

# CARBONIFEROUS SANDSTONES AND SHALES

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Zig-zag folding in Carboniferous sandstones and shales – at Hartland Quay, north Devon

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## CONTENTS

	PAGE
1. Brief Description	1
2. Geological Detail	2
3. Uses	4
4. Places To Visit	4
5. Photographs	6

## 1. BRIEF DESCRIPTION

Sandstones and shales, which date from a geological period called the Carboniferous, underlie much of Devon. These rocks are not easy to see except along the Atlantic coast and in small old roadside quarries. An extensive strip of Carboniferous rock forms a broad band across central and north Devon, and also around the flanks of Dartmoor.

The Carboniferous rocks across Britain are so named because they contain coal, which is a rock rich in a mineral called carbon. In Devon, no economic coal was found because the sediments were laid down in a sea, instead of in tree-choked swamps where more commercial coal forms. The rocks in Devon are dominantly marine shales and sandstones.

Great thicknesses of rock were formed in Carboniferous times, during a period of continental collision and mountain building (known as the Variscan Orogeny). Devon was at the centre of great dynamic activity which created its interesting variety of rocks.

Spectacular zig-zag patterns in the Carboniferous rocks can be seen along the Atlantic coast - at Hartland Quay, and at places inland. This illustrates how the rocks were crumpled and contorted by the collision of crustal plates, and thrust up into mountains.

Between the layers of sandstone and shale, other types of rock can be seen. Limestone is present in northeast Devon, and sparingly in other places. Lavas from volcanoes and layers of volcanic ash are common within the shales, and other igneous rocks also occur.

## **2. GEOLOGICAL DETAIL**

The extensive outcrop of Carboniferous strata across central Devon used to be known as the Culm, a term that is still used today in 'the Culm grasslands'. The name derives from the sooty coal that was mined in a few adits near Bideford in the nineteenth century. Consequently the name 'Culm Measures' was formerly applied to the sandstone and shale sequence in which it was found, being roughly equivalent to the Coal Measures found in South Wales.

Carboniferous strata were deposited between about 360 to 300 million years ago, following on over the older underlying Devonian rocks. In South Wales, the Midlands and Northern England and Scotland, and across Europe, the Carboniferous strata was characterised by the occurrence of large coal deposits of economic importance. Coal Measures were found in the upper parts, with the Millstone Grit and Carboniferous Limestone beneath. However, the coal seams that were the foundation of Britain's wealth in the nineteenth century were absent from Devon, so the county therefore failed to benefit from the mineral wealth.

In Devon, despite careful searching in the early days, no economic coal was found, because the sediments had been laid down in a sea instead of in tree-choked coal swamps. Here the succession is dominated by marine shales and sandstones, in several formations that are quite similar to each other. Moreover, spectacular folding of the strata can be seen on the west coast and at places inland. Limestone is present in northeast Devon, and sparingly in other parts. Basaltic lavas and layers of volcanic ash are common within the shales, and other igneous rocks, mainly dolerite, are also found.

A large part of central Devon is underlain by Carboniferous strata, predominantly hard grey sandstone layers with grey shale in between, which are intensely folded along east-west trends. The outcrop, up to about 45km wide, extends eastward from the Atlantic coast in a broad band as far as Exeter and Tiverton, where it disappears beneath Permian red beds. On the west coast, the cliffs show a spectacular series of folds trending east-west, mainly upright and including some V-shaped and zig-zag folds, the result of the Variscan earth movements that began in the Devonian and lasted until the Permian.

In Carboniferous times, coals were formed in swamps in South Wales, with massive deltaic sandstones and shales interbedded with the coal seams. But the sandstone and shales of the Devon area look very different – in the early days of geology, this caused much uncertainty and dispute as to their relative age. Ultimately it was realised that rivers flowing from the Welsh mountains formed deltas and delta swamps on its southern continental margin. The sea into which they flowed lay where Devon now is, with fine sediment carried down by the rivers settling on the sea floor as shales. Sand from the deltas periodically swept down to deposit layers up to 1m thick over a wide area – these sandstones are often termed greywackes. These rapid flows of intermixed

sediment and water are called turbidity currents because they were carried in turbid water. Evidence of the violence of the flow can be seen on the undersides of the sandstone layers as ripples, vortices and grooves caused by the ripping-up of the muddy sea bed as the overlying sand was deposited; and as the sand hardened to rock, these features were preserved as casts.

