There are marked surface valleys in the limestone.

What you immediately see however is the limestone pavement, and in May the spectacular unique flora. What is not appreciated is that the limestone pavement has developed under a soil cover. The high CO^2 level in soil air facilitates the chemical erosion. In the Burren this soil cover was removed about 2,500 BC when the Beaker people cleared the wooded cover. Residual soil has been dated from the base of the grykes.

There is the strange sight of stone walls dividing fields that seem to consist just of limestone pavement. Mound walls are 30-80 cms high and 80 to 100 cms across. They date from the early Bronze Age 2,500 to 1,500 BC, rest on bedrock and seem associated with the Beaker People. The fields were small and irregular and aligned NW/SE. Slab Walls made from upended slabs of limestone predate the parish system but are more recent than the tumble walls. These are linear, made of stone and standing one or two courses high. They are associated with the ring and stone forts that date 400AD to C17th. Early Christian sites are often associated with a precious spring where a clay band in the limestone brings water to the surface.

Cattle traditionally are grazed on the hills in winter. There are no frosts, and in summer they are moved to the low ground to graze land that is flooded in winter. The desperate search for feed in winter means any tree shoots are nibbled down. No sheep have been kept here since about 1950.

Image 5: View from Mullaghmore of bare limestone inside the national park

The general population of Carron was >1,000 in 1841 before the potato famine. In 2011, that figure had dropped to 106 and is still falling. It is the intense traditional grazing that led to deforestation in the area and kept the limestone pavement visible. It is reckoned the amount of pavement was twice present levels in 1841.

The average annual rainfall is approximately 1163mm p.a. Once tree cover was removed erosion of the thin soil, developed on glacial deposits, must have been rapid. So much slab limestone has been used in walls, monuments and forts it is hard to find the expected sculptures limestone pavement. In places limestone boulder erratics are left on the surface when all the smaller particles have been removed. On Slieve Elva there are boulders of Galway granite from an earlier glaciation.

A decreased population and changed agricultural practise has resulted in much recent growth of hazel shrub on areas previously exposed limestone pavement. This is from either a lowering of grazing intensity, or using a bred of beef cattle not able to thrive in these conditions on the winterage. Lack of summer grazing means the flowers grow without being trampled. Steps are being taken with EU funding, to encourage traditional farming methods to maintain the pavement. The feral goats do not help. Not only do they follow each other and jump over the wall at the same place, necessitating future repair, but they graze the good valley land the farmer wants for his stock.

Image 6: Feral goats are a problem

The limestone pavement is the result of Bronze Age clearance and a very particular agricultural regime. The unique flora is a mix of Ice Age remnants, woodland floor and southern European. This area now depends on the visitors, so do visit.

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My Top 5 Geological Sites of Pembrokeshire
By Megan Taylor (Year 13 Wells Cathedral)

Pembrokeshire is a small, yet beautiful county located in Southwest Wales on the coast of the Irish Sea. The county is home to Pembrokeshire Coast National Park designated in 1952, which is the only coastal national park in the United Kingdom. The Pembrokeshire Coast National Park was also recently ranked the second best coastline in the world by the National Geographic magazine and thousands of tourists visit it every year to visit its stunning beaches, castles and seas. However, there is more to Pembrokeshire than beautiful scenery and high levels of biodiversity. It is also renowned for its spectacular geology with a wide range of lithologies from different geological time periods. Travelling from the south of the county to the north it is possible to travel back in time through cross millions of years of geological history from Devonian

and Carboniferous to Silurian, Ordovician, Cambrian and even Precambrian periods. This has led to the Pembrokeshire Coast becoming one of the UK's most important venues for geological fieldwork and research. My mum's family is from Pembrokeshire and I've been there every summer since I was born, but it was only recently when I started A Level Geology in 2018 that I started to realise how diverse its geology. In the Easter holiday and this summer, I spent a lot of time re-visiting my favourite places and looking at their different geological features using advice from my school teacher and a helpful handbook (George, 2008). This has allowed me to write this article with my Top 5 Geological Sites of Pembrokeshire shown in Figure 1 below. I hope you enjoy it!

