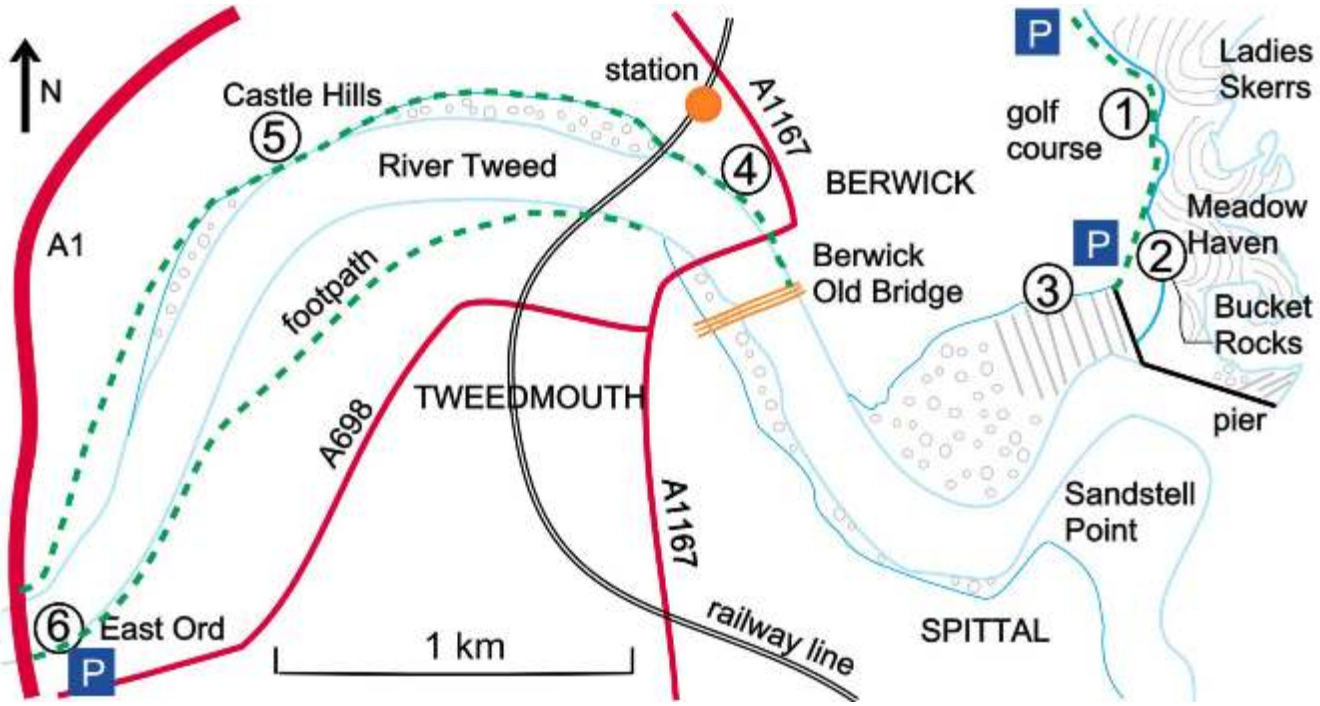
THE BERWICK MONOCLINE

The **Berwick Monocline** is an unusual fold structure formed by plate tectonic pressure at the end of the Carboniferous period 300 million years ago. Its effects can be seen along the coast from Cocklawburn, five kilometres south of Berwick, where there are small folds, to Burnmouth, seven kilometres north of Berwick, where the rocks are vertical. This walk covers a cross-section of the Berwick Monocline from east to west.

The walk is planned so that the reader can visit six locations to see features of the Berwick Monocline. The locations cover places that are accessible by road or footpath and all can be seen at low tide. However, locations 5 and 6 are not visible during the summer when they are hidden in trees. Convenient car parks are shown on the map but there is disc parking at other car parks and on streets in Berwick. The B1 Berwick Town Service bus travels from Morrisons, close to the A1 north of Berwick, to Spittal every 30 minutes, stopping at Golden Square in the centre of Berwick. The distance between locations 1 and 6 is about 5 kilometres following the coastal footpath, roads through Berwick town and River Tweed footpaths.