For more than 100 million years there was a vast process of mountain building over South West England – during the Devonian and Carboniferous periods (about 400 to 300 million years ago) and into the early Permian period. Caused by the collision of moving plates of the Earth's crust – known as 'plate tectonics' or 'continental drift' – deep troughs (or basins) formed below the narrowing sea and received vast volumes of sediments from the erosion of the nearby continents – from land to the north (Wales and North America) and to the south. The sand and mud sediments became deeply buried and turned into rocks, which were then folded and contorted and thrust up into mountains by the dynamic collision of the continental plates. This continued for over 100 million years, during which many kilometres thickness of rocks were formed (slates, mudstones, sandstones, etc). Great reefs of limestones formed along shallow sea ridges and there were also large volcanoes producing volcanic rocks (basalts, tuffs) and sills of dolerite. Later, molten granitic magmas were created deep beneath the mountains to form the granites of Dartmoor and Cornwall. This long period of earth movements and mountain building is known as the 'Variscan Orogeny'. It created a range of high mountains across modern South West England (similar to the modern Alps, Atlas and Rockies), extending from eastern Europe to North America.

The older Carboniferous strata, transitional from the underlying Devonian, include chert beds, which are flinty deep-sea deposits, interbedded with dark shale. Thin beds of limestone are also present, and the sequence is known as the Meldon Chert Formation at Meldon Quarry, near Okehampton, with shale, quartzite and volcanics. These extend in a curving outcrop around the north margin of the Dartmoor Granite, apparently shouldered aside by the granite as it intruded the surrounding rocks. In north Devon the equivalent sequence is the Codden Hill Chert, which overlies the Pilton Shale which also is transitional from the Devonian. Limestones at Westleigh and Bampton, in the northeast of the county, also belong to the early Carboniferous and are about the same age as the famous shallow-water Carboniferous Limestone of Wales, the Mendips and central England, though in Devon the limestones were deposited in deeper water.

Above these basal sequences, alternating beds of sandstone and shale characterise most of the Carboniferous sediment thickness in Devon. It is possible to divide these into three major formations, named after localities on the west coast but widespread across the county. These are, in ascending order, the Crackington, Bideford and Bude formations, although there is some overlap between the last two. The Crackington shows abundant evidence of deep-water deposition, with extensive turbidity marks on the undersides of sandstone beds, but the other two formations show evidence of being deposited in shallower seas or lakes, the Bude Formation in particular showing massive sandstone beds with some slumped sediment that might have been caused by earthquake shocks affecting loose sediment. The presence of ripple marks suggests an intertidal or lacustrine environment, and there are also many arthropod trails, made by primitive lobster-like or crab-like creatures.

Away from the main outcrop in north and central Devon, Carboniferous rocks are also found to the east and west of Dartmoor in what are often referred to as the Southern Successions. Pebbles of igneous rocks and volcanic ash occur in the lower parts of these successions, indicating a source to the south, and coarser to conglomeratic beds

higher up are called the Ugbrooke Sandstone which contains pebbles with Lower Carboniferous fossils – indicating that some tectonic activity was occurring to the south at the time, eroding recently-deposited sediments.

There was a complex history of igneous activity in south Devon, with lava flows and thick accumulations of volcanic ash, together with dykes and sills, notably in the Teign Valley. Thick ash deposits together with dolerite dykes are found at Meldon Quarry, where they are utilised for railway ballast and various grades of aggregate and roadstone. This area was also affected by the Dartmoor Granite, that heated the adjacent rocks as it cooled in the late Carboniferous/early Permian.

### **3. USES**

With an abundance of hard sandstones and tough igneous rocks, the Carboniferous is one of the most important geological units in Devon for useful rocks. Sandstone quarries include Venn in north Devon, while Meldon Quarry supplies very hard hornfels rock and chert, that have been baked by the thermal metamorphism of the nearby granite. Dolerite is quarried in the Teign Valley and limestone comes from near Bampton and Westleigh in the northeast of the county.

In very many smaller quarries worked in the past, building stone and roadstone were won by older methods, and many of these can still be seen beside the roads or settlements they helped to construct. For geologists these remnants are valuable, allowing observation and measurement of the strata or igneous rock types that would otherwise be covered over by soil.

The present utilisation of Carboniferous rocks is mainly confined to exploitation of the harder sandstone bands, which are crushed for aggregate and roadstone, and dolerite and limestone where they occur. In former times they were extensively used for building houses, walls, bridges and churches, most of them still in use today because of the durability of the stone

### **4. PLACES TO VISIT**

Please refer to the safety guidance about visiting geological sites on our website before visiting the places listed below.

#### **Hartland Quay [SS 224246]**

The spectacular cliffs north and south of the quay show massive sandstone beds with interbedded shale of the Crackington Formation, all of it being spectacularly folded by Variscan earth movements. Close examination of the sandstones shows many features formed by rapid turbid flows of intermixed sediment and water, where the underlying sea-bed muds were ripped and gouged by the currents, now preserved as casts in the underside of the sandstone beds.

Hartland Quay is on the SW coast path and there is ample car parking.

