Rocks And Geology: The Welsh Connection

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There are two main themes to this article: first, the Welsh influence on the science of geology and, second, the geological history over the last 550 million years that resulted in Wales being where it is today.

Throughout the world, all rocks older than 550 million years are termed Pre-Cambrian. 'Cambria' is the ancient Roman name for Wales so all rocks from the origin of the planet over 4 billion years ago to 550 million years ago are 'Pre-Wales'. The first three geological periods in which abundant fossils are found also have a Welsh connection. These are, from oldest to youngest, Cambrian, Ordovician and Silurian, the last two being names of ancient tribes that lived in what we know today as Wales.

Why the Welsh connection? The science of geology started in Britain, and the first eminent geologists studied rocks in mid and north Wales to unravel the sequences of rocks covering the period from 550 million years to around 400 million years. They decided to give the formations names with a Welsh connection. These names have been used ever since by every geologist in every country. Globally, over 90% of the geological stages in the history of the Earth are named after Wales or Welsh tribes.

Wales, at the commencement of the Cambrian age, was linked to England and located at the South Pole. A 550-million-year journey commenced as Wales and England moved north-west, linking up with Scotland and Ireland around 400 million years ago. Approximately 340 million years ago, Wales crossed the Equator on its northward journey, roughly where Dakar is today, and then continued in a north-westerly direction to where it is now. The driving forces were huge convection currents in the molten and semi-molten rocks beneath continents that were then, and still are now, pushing the continents around like giant ships on a sea.

Background

The Montgomeryshire Society, of which I am a member, holds a long weekend somewhere in Wales every second year. Hearing that I am a geologist, some of the Society's members asked me to explain the nature of the rocks in an area near Llanfyllin, Montgomeryshire, during a Sunday morning walk through some beautiful countryside. Producing a British Geological Survey map of southern Britain I proceeded to explain where we would have been when the rocks beneath our feet were formed, and the story of the Welsh connection with geology. This must have impressed someone because I was invited to make a presentation on the subject at a joint meeting of the Montgomeryshire Society and Cymmrodorion on 6 February 2012 in the Royal Academy for Engineers in London.

Although I was born in Anglesey my secondary education was in Welshpool, Montgomeryshire. I was good at geography and my teacher, Miss E. M. Hignett, persuaded me to do a one-year crash course to get an O-level in geology. I owe her a huge debt of gratitude because this led to my career as a geologist in the mining industry. I went on to get a degree in Geology at Liverpool University, and since leaving university have worked in the mining industry all over the world.

This article summarizes the presentation I gave on 6 February 2012. Many of the drawings that I used to illustrate the presentation were taken from two books, one produced in 2007 by the British Geological Survey, *British Regional Geology, Wales,* by M. F. Howells, and the second produced in 1999, *The Geology of Britain: An Introduction,* by Peter Toghill.[1] I highly recommend both books, the latter being more appropriate for non-geologists.

The presentation was in two parts, the origin of geological science including the importance of Wales in the development of geology, and how did Wales, and for that matter the British Isles, evolve.

The origin of geological science and the Welsh connection

The first complete book in the world dealing with geology was published in 1795: *The Theory of the Earth*, by James Hutton. At this time, canals were being built in Britain in order to transport bulk materials. The excavations exposed lots of rock formations and William Smith, who was working on the canals, demonstrated that different rocks had distinct fossils. This led to dividing the rocks up into distinct formations. The British Isles, from a geological perspective, is very fortunate in having rocks from all ages of the Earth's history in a relatively small area. This, in combination with the progress of the industrial revolution in Britain, helped promote the development of geology in this country and then the rest of the world.

By 1815, William Smith had produced the first geological map of England and Wales with rock formations defined by different fossils. Subsequently, more detailed investigations of the different rocks followed. What are termed 'type areas' were selected by eminent geologists to try to unravel the mysteries of the rocks. Two of the most important type areas were in mid and north Wales where in 1831 two of the most well-known geologists of the day, Adam Sedgwick and Roderick Murchison, began studying the rocks. Intense rivalry occurred between the two. Sedgwick was studying the rocks in and around Snowdonia while Murchison was working in the Welsh borderlands. Sedgwick designated the rocks he was studying the Cambrian, the Roman name for Wales. Murchison, who was studying younger rocks, termed the rocks he was studying the Silurian Formation, after an ancient Welsh tribe. Decades of debate followed concerning the boundary between the Cambrian and Silurian and it was only after both Sedgwick and Murchison had died that another geologist, Charles Lapworth, put forward the argument that the lower Silurian rocks of Murchison and the upper Cambrian rocks of Sedgwick were in fact the same. In 1879, Lapworth put forward the name Ordovician for those rocks between the Cambrian and Silurian, after another ancient Welsh tribe. Of course, there were many geologists studying different rocks during this period

1 M. G. Howells, *Wales: British Regional Geology* (British Geological Survey, Nottingham, 2007); Peter Toghill, *The Geology of Britain: An Introduction* (Shrewsbury: Swan Hill, 1999).

and gradually what is termed the Geological Column was formulated.

