Issue 8
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The Silurian

The Magazine of the Mid Wales Geology Club

Contents

The Magazine of the Mid Wales Geology Club
www.midwalesgeology.org.uk

Cover Photo: Chevron folding at Millook Cornwall. ©Chris Simpson

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Thank you to the contributors to this issue, who endured sessions of arm-twisting to produce an eclectic mix of articles. Ranging from structural geology to minerals.

The observant amongst you will realise we have an article for the next issue (one), clearly more are required.

Michele Becker

Submissions

Please read this before sending in an article.

Please send articles for the magazine digitally as either plain text (.txt) or generic Word format (.doc), and keep formatting to a minimum. **Do not include photographs or illustrations in the document.** These should be sent as separate files saved as maximum quality JPEG files and sized to a **minimum size of 1200 pixels** on the long side. List captions for the photographs at the end of the text, or in a separate file.

'Members Photographs' and cover photos are also wanted. Cover photos need to be in 'portrait' format and a minimum of 3000X2000 pixels.

Geology of Powis Castle and the Park

Powis Castle is famed for its lovely red stone and one of the finest gardens in Britain. It also has an interesting geological history, situated exactly on the Severn Valley Fault Belt, a major lineament which may well be a NNE extension of the Tywi Lineament, itself a component of the Welsh Borderland Fault System, more than a billion years old, dividing the Cymru terrane of Wales from the Wrekin terrane of England. The stone of the castle and its quarries is also situated exactly at the division between two geological periods, the Ordovician and the Silurian, a time of mass extinction of species.

Geological setting before deposition of the Powis Castle Conglomerate

The castle stands on one of two ridges of red rock, probably an anticlinal fold formed long after the conglomerate was deposited (**Fig. 1**). The Powis Castle Conglomerate is the basal stratum of the Silurian period in this district, laid down around 440 Ma ago. It lies unconformably on rock formed perhaps as much as 15 Ma earlier. In the late Ordovician, over 450 Ma ago, the Welshpool district was situated in deeper water offshore on the southeast margin of the Welsh Basin, an inland sea which at times covered most of Wales. Rivers flowing into the Welsh Basin from the east deposited muddy, silty sediment which formed a grey rock many hundreds of metres thick, now designated the Pwll-y-Glo Formation. Further Upper Caradoc sediments and then probably muddy sediments of the Ashgill, many more hundreds of metres thick, were deposited on the Pwll-y-Glo.

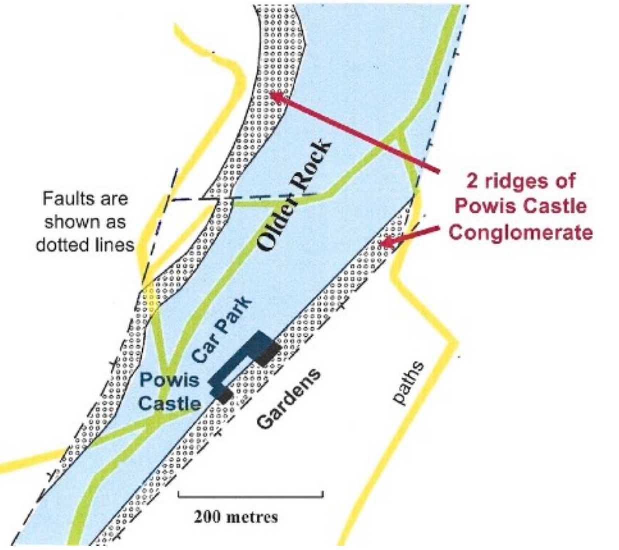

Fig. 1 *Plan showing two exposures of red rock probably an anticline.*

At the end of the Ordovician period, global cooling produced polar icing which caused global sea level to fall by up to 100 metres. The Welshpool district became emergent for millions of years. The Upper Caradoc, and the Ashgill mudstones deposited above it, were subject to continuing erosion which left rock of the Pwll-y-Glo Formation exposed. In the late Ordovician there was also a slight tilting and uplift of the district as the continent of Baltica bumped the continent of Avalonia. This is known in the region as the Shelveian Event. It caused substantial folding and uplift of the Shelve district to the east of Welshpool, but the buffering effect of the Severn Valley Fault Belt largely protected the area west of the Severn Valley from major uplift. As polar ice melted and sea level rose, sediment was once again deposited on this slightly tilted underlying strata of Pwll-y-Glo, now eroded flat, but with millions of years of non-sequence due to emergence and erosion.

The rock beneath the red conglomerate can be glimpsed at the side of a private path cutting north-south through the western ridge [SJ 2144 0643] (**Fig 2**). Nearby on the ridge the red conglomerate can also be seen, but this grey exposure beneath the tree is different: a grey mudstone now with patches of white lichen. It was formed millions of years earlier, covered by further hundreds of metres of mudstone, all of which was later eroded away, until it was covered again by rising sea level and the coarse shore face which became the Powis Castle Conglomerate. This underlying

Fig. 2 *The rock beneath the red conglomerate. Grey mudstone with patches of lichen. The castle appears top right.*

Pwll-y-Glo Formation is interpreted to lie in the core of the anticline now beneath the car park. In other places the mudstone contains abundant beds of storm-generated sandstone.

The Powis Castle Conglomerate was a beach

The conglomerate is exposed over a distance of around ten miles from just south of Berriew, to north of Guilsfield, rarely more than 30 metres thick, and steeply folded. Located on the Severn Valley Fault Belt it is very dislocated and often not seen. It once was a beach. **Figure 3** is based on a sketch by Dr Richard Cave, describing a possible depositional environment of the conglomerate.

