THE LLANDOVERY TRANSGRESSION OF THE WELSH BORDERLAND

by A. M. ZIEGLER, L. R. M. COCKS, and W. S. MCKERROW

ABSTRACT. The study of the evolution of several brachiopod genera has enabled the early Silurian shelf sequences of the Welsh Borderland to be correlated with the type area of Llandeilo, and, to some extent, with the graptolite zonal sequence. The transgression across the Borderland started at the beginning of Llandovery time, when areas in Montgomeryshire became inundated after a short break in deposition at the end of the Ashgill. The sea reached Shropshire, and possibly as far east as the Malverns and May Hill, by Middle Llandovery times. By late Upper Llandovery times, much of the English Midlands were covered.

Fossil communities indicate the relative depths in which the Llandovery sediments were deposited. With the advance of the sea, most sequences show a progressive increase of depth with time, although minor reversals are known. The many gaps in the local sequences are probably due to submarine erosion or non-deposition, rather than to uplift and sub-aerial erosion, because they are characteristically followed by progressively deeper-water communities. The community distribution indicates that a continuous gradient was maintained from the coast to the shelf margin, once the topographic relief of the original surface had been filled in.

DURING the Lower Silurian there was a spread of the shelf sea from Central Wales over the Welsh Borderland (text-fig. 1). Brachiopods are the dominant element in the shelf faunas of this region. Now that the evolution of several brachiopod genera is known in detail, it is possible to correlate the shelly deposits with the standard section at Llandovery.

Animal communities have been defined for this period, and they have been shown to reflect the depth of the sea. These communities are diachronous, and migrated as the transgression advanced.

The twin concepts, of evolving lineages as a basis for correlation and of animal communities as a basis for interpreting the environment, provide the foundation of this work.

BASIS OF CORRELATION

The type section of the Llandovery is to be seen south-east of the town of this name in Wales (Jones 1925). Brachiopods are the dominant faunal element in the area, but correlation of other shelly areas with the type section has had to await the study of the commoner brachiopod lineages. This approach contrasts with the tendency for workers in the shelf areas to have correlated Silurian beds by the assemblages of species present. Evolutionary sequences are now known for the stricklandiids (Williams 1951, St. Joseph 1935), the pentamerids (St. Joseph 1938), the atrypide Eocoelia (Ziegler 1966b) and the strophomenide Leptostrophia (Cocks 1967a).

Some brachiopod lineages and their relationship with the type Llandovery are shown in text-fig. 2. The only brachiopods on this list which do not occur at Llandovery itself are E. soleata, C. birta typica, and Pentameroides; their assignment to C5 is based on the fact that they are known to occur between C5 and basal Wenlock beds in adjacent areas of the Welsh Borderland.

Most of the Lower Silurian of the British Isles carries a fauna of graptolites. Lapworth (1878) and Elles and Wood (1901–18) established a sequence of graptolite zones which
have provided an accepted basis for correlation. A few graptolites of zonal value have
been found at Llandovery (text-fig. 2) but are only recorded from three horizons. Jones
(1925, p. 360) found graptolites referable to his actinatus Zone in A2 (this is now equated
with the lower part of the cyphus Zone—Toghill 1968): Jones also (1949, p. 52) cor-
relates B2 with the C. cometa Band, which is in the upper part of the conosulcatus Zone;
and he further records graptolites of the sedgwicki Zone (1925, p. 370) from beds
assigned to C1. This last fauna has been confirmed by our recent collecting from the
other known locality of this restricted facies near an old ford across the River Sefin
(Grid Ref. SN/7419 2811).
In addition to these finds from Llandovery itself, other links between the brachiopod and graptolite sequences have been determined in the upper half of the Llandovery of Shropshire (Cocks and Rickards, in press); but, as yet, firm ties are not proved for the whole Llandovery succession.

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<tr>
<th>Brachiopod Lineages</th>
<th>Graptolite Zones</th>
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<td>Ashgill</td>
<td>Dicella</td>
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TENT-Fig. 2. The correlation of brachiopod lineages and graptolite zones with the standard sequence at Llandovery. The asterisks against some brachiopods indicate that they have not been found at Llandovery; the tie-arrows indicate graptolite finds at Llandovery.

The limits of the Llandovery Series at Llandovery have not yet been properly defined, nor have they been firmly correlated with the sequence of graptolites. However, in this paper, we take the base of the series as equivalent to the base of the Glyptograptus perseculptus Zone, and the top of the series at the base of the Wenlock; or as equivalent
to the base of the *C. marcshisoni* Zone, in the sense of Elles and Wood (1901–18). This last zone is sometimes now divided into a lower *Cyrtograptus centrifugus* Zone and an upper, restricted, *C. marcshisoni* Zone.

**DISTRIBUTION OF ANIMAL COMMUNITIES**

By means of large collections from single beds (many with over a thousand specimens), it is possible to quantify the proportions of species present at each locality.

Five main benthiic animal communities have been defined by this means from the Llandovery (Ziegler 1965, Cocks 1967b, Ziegler, Cocks, and Bambach 1968). Each community is characterized by a particular faunal assemblage, consisting chiefly of brachiopods, and each has been named after a prominent brachiopod genus in the assemblage. They are the *Lingula* Community, the *Eocoeola* Community, the *Pentamerus* Community, the *Stricklandia* Community, and the *Clarinda* Community. At any one time, they occurred in this sequence, from the inferred coastline to the outer margin of the shelf. In beds of C1 and C2 age, *Pentamerus* and *Stricklandia* have evolved into *Pentamerotoides* and *Cosistricklandia* respectively, and the community names change correspondingly.

So far the communities have been described only from the Upper Llandovery, but, apart from *Eocoeola*, the characteristic genera also occur in the Middle Llandovery, and the *Stricklandia* and *Clarinda* Communities are present in Lower Llandovery beds. A *Cryptothyrella* Community occurs in the Lower and Middle Llandovery with associates of the *Eocoeola* Community, and it appears to be an early equivalent of the latter community; it is abundant in basal beds at several areas, and occurs also in North America (Ziegler and Boucot, in press).

In addition, during parts of the Middle and Upper Llandovery, the position of the *Eocoeola* Community in Shropshire is taken by the parallel *Rostricellula* Community (Cocks and Rickards, in press). Also, in places near the edge of the shelf, the *Clarinda* Community dwindles to a sparser 'Marginal *Clarinda*' Community, with many typical members absent.

Apart from the burrowing *Lingula*, all the Llandovery brachiopods were epifaunal. Thus the majority of Silurian level bottom communities contrast with equivalent modern communities in which are mainly infaunal. These Silurian communities were therefore less dependent on the type of substrate than their modern counterparts.

Rocky bottom communities are known at the base of some local sequences, although in all cases where these have been preserved they are accompanied by some soft-bottom elements.

The distribution of the main communities at three horizons in the Llandovery is shown in three maps at the end of the paper (text-figs. 12–14). While the actual depths represented by the communities are uncertain, the lines bounding them are presumed to parallel the bathymetric contours. Thus we have a picture of the changing configuration of the shelf sea during the transgression, and of the migration of the communities with time.

A distinction is drawn between 'basin' and 'graptolitic' facies. The former is restricted to areas (for example text-fig. 3, cols. 1 and 10) where rapid sediment supply, great
water depths, and considerable subsidence has resulted in large thicknesses of sediment. The term 'graptolitic' facies is used for rocks in which the dominant fossils are graptolites, and in which shelly forms, apart from a few orthocenes and epiphanitic bivalves, are generally absent. This facies represents one or other of two environments, firstly deposition under water which was too deep for benthic colonization at that time, or, secondly, water of any depth which had a foul bottom, lower temperature, or other physical conditions iminmal to a shelly fauna. When a graptolitic facies occurs to seaward of a Clorinda Community, we feel justified in selecting the first of these alternatives, and interpreting the occurrence as being too deep for a shelly fauna; this situation applies to all of the Llandovery in the Welsh Borderland. However the second alternative certainly applied at other times and places during the Lower Palaeozoic, for example this is how we would interpret the Wenlock Shale to the south of the Long Mynd, Shropshire.

Acknowledgements. We are indebted to the late Professor W. F. Whitard for his advice, fossil collections, and loan of field maps. Dr. M. L. K. Cattin kindly made his thesis and collections available, and conducted us to localities in the Tortworth Inlier. Drs. W. B. N. Berry, R. B. Rickards, and D. Toghill identified the graptolites we have found, and discussed older records.

The theses by Ziegler (1963) and Cocks (1965), both at Oxford, were supported in part by the Burdett-Couts Fund and the Department of Scientific and Industrial Research respectively. We are grateful to Mr. J. M. Edmonds and Mr. H. P. Powell for housing our thesis collections in the Oxford University Museum (Appendix 1), and for providing funds for their labelling. Collections made subsequently are deposited in the British Museum (Natural History) (Appendix 2) and the U.S. National Museum (Appendix 3). These last were prepared by Ziegler in the laboratories of Dr. A. J. Boucot at the California Institute of Technology from 1964–6. More recently, Ziegler has been supported by Grant 910–G from the Petroleum Research Fund, administered by the American Chemical Society; and by Grant GB–6592 from the National Science Foundation of America.

DESCRIPTIONS OF THE OUTCROPS

Three traverses across part of Wales and the Borderland (text-fig. 1) are represented by the composite sections in text-fig. 3.

In the following account, the areas studied in detail are treated first; i.e. the sections from Minsterley to Tortworth (text-fig. 3, cols. 5–6, 11–19, and 25–9). These constitute the classical Welsh Borderland area. Secondly, we discuss the small inliers to the east of the Borderland (text-fig. 3, cols. 7–9 and 20). We have examined collections from these areas, and include them for the sake of completeness. Finally we contrast these shelf sequences with areas to the west of the Borderland, which in Llandovery times formed the shelf margin and the basin. These areas are mostly in Wales (text-fig. 3, cols. 1–4, 10, and 21–3); we have collected in all of them, with the exception of the purely graptolitic sequences.

TEXT-FIG. 3. Three traverses across the Welsh Borderland (see text-fig. 1) showing local sections with communities, correlation, lithology, and stratigraphical relationships. True thicknesses are shown. The distances between columns are not the straight-line distances, but the N. 60° W. component of these distances.
Exposures of Llandovery sediments to the north and west of the Shelve Inlier, Shropshire (text-fig. 4), occur in a sinuous strip running north-east from north of Chirbury through Hope Valley and Venusbank to near Minsterley. Various outliers, including those at Bog, rest unconformably on the Ordovician of the Shelve Inlier. The area has been re-mapped, but the only major re-interpretation is based on new exposures indicating that the Venusbank 'outlier' is connected northwards with the outcrop in Hope Valley.

Whittard (1932) used the same stratigraphical names, i.e. Pentamerus Beds and Purple Shale, throughout Shropshire, but the Llandovery rocks of the Minsterley and Bog area differ in lithology and age from the beds in the Wenlock Edge outcrop (see below). Accordingly we propose new names: the Bog Quartzite, Venusbank Formation, and Minsterley Formation.

(a) Venusbank Formation and Bog Quartzite. The type section of the Venusbank Formation is in Hope Brook, running eastwards from near Hope Quarry. The base is exposed in both brook (SJ 3554 0207) and quarry (SJ 3550 0207), where a sandstone with occasional shale fragments rests on Hope Shales of Ordovician (Llanvirn) age. The top of the Formation in Hope Brook is taken above the highest of the dominant sandstones (SJ 3572 0215).
The base of the formation may also be seen in an outlier (SJ/3458 0146) two-thirds of a mile south-west of Hope Quarry (Tyler 1925), a most interesting formation, in which pebbles (up to 5 cm.) of Hope Shales, Stapeley Volcanics (Llanviri) and Upperstones Quartzite (Arenig) occur. This outlier occurs at 500 ft. O.D. (Ordnance Datum—feet above sea level) but another small outlier is present 150 yards to the east, on the side of the valley and between 550 and 700 ft. O.D.; Hope Quarry lies at 600 ft. O.D., and, to the south-east, the Llandovery at Venusbank (SJ/3535 0125) is at 800 ft. O.D. Thus the conclusions reached by Whittard (1932, pp. 893–5), of an irregular base to the Llandovery of the area, are confirmed; steep dips are absent and there is no detectable subsequent faulting. It appears that the present-day Hope Valley has been re-excavated along the line of a pre-Middle Llandovery depression, and that the Llandovery sea spread over a surface relief of 200–300 ft. in this area. The thickness of the Venusbank Formation varies between 0 and 200 ft. (0–65 m.).