The Geological Column starts, at the base, with Pre-Cambrian rocks which are the oldest rocks on the planet, from the Earth's origin over 4 billion years ago to approximately 550 million years ago when fossils started to become abundant. For the next 150 million years, during the Cambrian, Ordovician and Silurian periods, all life was in the sea. It was only 400 million years ago that the first fossils of land creatures occurring in the Devonian period, named after the county of Devon, appeared. These land creatures were invertebrates and in parallel with their evolution the first plants developed. Following the Devonian, the Carboniferous included a time when huge forests developed that were to produce much of the coal that has been mined over the last two hundred years. The Carboniferous concluded 290 million years ago to be followed by four major periods, Permian, Triassic, Jurassic and Cretaceous, ending 65 million years ago, the latter two famous for dinosaurs. During these four periods there were several mass extinctions of animals and plants both on land and in the seas, and during one of these approximately 95% of known species perished. In geological terms, the period from 65 million years to today is divided into the Tertiary to 2 million years and then the Quaternary, thus concluding the Geological Column.

It should be noted that after the Devonian, naming of geological formations becomes more international, the Permian named after the area around Perm in Siberia, the Jurassic after the Jura Mountains in Switzerland and so on, so the British geologists didn't have it all their own way. The British geologists did, however, establish the science of geology that evolved during the 1800s along with the understanding of evolution put forward by Charles Darwin.

The rocks beneath our feet: how Wales evolved – tools and influences

Geologists have been able to unravel the history of the continents over the last 550 million years far more easily than the period of the older rocks because abundant fossils from various animals that populated the oceans started to appear at this time. The continents of 550 million years ago were made up of ancient pre-Cambrian rocks, and were devoid of animal or plant life, as nothing existed on the continents apart from very primitive life such as algae.

Geologists have other tools available to them as well as the fossil record, to assist in understanding the evolution of the continents. These include well-developed geological maps of most of the world's land surface, an understanding of climatic changes, ability to age rocks, and an understanding of the Earth's magnetism which helps decipher the historical location of rocks by studying the orientation of iron bearing minerals.

Over the last 550 million years the Earth has always been changing. Apart from the evolution of plants and animals, the Earth's temperature has changed quite substantially and in parallel with this the sea levels. Historically, the Earth's surface temperature has been much warmer than it has been over the last 2 million years, and as a consequence the sea levels have been much higher. Only two other periods have been equally cool with such low sea levels as we have today, around 480 million years ago during the Ordovician period, and 200 to 300 million years ago during the Permian/Triassic period – before the age of the dinosaurs. The period from 200 to 300 million years ago appears to be the only time other than the last 2 million years when the Earth has had ice caps at the Poles.

There are many forces at work that have affected the Earth's climate over time, not least of all volcanic activity and the Sun.

From the Cambrian to the start of the Devonian (550 to 416 million years ago)

The variety of rocks found in the British Isles reflects a range of climatic conditions from very cold and temperate to tropical. From the Cambrian period of 550 million years ago to today, our islands have been subjected to ice ages, tropical conditions, deserts and temperate periods. Why?

It is now accepted that at the commencement of the Cambrian, when the first abundant fossils appeared, England and Wales were on the north-western edge of a continent called Gondwana, very close to the South Pole. Gondwana contained what is today South America, Africa, the Indian sub-continent and most of the rest of Asia, Antartica and Australasia. This continent was surrounded by an ocean that circumnavigated the globe, and thousands of kilometres to the north-west of England and Wales was another continent, Laurentia, with Ireland and Scotland on its south-east facing England and Wales.

Over the next 120 million years, England and Wales broke away from Gondwana and moved north-west and during the late Ordovician period collided with Laurentia, in particular Ireland and Scotland. At about this time Gondwana was dividing further, and Asia, without the Indian sub-continent, drifted north, crossing the Equator at around 400 million years ago. The rest of Gondwana also moved northwards but was still south of the Equator.

Devonian and Carboniferous (416 to 299 million years ago)

The collision of England and Wales with Laurentia was accompanied by lots of earthquakes, upheaval, mountain building, and volcanic activity. The rocks deposited in the ocean during the Cambrian, Ordovician, and early Silurian periods were contorted and folded and began to form mountains on the edge of Laurentia. New land was formed and the rocks formed during this period in Wales reflect this. They were a mixture of desert sands and near-shore sediments. This was the Devonian period, after the type area of Devon where studies were undertaken to understand the rocks of that period. The first known life appeared on land as invertebrates. The first plant life appeared.

