



## Pembrokeshire Geology – six suggested locations for a weekend visit

### Introduction

For such a small country Wales shows an extraordinarily varied geological history. Pembrokeshire, situated in the south-west corner, is an excellent place to see an overview of this history. Stunning coastal landscapes and beautiful countryside combine with a climate which is often warmer and drier than the rest of Wales. There are many coastal sections and inland exposures worth visiting but the six suggested locations give a good stratigraphic overview. For further details and maps of each locality please check out some of the guide books mentioned at the end. **If you visit, please be aware of tides, slippery rocks, steep cliffs and all the other usual safety issues!**

### Geological History

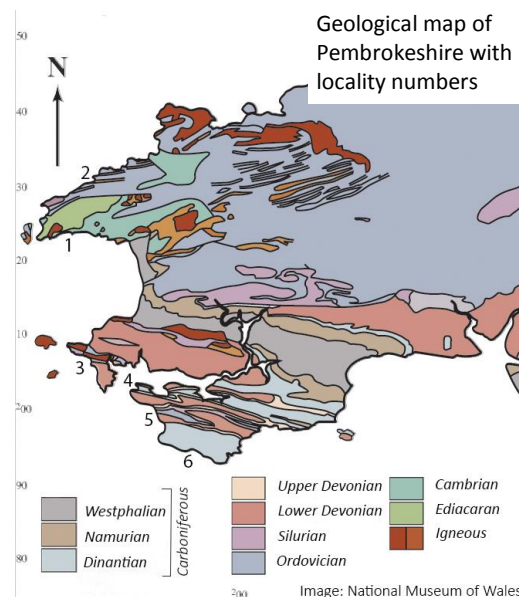
The oldest rocks seen in Pembrokeshire are the Precambrian lavas and ashes formed by volcanic eruptions, complete with igneous intrusions. Sedimentary rocks of the Ediacaran Period containing various enigmatic fossils are found in the adjacent county of Carmarthenshire. The Cambrian is represented by a sequence of sedimentary rocks showing a gradually deepening ocean. Middle and Upper Cambrian fossils can sometimes be found, and of particular interest are the large *Paradoxides* trilobites which have been found at Porth y Rhaw, near Solva, although these are extremely rare and should not be hammered if found. The deeper water 'Welsh Basin' environment of the Ordovician is characterised by muds and shales, rich in fossils such as brachiopods, trilobites and graptolites. Widespread underwater volcanic activity also produced rhyolites, pillow lavas and sills. Much of mid Wales is covered by the classic dark shales.

The shallower warm seas and volcanic islands of the Silurian Period led to a more diverse fauna of brachiopods and corals, along with bryozoans, orthocones and many other animals. The late Silurian saw the closure of the Iapetus Ocean and the resultant Caledonian Orogeny, the fabric of which is still seen in the rocks of north Pembrokeshire. The early Old Red Sandstone (ORS) facies is represented in Pembrokeshire by coastal sediments with primitive land plants and trace fossils of fish and amphibians. In Pembrokeshire this facies began during the Upper Silurian (Ludlow Series), persisted through the Devonian and into the lowest Carboniferous. Vast thicknesses of the ORS exist across south Wales, forming the Brecon Beacons and Black Mountains. The classic Carboniferous limestones (Dinantian) of south Wales were formed in warm equatorial seas, and fossils of corals, brachiopods, crinoids and molluscs are frequent. Local logging reveals fluctuating water depths and episodes of extreme storm conditions at times. Later in the Carboniferous, terrestrial and deltaic conditions resulted in deposition of the cyclic Namurian followed by the economically valuable Westphalian Coal Measures. Pembrokeshire has its own small coalfield although it was never mined on a large scale. Deformation in the late Carboniferous Variscan Orogeny caused the broadly east-west structure seen across much of south Wales, including the rocks of south Pembrokeshire.

The Permian is not seen in south Wales, but 'gash' or mega-breccias thought to be of late Triassic age are found within the Carboniferous Limestones in south Pembrokeshire and may represent collapsed cave systems or have a tectonic origin. Later Mesozoic deposits are only found offshore, whilst the Tertiary is solely represented by an Oligocene pipe clay at Flimston. Further episodes of uplift and erosion removed all other later deposits up until the Quaternary ice-age which covered south Wales and is evidenced by tills, raised beaches and other deposits as well as by erosional features and the fossilised remains of Pleistocene mammals in caves.