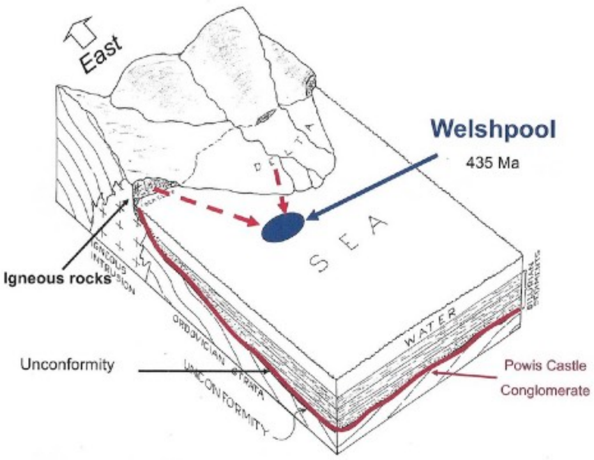

Fig. 3 *Depositional environment: A beach based on a sketch by Dr Richard Cave.*

Rivers flowing from mountainous land to the east formed a delta as they flowed into the sea bearing sand, mud and igneous quartz pebbles (**Fig. 4**) which are not local rock and must have travelled at least a hundred miles. There are also pebbles and larger cobbles of igneous rock, not all well rounded, and not having travelled very far, with the same composition and structure as the igneous rock of Standard Quarry just west of Welshpool. This hard, igneous intrusion would have been prominent at the time and probably exposed as sea cliffs along the beach.

Fig. 4 *The conglomerate with pebbles of distant quartz.*

The district was folded later, during the Acadian Orogeny

The conglomerate was originally laid down over a wide area of sea floor and remained more or less flat for over 40 million years. A continental sliding collision to the north-west eventually began to fold the district in the Acadian Orogeny. This lasted perhaps 50 million years, spread across North America and much of northern Europe but its main impact on Mid Wales occurred around 395 Ma in the early Middle Devonian when Scotland and England collided. West of the Severn Valley the folding was severe. The conglomerate at Powis Castle was folded into an anticline (**Fig. 5)**. The south-east ridge on which Powis Castle is built dips nearly vertically in places. The dip of the north-west ridge is more gentle, which is usual for an anticline verging from northwest to southeast. Older rock is exposed in the core of the anticline.

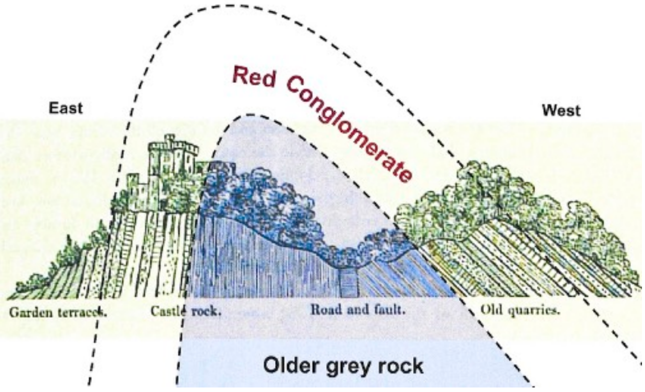

Fig. 5 *Murchison's anticline. Annotation of Murchison's woodcut from Silurian System (1839). Ridges young in opposite directions.*

Dr Richard Cave, in early notes and in chapter 2 of Geological Excursions in Powys (1993), raises another possibility for the structure of the two conglomerate ridges (**Fig. 6**). Opposite limbs of an anticline would each young outwards in opposite directions. However, a quarry face (SJ 2163 0647) on the outer edge of the castle ridge, near the statue of Hercules and close to the north-east corner of the castle, shows markings which can be interpreted as narrow ridges of groove-casts filling scrapes eroded by pebbles flowing onto the sea floor in turbidity currents. These groove-casts would show on the underside of the bed and therefore the bed would be younging into the quarry face, as opposed to facing outwards. In this case the two ridges

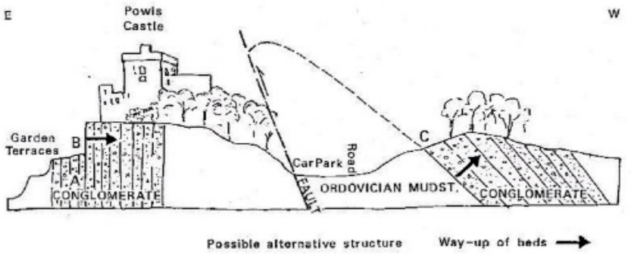

Fig. 6 *An alternative structural possibility, Cave's sketch of a possible ridge repetition by faulting. Arrows on the fault show fault movement. Ridges young in the same direction.*

are not opposite limbs of the same anticline but fault repetition of the same limb, with the opposite ridge lifting relative to the castle ridge. There would still be an anticline but with the other limb unseen. This is the Severn Valley Fault Belt so it is a possibility, but the consensus remains an anticline and this is the interpretation in the map of 2008 compiled by Cave & Waters. Checking such conjectures is made difficult by the scarcity of exposure in this very vegetated area.

The two ridges of conglomerate either side of the car park plainly diverge. When seen from the top of the car park, looking NNE with the castle on the right there is c15˚ between them. This can be explained by a plunge in the fold axis (**Fig. 7**). When a plunging fold is eroded flat the parallel symmetry disappears. The fold axis here appears to plunge downwards SSW towards the top of the car park.