① *Photo A shows a well known view from the coastal footpath. It is accessible from two car parks, one at Green's Haven (NU 003 536) near the golf clubhouse and another close to Meadow Haven (NU 006 528). The best time to see the features is just before or after low tide.*

Ladies Skerrs is a dome of **sandstones, mudstones** and **limestones**. Limestones and sandstones are more resistant to **erosion** by the sea than mudstones so they stand proud on the rocky foreshore. You can see the direction in which the beds of rock slope away from the centre of the dome (arrows on Photo A). The rocks were deposited on a horizontal sea bed during the **Carboniferous period** about 330 million years ago and were domed during **plate tectonic** activity 30 million years later.

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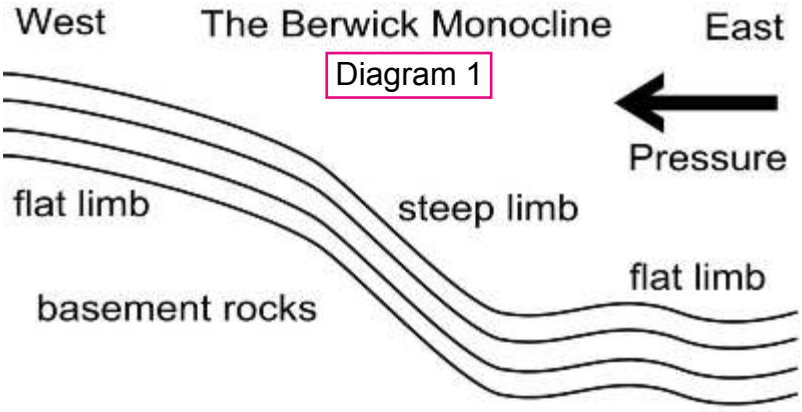
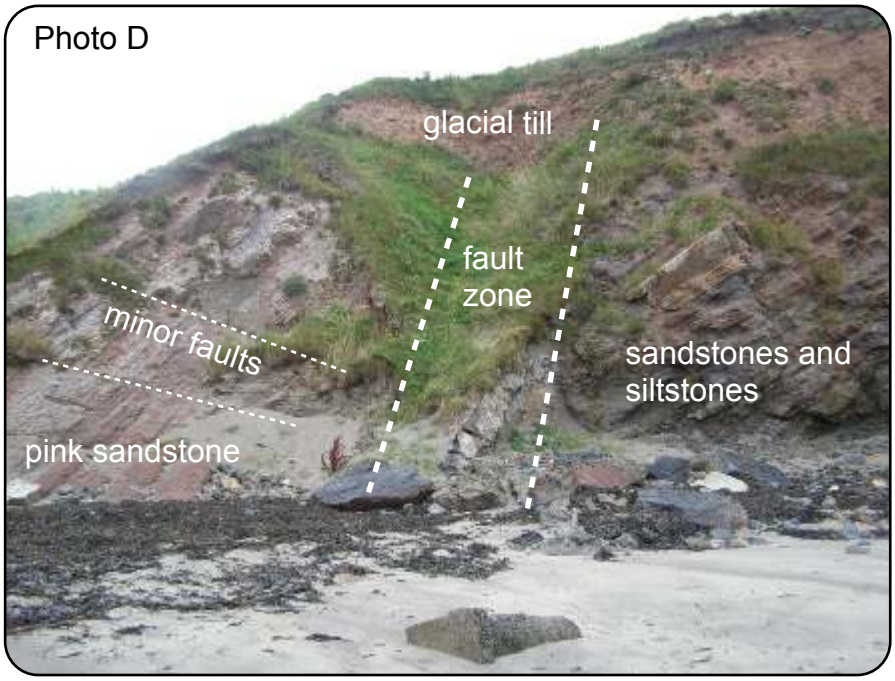