### Suggested locations for a two or three day visit

- Stop 1 St Non's Bay and Caerfai Bay where Precambrian tuffs are overlain by Lower and Middle Cambrian sediments.
- Stop 2 Abereiddi Bay and the Blue Lagoon have good exposures of Ordovician shales and are famous for their graptolite fossils.
- Stop 3 Marloes Bay is one of the most beautiful beaches in Wales, with exposures of marine Silurian overlain by the terrestrial Old Red Sandstone. Brachiopods, corals and trilobites may be collected from scree deposits.
- Stop 4 Freshwater West illustrates a good sequence from the Silurian up into the Devonian Old Red Sandstone with impressive calcretes and fluvial sequences.



- Stop 5 West Angle Bay has exposures from the Upper Devonian up through the Carboniferous Lower Limestone Shales (Avon Group), into the Main Limestone (Pembroke Limestone Group), with some spectacular folds and thrusts.
- Stop 6 The Green Bridge of Wales and Elegug Stacks are spectacular coastal features in the upper part of the Carboniferous Limestone with views across the flat landscape with its wave-cut '60 m platform'.

### Stop 1 St Non's and Caerfai Bay [SM 753 243]

St Non was the mother of St David, and the wishing well on this site is supposed to have been formed during a lighting flash at his birth. He is reputed to have been born on the site of the chapel, during a fierce storm, in about AD462.

Follow the footpath from the ruins of St Non's chapel to the coast path where you should first look for small outcrops of Precambrian Halleflinta (Pebidian Supergroup) – a translucent blueish silicified tuff. It is overlain unconformably by the steeply dipping Cambrian Caerfai Group. This comprises a basal quartz conglomerate which forms a prominent ridge across the hillside, and is overlain by greenish St Non's Sandstone, followed by the soft reddish Caerfai Bay Shale forming a prominent gully – also seen in the opposite headland. Walking

eastwards towards Caerfai Bay, you should then see the purple massive bioturbated Caerbwdy Sandstone, used to build St David's Cathedral. These beds are overlain by the grey, thinly-bedded sandstones of the Solva Group which form the tip of the headland. Walk down into Caerfai Bay to examine the Lower and Middle Cambrian sediments and try to find trace fossils in the St Non's Sandstone.



### Stop 2 – Aberiddi Bay [SM 796 313]

Aberiddi Bay is formed within the centre of the overturned Llanrian Syncline with unseen Caradoc shales in the centre. You will be looking at the underlying Upper Llanvirn rocks in each limb of the fold. This is the type area for the Llanvirn Series which is named after a nearby farm.

Walk from the car park towards the path leading round the northern headland, passing a row of old miners' cottages. Here you will see the Caerhys Shale Formation within the Blue Lagoon, a large flooded quarry now popular with divers and coasteerers. The north face of the quarry belongs to the Aberiddi Tuff, part of the Llanrian Volcanic Formation. It may appear that this bed lies on top of the steeply dipping shales, but in fact you are

on the overturned limb of the syncline, and the bedding is inverted here. There may be the opportunity to collect small pieces of the classic graptolite *Didymograptus murchisoni* here, but usually the scree is picked clean of fossils by the numerous visitors. At the entrance of the quarry you can see a hard calcareous mudstone which is the overlying Castell Limestone Formation (Caradoc).

From the car park, walk southwards back up the road to see an excellent roadside exposure of the Caerhys Shale Formation, in which graptolites are fairly common (but no hammering please !) Nearby you can see a small exposure of the Aberiddi Tuff, and in a quarry 50 m to the west, the underlying Cyfreddin Shales.

### Stop 3 Marloes Sands [SM 780 076]



Marloes cliffs with the Three Chimneys visible mid-right

An easy footpath leads from the National Trust car park about half a mile down to a broad bay with spectacular cliffs. Tide permitting, you can walk along the beach to the furthest end of the bay. On a high tide there is very little access to the beach, but you can walk along the cliff top.

