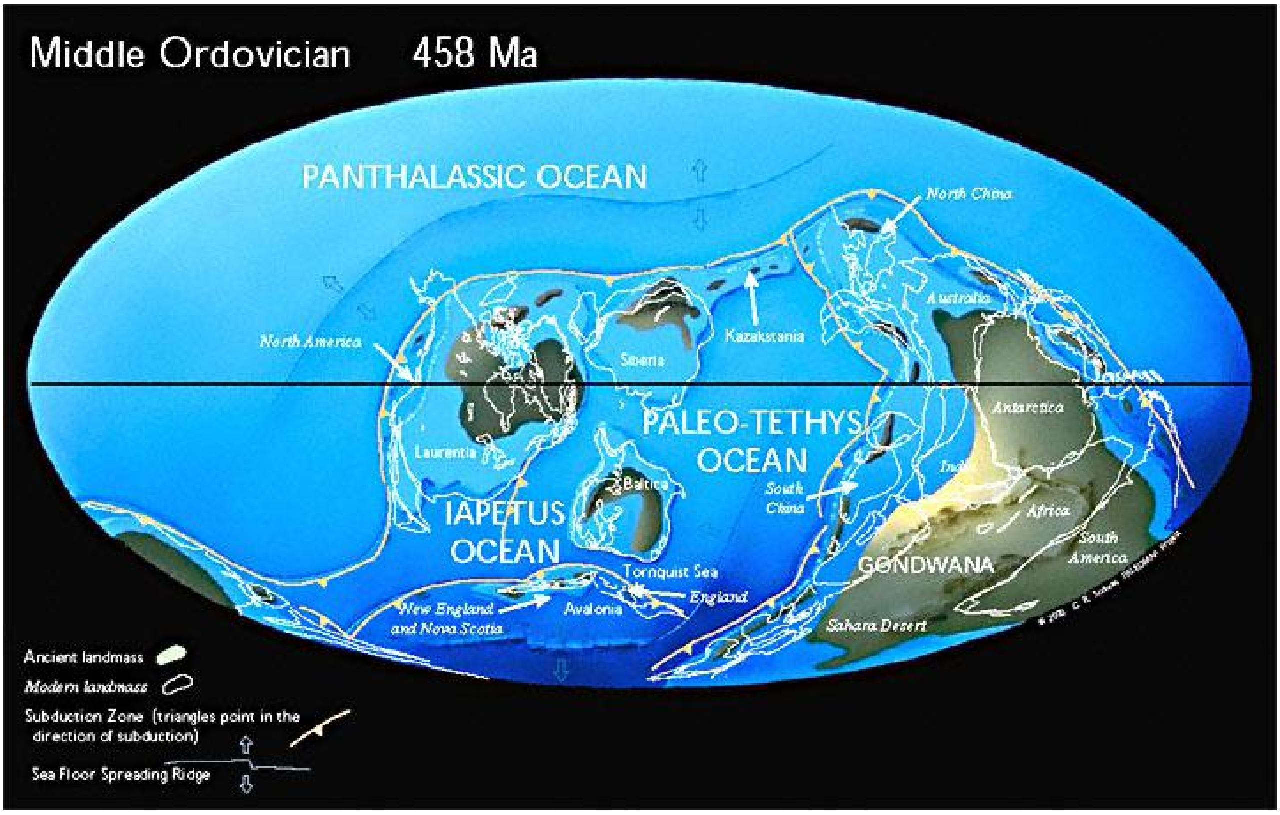
Geological History of the Welsh Basin: an outline

The Welsh Basin was a small sea in which were deposited the Cambrian to Silurian rocks of Wales and the borders. The succeeding Devonian Period represents the demise of the basin, and an international incident that resulted in the first instalment of British unification. This whole tale records a tectonic history that allows us to have a simple understanding of the sequence of the different rock types and environments, and allows us to immediately recognise the likely age of the great majority of rocks that you will encounter in the region. So, not only does it tie things together in a very satisfying way, it is also really rather useful...