The Berwick Monocline is a very unusual **fold** as it has only one steep **limb**, whereas most folds have two limbs (see Saltpan Rocks leaflet).
Below the rocks of north Northumberland lie older rocks which were folded and altered during a **plate collision** about 420 million years ago and now form a solid **basement.** The sediments which became the limestones, siltstones and mudstones were deposited in shallow seas 330 million years ago, above the basement. The **monocline** was formed when the **Variscan** tectonic plate collision 300 million years ago created pressure from the east, which pushed the younger **sedimentary** rocks against the basement rocks (Diagram 1). Probably both flat limbs were pushed into **domes and basins**, now seen clearly on Berwick's shoreline (Photos A and B) although not visible on the western limb.

② *Walk south along the coastal footpath, past the Coastwatch Tower and look at the rocks on the foreshore beyond the beach below you. The beds of rock change direction south of the Ladies Skerrs dome. This is the beginning of an adjacent basin called Bucket Rocks (Photo B).*
As you approach the car park turn left on one of several paths to reach the beach through a small area of sand dunes. When you are on the beach, turn left and look at the rocks in the nearest cliff.

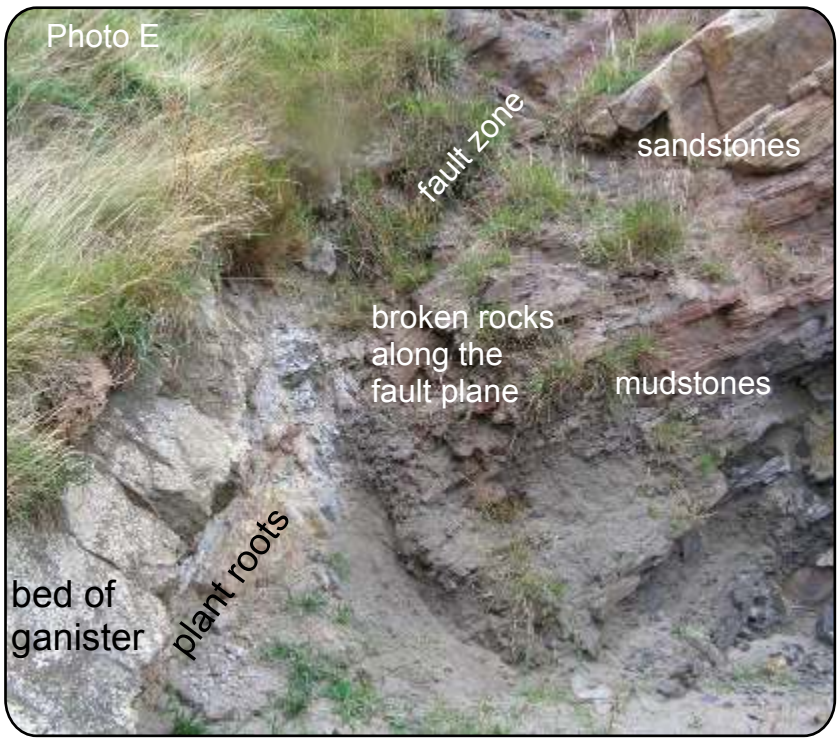
The first rocks to catch your attention will be the pink sandstones with dark red/brown **burrows** (Photo C). The sands were deposited in shallow water. Soft-bodied invertebrates burrowed into the sea bed, for protection or to find food. As there was plenty of iron in local rocks, water moving through the sands while they were being compressed by younger sediments during burial, **precipitated** iron which concentrated in the existing burrows.

Stand back from the cliff to see the rocks. Here is the Meadow Haven Fault, a major structure related to the Berwick Monocline.



There are several features which show that there is a **fault** here (Photo D). The rocks on each side of the fault are different, showing that there has been movement up and down, or possibly sideways, along the **fault zone.** Minor faults took up some of the strain when the rocks were under stress and can be seen in the rocks on either side. The rocks along the fault zone are often shattered, which you can see when you get close to the cliff. A gully has formed because the fault is a weak part of the rocks and allows water to penetrate. This fault would have caused many **earth-quakes** during its life, as it moved about 100 m in total, due to the crustal stresses which formed the Berwick Monocline.

