# Chapter 10 Culm Trough

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## Introduction

The Lower Carboniferous rocks of Devon and Cornwall are quite dissimilar from those of an equivalent age elsewhere in Britain. There are no thick developments of bedded limestone to produce characteristic landforms such as steep scars, upland pavements and deep gorges, but instead a relatively thin sequence of shale and chert forms rolling countryside in the lee of Exmoor and Dartmoor. Nevertheless, this very difference attracted the attention of many eminent geologists during the early 19th century and it is their work that provides the basis for our current stratigraphical understanding in this area.

Whilst Conybeare and Phillips (1822) first introduced the concept of the 'Carboniferous System', It was Sedgwick and Murchison (1840) who defined the sedimentary rocks of Carboniferous age in south-west England as 'Culm Measures'. This stratigraphical term is entrenched in the literature but its main purpose these days is to distinguish the fill of the E–W-trending Culm Trough from better known Carboniferous Limestone, Millstone Grit and Coal Measure sequences farther north. The core of the Culm Trough is dominated by rocks of Silesian age, but two narrow and discontinuous outcrops of Dinantian rocks occur along the northern and southern margins, creating a broadly synclinal pattern (Figure 10.1). This simple pattern, however, obscures a more complex tectonic setting because the northern outcrop is tightly folded and occurs largely *in situ,* whilst farther south, most of the Dinantian succession has been transported into its present position by low-angle thrust faults in the region between Bodmin and Dartmoor.

### History of research

In 1797, William Maton, a Fellow of the Linnaean Society, published a geological map of south-west England based on the observations he had made during his extensive travels around the peninsula between 1794 and 1796. Maton's map differentiated the major rock types but did not distinguish their age or structure. These refinements emerged when Sir Henry De la Beche conducted a series of field mapping projects during the 1820s that were to form the basis of the early [British] Geological Survey maps. These early maps distinguished a 'Grauwacke Group' that De la Beche correlated with similarly deformed sequences in Wales. Although Conybeare and Phillips (1822) had recognized the Carboniferous System at about the same time, De la Beche considered the 'Grauwacke' to pre-date it and this view was widely held until the 1830s.

Meanwhile, Sedgwick and Murchison began work in Devon in 1836 that led them to consider a Carboniferous age for much of the 'Grauwacke'. When their findings were published in 1840 they introduced the name 'Culm Measures', and distinguished between shale-dominated Lower Culm and sand-dominated Upper Culm successions. De la Beche was obviously influenced by their ongoing research for he adopted the same terminology in his regional memoir (1839) and subsequent map revisions.

A second phase of mapping began in 1870 through the efforts of William A.E. Ussher who was involved in the revision of almost all the existing [British] Geological Survey maps in south-west England. Remembered principally for his meticulous fieldwork, maps and accompanying memoirs, he also published several refinements (Ussher, 1887, 1892, 1901) to the Culm Measure stratigraphy of Sedgwick and Murchison (1840). Hinde and Fox (1895), who worked extensively on the distinctive radiolarian cherts of the Lower Culm, provided another important contribution during this period. Their Culm Measure succession, comprising basal dark shales with limestones, overlain by thin sandstones, cherry mudstones and a thick sequence of shales and sandstones, has survived, in principle, to the present day.

Subsequently, major advances in understanding the complex Lower Carboniferous stratigraphy were gained through systematic palaeontological studies around the Devonian–Carboniferous boundary (Goldring, 1955; Selwood, 1960; Selwood *et al.,* 1982) and within overlying horizons (Butcher and Hodson, 1960; Prentice, 1967). This emerging blostratigraphical framework was complemented by regional mapping projects that addressed both the northern outcrops (Prentice, 1958, 1960; Thomas, 1963a) and those farther south, around the flanks of Dartmoor (Dearman and Butcher, 1959). Much of this work is summarized in the regional guide for south-west England (Edmonds *et al.,* 1975).

