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SHROPSHIRE GEOLOGY—STRATIGRAPHIC AND TECTONIC HISTORY

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ABSTRACT

Despite its small size, Shropshire is unique in the remarkably varied geology it possesses—of the 13 recognised geological periods, 10 are represented in the area's rock sequences. This paper provides a comprehensive and up-to-date account of the stratigraphy of the county, with additional information on tectonic history included throughout.

I INTRODUCTION

This paper was originally intended as a revision of Dineley's "Shropshire Geology: An Outline of the Tectonic History", published in 1960. However, the result is really a new paper including stratigraphy and tectonics, and incorporating studies published since 1960. We have not included in this paper detailed palaeontology, and have only noted important fossil records where necessary. The reader is referred elsewhere for the complete fossil assemblages of the various geological systems. Similarly, we have not discussed the Quaternary period (Pleistocene and Holocene) in Shropshire, since this most important aspect of the geology of the county is beyond the scope of this paper, which is strictly limited to the solid rocks of the county.

Of the 13 recognised geological periods (including the Precambrian era for this purpose) 10 are represented in Shropshire by rock sequences, only the Tertiary (now separated into the Palaeogene and Neogene) and Cretaceous systems are absent, although even in the Tertiary we have evidence of tectonics and minor igneous activity. This is quite remarkable and makes Shropshire unique in Britain (if not the world) for displaying such a variety of geology in such a small area (Fig. 1). The diversity of scenery is thus explained and also the popularity of Shropshire with students of geology and physical geography.

Much of the early work on Shropshire geology was done in the 19th and early 20th centuries by such famous geologists as Murchison, Lapworth, Callaway, Watts, Cobbold, Stubblefield, Bulman, Whittard, etc., and many Shropshire place names such as Ludlow, Much Wenlock and Caer Caradoc, have found their way into international geological literature as the basis for standard terms such as Ludlow, Wenlock and Caradoc Series.

As well as the varied rock sequence, Shropshire has been affected by a number of periods of earth movements associated with orogenies whose centres have been some distance away. These earth movements, which we can now explain in terms of plate tectonics, have igneous activity associated with them, have produced numerous folds and faults (Fig. 2) and also explain the number of unconformities within the stratigraphic sequence (Fig. 3). The major episodes of earth movements which have affected the county are as follows on p. 61: –

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Name	*Age*	*Effects in Shropshire*
Alpine	Tertiary	Uplift. Folding and faulting in N. Some movement along old fault lines, including Church Stretton Fault.
Variscan (Amorican/Hercynian)	late Carboniferous/early Permian	Major uplift. Faulting of coalfield areas. Folding and faulting of Lower and Upper Paleaozoic rocks. Movement along old fault lines including Church Stretton Fault.
Caledonian	late Silurian/middle Devonian	Little late Silurian folding. Some mid Devonian folding. Major uplift and some faulting. Movement along Church Stretton Fault.
Taconian	late Ordovician	Folding and faulting of Ordovician and older rocks in west. Uplift at end of Ordovician. Major movement along Church Stretton and Pontesford-Linley Faults.
Unnamed	late Precambrian (At least 3 episodes in Shropshire)	Folding and faulting of Longmyndian. Initiation of Church Stretton and Pontesford–Linley Faults. Metamorphism of Rushton Schists and Primrose Hill Gneisses and Schists (? 2 episodes)

We shall now describe each geological period listing the main stratigraphic and tectonic events, and the igneous cycles associated with the tectonics.

II THE PRECAMBRIAN

The Precambrian, that vast period of time from the origin of the Earth 4600 million years ago to the start of the Cambrian period 570 million years ago, really contains several eras and in Shropshire we have evidence for only relatively young Precambrian rocks (?younger than 1400 million years).

The sequence contains an igneous suite (Uriconian Volcanics) overlain by a thick sedimentary sequence (Longmyndian Supergroup). Small but important outcrops of metamorphic rocks occur west of the Wrekin and show evidence of possible older basement. The Primrose Hill Gneisses and Schists show similarities to the Malvernian metamorphic rocks, and the Rushton Schists are possibly older.

All the Precambrian outcrops (Fig. 1). lie between, or along the line of, two major NNE–SSW faults, the Church Stretton and Pontesford-Linley Faults, both of which were initiated in Precambrian times and played such important roles in Precambrian and Lower Palaeozoic sedimentation. The Church Stretton Fault is really a system of up to 3 major sub parallel faults and probably had movement along it until Tertiary times. The Pontesford–Linley Fault only affects rocks of up to Ordovician age.

Precambrian Palaeogeography

The Iapetus ocean (proto-Atlantic) was well established (Fig. 4) and widening by late Precambrian times, and Shropshire lay on its "south eastern" margin, perhaps a few hundred kms within the continental mass. The Uriconian volcanics represent continental "Andean type" vulcanicity on the continental side of a subduction zone established near Anglesey which caused late Precambrian metamorphism in that area. The subduction zone was inclined south east under Shropshire and vulcanicity initiated within the continental mass. The Pontesford–Linley fault and Church Stretton fault system were initiated at this time parallel to the subduction zone, and subsidence between these two faults led to the formation of a shallow marine trough in which the Longmyndian was deposited. All the Longmyndian sediments suggest a shallow water environment, with dying bursts of Uriconian-type vulcanicity in the east (Fig. 5). The presence of Uriconian fragments within the western Longmyndian suggests

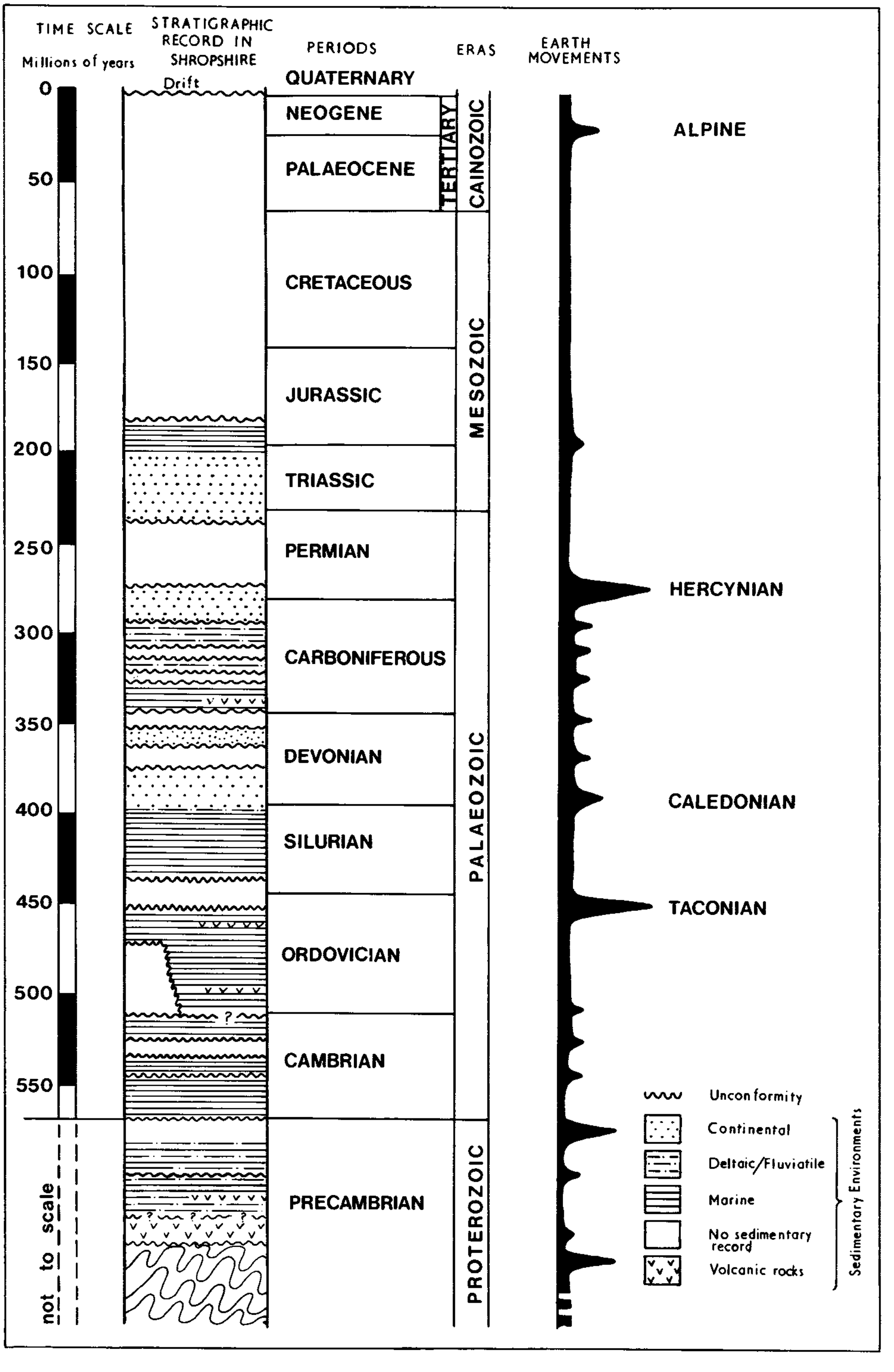

FIG. 3.
Geological time scale and record of stratigraphic and tectonic events in Shropshire.

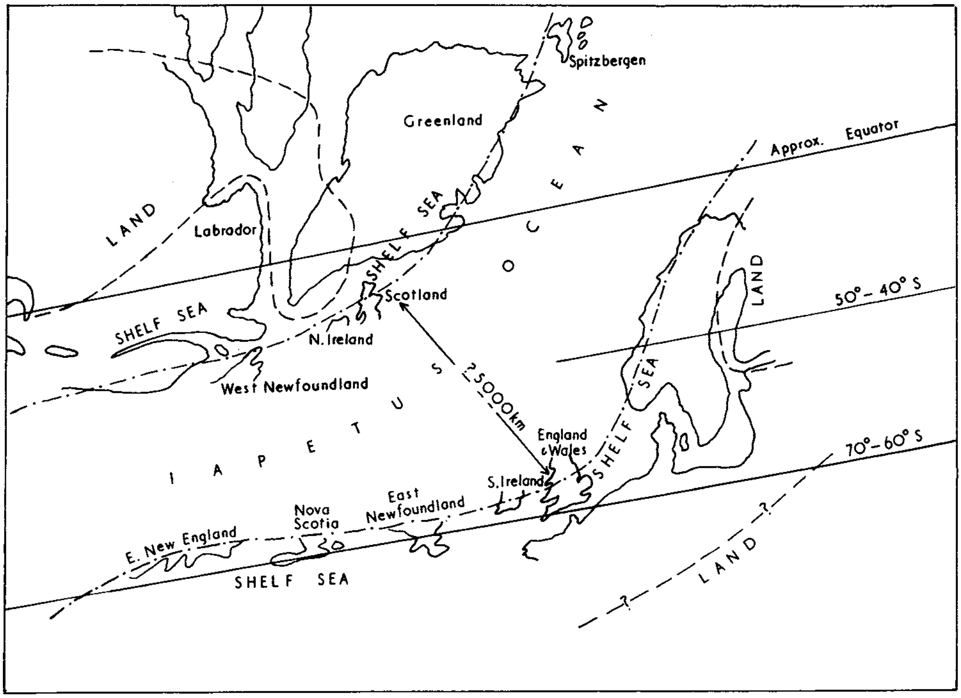

FIG. 4.
Cambrian (and late Precambrian) palaeogeography showing the position of the Iapetus Ocean, which started to close in the late Cambrian (Tremadoc), with the initiation of a subduction zone in its "north west" margin, followed by one on the "south east" margin in the early Ordovician. Both of these subduction zones caused widespread volcanic activity and metamorphism on either side of the ocean. Late Precambrian subduction zones had also been present, one of which caused volcanic activity on the "south east" margin in Shropshire, and metamorphism in Anglesey. The oceanic area narrowed throughout the Ordovician and Silurian. Palaeolatitudes from Cocks and Fortey (1982).

that the volcanics were already being eroded to provide source material. Uplift and erosion before the formation of the western Longmyndian (Fig. 5) explains the presence of these fragments and the major unconformity at the base of the western Longmyndian.

The Rushton Schists

These quartz-mica schists are low grade regional metamorphic rocks similar to parts of the Mona Complex on Anglesey. They are now considered to be older than the Uriconian Volcanics and the Longmyndian, and the metamorphism is probably associated with a subduction zone now recognised to have been located in the Anglesey area in the late Precambrian. They have a limited, 2 km^2 outcrop, mostly drift covered, SW of the Wrekin, but could be the basement to a much larger area of Shropshire. They are faulted against Uriconian Volcanics and Carboniferous rocks but overlain unconformably by the basal Cambrian Wrekin Quartzite.

Primrose Hill Gneisses and Schists

These metamorphic rocks, occupying a very small area (0.1 km^2) on Little (Primrose) Hill at the south west end of the Wrekin, are probably part of an igneous complex similar to the Malvernian "Gneisses" (Dunning, 1975). They include hornblende schists and biotite gneisses, with granophyric intrusions, some of which are very coarse grained (pegmatitic).

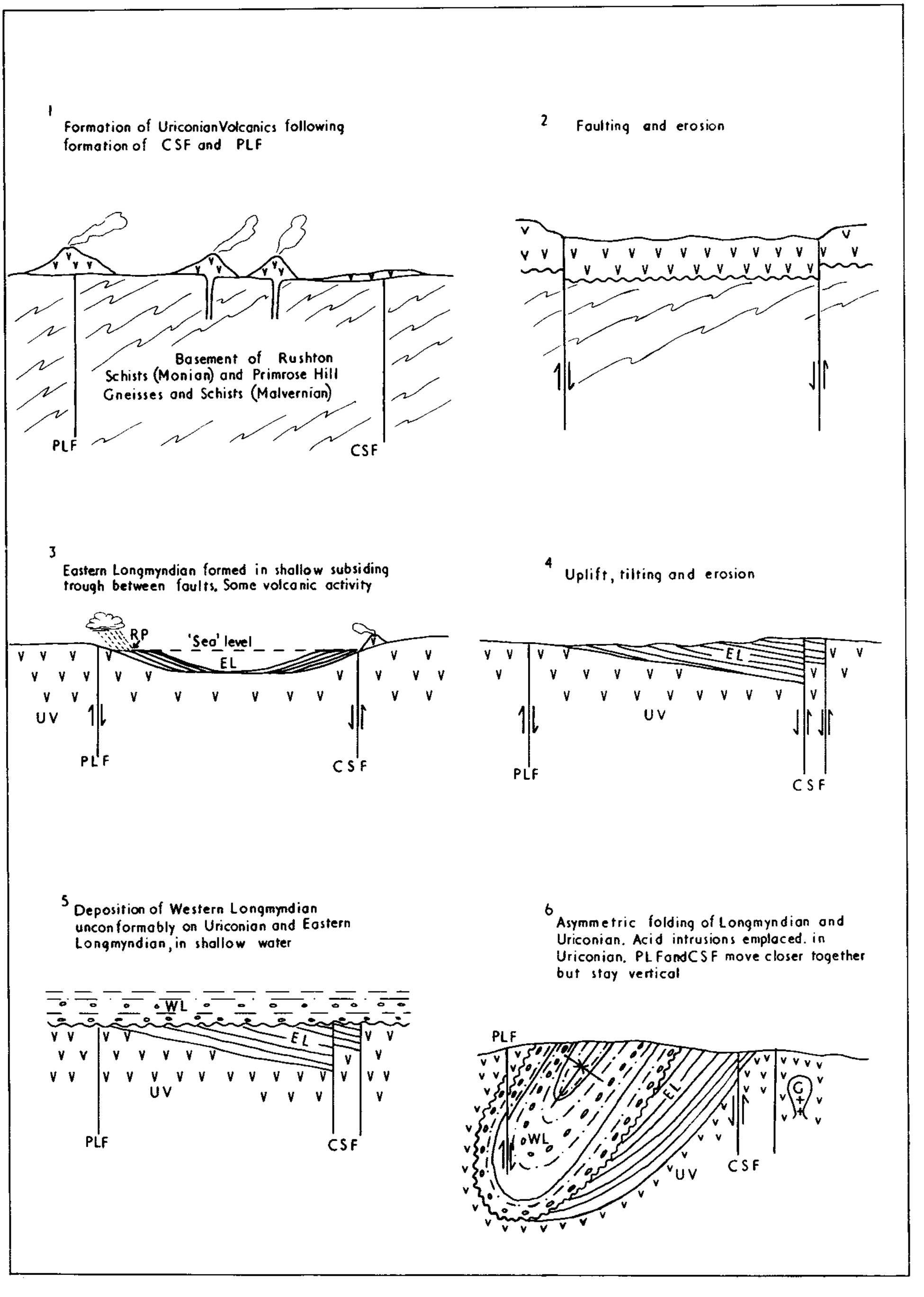

FIG. 5.

Stages in the formation of the Uriconian Volcanics, the Longmyndian and the formation of the Longmynd fold structure and associated faults. PLF, Pontesford–Linley Fault; CSF, Church Stretton Fault System; UV, Uriconian Volcanics; EL, Eastern Longmyndian; WL, Western Longmyndian; G, Granophyre; RP, Rain pits.

The Uriconian Volcanics

The metamorphic episode which produced the Rushton Schists and the Primrose Hill metamorphic rocks was followed by a late orogenic igneous episode, which is recorded from various parts of Britain. It is likely that the Church Stretton Fault and the Pontesford–Linley Fault were initiated at this time, and this is supported by the fact that all the outcrops occur along these faults and nowhere else. It is possible that extrusion took place along the fault lines.

The Uriconian Volcanics are a calc-alkaline suite of igneous rocks of tremendous variety, ranging from acid and basic lavas and tuffs together with acid and basic intrusions. The rock types include basalt, andesite and rhyolite lavas (the latter are particularly well-known). The basalts are often vesicular and the rhyolites flow-banded. The associated tuffs (ashes) are of the same composition and vary from fine grained ignimbrites to very coarse tuffs with volcanic bombs. The thickness of the volcanics is difficult to estimate as each hill mass is fault-bounded but 1200 m have been measured on Caer Caradoc and this is probably a minimum for the sequence. No vents have been identified in Shropshire but the presence of viscous rhyolite lavas suggests that material has not travelled far and could have erupted from fissures along the major faults. The volcanics are probably subaerial but some tuffs show evidence of having been laid down in shallow water. The sequence of lavas and tuffs is intruded by many dolerite dykes and sills, and by acid intrusions, such as the Ercall granophyre and the quartz porphyry of Cardington Hill.

Main outcrops of Uriconian Volcanics

The volcanics occur in two well-defined belts (Fig. 1) along the Pontesford-Linley Fault and the Church Stretton Fault System, which both trend NNE–SSW. The latter widens out north of the River Severn with the Brockton Fault on the NW and the Wrekin Fault on the SE. The two belts are often referred to as the Western and Eastern Uriconians, but there seems little doubt that the two outcrop belts are part of the same sequence with the Longmyndian rocks between in a large overturned syncline (Fig. 6). Each outcrop is fault-bounded and so it is difficult to correlate the sequence on, say, the Wrekin with that on Caer Caradoc, and so local sequences have been worked out (Greig *et al.*, 1968) for each hill mass.