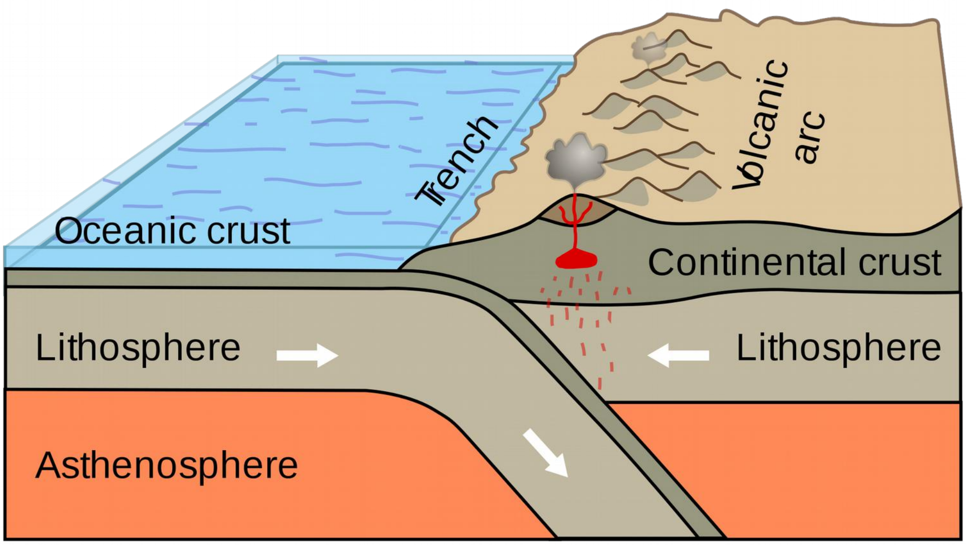


Ordovician palaeogeography (reproduced with permission from scotese.com). Avalonia is a chain of islands in the southern temperate zone.

Tectonic Setting

The key to the entire story is that England and Wales were part of a microcontinent named Avalania. This small plate also included parts of Belgium and France, southern Ireland, and some areas of Nova Scotia and New England, but was basically a thin sliver of continental crust. In Precambrian times, this sliver was part of Gondwana, the great southern supercontinent, and located close to the South Pole. It separated during the early Cambrian, with a new ocean (the Rheic Ocean) forming behind it to the south.

Between Avalonia and the next landmasses to the North (Laurentia and Baltica) lay the Iapetus Ocean. Scotland and northern Ireland were part of Laurentia at this time, in the southern tropics or subtropics! During the early Cambrian, at least, the Iapetus Ocean started to be subducted, initially beneath oceanic crust, and later beneath the continental crust of Avalonia. The entire ocean was gradually subducted, until none was left... and in that sequence lies pretty much the whole story!



A typical subduction-based tectonic setting. The back-arc basin normally forms behind the volcanic arc.

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Back-arc basins

A volcanic arc occurs as a reaction to subduction. Specifically, it is a reaction to water being dragged into the upper mantle due to the rocks being wet (both with free water in cracks and pores, and in the form of hydrous minerals that contain water within their structure). This might not seem very significant, but water affects the chemical balance of magma, suppressing the melting point. The result is that the surrounding bits of the upper mantle, which are usually a very soft solid... melt. With no change of temperature needed. The magma rises due to buoyancy, eventually hitting the crust and working its way upwards, until eventually a line of volcanoes are formed. Examples of this today are, for example, the Aleutian Islands, or the Carribbean volcanic island chain. There are differences depending on whether the crust above is continental or oceanic, but the process is much the same.