Systematic field mapping over the last three decades, mainly under the auspices of the British Geological Survey, has resulted in a series of 1:50 000 map sheets and explanatory memoirs that refine our geological understanding and challenge existing theories. These important sources of reference are, however, necessarily detailed and they sometimes fail to convey the regional sense that emerges only when adjacent areas are examined. More palatable, perhaps, are two books that consider the geology of Devon (Durrance and Laming, 1982) and Cornwall (Selwood *et al.,* 1998) as a whole. They serve to remind the reader that two centuries of research have contributed substantially towards integrating the Lower Carboniferous of the Culm Trough into the wider context of British stratigraphy.

## Stratigraphy

Sedgwick and Murchison (1842) first made the observation that many of the Lower Carboniferous sequences in the Culm Trough resemble those in the Belgian and north German segments of the Variscan fold belt, a view amplified by subsequent workers (e.g. Matthews, 1977a,b; Franke and Engel, 1982). The Culm Trough has now been mapped in some detail and a plethora of lithostratigraphical schemes have been established (Figure 10.2). These reflect a wide range of depositional facies which, along with poor exposure and tectonic complexity, conspire to hinder correlation.

There is no obvious lithostratigraphical boundary at the base of the Carboniferous System in south-west England. It occurs within a shale-dominated sequence that formed during a widespread phase of reduced subsidence and sedimentation (Goldring, 1962). Only occasionally do the shales contain adequate fossils to enable the Devonian–Carboniferous boundary to be recognized.

The overlying Dinantian beds of the Codden Hill Group are 250–275 m thick around Barnstaple, where they comprise grey shales, overlain by a thicker development of pale-weathering cherts, then more dark shales containing large lenses of limestone (Edmonds *et al.,* 1985). This succession has been resolved by Jackson (1991) into a more formal stratigraphy and tentatively correlated with British stage names. Farther east, in the Bampton and Westleigh region, the Dinantian sequence contains a greater proportion of limestone, including thick limestone turbidites, but is less securely dated (Figure 10.2).

In the area between Bodmin and Dartmoor, the structural setting is more complex due to large-scale overthrusting (Isaac *et al.,* 1982). A variety of paralic, shelf and basin facies are contained within successive nappes and there is no continuity between the stratigraphy at Yeolmbridge Quarry and Viverdon Down Quarry (Figure 10.2). Interestingly, although the Teign Valley is on the same trend (Figure 10.1), its succession more closely resembles that around Barnstaple, both being dominated by basinal shales and cherts. There is, however, greater evidence of contemporaneous volcanic activity in the Teign Valley, where numerous tuff bands and dolerite sills punctuate the sequence. Whilst the Teign Valley succession is strongly folded Into an anticlinorium, Selwood *et al.* (1984) suggest that it is largely in *situ* and occurs at the base of a pile of thrust sheets.

Towards the top of the Dinantian sequence, distinctive grey, calcareous and siliceous shales locally yield abundant bivalves and ammonoids. This important Interval, informally called the Tosidonia Beds' or Neoglyphioceras spirale Beds', is of Brigantian ($P_{1b}$–$P_{1d}$) age and is the most widespread stratigraphical marker in the basin (Figure 10.3). Above it, black shales and, ultimately, turbiditic sandstones predominate. The sandstones herald the onset of a diachro-nous phase of flysch sedimentation which resulted in the filling of the Culm Trough by the end of Westphalian C (Bolsovian) times. The Carboniferous System is unconformably overlain by the New Red Sandstone.

Biostratigraphical control is only patchily developed in the Culm Trough but correlation with the standard stages recognized elsewhere in Britain (George *et al.,* 1976; Riley, 1993) is gradually emerging. Shelf macrofossils are generally scarce but conodonts, miospores, ammonoids and bivalves are more widespread and underpin most age determinations (Figure 10.3). The conodont scheme (Stewart, 1981) used here has proved particularly useful in the Culm facies, as has the miospore zonation that was developed principally for the Carboniferous succession of Ireland (Higgs *et al.*, 1988a,b).