Along the eastern outcrop the most northerly outcrop is at Lilleshall Hill (Fig. 1) and then the mass of the Ercall and the Wrekin follows to the south west along the Wrekin Fault. Wrockwardine and Charlton Hills occur along the Brockton Fault to the NW and then the two faults merge as the main Church Stretton Fault System crossing the River Severn. The next major outcrop to the SW is at the Lawley and then the outcrop is continuous, but much faulted, SW through Caer Caradoc, Helmeth, Hazler, and Ragleth Hills. To the east of Caer Caradoc, separated from the main outcrop by faults and thrusts, is the large Uriconian area of Cardington, Willstone and Hope Bowdler Hills, overlain by Cambrian strata. The most southerly outcrop is the isolated fault-bounded Wart Hill, famous for its views of the surrounding geology.

Along the western outcrop (Fig. 1) the most northerly exposures are at Plealey and then, just to the SW, occurs the striking mass of Earl's Hill and Pontesford Hill with a great variety of faulted volcanics and large dolerite intrusions. There are no outcrops along the Pontesford–Linley Fault for some 5 km but then the outcrop is continuous, although poorly exposed, south westward towards Lydham. In this southern area the volcanics are faulted against (Tremadoc) Shineton Shales on the west; but on the east, James (1956) was able to show that they appear to overlie western Longmyndian sediments. In fact the whole sequence was shown to be inverted (Fig. 6) and the Longmyndian is uncomformable on the Uriconian. Thus in this area we have direct evidence for the volcanics being older than the Longmyndian.

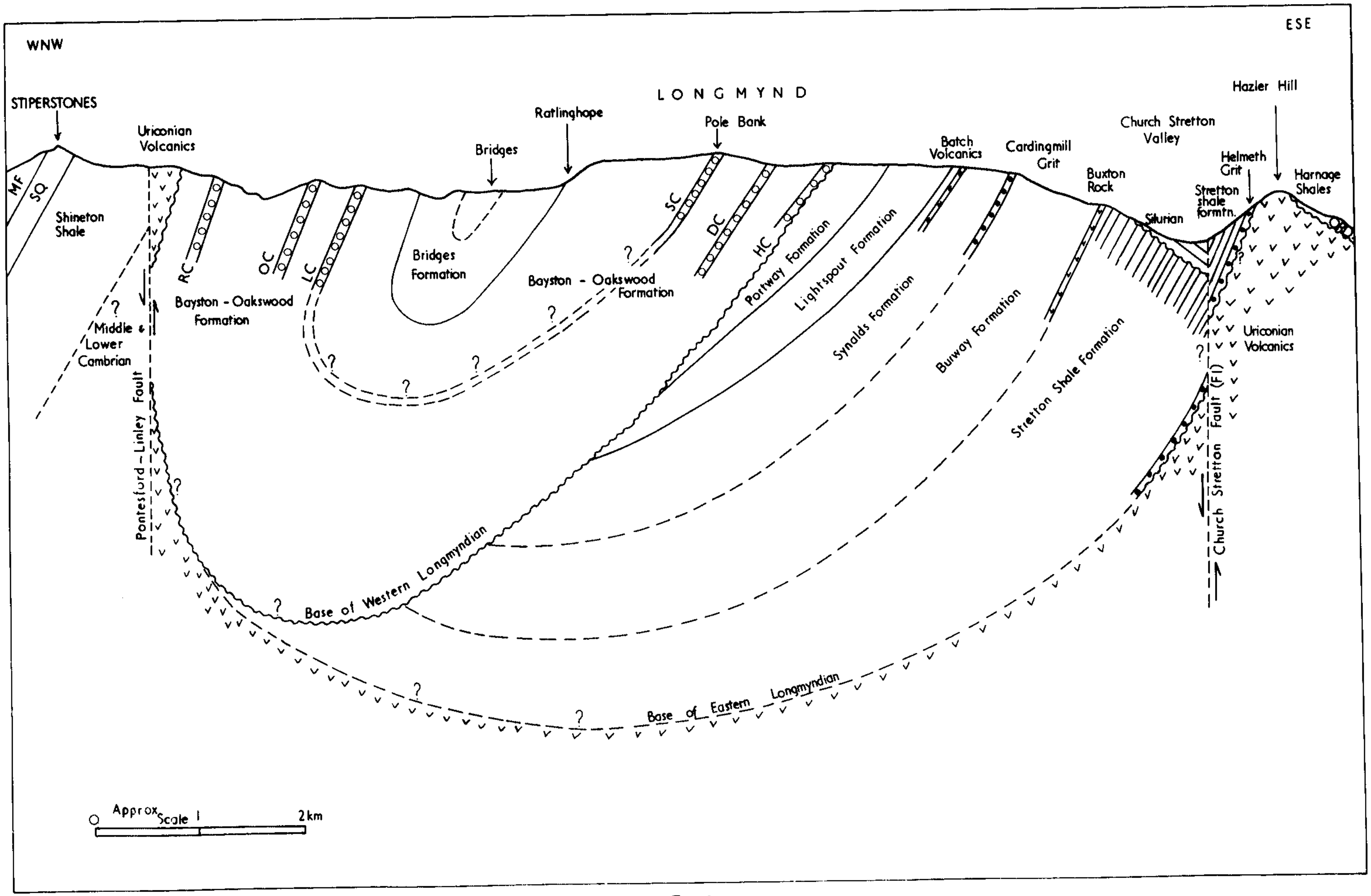

FIG. 6.

Diagrammatic cross section from the Stiperstones to Church Stretton to show the Longmynd fold structure and associated faults. Thickness of beds not to scale. MF, Mytton Flags; SQ, Stiperstones Quartzite; RC, Radlith Conglomerate; DC, Darnford Conglomerate; HC, Haughmond Conglomerate; OC, Oakswood Conglomerate; LC, LawnHill Conglomerate; SC, Stanbatch Conglomerate.

The Longmyndian Supergroup

The sediments of the Longmyndian are remarkable in that they comprise up to 8000 m. of very late Precambrian shallow water sediments. The whole sequence was probably deposited in a subsiding shallow water trough between the Church Stretton Fault and the Pontesford-Linley Faults, in a deltaic (near to shoreline) environment (Greig *et al.*, 1968, pp. 74–76). However there is a major unconformity in the middle of the sequence. The sequence is divided into two major groups, the higher Wentnor Group (or Western Longmyndian) (3700 m) and the lower Stretton Group (or Eastern Longmyndian) (4300 m) with a major unconformity between. The detailed sequence is as follows: –

Wentnor Group

Bridges Formation—purple sandstones	600–1300 m
Bayston–Oakswood Formation—purple sandstone with conglomerates	1200–2400 m
UNCONFORMITY	

Stretton Group

Portway Formation—green and purple sandstones	180–1070 m
Lightspout Formation—grey green sandstones and siltstones	520– 820 m
Synalds Formation—purple shales and sandstones	480– 850 m
Batch volcanics (tuffs) at top	
Burway Formation—greenish grey and sandstones and shales, Cardingmill Grit at top and Buxton Rock at base	600 m
Stretton-Shale Formation—greenish grey shales with Helmeth Grit at base	? 960 m

The exact relationship between the Stretton Shales and the Uriconian Volcanics is uncertain but is likely to be an unconformity. The Helmeth Grits (about 30 m thick) pass up into the Stretton Shales on the east side of the Church Stretton Fault. The relationship of this outcrop with the main outcrop to the west of the fault is not known, and no marker horizons allow correlation in the steeply dipping sequence, thus the thickness of the Stretton Shale is questionable. The absence of sedimentary structures in this sequence of thinly laminated shales suggests it may be of deep water origin. Immediately above the Stretton Shales is a thin fine grained volcanic ash, the Buxton Rock. The remainder of the Stretton Group contains numerous sedimentary structures (ripple marks, rain pits, etc.) indicating very shallow, often intertidal conditions, and a volcanic horizon, the Batch Volcanics, indicates a short period of subaerial volcanic outbursts in the Synalds Formation.

The Wentnor Group lies with a marked unconformity on the Stretton Group, and indeed in the west the whole of the Stretton Group is cut out and the Wentnor Group rests unconformably on the Uriconian (with an inverted contact). The Wentnor Group is coarser than the Stretton Group, is predominently purple, and contains a number of conglomerate bands which can be matched on either side of the axis of the overturned syncline which the Longmyndian was folded into at the end of the Precambrian. The overturning of the syncline to the SE (James, 1956) has resulted in nearly all the Longmyndian rocks dipping steeply NW. The formation of the Uriconian, Longmyndian, and the syncline can be explained as shown in Fig. 5.

The Longmyndian rocks form the main mass of the Longmynd itself, and areas to the west between the Longmynd and the Stiperstones, where the conglomerates in the Wentnor Group form conspicuous hills. A narrow outcrop of both Wentnor and Stretton Groups continues northward (Fig. 1) to form Lyth Hill and, north of the River Severn, Haughmond Hill. South of the Longmynd, along the Church Stretton Fault there are outcrops of both Wentnor and Stretton Groups, but mainly the former, in faulted terrain as far south as Hopesay Hill.

No fossils have been found (so far) in the Longmyndian rocks or the Uriconian Volcanics, although volcanics in South Wales and Charnwood Forest have yielded late Precambrian fossils. Perhaps some of the tuffs in the Uriconian sequence will eventually yield fossils.

THE AGE OF THE SHROPSHIRE PRECAMBRIAN ROCKS

Dunning (1975) gives a summary of all of the evidence on the exact age of the rocks, none of which is conclusive, except that all are considered late Precambrian. The Rushton Schists are probably older than the Primrose Hill Gneisses and Schists and if the latter are equivalent to the Malvernian, then both groups are younger than 1400 million years (Myr) but older than the Uriconian Volcanics which are suggested as being around 700 Myr old but could be as young as 620 Myr. The Longmyndian could be between 600 and 580 Myr, which would allow time for a very late episode of Precambrian folding. Bath (1974) determined a maximum depositional age of 590 Myr for the Longmyndian, based on Sr initial ratios of shales. Other evidence suggests the Longmyndian may be as old as 950–900 Myr and the Uriconian 1000–950 Myr.

More recent work (Patchett *et al.*, 1980; Naeser, Toghill and Ross, 1982) has produced "Cambrian" dates for the Uriconian Volcanics and the Longmyndian. A Rb–Sr date of 558 ± 16 Myr for the Uriconian Volcanics (Patchett *et al.*, 1980 p. 651), and a slightly later date of 533 ± 13 Myr for the intrusive Ercall granophyre (*ibid* p. 651) is of great interest, since both are overlain demonstrably by the Lower Cambrian Wrekin Quartzite. Fission track dates of 526 ± 18 Myr and 528 ± 41 Myr (Naeser *et al.*, 1982) from the lowest Longmyndian (if not reset) would fit in with this time scale, and might suggest that the base of the Cambrian should be revised in terms of absolute age and may be around 530 Myr. Conversely the Uriconian Volcanics and Longmyndian could be lowest Cambrian, and the Wrekin Quartzite, could be of middle Lower Cambrian age. The Longmyndian must, of course, have been folded before the deposition of the Wrekin Quartzite.

III THE CAMBRIAN PERIOD

Rocks of the Cambrian period (570–510 m years ago) are well known from Shropshire, and in fact the sequence is of international importance since it contains, in the Lower Comley Limestones, a sequence of trilobite faunas which is used to define the Comley Series (Cowie *et al.*, 1972), a term used now in Britain in place of the old term "Lower Cambrian".

The sequence at Comley also yielded the very first British olenellid trilobites, collected by Callaway and described by Lapworth in 1888 as *Olenellus callavei.** This discovery proved Lower Cambrian rocks for the first time in Britain. Although Shropshire is well known for its Cambrian fossils they are difficult to find, except in the Shineton shales, but the painstaking efforts of Callaway, Lapworth, and particularly Cobbold, have established a large and varied sequence.

For the purpose of this paper the Tremadoc Series is included in the Cambrian and the full Cambrian sequence is as follows over leaf: —

*Now known as *Callavia (Olenellus) callavei.*

Tremadoc Series (Upper Cambrian)	Shineton Shales	900 m
Merioneth Series (Upper Cambrian)	Black Shales	5 m
	Grey (*Orusia*) Shales	20 m
non-sequence		
St. David's Series (Middle Cambrian)	Upper Comley Sandstone	180 m
unconformity		
Comley Series (Lower Cambrian)	Lower Comley Limestones	1.8 m
	Lower Comley Sandstone	150 m
	Wrekin Quartzite	50 m

Cambrian Palaeogeography and Tectonics

In the Cambrian, Shropshire (Fig.4) lay on the "south" side of the still widening Iapetus Ocean which separated southern Britain from Scotland during the whole of the Lower Palaeozoic. However, during the late Cambrian (Tremadoc) the Iapetus Ocean probably started to close with the initiation of a subduction zone on its "north west" margin. In many places along the Church Stretton Fault System, the Wrekin Quartzite is seen resting unconformably on the Uriconian Volcanics (or the Rushton Schists) but nowhere is it seen resting on the Longmyndian. The Wrekin Quartzite is a shallow water deposit, often conglomeratic, and with ripple marks, which suggests that, after folding and uplift of the Longmyndian and Uriconian, a shallow water marine transgression affected the area (and presumably most of the Midlands since Lower Cambrian quartzites occur in other areas as well—Malverns, Lickey Hills and Nuneaton). In Shropshire the sequence is (apart from the Tremadoc) a thin shallow-water marine one with a number of minor unconformities and non-sequences in the Comley Series and St. David's Series (Lower and Middle Cambrian), whilst a great deal of the Merioneth Series (Upper Cambrian) is missing—the whole of the Maentwrog and Ffestiniog Stages. Most of the Tremadoc Series seems to be present and the much thicker Shineton Shales represent a deeper water sequence. Thus the very thin pre-Tremadoc Cambrian sequence in Shropshire (only 400 m) contrasts with the sequence in North Wales where 3500 m of coarse grits and greywackes occur in the deeper basin area to the west.

No volcanic or igneous rocks of Cambrian age occur in Shropshire. The well known intrusion of camptonite (syenite) at Maddocks Hill near the Wrekin, intruded as a sill into vertical Shineton Shales, is of late Ordovician age. The absence of igneous activity is due to the fact that during most of the Cambrian the Iapetus Ocean was widening (with Shropshire on its southern shoreline) with little or no tectonic activity in the shoreline areas (as is the situation in the present widening Atlantic Ocean). However there were minor earth movements and fluctuations in sea level in Shropshire, probably associated with the Church Stretton Fault, giving rise to the breaks in the sequence.

Outcrops of Cambrian rocks

Cambrian rocks occur (Fig. 1) in close association with the Uriconian Volcanics along the lines of the Church Stretton Fault System and the Pontesford–Linley Fault. The Wrekin area (Figs. 1 and 7) provides an excellent section through most of the sequence, although the Upper Comley Sandstone is faulted out east of the Wrekin Fault. The Wrekin quartzite is at its thickest in this area and rests with a marked unconformity on the Uriconian Volcanics. Wrekin quartzite conglomerates contain pebbles of the Uriconian Volcanics.

The most northerly outcrop of Cambrian rocks in the county is a small inlier at Lilleshall Hill where Lower Comley Sandstone is faulted against Uriconian Volcanics. Southwest of the Wrekin the Shineton Shales occupy a large area centred about Cressage and Sheinton, north and south of the River Severn.

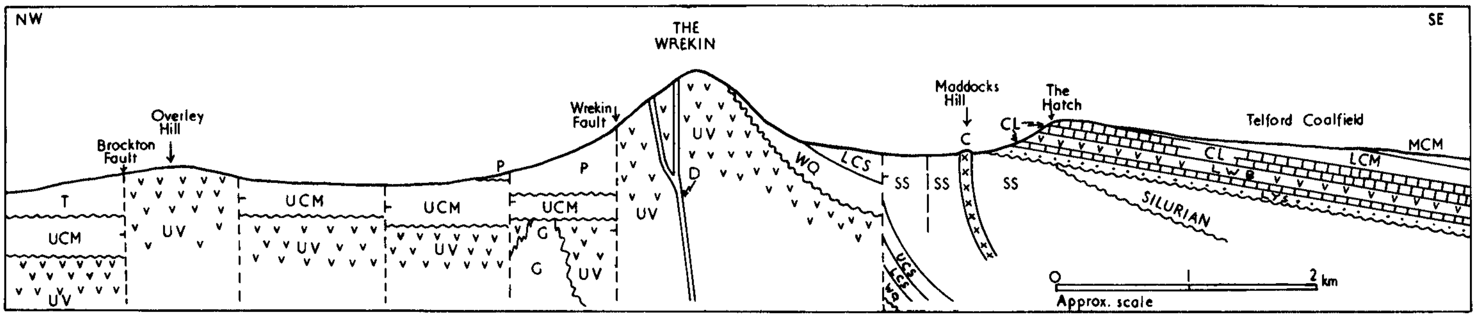

FIG. 7.

Diagrammatic cross section across the Wrekin area. Thickness of beds not to scale. P, Permian (Bridgnorth/Lower Mottled Sandstone); UCM, Upper Coal Measures; UV, Uriconian Volcanics; G, Granite, proved in I.G.S. Wrekin Buildings Borehole (Telford 1:25000 Sheet); D, Dolerite, WQ, Wrekin Quartzite; LCS, Lower Comley Sandstone, UCS, Upper Comley Sandstone; SS, Shineton Shales; C, Camptonite; LYS, Lydebrook Sandstone; LWB, Little Wenlock Basalt; CL, Carboniferous Limestone; LCM, Lower Coal Measures; MCM, Middle Coal Measures.

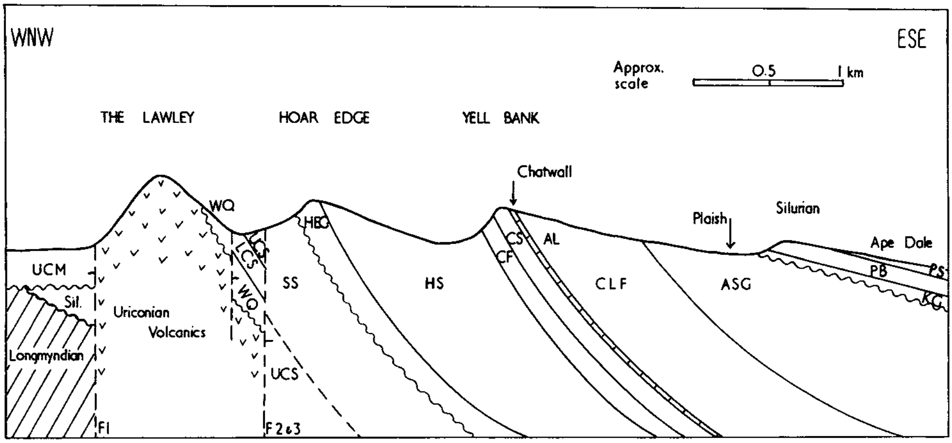

FIG. 8.
Diagrammatic cross section from the Lawley to Ape Dale. Thickness of Beds not to scale. UCM, Upper Coal Measures; WQ, Wrekin Quartzite; LCS, Lower Comley Sandstone; UCS, Upper Comley Sandstone; SS, Shineton Shales; HEG, Hoar Edge Grit; HS, Harnage Shales; CF, Chatwall Flags; CS, Chatwall Sandstone; AL, *alternata* Limestone; CLF, Cheney Longville Flags; ASG, Acton Scott Group; KG, Kenley Grit; PB, *Pentamerus* Beds; PS, Purple Shale; F1, F2, F3 branches of Church Stretton Fault.

