# Permo-Carboniferous earth movements, Bristol and Gloucester region

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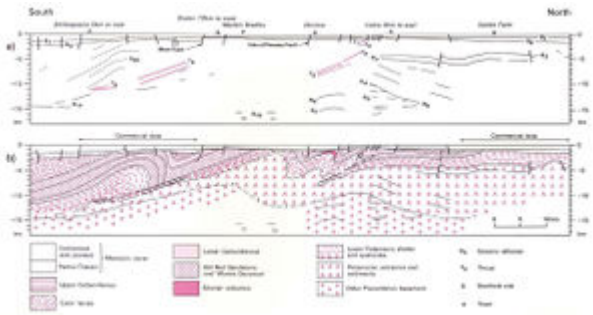
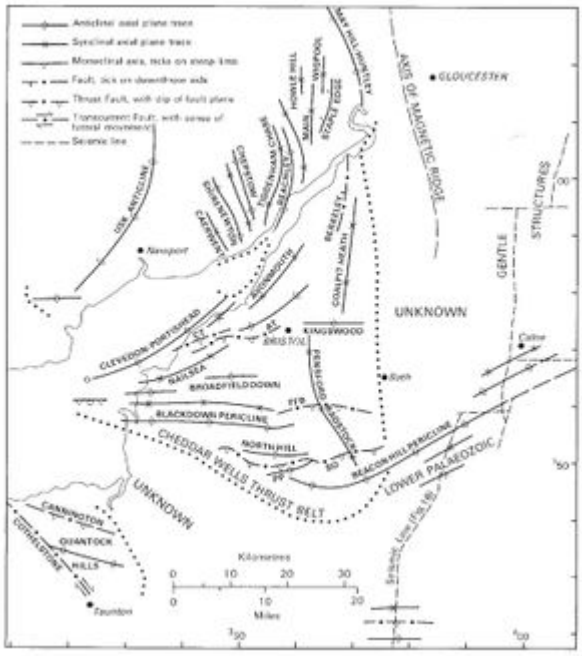
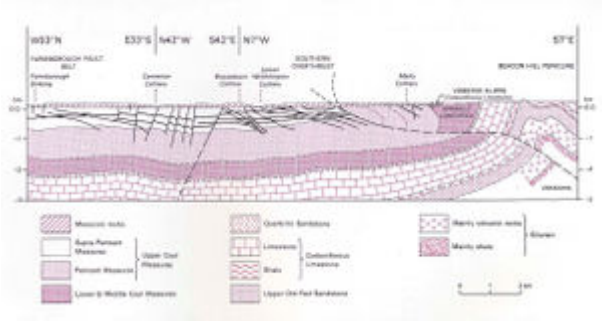
## Permo-Carboniferous movements



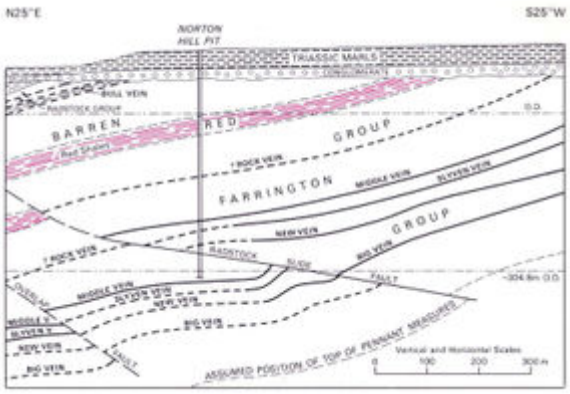
North–south sections showing a) principal reflectors identified from seismic reflection sections and b) geological interpretation of reflection events (after Chadwick, Kenolty and Whittaker, 1983). (P948971)



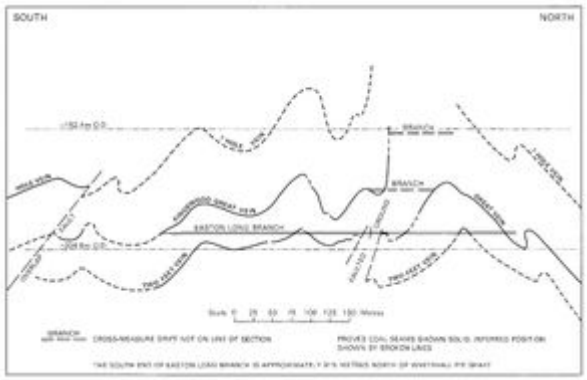

Major structural features in the Palaeozoic rocks of the region and of the adjoining area to the west as far as the Usk Anticline. Abbreviations: AT Avon Thrust, CT Clevedon Thrust, FFB Farnborough Fault Belt, PP Pen Hill Pericline, SO Southern Overthrust. (P948970)