The formation is well exposed at Hope Quarry (SJ/3550 0207), where a thickness of 30 ft. (10 m.) is visible. Sandstone beds up to 3 ft. (1 m.) thick occur there, sometimes including shales or mudflakes at or near their base, with each unit fining up into unfossiliferous silts. Some of the sandstones have parallel laminae throughout, but cross-bedding is absent, apart from very occasional ripple cross-lamination on the tops of one or two sandstones. Unit bases are sharp, with no visible bottom structures apart from worm traces. Low-angle channelling occurs with occasional silty partings at the base of the channelling sandstone. These sediments may represent proximal turbidites filling a previously scourred channel of Pentamerus- and Stricklandia-Community depth.

The Llandovery also rests unconformably on the Ordovician in some poorly exposed outliers near Bog (SO/355 979) and at Round Hill (SO/348 993). Many large loose blocks of coarse quartzite are present; often containing pebbles and shale chips. These beds are termed the Bog Quartzite.

Fossil communities. The Hope Valley sections of the Venusbank Formation have mainly yielded fossils of the Stricklandia Community (Locs. 66–70, 72, 73); the exceptions are the presence of Pentamerus Communities at some places near the base of the formation (Loc. 74 and at SJ/3555 0107). This suggests that the irregular landscape was covered by a moderately deep shelf sea (Pentamerus Community) that soon became slightly deeper (Stricklandia Community). However, there may have been some fluctuation in depth, as Whittard (1932, p. 876) reports Pentamerus above Stricklandia-bearing beds in Hope Quarry. In Ox Wood Dingle (Loc. 67), 4 miles west of Hope Valley, the Stricklandia Community is also present. However, early shallow-water conditions may be indicated at The Stubbis (2 miles north-west of Hope Quarry—SJ/324 033) where Whittard records (1932, p. 874) Liagula in growth position near the base of the Venusbank Formation.

The fauna of the Bog Quartzite (Locs. 65, 66) is a mixture of a near-shore Cryptothyroidea Community with some rocky-bottom elements (Ziegler, Cocks, and Bambach 1968).

Correlation. All the collections from the Venusbank Formation and Bog Quartzite have yielded Stricklandia; the subspecies present at Bog is S. lenz intermedia indicating a
Middle Llandovery age; the subspecies from the Venushank Formation is at the boundary between *S. lens intermedia* and *progressa* and is B₂ to C₃ in age. A collection from near the base of Hope Quarry (Loc. 70) includes the graptolite *Chinacograptus aff. rectangularis* (identified by R. B. Rickards), which indicates a Middle Llandovery age for the lower part of the formation. Whittard (1932, facing p. 896) records *Monograptus punctatus* pertinax from the "Pentamerus Beds of the Wilmington-Mminsterley area"; this suggests that at least some of the Venushank Formation is of early Upper Llandovery age.

(b) *Minsterley Formation*. The type section goes diagonally across the strike of the formation and is in Hope Brook. The base is taken above the top sandstone of the Venushank Formation (SJ 3572 0215), and the top above the last parfullish bed in the exposure to the south of Wagbeach (SJ 3642 0270). The thickness of the Minsterley Formation is about 400 ft.

The lowest beds seen are calcareous siltstones and mudstones, with occasional coarser beds; these represent a distinct sedimentary environment unknown elsewhere in the Welsh Borderland. They pass up into maroon, green, or blue mudstones, the top 150 ft. (45 m.) being of the same dominantly purple colour as the Hughley (Purple) Shales on the main Wenlock Edge outcrop. The mudstones contain some interbedded siltstone and bands of fragmented shells. Locally, the Minsterley Formation overlaps the Venushank Formation, e.g. at Estell (Whittard 1932, p. 877) and east of Minsterley; in these areas the formation tends to be coarser. The Minsterley Formation is followed by several hundred feet of unfossiliferous turbidites, well exposed in Hope Valley, which may be either late Llandovery or early Wenlock in age.

*Fossil communities*. Collections in Hope Brook (Loc. 71) and Minsterley-Habberley Lane (Loc. 75) are both in the *Chlorinda* Community; this indicates that the Minsterley Formation was deposited in deeper water than the underlying Venushank Formation.

*Correlation*. The brachiopods collected from the Minsterley Formation provide no precise evidence of age, but Whittard's (1932, p. 877) record of graptolites from Locality 75 includes *Monograptus halli*, *M. becki*, and *M. cf. proteus*. This assemblage indicates a *turrilitatus* Zone age (Cocks and Rickards, in press). A lack of fossils in the upper part of the formation, and in the overlying turbidites, makes it uncertain whether it terminates, even approximately, at the end of Llandovery time.

NORBURY AND CHURCH STRETTON

Text-fig. 3, cols. 12 and 13

A long winding outcrop of Llandovery rocks borders the south side of the Cambrian and Ordovician rocks of the Shelve Inlier, and continues all around the southern part of the Pre-Cambrian rocks of the Long Mynd (text-fig. 4). The formation names which we use for this area are the same as those used by Greig et al. (1968); the Pentamerus Beds and the Hughley (or Purple) Shales. The area, sometimes termed the southern Long Mynd-Shelve Outcrop, was mapped by Whittard (1932, pl. 59, 60) and more recently by the Geological Survey (Church Stretton Sheet, New Series, no. 166). Six
boreholes were drilled to assist the Survey in their mapping, and four of these passed through beds of Llandovery age (Cocks and Rickards, in press). These are called the Eaton Farm (text-fig. 3, col. 12) and Robury Ring Boreholes, both of which are to the west of the southern Long Mynd spur, and the Hamperley (text-fig. 3, col. 13) and Springbank Farm Boreholes, both of which are to the east of the Long Mynd spur and in the Church Stretton Valley. A fifth borehole, at Bottyle (also shown on text-fig. 4), did not penetrate to the local base of the Wenlock.

(a) Pentamerus Beds. Between Plowden (SO/382 874) and Little Stretton (SO/445 921), up to 60 ft. (20 m.) of conglomerates are intermittently present below mudstones and other sediments with Pentamerus. These beds, when fossiliferous, contain a Lingula Community, and, in parts, the formation name Kenley Grit (used in the adjacent Wenlock Edge outcrop—see below) might be employed. However, as the conglomerates fill quite small topographic pockets, and locally vary both in lithology and possible age, we follow Whittard (1932) and the Geological Survey (Greig et al. 1968) in treating these beds as a local coarse base to the Pentamerus Beds. The Hamperley and Springbank Farm Boreholes both revealed complete sections through the Pentamerus Beds, which are 480 (157 m.) and 170 ft. (56 m.) thick in the respective cores (although these thicknesses may be affected by minor faulting).

Whittard (1932) interpreted the basal deposits to the south of the Long Mynd as a beach with sea stacks. However, from faunal and sedimentological considerations, it seems more probable that most of the sedimentation occurred sub-tidally, and certainly a fairly deep-water Pentamerus Community was established at Hillend Farm (Loc. 62), only 20 ft. (7 m.) above the unconformity with the Pre-Cambrian.

The Pentamerus Beds are absent in the large embayment to the west of the southern Long Mynd spur (text-fig. 3, col. 12) and also south of The Rovers (SO/323 915); at both places Hughley Shale rests directly upon the unconformity. However, between these two places, at Norbury (Locs. 63 and 64), a local lens of calcareous sandstone, often crowded with Pentamerus, is present between the unconformity and the Hughley Shale, and this lens is termed 'Pentamerus Beds'. Further west, near Snead, Whittard (1932, p. 871) recorded 280 ft. of Pentamerus Beds, but his description shows that the lowest Silurian rocks contain a limited shelly fauna, perhaps representing an environment deeper than the Cladina Community.

Fossil Communities. In the Hamperley Borehole, the Lingula Community is present between 65 and 115 ft. (21–38 m.) above the base (Cocks and Rickards, in press). This is followed by a ?Rostrocellula Community, which is a parallel community to that of Evocoelia, and occupies a similar position, between Lingula and Pentamerus Communities. In the borehole, a Pentamerus Community succeeds the ?Rostrocellula Community, and is itself succeeded by a Stricklandia Community. After the Stricklandia Community, there was a reversion to the Pentamerus Community immediately below the Hughley Shales. In the Springbank Farm Borehole, the Pentamerus Beds carry a Pentamerus Community throughout, although at approximately two-thirds up the formation, the proportion of Stricklandia increases enough to be termed a Pentamerus/Stricklandia mixture for that part of the core. This mixture was probably contemporary with the Stricklandia Community in the Hamperley Borehole.
In the surface exposures, the *Lingula* Community is developed in various parts of the basal coarse facies. At Marshbrook (Loc. 61) we have collected a mixed *Lingula*?*Rostricellula* Community, *?Rostricellula* is a close homomorph of *Eoecelia* and was listed as the latter by Whittard (1932, p. 864). *Pentamerus* Communities occur at Hillend Farm (Loc. 62) and at Norbury (Locs. 63 and 64). Further to the west, deeper water was present near Snaud, the basal *Pentamerus* Community, Whittard (1932, p. 872) records a fauna which we interpret as a 'Marginal' *Clorinda* Community.

Correlation. Graptolites from the Hamperley borehole indicate the *convolutus* Zone for the middle part of the formation, with the *sedgwickii* Zone above. The *sedgwickii* Zone is also proved for the middle of the Springbank Farm core. The brachiopod collections from Hillend Farm and Norbury both contain *Eoecelia*, but the former locality carries *E. heenstraera* (indicating C1a age), while at Norbury *E. intermedia* is present (Ziegler 1966b), and indicates a C1b age for beds near the local base of the formation.

Whittard (1932, p. 872) records *Climacograptus* sp., *Monograptus halli* and *M. dextrorsus* from Snaud; these indicate the *turrilatus* Zone. This evidence, together with Whittard's statement (1932, p. 873) that 'there is a gradation along strike from arenaceous to argillaceous sediments', points to a fairly rapid increase in depth westwards from the Long Mynd during C1 times. It also emphasizes that both base and top of the Pentamerus Beds are diachronous.

(b) *Hughley* (or *Purple*) Shales. These beds are not well exposed south of the Longmynd-Shelve Inlet. The Hamperley borehole shows a thickness of 150 ft. (49 m.) and Whittard (1932, p. 866) estimated a thickness of 200–30 ft. of Hughley Shales to the south of the Long Mynd. To the west of the Long Mynd spur there is a greater thickness: 360 ft. (114 m.) is seen in the Eaton Farm borehole, although small faults may have affected this figure. Still further west, near Snaud, Whittard (1932, p. 871) estimated that a minimum of 250 ft. were present. The formation is distinguished from the underlying Pentamerus Beds and overlying Wenlock Shale mainly by its colour, which is a characteristic maroon or purple, although green and brown bands also occur. The Pentamerus Beds are usually blue-hearted mudstones, and the Wenlock Shale grey and slightly silty. The contacts between the formations are usually sharp.

Fossil Communities. Whittard (1932, p. 869) reports a *Clorinda* Community fauna between Plowden and Minton, and this community is also present in the Eaton Farm, Robury Ring, Hamperley, and Springbank Farm boreholes. Above the *Clorinda* Community in the two boreholes to the west of the southern Long Mynd spur, a 'Marginal' *Clorinda* Community occurs, which probably indicates (Cocks and Rickards, in press) a continued deepening of the sea.