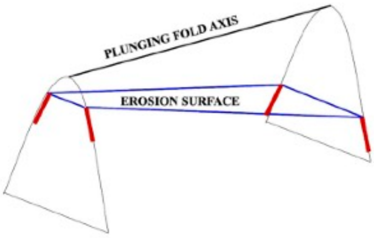

Fig. 7 *Geometry of eroded plunging axis.*

The rich colouring of the conglomerate came even later

The conglomerate was grey when deposited. It is an iron oxide coating which provides the red colouring of this rock. Neither the sand and mud nor the igneous rock of the beach had enough surface iron oxide to be strongly coloured. The iron is assumed to come from ground water rich in iron from circulating through red desert sand and then precipitating an oxide coating within the porous stratum of the conglomerate below. It could not have come from the Old Red Sandstone of the Devonian because this part of Wales was emergent at that time and the Devonian sediments were not deposited. Deposition re-commenced in the Carboniferous but that was eroded following emergence after the Variscan Orogeny. In the Permo-Triassic period, around 250 Ma, the desert sands of Pangaea would have lain in the district, and not far separated from the basal Silurian, with most of the intervening rock eroded away. Today, Permian rocks are exposed only a few miles away in Shropshire.

The conglomerate contains substantial igneous rock, traced back to Standard Quarry

Clasts in the conglomerate display a trachytic structure, the same as nearby Standard Quarry. It has a fine grain size, coloured grey with a faintly greenish tint due to chlorite derived from pyroxene decomposition. Under a microscope it is seen as abundant minute rectangular alkali feldspars within an even finer matrix. The feldspars have a distinctive parallel alignment probably imposed by the flowing magma as it was intruded, 'like a shoal of tiny fish' wrote Cave (**Fig. 8**). Wade (1911) identified it as the mineral bostonite, a description not much used these days. The magma was intruded into Ordovician rock during the Caradoc. It did not intrude the basal Silurian conglomerate, which can be seen lying over the igneous intrusion in the north-east corner of Standard Quarry.

Fig. 8 *Standard Quarry trachyte with flow orientated feldspars and decomposition chlorite crystals, magnified x50 diameters, image from Wade (1911).*

A trail of igneous clasts becoming progressively smaller can be followed from the quarry, south through the Powis castle estate to the ridge of the conglomerate on which the castle stands. Old quarries are situated along the western ridge, now very overgrown. The furthest north point on the ridge where rock exposure could be seen is a low cliff face which may be where an E-W fault has cut off the ridge displacing it to the west (SJ 2170 0697). It could not be accessed closely but photographs from below show split rounded boulders more than 0.5 metre in diameter (**Fig. 9)**. Boulders of this size do not usually move far on a shoreline when sea level is rising and sedimentation is fast.

Fig. 9 *Boulders in the Western Ridge up to 1 metre in diameter can be found in the conglomerate, evidently from the igneous intrusion now represented by Standard Quarry.*

Just over 100 metres further south along the western ridge (SJ 2161 0687) a small exposure can be found on the east flank. The castle is in the distance showing how much the fold plunge causes the two ridges to diverge to the north (**Fig. 10**). The exposure shows cobbles of the greenish grey igneous rock c12 cm diameter, well rounded by beach action (**Fig. 11**) though some are much smaller. The conglomerate matrix mostly lacks the red colouration here. The cobbles decrease further in size in the 500 metres south to the locality opposite the castle on the park drive, eventually become mostly only coarse sand grains and residual small quartz clasts from igneous rock.

Fig. 10 *Western ridge with the castle in the background, trachyte cobbles are revealed in scrapes just below the edge.*

Fig. 11 *Trachyte cobbles on Western ridge here c12 cm diameter, become smaller proceeding towards the castle.*

In places the conglomerate is richly fossiliferous

Fossil remains are not well preserved on a coarse and mobile beach. However, as the sea level rose and the shoreline advanced, the water deepened, the sediment became finer, and the sea floor passed below storm wave base, becoming more tranquil. At a water depth of perhaps 30 metres it was permanently colonised, the fossils preserved, and there is evidence of large swathes of crinoid, a creature with a stem attached to the seafloor and five feathery arms (**Fig. 12**) with which it collected plankton and organic debris. The soft body of the creature is rarely preserved but the stem is composed of calcareous ossicles which preserve well. The abundance of ossicles, 3-10 mm in diameter, in some of the castle building stones (**Fig. 13**) shows the abundance of crinoids on the sea floor. Wade (1911) listed the fossil as *Glyptocrinus*, in his fossil assemblage of the Powis Castle Group, as it was then called.

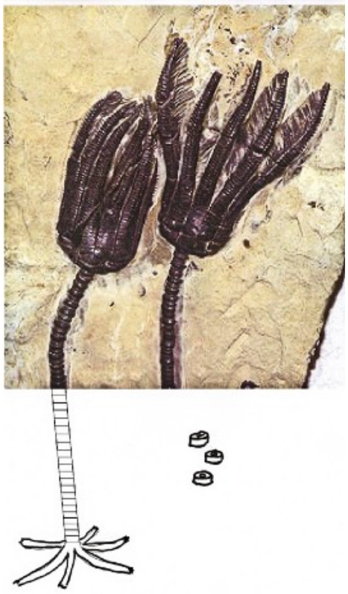

Fig. 12 *The form of crinoids soft theca, mouth and arms are rarely preserved (this fossil is from elsewhere), but the stem ossicles fossilise well.*

Fig. 13 *Abundant crinoid ossicles in the Castle entrance wall, whole ossicles here are typically 3-10 mm diameter but most are fragmented.*

Wade lists seventeen species of Lower Silurian fossils in the park, mostly brachiopods. Only one rugose coral is listed, from the genus *Streptelasma*, a solitary, as opposed to colonial species. Specimens corresponding to this description appear in the red walls of the entrance (**Fig. 14**). Wade describes a typical dimension of 26 mm across the cup, and suggests that it has numerous septa, typically 72, often reaching the centre of the calyx; the specimen shown here may have slightly more. Also listed in Wade is the colonial fossil genus *Favosites*, a good specimen of which was found during a 2012 excursion and remains in the Mid Wales Geology Club's collection (**Fig. 15**). This was not in-situ but was embedded in the disturbed surface of the area of one of the old quarries on the western ridge (SJ 2161 0695). Wade (1911) identified both *F. gotlandica* and *F. aspera* in the park.