Horizontal section across the Radstock Coal Basin. The structure at depth remains unproved because no workings penetrate to the Pennant Measures north of the Southern Overthrust. (P948972)




Overthrust faulting. The 'Radstock Slide' at Norton Hill Colliery, Avon. (P948973)




Section through part of the Middle Coal Measures at the western end of the Kingswood Anticline, Easton Colliery, Bristol (after E H Staples). (P948974)

The main Variscan earth movements represent the most cataclysmic event to have affected the rocks of the region. The main movements took place between late Carboniferous (Stephanian) and earliest Permian times, shown by evidence in south-west England. In the present region the youngest deformed rocks are the Cantabrian Coal Measures of the Forest of Dean, and the oldest undeformed rocks are Permian strata proved at depth, beneath the Mesozoic rocks of the Central Somerset Basin.

The region spans the Variscan Front, to the south of which the Devonian and Carboniferous rocks are folded and thrust-faulted along dominantly east-west lines. Eastwards from here seismic reflection evidence is now available to show a cross-section of the front at depth beneath the cover

of Mesozoic strata (P948971). Between Belgium and south-west Wales the foreland area to the north of the front is characterised by a chain of late Carboniferous coal measures basins whose development is linked to that of the rising Variscan Fold Belt to the south. In the present region these comprise the Forest of Dean, Bristol-Somerset, Severn and Oxfordshire coalfields. South of the front, the Variscan Fold Belt within the region is divisible into two zones, a northern zone comprising the former area of Old Red Sandstone and Carboniferous Limestone shelf sedimentation, and a southern zone with thick marine Devonian and basinal Carboniferous shale ('Culm') sequences. The major anticlinal fold depicted in the southern zone is thought to be structurally analogous to the North Devon–Quantocks anticline. The rocks of the Variscan Fold Belt are highly disturbed and commonly cleaved, whilst those of the foreland are much less disturbed.

The structural pattern within the region (P948970) indicates that the trend of the folds veers anticlockwise from an east-west trend within the Variscan Fold Belt in the south, to a nearly north-west-south-east trend in the north. In conformity with these trends, the steeper limbs of the folds change from north-facing in the south to south-west-facing in the north. These changes may be related to increasing distance from the main Variscan fold belt and show the increasing influence of inherited basement structures. Thus the north-easterly trends west of Bristol appear to reflect the influence of the Lower Severn Axis, while the northerly directed trends farther north appear to be related to the Malvern Fault Belt.

The base of the Carboniferous in the Pensford and Radstock areas is estimated to lie at from 2800 m below OD to a maximum of 3600 m, and in the deepest part of the Coalpit Heath Syncline the figure is about 2300 m. Although much of this depression is due to epeirogenic movements, mainly during the Carboniferous period, it cannot all be so explained and an important structural basin must have formed during an early phase of the Variscan movements. This was subsequently much modified by east-west-trending structures belonging to the later, main phase of the movements.

## Cannington–Mendips

The largest known Variscan fault of the district lies to the north of Bridgwater, where Namurian strata are downthrown against the Middle Devonian Ilfracombe Beds on its north side, a stratigraphical interval estimated to represent at least 4 km of strata. The extensive Mesozoic cover unfortunately obscures the detailed relationships and doubt must remain as to the nature of the fault, but the most likely possibility is a high-angle reverse fault, possibly low-angle at depth and lying en échelon with that recently recognised on seismic reflection evidence to the east (Figure 16; Chadwick et al., 1983)[1]. No further exposures are seen until the Men- dips are reached, though the seismic data indicate the presence of large folds involving the Tremadoc-to-Carboniferous succession.