Behind the volcanic arc, something different happens. A back-arc basin is formed by a peculiar quirk of tectonics: when subduction occurs, the forces acting on the sinking plate pull it not only downwards, but (from the perspective of the over-riding plate) also backwards. The connection between plates, though, is extremely sticky. This means that the over-riding plate is slowly stretched, and after the thickened crust of the volcanic arc, it actually gets thinner. The crust then sags, forming a marine basin. In extreme cases this can form a rift, where the continental crust separates entirely and a new ocean basin is formed.

In Avalonia's case, the island arc ran up the Irish Sea and through eastern Ireland, and the back-arc basin—the Welsh Basin—developed to the east of it. Through the 120 million years or so of its evolution, various aspects (such as the extent of volcanic activity) gradually changed... but that's the story in a nutshell.

Continental Collision

Eventually, the Iapetus Ocean was entirely subducted, and Avalonia collided with Laurentia, joining Scotland to England, and fusing what would become Ireland together. The process of final approach was complex, with multiple planes of subduction freezing and opening to create the extraordinary array of faulted blocks and slices that we see in the Southern Uplands and in Anglesey. Finally, though, in the late Silurian, there was nothing left to give... and Avalonia ploughed into the southern face of a large continent. The result was a predictably impressive mountain range, rather like the Himalaya today (formed by India colliding with Asia).

This mountain range included the Caledonides of Norway, the Highlands of Scotland, and the Appalachians of the USA. The mountains remaining now are the eroded roots of the range, gradually brought to the surface by the erosion of the summits over 400 million years. Originally buried deep within the crust, and affected by major tectonic forces, these rocks have been severely metamorphosed, to form the familiar schists and gneisses of the Scottish Highlands.

Where the metamorphism is not so intense, neither was the burial. The Welsh Borders, therefore, were not buried deeply, and must have been underneath only gentle foothills. Travel northwestwards, though, and the rocks become progressively more slaty and more deformed. This happens at depths of typically around 10–15 km, all of which has since been eroded away. In comparison with high-grade metamorphic rocks, this isn't very deep (diamonds need around 90 km of overburden to reach the necessary pressures), and suggests foothills rather than high mountains.

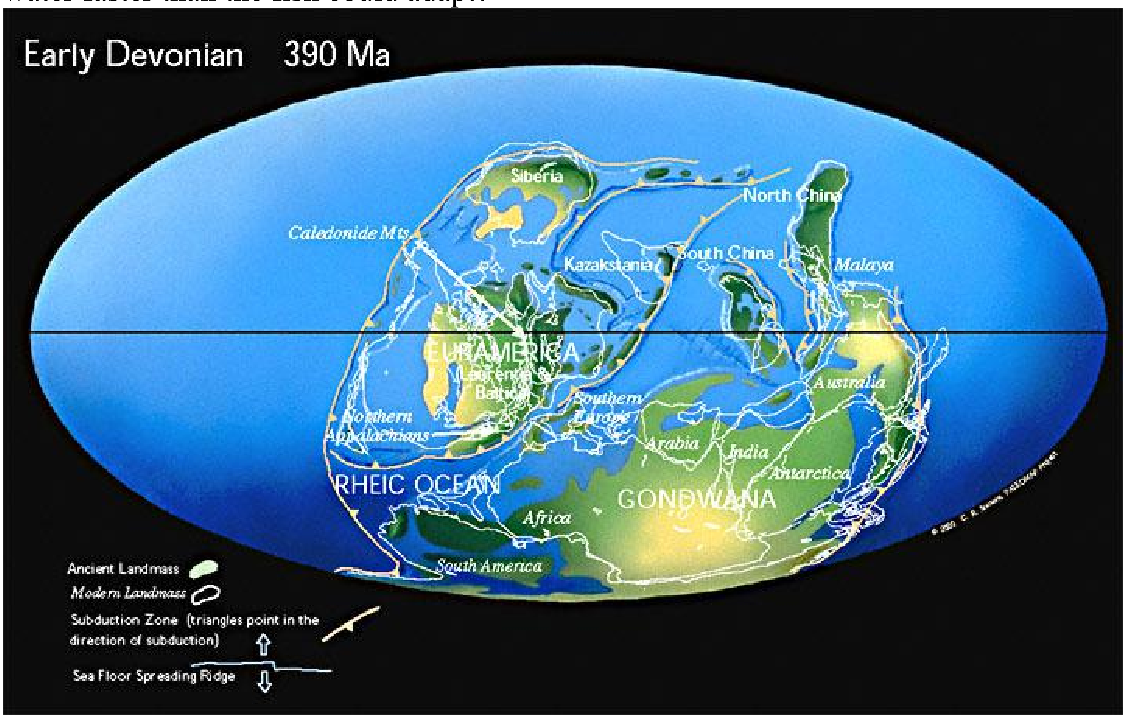
Characteristics rocks, by Period
(*Precambrian*: these little isolated pockets of exposed rock are very diverse in age and nature, and no generalisation can be made. They are usually a little more metamorphosed than the younger rocks, however!)