Fig. 14 *Solitary coral in the castle entrance wall probably the genus Streptelasma c20 mm dia.*


Fig.15 *Colonial fossil from the western ridge. Genus Favosites, consisting of a cluster of polygonal tubular corallites.*

A single bryozoan was listed by Wade, from the widespread genus *Monticulipora*. Bryozoans are colonies of tiny zooids forming a moss-like animal, though *Monticulipora* can sometimes have a bulkier morphology more like a coral. This species is noted as being 'from underlying beds' and it is considered to be confined to the Upper Ordovician. There are bryozoans in the conglomerate rock (**Fig. 16**) of the castle entrance walls and they are intimately mixed with Silurian crinoid ossicles; either *Monticulipora* survived the extinction to earliest Silurian or this is not *Monticulipora*.


Fig. 16 *Bryozoans in the conglomerate, colonial moss animals. Holes in the colony exoskeleton are 0.2 mm dia.*

Geologists have been unravelling the story of the conglomerate for nearly 200 years

Roderick Murchison, one of the most famous English early Victorian geologists explained much about the geology of the castle and park in his magnus opus, Silurian System, published in 1839 and dealing with much of Wales and the borders. He visited the castle first in 1832, interpreting the two ridges of conglomerate as an anticline, and tracing the conglomerate north through Welshpool and across the igneous intrusion in Standard Quarry. He did not at that time appreciate the large and important gap in the geological succession and considered the red conglomerate to lie conformably on the underlying mudstone and therefore 'form the upper strata of the Caradoc Sandstone or Lower Silurian rocks' (what today we call the Ordovician). But he was wrong.

It was a young Welshpool amateur geologist, Joseph Bickerton Morgan who realised around 1890 that the geological change at the end of the Ordovician period could locally be placed below the red conglomerate, and there had to be a large gap in the succession there. One of the great mass extinctions of species occurred during that time and Morgan's careful study of fossils found that species in the underlying rocks were different to those in the conglomerate and above. He called for the geological map to be redrawn locally, and would surely have worked on that had he not died in 1894 at the tragically young age of 32 years. None of his papers and maps were recovered after his death. In 1911 Arthur Wade published a detailed paper in the Journal of the Geological Society, on north-east Montgomeryshire. This updated the knowledge of the Powis Castle Conglomerate.

The final stage of understanding began in the 1950s with studies by Cave and others, leading to a much fuller explanation of the geological history of the district, culminating in 2008 with the first modern geological map of

Welshpool, drawn together by Cave. This is strictly a provisional map, relying as it does on a large amount of previous mapping work, but for a provisional map it is remarkably comprehensive and detailed. This and the Sheet Explanation, also by Cave, are indispensable in understanding the geology of the district.

Acknowledgements

The late Dr Richard Cave worked in the district for over fifty years, from his PhD thesis to the publication in 2008 of the first modern geological map. He drew attention to earlier study of the conglomerate and wrote notes on a geological walk around Welshpool, some parts of which were subsequently published in Geological Excursions in Powys (1993). He led members of Mid Wales Geology Club (MWGC) on a memorable 2004 field trip around the castle grounds. Dr Tim Palmer and Dr Bill Fitches helped members of MWGC to prepare for an evening geology field trip in the park at Powis Castle in 2012 (**Fig. 17**), part of a National Lottery funded public outreach programme at that time. MWGC members, especially Bill Bagley and Tony Thorp, both grappled with the geology and scythed the nettles blocking visibility of it. Some of the park exposures mentioned here were visited by kind permission of the private Powis Castle Estate, and are not owned by the National Trust nor open to the public.

Fig. 17 *Mid Wales Geology Club members on a walk in the park in 2012 (photo Bill Bagley).*

Colin Humphrey

References

Cave R. 1993 In Woodcock NH & Bassett MG. Geological Excursions in Powys.
Cave R. 2003 Geology of the Welshpool district, BGS Sheet Explanation and Sheet 151 Welshpool.
Wade A. 1911 Llandovery and Associated Rocks of North-Eastern Montgomeryshire, Quarterly Journal of the Geological Society.

Geological Excursion: Crychell Moor Pingos (Near Llananno)

Grid Ref. SO 077735
Maps
Topography ***OS Explorer 1:25 000 No. 214*** *"Llanidloes and Newtown"*
Geology ***BGS 1:50 000 Sheet 179*** *"Rhayader" (Available as either Solid or Drift)*

The path is very exposed on the hill and appropriate clothing and footwear are required, together with gum boots if the short cut is to be taken.

The "full" walk totals 9km, but there is a short cut involving fording a brook and negotiating some fields which may be boggy requiring gum boots, but reducing the distance to 7.5km. For an even shorter walk, the start and end points can be taken from where Glyndwrs Way leaves the council road at SO 085747. This further reduces the distance to 5.6km, however parking there is very limited.