The Mendip ridge (or 'axis') constitutes an envelope of Old Red Sandstone and Carboniferous Limestone that wraps around the south and south-western edge of the Radstock Syncline. It consists of four en échelon periclines, the axes of which run approximately east-west. The folds are strongly asymmetrical, with steeper northern limbs that may be vertical or even overturned towards the north. Southerly dipping displacements parallel to the fold axis comprise thrusts or reverse faults associated with the steep limbs, and normal or lag faults associated with the gentler dipping southern limbs. Both these fault-types may end against or pass laterally into faults that cut across the fold axes at a high angle and which may have an appreciable component of lateral displacement. A slightly later phase of movement is represented by the Cheddar–Wells Thrust/Belt which consists of several folds and thrust slices that were apparently piled up against the south-western side of the Mendip 'Axis'. In the Mendip area as a whole the limestones and sandstones involved in the structures behaved competently, giving rise to mainly concentric folding, although in local conditions of extreme stress, as in parts of the Cheddar–Wells Thrust Belt, the Lower Limestone

Shale behaved incompetently and formed a plane of decollement above which the Carboniferous Limestone was folded independently of the underlying Devonian strata.

An analysis by Williams and Chapman (1986)[2] of the Mendip–Bristol area, using rigorous geometrical reconstruction techniques, has re-interpreted the structural evidence in terms of 'thin skin tectonics' similar to those described from the Appalachians and elsewhere. It is postulated that the observed thrusts flatten at depth and join a gently (3°) dipping plane of décollement that underlies the whole area at a depth estimated to range from 3 to 5 km. The klippen of Carboniferous Limestone (see below) that lie in front of the Mendips are considered to be the remnants of 'first generation' thrusts that outcrop farther south but were folded as 'second generation' folds and thrusts formed in a 'piggy back' development.

## East of the exposed coalfields

The eastern side of the Radstock Syncline is virtually unknown because mining never extended eastwards of the incrop of the Radstock Formation beneath the Mesozoic cover rocks. It was conjectured by Welch, in a classic paper (1933)[3], that a mirror image of the Mendip ridge with en échelon periclines of Old Red Sandstone and Carboniferous Limestone might be present to the east of the syncline. Since that time, data from an aeromagnetic survey, boreholes and, most recently, a seismic reflection survey indicates that this is probably substantially correct (P948971), except that the individual folds are aligned in a north-east-south-west rather than an east-west direction. Large areas of Tremadocian rocks are now known to be present immediately beneath the Mesozoic cover east of the folded Devonian and Lower Carboniferous rocks that represent the eastern continuation of the Mendip Axis.

## Radstock and Coalpit Heath synclines

The structure of the Radstock Syncline is markedly different from that of the Mendips; the folding is relatively gentle, apart from the southern end, and the release of stress was predominantly by faulting. This difference is due to the strongly incompetent nature of the Lower and Middle Coal Measures which allowed the thick mass of competent sandstones comprising the Pennant Measures to fold independently of the strata below.

This is most clearly seen at the southern end of the coalfield where the Lower and Middle Coal Measures are flanked on their south side by the steeply dipping Carboniferous Limestone, which comprises the northern limb of the Beacon Hill Pericline, and on their north side by a huge fold of regularly dipping Pennant Measures that are inverted over much of their length (P948972). The intervening Coal Measures are strongly contorted and squeezed. At Vobster and Luckington, klippen of Carboniferous Limestone rest directly on these measures, which have been mined underneath. The mode of structural emplacement of these klippen, and apparently similar ones north of the Blackdown and North Hill periclines at Churchill and East Harptree respectively, has long been a matter for debate. One explanation has been given above; another (P948974) postulates the development of 'knee' folds in the incompetent Coal Measures that formed in front of the rising periclines and which, as folding proceeded, led to large-scale inversion, then stretching, and finally gravitational gliding. These processes were no doubt aided by the weight of the superincumbent flap of Pennant and higher measures in the upper part of the fold, which may itself have become detached from the crest of the fold before folding ceased. The front of the Pennant fold is terminated by a reverse fault, or thrust, known as the Southern Overthrust (or Great Southern Overthrust) which has an estimated upthrow to the north of at least 750 m. It has generally been considered, hitherto, that the overthrust died out within a fairly short distance to the south, but recent seismic evidence along the strike to the east indicates the likely persistence of thrust faults at some

considerable depths (P948971). This supports the supposition that the Southern Overthrust is represented westwards, beyond the confines of the coalfield, as the Emborough Thrust, and then as the South-Western Overthrust in the Cheddar-Wells Thrust Belt even farther to the west.