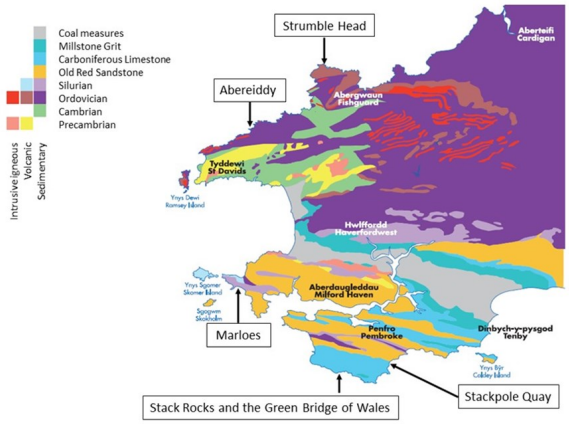

Figure 1: The Geology of Pembrokeshire, based on a map produced by the Pembrokeshire Coast National Park Authority

Abereiddy Bay

Abereiddy Bay is located in North Pembrokeshire (Figure 1) and has become a popular spot in recent years for geologists and holidaymakers alike. In the 19th Century, Abereiddy was the site of an important slate quarry employing many people locally. However when the slate production ceased in 1901 the quarry was blasted open to make a harbour entrance. This flooded quarry, a designated SSSI for its marine ecosystems, has now become known as the Blue Lagoon and is a popular diving, swimming and cliff diving area, a place my brother and I have visited many a time over the years. Abereiddy has also become known for its abundant collection of graptolite fossils, a colonial planktonic creature common in the Lower Paleozoic. Graptolites are very important zone fossils used in relative dating methods due to their high abundance, rapid evolution, well preserved fossils and that they were facies-free when alive which has led to them becoming geologically widespread. The most abundant graptolites at Abereiddy are the Tuning-Fork Graptolite, Didymograptus murchisoni. This species existed for a relatively short period of time, during the Middle Ordovician, between 470 to 464 mya. The graptolites at Abereiddy are found in the Ordovician Black Shales between the slate and volcanic rocks on either headland of Abereiddy Bay which form the fold limbs of the asymmetrical Llanrian Syncline, the axis of which is found at the southern end of the bay.

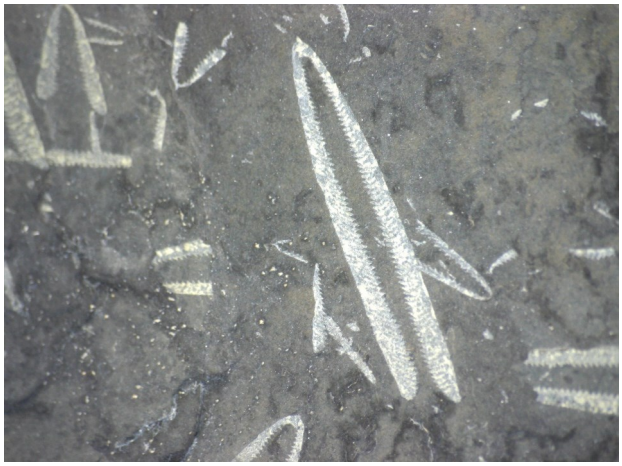

Image 1: 'Tuning fork' graptolite. The didymograptus murchisoni' graptolite is the most abundant species found at Abereiddy Bay found in the Ordovician Shales there. (Source: https://commons.wikimedia.org/wiki/

Image 2: The Blue Lagoon at Abereiddy Bay. Once an old slate quarry this sheltered harbour is now an SSSI and a popular spot for swimming, diving and cliff jumping with holidaymakers. (Source: https://www.countryfile.com/go-outdoors/days-out/day-out-abereiddy-bay-pembrokeshire/)