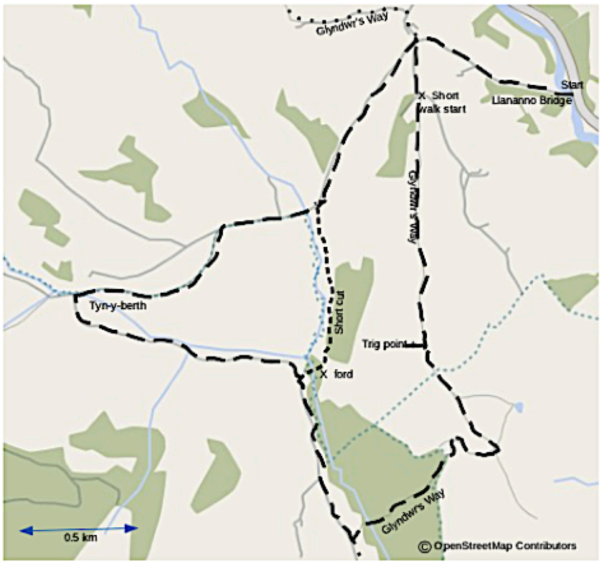

Fig. 1 *Routes – Main route shown as long dashes. Shortcut shown as short dashes.*

A trip into the Ice Age

The normal start point is on the A483, at Llananno Bridge, south of Llanbadarn-Fynydd, at the Bwlch-y-Sarnau turn-off, where parking is easy on the verges (SO 092747).

The main purpose of the walk is to look at the somewhat enigmatic Ice Age structures on Crychell Moor known as ramparted depressions or pingos. These glacial or periglacial structures are best viewed from above before meeting them up close. Accordingly, we gain height first by climbing to the trig point on Ysgwd-ffordd before descending to the valley floor.

Opposite the bridge at the start point is a spectacular cutting showing a ~50m section through the Penstrowed Grits formation. These are marine sedimentary rocks formed some 430 million years ago (Ma) in the Silurian Period when sandy to silty slurries flowed down from the continental shelf into deeper water, forming the thicker and harder more massive beds. They are termed "turbidites" and may have been triggered by storms or seismic shocks. They are separated by very thinly laminated shaley beds formed when fine debris and dead plankton settled in quiet conditions. These are called "hemipelagites" and sometimes have a periodicity of two or three to a millimetre. This may represent a cyclicity in response to annual blooms of algae. (The sections along the A483 towards Llanbister show interesting folding and faulting and could be explored on another occasion)

The walk goes over the bridge and along the Bwlch-y-Sarnau road for 700m before turning left on an unclassified road, joining the signposted footpath “Glyndwr's Way” and, in 250m, turns right through a field gate onto a track (fence and treeline on your left) which follows the ridge of Ysgwd-ffordd as far as the trig point at SO 084735. On your right (west) you look out over the valley of Crychell Moor and you start to see the patterns of the ramparted depressions or pingos on the valley floor. On your left, looking north-west, you can see Castelltinboeth, probably built by Roger Mortimer in the 13th century. Just the substantial ditch and some remains of a gatehouse teetering over it remain.

Fig. 2 *View from the ridge over Crychell Moor.*

Fig. 3 *Ramparted depressions show up clearly as reedy areas on the moor below.*

For the best view, continue along the ridge towards the trig point (SO 084735) and when level with it, bear right on a path through the gorse to a vantage point just past it where the moor is laid out before you in plan view.

If weather permits this is a good point to have a bite and a discussion.

Discusion
What this walk explores is terrestrial, comparatively recent and occurred at a time when humans were around, so it is an opportunity to visualise the environment that would have been familiar to our human ancestors.

Fig. 5: *Google Earth view of Crychell Moor ©Source: Crychell Brook 52°21'14"N3°21'24"W Google Earth 30/11/2008. 06/05/2022.*

Solid Geology
Along the ridge, you have been walking on Wenlockian Penstrowed Grits which form much of the high ground to the east and north. They overlie the thinner Nant-ysgollon Mudstones and the more easily eroded Dolgau Mudstones Formation which are in the Llandovery Series (earlier Silurian) and which underly the valley floor. Older Ordovician rocks of the Cwmcringlyn Formation comprise the higher ground towards Abbey-cwm-hir on your left (south-west).

Superficial or Drift
The structures of interest are evident all over the drift covered valley floor. (Unfortunately some fields have been tilled, but what remains is still impressive.)

Although "pingo" is just an Inuit word for a hill, geologists have developed a more specific definition, that being a periglacial elevation formed in one of two ways.

"Open" pingos form in hilly areas where a source of water such as a spring, injects into the permafrost, freezes and raises the overburden, forming a symmetrical mound, a pingo.

"Closed" ones form in flat lake basins where advancing permafrost generates upward pressure and the enclosed wet soil freezes, again raising a mound.

The structures before us may have been thus formed, but there is another possible mechanism. Ice does not retreat symmetrically and wasting ice can leave a multitude of melting "icebergs" plus detritus which thaws slowly, leaving kettle holes and bogs which can develop into very similar structures.

Which process went on during deglacification here? The one is late glacial and the other periglacial. Or, is it neither, but more complex?

Reconstructing this environment during its formation provides a window into our past, enabling us to imagine Wales at an interesting time when our hardy ancestors may have been occupying land as the glaciers retreated. We know that Neanderthals were around some 200,000 years ago (BP) occupying Pontnewydd Cave, near St. Asaph and at about 30,000 years BP, Homo sapiens like the "Red Lady" of Paviland were occupying limestone caves on Gower in South Wales overlooking the Bristol Channel.

However Mid Wales would have been uninhabitable near The Last Glacial Maximum which was about 18,000 years BP, but after that the glaciers retreated sporadically, with minor advances and retreats, allowing animals and humans to come back. We know the unfortunate Condover mammoths came to grief some 12,700 to 12,300 years BP, when they fell in, or got stuck in, a kettle hole. A final significant advance, the Loch Lomond Re-advance, took place at ~11,000 years BP before the climate ameliorated in the subsequent Holocene Epoch.

We can envisage the Crychell environment at the time. At the Last Glacial Maximum (LGM), ice from the direction of Plynlimon in the north-west would have been moving east and south, probably approaching Crychell along the Ffrwd Wen valley (facing us) and exiting via the Ithon and Teme valleys towards Hereford, so most of the solid geology would have been covered. (Ice can of course go uphill as well as downhill).