Correlation. Graptolites from the boreholes show a sequence from within the *turrilatus* Zone, through the *crispus* Zone and into the *griestoniensis* Zone. The top 75 ft. (25 m.) of the Hughley Shale in the Eaton Farm borehole are above the *griestoniensis* Zone, but carry no diagnostic graptolites. Thus the presence or absence of the highest Llandovery *crenulata* Zone is not yet confirmed.
Llandovery rocks crop out in a strip twenty miles long, which parallels, and directly underlies, the rocks of Wenlock Edge (text-fig. 4). Whittard (1928) described this 'Main' outcrop in detail in three formation names which he used, i.e. Arenaceous Beds, Pentamerus Beds, and Purple Shales. These have been subsequently named by the Geological Survey Kenley Grit, Pentamerus Beds, and Hughley Shales. The northern part of this area was covered by the Shrewsbury Memoir (Pocock et al. 1938), and the southern part by the Church Stretton Memoir (Grieg et al. 1968). A recent revision of the northernmost part of the area was prompted by a very large temporary exposure at Devil's Dingle (Cocks and Walton 1968).

(a) Kenley Grit. A maximum thickness of 200 ft. (65 m.) is reached near Kenley itself (SJ/558 004). Four-and-a-half miles to the south-west, the Kenley Grit dies out near Greatton (SO/519 946). To the north-east, it thins more gradually, and is 35 ft. (11 m.) thick in Harper's Dingle (SJ/634 072), near the point where the Llandovery is covered by the Carboniferous, 6 miles from Kenley.

The formation consists of conglomerates, sandstones, arkoses, and some finer beds, but to the north-east there is no conglomerate except at the base; these basal pebbles are mainly derived from Uricianian rocks, but occasional Cambrian and Ordovician pebbles are present (Whittard 1928, p. 740). The formation rests with strong unconformity upon Ordovician and older rocks, and is distinguished from the overlying Pentamerus Beds by the abundance of coarse clastics and the absence of calcareous beds.

Fossil communities. The fossils recorded from the Grit (Whittard 1928, p. 741) all belong to the Lingula Community. Lingula itself occurs near the top of the formation at Morrellswod (near Loc. 46) and Shenton Brook (near Loc. 50); it is also present in an old quarry near Kenley (Pocock et al. 1938, p. 106). An assemblage with abundant rhynchoellides, referable to the Lingula Community, but without Lingula itself, occurs at Cressage Park, two miles east of Kenley (Whittard 1928, p. 741).

Correlation. No fossils found in the Grit are of zonal significance; however, at Morrellswod (Loc. 46), beds of C2 stage occur immediately above the Grit, which must therefore be earlier.

(b) Pentamerus Beds. The Kenley Grit passes up gradationally into the Pentamerus Beds, but to the south-west, where the Grit is absent, the Pentamerus Beds rest unconformably upon Uricianian, Tremadoc, and Ordovician rocks. The Pentamerus Beds reach a maximum thickness of between 400 and 500 ft. (about 150 m.) in the northeastern half of the area, and thin southwards to nothing in the vicinity of Wistanstow (SO/431 857). A Pentamerus-bearing conglomerate 1 in. thick has been reported (Whittard 1928, p. 749) in the bed of the Onny River (Loc. 60), but is absent higher up on the river bank, where Hughley Shales rest directly upon the Ordovician. The lithology of the Pentamerus Beds consists of blue mudstones, with sporadic shelly limestones, and less fossiliferous siltstones and concretionary limestones. At the extreme north end of the outcrop the 'Dingle Conglomerate' is seen near the base of the Pentamerus Beds in Harper's Dingle (SJ/6328 0704); the bed is confined to this one locality, and consists
of pebbles of Uriconian rock and Pentamerus shells set in a matrix of quartz sand and calcite (Whittard 1928, p. 745, Pocock et al. 1938, p. 107). Apart from this distinctive conglomerate, the Pentamerus Beds may be differentiated from the Kenley Grit by their palaeontology, finer grain size, and more calcareous sediments, but the contact between the two formations is gradational. The top of the Pentamerus Beds is usually sharp, with the colour change to the Hughley Shales, but the contact is sometimes confused by the presence of small turbidite bands (e.g. at Sheinton Brook—Loc. 51).

Fossil communities. A collection from near Gilberries (Loc. 57), in the lower part of the Pentamerus Beds, contains abundant *Hyattidina*. This genus does not fit precisely into any of the main Llandovery communities as at present defined (Ziegler 1968), but abundant *Hyattidina* are associated with the *Eoecolia* Community in New York State and also at Presteigne (Locs. 90 and 93); we conclude that the Gilberries collection represents an intermediate environment between the *Lingula* Community of the Kenley Grit, and the deeper-water communities of the remainder of the Pentamerus Beds.

Collections from north-west of Merrishaw (Locs. 52 and 53) and near Tickleton (Loc. 59) are typical of the *Pentamerus* Community. At about the centre of the outcrop, the deeper-water *Stricklandia* Community is present (Loc. 54) and in Sheinton Brook (Loc. 50), although this last collection only contains 1% of *Stricklandia*. At Morrellswood (Loc. 46) an assemblage dominated by *Rostricellula* is present, this assemblage also occurs in the Church Stretton area (see above), where it is interpreted as a parallel community to that of *Eoecolia*.

Correlation. *Eoecolia hemisphaerica* indicates a C₂₃ age for the Pentamerus Communities at Tickleton (Loc. 59) and Merrishaw (Loc. 52). The *Stricklandia* Community at Sheinton (Loc. 50) and the collection from Merrishaw (Loc. 53) contain *S. lens ultima* of C₂₄₄ age. Our evidence is thus consistent with a progressive increase of depth from C₁ to C₄ times during the deposition of the Pentamerus Beds of the Wenlock Edge Outcrop. Graptolites from various parts of the formation (Whittard 1928, Pocock et al. 1938) are all attributable to the *turriculatus* Zone, which is equivalent to C₂₃ times.

(c) Hughley (or Purple) Shales. This formation has a thickness varying from 0 to 500 ft. (0–150 m.). The lithology is dominantly purplish mudstone, but occasional coarser turbidite bands also occur locally. The basal contact with the Pentamerus Beds is sharp and there is overlap on to the Ordovician to the south-east. North of Much Wenlock there is an apparently conformable upper contact with the Buildwas Beds; Cocks and Rickards (in press) conclude that these basal Wenlock beds may include equivalents of all the Lower Wenlock graptolite zones. However, as one proceeds south-west down the outcrop, the Middle Wenlock overlaps both the Lower Wenlock and the Hughley Shales and comes to rest unconformably on the Ordovician four miles south of the Long Mynd.

Fossil Communities. Most of the collections from the Hughley Shale of the Main Outcrop are typical of the *Chorinda* Community (Locs. 47-9, 51, 55, 56, 58, and 60), which reflects a deeper-water environment than that of the Pentamerus Beds. However, near the top of the formation to the north of the River Severn, Cocks and Walton (1968) describe a *Chorinda/Stricklandia* mixture, indicating some slight local shallowing in latest Llandovery times.
Correlation. The oldest brachiopod fauna collected from the Hughley Shale is from the very base of the formation in Sheinton Brook (Loc. 51), where *Eocoelita intermedia* indicates a C₃₆ age. *E. curtisi*, of C₃₇ age occurs in collections from Boathouse Coppice (Loc. 49) and Wall-under-Heywood (Loc. 58). *Costistriktzia linearata* and *Eocoelita sulcata* indicates a C₄₃ age for collections from Boathouse Coppice (Loc. 47), Donnis (Loc. 55), and Hughley (Loc. 56), all very near the top of the formation. Thus the brachiopod evidence indicates that the formation spanned the period C₃₆ to C₄₃. Graptolites from the Onny River (Loc. 60) indicate the *turriculatus* Zone (probably equivalent to C₃₃), at several localities in the north-east part of the outcrop the *grisoniensis* Zone has now been proved. This last occurs in conjunction with C₃₃ indicators such as *Eocoelita curtisi*, and the probable presence of equivalents of the highest Llandovery *cornutata* Zone may be inferred by the presence of the C₃₃ brachiopods.

PRESTEIGNE

Text-fig. 3, cols. 24 and 25

To the south of Presteigne, Radnorshire, the Upper Llandovery crops out along the B4365 road between Nash Scar and the railway bridge near Corton (text-fig. 5); we propose the name Folly Sandstone for these beds. They are folded in an antilíne with
its axis extending west-south-west through The Folly (SO 316 633). These Llandovery beds are overlain by a thin (15-20 ft.—about 6 m.) development of the Nash Scar Limestone to the north; to the south their contact is obscure, and the Folly Sandstone may either dip below or be faulted against the 200 ft. (65 m.) of limestone seen in Nash Scar Quarry. The outcrop is covered by drift east of The Folly, and is cut off by an extension of the Church Streton Fault to the west of Nash Wood. The only published map of the area is the Geological Survey, Old Series, no. 56, NE. and SE., of more than a century ago; but it shows the Llandovery correctly, except for a possible fault north of Nash Scar quarry. The most recent description of these rocks was published in abstract form by Kirk (1951).

The Folly Sandstone consists of dark sandstones in beds ranging from a few inches to a few feet thick. There are many thin conglomerates with rounded pebbles up to 1½ in. (4 cm.) in diameter. The thickness of the Folly Sandstone is in excess of 100 ft., but its base is not exposed. At Old Radnor, 4 miles to the south-west, this unit is missing altogether and Precambrian conglomerates and mudstones occur unconformably beneath the Dolyhir Limestone, the Old Radnor equivalent of the Nash Scar Limestone (Kirk, 1951, p. 56; Garwood and Goodyear, 1918, pl. vii). On the north side of the Presteigne incline (SO 3152 6347), the contact with the Nash Scar limestone appears to be a disconformity; over an exposed distance of about 20 ft. the limestone rests on various sandstone beds indicating a relief of about 4 ft.

Fossil communities and correlation. The stricklandiids from this area have recently been described by Ziegler (1966a). Collections from above Nash Scar quarry (Loc. 93) and from south of The Folly (Loc. 90) yielded *Eocoeola homsphaericus*; the latter locality also yielded *Stricklandia levis auct. progressus*. These collections are both representative of the *Eocoeola* Community and are both C3–C4 in age. *Pentamerus* Community collections have been made in the Folly area (Locs. 91 and 92) from higher beds than Locality 90, but the presence of *E. homsphaericus* shows they are also of C3–C4 age. The *Pentamerus* Community is again present in Corton House Quarry (Loc. 89) and in Folly road a few feet under the base of the Nash Scar Limestone (Loc. 88); both these collections contain *S. levis auct. progressus* which shows that the top of the Folly Sandstone is still C3–C4 in age.

The evidence from the Folly Sandstone shows that the Nash Scar Limestone could be as old as C3, but the presence of *Rhipidium* (in the Garwood Collection, Geological Survey Museum) proves that part, at least, is Wenlock. An upper age limit is provided by the occurrence of *Cyrtograptus symmetricus* of Wenlock age in the overlying shales (Kirk 1951, p. 56).

**ANKERDINE HILL AND OLD STORRIDGE COMMON**

Text-fig. 3, cols. 15 and 16

Llandovery beds are exposed in a faulted block at Ankerdine Hill, 6½ miles north of West Malvern, and again in the core of a north-plunging anticline at Old Storridge Common, 3 miles north of West Malvern (text-fig. 6). The base of the Llandovery succession is not exposed in either area. Groom (1910, p. 704) applied the terms, Cowleigh Park Beds, Wych Beds, and Woolhope Shales to the Llandovery rocks of the contiguous Malvern Hills area. However, the term Woolhope Shales is confusing and in any case this relatively thin unit cannot be distinguished with certainty from the Wych Beds.
TEXT-FIG. 6. Locality map of Anchordine Hill and Old Storridge Common, Worcestershire. This map is continuous with text-fig. 7.
We therefore reject the term Woolhope Shales for these Llandovery beds and regard the Wych Beds as extending up to the first appearance of the dominantly calcareous beds of the Woolhope Limestone. The latter is a gradational contact and could, of course, be diachronous.

(a) Cowleigh Park Beds. Fine green sandstones and siltstones make up the lowest beds exposed on Ankerdine Hill, while at Old Storridge Common the sediments are coarser and thicker bedded (up to 2 ft.) sandstones. Lack of exposures and the presence of faults make thickness estimates very uncertain; minimum exposed thicknesses are about 200 ft. (65 m.) at Ankerdine Hill and 400 ft. (130 m.) at Old Storridge Common.