However, the detailed correlation between these microfossils and the ammonoids is still insecure because they rarely occur together in the same strata. Trilobites, brachiopods and ostracodes provide stratigraphical refinement locally, particularly in the Courceyan and Chadian stages, but successions of Arundian, Holkerian and Asbian age are more difficult to discriminate because they are usually condensed and poorly fossiliferous. For this reason the assignment of lithostratigraphical units to particular stages is, in the Culm Trough, the exception rather than the rule.

### Geological setting

During Devonian times, south-west England was located at the southern margin of the 'Old Red Sandstone' continent. Intense tropical weathering produced an enormous volume of sediment that was deposited in continental and nearshore settings whilst, in the deeper water farther south, shales, limestones and contemporaneous volcanic rocks accumulated.

Sedimentation during Dinantian times was influenced by rapid subsidence and an episodic northward marine transgression (Clayton *et al.,* 1986) that drowned the Devonian coastline and created a deep basin — the Culm Trough. This basin, variously attributed to a foreland, thrust-top or pull-apart tectonic setting, was effectively starved of sediment input and received only small amounts of shale and radiolarian chert and even less coarse-grained sediment. In north and mid-Devon, sediments and fossils were swept into the basin by turbidity currents that scoured the carbonate shelf area to the south of the Wales–Brabant Massif (Thomas, 1982). Farther south, in mid-Cornwall and south Devon, the Dinantian succession is equally thin and comprises radiolarian chert, black shale and volcanic tuff. Occasional coarse deltaic and turbiditic sandstones developed in advance of the migrating Variscan deformation front that formed the southern margin of the Culm Trough. The range of palaeoenvironments envisaged for the Culm Trough during Dinantian times is illustrated in (Figure 10.4).

Throughout Silesian times, clastic sedimentation assumed increasing importance as the basin Filled, initially with sandy turbidites and then with thick, south-prograding deltaic and paralic sequences (Thomas, 1988). At the close of the Carboniferous Period, the Variscan deformation culminated in widespread folding, thrusting and the intrusion of major granitic plutons such as Bodmin Moor and Dartmoor. The thrust and nappe terrane to the south (Isaac *et al.,* 1982), with its wide range of facies, indicates that the Culm Trough was originally far more extensive before suffering tectonic shortening of at least 50% during the deformation phase. Thus the current Dinantian outcrops do not convey their spatial relationship at the time of deposition, but rather reflect large-scale, northerly directed thrusting that has telescoped the southern successions to within 40–50 km of the folded, but little displaced, northern outcrops between Barnstaple and Westleigh (Figure 10.1).