After the LGM when climate ameliorated, although the ice would have retreated, it would still be delivering water and sediment via Ffrwd Wen and Crychell Brook. The solid geology would have emerged as now, but the valley floor would have been a watery wasteland.

A recent temporary excavation, visible from the road, at Tyn-y-Berth (See **Fig. 7** below) showed a number of horizontal beds, graded from cobble downward and mainly angular, but some rounded (See **Fig. 8** below). This indicates sporadic flooding by meltwater.

The outlines of the depressions are generally circular or curvilinear, not elongated and with no linear features indicating limits or movements of ice or water. This would imply that calm conditions prevailed during their formation, more likely during periglacial than glacial times.

We should remember that the formation of the these depressions may well not be textbook open or closed pingos or a slowly wasting ice field, but more complex. The valley floor is quite uniformly flat and one can imagine a lot of sediment-laden water around, with ponding, flooding, freezing and thawing. Vegetation could have been growing on any drier or higher patches and this could increase its exposure to sunlight and accelerate its growth. It can have a major influence because it also stabilises sediment, insulates it from both heat and cold, alters its albedo and affects water properties.

All these factors, together with the way water moves within till, both frozen and unfrozen could be important. Open minds are needed and the jury is still out!

Continuing the walk

To continue, return to the track, heading south for 600m, then turn right (still on Glyndwr's Way) downhill for 200m, past a small rocky scraping before turning left (signposted), down again and through a gate into a wood. Go down though the wood, past Neuadd-fach, to a bridge over the brook and up the tarmac drive to the council road at SO 081726, where turn right and walk 700m to a gate across the road at SO079734 (obey the 'close the gate' sign) and continue on the unfenced road.

Fig. 6 *On the moor, depressions from ground level.*

Past the gate the moor on the left is covered with curvilinear signs of ramparted depressions (NB If significantly investigating, ask first at the Tynyberth Farm, 1km ahead of you).

Fig. 7 *Temporary excavation at Tyn-y-Berth, showing horizontal graded beds.*

Generally, the centres of these circular depressions are boggy and peaty and the ramparts are more solid. A sample from half a metre below the turf on a previous visit was fine beige silty clayey material, possibly loess. (sometimes characteristic of periglacial conditions)

Fig. 8 *Spoil from Excavation at Tyn-y-Berth, showing clasts from cobble downward and mainly angular, but some rounded, possibly indicating meltwater flooding events.*

Shortcut or Road?

At this point one should decide whether to carry on or to take the shortcut which avoids the long walk along the road via Tyn-y-Berth, saving some 2km.

For the long walk

Continue along the road towards Tynyberth Farm.

Shortly after the farm, turn right and continue along the road for 2.5km, crossing Glyndwr's Way as you top the ridge, and return to the start at Llananno Bridge, or turn right to the start of the shorter walk.

For the shortcut

There is a "Footpath" sign on the road pointing slightly right shortly past the gate. It heads for a ford which is easily missed. It is best to keep to the right to hit Crychell Brook well south of the ford and work back up. The ford is on shallows at a significant meander (an accurate GPS is SO 07903,73446.)

Cross the ford and head north-east to a gate visible through the trees. Through the gate, go north, keeping the brook on your left hand side. (It can be boggy and the firmest ground is often nearer the brook.) Continuing north, through a gate and an old hedge line, in 700m, go through the field gate and turn right on the council road. In 900m you meet Glynder's Way at the crossroads upon topping the ridge. Go straight on for Llananno Bridge or turn right if you are on the shorter walk.

Tony Thorp

Selected reading

Crychell Moor is a Central Wales RIGS (Regionally important geological site).
Summary at:
https://www.geologywales.co.uk/central-wales-rigs/PDFs/crychell_moor.pdf

Described in detail in:
ROSS, N. (2006). A re-evaluation of the origins of Late Quaternary ramparted depressions in Wales: Unpublished PhD Thesis, Cardiff University. (Actual)pp151-169
Accessed 10/05/2022 via:
https://www.semanticscholar.org/paper/Re-evaluation-of-the-origins-of-Late-Quaternary-in-Ross/f4fb93973f0061fef6063326757d106931fefad0

A more readable account of "Pingos" in Wales (but not including Crychell Moor) in the published paper:
Ross N, Brabham P, Harris C (2020). *The glacial origins of relict 'pingos',Wales, UK. Annals of Glaciology 1–13.*
https://doi.org/10.1017/aog.2019.40

A comprehensive account of the deglaciation of the Welsh Ice Cap is in:
Glasser, et al. *Late Devensian deglaciation of southwest Wales from luminescence and cosmogenic isotope dating. Journal of Quaternary Science, 33(7), 804-818.*
https://doi.org/10.1002/jqs.3061

A Field Trip to North Cornwall and North-west Devon.

Part 1

This report is based on a recent guided geology tour of the area led by Chris Darmon and Colin Scofield from **geosupplies.co.uk**. We stayed in Bude for a week and explored mainly the coast from Trevone in the West to Hartland Quay in the East. There were many memorable geological sites seen during the week, so this field trip report has been divided in two. Part I will detail the amazing folding which has taken place in the sedimentary rocks of this area. Part II will consider other memorable sights seen over the week.

Geological Setting

This coast is made up of rocks from the Devonian and Carboniferous periods. The oldest rocks we saw were the Meadfoot Beds (slates) from the lower Devonian at Trevone. The youngest rocks were the Hartland Quay shales from the Carboniferous period, roughly 320Ma

The whole area has been affected by the Variscan orogeny, roughly 380 – 280Ma. The most striking feature of the trip was the degree of sedimentary rock deformation, and the wide variety of appearances resulting from these tectonic movements – usually the result of multiple episodes of folding, faulting and thrust formation, rather than one single episode.