Fossil communities. In the Old Storridge Common area, fossils diagnostic of the Liogula Community have been recorded by Lamont and Gilbert (1945, p. 642) near the axis of the anticline, and therefore probably low in the Cowleigh Park Beds. The Eocoeola Community occurs within a few feet of the top of the formation in Leigh Brook (Loc. 36) and in a north-flowing tributary (Loc. 35). It also occurs in lower beds south of Leigh Brook (Locs. 34 and 87). At Ankerdine Hill, the Eocoeola Community is represented in all three collections obtained (Locs. 42–4), but the relative stratigraphic positions of these are not known.

Correlation. All the Eocoeola obtained from the Cowleigh Park Beds at Ankerdine Hill and Old Storridge Common are E. hemisphaerica of C1–C2 age; the type of this species comes from Ankerdine Hill (Ziegler 1966b). The lower beds with the Liogula Community may either be of a very early Upper Llandovery or a late Middle Llandovery age.

(b) Wych Beds. The Wych Beds consist of shales with some siltstones (less than 10% of the formation). The base is exposed in Leigh Brook (Loc. 37) near the disused Gunwich Mill (SO 7430 5152) west of Old Storridge Common. The contact is sharp, but, although there is palaeontological evidence of a non-sequence, there is no sign of erosion of the underlying Cowleigh Park Beds. The formation appears to be about 400 ft. (130 m.) thick in the section west of Gunwich Mill.

Fossil communities. The basal few feet of Wych Beds at Gunwich Mill (Loc. 37) contain a Pentameroides Community. The non-sequence at this locality is thus followed by deeper-water conditions than in the Eocoeola Community of the Cowleigh Park Beds. The evidence suggests a progressive increase in water depth throughout Upper Llandovery times with a long pause in sedimentation at this locality before the deposition of the finer grained Wych Beds. A Pentameroides Community has also been obtained from loose blocks on Ankerdine Hill (Loc. 45) and may represent a similar low horizon in the Wych Beds.

The Pentameroides Community is followed by the Costistricklandia Community some 10 or 20 ft. (about 5 m.) above the base of the Wych Beds; collections low in the formation were obtained from a track in Conroy Copice (Locs. 38, 39) and in a north-flowing tributary of Leigh Brook (Loc. 40) to the south and south-west of Old Storridge Common. A continued increase in the depth of water is indicated by the occurrence of the Clorinda Community near the top of the Wych Beds to the north-east of Mousehole Bridge (Loc. 41).
Correlation. The basal Wych Beds at Gunwiche Mill contain Eococelita curtisi, showing that these beds are of C3 age and that the non-sequence covers the whole of C4 time. The collection from Ankerdine Hill also contains E. curtisi.

The highest Wych Beds near Mousehole Bridge yield E. subata of C4 age. No fossils of C4 age have been collected on Ankerdine Hill, and it is probable that the higher parts of the Wych Beds have been cut out by faulting.

MALVERN HILLS

Text-fig. 3, cols. 17, 18, and 19

Llandovery rocks crop out continuously from Old Storridge Common south through West Malvern to Herefordshire Beacon (text-fig. 7). They appear again south of Herefordshire Beacon in the area to the east of Eastnor (text-fig. 8). As in the Old Storridge Common area, we recognize two formations, the Wych Beds (named from The Wyche 1½ miles south of West Malvern) and the Cowleigh Park Beds (Cowleigh Park, 1 mile north of West Malvern contains many small exposures of this lower formation). This area has been mapped by Groom (1899, 1900) and by Phipps and Reeve (1967). We differ from these authors in our interpretation of the Llandovery in two main respects: the upper limit of the Wych Beds is taken immediately below the Woolhope Limestone (see above); and we have no doubt that an unconformity is present below the Silurian along the west side of the Malverns (Reading and Poole 1961, 1962, Ziegler 1964). The Cowleigh Park Beds rest on Cambrian shales east of Eastnor and probably again east of Cowleigh Park; to the south-east of Cowleigh Park they are inferred to rest on Malvernian. Between West Malvern and Ragged Stone Hill (at the south end of the Malvern Hills—SO759363) the Cowleigh Park Beds are overlapped by the Wych Beds which rest directly on the Malvernian.

(a) Cowleigh Park Beds. Exposures of this formation are scattered, but our mapping suggests that there are at least four distinct members:

1. A basal member of up to 15 ft. (5 m.) of red micaceous mudstone interbedded with several thin (4 in. (10 cm.) or less) green sandstones composed of round quartz grains about 1 mm. in diameter. These were exposed during a Geologist's Association field trip in 1963. leader Mr. N. E. Butcher, with the aid of a mechanical digger, near the base of the Silurian to the south-west of Bronsil Castle.

2. About 100 ft. of light brown siltstones and sandstones containing fossils of the Lingula Community and occasional pebbles of Malvernian rock. This lithology crops out in both Cowleigh Park and in the Eastnor Obelisk—Howler's Heath area (Loc. 32, 23, and 24).

3. A coarse pink sandstone about 100 ft. (33 m.) thick which forms a ridge extending south-south-east from Rough Hill (SO758482) into Cowleigh Park. A similar topographic feature extends from Eastnor Obelisk to the eastern margin of Howler's Heath, and, though there are no outcrops there, loose blocks of a similar pink sandstone occur, containing chips of Cambrian shale.

4. Up to 200 ft. (65 m.) of unsorted purple conglomerates with angular pebbles up to 3 cm. in diameter, interbedded with coarse green sandstones up to a foot thick. This unusual lithology is known only from Cowleigh Park (SO76164723) and may be restricted to this area which is immediately adjacent to the Malvernian ridge source area.
TEXT-FIG. 7. Locality map of the northern Malvern Hills, West Malvern, and Cowleigh Park areas. This map is continuous with text-figs. 6 and 8.
To the south-west of the Malverns, Holl (1865, fig. 4) and Groom (1899, p. 167) have described the unconformable relationship at the base of the Cowleigh Park Beds where the Llandovery rocks rest on the Tremadocian Bronsil Shales between the Obelisk and Howler’s Heath. Although Cambrian shales have never been mapped to the north-west of the Malverns, it is probable that a similar unconformity exists in the Cowleigh Park area; Groom (1900, p. 157) states that Cambrian shale was exposed in a well 1 mile north of West Malvern, near the foot of North Hill. Our interpretation of the geology is given in text-fig. 7.

The pebbles in the conglomerates show that a landmass composed of Malvernian and Cambrian rocks was being eroded—this source area may have extended eastwards from the present-day Malvern Hills. The thickness of the Cowleigh Park Beds is perhaps 250 ft. (80 m.) at the Eastnor Obelisk. At Cowleigh Park there is probably between 350 and 400 ft. (100–30 m.), but lack of exposures and the possible presence of faults make this estimate uncertain.

**Fossil communities.** The Lingula Community is the only fossil community represented in the Cowleigh Park Beds of the Malverns; the fossils are confined to the second (siltstone and sandstone) member. They have been collected from Cowleigh Park (Loc. 32), south of the Obelisk (Loc. 23), and north of Howler’s Heath (Loc. 24). This community indicates very shallow marine conditions, and it is possible that some of the Cowleigh Park Beds are beach deposits. The coarseness of the sediments and the absence of the Escroella Community indicate environments nearer to the shore-line than those in correlated beds to the north-north-west near Old Storridge Common and Ankerdine Hill, and to the south-south-west at May Hill.

**Correlation.** No fossils of value in correlation occur in the Cowleigh Park Beds of the Malverns. Comparison with Old Storridge Common to the north and with May Hill to the south suggests an early Upper Llandovery or late Middle Llandovery age.

**(b) Wych Beds.** The Wych Beds are seen resting on the fourth (conglomerate) member of the Cowleigh Park Beds at the Cowleigh Park football field (SO/7616 4723); the basal 6 ft. (2 m.) are coarse sandstones (they appear to be re-worked Cowleigh Park Beds) with occasional broken Pentamerolites, which probably indicate a deeper-water environment than in the Cowleigh Park Beds; these sandstones are followed by siltstones and green siltstones of the main mass of the Wych Beds. The only other two exposures of the base of the Wych Beds are on the western margin of the Malvern Hills at West Malvern (SO/7646 4554) commonly known as the Sycamore tree quarry (Robertson 1926, p. 168), and the Gullet Quarry (SO/7612 3811) (Reading and Poole 1961); at both these places a basal conglomerate is present, up to 2 or 3 ft. (1 m.) thick. The conglomerate consists of rounded boulders of various Malvernian rocks, ranging from 4 mm. to 80 cm. in diameter, set in a matrix of green siltstone and mudstone—typical of the Wych Beds—containing a rich fauna of brachiopods and corals (see below).

The Wych Beds are poorly exposed and their thickness is determined with difficulty; estimates of about 400 ft. (130 m.) have been obtained from sections near Eastnor Obelisk and in Cowleigh Park. This is about the same thickness as at Old Storridge Common. It includes all the beds up to the base of the Woolhope Limestone, that is, where calcareous nodular beds become abundant.
TEXT-FIG. 8. Locality map of the southern Malvern Hills.
This map is continuous with text-fig. 7.
Fossil communities. The fossils in the matrix of the conglomerates at West Malvern (Loc. 30) and the Gullet Quarry (Loc. 26) contain many species that are absent elsewhere in the Upper Llandovery of the Welsh Borderland, apart from Bog, Shropshire, and are interpreted (Ziegler, Cocks, and McKerrow 1968), as a mixture of rocky-bottom and soft-bottom animals. Rocky bottom communities are usually in the areas of erosion, and do not frequently get preserved, but in this case the beds immediately above the conglomerate at the Gullet Quarry contain a *Pentameroides* Community (Loc. 27), and the fauna on the rounded boulders probably lived well below low-tide level and uncovered by sediment for a long period.

At Cowleigh Park (SO/76164723) the basal 6 ft. (2 m.) of the Wych Beds are coarse sandstones containing broken *Pentameroides*, and at the same exposure (Loc. 33) the *Costestwicklandia* Community was found in typical Wych Beds lithology a few feet above the highest sandstone. Higher horizons in the Wych Beds also yield the *Costestwicklandia* Community at Gullet Quarry (Locs. 28, 29) and on the south side of Howler's Heath (Loc. 25). The *Claronia* Community has been found at West Malvern (Loc. 31) indicating, as at Old Storridge Common, still deeper water in the upper part of the Wych Beds.

Correlation. At Gullet Quarry *Eococelia curta* is present in the basal Wych Beds (Locs. 26, 27). This species is of C₃ age, as is *Costestwicklandia lirata alpha* which occurs in higher beds at Gullet Quarry (Locs. 28, 29). The Cowleigh Park (Loc. 33), and West Malvern (Loc. 31) collections contain *C. lirata typica*, showing that, in the Malverns, the greater part of the Wych Beds is of C₄ age.

**Woolhope**
Text-fig. 3, col. 26

Squirrel and Tucker (1960) proposed the names Lower Haugh Wood Beds and Upper Haugh Wood Beds for the Llandovery rocks exposed in the Woolhope dome, east-south-east of Hereford. The former are at least 280 ft. (80 m.) thick, their base unexposed, and are lithologically similar to the Wych Beds of the Malverns. The Upper Haugh Wood Beds are 30 ft. (10 m.) thick; the basal 20 ft. (7 m.) are purple and green muddy siltstones, but more calcareous beds are present in the top 10 ft. (3 m.).

Fossil communities. In the Lower Haugh Wood Beds the *Costestwicklandia* Community is represented by collections from Kidley Coppice (Loc. 85) and Rudge Wood (Loc. 86). Judging from the faunal lists of Squirrel and Tucker this community is also present in the Upper Haugh Wood Beds.