Due to intensive mining in the past, the structure of the Upper Coal Measures is best known in the central parts of the Radstock Syncline, northwards from the Southern Overthrust. Faulting normal to the axis of the syncline is widespread and appears to be arranged in three belts. The southern half of the syncline is characterised by numerous low-angle thrust faults dipping in a southerly direction and of which the Radstock Slide (P948973) is the best known. A similar, though smaller group of southerly-dipping overlap faults, with an overall northwards throw of around 200 m to 250 m, is present at the northern limit of the syncline, and is known as the Farmborough Fault Belt. In the middle and deepest part, between Braysdown and Dunkerton, there is a swarm of east–west- to ESE–WSW- trending normal faults that dip to the north and rotate successive blocks downwards to the south, and which may possibly be related to underthrusting beneath. Cross-cutting these faults, there is a later series of north-south-trending normal faults subparallel to the axis of the syncline that apparently represents a final tensional phase of earth movement. The Clandown and Luckington faults are the most important of these; the former has a maximum downthrow to the west of 220 m.

The known Coal Measures of the western and northern parts of the Pensford Syncline are relatively far less disturbed than those of the Radstock Syncline but, farther north, the Kingswood Anticline (P948974) provides a striking contrast in which steep disharmonic folding is accompanied by thrust faulting, not only from the north and south but also from the east and west (Kellaway and Hancock, 1983, p.102)[4]. The structure appears to owe its prominence to the incompetence of the Lower and Middle Coal Measures, for the structure in the adjacent massive Pennant Measures on either side is much simpler. Along the main axis of the anticline, it appears that the earliest stress relief was upwards and, indeed, some of the folds are diapiric, i.e. they burst through the overlying strata.

Farther north the Coalpit Heath Syncline exhibits a relatively simple structure, with prominent north–south and east–west-trending tensional faults in its central parts. The syncline conforms to the regional structural pattern with its north–south elongation and appreciably steeper dips (up to 40°) on its eastern limb.

## West of Bristol

North of the Mendips and west of the main coalfields, the exposed Devonian–Carboniferous successions comprise mainly competent limestones and sandstones, the Lower and Middle Coal Measures having been largely overstepped by the Pennant Measures; hence the folding is typically concentric, except in areas of most intense deformation. The belt of most complex structure, including important thrusting from the south and the south-east, stretches from Clevedon and Portishead, through the Avon Gorge, to King's Weston and Henbury, and thence to Thornbury. Here, both the Lower Limestone Shale and the Clifton Down Mudstone may locally behave incompetently, thereby leading to disharmonic folding above and below these formations. Within this belt, on the King's Weston–Henbury ridge, the strata are highly disturbed and extensively overturned to the north and north-west, while the intense folding of the Lower and Middle Coal Measures in the Cattybrook area, south-west of the Patchway Railway Tunnel, is associated with the north-east-trending Ridgeway Thrust Fault.

West of the River Severn, the progressive southwards anticlockwise swing of the fold axes reaches its greatest extent with the main folds in the Forest of Dean, which trend NNW–SSE. Faulting is normal and the folds are asymmetrical, with the steeper limbs facing to the west-south-west. The main Variscan folding is closely aligned, but not coincidental with that of the earlier intra-Carboniferous phase.

# References


1. ↑ Chadwick, R A, Kenolty, N, and Whittaker, A. 1983. Crustal structure beneath southern England from deep seismic reflection profiles. *Journal of the Geological Society of London*, Vol. 140, 893–911.
2. ↑ Williams, G D, and Chapman, T J. 1986. The Bristol-Mendip foreland thrust belt. *Journal of the Geological Society of London,* Vol. 143, 63–73.
3. ↑ Welch, F B A. 1933. The geological structure of the eastern Mendips. *Quarterly Journal of the Geological Society of London,* Vol. 89, 14–52.
4. ↑ Kellaway, G A, and Hancock, P L. 1983. Structure of the Bristol district, the Forest of Dean, and the Malvern Fault Zone. 88-107 in *The Variscan Fold Belt in the British Isles*. Hancock, P L (editor). (Bristol: Adam Hilger.)



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