Various granitic plutons were formed around this time in Cornwall – but they did not have much impact on the coastal geology we see now. We did see an occasional igneous intrusion. We also saw some peri-glacial features – but no true glaciers were formed this far South.

The coast at Bude

The beach at Bude and the coast path northwards past Maer Cliff have plenty of striking sedimentary features. It is worth walking along both the cliff top and the beach because some features are best seen from one of these viewpoints. The rocks here are the Bude Sandstones – a sequence of sedimentary beds >1.2km in thickness from the upper Carboniferous period.

Chris Simpson.

Photo. 1

An eroded anticline on Crooklets Beach. Left is one limb and the centre is the other limb.

On the right hand side there are roughly horizontal beds butting up against the anticline.

Photo. 2

A closer view of the junction between the anticline and the adjacent horizontal beds. These have been forced up almost vertically. (Ignore the large dark boulders which have been put there to stop coastal erosion.)

Photo. 3

Further south, an obvious syncline in the cliff face. The northern limb (left side) is steep, while the southern limb (right side) is shallow. This is entirely consistent with compression due to the Variscan orogeny much further to the south.

Photo. 4

Maer Cliff immediately north of Crooklets Beach. The next three photographs show (clockwise from top left) the right hand side, the centre and the left hand side of this section of Cliff.

Photo. 5

The right hand side.

Photo. 6

The central section.

Photo. 8

Another view of the bottom part of ***Photo.7****.*

The sharp, almost right-angle folding shown here is known as box folding and is often seen in extreme folds.

Photo. 7

The left hand section.

Photo. 9

A plunging anticline on the beach seen from the cliff top – it is much easier to work out the relationships of the beds to one another from this lofty viewpoint.

***Photo. 10** A closer view of the anticline. The V-shape indicating that this is a plunging structure is clearly shown.*

Photos. 11 and 12 *depict chevron folding at two locations Hartland Quay (**photo 11 on left)** and Millook (**12**). Observing the two photos side by side one can see that the folds at the locations would form a right angle. Those at Hartland Quay are upright whilst those at Millook are recumbent with horizontal axes. Both structures are within the Crackington Fm, sandstone /mudstone turbidites which is Carboniferous in age.*

Chevron folds are are characterised by straight limbs that abruptly bend on one point, at their hinge zone and are formed by deformation of rocks of different competences. The more competent sandstones slide over the less competent mudstones. The rocks at Hartland Quay and Millook were deformed during the Variscan orogeny.

Photo.13

A closer view of the tight folds at Millook. The quartz veins are limited to the thick sandstone beds. These crack when they are folded, allowing access for hydrothermal fluids to circulate, leading to quartz veining.

The shale bed right of centre shows axial cleavage – a feature of tight folding in these sandstone/mudstone series.

Opal

Opal is a mineraloid that can be highly complex in composition, and very varied in physical appearance. Although opal has the appearance of a mineral, it lacks the crystalline structure that defines a mineral. It is hydrated silica, or more correctly a hydrated amorphous form of silica, and has the chemical formula of SiO_2 nH_20 Hydrated because it has a water content, and amorphous because it has a non-crystalline structure. The water content is usually between 6% to 10% but can be as low as 3% and as high as 21%.

The formation of opal is a very slow process, and is the result of the accumulation of silica gel in underground crevices and cavities. Australia is the source of over 90% of the worlds precious opal, and the process which created the silica gel has been subject to debate, but recent new research published in the Australian Journal of Earth Sciences has put forward the most likely theory. Between 100 and 97 million years ago during the Cretaceous period, a large area of central Australia was covered by the Eromanga sea. **(Fig. 1).** As the sea retreated, increased acidity levels at shallow depth released silica through the weathering process of sandstone. As the sea level lowered, further weathering then lowered the acidity, and conditions were created, which allowed precious opal to fill cavities and crevices in the dried up sea bed, even at shallow depths. The cavities and crevices in the seabed occurred for a variety of reasons, The main reason was leaching of carbonates from the rocks, and from fossil remains. Another reason was the formation of voids in ironstone nodules. Cavities were also created as the result of minor, and sometimes major faulting.

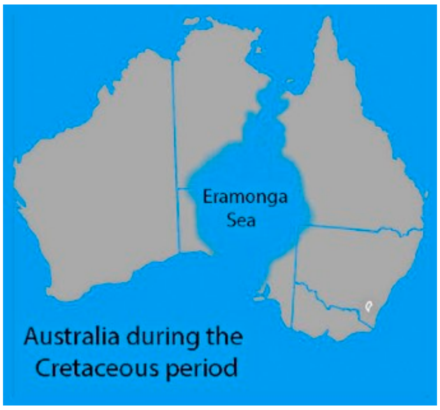

Fig. 1 *© Creative commons by Bubbles.org*

The basic requirements for the formation of opal have now been described, a source of silica rich fluid, and cavities to accept the fluid.

There are two basic classes of opal, common opal, commonly called "Potch" by miners and precious opal, both of which produce a number of different varieties. The way that silica gel is deposited, and eventually converted to a solid, determines both the class and variety of opal.

The silica rich fluid deposits silica in the form of microscopic spheres,(**Fig. 2)** and it is at this point that the class of opal is determined. The spheres can be deposited in a very orderly fashion, layer by layer, and providing the spheres are regular in size, refraction of light takes place, and precious opal is formed. (**Fig. 3**) However, if the deposition is irregular, and the spheres vary in size, refraction does not take place, and common opal is formed.