Correlation. *C. lirata typica* occurs in both the Lower and Upper Haugh Wood Beds, indicating a C₄ age. The *Petalocrinus* Limestone is present in the highest 10 ft. (3 m.) of the Upper Haugh Wood Beds; it was found by Pocock (1930, pp. 60–1) at equivalent horizons in the May Hill and Malvern areas, but these exposures are now obscure. It is very close to the lithological boundary at the base of the Woolhope Limestone, and we conclude that this limestone is of late C₄ or early Wenlock age.

**May Hill**
Text-fig. 3, col. 27

Llandovery Beds are exposed in the core of an anticlinal structure at May Hill, 8 miles west of Gloucester (text-fig. 9). Two formation names, Huntley Hill Beds and
Yarlleton Beds, were proposed by Gardiner (1920) who also proposed the term Huntley Quarry Beds for 'Fine and somewhat coarse grits, containing lapilli' for beds in the vicinity of the quarry. At the present time, volcanic flows with interbedded red-beds are seen in Huntley Quarry, and these apparently underlie coarse sandstones with angular fragments of the volcanic rocks which grade up into fossiliferous Llandovery sediments.
The contact is obscure and faulted but it is probable that the Llandovery lies unconformably on these volcanics, which might possibly be correlated with similar volcanics in the Malvern Hills assigned to the Pre-Cambrian Warren House Series (Groom 1910). We regard the coarse grits in the vicinity, which have sometimes been included in the Huntley Quarry Beds, as the basal part of the Huntley Hill Beds, and propose the term Huntley Quarry Volcanics for the volcanic rocks and their associated red beds.

We also differ from the current literature concerning the relationship of the Yarlleton Beds and the Woolhope Limestone. It has long been known (Phillips 1848, pp. 184–5) that a series of sandstones occur within the Woolhope Limestone sequence at Little London (SO700 184) in the southern part of the inlier. Our mapping shows that the sandstone at Old Oaks Farm Quarry (loc. 21) and the stream section near Hill Farm (loc. 22) in the north-west and central parts of the inlier are also within the Woolhope sequence; in these two areas Lawson (1955) mistakenly referred these Woolhope sandstones to the Llandovery. Except for these minor points, we agree with Lawson’s map of the Llandovery beds.

(a) Huntley Hill Beds. Lawson’s (1955) minimum thickness of 600 ft. (200 m.) is probably an underestimate. The Little London stream section (SO7085 1832 to SO6997 1834) where the beds, with the exception of one outcrop, dip continuously to the west, suggests a thickness of about 850 ft. (280 m.). The oldest beds exposed in this section are on strike with the basal beds at Huntley Quarry, and are therefore near the base of the formation.

The Huntley Hill Beds are mostly grey coarse sandstones and conglomerates; they weather to a buff colour and are often reddened in areas close to the Triassic cover. The sandstone beds are normally one to 2 ft. thick; they show lateral changes in thickness, and they have little internal structure except towards the top of the formation where thinner bedded sandstones are present with fine parallel laminations. Shales are rare, but a few tens of feet of shale are exposed in the Little London stream (SO7057 1837) at about 300 ft. above the base of the formation.

The pebbles in the conglomerates include the distinctive quartz-orthoclase plutonic rocks of the Malvern Hills. Volcanic pebbles are also present and could have been derived from other Malvern rocks or, in the case of the angular andesite porphyry pebbles, directly from the Huntley Quarry Volcanics. There is no doubt that adjacent pre-Cambrian rocks were being eroded at this time.

Fossil communities. The lowest 350 ft. (115 m.) of the Huntley Hill Beds are largely barren of fossils, but Lingula pseudoparallela has been reported from the basal sediments of Huntley Quarry (Symonds 1872, pp. 147–8). Eoecocella hemisphaerica and other representatives of the Eoecocella Community have been collected in the Little London stream section at about 350 ft. (loc. 6) and 410 ft. (loc. 7) above the supposed base of the formation; closely similar assemblages also occur near Dursley Cross (loc. 9) and on the south-east side of May Hill (loc. 4). At higher stratigraphical levels there is a reversion to the Lingula Community; about 440 ft. (140 m.) above the base in the Little London stream (loc. 8), and in old quarries on Brights Hill (locs. 9, 10). The highest Huntley Hill Beds are poorly exposed; a single fossil locality near old quarries at the top of Nottwood Hill (loc. 11) has yielded the Eoecocella Community, with E. intermedia at about 610 ft. above the base of the formation.
Correlation. The lowest, largely unfossiliferous 350 ft. (115 m.) may be pre-Uppen Llandovery in age. The beds between 350 and 410 ft. (115-35 m.) from the base of the formation in the Little London stream section are known to be of C₂ or C₃ age from the presence of *E. henispharica*, as are the beds that have been correlated with these at Dursley, Cross and May Hill. The Nottswood Hill quarries at around 610 ft. (200 m.) from the base contain *E. intermedia* of *C₂* or *C₃* age.

(b) Yarlton Beds. The lower contact of the Yarlton Beds is not exposed, but there appears to be a gradational transition from the coarse sandstones of the Huntley Hill Beds to the fine laminated sandstones (typically 3-4 in. thick), siltstones and shales of the Yarlton Beds. The formation is about 500 ft. (160 m.) thick.

Fossil communities. Fossil localities are abundant in the Yarlton Beds, but there are no well-exposed sections showing the stratigraphic relationships between exposures more than a few feet apart, as most of the outcrops occur along streams in the vicinity of faults. The fossil collections however can be arranged stratigraphically by comparing the *Eocelia*, *strikklandiids* and pentamerinids with contemporaneous sections at Llandovery and in other parts of the Welsh Borderland. Table 1 summarizes the data for eleven localities at May Hill. The method used for calculating percentages is described in Ziegler, Cocks, and Bambach (1968, p. 4).

Except for the two collections (Loes, 18, 19) within 100 ft. (33 m.) of the Woolhope Limestone, all the Yarlton fossils belong either to the *Pentameroids* or *Costistricklandia* Communities or to mixtures of the two. Some changes in community composition apparently took place in a short period of time, for example, Locality 16, with 34% *Pentameroids* and 44% *Costistricklandia* contains elements of both communities but occurs a few inches above Locality 15 which consists of 82% *Clorinda*. Locality 16 may have a fauna from the boundary between the *Costistricklandia* and *Pentameroids* Communities, or it may be due to mixing of faunas after death. Locality 18 is interpreted as a death assemblage; it contains fairly abundant *Eocelia* together with some deeper-water species. The highest locality in the Yarlton Beds, 19, is assigned to the *Clorinda* Community and represents deeper water than the earlier faunas.

Correlation. The majority of the Yarlton Beds are of *C₂* and *C₃* age (Table 1). It is possible that the basal parts are *C₁*; Locality 12 has no *Eocelia* nor pentamerinids, and the strikklandiids are fragmentary and cannot definitely be assigned to *Stricklandia* or *Costistricklandia*, so it could represent an earlier horizon than the remaining collections.

At May Hill there is a transition between the Llandovery and Wenlock Beds. Phillips (1848, pp. 74-5, 184-5) arbitrarily drew the contact at the first appearance of *limestone*. Unfortunately the Woolhope Limestone and the overlying Wenlock Shales in the southern part of the Welsh Borderland have not yet yielded any graptolites that allow correlation with the graptolite zones and Phillips’ arbitrary criterion must continue for the time being.

TOWORTH

Text-fig. J, cols. 28 and 29

Curtis (1955) has assigned the Llandovery rocks of this area (text-fig. 10) to two formations: the Damery Beds and the Torton Beds. These are separated by the 'Upper
Trap", an andesite flow with a fossiliferous ashy tuft bed on its upper surface (Reed and Reynolds 1908, p. 515, Reynolds 1924). The basaltic 'Lower Trap', considered intrusive by Reynolds (1924) but extrusive by Curtis, occurs at the base of the Damery Beds, resting unconformably on Tremadocian shales. Both basalt flows towards the north-west, and appear to be absent north of Stone. 

(a) Damery Beds. This unit is comprised of about 500 ft. (160 m.) of alternating fine-grained sandstone and shale beds (Curtis, 1955), with the former being dominant in the lower part of the unit.

Table 1. Critical community and dating elements of the collections from the Yarleton Beds (E. Eoecelia; P. Pentameroides; S. Costistricklandia; and C. Clarinda)

<table>
<thead>
<tr>
<th>Section</th>
<th>Loc.</th>
<th>Community elements</th>
<th>Community</th>
<th>Dating elements</th>
<th>Date</th>
<th>Stratigraphical notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream 450 yd. W. of Hay Farm (NE. side of May Hill)</td>
<td>19</td>
<td>7% 0% 3% 10%</td>
<td>E. soluta</td>
<td>C</td>
<td>C4</td>
<td>Within 100 ft. of Weolyhope Lst.</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>18 0 1 1</td>
<td>E. soluta</td>
<td>C</td>
<td>C4</td>
<td>Loe after from Loe. 19.</td>
</tr>
<tr>
<td></td>
<td>84</td>
<td>3 0 8 1</td>
<td>E. soluta</td>
<td>C</td>
<td>C4</td>
<td>10 ft. above Loe 83.</td>
</tr>
<tr>
<td></td>
<td>83</td>
<td>12 18 26 0</td>
<td>E. soluta</td>
<td>C</td>
<td>C4</td>
<td>(See above.)</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>0 42 0</td>
<td>E. soluta</td>
<td>C</td>
<td>C4</td>
<td>(See above.)</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>4 0 4 0</td>
<td>C. livata</td>
<td>C</td>
<td>C4</td>
<td>A few inches above Loe. 15.</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0 34 44 0</td>
<td>C. livata</td>
<td>C</td>
<td>C4</td>
<td>(See above.)</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0 29 8</td>
<td>C. livata</td>
<td>C</td>
<td>C4</td>
<td>(See above.)</td>
</tr>
<tr>
<td>Stream NW. of Hill Farm (NE. side of May Hill)</td>
<td>14</td>
<td>3 37 7 0</td>
<td>E. curtisi</td>
<td>C</td>
<td>C4</td>
<td>Pennamaloides sp.</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>3 34 19 0</td>
<td>E. curtisi</td>
<td>C</td>
<td>C4</td>
<td>Pennamaloides sp.</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0 34 0</td>
<td>E. curtisi</td>
<td>C</td>
<td>C4</td>
<td>Pennamaloides sp.</td>
</tr>
</tbody>
</table>

Fossil Communities. The Eoecelia Community is present in the basal 130 ft. (43 m.) of the Damery Beds. Collections have been made within a few feet of the top of the Lower Trap in Damery Quarry (Loo. 82), and in higher beds at Charfield Green (Loc. 1) and near Damery Bridge (Loc. 77). The Pentameroides Community has been recognized in two collections, 10 ft. (3 m.) stratigraphically apart in the middle of the formation at Charfield Green (Loo. 78, 79). Still deeper water is indicated by the presence of the Costistricklandia Community in the top two-thirds of the Damery Beds; collections have been made on the road south of Damery Bridge at about 165 and 176 ft. (54-7 m.) above the base of the formation (Loo. 80, 81), and in the railway cutting at Charfield Green (Loc. 2) within 25 ft. (8 m.) of the top of the formation.

Correlation. Eoecelia curtisi occurs in all the collections from the lowest third of the Damery Beds, and Costistricklandia livata alpha is present in the collections from the upper two-thirds of the formation. These spots that all the Damery Beds are of C4 age. The stream south of Charfield Green (Loc. 2) is the type locality of E. curtisi (Ziegler 1966b, p. 537).
(b) Tortworth Beds. The lithology of these beds is similar to the shales and fine-grained sandstones of the Damery Beds. Exposures are rare except near the base; Curtis (1955) estimates the thickness at 200 ft. (65 m.), but the upper contact appears to be gradational with an impersistent limestone forming the base of the Wenlock in the western parts of the Tortworth inlier.