Cambrian: Typified by long sequences of homogeneous sandstone (early Cambrian; e.g. the Rhinog Grits), black mudstone (middle Cambrian; e.g. Menevian of Pembrokeshire) and mixed fine sandstones, siltstone and mudstone (late Cambrian; *Lingula* Flags). There is some volcanism, but not very much, and the changes in rock type are very gradual. Great thicknesses of monotonous sedimentary rocks were ultimately formed, which can be recognised as easily mappable units across half of Wales.

Ordovician: Extremely diverse, but typified mostly by grey-black graptolitic mudstones and siltstones in offshore settings, through to major volcanic deposits in island settings. Aside from the mudstones, there is very little consistency, and formations are often recognised only in particular areas. In the shallow-water areas in and near the borders, micaceous sandstones are typical.

Silurian: Generally low-carbon, grey-green (offshore) or grey-blue (platform) siltstones and limestones, until the latest beds. In central Wales these are frequently laminated, and closer to the shoreline they are increasingly interbedded with thin transported sandstone layers, often full of shelly debris. On the platform, reefs were developed extensively in, e.g., the Wenlock Limestone Formation; these are gradational with the transported beds and deep-water deposits offshore.

The Ludlow Bone Bed represents the final moments of the Welsh Basin, but remains enigmatic: is it the result of the salinity in the last parts of the 'marine pond' being diluted by fresh water faster than the fish could adapt?



Devonian: The Old Red Sandstone (latest Silurian and Devonian) is a thick sequence of run-off products resulting from the Caledonian Orogeny: sandstones, mudstones and conglomerates laid down in extensive river and lake systems. Almost all of this was terrestrial, with marine fossils only in the oldest beds, just above the Ludlow Bone Bed. Although early land plants can be found in the Old Red, the land was fairly arid due to passing through the southern subtropical arid zone (comparable with a similar zone that contains the Atacama and Namib deserts today).

Carboniferous: After the end of the Welsh Basin, tectonics continued unabated... with the formation of Pangaea as (what-would-become) Wales drifted north over the equatorial region. This resulted in vast river drainage, steadily filling the shallow seas of the Carboniferous Limestone with sand and mud (the Millstone Grit), followed by the formation of dense swamps that covered an area the size of western Europe. This, of course, led to the coal deposits.

Permian: Still later, the area drifted further north, through the northern arid tropical zone... at the same time as the full development of the Pangaea supercontinent. This, unsurprisingly, led to the creation of vast deserts that are represented by the New Red Sandstone.

Thought for the day

The broad pattern of rock types is therefore dictated as much by tectonic setting and latitudinal position as it is by the precise environment. The local environments are themselves a consequence of the tectonics and geography, which is of course why there are no carbonate platforms around the UK today. With an understanding of this history always in the background of your mind, it all makes a *lot* more sense when it comes to interpreting what you're seeing in the rocks!