On a low tide, first walk to the far south-east end of the bay where you can examine the Wenlock Grey Sandstone Group passing conformably up into the red Milford Haven Group (Ludlow, Old Red Sandstone facies). Then turn and make your way back along the beach. The Silurian here is very complicated by extensive faulting so that many beds appear out of sequence, including basalt flows and tuffs within the Skomer Volcanic Group (Llandoverly). Check out the distinctive Three Chimneys – three prominent vertical sandstone beds (right side of the image). Many

rocks contain a variety of decalcified fossils, including corals, brachiopods, crinoids and bivalves. Fossils may be collected at the hollow known as Mathew's Slade where the overlying Coralliferous Sandstone Group of Llandoverly/Wenlock age has a distinctive fauna, mainly of brachiopods.

### Stop 4 Freshwater West [SM 885 995]

This spectacular pair of beaches was used in 2010 for the filming of both Harry Potter and Robin Hood. The southern end is adjacent to the MOD firing ranges and many classic localities are now inaccessible. Depending on the current beach level some or all exposures may be buried by sand or pebbles. Park in the main car park and look at the nearest part of the beach before you descend. You may be able to see the line of the Flimston tear fault trending along the bay. Walk down to the most northerly exposed rocks at this end of the bay. If the beach level is very low you may be able to pick out some of the Ordovician Llanvirn Shale, or the overlying top few metres of the marine Silurian (Wenlock) Gray Sandstone Group (with pebble-sized conglomerates), overlain unconformably by cobble sized conglomerates of the Freshwater East Formation. As you walk southwards towards Little Furzenip (the sea stack), note the change to the fine-grained facies of red and green mudstones of the Moors Cliff Formation, including the thin Townsend Tuff Bed which marks the Silurian/Devonian boundary.



Flimston fault cutting across Silurian rocks, Freshwater West

If the tide allows, pass through the gap in the headland, or otherwise return to the cliff top and walk round to the southern bay.



Ridgeway Conglomerate with distinctive red and green clasts

Here again a low beach level should reveal an excellent view of the dextral strike slip fault. Examine the massive red and white Chapel Point Calcrete, then walk further south to see the classic fining upwards fluvial cycles of the Lower Devonian Freshwater West Formation. If the beach level is low enough, you may be able to find some of the huge *Beaconites* burrows within the channel sands of the Conigar Pit Sandstone Member. The overlying Rat Island Mudstone Member is devoid of such channels and represents a floodplain deposit. Above this are the massive alluvial fans of the distinctive Ridgeway Conglomerates which contain no fossils and cannot therefore be dated. Lying unconformably above the conglomerates is the Gupton Formation of the Shrinkle Sandstone Group, which has been dated by rare scales of the fish *Holoptychius*, of Upper Devonian age. Do not try to go beyond the south end of the beach as this a restricted military area.

### Stop 5 West Angle Bay [SM 855 033]

West Angle Bay has been designated as a Site of Special Scientific Interest as one of the richest sites for marine flora and fauna in southwest Wales. Particularly important are the cushion stars, and a rare ostracod. Geologically it is important for its structures, and also the section from the Devonian Ridgeway Conglomerate up into the Lower Carboniferous Main Limestones (Pembroke Limestone Group).

Walk along the coastal path to the north of the beach car park until you are at the closest point to Thorn Island. The island and the prominent red stack just offshore (at high tide) are formed of steeply dipping Devonian Ridgeway Conglomerate overlain by the Gupton Formation as seen at Freshwater West. The harder Ridgeway Conglomerate forms the prominent stack and island. Turn and head back along the coastal path looking for the Upper Devonian West Angle Formation which is a fluvial semi-arid flood plain deposit.