Fossil communities. The only collections from the Tortworth Beds are from near the base. In Daniel's Wood (Loc. 5), the *Eooelia* Community is present within a few feet
of the Upper Trap which is 150 ft. (50 m.) thick here; but north-east of Stone (Loc. 76) the Cosistrieklandia Community occurs in the basal foot of the Torwood Beds where the basalt is only about 15 ft. (5 m.) thick. The different thicknesses of the lava appear to have controlled the local depth of water; Cosistrieklandia Community depths are present before and after the flow where it is thin, but where the flow is 150 ft. (50 m.) thick the deeper-water Cosistrieklandia Community at the top of the Damery Beds is replaced by the shallower-water Eocaelia Community above the andesite (Ziegler 1965).

Correlation. Eocaelia sulcata is present in both collections from the base of the Torwood Beds; Cosistrieklandia lirata alpha is also present north-east of Stone (Loc. 76). The presence of C. lirata alpha and E. sulcata indicates that the horizon must be near the C₃-C₄ boundary.

WALSALL AND GREAT BARR

Text-fig. 3, col. 6

Butler (1937) has described Llandovery rocks in the Walsall Borehole, and Jukes (1853) and Eastwood et al. (1925, p. 11), mention a very small area of the Llandovery rocks at Great Barr near the Eastern Boundary Fault of the South Staffordshire Coalfield. The Walsall Borehole penetrated Wenlock Limestone, Wenlock Shale, Barr Limestone, and below this, some 457 ft. (150 m.) of shales, mudstones, siltstones, and sandstones before hitting Cambrian quartzite with a dip differing by 8° to 15° from the Silurian. Some of the beds beneath the Barr Limestone are Wenlock in age as Cyrtograptus microhorion has been recorded 36 ft. (12 m.) below this unit (depth 831½ ft.), but 74 ft. (24 m.) below the Barr Limestone (depth 870 ft.) are purple and green shales, similar to the Hughley Shales of Shropshire, and we prefer to draw the Wenlock-Llandovery boundary at this point. Butler records 24 bentonitic clays above depth 870 ft., and 25 bentonites below this depth; one bed is 7 in. (18 cm.) thick, the remainder range from 2 in. down to ¾ in. (5 cm.-1-5 mm.).

Fossil communities. The beds from 28 to 303 ft. (9-5–100 m.) above the base of the Silurian (depths 1225 to 950 ft.) contain Cosistrieklandia; in this sequence, Pentameroides (previously recorded as Pentamerus oblongus) is known only over a short thickness (233-48 ft. (76-81 m.) above base, or depths 1020 to 1005 ft.), so it appears probable that the Llandovery beds accumulated mainly in the moderate depths characteristic of the Cosistrieklandia Community. This interpretation agrees well with Butler's (1937, p. 251) picture of the depositional environment. The Cosistrieklandia Community also occurs at Great Barr where a Llandovery horizon is exposed south-south-east of the house formerly known as the Australian Arms (SP/038957).

Correlation. Cosistrieklandia lirata alpha occurs between 28 and 93 ft. (9-5–31 m.) above the base of the sequence (depths 1225 to 1160 ft.) (Butler, 1937, p. 247), showing that the oldest Llandovery in this area is of C₃ age. C. lirata typica has been recorded between 123 and 283 ft. (41–93 m.) above the base (depths 1130 to 970 ft.), which proves a C₄ age for these beds. Graekeosites occur at several horizons; those that Miss Elles examined from below 120 ft. (39 m.) from the base (depth 1133 ft.) are 'suggestive of the Upper Valentinian', and those below 27 ft. (9 m.) from the base (depth 1226 ft.) suggest a horizon at least as low as the M. griersoniensis Zone (Butler 1937, p. 246). At the Great Barr exposure, we have collected C. lirata typica.
Llandovery rocks rest with slight angular unconformity on the Lickey Quartzite (Cambrian) to the north and south-east of Rubery (Wills et al. 1925, 1938, Eastwood et al. 1925, p. 12); the latter authors infer that it occurs in hollows in the quartzite. Wills et al. (1925, p. 68 and 1938, p. 177) describes the Rubery Shales Series as consisting of a minimum of 40–50 ft. (13–16 m.) of shales and thin sandstones with some calcareous beds; these rest on 100 ft. (33 m.) of Rubery Sandstone Series which are coarse and fine sandstones, some shale and a basal conglomerate.

**Fossil communities.** Costistricklandia is present in both the Rubery Sandstone series and the Rubery Shale Series; the faunal list of Wills et al. (1925, pp. 72–73) suggests that the Costistricklandia Community is present throughout the whole Llandovery sequence in this area, although *Pentameroides* does occur in some beds.

**Correlation.** Costistricklandia *lirata alpha* is abundant in the Rubery Sandstone Series (St. Joseph 1935, p. 419) and *Pentameroides* also occurs (previously recorded as *Pentamerus oblongus*). The higher Rubery Shale Series contains *C. lirata alpha*, *Monograpthus marit* and *M. nubis*. It is concluded that the section described by Wills et al. (1925, p. 68) is all of C4 age.

The fossils listed (Eastwood et al. 1925, pp. 14–15) as coming from Wenlock beds near Rubery Hill Asylum (SO992778) include undoubted Llandovery fossils, but we have not examined this locality.

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**COVENTRY**

Text-fig. 3, col. 9

Shotton (1927) records Upper Llandovery sandstone pebbles from the Corley Conglomerate of Upper Carboniferous age, which is exposed from Coventry to Corley and Hollyberry End (SP262/825) 6 miles to the north-west. Shotton has shown that, approaching Coventry from the north-west, the proportion of Llandovery sandstone pebbles increases from 40% at Hollyberry End, to 70% at Corley (SP306/50) and 85% at King Street, Coventry (SP337/57). This traverse along the present outcrop of the Corley Conglomerate runs obliquely to a south-south-eastward extension of the Nuneaton Ridge (composed of Cambrian and Precambrian rocks), and Shotton suggests (1927, p. 616) that this ridge was capped by a strip of Upper Llandovery rocks (as at Walsall and Rubery) which provided the pebbles. It is probable that the source area extended north-north-west from around Binley, 3 miles east of Coventry.

**Fossil communities.** The faunal list (Shotton 1927, pp. 609–10) contains 55 species, which, with one or two possible exceptions, are typical of, or known in, the *Eocellia* Community. Stricklandiids, which are dominant to the west at Rubery and Walsall, are absent, as are *Pentameroides* and other elements of the offshore communities.

**Correlation.** Examination of *Eocellia* in pebbles (some kindly lent from the Birmingham University collections by Professor Shotton, others in the Sedgwick Museum, Cambridge) show the present of *E. intermedia*, *E. curtisi*, and *E. sulcata*, which indicates
ages from $C_{5-4}$ through $C_3$ to $C_4$. This is the only record of Silurian beds as old as $C_{5-4}$ to the east of the Malvern line.

LOWER LEMINGTON

Test-fig. 3, col. 20

Silurian rocks are recorded below Coal Measures in Stratian's (1913) description of a borehole 350 yd. W. 22° N. of Lower Lemington Church, 1 mile north-east of Moreton-in-Marsh. Grey shales with sandstone and limestone occurred from a depth of 1546 ft. (510 m.) to the completion of the hole at 1700 ft. (558 m.); allowing for a dip of 22°, the strata proved are about 140 ft. (46 m.) thick.

Fossil communities. Examination of the fossils in the Geological Survey collections (JP3143-61) from between 1590 and 1682 ft. show an Eoecelia Community present throughout this thickness.

Correlation. The Eoecelia present are all E. sulcata, indicating a $C_4$ age for all the fossiliferous Silurian beds that were penetrated.

EASTERN MENDIPS

Curtis (1955) summarizes the earlier work of Reynolds (1907, 1912, 1929) on the stratigraphy of the Silurian inlier which extends 3½ miles westwards from Downhead, Somerset:

3. Wenlock mudstones with some micaceous sandstones (120 ft.—40 m.).
2. Andesites and tufts (at least 400 ft.—130 m.).
1. Tufts (110 ft. (36 m.) seen). These oldest beds have, in the past been assigned to the Upper Llandovery.

Fossil communities. A collection from a field 1 mile west of Downhead (Loc. 94) yielded a dominance of Saltopina and Sphaerirhyncha, which suggest a near-shore environment for beds which our interpretation of the literature suggests are beneath the andesites.

Correlation. It is probable that there are no Llandovery beds exposed in the inlier. Collections from tufts (ST6752 4584) suggest an environment similar to the Eoecelia Community of the Llandovery, but no Eoecelia or other distinctive Llandovery forms have been found by us or recorded in the literature. We have examined the specimens (GSM DEW 3833-935) upon which Green (1962) based his report of beds attributable to the Llandovery, and conclude that they are also of Wenlock or Ludlow age. We thus tentatively consider these beds to be of Wenlock age. This conclusion is supported by the presence of Acaetea downingiae (Reynolds 1907, p. 227, Curtis 1955, p. 7) which we believe to be absent in the Llandovery.

RUMNEY

The Silurian inlier at Rumney (Rhymney), 2½ miles north-east of the centre of Cardiff, has been described by Sollas (1879). The Silurian beds in this inlier have always been assigned to the Wenlock and Ludlow, although Sollas recorded Pentamerus and Stricklandia.

The problem has been investigated by Dr. M. G. Bassett, who kindly writes: 'I am certain that all the beds are Wenlock-Ludlow. The best exposure at present is at
Penylan Quarry, where virtually the oldest beds brought to the surface in the inlier are exposed. These beds are certainly below the Rumney Grit, and hence older than the horizons from which Sollas quoted his diagnostic Llandovery brachiopods. The beds at Penylan contain abundant *Meristina obtusa*, which I consider to be a good indicator of late Wenlock age. This is supported by the occurrence of other fossils which could only be Wenlock or Ludlow in age. In addition there are many Wenlock brachiopods from the inlier at the National Museum of Wales which bear old labels mis-identifying them as *P. oblongus* and *Stricklandia*.

**Breidden Hills**

Text-fig. 3, col. 4

Watts (1885, pp. 536–7) gave the first description of the Llandovery beds of the Breiddens, and Wade (1911, p. 419) subdivided these beds into a lower unit, the Cefni Beds, and an upper unit, the Buttington Shales. The use of local names is preferable to the Shropshire names employed by Whittard (1932, pp. 880–2) in his description of this area. These beds are exposed sporadically along a 5-mile strip of country north-east of Buttington Station; the largest exposures are in the Brick Works (SJ/265 100) a quarter of a mile east of the station, and adjacent road sections.

(a) *Cefni Beds*. Whittard (1932) states that these consist of about 300 ft. (100 m.) of sandy mudstones with calcareous sandstones and occasional conglomeratic beds, but in the south-west the calcareous beds are more common. Ripples exposed at the top of the formation, over a large face in Buttington Brick Works, give a direction of movement from east to west.

*Fossil communities*. Whittard (1932, p. 881) mentions two fossil localities: north of Middletown in the centre of the outcrop (SJ/3008 1276) within 50 ft. (16 m.) of the base, and at the south-west end, south-east of Buttington Station (SJ/2633 0997) within 100 ft. (33 m.) of the base of the formation. Our collections show that the *Stricklandia* Community is present in both places.

*Correlation*. The presence of *Stricklandia lens* cf. *intermedia* suggests a Middle Llandovery age for the lower part of this formation.

(b) *Buttington Shales*. Whittard (1932, p. 881) described maroon, green, and blue mudstones with some calcareous beds up to 6 in. (15 cm.) thick, becoming uniformly maroon towards the top; he estimated their thickness to be about 350 ft. (115 m.). The upper contact is defined by an abrupt termination of the maroon-coloured beds; above this Cocks and Rickards (in press) record the presence of a complete succession of Lower Wenlock graptolite zones at Buttington Brick Works.

*Fossil communities*. The Buttington Shales have few fossils, but we have a collection, from near the top of the sequence in the Brick Works, in the *Chorinda* Community. Whittard (1932, p. 882) also found fossils in loose blocks at the north-east end of the outcrop; his faunal list is also typical of the *Chorinda* Community.

*Correlation*. It is not possible to state what horizon within the Llandovery is represented by these two collections from the Buttington Shales, but they are overlain with apparent conformity by a basal Wenlock *centrifugus* Zone fauna.
Wade (1911) described two formations of Llandovery age in the Welshpool area, the Powis Castle Beds and the higher Cloddiab Beds. The poorly exposed outcrop extends from Belan (2 miles south-west of Welshpool) to the Llansantffraid ym Mechain area, north-east of Meifod (see below).