Stack Rocks and the Green Bridge of Wales

This part of the Pembrokeshire Coast National Park is located in the Castlemartin Artillery Range in South Pembrokeshire (see Figure 1). It is still actively used by the military for training purposes, and as a result the land is not fertilised and is very biodiverse. It is designated as a Site of Special Scientific Interest (SSSI), a Special Protected Area (SPA), and a Special Area of Conservation (SAC) to protect its rich geological and fossil heritage. The area is comprised of high, dramatic Carboniferous Limestone cliffs forming some of the most famous geomorphological features in the UK including wave cut platforms, stacks, blow holes and limestone cave systems. These cliffs are also very important for wildlife as they provide habitats for vast colonies of seabirds such as guillemots, razorbills and fulmars and nesting sites of choughs, ravens and peregrines. This area is also very well known for rock climbing and it is quite common to see a person scaling vertical 40m cliffs, formed by differential marine erosion along vertical joints and small faults, during the summer months. The Green Bridge of Wales is an almost textbook example of a

natural sea arch with a span of roughly 25m. This arch is mostly massively bedded Carboniferous Limestone, known as Stackpole Limestone, with interbedded mudstone. Eventually this arch will collapse to form two sea stacks due to weathering and erosion by the wind, rain and, of course, the sea with its powerful wave action. I've visited this spot in very stormy weather, where the winds are so strong it's tricky to stand up and the spray from the waves drenches you as you near the edge! Stack Rocks is located about 300m away to the East and is an example of two limestone pinnacles known as the Elegug Stacks. 'Elegug' is the Welsh name for guillemots. There is a fault that separates the two stacks which downthrows to the East. This is shown by a prominent palaeokarst on the surface of the larger stack while it is also visible in the centre of the smaller stack.

Image 3: The sheer limestone cliffs near Stack Rocks. (Photo taken by the author, 21/04/19).

Strumble Head

Strumble Head is located in North Pembrokeshire, West of Fishguard (see Figure 1). This area is known as the Pencaer Peninsula, though it isn't actually a peninsula, with the Strumble Head lighthouse creating a focal point on the coast. This area is part of the Strumble Head Volcanic Group and compromises a mixture of subaqueous felsic tuffs, rhyolites and felsic-mafic pillow lavas which are interbedded with black shales and turbidites.

Image 4: Pillow Lava at Strumble Head. (Photo taken 13/08/19).

These rocks were formed in an elongated caldera with the southern margin marked by the Fishguard-Cardigan Fault. The volcanic and sedimentary rocks of this area are both interrupted by dolerite and gabbro intrusions which occurred at the same time as the volcanic activity. At the Strumble Head lighthouse there is a large area of pillow lava. Pillow lava is formed when basalt lava is extruded from fault-defined submarine fissures. When the lava comes into contact with the sea water it cools rapidly forming concentric fractures and a glassy outer layer which then acts to insulate the inner pillow so it cools more slowly. As this outer glassy obsidian layer insulated the inner pillow, it also trapped gas volatiles which were exsolved from the lava creating vesicular texture.

Image 5: Vesicular texture found at Strumble Head, below the car park, at the large pillow lava area. (Photo taken by the author,

Image 6: Amygdaloidal texture found at Strumble Head, mineral unidentified. (Photo taken by the author, 13/08/19)

Some of these vesicles were then later infilled by precipitated minerals such as calcite or chlorite creating an amygdaloidal texture however many of the amygdales were then later removed by weathering.

Stackpole Quay

Stackpole Quay is located in South Pembrokeshire and is owned by the National Trust. It is part of the Stackpole Estate SAC, SPA and has multiple SSSI designations for both its geology and biodiversity. This area of coastline is particularly interesting as there are many faults and folds and dramatic coastal features which show the tectonic history of the area.

Image 7: Syncline in the Visean Limestone at the Northern Bay of Stackpole Quay with fold axis running SEE to NWW and plunging to the SEE. (Photo taken by the author, 23/04/19).

At Stackpole Quay it is possible to see the boundary between the Old Red Sandstone containing conglomerates and sandstones and mudstones laid down in the Devonian and Silurian periods between 408-427 Ma and the Grey Carboniferous Limestone (from the Visean Age) containing coral fossils, brachiopods, fishes, bivalves and many other less abundant fossils. This shows that at this time the area was submarine in a tropical latitude due to the presence of the corals. Also at the North Cove of Stackpole Quay there is a dramatic exposed syncline which, along with the 2m fault breccia and gouge (in the Quay Harbour) and the slickensides, present both here and at nearby Barafundle Bay, show the forceful tectonic activity that this area underwent in the Variscan Orogeny in the Late Paleozoic and subsequent tectonic forces after this event.