Further southwest along the Church Stretton Fault, the Lawley (Fig. 8) is flanked on the east by an apparently "complete" Cambrian sequence, though poorly exposed, and a similar situation occurs on the east side of Caer Caradoc where the outcrops, including the Comley area, are much faulted (Fig. 9). Comley quarry shows the only natural exposures in the Comley Limestones. This locality, now a geological reserve, shows a complete sequence in these unique, only 1.8 m thick rocks, containing amongst others, the trilobite *Callavia (Olenellus) callavei.* Cobbold found other exposures by digging trenches in the surrounding Comley and Cwms areas. East of the Cardington Hills around Hill End (Figs. 1 and 9) a "complete" Cambrian sequence has been mapped by the Geological Survey, but only the Wrekin Quartzite and the Shineton Shales are exposed, the former resting unconformably on a Precambrian intrusion of quartz porphyry in the Uriconian Volcanics.

There are no exposures of Cambrian rocks south of Church Stretton but east of the Longmynd an important outcrop of Shineton Shales occurs (Fig. 1). This long narrow outcrop is faulted to the east against Longmyndian and Uriconian rocks by the Pontesford–Linley Fault, and to the west is overlain (unconformably ?) by the Arenig Stiperstones Quartzite at the base of the Ordovician, and so in this area there is little or no break between the Cambrian and the Ordovician. As there are no older Cambrian Strata west of the Church Stretton and Pontesford–Linley Faults, it is not known what effect the faults had on early Cambrian sedimentation in this area. They certainly didn't affect the deposition of the Shineton Shales which appear similar on both sides of the faults.

IV THE ORDOVICIAN

A great variety of igneous and sedimentary rocks of the Ordovician period (510–445 million years ago) occur in Shropshire (Fig. 1) and have been made famous by the studies of Lapworth, Watts, Whittard, Dean and many others. The sedimentary rocks contain abundant fossils of both the shelly and graptolitic facies, and late Ordovician mineralization resulted in the formation of lead, zinc, copper and barium minerals (in certain areas) which have been

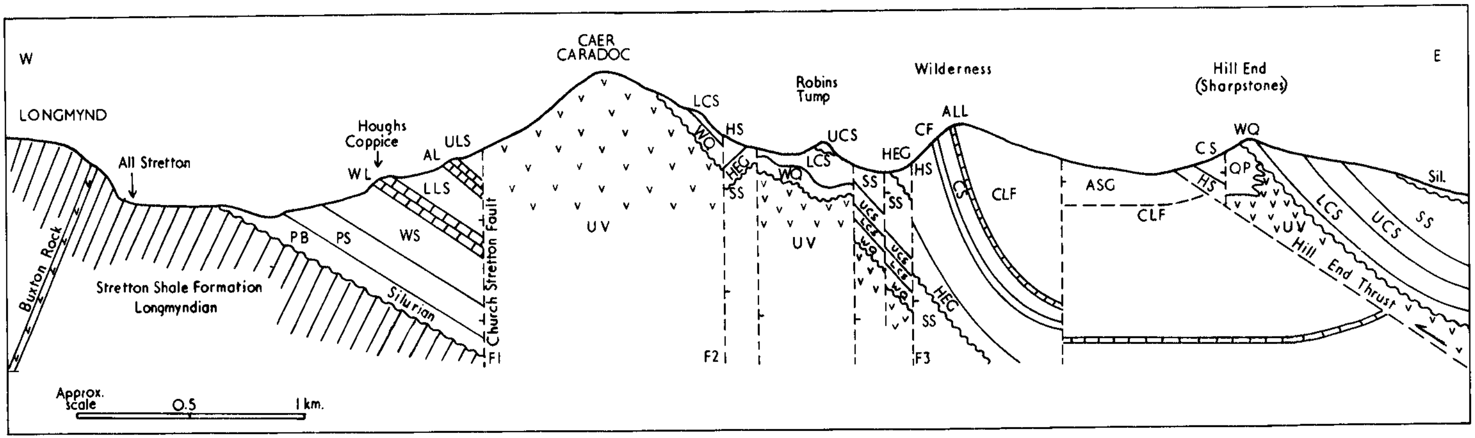

FIG. 9.

Diagrammatic cross section from the Longmynd, across Caer Caradoc, to Hill End. Thickness of beds not to scale. PB, *Pentamerus* Beds; PS, Purple Shale; WS, Wenlock Shale; WL, Wenlock Limestone; LLS, Lower Ludlow Shale; AL, Aymestry Limestone; ULS, Upper Ludlow Shale; UV, Uriconian Volcanics, WQ, Wrekin Quartzite; LCS, Lower Comley Sandstone; UCS, Upper Comley Sandstone; SS, Shineton Shales; HEG Hoar Edge Grit; HS, Harnage Shales; CF, Chatwall Flags; CS, Chatwall Sandstone; ALL, *alternata* Limestone; CLF, Cheney Longville Flags; ASG, Acton Scott Group; QP, Quartz Porphyry in UV. F1, F2, F3, branches of Church Stretton Fault. This figure clearly shows that the Church Stretton valley is not a rift valley (cf. Dineley, 1960, Fig. 5), since the main fault (F1) simply downthrows Silurian rocks to the west where they rest unconformably on Longmyndian rocks in the floor of the valley.

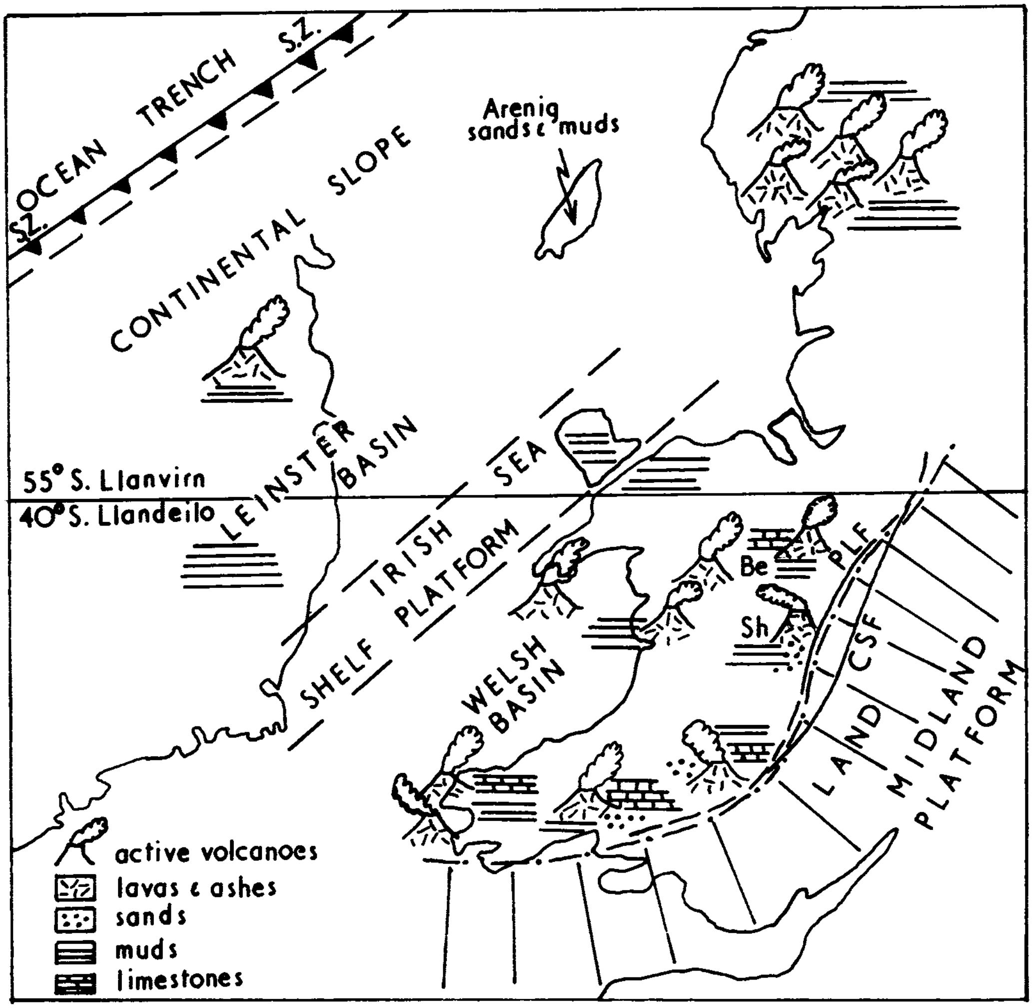

FIG. 10.
Lower Ordovician (Llanvirn–Llandeilo) palaeogeography of Southern Britain. Palaeolatitudes based on Cocks and Fortey (1982). PLF, Pontesford–Linley Fault; CSF, Church Stretton Fault; Be, Berwyns; Sh, Shelve area; S.Z., Subduction Zone.

exploited since Roman times, but more particularly in the nineteenth and early twentieth century.

Ordovician Palaeogeography and Tectonics

The county is well known for showing the classic facies changes east and west of the Church Stretton Fault System (Caradoc and Shelve areas), although it is the Pontesford–Linley Fault across which the change really takes place. Igneous rocks occur only in the west, and these reflect the position of Shropshire (in plate tectonics terms) during the Ordovician. The county lay on the southern margin of the Iapetus Ocean which continued to close slowly during the Ordovician. A subduction zone to the north west of the Lake District (Figs 10 & 11) caused volcanic activity, often of the island arc type. Vast thicknesses of lavas and ashes were extruded, both submarine and subaerial, in the Lake District and Snowdonia. In west Shropshire, the volcanics are much thinner. Both the Llanvirn volcanics (Stapeley Volcanics)

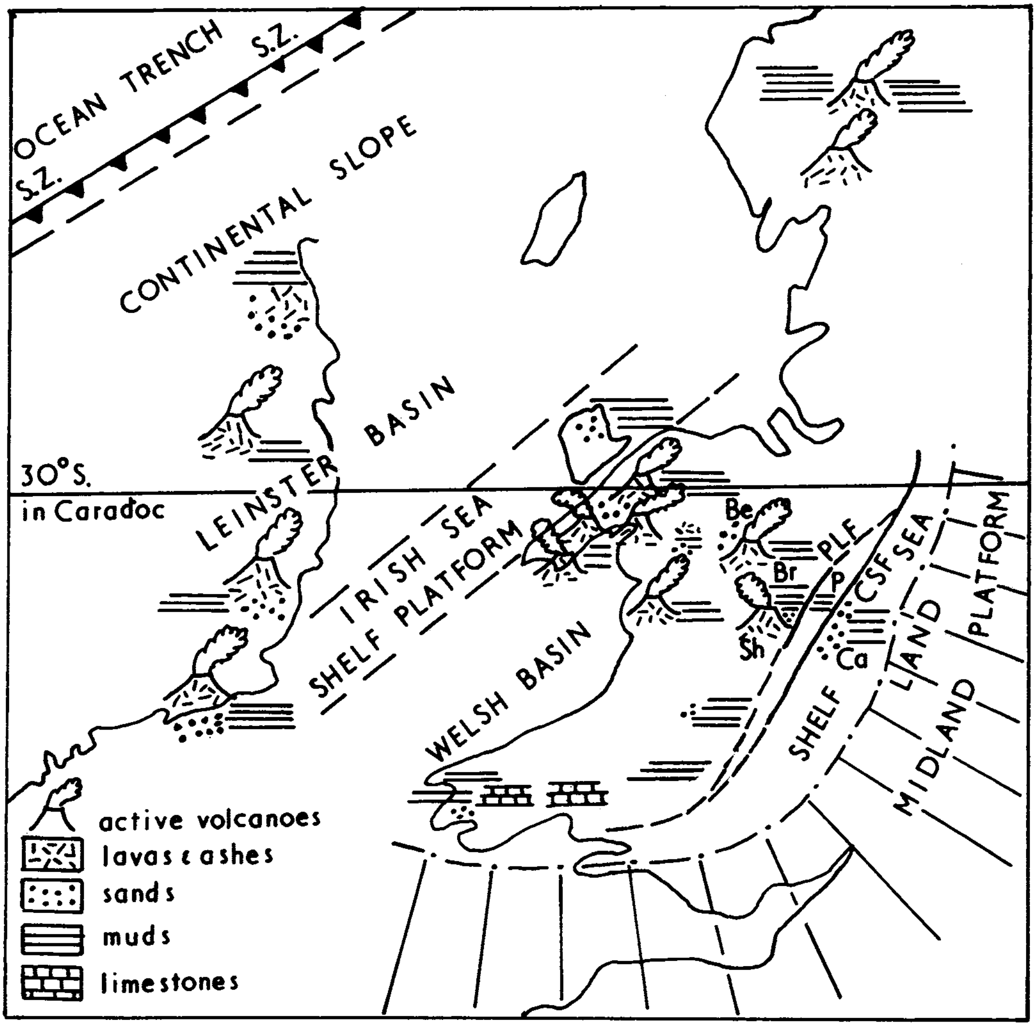

FIG. 11.
Upper Ordovician (Caradoc) palaeogeography of Southern Britain. PLF, Pontesford–Linley Fault; CSF, Church Stretton Fault; Ca, Caradoc area; Sh, Shelve area; Br, Breiddens; Be, Berwyns; P, Pontesford; S.Z., Subduction Zone.

and the later Caradoc volcanics (Whittery Volcanics, etc.) probably came from local volcanoes situated in, or close to, the Shelve area (Figs. 10 & 11). Intermediate and basic intrusions occur as a later stage associated with the Taconian orogeny which folded the Ordovician rocks at the end of the period and also resulted in widespread mineralization of the Shelve area.

At the end of the Tremadoc, the sea must have retreated to the north west since the basal Ordovician beds in the Shelve area are shallow water sandstones, the Stiperstones Quartzite. The main sequence in the Shelve area (and probably other western areas as well) represents deeper water with a mixed shelly and graptolite fauna plus volcanics. The sequence here is complete from the Arenig up into the middle Caradoc Series (No Ashgill Series rocks occur in Shropshire except west of Oswestry, since this was presumably the time of the Taconian orogeny). The main transgression of the sea eastward across the Pontesford–Linley Fault did not occur until the beginning of the Caradoc (Fig. 11) since there are no older Ordovician

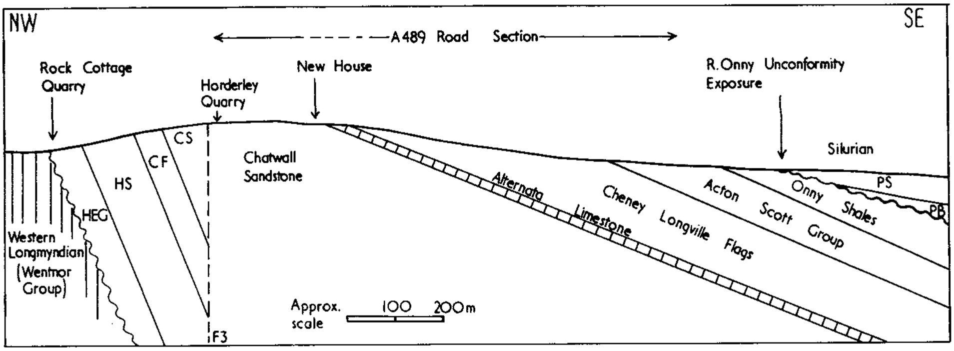

FIG. 12.
Diagrammatic cross section through the Ordovician rocks (Caradoc Series) along the Onny Valley. Thickness of beds not to scale. HEG, Hoar Edge Grit; HS, Harnage Shales; CF, Chatwell Flags; CS, Chatwell Sandstone; PB, *Pentamerus* Beds; PS, Purple Shale; F3, branch of Church Stretton Fault.

rocks in the type Caradoc area, or at Pontesford, and in these eastern areas the Caradoc rocks rest with a marked unconformity on Precambrian or Cambrian sediments (Fig. 8 & 12). The sequence in the east is entirely shallow water with an abundant shelly fauna, and this area is of course the classic type area for the Caradoc Series. The lack of abundant limestones and the affinities of the trilobites and brachiopods suggest a cold water environment. A late Ordovician glaciation is now recognised in various parts of the world, suggesting world wide cooling, since Shropshire was not in particularly low latitudes (Fig. 11).

Outcrops of Ordovician rocks

There are five main outcrops in the county (Fig. 1): 1) the type Caradoc area east of the Pontesford–Linley and Church Stretton Faults, 2) the Shelve area, west of the Faults, 3) the Pontesford area east of the Pontesford–Linley Fault, 4) the Breidden Hills (partly in Powys), and 5) the area west of Oswestry where sedimentary rocks of the Berwyn Dome extend into west Shropshire.

The type Caradoc Area

A large outcrop of Ordovician rocks entirely of Caradoc age occurs east of the Pontesford–Linley Fault, and within, and to the east of, the Church Stretton Fault System (Figs 1 and 2). The outcrop extends from Harnage in the north, southwards passing east of Caer Caradoc and the Stretton Hills, and across the Onny Valley. In fact the outcrop is split into two by the Precambrian volcanic area around Cardington Hill. In this large area the generalised sequence is as follows: –

	Onny Shales	0–120 m
	Acton Scott Group	60–180 m
Caradoc Series	Cheney Longville Flags	80–240 m
	alternata Limestone	0– 20 m
	Chatwall Sandstone	40–160 m
	Chatwall Flags	30–100 m
	Harnage Shales	100–300 m
	Hoar Edge Grit	0–120 m

There are marked variations in thickness along the outcrop and in particular the Onny Shales are only present south of Church Stretton. The Hoar Edge Grit rests with a marked unconformity on older rocks ranging in age from Precambrian (Longmyndian) in the Onny Valley (Fig. 12), to Cambrian Shales at Hoar Edge itself (Fig. 8). Around Hope Bowdler (Fig. 13), the Hoar Edge Grit is missing and the Harnage Shales rest directly on Uriconian Volcanics with a marked unconformity. Neptunian dykes in this area show the gradual transgression of the Caradoc sea over a deeply eroded landscape of Precambrian rocks, all the Cambrian having been stripped off.