The fault zone is complex (Photo E). The sandstones and mudstones became smashed up the nearer they were to the fault zone. The steeply sloping bed of **ganister,** a tough sandstone, lies along the fault zone. It is hard to know why the ganister is dipping more steeply than the surrounding rocks but it may have been caught in the fault zone while the fault was moving during an earthquake.



Ganister is the rock formed from the sandy soil in which trees grew in the hot, wet equatorial climates. If you look on the underside of the ganister bed you can see many fossilised tree roots (Photo F). Above the ganister (on the left side of the bed facing the cliff) a seam of **coal** is visible, representing the vegetation cover which grew in the sandy soils. These features are close to beach level and are often covered by sand.

③ *Walk back to the road near the car park, down to the pier and along Pier Road (Photo G). If the tide is low enough you will see beds of rock running out to sea, many hidden under seaweed.* These rocks are mostly limestones, siltstones and mudstones, although there is a thin seam of coal amongst them. They are the same rocks as those found at Saltpan Rocks, Cocklawburn, but this time they are not folded but are **dipping** steeply towards the north-east so that the viewer only sees the edges of each bed. (Photo H).

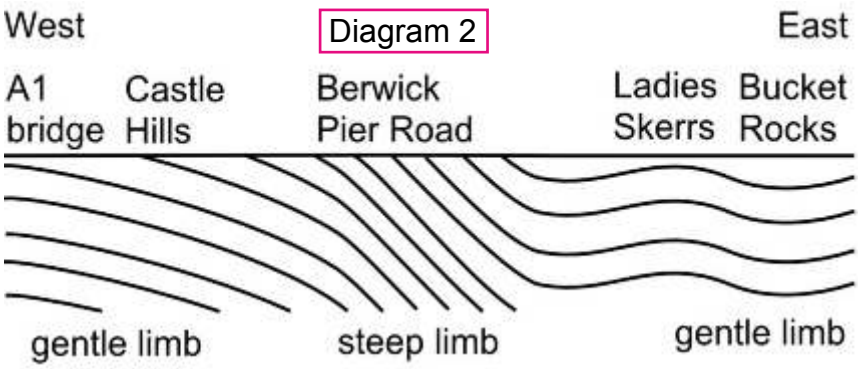


Diagram 2 is a modification of Diagram 1, showing that the top of the Berwick Monocline has been removed by **erosion** over the last 300 million years, with the basement rocks and the bottom beds of the monocline still below the surface but not shown on this diagram. The domes and basins of the shoreline are part of the eastern flat limb of the monocline, but by walking from Meadow Haven to Pier Road you have reached the steep limb of the monocline. You can see the effects in the dip of the beds in Photo H. The steeply dipping beds extend under the Tweed estuary but are covered by the silt and mud of the river and the sandy beaches at Spittal. They appear again as the rocks which dip at about 30° in the cliff at Hud's Head (see Spittal leaflet).

④ *To reach the next point at which you can see any solid rock, walk along Pier Road, through Ness Gate and onto the Ramparts or through the town streets towards the quay and the old Berwick bridge. As you walk through Berwick, you are walking over the steep limb of the monocline, which can't be seen again until beyond the concrete road bridge.*

There is a wide path under the bridge which leads to the path along the north side of the river (which is locally called the New Road) (Photo I).
At low tide in the river you can see ribs of exposed rock below the path beyond the Berwick Rowing Club building. These are covered with sea weed in places but it is possible to see that the rock dips steeply downstream (Photo J). This sandstone is the Fell Sandstone, a tough and resistant rock which crosses the river at this point and which provided good foundations for the arches of the Royal Border Bridge.