By 380 million years ago, England, Wales, Scotland, and Ireland were together but, due to the formation of mountains and other tectonic activity, were on the east side of the Laurentian continent and 30 degrees south of the Equator. In much of the British Isles, this was a period of conditions similar to the deserts of the south-western USA today.

Gradually, Wales and the other countries moved towards the Equator, arriving there around 340 million years ago. Britain was still part of Laurentia, as was North America, Greenland, and most of Northern Europe. The climate was tropical and the rocks that were deposited reflect this. This is the Carboniferous period, which has three main phases. The first was a period of shallow tropical seas, similar to the Caribbean today, where corals and limestone rocks were deposited. Today these rocks form many of the prominent geographical features such as the Great and Little Orme in Llandudno, many of the hills around the north and south Wales coalfields, and in England the Pennines and the Mendip Hills. The second phase of the Carboniferous was a period when coarser sand-sized sediments filled up the near-shore oceans, forming what is commonly known in Britain as the Millstone Grit. As the seas became land, tropical forests flourished, which led to the formation of the third phase of coalfields formed by the death of the prolific tropical forests.

Gondwana, including the Indian sub-continent, was still south of the Equator and the rest of Asia was north of the Equator, roughly where it is today.

After the Carboniferous (299 million years ago to today)

Britain continued to move north-east from the Equator, but during the next 100 million years the continents merged together to form one giant continent called Pangaea. Gondwana and Laurentia had joined up and had moved north-east to collide with Asia. Britain was stranded in the middle of Pangaea in the sub-tropics some 10 degrees north of the Equator. As it was landlocked, most of the rocks formed at the time were terrestrial: desert. During this period, the Permo-Trias (299 to 199 million years ago), Britain was an arid desert with flash floods. Gradually, erosion of the land resulted in plains with salt lakes, and finally, at the end of the Trias, encroachment of the sea.

At the end of the Permian, there was a massive event that caused the extinction of 95% of the known species at the time. Many sea creatures such as trilobites disappeared completely and for others such as corals and brachiopods many of their species became extinct. On land, large numbers of reptile and amphibian species disappeared to be replaced by early dinosaurs. At the end of the Triassic, there was another major extinction when 80% of the known species became extinct. Small burrowing mammal-like reptiles survived but it took another 180 million years before they evolved into true mammals.

After the mass extinction at the end of the Triassic, the Jurassic and Cretaceous periods of shallow seas surrounded by land occurred. The continents started to split up, beginning to resemble the continents we have today. Britain continued its north-easterly journey, dinosaurs ruled the land and ammonites were very prominent in the oceans. Most of Wales during this time was land and most of the deposition of Jurassic and Cretaceous rocks in Britain such as the Cotswolds (Jurassic) and the Chalk (Cretaceous) was to the south-east of Wales. There are, however, some Jurassic rocks near Barry in Glamorgan which, at the time, was on the coast with an ocean to the south and east.

At the end of the Cretaceous period, 65 million years ago, yet another mass extinction occurred when 75% of all living creatures became extinct. This is famous because this was the end of the dinosaurs.

Wales's journey has continued in a north-easterly direction, changing from the sub-tropical during the Jurassic and Cretaceous to the temperate zones we find ourselves in today. We are still moving and will continue to move as large ships on a semi-molten sea. Why?

What is moving the continents?

We live on continents that can be compared with pieces of peel on the outside of an orange. Most of the Earth beneath the skin consists of molten and semi-molten material that is hot and moves. Large convection currents in this molten and semi-molten material have been at work throughout the Earth's history and it is these currents that are responsible for moving continents, changing the shape of continents, forming mountains, and associated activity such as earthquakes and volcanoes. The two classic examples today are in the Atlantic and Pacific. In the Atlantic a major convection current system aligned in a north-south direction is pushing Africa/Europe away from the Americas at around one centimetre per year. It has resulted in the mid-Atlantic ridge which is best known for the volcanic islands of Iceland, Ascension, Saint Helena, Tristan da Cunha, and so on. In the meantime, in the middle of the Pacific another convection system is pushing the Americas to the east and Asia/Australia to the west. The Americas are being squeezed and this has resulted in what is termed a subduction zone along the entire length of the western coast of the Americas from Alaska to Cape Horn. This is the cause of major earthquakes in California, Alaska, Chile, and so on.

There is no reason to suppose that the convection currents beneath us cannot change directions and interrupt Wales's journey further north. For the last 550 million years, however, we have moved in a gentle arc from the South Pole to where we are today averaging around three centimetres a year.

I hope the presentation and this short paper have given the non-geologist an insight into the geological history of Wales and the important role Wales has played in the development of geological sciences.