Most of the Caradoc sequence is one of shallow water sandstones, shales, flags and thin limestones with a rich shelly fauna which has been well documented (Dean, 1958). Some horizons in the Harnage Shales and Chatwall Sandstone contain graptolites, and beds such as the *alternata* Limestone are literally fossil shell banks of brachiopods. Igneous rocks are only known from one locality in the south where a thin basalt lava occurs in the Harnage Shales (Grieg *et al.*, 1968, pages 108 and 121).

Tectonics within the Caradoc area

The rocks of the Caradoc area are folded and faulted (Figs. 8, 9, 12 & 13). The folding is seen as a gentle dip to the south east which increases to near vertical around the Church Stretton Fault System. As Ashgill rocks are absent from the area and the succeeding Llandovery rocks (Lower Silurian) are unconformable with a marked overstep across the Ordovician, it would appear that the folding and faulting is late Ordovician (Taconian) in age, as in the west. Movements along the Church Stretton Fault System probably caused the folding and faulting. Earlier vertical movement, as well as along the Pontesford–Linley Fault, probably ensured that the area remained land in early Ordovician times. Post Caradoc movements were mostly vertical but in the complex and faulted ground around Caer Caradoc and the Cardington Hills a number of thrusts are post Caradoc in age (e.g. the Sharpstones Thrust) and are probably late Ordovician.

It is worth noting here that the Church Stretton Fault System is really a number of subparallel faults (the 3 main faults have been numbered F1, F2 and F3 by Cobbold and the Geological Survey (Fig. 9). Movement along the fault system affected rocks ranging in age from Precambrian to Triassic. Dating the age of a particular movement is difficult. However, it must be stressed that the Church Stretton Valley is not a rift valley (cf. Dineley, 1960, Fig. 5). It can be clearly seen from Fig. 9 (which closely follows the direction of Dineley's Fig. 5) that the main Church Stretton Fault (F1) simply downfaults Silurian rocks to the west where they rest unconformably on Longmyndian rocks in the floor of the Church Stretton Valley. The vertical displacement here on the main fault (F1) is about 1100 m to the west.

The Shelve Area

This classic area has been made famous by the work of Lapworth, Watts, Whittard and Dean. A complete sequence of Ordovician rocks occurs from the base of the Arenig into the middle of the Caradoc Series (Soudleyan Stage). The highest beds exposed, the Whittery Shales, probably equate with the top of the Harnage Shales of the Caradoc area (Dean, 1958; Whittard, 1979), and there are thus no beds in the Shelve area equivalent to the higher beds of the Caradoc area, although they could be underneath the Silurian of the Long Mountain area, or under the drift of the Marton valley. Conversely, the Shelve area has beds of Arenig, Llanvirn and Llandeilo Series age, during which time the Caradoc area to the east was a land mass.

The sequence of rocks is extremely varied and comprises 4500 m of shallow water sandstones, deeper water dark shales, siltstones, some limestones and a great variety of volcanic (extrusive) rocks, mainly ashes (tuffs). There is a large suite of andesitic and basic intrusions

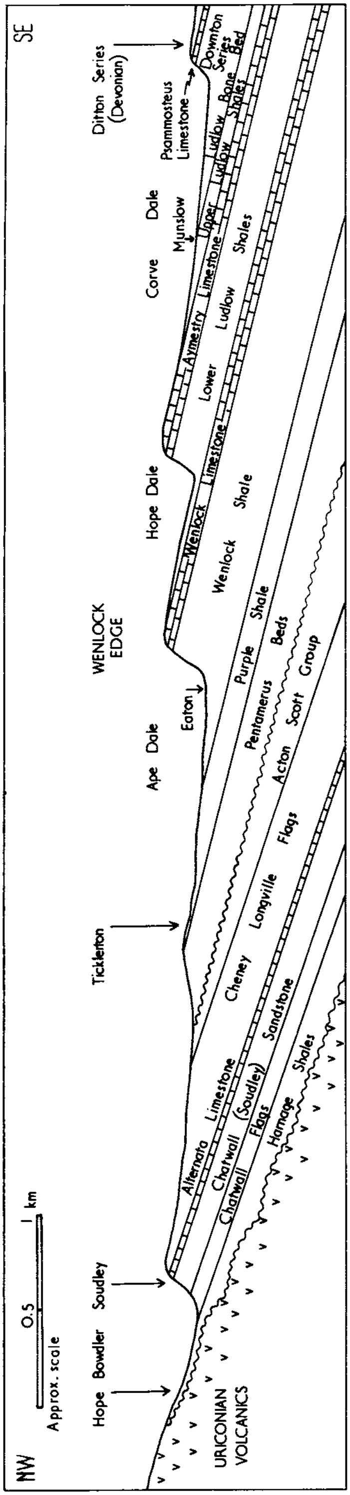

FIG. 13.

Diagrammatic cross section from Hope Bowdler to Corve Dale showing the scarp and vale landscape within the Ordovician and Silurian rocks, including Wenlock Edge. Thickness of beds not to scale.

of late Ordovician (Taconian) age, and much mineralisation, which also affects the neighbouring Longmyndian. The fauna is mixed shelly and graptolitic, some beds being mainly shelly, e.g. the Meadowtown Beds, and others mainly graptolitic, e.g. the Betton Beds, although both faunal facies can often be found in the various formations.

Whittard, compiled by Dean (1979) has provided a comprehensive account of the stratigraphy, including a new detailed map of the area. The rock units are given correct modern nomenclature, e.g. Betton Member, Stiperstones Member etc., but for this account parts of the previous classification of Whittard (1952) and Dean (1958) will be used since the member names are essentially the same and more descriptive of lithology—Stiperstones Quartzite means more to the reader than Stiperstones Member.

The complete sequence of rocks is as follows, after Whittard, compiled by Dean (1979).

Caradoc Series	Chirbury Formation	Whittery Shales	305 m+
		Whittery Volcanics	90 m
		Hagley Shales	305 m
		Hagley Volcanics	107 m
		Aldress Shales	305 m
		Spy Wood Grit	90 m
Llandeilo Series	Middleton Formation	Rorrington Shales	305 m
		Meadowtown Beds	400 m
		Betton Beds	180 m
		Weston Beds	?430 m
Llanvirn Series	Shelve Formation	Stapeley Shales	?240 m
		Stapeley Volcanics	?430 m
		Hope Shales	240 m
		Mytton Flags	910 m
Arenig Series		Stiperstones Quartzite	120 m

The Stiperstones Quartzite is a shallow water quartz sandstone now metamorphosed into a quartzite. In contains conglomerates and thin shales and lies with a slight unconformity on the Tremadoc Shineton Shales. The actual junction is quite sharp, and, as there is no discordance in dip, the junction may be a disconformity as part of the Shineton Shales faunal sequence is missing. The main mass of quartzite forms the spectacular craggy ridge of the Stiperstones with its obvious frost-shattered tors. The succeeding Mytton Flags are the thickest unit, 900 m of blue grey flaggy siltstones which pass up into the finer grained Hope Shales. Here the first volcanic ashes appear (termed "chinastones" around Hope) and these ashes become the dominant lithology in the succeeding Stapeley Volcanics comprising massive waterlain andestic tuffs, with some lavas, and interbedded shales, possibly erupted from shallow submarine vents as the Iapetus Ocean closed (Fig. 10). The overlying Stapeley Shales pass up into coarser beds which contain sandstones, shales and tuffs. The Betton Beds are blue-grey shales and flags and grade up into the Meadowtown Beds of Llandeilo age which comprise limestones, flags and tuffs, with a rich shelly fauna. The overlying Rorrington Shales show a return to more graptolitic black shales, whereas the succeeding Spy Wood Grit (sandstone and shale) contains a shelly fauna which allows correlation with the Hoar Edge Grit of the Caradoc area. The remainder of the succession (listed above) comprises alternations of shales and ashes. The Whittery Volcanics contain some very coarse agglomerates that led Whittard

(1979) to suggest that these perhaps represented a vent for the Shelve volcanic sequences of Caradoc age (Fig. 11).

Tectonics of the Shelve Area

In late Ordovician time the Taconian orogeny folded the area into a structure comprising two major NNE–SSW folds—the Ritton Castle Syncline and the Shelve anticline (Fig. 14). Apart from these major folds the whole area is affected by considerable faulting, particularly tear faults which have offset the outcrops for considerable distances. None of these faults cut the Pontesford–Linley Fault, which is clearly of a different type and separates the Shelve area from the Ordovician outcrop at Pontesford, and has close affinities with the type Caradoc area succession. The fault could have acted as a strike-slip fault in which the movement was essentially horizontal, but vertical movement along it must have occurred to keep the eastern areas as a land mass in the early Ordovician.

Intrusive Igneous rocks

The Shelve area has a number of both large and small intrusive masses of dolerite and andesite, although it would appear that some of the so-called andesite intrusions contain coarse ashes and possible lavas. The area has numerous dolerite dykes and larger bodies such as the gabbro of Squilver (Disgwylfa), but the most well known intrusion is the phacolith of Corndon Hill, a mass of dolerite intruded into the pre-existing arch of the Shelve anticline in the Hope Shales. Associated with the Corndon dolerite is the ultrabasic picrite of Cwm Mawr, famed for its stone-axes. South west of Corndon Hill the hills of Todleth, Roundton and Lan Fawr are large masses of andesite, previously mapped as intrusions, but which also contain coarse ashes and possible lavas.

Mineralisation of the Shelve Area

Late Ordovician mineralisation, presumably the last phase of igneous occurrences in the area, affects the Shelve area and has given rise to the well known occurrences of lead-zinc and barytes in the area. The veins occur in two main areas 1) the outcrop of the Mytton Flags in the east, and in the Shelve anticline 2) the harder volcanics and sandstones in the west. Most of the soft beds without major joints such as the Hope Shales, are devoid of minerals. In the west mineralisation is entirely barytes whereas in the Mytton Flags it is mainly lead-zinc (galena-sphalerite) with barytes at shallow levels only. The mineralisation also affects large areas of the adjacent Western Longmyndian where barytes is the main mineral with some copper. Most of the veins in the Shelve area follow major faults or joints, particularly in the Mytton Flags, and it is worth noting that few veins, if any, penetrate the Stiperstones Quartzite.

The Pontesford area

1.2 km east of the northern end of the Shelve area lies the small isolated outcrop of the Pontesford Shales on the north east side of the Earl's and Pontesford Hills. Here, just to the east of the main Pontesford–Linley Fault, Dean and Dineley (1961) described a basal conglomerate resting on Uriconian Volcanics. This is followed by 50 m of shales and mudstones with a graptolite and shelly fauna which compares directly with the Harnage Shales of the Caradoc area, as does the lithology. Because of this similarity between the rocks and the fauna the area is quite clearly part of the Caradoc area sequence and cannot be compared with the much closer Shelve sequence. Thus the importance of the Pontesford–Linley Fault in marking the change between the two faunal and lithological facies of the Shelve and Caradoc areas is shown, and the change takes place over a remarkably small distance.

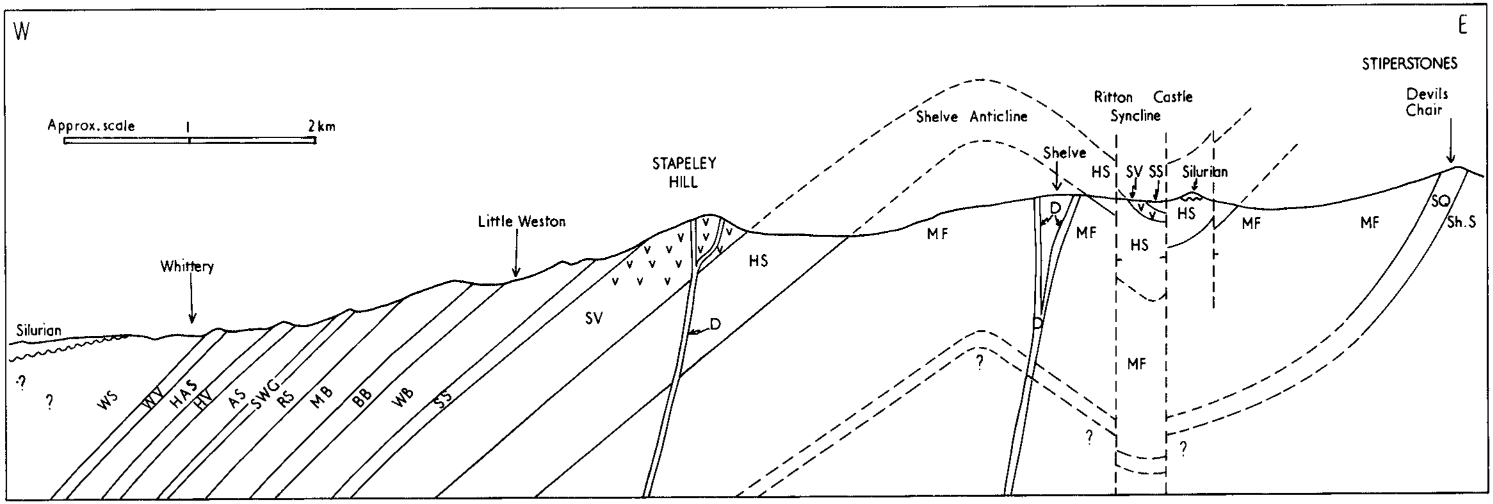

Fig. 14.

Cross section through the Ordovician rocks of the Shelve Area. Thickness of beds not to scale. West of Stapeley Hill the section is diagrammatic. Information from map in Whittard (compiled by Dean) (1979). WS, Whittery Shales; WV, Whittery Volcanics; HAS, Hagley Shales; HV, Hagley Volcanics; AS, Aldress Shales; SWG, Spy Wood Grit; RS, Rorrington Shales; MB, Meadowtown Beds; BB, Betton Beds; WB, Weston Beds; SS, Stapeley Shales; SV, Stapeley Volcanics; HS, Hope Shales; MF, Mytton Flags; SG, Stiperstones Quartzite; ShS, Shineton Shales; D, Dolerite.

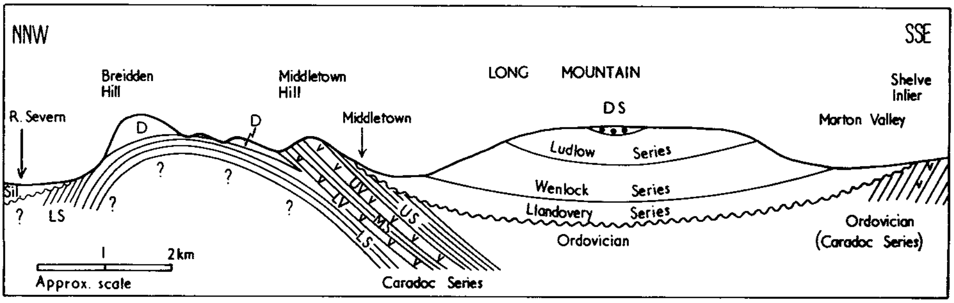

FIG. 15.
Diagrammatic cross section across the Breidden anticline and Long Mountain syncline. Thickness of beds not to scale. Sil, Silurian; LS, Lower Shales; LV, Lower Volcanics; MS, Middle Shales; UV, Upper Volcanics; US, Upper Shales; D, Dolerite; DS, Downton Series.

The Breidden Hills

Although some distance (14 km) NNW of Shelve, the Breidden Hills (Fig. 15) show much similarity with the higher parts of the Shelve sequence and also contain large dolerite and andesite intrusions. The area is separated from Shelve by the syncline of the Long Mountain made up of Silurian rocks but there is no reason why the Shelve sequence should not re-appear to the north as suggested by Dineley (1960, Fig. 2). The succession, all of Caradoc age, is as follows, although Whittard (1979) suggested that there could be duplication of strata due to faulting. The rocks are overlain unconformably by Silurian rocks to the south.

Upper Shales Upper Volcanics Middle Shales Lower Volcanics	570 m
Black Grit	6 m
Lower Shales	240 m

Some of the ashes in the Upper Volcanics are very coarse (bomb rock) and possibly are agglomerates. The sequence is intruded by a mass of andesite on Moel-y-golfa and a dolerite intrusion (in the Lower Shales) similar to that of Corndon Hill forms the steep-sided Breidden Hill. Little modern work has been done on the area but Whittard (1979) suggested that the shelly and graptolite fauna and rock sequence correlated with the Hagley and Whittery shales and volcanics of Shelve. The anticlinal structure is not certain since it only affects the Lower Shales.

The area west of Oswestry

A small part of north west Shropshire (Fig. 1) includes the eastern fringe of the Berwyn Dome where a thick sequence of Ordovician sediments and volcanics passes under Carboniferous Limestone. The axis of the main fold strikes due east under the Carboniferous rocks and the rock sequence is repeated on both limbs of the fold. The succession is as follows, worked out by the Geological Survey

Ashgill Series	Shales
Caradoc Series	Bryn Beds (Shales) Teirw Beds (Slates and sandstones) Cwm Clwyd Ash
Llandeilo Series	Mynydd Tarw Group (Shales and mudstones, ashes at base not seen in Salop)

Thicknesses are difficult to estimate as the whole area is drift-covered but must be 2000 m at least. The sequence contains a number of acid intrusions (keratophyres) said to be in volcanic necks, and agglomerates. The area is part of the deeper-water basin area of Wales and includes the only Ashgill rocks found in Shropshire. Sedimentation in this area must have continued until the end of the Ordovician. There is little break between the Ordovician and Silurian in this area and so the folding of the Berwyn Dome (which includes the Silurian sequence) must be post Silurian—pre Carboniferous, and is probably Caledonian in age. The area is thus tectonically part of Wales and the Taconian orogeny had little effect in this area.

The Effects of the Taconian Orogeny in Shropshire

Apart from the Berwyn area (above) no Ashgill rocks occur in Shropshire, and at the end of Caradoc times the sea was pushed westwards into Wales where a complete marine Ashgill sequence occurs. The Taconian orogeny in Shropshire is thus of Ashgill age. It did not affect the Berwyn Dome where the folding is essentially Caledonian (late Silurian).

However, most of Shropshire was folded and faulted during the Taconian orogeny and became a land mass which was later invaded from the west by the Silurian (Llandovery) sea. This moved slowly eastward laying down horizontal strata on the eroded Ordovician and older rocks.

The main Taconian tectonic events (Fig. 2) are 1) The folding and faulting in the Caradoc area along the Church Stretton Fault System 2) Formation of the Ritton Castle syncline and Shelve anticline and associated faulting in the Shelve area 3) Movement along the Pontesford–Linley Fault which separated the Shelve and Caradoc areas 4) Folding and faulting of the Breidden Hills area 5) Intrusion of intermediate and basic intrusions in the Shelve area and the Breiddens 6) Mineralisation of the Shelve area and western Longmynd.