⑤ *Follow the New Road upstream under the railway bridge and towards the wooded grounds of Castle Hills (NT 988 534).* From the path, you can see sandstone crags which show a gentle dip to the east (Photo K) although they are obscured during the summer by trees. You have now reached the upper flat limb of the Berwick Monocline, which may also have been folded into basins and domes, although there is very little rock to be seen elsewhere along this part of the River Tweed (Photo L).

⑥ *The upper flat limb of the Berwick Monocline can be seen in the rocks of the river bank near the A1 bridge (Photo M). Footpaths along both banks of the river are likely to be muddy and include stiles. The horizontal sandstones are best seen on the river banks upstream and downstream from the A1 bridge. Parking is available at the East Ord car park from which there is a path over a stile directly onto the road bridge.* Here the sandstone beds are horizontal and are unaffected by folding, so you are now at the western flat limb and have completed your crossing of the Berwick Monocline.

THE VARISCAN PLATE COLLISION

The Carboniferous rocks of the Northumberland coast were involved in a tectonic plate collision at the end of the Carboniferous period 300 million years ago. As part of the plate tectonic activity, two smaller plates collided, creating a chain of high mountains.

North Northumberland was at the northern margin of this mountain-building event but the local rocks were under pressure from the east and were pushed against the much older basement rocks of the Southern Uplands, as if they were a rug on a slippery floor which is pushed up against a wall. The Berwick Monocline is one of the marginal effects of the Variscan plate collision (Diagram 3).

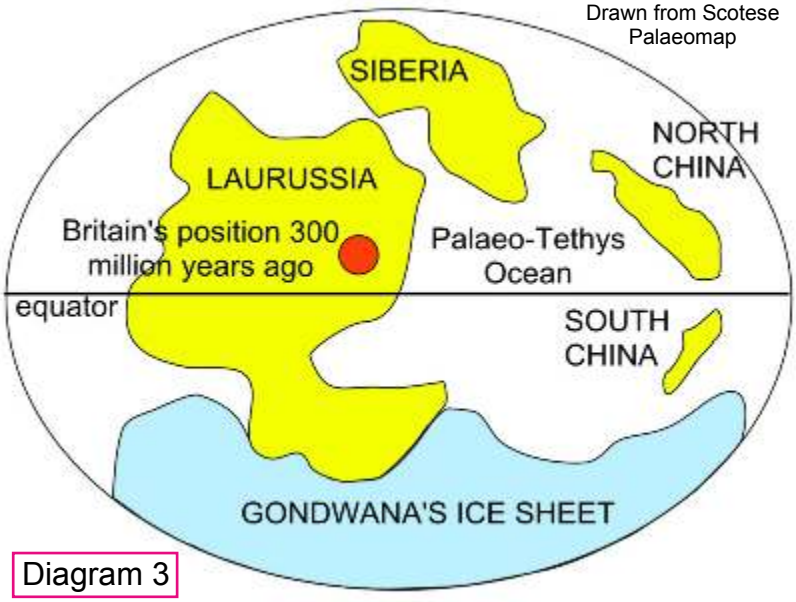
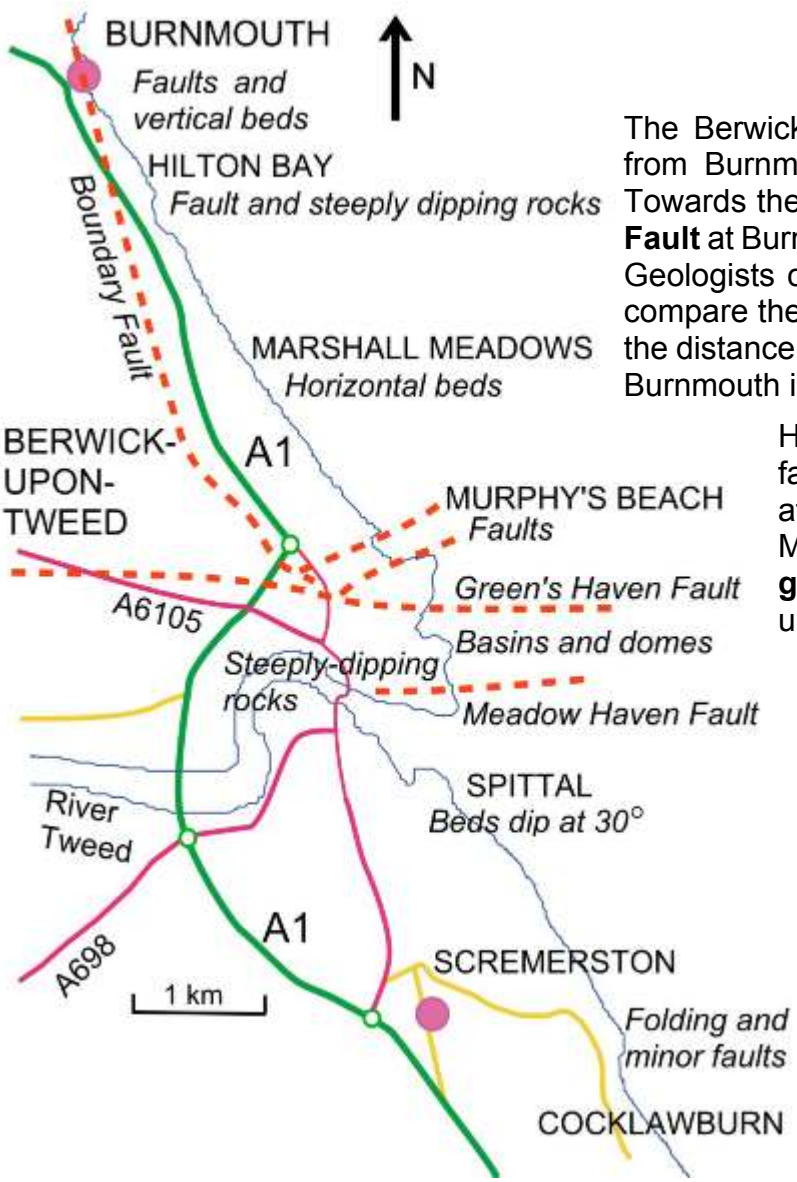


