. J. G. S. vol. xxxviii. p. 316) discussed the age of the *Leptæna*-limestone of Mr. Törnquist, which occurs in Dalecarlia, and has referred it to a position above the *Lobiferus*- and *Retiolites*-shales of that region. This was certainly a mistake, due to ignorance of the phenomena presented by a greatly disturbed region at the time of examination.

Dr. Fr. Schmidt has shown (Q. J. G. S. vol. xxxviii. p. 523) that the fauna of the stage F of the East Baltic provinces is that of the *Leptæna*-limestone of Osmundsberg.

The *Leptæna*-limestone contains a mixture of faunas of several of the Haverfordwest beds, viz. :—the Lower Llandovery, *Trinucleus-seticornis* beds, and perhaps even of the Robeston-Wathen limestone, the corals of which also occur in the *Leptæna*-limestone.

§ 4. Conclusion.

We have endeavoured, in this paper, to establish the succession in the district under consideration. That certain difficulties are not yet cleared up is admitted. Our inability to discover any section showing normal Sholeshook limestone resting upon normal Robeston-Wathen limestone is unfortunate. In separating these stages from each other, we are influenced by the lithological and palæontological differences between the two deposits, and by comparison with similar beds in other areas. But for this, we should be disposed to look upon the Robeston-Wathen limestone as a local development of the Sholeshook limestone. We may note, however, that there are many places in the district where one or more of the limestones can be satisfactorily proved to have been crushed out.

As already explained, also, the relation of the conglomerate to the succeeding beds requires further study.

These minor difficulties have been encountered when studying portions of the sequence which are typically developed elsewhere. As they do not greatly affect our establishment of the sequence in this area, and as other difficulties would probably arise upon further exploration, the announcement of our results might be indefinitely postponed, and we therefore venture to bring our work before the Society, in the belief that what we have done will prove sufficient to furnish a clue to the solution of a very interesting question, viz. the nature of the foldings which have affected the district.

EXPLANATION OF PLATE XV.

Fig. 1. Geological Sketch-Map of the neighbourhood of Haverfordwest. The map, based on that of the Geological Survey, is simply intended as a sketch-map, showing the general distribution of the beds; and the boundaries in many places are only approximately correct. The Redhill beds and Slade beds have been represented by the same sign, as we have not traced the boundary between them over the whole district. The *Dicranograptus*-shales of Grondre and Longford may extend further east than represented.

2. Section in Quarry south-east of Trefgarn Bridge.
3. Section through Robeston Wathen.
4. Section in the Lane north of Prendergast Church.
5. Diagram-section along the Railway from Haverfordwest Station to north of Crundale.

DISCUSSION.

The PRESIDENT expressed his pleasure at seeing that such admirable work had been done by Cambridge geologists.

Dr. HICKS stated that the Authors had entirely confirmed his views that the rocks of Roch Castle and Trefgarn which he had referred to the Archæan were not, as believed by the Geological Survey, intrusive rocks penetrating Lower-Silurian strata. The recognition of the important fact that these are of Pre-Cambrian age was absolutely necessary before the geology of the area could

possibly be interpreted. The succession of the rocks in this district had never been unravelled till the Authors undertook the task.

Prof. HUGHES remarked on the absence of the evidence of the occurrence of the Harlech Grits except the basement-bed, of the Menevian, the Tremadocs, part of the Arenigs, and other formations. He thought the Hirnant limestone really consists of two members which are separated by a great break, and the lower of these only is represented by a limestone in the area described. He thought it probable that the equivalents of the Upper Conglomerates might be found in the Malvern district, and that they form the base of the Silurian.

Mr. MARR thought that the beds in Trefgarn-Bridge Quarry exhibit signs of faulting, which may account for the apparent absence of some of the strata. He thought that a great confusion had arisen as to the position of the conglomerates at the base of the Silurian.