One other episode of folding could possibly have taken place in the late Ordovician, and that is the folding of the Longmyndian (Figs. 5 and 6), although this is traditionally considered as having occurred in the late Precambrian. The age of the Longmyndian sediments themselves is not entirely certain, and they could possibly represent an exotic Cambrian sequence, although a late Precambrian (Vendian) age does seem the most likely. The only direct evidence for the age of the folding (and the sediments) is that they are pre-Silurian (Llandovery), since all round the southern and eastern flanks of the Longmynd the Llandovery rocks rest with a marked unconformity on the steeply dipping and eroded Longmyndian rocks. Elsewhere the junction between the Longmyndian and strata of the Cambrian and Ordovician age is always faulted. The contact between the Lower Cambrian Wrekin Quartzite and the so-called Western Longmyndian in the Cwms area south east of Caer Caradoc, although said to be an unconformity, is poorly exposed and may be faulted. However, the Wrekin Quartzite does definitely overlie the Uriconian Volcanics with a marked unconformity, and since the latter is followed by the Longmyndian some slight folding immediately after the formation of the Longmyndian must have occurred, although not necessarily the main episode. The main folding could have been late Ordovician and this theory is supported by the parallel nature of the axis of the Longmynd overturned syncline and the folds of the Shelve area (Fig. 2); the strike of the Longmyndian rocks is similar to that of the Shelve area; and the dips are all steep to the north west throughout the Longmynd and eastern Shelve area.

If this is the case it is also possible that the Pontesford–Linley Fault and the Church Stretton Fault, but more particularly the former, acted as tear faults in the late Ordovician. The deep water facies of the Hope Shales suggests the Shelve area may have been further away from the continental shelf in Llanvirn times than is indicated on Fig. 10, and later lateral movement along the Pontesford–Linley Fault could have brought the Shelve area sedimentary sequence into closer proximity with the Pontesford area with its shallow water Caradoc sequence, as well as possibly bringing the Longmyndian sequence into its present structural position between the two faults.

V THE SILURIAN PERIOD

Shropshire provides classic exposures of shallow water shelf deposits from the Silurian period (445–395 million years ago). Murchison laid the foundation for much of his Silurian System on the rock sequence in Shropshire, and such terms as Wenlock and Ludlow Series are now, of course, international terms. Since Murchison, numerous people have studied the area, and since 1960 a great deal of work has been put into the detailed refinement of the Wenlock and Ludlow Series in their type areas by workers such as: Holland, Lawson and Walmsley (1963); Cocks, Holland, Rickards and Strachan (1971); Bassett *et al.* (1975) and many others. The Llandovery transgression was made the basis of a modern detailed study by Ziegler, Cocks and McKerrow (1968).

These modern studies have set up stages in the Llandovery, Wenlock and Ludlow Series, and provided new terms such as Elton Beds in place of parts of the (old term) Lower Ludlow Shales, and Bringewood Beds in place of parts of the Aymestry Limestone, etc. (see chart). However many of these old terms are still useful to the student studying the area, and in this account we shall use them, although the new classification of strata is listed below.

Murchison originally included the non-marine Downton Series in his Silurian System, but later this was included in the Old Red Sandstone and classed as Devonian. However, since 1960 Silurian workers in this country have realised that the change from marine to non-marine facies takes place in Britain at an earlier date compared with the rest of the northern hemisphere, where marine beds continue through into the Devonian with graptolite faunas. Consequently, the base of the Devonian is now taken internationally at a level in the marine graptolite sequence which is probably represented in Britain by non-marine beds at the junction of the Downton and Ditton Series. In Britain we now follow international practice and the Downton Series is now placed at the top of the Silurian. The base of the Devonian is drawn at the base of the Ditton Series, which in Shropshire is represented by the *Psammosteus* Limestone. However, we can still call these non-marine rocks the Old Red Sandstone, as the Geological Survey do on the partly revised Shrewsbury (152) Sheet, but they are of Silurian age. The term Downton Series may be superseded by a more internationally acceptable term from the marine facies areas in the near future.

Silurian Palaeogeography

Over Southern Britain the Silurian period saw the final closure of the Iapetus Ocean. In Shropshire, after the late Ordovician Taconian orogeny, the sea retreated to the west, probably to a north-south line from the Welshpool area to the Berwyns. In these latter areas Ashgill sediments (highest Ordovician) occur and sedimentation continued through into the Silurian without a break. In the early Silurian (middle Llandovery) the sea again transgressed eastwards over Shropshire (Fig. 16) to form shallow water Llandovery deposits over the whole county. These are fairly uniform in composition. Whittard (1932) showed how these early Silurian sediments were formed as the sea lapped around the Longmynd-Shelve area, forming beach deposits around steep shorelines with cliffs and sea-stacks (Fig 17).

The most well-known Silurian rocks in Shropshire belong to the shallow water shelf facies deposited on the Midland Platform east of the Church Stretton Fault System (Fig. 16). However west of the "Fault" the Silurian sequence (apart from the Llandovery) slowly changes

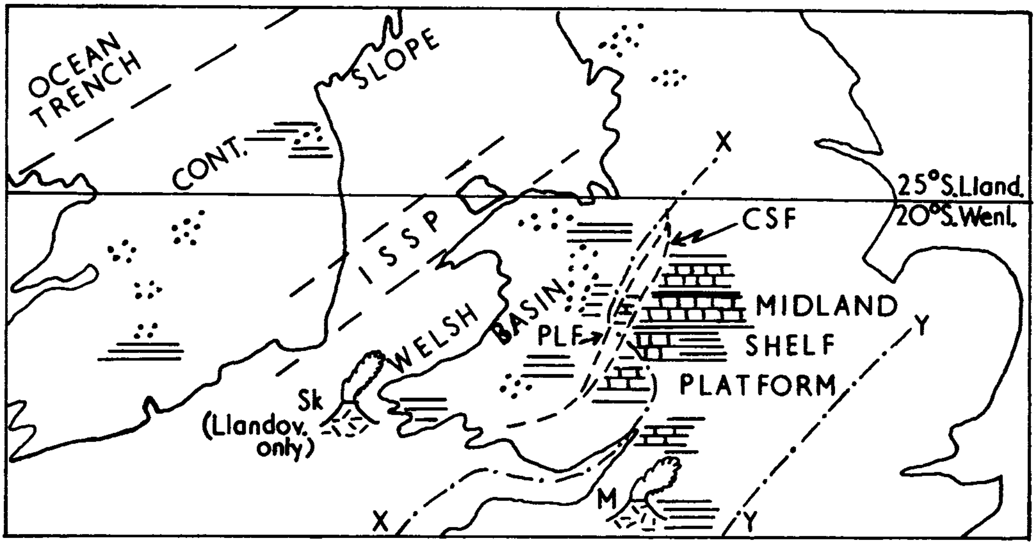

FIG. 16.
Wenlock palaeogeography of Southern Britain. Note the formation of limestones on the Midland Shelf Platform, following its submergence by a transgression of the sea in the late Llandovery. The lines x-x and y-y mark the shoreline around the Midland Platform at the end of the middle Llandovery. M, Mendips; Sk, Skomer Volcanics of Llandovery age; ISSP, Irish Sea Shelf Platform; PLF, Pontesford Linley Fault; CSF, Church Stretton Fault. Other symbols as in Figs. 10 and 11. Palaeolatitudes after Cocks and Fortey (1982). Lland. = Llandovery, Wenl. = Wenlock.

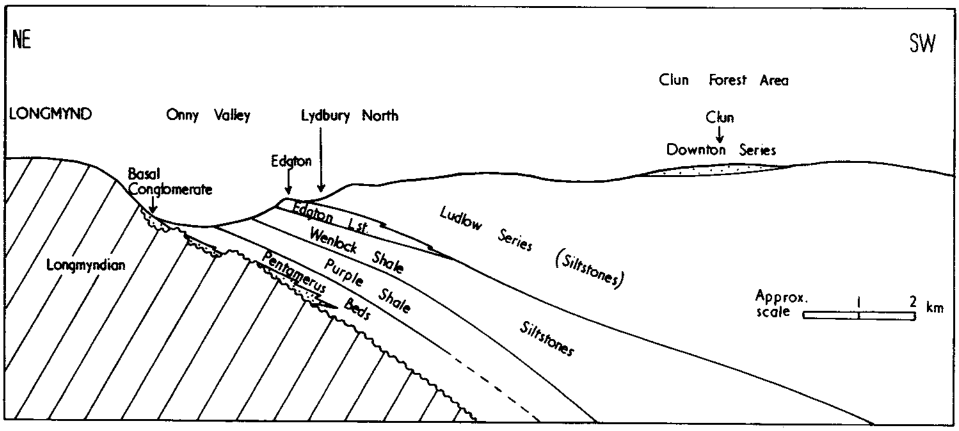

FIG. 17.
Diagrammatic cross section from the Longmynd to Clun Forest to show the change in facies of Silurian sediments. Thickness of beds not to scale.

into a thick basin facies which is further developed in Wales. It is represented in Shropshire by the Clun Forest and Long Mountain areas. The westward change in the Ludlow area shows the proximity of the continental slope to the west. It would appear that the Pontesford–Linley Fault ceased to be an active feature affecting Silurian deposition and the Church Stretton Fault System was the controlling factor. The Downton Series also changes west of the Church Stretton Fault System and it is worth noting that there are no Downton Series rocks north west of the Long Mountain (i.e. in North Wales). This late Silurian time was represented in Wales by the folding of the Caledonian orogeny, the effects of which were not so great in Shropshire (see below).

The generalised sequence of Silurian rocks in the "shelf" area is as follows

Series	Stages / Beds	Stage	Formation	Thickness
Ditton Series (Devonian)			*Psammosteus* Limestone	
"Downton" Series (Old Red Sandstone)	No Stages		Ledbury Group (Marls and cornstones)	150–460 m
			Temeside Shales	25–46 m
			Downton Castle Sandstone	6–15 m
			Ludlow Bone Bed	0–15 m
Ludlow Series	Whitcliffe Beds	Ludfordian Stage	Upper Ludlow Shales	32–125 m
	Leintwardine Beds		Aymestry Limestone	25–65 m
	Bringewood Beds	Gorstian Stage	Lower Ludlow Shales	180–260 m
	Elton Beds			
Wenlock Series	Homerian Stage		Wenlock Limestone (Much Wenlock Limestone)	30–137 m
			Wenlock Shale: Coalbrookdale Formation (including Farley Member)	305 m (Coalbrookdale and Buildwas Formations)
	Sheinwoodian Stage		Wenlock Shale: Buildwas Formation	
Llandovery Series	Telychian Stage		Purple Shale	0–107 m
	Fronian Stage		*Pentamerus* Beds	0–122 m
			Kenley Grit	0–46 m

marked unconformity

Outcrops of Silurian rocks

The main areas of Silurian rocks (Fig. 1) are:-

1) The Main Outcrop: the area east of the Church Stretton Fault System centred around Wenlock Edge where the sequence is generally as above.
2) Areas west of the Church Stretton Fault System around the flanks of the Longmynd and the Shelve Areas.
3) Clun Forest
3) Long Mountain.

The Main Outcrop

This large area stretches from Ironbridge in the north east to Ludlow in the south west, and contains the classic ground around Wenlock Edge and Ludlow. Apart from local variations the thicknesses of strata are as tabled for the shelf area. The succession of scarps and vales (Fig. 13) has been studed by countless students of geology and geography.

The Llandovery rocks rest with a marked unconformity on Ordovician rocks of various ages. The basal Kenley Grit is a conglomeratic sandstone of "upper" Llandovery age (the sea did not reach the area until this time).

Its outcrop is thickest in the north but east of Cardington it is overstepped by the *Pentamerus* Beds and does not occur further south. The *Pentamerus* Beds are calcareous sandstones and shales with abundant brachiopods (hence their name). They too are overstepped in the south, just north of the Onny Valley, by the Purple (Hughley) Shales, which have a continuous outcrop from north of Ironbridge to south of the Onny Valley, where they are overstepped by the Wenlock Shale. The Llandovery rocks are all shallow-water deposits indicating the slow transgression of the sea from the west, in particular by the overstepping of one formation by another as the sea encroached onto the ancient landscape.

However, by the time the Wenlock Shale was being deposited the depth of sea was uniform over the whole of the Main Outcrop area and the outcrop is continuous from Ironbridge to Ludlow. The formation is thickest under Wenlock Edge (Ape Dale) where Bassett *et al.* (1975) have defined two "new" stages in the Wenlock Series (the Sheinwoodian and the Homerian). They have divided the Wenlock Shale into the Buildwas Formation below and the Coalbrookdale Formation above, the latter including the Farley Member (equivalent to the old term "Tickwood Beds"). The succeeding Wenlock Limestone (Much Wenlock Limestone of Bassett *et al.*, 1975) is developed from Lincoln Hill at Ironbridge to (the far south) around Ludlow. The limestone is well known for its coral reef developments which are now considered to be patch reefs (not a barrier reef) which developed in a warm, shallow, clear, subtropical sea as patches surrounded by areas where muddier limestones developed. During Silurian times (Fig. 16), southern Britain lay just south of the equator, steadily drifting north. The reef masses are rich in corals, crinoids, bryozoa and stromatoporoids. They are locally called ballstones but do not occur south west of Easthope, where the limestone becomes thicker with only solitary corals. Presumably, the sea in this area was not clear enough for reef development. However the same reef development appears again around Dudley, 40 km to the east (where they are called Crogballs), so the reef environment presumably covered quite a large area.

The succeeding Lower Ludlow Shales, Aymestry Limestone and Upper Ludlow Shales outcrop as a continuous band from Ironbridge to Ludlow. The twin escarpments of Wenlock Edge and the Aymestry Limestone with Hope Dale in between, are conspicuous and famous features of the Shropshire landscape (Fig. 13), seen and drawn by countless students. The Ludlow Series has been divided into stages (see chart for Main Outcrop) and the same names are used to define the Elton Beds, Bringewood Beds, Leintwardine Beds and Whitcliffe Beds (Holland, Lawson and Walmsley, 1963) which take the place of the older terms, and are now in most modern works. However, the usefulness of the old rock terms (lithostratigraphic units) has been explained above, and in fact they are still used by the Geological Survey. In 1981 these stages were themselves superseded by the terms Gorstian and Ludfordian (Martinsson, Bassett and Holland, 1981).

The Aymestry Limestone has no reef facies, only solitary corals, but in places contains thick shell banks of the brachiopod *Kirkidium knightii*, particularly on View Edge. At the top of the Upper Ludlow Shales (Whitcliffe Beds) there is a change in this area from marine to non-marine facies marked by the disappearance of graptolites and many brachiopods and by the appearance of bivalves and gastropods. The well-known Ludlow Bone Bed (only a few centimetres thick) contains the earliest abundant British vertebrate fossils (fish spines and scales) and then the Silurian sequence is completed by the non-marine sandstones and marls of the Downton Series forming the floor of Corve Dale (Fig. 13). The overlying

Devonian Ditton Series follows conformably (without a break), the base being taken at the base of the *Psammosteus* Limestone.

Areas west of the Church Stretton Fault System around the flanks of the Longmynd and Shelve area

In this area (Fig. 17) the Llandovery sequence is as in the Main Outcrop except that the *Pentamerus* Beds and Purple Shales are somewhat thicker (100 m and 180 m), perhaps indicating slightly deeper water west of the Fault System. The basal grits have no local name and and occur as lenticular masses, often quite thick. They tend to die out westward and cannot really be called Kenley Grit. Whittard (1932) mapped the Llandovery in great detail and was able to show a gradual transgression of the sea from the west over a deeply eroded and irregular landscape of Precambrian and Ordovician rocks. He mapped old cliff lines and sea stacks around the southern Longmynd where coarse basal conglomerates up to 90 m thick rest with a marked unconformity on nearly vertical Longmyndian strata. The basal grits pass upwards or laterally into richly fossiliferous Llandovery strata which outcrop all round the Shelve area (except in the east) and around the southern and eastern parts of the Longmynd. The *Pentamerus* Beds are particularly well exposed, and also occur in the Shelve area at heights of up to 400 m above sea level, showing that the sea did cover all this area at some time during the Llandovery.

The succeeding Wenlock and Ludlow rocks only outcrop to the south of the Shelve area and the Longmynd, and show a marked difference from the Main Outcrop. The sequence is thicker (100 m plus) and, south of the Longmynd, the Wenlock Limestone is replaced by the Edgton Limestone (40–60 m)—a muddy limestone without coral reef material. The whole of the Ludlow Series is represented by 650 m of shales and siltstones, locally with slumped beds, and with no Aymestry Limestone development. Clearly this is a deeper water sequence than the Main Outcrop, and this thick higher Silurian sequence is well exposed between Horderley and Bishop's Castle.

The strip of Silurian rocks on the southern flank of the Longmynd passes north east along the Church Stretton valley, forming the floor of the valley for all of its length, and resting unconformably on Longmyndian strata to the west. Near All Stretton and on the west slope of Caer Caradoc, (Fig. 9) there is a complete sequence in the Silurian directly west of the main (F. 1) Church Stretton Fault, faulted against Uriconian Volcanics. The Llandovery and Wenlock Shale are drift covered but the Wenlock Limestone, Lower Ludlow Shale, Aymestry Limestone and Upper Ludlow Shales are all exposed. The sequence is essentially the same as in the Main Outcrop, even though the area is west (if only just) of the Church Stretton Fault System. The Church Stretton Fault here must have a vertical displacement of 1100 m to the west to bring down the Silurian strata into the Church Stretton valley. This displacement is calculated by projecting the dip of the main outcrop of the Wenlock Limestone westwards at its average dip of 10°.

Clun Forest

The Silurian of the Bishop's Castle–Horderley area merges south west into the large basin of Clun Forest (Fig. 17). The rocks here are entirely of Ludlow Series and Downton Series age (Earp, 1938; 1940) and mainly graptolitic. The Ludlow comprises a great thickness (2000 m) of siltstones and mudstones with many slumped beds. The Downton Series is represented by about 600 m of siltstones, shales and mudstones forming large outliers around Clun. The Ludlow Bone Bed and the basal beds of the Downton Castle Sandstone are represented here by a thicker sequence (6 m–12 m) of fossiliferous silty beds known as the *Platyschisma helicites* Beds and the remainder of the sequence has important plant remains. No beds younger than Downton Series occur in the area.

Long Mountain

The Silurian sequence of Long Mountain occurs in an asymmetric syncline between the Breidden Hills and the Shelve area (Fig. 15). The main folding is post Silurian, pre-Carboniferous (i.e. Caledonian) although the open syncline of the Hanwood Coalfield is nearly co-axial with the Long Mountain syncline, and may have tightened the fold. Strata range in age from Llandovery right through to Downton Series (Das Gupta, 1932; Palmer, 1970). The Llandovery sequence is as in the rest of the county and rests with an unconformity on Ordovician (Caradoc) rocks. The Cefn Formation (90 m) equates with the *Pentamerus* Beds and the Buttington Formation (107 m) is similar to the Purple Shales. The remainder of the Silurian bears close similarity to that of the Bishop's Castle–Clun Forest areas, being a thick, mainly graptolitic, basin type sequence. The Wenlock is represented by the Trewern Brook Mudstone Member (457–610 m), comprising graptolitic mudstones with a lenticular development of shelly calcareous mudstones in the upper part. The Ludlow comprises up to 730 m of siltstones, often calcareous—the Long Mountain Siltstone Formation with a graptolite fauna, and with slumped beds and turbidites; and the higher Causemountain Formation comprising siltstones, which become more calcareous towards the top, with a shelly fauna. A thin bone bed marks the base of the Downton Series followed by a thin development (less than 2 m) of the *Platyschisma* Limestone. Non-marine flags and coarse siltstones (180 m thick) complete the succession within the Downton Series. No younger rocks occur in the Long Mountain area.