Diagram 3



EFFECTS PRODUCED BY THE BERWICK MONOCLINE

The Berwick Monocline's effects can be seen on the shore from Burnmouth in the north to Cocklawburn in the south. Towards the north the effects are greatest and the **Boundary Fault** at Burnmouth has a vertical **displacement** of a kilometre. Geologists can calculate the displacement because they can compare the rocks on either side of the fault and can estimate the distance between them, even though the Boundary Fault at Burnmouth is hidden below the beach shingle.

Hilton Bay is very inaccessible but also has complex faulting and steeply dipping rocks. The sandstones at Marshall Meadows are unaffected by the Berwick Monocline because they lie above a huge mass of **granite**-like rock which extends from the coast out under the North Sea.

The two faults on the Berwick beaches, at Green's Haven and at Meadow Haven, also have a considerable displacement and the domes and basins in between are caused by the stress set up by the movements of the two faults over many millions of years.

Further south the beds were less affected by the basement blocks of the Cheviots and the Southern Uplands and therefore the stresses on the sedimentary rocks as they were pushed towards the basement were reduced, although between Saltpan Rocks and Sea House at Cocklawburn there are some very impressive small scale folds.

USEFUL REFERENCES

Northumbrian Rocks and Landscapes - A Field Guide 1995 (ed. C. Scrutton) Yorkshire Geological Society

H.Roper 1997 *Origin of the 'Berwick Monocline': geometrical and geophysical considerations.* Scottish Journal of Geology, Volume 33.

USEFUL MAPS

OS 1:50,000 Landranger 75 Berwick-upon-Tweed

OS 1:25,000 Explorer 346 Berwick-upon-Tweed

British Geological Survey 1:50,000 (England) Sheets 1 & 2 Berwick-upon-Tweed and Norham (Solid)