Image 8: Solitary Rugose Coral fossil in the Carboniferous Limestone at Stackpole Quay. Approximately 2cm in diameter (Photo taken by the author, 23/04/19).

Marloes Beach

Marloes is a long, sandy, tidal beach located in West Pembrokeshire which is about 1.5 km long and very popular with tourists, nature lovers and geologists alike. This beach is located near the Deer Park at Martin's Haven where the boats for day trips to the Skomer Island Marine Nature Reserve and Skokholm just offshore and Grassholm lying 7 nautical miles out to the West, leave to see the internationally important seabird colonies on the islands. There are over 350,000 nesting pairs of Manx Shearwaters alone on Skomer, and 39,000 pairs of gannets breeding on Grassholm. The area is also famous for its Atlantic Grey Seal colony, and in the Deer Park it is possible to see Grey Seal pups in the Autumn with good eyesight and a pair of binoculars!

Marloes is very important for geology as the lithology changes several times along the beach, allowing several different rock types to be examined in a relatively short walking distance. Starting at the NW end of the beach there is Matthew's Slade, a small grassy hollow comprised of the Silurian Coralliferous Group. Moving along the beach to the SE the Silurian lithology changes to Grey Sandstone, then the Skomer Volcanic Group containing many small dyke intrusions, and then a larger intrusion of Microgabbro. This is then followed by the Coralliferous Group and the Grey Sandstone again, and southern end of the beach the headland is made of the Ordovician Albion Sands Formation. There are also several faults along the beach all of which run from SWW to NEE, parallel to the bed direction.

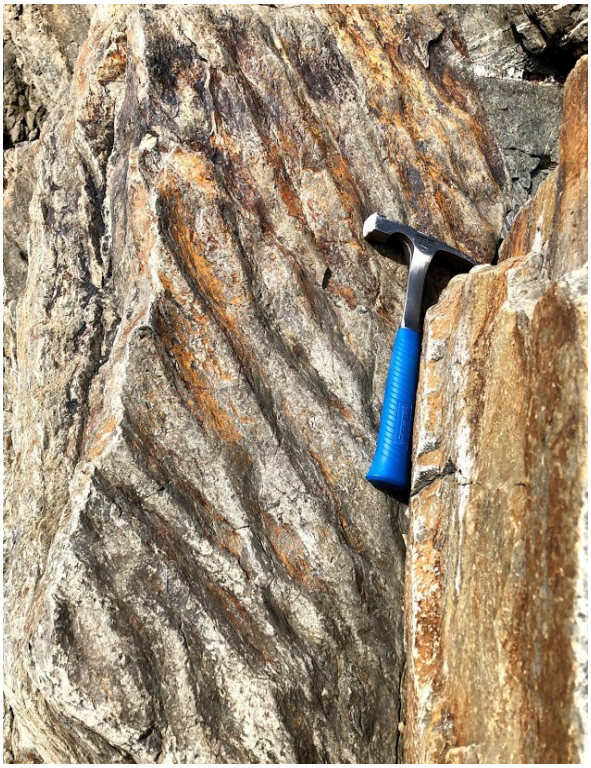

Image 9: Symmetrical Ripple marks in the Ordovician Coralliferous Group. Hammer for scale. (Photo taken by the author,