Silurian Tectonics and the Caledonian Orogeny in Shropshire

Downton Series rocks are the youngest seen in Clun Forest and the Long Mountain, there being no Devonian deposits. North west of the Long Mountain, in Wales, Ludlow Series rocks were the youngest Silurian rocks deposited, and in this area the late Silurian (Downton Series) was the time of the Caledonian orogeny which produced the folding of the Berwyn Dome (Fig. 2). Caledonian folding also produced the Long Mountain syncline and structures in Clun Forest but this folding must be slightly younger, post-Downton Series. The Caledonian orogeny had little effect in other parts of Shropshire which were even further away from the orogenic centre, particularly east of the Church Stretton Fault System. In the Ludlow area and Wenlock Edge–Corvedale area, there is a continuous passage from the Downton Series through into the Devonian Ditton Series with no unconformity present. However, the beds are all non-marine, and so although no folding occurred in this area during the Caledonian orogeny, it obviously caused the area to rise above sea level at the end of the Ludlow as part of the Old Red Sandstone continent. However, fold structures such as the famous Ludlow anticline were initiated in Middle Old Red Sandstone times (see later) but can be considered as late Caledonian. These folds were reactivated during the Variscan orogeny to affect rocks of late Carboniferous age on the Clee Hills. It is quite possible that a good deal of faulting in Shropshire is of Caledonian age, since many of the faults in the Wenlock Edge area do not cut the Devonian (Ditton) strata. Many Caledonian faults could have had movement along them in the later Variscan orogeny and so their original movement is difficult to date. Movement along the Church Stretton Fault System occurred during the whole of the Silurian as it separated the western basin from the eastern shelf. Movement intensified at the height of the Caledonian orogeny, but the 1100 m vertical displacement on the Church Stretton Fault referred to above was probably one of the latest movements on the fault, probably post-Carboniferous.

VI THE DEVONIAN PERIOD

The Iapetus Ocean finally closed at the end of the Silurian period creating a continental mass with high mountains over central and northern Britain, and the sea retreated to the south. The Devonian period in Shropshire is represented by the Old Red Sandstone, the non-marine (continental) facies of the Devonian. Sediments of this rock group are well exposed in the south of the county around the Clee Hills, but occur no further north (Fig. 1). These were formed in shallow relic seas and lagoonal areas on the southern seaward edge of the continental mass (Fig. 18).

The Devonian period lasted from 395–345 million years ago, but what precise time intervals the Old Red Sandstone of Shropshire represents within this 50 million year period is difficult to estimate, since correlation with the marine stages of the Devonian is difficult, through lack of marine fossils. By International agreement the base of the Devonian is now taken at the base of the *Monograptus uniformis* Zone in the marine graptolite sequence in eastern Europe and elsewhere. This probably equates with the base of the Ditton Series (base of *Psammosteus* Limestone) in Shropshire and the Downton Series is now placed in the Silurian, as Murchison originally intended. The absence of structural and faunal evidence to define the base of the Devonian in Shropshire has led to the development of subdivisions throughout the sequence based on lithostratigraphic evidence, (House *et al.*, 1977).

Outcrops of Devonian Rocks (Old Red Sandstone)

The Old Red Sandstone is best exposed on the lower slopes of both Brown Clee and Titterstone Clee Hills. Brown Clee Hill has outcrops representing the Ditton, Abdon and Woodbank Groups of the Lower Old Red Sandstone. The Farlow Group of the Upper Old Red Sandstone is missing. Titterstone Clee Hill again has outcrops of the Ditton, Abdon and Woodbank Groups (although the latter only appears on the north-eastern slopes) and in addition has a small outcrop of Farlow Group rocks on its northern flank in the vicinity of the village of Farlow. The unconformity which exists at the base of the Farlow Group is suggested by the non-appearance of the Woodbank Group at this point.

Old Red Sandstone Palaeogeography of Shropshire

The development of the Old Red Sandstone continent during the Devonian Period led to large-scale lacustrine, fluvial and estuarine deposition on the landmass margin (Fig. 18). In turn, this variety of environments allowed the colonisation by, and development of, land-plants (which had first appeared in the Late Silurian) and of armoured freshwater fishes. The overall "red" appearance of the sequence reflected the oxidation of iron within the sediment, and due to the primitive development of plants, the lack of organic matter to reduce the iron to its green, ferrous state. The well-developed calcareous palaeosols (cornstones) closely resemble calcretes which are developing today within latitudes of 35°, or less. In areas of calcrete formation mean annual temperatures are between 16°–20°C, and rainfall between 100 mm–500 mm. This evidence suggests a similar latitudinal position for the Old Red Sandstone Continent, a position which corresponds with palaeomagnetic data (Fig. 18) (Anderton *et al.*, 1979, p. 122).

Tectonics of the Clee Hill area

The Devonian rocks of Shropshire reflect the terminal stages of the Caledonian Orogeny. The absence of any Middle Devonian sediment suggests that uplift and subaerial erosion

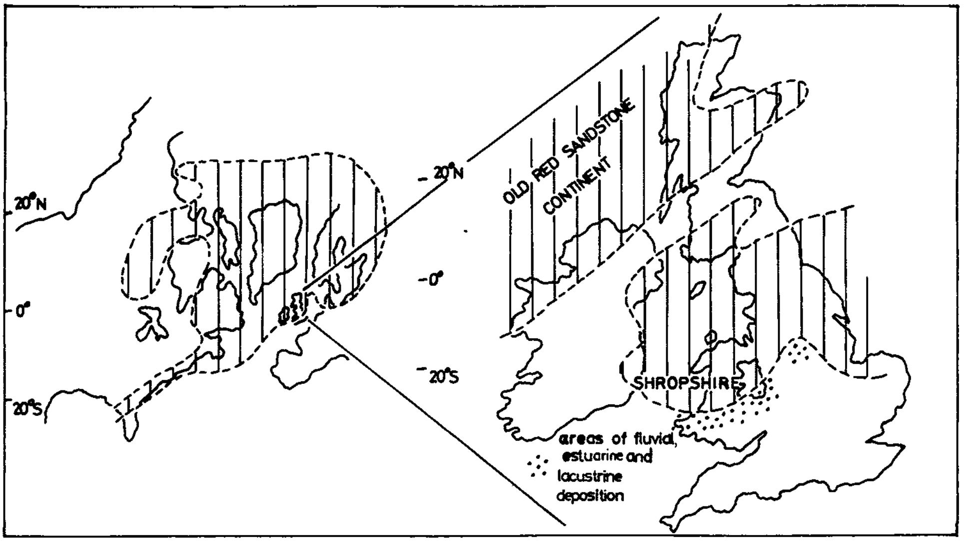

FIG. 18.
Late Devonian palaeolatitudes determined from palaeomagnetic data; and, upland and highland areas of the late Devonian period in "Britain" together with surrounding lacustrine, fluvial and estuarine areas.

occurred following deposition of the Woodbank Group, leaving the Upper Devonian Farlow Group deposited unconformably on lower groups.

The main structures produced by this marginal Caledonian orogenic activity (the more intense earlier folding being seen in the Lower Palaeozoic sediments further west) are the north-east to south-west aligned gently folded Brown Clee and Titterstone Clee Synclines, and associated Ludlow anticline (Fig. 2).

The degree of folding produced by this terminal Caledonian orogenic activity is difficult to ascertain, as the area was subsequently affected by the Variscan Orogeny.

VII The Carboniferous Period

The initial stage of the Carboniferous Period in Shropshire reflects a return to marine conditions following the non-marine sedimentation of the Devonian Period. The Carboniferous Limestone of the Dinantian Series was to herald a period of deposition lasting from 345 million years to 280 million years ago, throughout which time a gradual change to terrestrial sedimentation was again seen.

The changing sedimentary facies throughout the Carboniferous Period produced a range of important mineral resources including coal, ironstone, limestone and refractory clays. It was the recognised economic value of these minerals which led to the intense exploration and documentation of rocks from this period.

Throughout the Carboniferous Period, crustal instability was to be an important control of sedimentation. The movements are recognised as precursory tectonic events to the main Variscan Orogeny, which brought the Carboniferous Period to a close. The Carboniferous in Western Europe is subdivided as follows: –

Series	Stage	Coral, Brachiopod Zone	Goniatite Zone
Stephanian			
Westphalian	D C B A		 A G_2
Namurian	Yeadonian Marsdenian Kinderscoutian Sabdenian Arnsbergian Pendelian		G_1 R_2 R_1 H E_2 E_1
Dinantian	Brigantian Asbian Holkerian Arundian Chadian Courceyan	D_2 D_1 S_2 C_2, S_1 C_1, C_2, S_1 K, Z	P_2 P_1 B P_e G_a

Dinatian Rocks in Shropshire

Outcrops of Dinantian age can be found in three principal localities—the Telford area, the Oswestry area and Titterstone Clee Hill (Fig. 1).

The Titterstone Clee Hill outcrop comprises a narrow band of Carboniferous Limestone on its northern and southern flanks. An exposure in the village of Farlow, on the northern flank, reveals that the Limestone rests unconformably on Devonian Farlow Group sandstones. The basal Carboniferous rocks are the Lower Limestone Shales, of Courceyan age, and pass upwards into the Oreton Limestone. This limestone correlates with the Pwll-y-Cwm Oolite, found at Clydach, South Wales, and is possibly of Chadian age (George *et al.*, 1976, p. 21).

The significance of the correlation between the Oreton Limestone and Pwll-y-Cwm Oolite is that the oolitic facies of the Dinantian has been equated with high-energy shallow subtidal conditions of deposition (Anderton *et al.* 1979. p. 140).

The Dinantian rocks of the more northerly Telford and Oswestry areas appear to be younger than those found in south Shropshire, and are of quite different character.

The Oswestry outcrop occurs between Chirk and Llanymynech Hill. The rocks, which are predominantly limestone, lie with marked unconformity on Lower Palaeozoic rocks. The Dinantian sequence begins with grey shales passing into buff and white rubbly limestones (the Lower Limestone). The entire sequence is some 85 m thick and is of Asbian age. This is succeeded by 70 m–100 m of dark, well-bedded limestone (the Upper Grey Limestone) and Sandy Limestone of variable thickness. This sequence is of Brigantian age.

Two Dinantian age outcrops are seen in the Telford area. The Little Wenlock outcrop comprises the Lydebrook Sandstone of Asbian age (which attains a maximum thickness of 21 m) passing up into 16 m of creamy white limestone. This is divided some 1.0 m above its base by a microporphyritic olivine basalt lava flow which retains a constant thickness of 30 m. The entire limestone sequence is Brigantian.

The second Dinantian-age outcrop in Telford occurs at Lilleshall. The entire sequence is some 85 m thick and varies from impure limestones resting unconformably on Cambrian rocks at the base, through shales with thin limestones, to nodular limestones at the top. The shales with thin limestones have been designated Courceyan, due to the presence of the diagnostic species *Avonia* c.f. *bassa* and *Spirifer* c.f. *tornacensis.* Succeeding units have been dated as Asbian, and the highest limestones as Brigantian age (George *et al.*, 1976, p. 27).

Dinantian Palaeogeography of Shropshire

The absence of Dinantian rocks from mid-Shropshire is a feature common to mid-Wales and parts of the English Midlands (Fig. 19). This suggests that deposition occurred in two distinct basins—the Central Province Basin, to which the Telford and Oswestry outcrops belong, and a South West Province Basin, to which the Titterstone Clee Hill outcrops belong. The intervening non-depositional area of St. George's Land/Mercian Highlands was a much eroded upland relic of the Old Red Sandstone continent.

The different ages, and lithologies of the north and south shoreline rocks can now be appreciated. Although both sequences thicken appreciably away from the landmass margins, the predominantly Asbian and Brigantian rocks of the northern margin show that a shoreline of low-relief existed until a marine transgression of Asbian age. The low-lying nature of the landmass prior to the Asbian marine invasion is suggested by an absence of land-derived clastic sediment in the southern margins of the Central Province Basin.

Much earlier deposition occurred on the southern shoreline of the landmass, as shown by the Courceyan and Chadian sequences. The absence of any younger rocks may be attributed to late Dinantian (Sudetic) earth movements causing uplift and shrinking of the south west Province Basin.

Namurian Rocks in Shropshire

The main outcrops of Namurian rocks in Shropshire occur in the Oswestry area, where they follow the eastern margin of the Dinantian outcrop (Fig. 1), and on the summit of Titterstone Clee Hill. They represent a thin development of the classic "Millstone Grit" of northern England.

The Namurian in the Oswestry area, referred to as the Cefn-y-Fedw Sandstone, comprises 90 m of grits and sandstones, with insignificant shale horizons. The lower and upper boundaries of the Cefn-y-Fedw Sandstone are everywhere conformable with Dinantian and Westphalian rocks respectively.

The Namurian equivalent on Titterstone Clee Hill, the Cornbrook Sandstone, has an unconformable junction with underlying Devonian and Carboniferous rocks. It develops into some 200 m of coarse feldspathic sandstone with minor shale partings. The precise age of the sequence is, however, in doubt as palynological evidence has attributed the upper part of the Cornbrook Sandstone to the Westphalian Series (Hains and Horton, 1969, p. 38).

Namurian Palaeogeography of Shropshire

Sudetic earth movements caused renewed uplift of the degraded St. George's Land/ Mercian Highlands to produce the Wales–Brabant Uplands. This caused subaerial erosion and

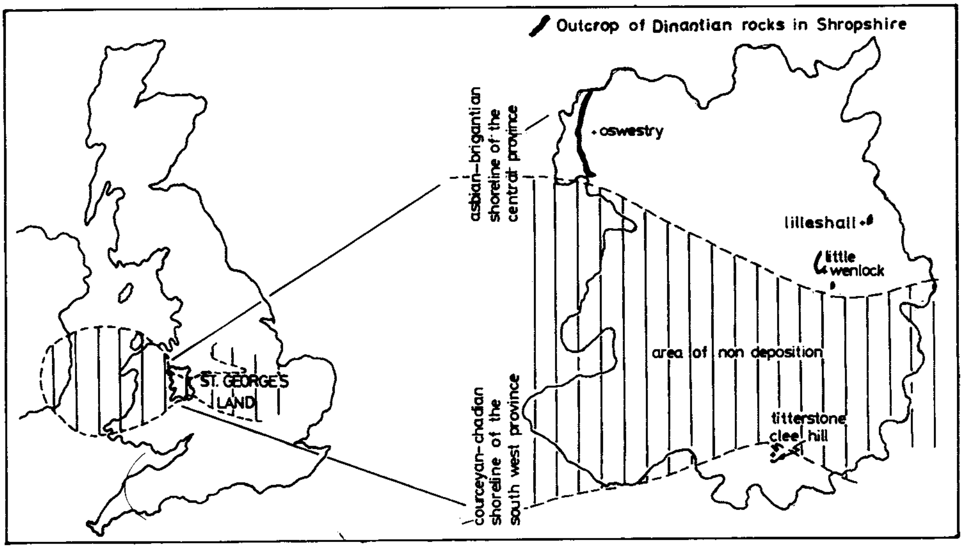

FIG. 19.
St. George's Land during the Dinantian. Northern shoreline reflects the limits of Asbian/Brigantian deposition, whereas the Southern shoreline reflects earlier Courceyan/Chadian deposition.

subsequent deposition on both northern and southern shores of the landmass. The thickness of both the Cefn-y-Fedw Sandstones and Cornbrook Sandstone is, however, insignificant when compared with the Namurian sequences of Lancashire (2000 m thick) and the Gower (700 m thick). This sequence, and continued sedimentation across the Dinantian/Namurian boundary in the Oswestry area, suggests that Sudetic earth movements were of low intensity.

The stable characteristics of the east-west orientated landmass, part of which Shropshire now represents, was again instrumental in producing much thinner sequences than those found in the unstable basinal areas to the north and south. It is possible, however, that the northern and southern basins were at times connected, and that the Cefn-y-Fedw Sandstone and Cornbrook Sandstone are of a common origin, and are not separate basin-margin deposits (Owen, 1976, p. 82).

Westphalian Rocks in Shropshire

Westphalian rocks comprise, lithologically, the Lower, Middle and Upper Coal Measures. The base of the Westphalian Series is taken as the *Gastrioceras subcrenatum* marine band. The top of the Series is more difficult to define in Shropshire, but is generally taken to be a widespread unconformity occurring in Westphalian C and D zones, (the precise position varies with locality), above which Permian Breccias (e.g. the Alberbury Breccia) have developed (Smith *et al.*, 1974, p. 26). The Westphalian Series contains a wide variety of mineral resources, the exploitation of which allowed Britain to become an important manufacturing nation. The nature and occurrence of Westphalian rocks, is therefore, particularly well known, those of Shropshire being no exception.

Westphalian rocks occur in the vicinity of Coalbrookdale, Shrewsbury, Oswestry and the summits of Brown Clee and Titterstone Clee Hills (Fig. 1). The Lower and Middle Coal Measures are represented at each location with the exception of the Shrewsbury Coalfield. The absence from this locality may be explained by deposition over an axial region (possibly the Haughmond-Longmynd Axis) producing thin Lower and Middle Coal Measure sequences, which were subsequently removed by post Middle Coal Measures (Malvernian) earth movements. Much thicker Lower and Middle Coal Measures in the Oswestry, Clee Hill and Coalbrookdale coalfields suggests deposition in subsiding basins on the periphery of the axial zone.

The term "Coal Measures" is, lithologically, a general expression referring to a variety of mudstones, siltstones, sandstones and coal-seams which need not be laterally continuous between different areas. General characteristics of the Lower, Middle, and Upper Coal Measures can, however, be outlined.

The Lower Coal Measures comprise non-marine sandstones with subordinate clays and ironstones passing vertically into the Middle Coal measures which have dominant mudstones and ironstones—sandstones and fireclays are subordinate. The thicker, more economic coal seams appear more frequently in the Middle Coal Measures. Marine bands which represent marine incursions with associated brachiopod fauna, are also found extensively throughout the Lower and Middle Coal Measures. Unlike other lithologies, marine bands are laterally extensive. Nineteen major examples are known in Great Britain but this number only occurs in the centre of major subsiding coal-basins. They infer extensive eustatic rise and flooding of paralic zones. Five marine bands can be found in the Lower and Middle Coal Measures of the Coalbrookdale Coalfield.