(a) Powis Castle Beds. This unit consists of 100 ft. (33 m.) of massive bedded conglomerates; sandstones, shales and limestones are also present (Wade 1911, p. 431). It rests on Ashgill beds (Philippiella parahola age) in the Gwern y Brain (SJ/219 128) (Cave 1965, p. 282) and at the Laundry (SJ/197 103) (ibid., p. 295). Towards Welshpool the uppermost Ordovician beds are overstepped and the Powis Castle Beds rest on Lower Caradoc rocks (Harnagian Stage). In the Gwern y Brain, the Powis Castle Beds contain angular pebbles of these Ashgill and Caradoc units.

Fossil communities. A collection from the Gwern y Brain (SJ/2186 1283) within 10 or 15 ft. (3–5 m.) of the base of the Powis Castle Beds has yielded nothing but derived fossils from the underlying units, but the angularity of the pebbles and boulders is very suggestive of deposition in non-marine conditions. We have found the Cryptothyrella Community, a probable early Llandovery equivalent of the Eoecella Community, in a loose block in the southern part of the area, 600 yd. west of Belan Locks (SJ/2100 0518). On Cherry Tree Bank (SJ/2226 0831) on the north edge of Welshpool, we have collected Chloridea from the higher beds of the unit, and this would suggest that some of the Powis Castle Beds accumulated in deeper water; this conclusion is strengthened by the presence of Stricklandia lens in the conglomerates in the north of Powis Castle Park. In fact, the full depth range of communities may be present in the formation.

Correlation. The fact that the overlying Cloddiab Beds contain a Lower Llandovery graptolite fauna (vesiculosus Zone) suggests that the Powis Castle Beds are of Lower Llandovery age, and suggests a short pause in sedimentation between the Ashgill beds in the Gwern y Brain and the earliest Silurian. The presence of Stricklandia lens indicates a Llandovery as opposed to a late Ordovician age for the unit.

(b) Cloddiab Beds. Around Welshpool, upper Silurian beds rest directly on the Powis Castle Beds, but from Cloddiab northwards, some 250 ft. (80 m.) of mudstones and siltstones are seen above the conglomerates.

Fossil communities. A collection from the Cloddiab Beds at Y Frochas (SJ/1955 0824) yielded the Chloridea Community.

Correlation. Wade (1911, p. 434) reported Climacograptus inomatus, C. cf. rectangularis and C. medius from the lower part of the formation near Cloddiab. These indicate the vesiculosus Zone, but as they were found only 20 ft. (7 m.) above the base of the formation, it is possible that the Middle and Upper Llandovery is also present—the Cloddiab Beds extend upwards into Wenlock strata with no change in dip.
The Llandovery outcrop extends northwards from Welshpool for 7 miles to the Llansantffraid ym Mechain area (Whittington, 1938), and thence changes direction south-westwards to Meifod (King, 1928). King recognized four formations which he labelled V₁, V₂, V₃, and VS and Whittington employed this terminology at Llansantffraid ym Mechain.

(a) **Craig-wen Sandstone (V₁)**. This basal unit is a 30-ft. (10 m.) sandstone with some large calcareous concretions near the base. The sandstone fills hollows cut in Ashgill mudstone south-west and west of Meifod at Craig-wen and Glan-yr-afon-isaf (King 1928, pp. 682-3). These hollows are a foot or more in depth and contain angular fragments of Ashgill mudstone.

**Fossil communities.** King (1928, pp. 682-7, 699) records two communities from the Craig-wen Sandstone. In the calcareous beds fragmentary corals and brachiopods are present, while the sandstone contains 70% orthids, 20% *Cryptothyrella* (the *Merisina erassu* of earlier reports), and about 10% rhynechitellids. Our collection from the basal 1½ ft. (50 cm.) of the unit at Craig-wen Quarry (SJ 0991 0919) has yielded the *Cryptothyrella* Community, the probable early Llandovery equivalent of the *Eocelia* Community.

**Correlation.** The fossils of this unit are not diagnostic as to age, but the underlying Ashgill unit has yielded graptolites normally associated with the *Dicellograptus aniceps* zone (King, 1928, p. 698) and the overlying formation has yielded late Lower Llandovery graptolites, so the Craig-wen Sandstone is probably of late Lower Llandovery age.

(b) **Blue silty mudstones (V₂)**. Blue-black micaceous shales and hard siltstones (V₂a) come at the base of this formation west of Meifod; higher beds (V₂b and V₂c) in this 630-ft. (205 m.) formation are blue mudstones with silty siliceous bands and calcareous nodules (King 1928, pp. 687-8). Five miles north-east of Meifod, Whittington (1938, pp. 438-42) describes blue mudstones and limestones near Tre-wylan House and Gelli Farm (which he correlates with King's V₂b beds) resting on Ashgill. Similar beds occur at Godor and it would seem likely that the outcrop is continuous with that of Meifod. Beds like King's V₂b are recorded at Godor and Sarnau (Whittington 1938, pp. 440-1).

**Fossil communities.** King (1928, p. 699) lists *Stricklandia* and *Clorinda* [*Barrowicella*] as common in V₂a; and *Clorinda* as common in V₂b. This suggests deeper water than in the Craig-wen Sandstone.

**Correlation.** In the lower part of this unit, *Climacograptus normalis*, and what Dr. G. L. Elles thinks may be a specimen of *Monograptus aciaces* have been found (King 1928, p. 688). These species would suggest the zone of *M. cyphus* (late Lower Llandovery), but the unit may extend into the Upper Llandovery as the lowest graptolite fauna in the overlying formation is in the *turrilatus* Zone.

(c) **Pale grey and purple-red shales (V₃)**. King's (1928, p. 690) V₃ beds start with an abrupt change of colour from grey-blue mudstones to pale dove-grey fine mudstones; they consist of 330 ft. (110 m.) of pale grey and red shales.
Fossil communities. Apart from some fragmentary trilobites and brachiopods near the base, graptolites are the only fossils present.

Correlation. The zones present range from *turrilatus* to *crenulata* (King 1928, p. 690) and represent the upper two-thirds of the Upper Llandovery. The red shales occur in the *cripus* and *griestoniensis* Zones; they are the oldest dated red beds known in the Welsh Llandovery succession.

(d) Passage Beds (VS). King (1928, p. 691) records 60 ft. (20 m.) of blue-grey mudstones above $V_n$ beds.

Fossil communities. Benthic forms are absent from this unit.

Correlation. King found *Monoclonocis crenulata* in these beds to the north-east of Meifod, so they are assigned to the topmost Upper Llandovery. They are followed by lowest Wenlock beds with a similar lithology.

TRANNON AND LLANILOES

Text-fig. 3, cols. 1 and 10

These areas are in the middle of the graptolitic-greywacke facies of central Wales and have been included here because they contrast with the dominantly shelly facies of the Welsh Borderland areas already described. Wood (1906) and Jones (1945) have described the stratigraphy of the areas. At Trannon (called Tarannon by Wood) at least 3650 ft. (1100 m.) of Llandovery sediments (we use Llandovery to include all the beds up to the base of Wood’s *murchisoni* Zone) are present, and 9670 ft. (2975 m.) at Llaniloes. In both areas the whole succession consists of graptolitic shales with greywackes at some horizons. The base of the Silurian is not quite reached near Trannon, but at Llaniloes a sharp but comfortable base is present.

Greywackes are especially abundant in the *griestoniensis* Zone. Bassett (1963, pp. 57–9) interprets the Talerdig Grits of Trannon and the contemporary Moelfre Group of Llaniloes as turbidites and comments on the problems in estimating the depth of water in which they were deposited. We would consider that these turbidites could have been laid down over a very large depth range, provided that the depth was greater than that of the *Clivula* Community, which is completely absent around Trannon.

The highest Llandovery consists of purple and green mudstones which contain a fauna characteristic of the *crenulata* Zone. There is a gradational passage upwards into the Wenlock beds.

BUILTH WELLS

Text-fig. 3, col. 23

Upper Llandovery rocks occur in a very narrow discontinuous belt running north-east from Park Wells (SO 027 519—1 mile west-north-west of Builth Wells) for a distance of 4 miles (Jones 1947). The beds consist of about 30 ft. (16 m.) of coarse sandstone and mudstones, resting unconformably on Ordovician beds, and overlain unconformably by beds of Lower Wenlock age. The Wenlock overstep is considered to be responsible for the discontinuous outcrops (Jones 1947, p. 35).

Fossil communities. A collection from Trecoed (SO 0527 5516) has yielded an abundance
of *Pentamerus* and *Stricklandia*, suggesting a mixture of these two communities. These came from a coarse sandstone about 14 ft. (5 m.) above the base of the Llandovery.

**Correlation.** *S. lens ultima* is present, indicating a C.3.a age for this horizon.

**GARTH**

Text-fig. 3, cols. 21 and 22

The Garth area is situated some 15 miles north-east of Llandovery and is part of the same belt, which, during Llandovery times, formed the junction of the stable shelf to the south and east and the subsiding basin to the north and west. The two columns representing this area were selected to illustrate some of the many lateral changes in thickness and lithology in the Llandovery rocks of the Garth area. Andrew (1925) divided the Lower Llandovery into three formations, A, A, and A; designated the Middle Llandovery B; and divided the Upper Llandovery into C, C, C, and C.

(a) **Lower Llandovery.** The basal Llandovery sandstones and conglomerates rest on Bala mudstones with a sharp boundary; these are followed by mudstones with occasional sandy beds, all totalling 1880 ft. (600 m.) in the centre of the area, but thinning to 1200 ft. (400 m.) in the south-west (Andrew 1925, pp. 392, 402).

**Fossil communities.** No fossils are recorded in A. In the southern part of the area, the *Stricklandia* Community is present in A, and both *Stricklandia* and *Clarinida* occur in A, but the shelly faunas become sparse or absent in the north (Andrew 1925, pp. 396–7), that is, towards the basin.

**Correlation.** Andrew (1925, p. 403) considered 'on faunal and lithological grounds': that his units 'A, A, and A' appear accurately to represent A, A, and A of the southern part of the Llandovery area. It is of importance to note that the top 20 ft. of the 'Bala' beds of Garth contain *Glyptograptus cf. perisculptus* and *Mesograptus cf. modestus var. parvulus*, which . . . are usually associated with the basal zone of the 'Valentinian' (Andrew 1925, p. 392). This fauna indicates the *perisculptus Zone*, the base of which is now conventionally taken (e.g. Toghill 1968) as the base of the Llandovery in the graptolite sequence. If Andrew was correct in equating his unit A with the A sandstone at Llandovery itself, then the base of the formation is probably diachronous. The latter conclusion is supported by recent unpublished sedimentological work by Dr. M. A. Woollands.

(b) **Middle Llandovery.** Only a small thickness of mudstones is present in a restricted area in the south-east of the Garth area (Andrew 1925, p. 397). The few specimens recorded are suggestive of the *Clarinida* Community. Andrew suggested a correlation with B of Llandovery on the basis of lithological resemblance (Andrew 1925, p. 403), but its age is still not definitely known.

(c) **Upper Llandovery.** The lower three Upper Llandovery units of Andrew (C, C, C) comprise a sequence of mudstones, argillaceous sandstones, and rather prominent conglomerates which is very variable in thickness (0–300 ft., 0–100 m.). The upper unit (C) consists of 150–1000 ft. (50–330 m.) of olive-green and purple mudstones, similar in colour and lithology to the high Llandovery of many other areas; it overlaps earlier
beds, coming to rest on $A_0$ at the extreme south-western and north-easterm ends of the area, according to the mapping of Andrew. $C_d$ passes up without a break into beds containing the basal Wenlock zone of *Cyrtograptus marchisoni* (Andrew 1925, p. 400).