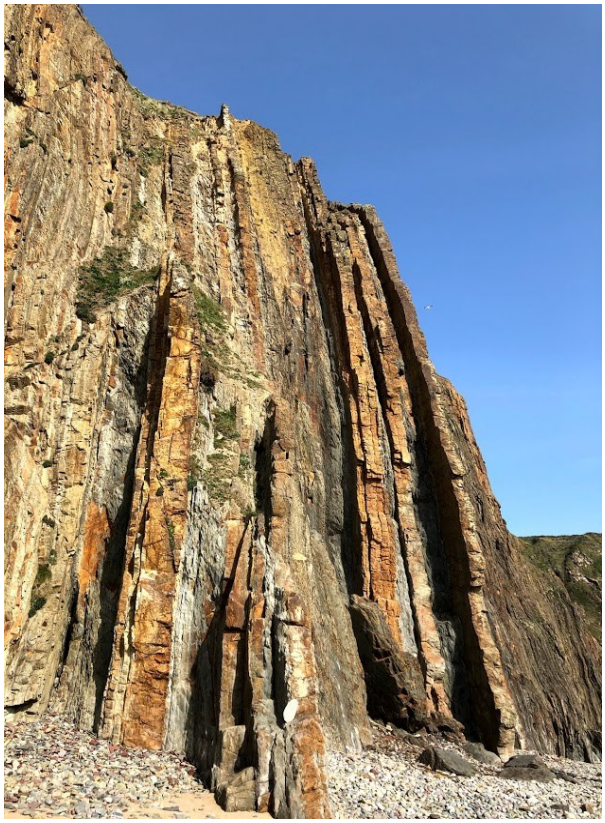

Image 10: The Three Chimneys feature at Marloes Sands. (Photo taken by the author, 20/04/19)

As there are so many things to talk about at Marloes, I am going to focus on a couple of places. Firstly, as soon as you reach the beach it is very easy to spot one of the many large Coralliferous boulders which litter the beach showing clear symmetrical ripple marks. This shows that at the time of deposition this area was submarine in a tidal area, not so different to today! Further down the beach is a famous feature known as The Three Chimneys which are three, almost vertical, beds of weathered ferruginous sandstones. The bases of the sandstone show low level load casts. In the early Silurian, Marloes was located near the northern edge of a large landmass with several Basaltic Volcanoes on nearby Skomer Island. This explains the marine features such as the symmetrical ripple marks and also the minor and major intrusions of the area.

Pembrokeshire is such a special place. It is both geodiverse and biodiverse. For the geologist it provides a fantastic opportunity to see evidence of several different paleoclimates and geological features in one relatively small area. For me, Pembrokeshire is a really special place for all of these reasons and several personal ones. It is a landscape I've grown up knowing, but I've seen it with different eyes since I started my A Level Geology course. It is really easy to see why this area was been designated as the UK's only coastal National Park, and hosts so many SSSI, SPA and SAC designated sites. It is an extraordinary place, beautiful, awe-inspiring and fascinating. I hope you will consider visiting it to explore it for yourself!

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O'ahu, Hawaii. May 2018
By Mellissa Freeman

The Open University Geological Society ran a trip to Hawaii that I was lucky enough to be on in May 2018. We spent a few days exploring the geology on O'ahu before heading on an un-successful lava hunting quest to Big Island. We arrived just after the large earthquake and the start of fissure eruptions that dominated the news for a few weeks. Anyway, it's not all about volcanos! This is just a whistle stop tour of some of the locations we visited along the south and west of the island.

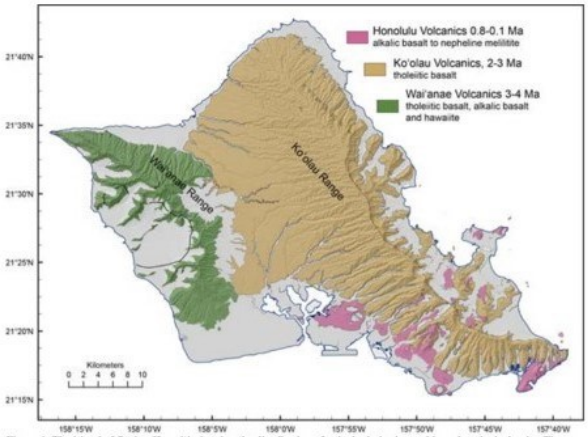

Figure 1. The island of O'ahu, Hawai'i, showing the distribution of principal physiographic and geological units. The Wai'anae and Ko'olau ranges represent the remnants of individual major shield volcanoes.

O'ahu is the third largest of the Hawaiian Islands and is known as 'The Gathering Place'. The island is made up of two deeply eroded shield volcanos; these forming the mountain ranges along both sides of the island (east and west). Wai'anaea is the oldest and is on the west of the island. It would have risen above sea level approximately 4 MA ago producing mainly alkalic basalts before becoming dormant. A