A marked unconformity occurs everywhere at the base of the Upper Coal Measures. The unconformity is traditionally and erroneously known as the Symon Fault in the Coalbrookdale Coalfield. The sequence is again typified by laterally discontinuous marls and mudstones, siltstones and sandstones. Coal seams do, however, become thinner, and disappear by the close of the Coalport Formation—Coed yr Allt Bed times. Beds of late Upper Coal Measure times also show an increased reddening in colour. This increased oxidation of ferruginous minerals heralds an onset of more arid conditions.

The formations have been well studied in the Geological Survey (I.G.S.) re-survey of the Telford area (1978, 1:25000 map), and also parts of the revised sheet 152 (Shrewsbury, 1978). In the Coalbrookdale coalfield south east of the Wrekin Boundary Fault (Figs. 1 and 2) the sequence comprises (in descending order): Keele Beds, Coalport Formation and Hadley Formation (Etruria Marl facies). North west of the Wrekin Boundary Fault the sequence comprises Keele Beds, Coed-yr-Allt Beds, and Ruabon Marl at the base. This latter sequence, without the Ruabon Marl, extends westward into the Shrewsbury–Hanwood and Leebotwood coalfields, where the Coed-yr-Allt beds have been exploited in the past for thin coals.

Westphalian Palaeogeography of Shropshire

Throughout Namurian times large volumes of felspathic sandstones and grits had been deposited as deltas in broad swathes across the area of present-day Britain. Deltaic deposits into paralic basins continued in the Westphalian, producing a landscape of laterally eroding distributary channels interspersed with large areas of swamp and lake. This landscape supported a luxuriant vegetation with *Lepidodendron* growing on mid-swamp, and smaller species, typified by *Calamites*, growing in marginal swamp areas. The swamp conditions inhibited bacterial decay of this organic matter and allowed layers of swamp peat to form, which, when compressed and reduced to some 20% of its original thickness by diagenetic activity, became coal-seams.

The formation of over 30 m of coal-seams in the Coalbrookdale Coalfield suggests original swamp peat thicknesses to be in excess of 150 m. Rapid rates of primary productivity are therefore envisaged, and a climate similar to that of present day equatorial rain forest areas proposed.

Rocks of late Westphalian age increasingly show the effects of oxidation. The disappearance of coal seams, and increasing development of red-beds suggests a climatic change to more arid conditions. Palaeomagnetic data suggests a late-Westphalian position for Britain at 8°–10° N of the equator. The northward movement to this latitude from an equatorial position would account for the climatic change.

Carboniferous Igneous Activity in Shropshire

Basic igneous rocks of Carboniferous age outcrop on the summits of Brown Clee and Titterstone Clee Hills, and near Little Wenlock.

The Clee Hills outcrops are olivine-dolerite. Brown Clee Hill has three small outcrops at Abdon Burf, Green Lea and Clee Burf, in each case underlain by Lower and Middle Coal Measures. Titterstone Clee Hill shows a more substantial development of the olivine-dolerite, the total thickness of which reaches 91 m (Hains and Horton, 1969, p. 55). It lies within the Coal Measures, with the exception of the north-western area of outcrop, where the base is in contact with the Old Red Sandstone. The quarry workings on Titterstone Clee Hill show both lower and upper margins of the dolerite. The lower margin shows the effects of baking in the underlying sandstone. Evidence of baking is less readily seen at the upper margin, but the contact with the overlying coal measures is sharp, and shows little evidence of weathering. The inferred intrusive nature of the body is upheld by palaeomagnetic studies undertaken by Everitt (Greig *et al.*, 1968, p. 320).

The Little Wenlock Basalt occurs within the Carboniferous Limestone, and thickens from 25 m at an outcrop on the western edge of Coalbrookdale Coalfield to over 60 m further eastwards. The lava is an amygdaloidal olivine basalt, the extrusive nature being proven by the presence of a weathered slaggy upper surface (Hains and Horton, 1969, p. 31).

The Variscan Orogeny

Tectonic movement throughout the Carboniferous Period controlled the different sedimentary facies seen in the Dinantian, Namurian and Westphalian of Shropshire. Reactivation of the Old Red Sandstone—St. George's Land Central Highland area into the Wales-Brabant Massif initiated and controlled the thickness of Namurian sedimentation in the area. Later, minor movements produced the unconformity between the Middle and Upper Coal Measures and locally within the Upper Coal Measures of the Oswestry area. The movements also produced the crustal flexing which controlled the periodic marine invasions of the Coal Measures.

The most intense Variscan tectonic activity occurred in late Westphalian times, and brought to a close the Carboniferous Period. In Shropshire, the primary effects of this phase of the orogeny are seen in the reactivation of late Caledonian structures (such as the Brown Clee and Titterstone Clee synclines, and Ludlow Anticline) and the gentle folding of Upper Palaeozoic rocks. This resulted in the formation of broad synclinal areas of Carboniferous rocks typified by the Cheshire–North Shropshire Basin and the Coalbrookdale Coalfield–West Staffordshire Basin (Dineley, 1960, p. 7).

Extensive and important faulting also occurred during the Variscan tectonic activity in Shropshire. Many Caledonoid faults were re-activated, which dislocated and separated the basinal coalfield areas. A further important development was the activation of faults extending northwards into the Cheshire–North Shropshire Basin to develop major graben structures. These structures were to strongly influence sedimentation throughout the Permo-Triassic.

VIII The Permian Period

The Permian Period (280–225 million years ago) in Shropshire is represented by sedimentary rocks produced from the subaerial erosion of Variscan uplands. The Permian formations are typically red, are lacking in fossils, and indicate deposition on a semi-arid continent. The lack of fossils makes dating and correlation of Permian rocks extremely difficult. The base of the Permian in the English Midlands has been arbitrarily defined as a widespread unconformity at the base of the Alberbury Breccia, or its lateral equivalents the Enville Beds and the Clent Breccia. Definition of the top of the Permian presents similar problems. A further arbitrary position—the unconformity at the top of the Bridgnorth (Lower Mottled) Sandstone—has been designated the upper Permian boundary (Smith *et al.*, 1974, p. 9). The subdivisions of the Permian in Shropshire are as follows

Period	Stage	Lithostratigraphic Units
Permian	Upper	Bridgnorth or
	Lower	Dune Sandstone Formation Alberbury/Enville/ Clent Breccia

The Bridgnorth (Lower Mottled) Sandstone used to be classified as Bunter (Lower Triassic), but is now considered to be of Permian age and so cannot be called the Bunter Sandstone. New terminologies have now been accepted for the British Permo/Triassic (New Red Sandstone) rocks (see page 97).

Permian Rocks in Shropshire

The main outcrops of Permian rocks in Shropshire occur to the north and east of the River Severn. Several small outliers do, however, occur to the southwest of this line (Fig. 1).

The Alberbury Breccia is the basal Permian formation in West Shropshire. The rock is best exposed between Alberbury and Cardeston (Mercer, 1959, p. 9), although a small outlier does occur 2 km west of Pitchford. The equivalent rock in south east Shropshire is the Clent Breccia, small outcrops of which are exposed some 4 km south of Claverley. Lithologically, both Alberbury and Clent Breccias are similar, with large fragments of red marl and Carboniferous Limestone in a red sandstone matrix. In the west, the succeeding Bridgnorth (Lower Mottled) Sandstone lies with unconformity on the Alberbury Breccia or Keele Beds; in the east, rests unconformably on the Enville Beds; and elsewhere, on even older rocks. East of Telford, the Enville Beds comprise sandstones with calcareous conglomerates, and always separate the Keele Beds from the Bridgnorth Sandstone. The Bridgnorth Sandstone underlies broad tracts of east and north Shropshire but is often obscured by Quaternary deposits. It is a well sorted bright red dune sandstone, commonly revealing large-scale cross stratitification— a feature which is particularly well exposed in the cliffs of the Bridgnorth area.

Permian Palaeogeography of Shropshire

Permian rocks in Shropshire resulted from the rapid, subaerial erosion of Variscan highlands, and deposition in developing graben systems. The breccia formations are typical molasse deposits—the large angular calcareous clasts representing scree material eroded from upland Carboniferous Limestone outcrops, and deposited in intermontane troughs.

The Bridgnorth Sandstone represents a continuation of deposition under terrestrial conditions. The well-sorted, cross-stratified nature of the sandstone indicates a largely aeolian origin, although occasional indications of intermontane lake deposition may be seen.

Both breccia and sandstone quartz grains have a strong red iron oxide pellicle, a further indication of oxidation in a subaerial environment.

The development of fine, well-sorted aeolian sandstones in late Lower Permian times may be the result of climatic change induced by peneplantation. The elimination of prominent topographic features precluded orographic rainfall, and allowed aeolian activity to become increasingly important in a developing semi-arid landscape.

Further evidence for location within a semi-arid environment comes from palaeomagnetic studies. They reveal that the position of the English Midlands in early Permian times would have been approximately 8°N of the equator, moving to almost 20°N at the Permo-Triassic boundary. This position in the dry sub-tropical anticyclonic belt is inferred for much of the Permian (Owen, 1976, p. 101). In addition widespread collision of continental plates during the Permian is hypothesised. This resulted in the formation of a supercontinent—Pangaea—and added the prospect of continentality aiding the development of an arid climate.

Crustal instability played an important role in the development of the Permian formations in the Midlands. The local variations in thickness of the Bridgnorth sandstone of the Kidderminster area (Hains and Horton, 1969, p. 64), the possible unconformity between the Alberbury Breccia and the Bridgnorth Sandstone in west Shropshire and the development of up to 180 m of the same sandstone in the subsiding north Shropshire–Cheshire Basin indicate this. Tensional stresses associated with the initial split-up of the Pangaea continued to be a dominant control of sedimentation throughout the Triassic.

IX THE TRIASSIC PERIOD

The Triassic Period in Shropshire opened 225 million years ago with similar conditions, and hence rocks, to those seen in the Permian. Non-marine deposition continued throughout the Period, with the exception of a brief marine incursion producing the Tarporley Siltstone and the Period ended 190 million years ago. The lack of macro-fossils is a feature of many of the Triassic rocks in east Shropshire and the Shropshire–Cheshire Basin. Problems of correlation have been partly overcome by the analysis of miospores. Miospores are found both within the non-marine sedimentary rocks of the English Midlands and the marine sedimentary rocks of the European mainland. It is upon the latter that the standard sequence of Triassic stages has been developed. Therefore, a tentative correlation is possible, but further palynological research is required (Warrington *et al.*, 1980, p. 18).

The base of the Triassic in north Shropshire is taken as the Kinnerton Sandstone Formation at the base of the Sherwood Sandstone Group. The precise position of the Triassic Permian boundary within the formation is unclear (Warrington *et al.*, 1980, p. 31). It is more obviously displayed in east Shropshire where the Kidderminster Formation (Bunter Pebble Beds) represents the base of the Sherwood Sandstone Group. The Penarth Group represents the top of the Triassic in Shropshire. The Triassic stages and rocks of the area, and how they correlate with the previously used terms—Bunter and Keuper Sandstones—are shown opposite.

Period	Stage	Group	Formation	Former terminology
Triassic	Rhaetian	Penarth	Lilstock Formation Westbury Formation	Generally Comparable to former Rhaetian
			Blue Anchor Formation	Tea Green Marls
	Norian	Mercia Mudstone Group	Mudstone	Upper Keuper Marl
	Carnian		Wilkesley Halite Formation	Upper Keuper Saliferous Beds
	Ladinian		Mudstone	Middle Keuper Marl
	Anisian		Northwich Halite Formation	Lower Keuper Saliferous Beds
			Mudstone	Lower Keuper Marl
			Tarporley Sandstone Formation	Waterstones
	Scythian	Sherwood Sandstone Group	Helsby Sandstone Formation	Keuper Sandstone (excluding Waterstones)
			Wilmslow Sandstone Formation	Upper Mottled Sandstone
			Chester Pebble Beds	Bunter Pebble Beds
			Kinnerton Sandstone Formation	Lower Mottled Sandstone (Permian) Extends beneath Kinnerton Sandstone formation

Triassic Rocks in Shropshire

The occurrence of Triassic rocks in Shropshire closely follows that of Permian formations (Section VIII) with outcrops occurring on the north Shropshire Plain and the margin of the county to the east of the River Severn. Much of this area is covered by Pleistocene and recent deposits which results in patchy Triassic exposures.

The Sherwood Sandstone Group is (with the exception of the Chester Pebble Beds Formation, best seen in the Market Drayton area) exposed in the small hills of the North Shropshire Plain, the most accessible of which is Grinshill Hill. The Wilmslow Sandstone Formation (equals Keuper Sandstone of earlier accounts) of Grinshill village passes up into the Helsby Sandstone Formation at the foot of the Hill. These cross-stratified, well-sorted orange-red sandstones are succeeded by the Tarporley Siltstone Formation towards the top of the hill. The junction between the two is marked by an obvious change in lithology and bedding structures and fossil content. The Tarporley Siltstone is a yellow-green micaceous siltstone with gently-dipping subparallel beds. Equivalent beds in Bromsgrove, Worcestershire, have been found to contain marine microplankton fossils (Warrington *et al.*, 1980, p. 79).

The junction also marks the passage into the Mercia Mudstone Group (equals Keuper Marl of earlier accounts), the red-brown Mudstones which succeed the Tarporley Siltstone being the youngest Triassic rocks to outcrop in Shropshire. The positions and lithologies of the drift covered formations of the Mercia Mudstone Group and Penarth Group, have been defined by shallow excavations and boreholes. The Mudstone Formation (the lower part of which is seen on Grinshill Hill) is intercalacted by two halite formations before changing towards its upper boundary into the "Tea Green Marl" facies, Blue Anchor Formation. This represents a change from red, calcareous clays and saliferous strata to grey, green and white marls.

The Penarth Group (Rhaetic Series) has been proved to rest non-sequentially on the Mercia Mudstone Group in the Prees outlier. The Westbury Formation comprise dark grey pyritised mudstones, with thin lenticles of limestone and thin strata of sandstone and siltstone, throughout which thin layers of fish remains occur. Other macrofossils including *Chlamys valoniensis*, *Protocardia rhaetica*, *Rhaetavicula contorta* and *Natica oppelii* have also been found (Hains and Horton, 1969, p. 73). This represents an obvious and marked change from the preceding formation. The upper, Lilstock Formation of the Penarth Group reverts to light-coloured calcareous mudstones and siltstones.

Triassic Palaeogeography of Shropshire

The Triassic rocks of Shropshire and the West Midlands represent deposition in a landscape dominated by narrow horst and graben structures. The dominant structure in north Shropshire was a graben extending northwards to join the larger Manx-Furness Basin. The north-south aligned Worcester Graben was also instrumental in directing sedimentation over much of the north west Midlands as witnessed by the Chester Pebble Bed Formation. This formation contains many exotic fragments which originated in the Armorican Highlands to the south west and which were deposited by vigorous fluvial deposition directed into the sea by the Worcester Graben (Audley-Charles, 1970, plate 7). The finer, cross-stratified nature of the Wilmslow and Helsby Sandstone Formation suggests a decrease in the energy of the river systems which may have resulted from erosion and lowering of local uplands.

The dominance of fluvial deposition was ended with the formation of the Tarporley Siltstone. This formation in Shropshire represents a marine incursion which can be traced laterally into Saxony and Southern Europe, where it also becomes far thicker. The inference is that a transgression into northern Europe from the southern (Tethyan) ocean occurred, the latter stages of that transgression depositing the Tarporley Siltstone on a slightly elevated but subdued landscape.

The succeeding saliferous marls of the Mercia Mudstone Group indicate that the marine conditions were short-lived, and heralded a return to a more arid, non-marine environment. The presence of two saliferous formations of combined thickness in excess of 450 m represents the main evidence for this. Each saliferous formation comprises intercalated halite and mudstone strata produced by deposition in and the evaporation of shallow water. A playa lake landscape developing into evaporite-encrusted mudflats was envisaged by Tucker (1978).

The landscape was subject to yet further change in the late Triassic. The Blue Anchor Formation "Tea Green Marl" facies, and the Penarth Group formations indicate the onset of marine conditions which were to last in areas of Britain until the late Cretaceous, although direct evidence of marine conditions in Shropshire only extends into the Lias. The inferred pluvial periods producing extensive playa lakes in the mid-Trias represents a climatic change from the predominantly arid climate of the Permian and lower Trias. This may have been produced by a northward movement of Pangaea away from low-latitude semi-arid and arid areas. Van der Voo and French (1974) suggest a late Triassic position for Britain of 30°–40° N.

Triassic Tectonic Activity

The existence of crustal tension and the development of horst and graben systems has already been indicated. Continued graben subsidence throughout the Triassic is suggested by an accumulation of over 2000 m of rock in north Shropshire whereas deposition in stable areas (Shropshire east of the Ercall Mill, for instance) amounts to little over 600 m, (Fig. 2).

X Jurassic

The youngest geological succession to occur in Shropshire, with the exception of Pleistocene and recent deposits, is represented by the faulted Lower Jurassic outlier extending from Wem north-eastwards to Audlem. This area is predominantly drift-covered, the principal outcrop being at the village of Prees. The village is built on Middle Lias clays and silts, with a small crescentic outcrop of Lower Liassic clay, being found 1 km to the south east. The Lower Liassic age of this clay has been confirmed elsewhere in the Shropshire–Cheshire Basin by the presence of *Psiloceras planorbis* (Warrington *et al.*, 1980, p. 35). The presence of the Lower Jurassic formations indicates a continuation of the marine conditions initiated in the late Triassic.

Post Triassic Igneous and Tectonic Activity

Post Triassic tectonic activity is indicated by the gentle dips of the Triassic formations throughout Shropshire. There is also evidence of considerable post-Jurassic faulting (Fig. 2). The Wem Fault has a downthrow in excess of 1500 m to the north-west, and both the Church Stretton Fault and the Ercall Mill Fault show evidence of post-Triassic movement (Hains and Horton, 1969, p. 73).

A porphyritic dolerite dyke which intrudes the Triassic rocks on Grinshill Hill is of Tertiary age. The heavily weathered dolerite shows evidence of post-formation mineralisation by barytes.