### GCR site coverage

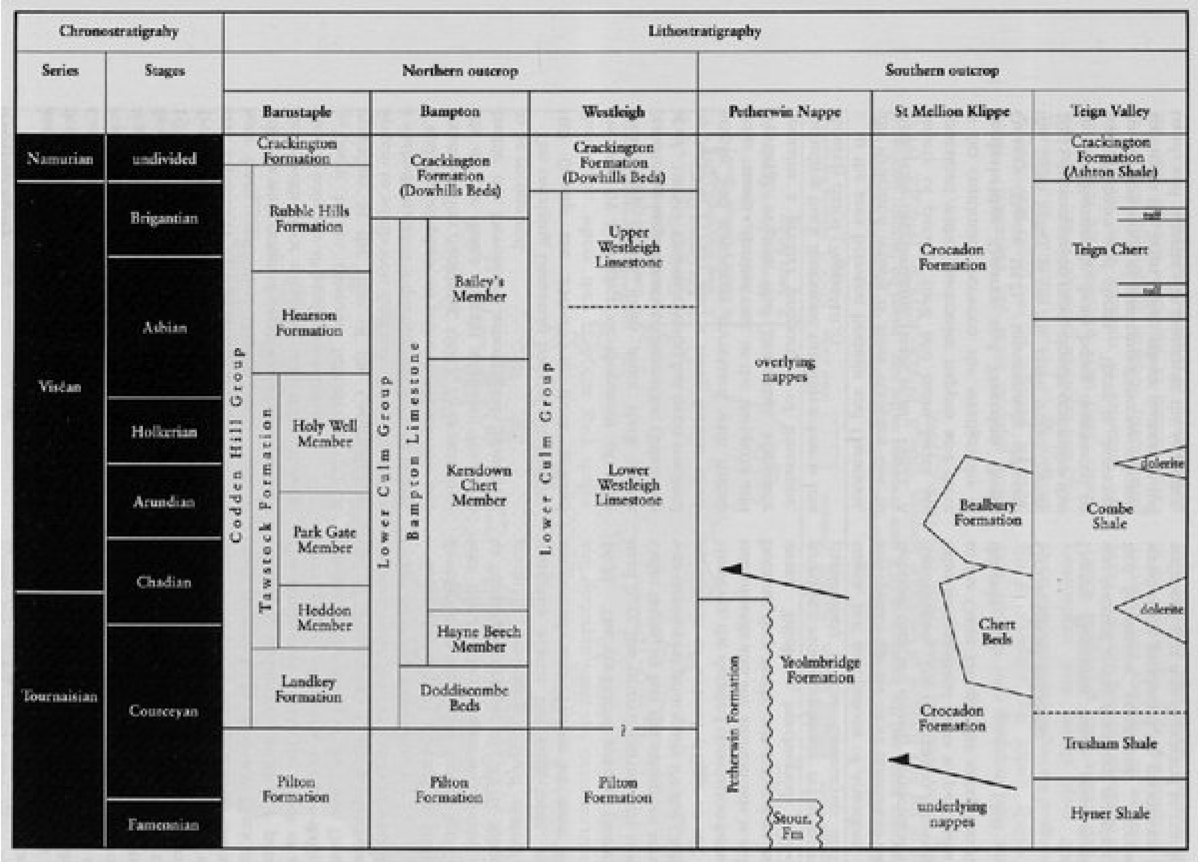
The nature of exposures in the Culm Trough is very variable. Although the coastal sections are unrivalled, most of the Lower Carboniferous outcrops are restricted to quarries and road cuttings. Consequently, they tend to be limited in scale, accessibility and permanence. The nine sites, discussed below, range from latest Devonian to Arnsbergian in age and thus encompass the entire Lower Carboniferous interval. Fossil evidence for the Pendleian and Arnsbergian stages is rather meagre although the basal beds of the Crackington Formation in mid-Devon yield ammonoids that suggest there is a conformable passage between the Lower and Upper Carboniferous sequences in south-west England. Cleal and Thomas (1996) specifically address sites within the Upper Carboniferous sequence, concentrating mainly on the Namurian sections exposed along the north coast.

The first six sites are located in the northern outcrop (Figure 10.1) and (Figure 10.2) and they illustrate a wide stratigraphical diversity. In the Barnstaple area, the Fremington Quay coastal section spans the Devonian–Carboniferous boundary and includes the stratotype for the upper part of the richly fossiliferous Pilton Formation. Nearby, the chert-dominated succession at Park Gate Quarry provides important fossils of Chadian age and the stratotype for the Tawstock Formation. Farther inland, around Bampton, the disused quarry at Kersdown Quarry reveals an important stratotype for part of the Viséan chert and limestone succession; the transition beds across the Brigantian-?Pendleian boundary are exposed at Kiln Cottage Quarry. At the eastern end of the outcrop, a thicker development of limestone (the Upper Westleigh Limestone) is spectacularly preserved in the disused quarry at West Whipcott Quarry. Similar lithologies at Stout's Cottage Quarry contain unique fossil assemblages that indicate a late Viséan age for this localized turbiditic sequence that was derived from an adjacent shelf.