**Fossil communities.** Andrew's faunal lists (1925, pp. 398–9) show that $C_e$ contains a *Pentamerus* Community, which indicates a shallowing after the Middle Llandovery. $C_b$ has yielded a fauna which includes *Pentamerus*, *Stricklandia*, and *Chorinida*, suggesting a return to deeper water. It is not possible to determine the community present in $C_e$, but increase in depth is again shown by the graptolites present in $C_a$.

**Correlation.** The Upper Llandovery of Garth can be tentatively correlated with the beds of Llandovery on gross lithological and faunal grounds. Andrew and Jones (1925, p. 412) suggest it may be equivalent to $C_{4\alpha}$. The presence of beds with *Monograptus priodon* and *Monoclinacis crenulata* conformably below the basal Wenlock shows that the highest Llandovery is present in this area.

**CHRONOLOGICAL SUMMARY**

Text-fig. 11 illustrates the chronological sequence of Llandovery deposits in the Welsh Borderland. It brings out the fact that, although the spread of the sea was continuous from Lower Llandovery times, there were several gaps in sedimentation. In general, however, there is evidence of a progressive deepening at any one locality.

**Lower Llandovery (A$_{1\alpha}$) times**

The shelf was narrow during the Lower Llandovery, and deposits are confined to an area west of Welshpool and Garth (text-fig. 12). In the basin area of Central Wales (text-fig. 11, cols. 1, 10, 21, and 22), basal Llandovery graptolitic shales follow above similar Ashgill sediments without a break. At Trannan and Llandiloes this facies continues throughout the Lower Llandovery, but at Garth *Stricklandia* and *Chorinida* Communities are present, showing that shallowing took place there in A$_{2\alpha}$ times. This was probably followed by a depositional break, as no A$_1$ has been proved at Garth.

On the edge of the basin at Meifod and Welshpool (text-fig. 11, cols. 2 and 3), there was uplift of Ashgill sediments prior to the deposition of beds containing A$_{1\alpha}$ shallow-water *Cryptograptida* Communities. In Shropshire, to the east (text-fig. 11, cols. 5, 6, 11–14), the Caradoc and earlier rocks are seen to be considerably folded before the Middle Llandovery. If these movements are correlated with the basal A$_1$ non-sequence at Meifod and Welshpool, then it may be that the acme of this folding occurred at the very beginning of the Silurian. After the initial uplift, the shallow-water A$_{1\alpha}$ beds at Meifod and Welshpool are followed by deeper-water A$_{2\alpha}$ *Stricklandia* and *Chorinida* Communities. The general subsidence characteristic of the Welsh Borderland throughout the Lower Silurian thus started as early as A$_{2\alpha}$ times.

**Middle Llandovery (B$_{1\alpha}$) times**

In the basin (text-fig. 11, cols. 1 and 10), the graptolitic facies continues without break; this facies spread over the basin margin at Meifod (text-fig. 11, col. 2) in B$_1$ time, when the *Chorinida* Community was replaced by graptolites. At about the same time, the sea
Text-fig. 11. Three sections across the Welsh Borderland (see text-fig. 1 and 3) showing communities plotted against time.
deepened at Welshpool (text-fig. 11, col. 3) and spread over West Shropshire (text-fig. 11, cols. 4, 5, 11, and 13) and may have just reached the Malverns (text-fig. 11, cols. 15–17) by the end of Middle Llandovery times. It is worth noting here that there are no Middle Llandovery sediments in nearby sections at Eaton Farm and Wistanstow.

Text-fig. 12. Palaeogeography of the area during Lower Llandovery (A1) time. E. Cryptothyrella Community; S. Stricklandia Community; C. Clorinda Community; G. graptolite facies.

Note. The coastline is shown as a smooth curve, but we envisage a coastal topography perhaps similar to Essex at the present time (this applies also to text-fig. 13 and 14). The size of some of the smaller outcrops is enlarged for greater clarity, and the Upper Severn Estuary is omitted.

(text-fig. 11, cols. 12 and 14). The earliest deposits at these localities contain C2–3 Clorinda Communities; this shows that the sea was deep before sedimentation commenced, and that the advance of the sea was not everywhere accompanied by a supply of sediments. Thus the sea probably extended over the Eaton Farm and Wistanstow areas in Middle Llandovery time.
Early Upper Llandovery (C$_{1}$) times

At Trannon, Meifod, and Llanidloes (text-fig. 11, cols. 1, 2, and 10) the graptolite facies continues, both in the basin and on the edge of the shelf (text-fig. 13). In West Shropshire (text-fig. 11, cols. 4 and 5) the sea is seen to have deepened with the replace-

ment of the Stricklandia Community by the Clarinda Community. South of the Longmynd (text-fig. 11, col. 13) the communities show a minor reversal, but there was an over-all deepening from C$_{1}$ to C$_{2}$ times. At neighbouring sites (text-fig. 11, cols. 12 and 14) sedimentation commenced for the first time with the deposition of deep-water Clarinda Communities resting directly on Pre-Cambrian and Ordovician rocks.

In the Wenlock Edge outcrop, and in the Malverns and at Presteigne (text-fig. 11, cols. 6, 15–17, and 25), there are undoubted early Upper Llandovery sediments; these contain shallow-water communities showing the progressive deepening so characteristic
of this transgression. There is a sequence from a basal Lingula Community (not exposed at Presteigne) deepening to Eocelia or Pentamerus Communities. At May Hill (text-fig. 11, col. 27) there is a minor reversal in the progressive deepening as Lingula and Eocelia Communities alternate.

![Text-fig. 14. Palaeogeography of the area during late Upper Llandovery (C₄) time. E, Eocelia Community; P, Pentamerus Community; S, Cystisverklandia Community; C, Choriade Community; G, graptolite facies.](image)

At Garth and Builth (text-fig. 11, col. 21–3) no beds of C₄ age are present; this is probably to be accounted for by non-deposition in a sea of Pentamerus Community depth, as this community is present above the non-sequence in beds of C₃ age.

**Late Upper Llandovery (C₄) times**

During this time, basin facies (the Pale Shales) continue at Garth (text-fig. 11, col. 21), but, in Wenlock times, graptolitic deposits are present at Builth as well (col. 23); an eastwards spread of this deep environment thus presumably occurred in C₄ times (text-fig. 14). A similar C₄ spread probably took place over the edge of the basin from
Montgomeryshire into West Shropshire (text-fig. 11, cols. 2-4); this deepening of
the sea may also be related to the turbidites at Minsterley (which are of late Upper
Llandovery [post C₄] or early Wenlock [pre-riccartonensis Zone] age).

On Wenlock Edge (text-fig. 11, col. 6), the progressive deepening, mentioned above,
continues through most of C₄ but in late C₄ time there is an indication of slight
shallowing in the beds immediately below the Buildwas Beds.

From sandstone pebbles in the Upper Carboniferous north-east of Coventry (text-fig.
11, col. 9), Eocolla has been found, ranging in age from C₄ to C₆. However, at Walsall
and Rubery (text-fig. 11, cols. 7 and 8) the earliest Silurian deposits contain C₄ beds with
Costestrichlandia Communities and rest directly on Cambrian rocks; here, as in Shrop-
shire during C₃ (see above), we have strong indications that the sea was present at
Walsall and Rubery well before sedimentation commenced. The evidence from Lower
Lemington (text-fig. 11, col. 20) suggests a shallow sea there in C₃ times, but the local
base of the Silurian is unseen.

In the Malvern areas (text-fig. 11, cols. 15-19), no beds of C₃ age are known: this
non-sequence is followed by C₄ beds with Pentameroides and Costestrichlandia Com-
munities which overlap the C₃ deposits (which contain Lingula and Eocolla Com-
munities), and rest in places on the Pre-Cambrian. Text-fig. 11 shows that there is a
progressive deepening of the sea across this non-sequence; thus there is no suggestion
of any marine regression during C₃ time in the Malvern area.

A different type of stratigraphical break is present beneath the Nash Scar Limestone
at Presteigne and Old Radnor (text-fig. 11, cols. 24 and 25); a shallow-water Wenlock
algal limestone rests unconformably on C₃ beds (with a Pentamerus Community) at
Presteigne, and on Pre-Cambrian at Old Radnor. There must have been shallowing
during this interval, and local uplift may well have occurred here during the late Upper
Llandovery.

The progressive deepening, seen or inferred for C₄ beds of most areas, was also
present to the south of the Malvern in the May Hill and Tortworth areas (text-fig. 11,
cols. 27-9). At May Hill the communities range from Eocolla through Pentameroides
and Costestrichlandia to Chlorina, and at Tortworth the Stone succession (col. 28) also
shows a progressive sequence. This last sequence contains a 15-ft. (5-m.) thick basalt
within the beds containing the C₄ Costestrichlandia Community. But at the other end of
the Tortworth Inlier (at Charfield Green, text-fig. 11, col. 29) the basalt has thickened
to 150 ft. (50 m.), and is followed directly by beds containing an Eocolla Community.
We conclude that the sudden shallowing of the shelf sea by 150 ft. is directly responsible
for the replacement of a Costestrichlandia Community by an Eocolla Community;
this implies that the depth range of the intervening Pentameroides Community is signif-
ically less than 150 ft.

CONCLUSIONS

The elucidation of the evolution of several brachiopod genera has enabled wide cor-
relation of the 13 subdivisions of the Llandovery established in the type area by O. T.
Jones. Recognition of similar assemblages of fossils at different times has led to the
establishment of five main animal communities. In the Silurian the marine communities
of the shelf were largely epifaunal and relatively independent of substrate; depth was
thus the main controlling factor in community distribution.
In the shelf regions on the Welsh Borderland, the Llandovery always rests unconformably on older rocks; on the margin of the basin there is only a small break at the very base of the Lower Llandovery; and in the basin of Central Wales there is conformity between the Ordovician and Silurian. From A1 to C3 there was a progressive spread of the sea to the east and south. In the Lower Llandovery marine deposits are present at Welshpool and Garth; by Middle Llandovery times West Shropshire had been submerged; and by early Upper Llandovery (C3) times the sea had transgressed as far as the Malverns and May Hill; it did not reach Tortworth until the late Upper Llandovery (C5). The theory (Jones 1938) that there was a sudden submergence of the whole area at the beginning of the Upper Llandovery cannot now be accepted.

With few exceptions, each local sequence shows a progressive increase of depth with time. This progressive depth increase can even span periods of non-deposition, for example the C2 beds above the non-sequence in the Malverns were laid down in deeper water than in C2 beds below the break. We have concluded that, where a deeper-water community is present at the base of a local sequence, the sea was present for some time before deposition commenced. It follows that the spread of the sea with time was even more uniform than the sedimentary sequences record. It also follows that there were periods when no sediments were being deposited in certain parts of the sea floor; this may have been due either to lack of sediment supply or to no deposition or erosion in current-swept areas.

The Welsh Borderland is on the south-eastern margin of a Lower Palaeozoic geosyncline which included the Lake District, the Southern Uplands of Scotland and much of central Ireland. Both this margin and the western margin in County Galway show an extension of the sea during Llandovery times, but at the same time north-east Newfoundland (and perhaps also parts of the Midland Valley of Scotland, for example Lismahago) showed deposition from deep-water basin sediments to shelf or even non-marine conditions. When the Welsh Borderland is viewed as part of this larger region, it seems improbable that the advance of the sea during Llandovery times was due to eustatic deepening.

Although there was probably little structural control of sedimentation from place to place within the Welsh Borderland at this time, there were three major tectonic regions affecting the area:

(i) The basin region to the west which subsided rapidly, accommodating large thicknesses of sediment (nearly 10,000 ft. (3000 m.) of Llandovery beds at Llandiloos).
(ii) The shelf region, which subsided slowly throughout the whole of Llandovery time, and upon which thinner sediments accumulated.
(iii) A region of uplands to the south and east, which provided the sediment for both of the other regions.

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### APPENDIX 1

**Locality of collections in Oxford University Museum**

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* Collections from loose blocks.
### APPENDIX 2

**Locality of collections in British Museum (Natural History)**

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### APPENDIX 3

**Locality of collections in United States National Museum**

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*Collections from loose blocks.*
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* Collections from loose blocks.

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University of Chicago  
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