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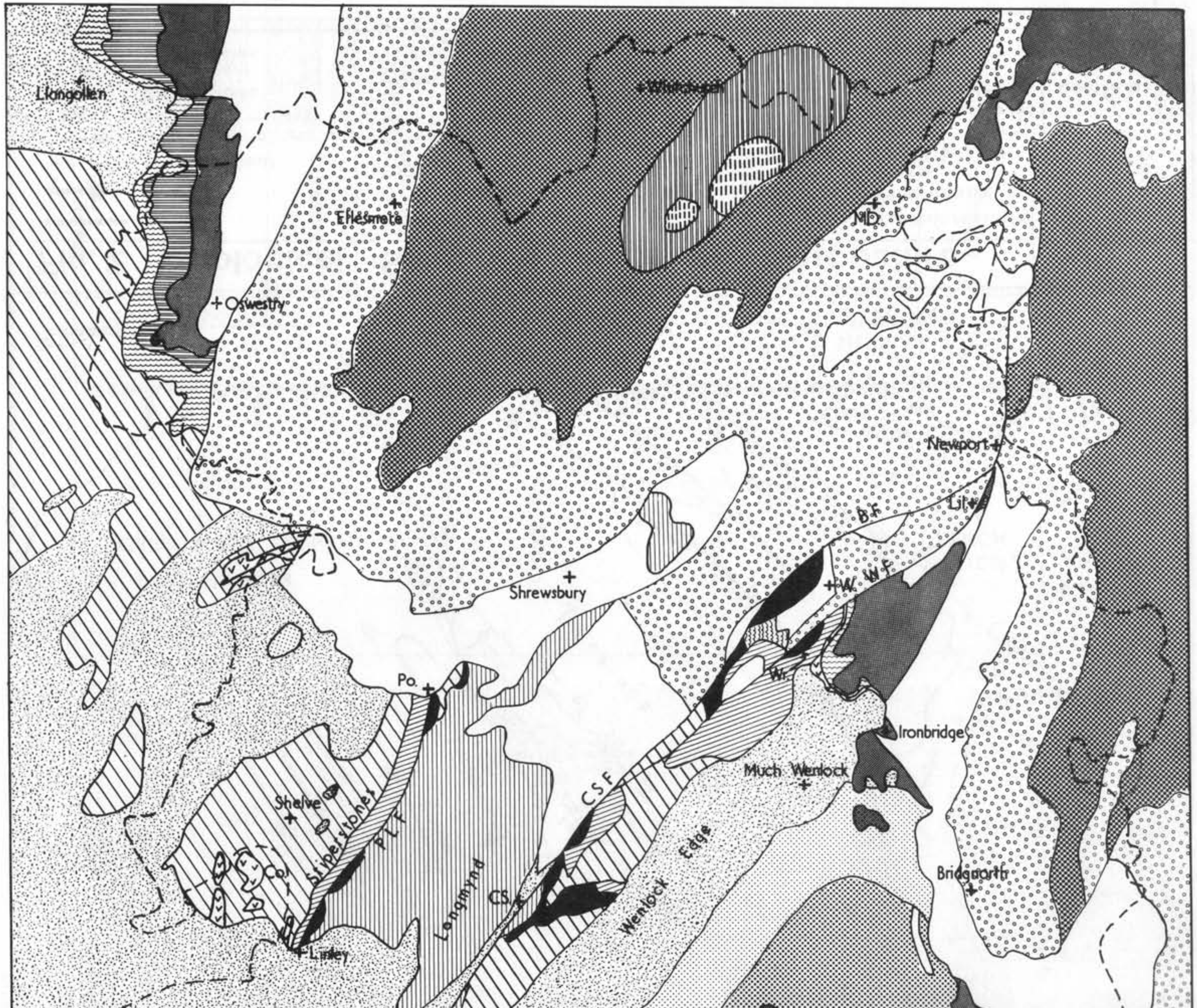
Llangollen
Ellesmere
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Newport
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W. W.F.
Shrewsbury
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Po.
Ironbridge
Much Wenlock
Bridgnorth
C.S.F.
Shelve
Stiperstones
P.L.F.
Longmynd
CS.
Wenlock Edge
Col
Linley

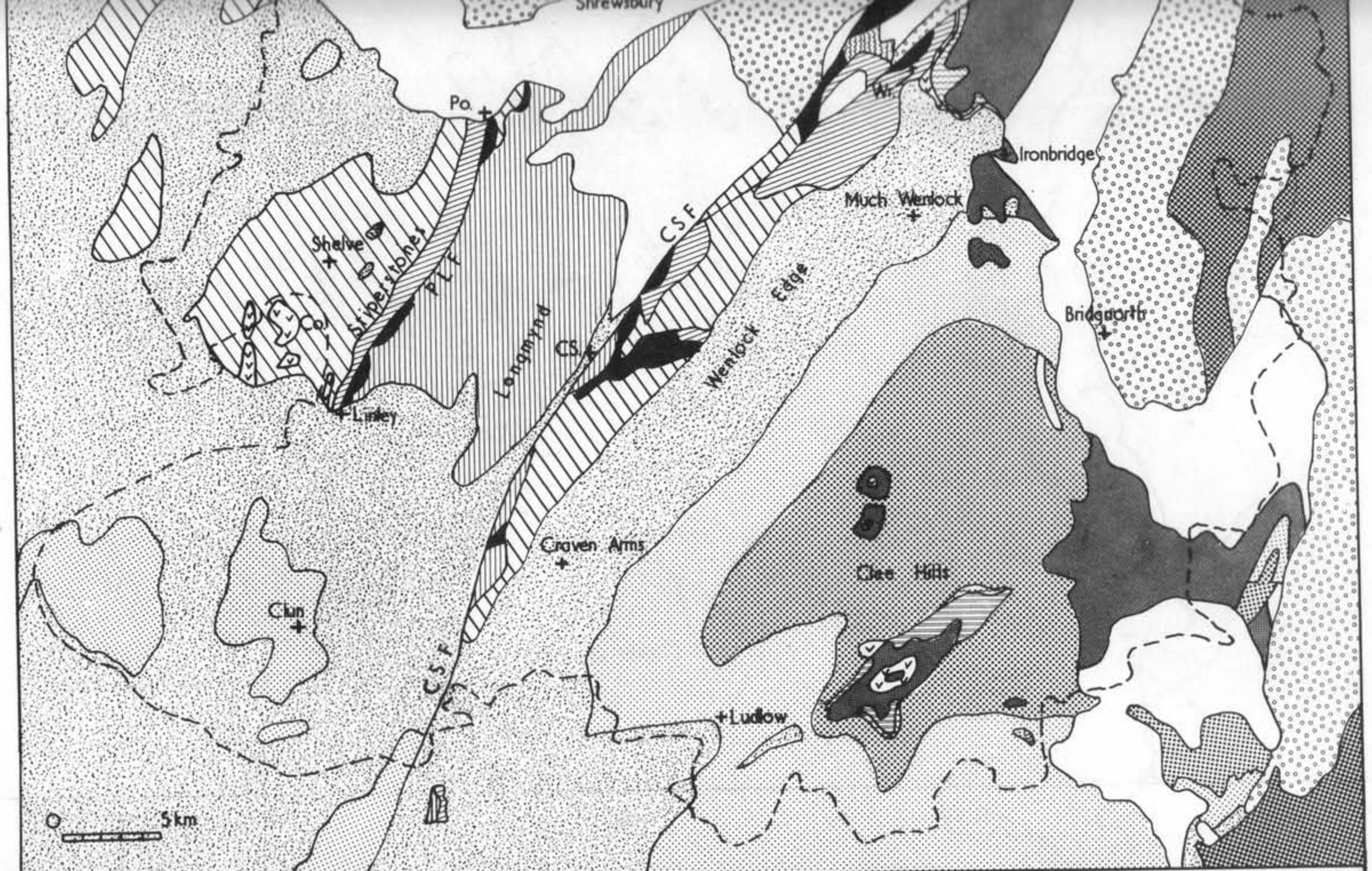
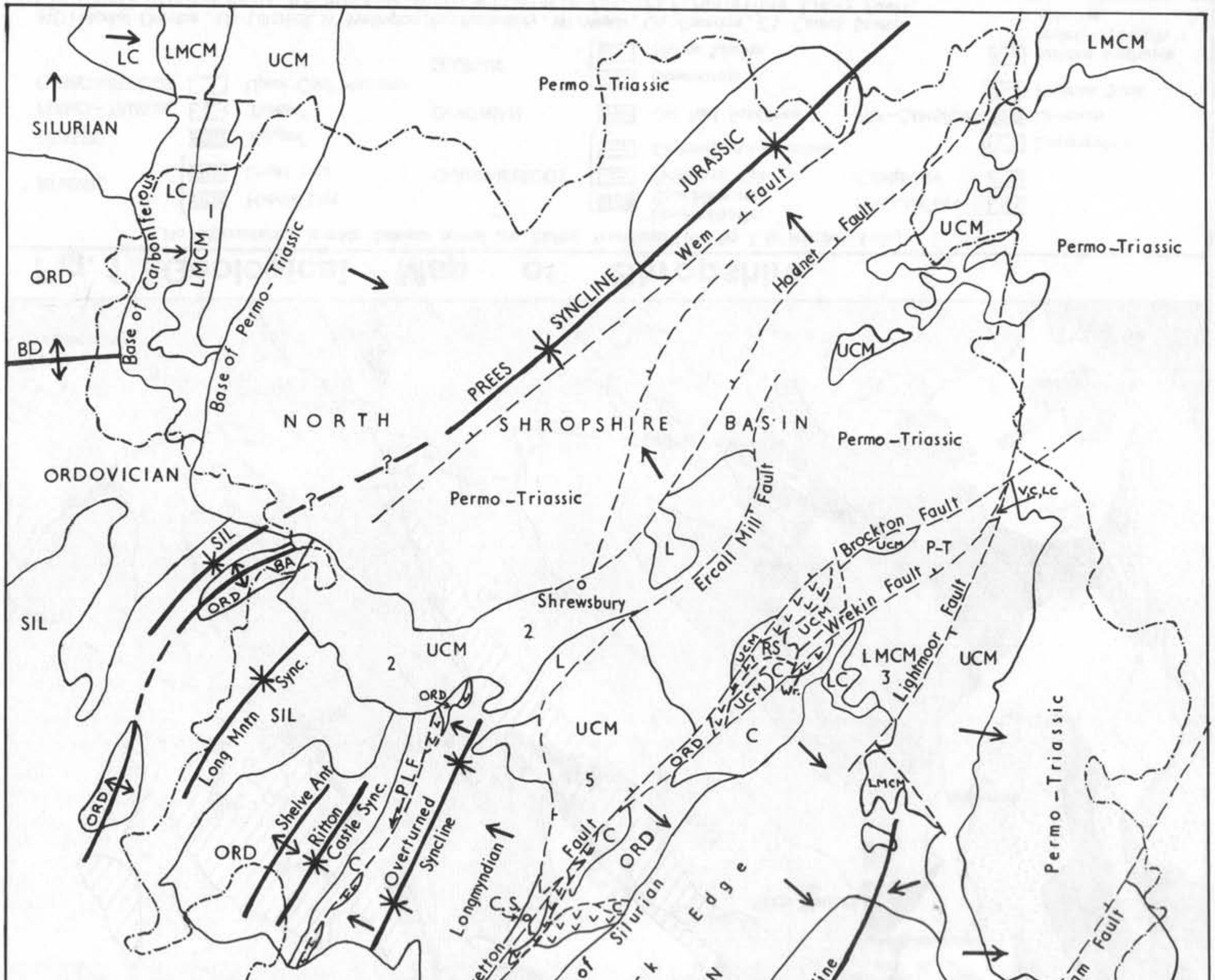


Fig. 1 Geological Map of Shropshire

No differentiation is made between normal and faulted boundaries (see Fig. 2 for principal faults)

- JURASSIC: Middle Lias; Lower Lias
- TRIASSIC: "Keuper"
- PERMO - TRIASSIC: "Bunter"
- CARBONIFEROUS: Upper Coal Measures
- CARBONIFEROUS: Lower & Middle Coal Measures; "Millstone Grit"; Carboniferous Limestone
- DEVONIAN: Old Red Sandstone
- SILURIAN: Downtonian; Marine Silurian
- ORDOVICIAN
- CAMBRIAN
- PRE-CAMBRIAN: Longmyndian; Uriconian; Rushton Schist
- Intrusive & extrusive andesites, basalts & dolerites.

MD: Market Drayton, Lil: Lilleshall, W: Wellington, Po: Pontesbury, Wr: Wrekin, Co: Corndon, CS: Church Stretton.
CSF: Church Stretton Fault, BF: Brockton Fault, WF: Wrekin Fault, PLF: Pontesford Linley Fault.



LC
LMCM
UCM
SILURIAN
ORD
BD
Base of Carboniferous
Base of Permo-Triassic
NORTH SHROPSHIRE BASIN
ORDOVICIAN
Permo-Triassic
JURASSIC
PREES SYNCLINE
Wem Fault
Hodnet Fault
UCM
LMCM
Permo-Triassic
Ercall Mill Fault
Brockton Fault
P-T
Wrekin Fault
Lightmoor Fault
VC,LC
Shrewsbury
SIL
BA
ORD
Long Mntn Sync.
Shelve Ant.
Ritton Castle Sync.
PLF
Overturned Syncline
Longmyndian
C.S.
Silurian
Edge
RS
Wr.
L
C
1
2
3
5
Fault

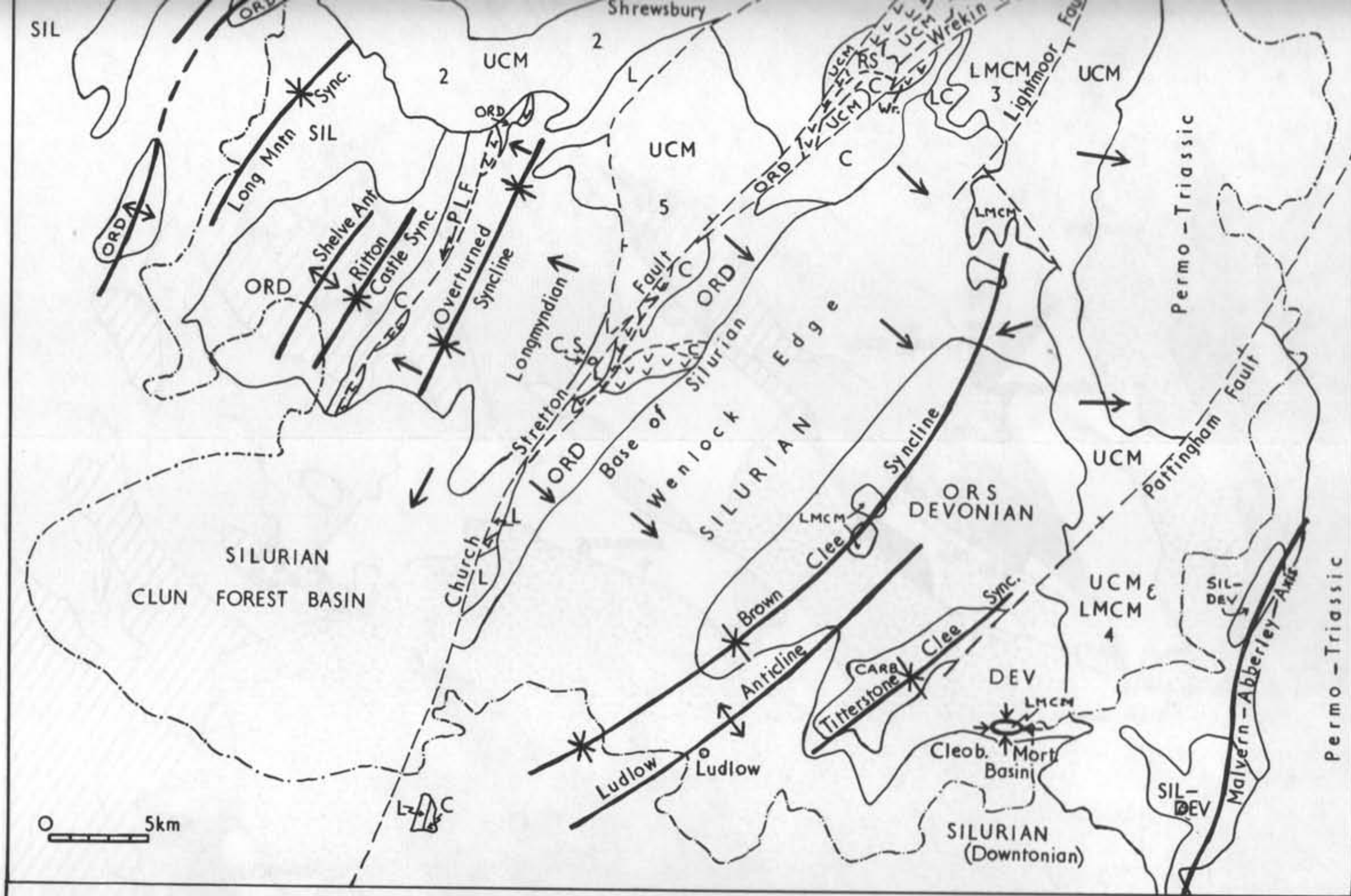


Fig. 2 Geological Structure Map of Shropshire

	Anticline	RS	Rushton Schist	PLF	Pontesford-Linley Fault	
	Syncline	C	Cambrian	P-T	Permo-Triassic	
	Principal Fault	ORD	Ordovician	Wr.	Wrekin	
	General dip of strata	SIL	Silurian incl. Downtonian	C.S.	Church Stretton	
BA	Breidden Anticline	DEV	Devonian (Old Red Sandstone)	1	Oswestry	Coalfields
BD	Berwyn Dome	LC	Lower Carboniferous & Namurian	2	Shrewsbury-Hanwood	Coalfields
vvv	Uriconian	LMCM	Lower & Middle Coal Measures	3	Coalbrookdale	Coalfields
L	Longmyndian	UCM	Upper Coal Measures	4	Wyre Forest	Coalfields
				5	Leebotwood	Coalfields

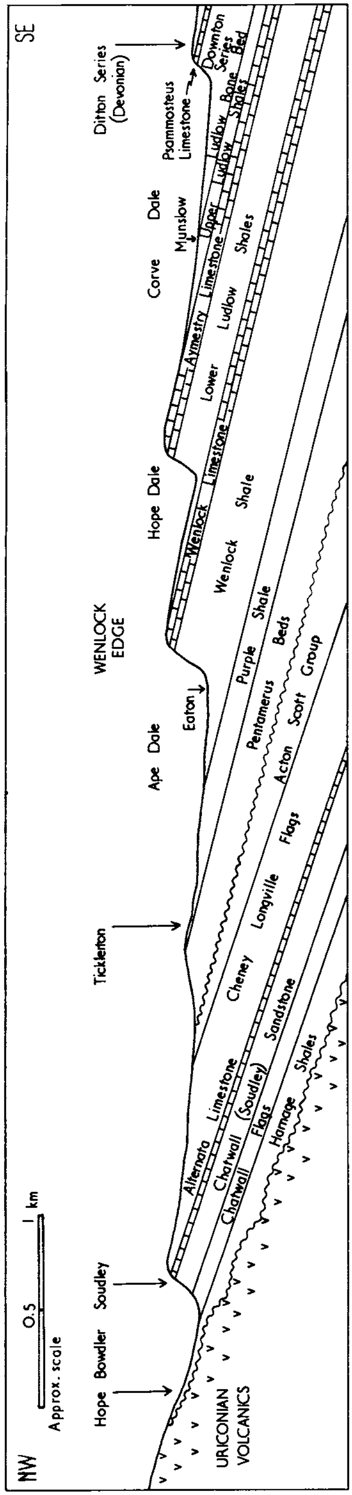


FIG. 13.

Diagrammatic cross section from Hope Bowdler to Corve Dale showing the scarp and vale landscape within the Ordovician and Silurian rocks, including Wenlock Edge. Thickness of beds not to scale.