#### **Meldon Quarries, Okehampton [SX 566923]**

Hard ballast and aggregate have been worked here for railway use for many years, and slate, quartzite, chert and dolerite are present. Being less than 1km from the margin of

the Dartmoor Granite, they have been affected by the thermal metamorphism effects of the cooling granite, with some interesting minerals being found.

There is no public access to the working quarry (unless by prior private arrangement only), however there is access by public footpath to the adjacent Meldon Rock Park which exhibits boulders of the variety of rocks in the quarry, and also nearby exposures of the geology of the Meldon area. Foot access may be gained from the Granite Way cycleway and footpath, and there is car parking nearby in the Okehampton Hamlets car park.

### **Bonhay Road, Exeter [SX 914927]**

Interbedded sandstone and shale beds of the Crackington Formation can be seen in this ancient river cliff, but are best seen from the opposite roadside. Sandstone beds up to 1m thick alternate with shale, and all have been deformed into a near-vertical position by the Variscan earth movements. The site is a Site of Special Scientific Interest (SSSI).

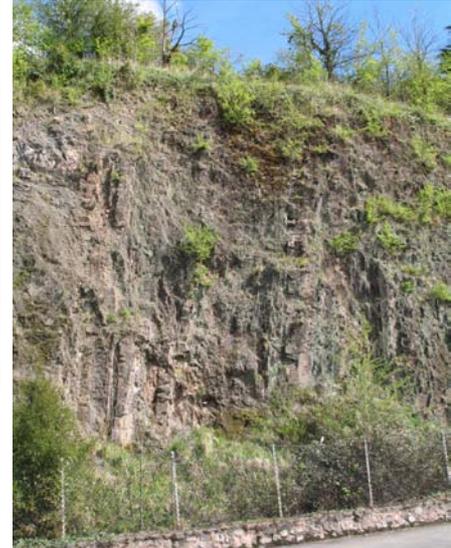
### **Bickleigh Wood Quarry [SS 945179]**

Thick beds of sandstone of the Crackington Formation can be seen in the old quarry, on the east side of the A396, near a lay-by. These were formed in deep water by turbidity currents, and many features of this type of deposition can be seen in this quarry, which is well-known for the scour marks and flute marks seen on the underside of the sandstone beds. Some soft-sediment slumping can also be found. The site is a Site of Special Scientific Interest (SSSI) and is protected by law – do not use a hammer or remove any specimens.

## 5. PHOTOGRAPHS



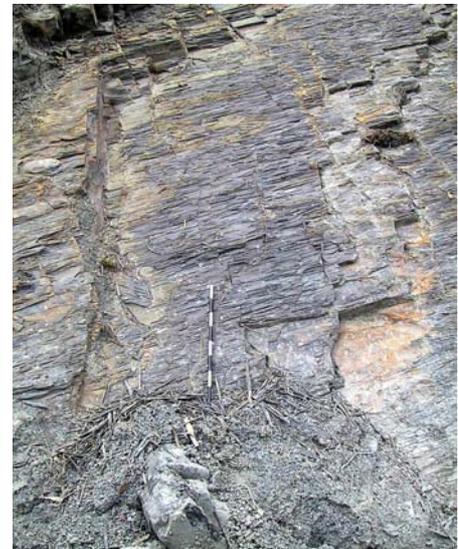
Interbedded sandstones and shales with zig-zag folds - in cliffs south of Hartland Quay. © DP Roche



Bonhay Road, Exeter (a SSSI) – an old river cliff exposure. © DJC Laming



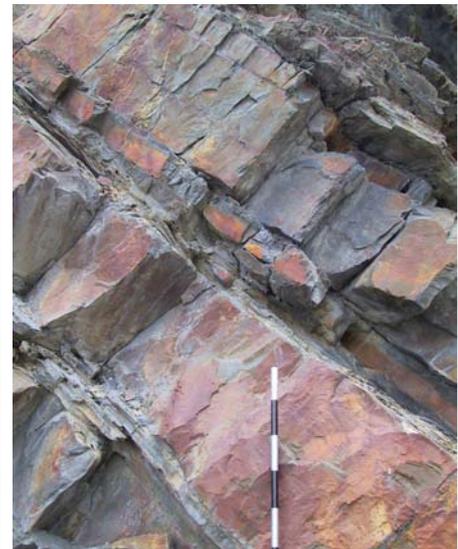
Black chert bands formed of silica from marine sponges, in the Westleigh Limestone and used in buildings. © SJ Parkhouse



Shales with fissile cleavage and bedding, north Devon. © C Nicholas



Folded Carboniferous Limestone strata at Westleigh Quarry, near Burlescombe, east Devon. Shallow sea limestone debris washed down to deep sea by turbidity currents. © SJ Parkhouse



Thick beds of sandstone with thin interbeds of shale - typical of the Carboniferous in Devon. © C Nicholas