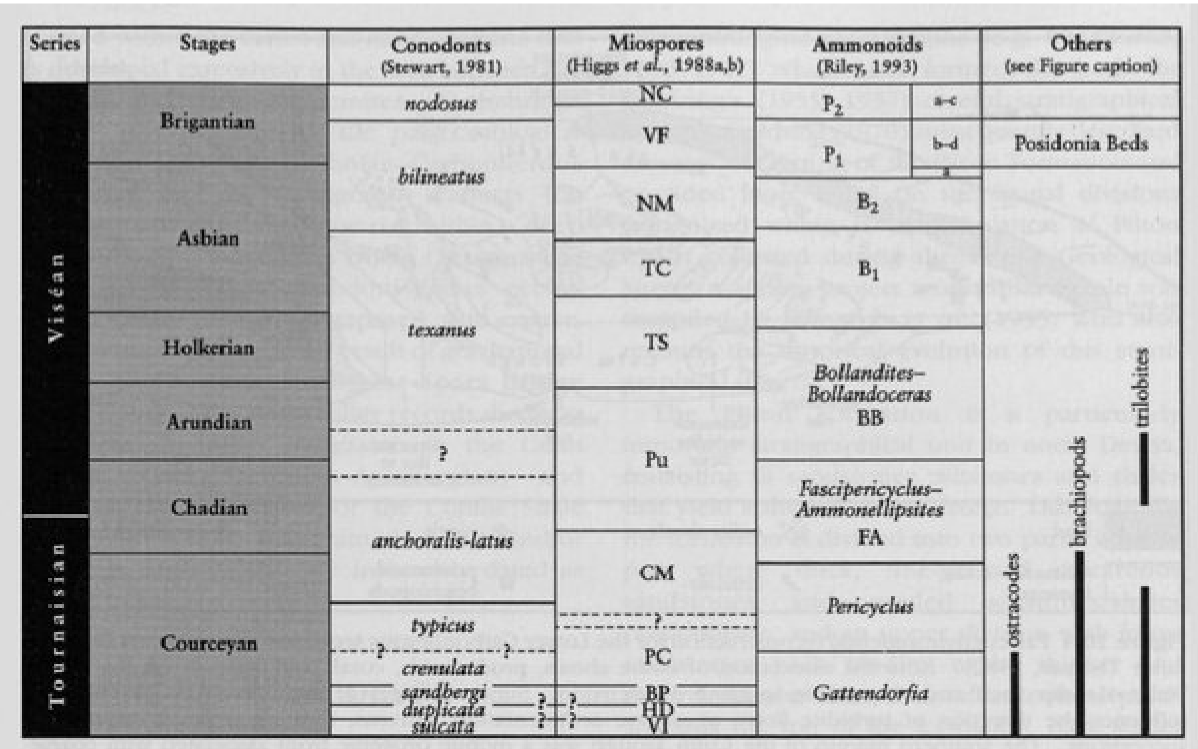
The remaining three sites occur much farther south (Figure 10.1) and (Figure 10.2). Yeolmbridge Quarry and Viverdon Down Quarry are located within the thrust and nappe terrane that is developed extensively in the area between the Bodmin and Dartmoor granites. Yeolmbridge Quarry is a key site for the palaeontological definition of the Devonian–Carboniferous boundary and its stratigraphy reflects the development of a submarine rise within a deep marine basin. At Viverdon Down Quarry, a late Courceyan–Chadian conodont fauna occurs within cherts that are juxtaposed with coarse, feldspathic sandstones as a result of gravitational sliding or thrusting. Finally, the Spara Bridge road cutting in the Teign Valley records the most complete Dinantian succession in the Culm Trough (late Devonian-Arnsbergian) and Includes the stratotypes for the Combe Shale and Teign Chert, fine-grained clastic and/or siliceous deposits that are insecurely dated as Viséan in age.

References


*(Figure 10.1) Simplified geological map of central south-west England showing the northern and southern outcrops of Dinantian strata and the locations of GCR sites described in the text. Based on [British] Geological Survey maps of the area (Institute of Geological Sciences, 1969c,d, 1974a,b,c,d, 1975c, 1976c,d,e, 1977d, 1980a,b, 1982; British Geological Survey, 1993b, 1994, 1995b,c, 1998).*