Ridgeway Conglomerate forming Thorn Island at West Angle



Folded beds of the Lower Limestone Shales in the 3<sup>rd</sup> North Cove

The lower Conglomeratic Member is red coloured, with both sandstone and conglomerate horizons containing exotic clasts, as well as calcretes. Above this is the Heterolithic Member which trends upwards to a grey colour, and exhibits fining upward sequences and beds of macerated plant remains with occasional fish teeth and bivalves. Palynological dating gives an Upper Devonian age within the deep cleft next to a sea stack. However, the top beds on the sea stack are thin sandstones and interbedded shales which have been dated palynologically to the Tournaisian (Lower Carboniferous, Dinantian). The transition to fully marine Lower Limestone Shales is further above this, in the centre of the Third North Cove.

West Angle cliffs are also worth a mention for the late Pleistocene deposits (from 140,000-10,000 BP). A layer of sandy loam at the top of the cliffs is underlain by a reddish sand and pebble bed of about 3 m thickness, which probably represents outwash from the Irish Sea ice sheet. Below this in places are deposits of darker clays with sands, silts and shell fragments representing a marine transgression, and then an orange unit with sub-angular clasts. In places a lower bed has been excavated, containing igneous erratics, and this represents an earlier and more extensive glaciation.

Returning to the main bay by the car park, note that this has a synclinal structure with the basal Carboniferous (Tournaisian) beds, the Lower Limestone Shales (Avon Group), forming the headlands. They are mostly vertically bedded, and the upper part forms a prominent rib dividing the Third and Second North Coves. These pass up into the Main Limestone (Pembroke Limestone Group/Black Rock Limestone Subgroup), which form the centre of the bay and which can be best seen in the Second North Cove. Here you can also see some interesting periclinal folds, and the multiple lines of an obvious thrust complex which brings the Lower Limestone Shales back into the next small headland.



Thrust fault displacing Lower Limestone Shales over the Main Lst.

In Limekiln Cove, nearest to the car park, you can see the Main Limestone together with some of the folds and faulting which characterise it here. Fossils of the storm driven Carboniferous seas are common.

## Stop 6 Green Bridge of Wales [SR 925 944]

There is very short walk from the car park to the viewpoint for this classic landmark which is carved out of the Pen-y-Holt and overlying Stackpole limestones (of Arundian and Holkerian age respectively). In 2017 a large section of the outer part of the arch fell into the sea during storm Ophelia.

A short distance further on, the Stack Rocks, or Elegug Stacks, are the remains of a former archway. These are also famous for their colonies of nesting Guillemots.

Further along the coast is the tiny St Govan's Chapel, built on the cliffs in a small cove with a huge limestone boulder forming one wall.

Look along the cliff top which is uniformly level at around 60 m above sea-level across much of Pembrokeshire. This is due to marine erosion during a period with extreme high sea-level relative to the land during the Tertiary.



Green Bridge of Wales (2014). A storm in 2017 removed much of the seaward section



St Govan's Chapel

### There's more...

These are just six localities which give a snapshot of the diverse landscape and geology that Pembrokeshire has to offer, and accessible over a long weekend visit. Given more time, you might also want to explore the igneous intrusions which form the hills north of St David's, or the Upper Carboniferous (Westphalian) exposures round Broadhaven and also east of Tenby, amongst many others.

With castles and ancient forts, hills and moorland, tiny coves and broad bays, Pembrokeshire truly has an incredibly wide diversity of geology, nature and landscape to explore and enjoy.

### Further reading:

Bassett, M.G. (ed.) 1982. *Geological excursions in Dyfed, south-west Wales*. National Museum of Wales, Cardiff, 327 pp.

Downes, J. 2011. *Folds, faults and fossils: exploring geology in Pembrokeshire*. Llygad Gwalch, Pwllheli, 264 pp.

George, G.T. 2015. *The geology of South Wales*. 2<sup>nd</sup> edition. Gareth@geoserve.co.uk, 282 pp.

Howells, M.F. 2007. *British Regional Geology: Wales*. British Geological Survey, Nottingham, 230 pp.

Bassett, D. A. and Bassett, M. G. 1971. *Geological excursions in South Wales and the Forest of Dean*. Geologists' Association South Wales Group, Cardiff, 267 pp.

Owen, T.R. 1973. *Geology explained in South Wales*. David and Charles, Newton Abbot, 211 pp.

For further information and other walks leaflets see the South Wales Geologists' Association website: <http://swga.org.uk/>