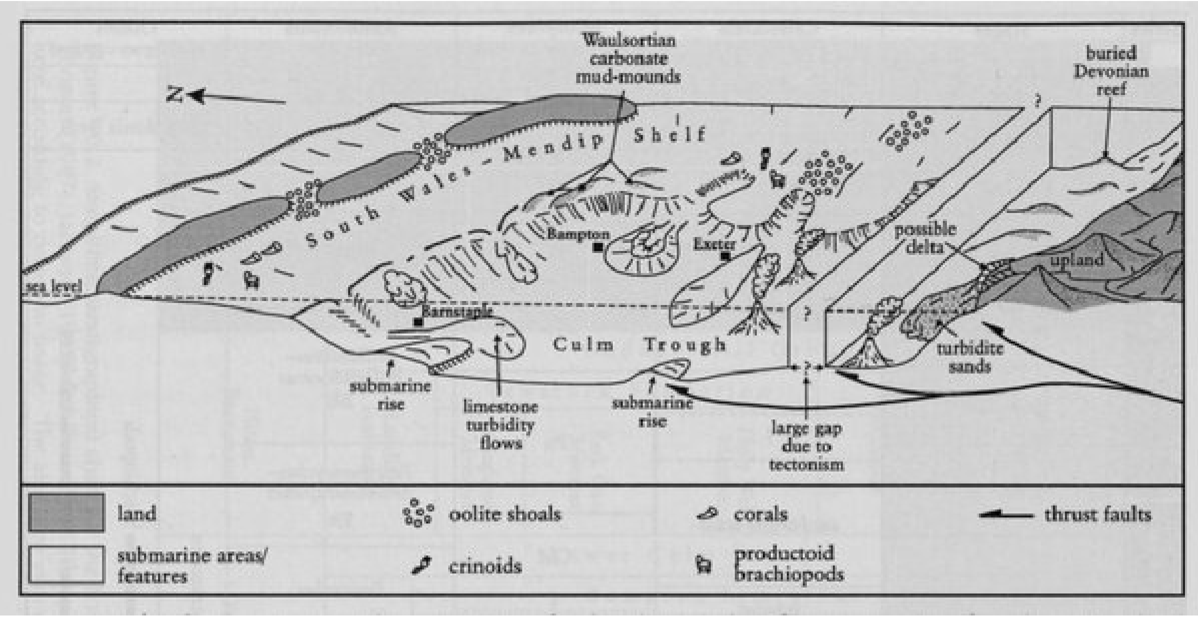



*(Figure 10.2) Simplified stratigraphical chart for the Lower Carboniferous strata of the Culm Trough. Compilation based on information from Seiwood and Thomas (1987), Jackson (1991) and Owens and Tilsley (1995). Much of the stratigraphical nomenclature in the CuIm Trough is informal and is reproduced here according to common usage. The aim is to summarize a range of differing successions rather than imply that the rock units are well dated and have isochronous boundaries. Note that the Chert Beds and the Bealbury Formation in the Crocadon Formation of the St Mellion Klippe may be olistoliths or isolated thrust-bound units; see Viverdon Down Quarry GCR site report (this chapter) for further details. Half-arrows represent thrust faults. Stour. Fm — Stourscombe Formation. Not to scale.*




*(Figure 10.3) Biostratigraphical schemes for the Lower Carboniferous strata in the Culm Trough based on conodonts, miospores and ammonoids. The distribution of other useful fossil groups is also shown; entomozoid ostracodes are*

*locally abundant in the Courceyan Stage (Selwood et al., 1982; Gooday, 1983), as are diverse trilobite and brachiopod faunas (Goldring, 1955, 1970). Trilobites are more sporadic in the Chadian (Owens and Tilsley, 1995) and younger stages (Prentice, 1967) but the concurrence of Posidonia becheri and Neoglyphioceras spirale is a common feature within the early Brigantian Posidonia Beds (Thomas, 1982; Riley, 1993).*




*(Figure 10.4) Palaeoenvironmental reconstruction for the Lower Carboniferous sequence of south-west England (after Thomas, 1982). Note the association of oolite shoals, productoids, corals and crinoids on the South Wales–Mendip Shelf and its possible southward extension. Subtle changes of basin-floor topography may influence the direction of turbidite flows or dictate sedimentation patterns, forming isolated rise-related successions. The southern margin of the Culm Trough was a mobile orogenic front associated with coarse clastic and volcanic rocks. Half-arrows represent northward-propagating Variscan thrust faults.*