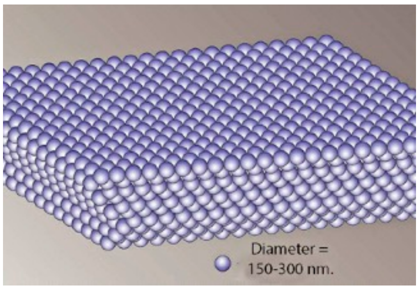

Fig. 2 *Idealised molecular structure of precious opal: an orderly array of silicon dioxide spheres. ©Dpulitzer/Creative Commons.*

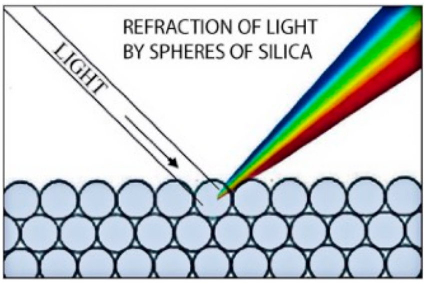

Fig.3

Opal can only form at relatively shallow depths due to limitations imposed by the temperature gradient which states that there is a rise in temperature of approximately 25˚C per km of depth. As opal can only form at a maximum temperature of 30˚C, it is obvious that it will not form at a depth slightly more than 1km. However these figures may vary slightly due to the influence of local conditions. Local conditions will also determine whether the silica spheres will be deposited in an orderly or disorderly fashion, i.e precious opal, or common opal (**Fig. 4**).

Even the slightest variation in conditions during deposition has an effect, and for this reason there are different varieties of opal.

Fig. 4 *Common opal, image of unknown provenance.*

Some varieties are easily recognised, and have attracted names which are descriptive of their appearance, but inevitably some opal can only be described as uncategorised. There are far too many varieties to be mentioned in this short article, so the following descriptions are a selection of six of the most well known varieties.

The most sought after type of opal is precious opal, but even here there are different varieties. Black opal is the most sought after variety (**Fig. 5**). Though called black opal, the black is really a reference to any dark background, most often a dark blue, and for this reason it is also referred to as dark opal. It is desirable because the dark background highlights the "play of light".

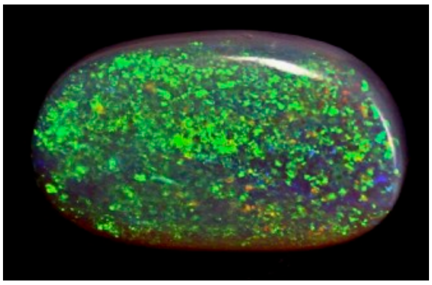

Fig. 5 *Giant black opal by Danmekis.*

In contrast to dark opal, the bulk of precious opal is classed as light opal (**Fig. 6**). This type of opal has a base that is obviously light coloured and may be almost transparent. If the base is very milky in appearance it is sometimes called "milk"opal.

Fig. 6 *Light opal by sevenopal.*

Blue opal is described as a variety exclusively found in Peru, however blue opal is also found on a smaller scale in Slovakia. It is considered to be one of the rarer varieties and is a semi opaque to opaque blue to green stone, which is attractive in it's own right, but even more so when a play of colour is also present (**Fig. 7**).

Fig. 7 *Blue opal by Eva Kröcher.*

Fire opal is really a reference to it's base colour, which can vary between red, orange, and yellow (**Fig. 8**). In all other aspects the opal is no different to dark opal, or light opal. It is said that "beauty is in the eye of the beholder", so different preferences will be expressed by prospective purchasers or collectors.

Fig. 8 *Fire opal by Géry Parent.*

Hyalite is a variety of clear opal which can be called water opal (**Fig. 9**). Mullers opal, or jalite. It exhibits a bubbly appearance, and may occasionally have a touch of colour, probably due to trace impurities. It has a water content between 3% and 8%,and is formed as a volcanic sublimate in volcanic rock. It can be distinguished from silica glass which can have a similar appearance by subjecting it to ultraviolet light, which will cause it to display a bright green fluorescence.

Fig. 9 *Hyalite opal on vesicular porphyritic leucite tephrite by James St. John.*

Almost all opal is deposited in sedimentary rock, However, an exception is boulder opal which is a particular type of opal that is deposited in cracks and crevices in ironstone or ferruginised sandstone boulders and

Fig. 10 *Boulder opal by James St. John.*

Fig. 11 *Matrix opal: Precious opal in basalt (www.mindat.org) by James St. John.*

Fig. 12 *Boulder opal Yowah nut (www.mindat.org) by Robert M Lavinsky.*

concretions. (**Fig. 10**). These deposits are usually very thin , and test the cutters skill in extracting them from the rock. Some boulder deposits are classed as matrix opal because the opal occurs as a network of infilled voids, or between grains of the host rock (**Fig. 11**). Another type of boulder opal is pipe opal, which as the name suggests is deposited in pipe like structures in the host rock, sometimes several centimetres in diameter. The most unusual type of boulder opal is found exclusively in the Yowah opal field in Queensland, Australia. This precious opal is found as the core in Yowah “nuts” which are ironstone nodules and concretions (**Fig. 12**).

Fig. 13 *Wood opal from Hungary by Szilas in East Slovak Museum, Kosice.*

Although petrified wood is commonly composed of the mineral chalcedony, it can be composed of opal, and it is then called opalised wood (**Fig. 13**). The difference is hard to distinguish by eye, but can be determined by testing specific gravity, hardness, and refractive index. Other fossils can also be opalised, and even major fossils including a complete Mesozoic Pliosaur have been discovered in Coober Pedy, S.Australia (**Fig. 14**).

Fig. 14 *Opalised Cyrenopsis fossil bivalves by James St. John.*

To summarise, it is obvious that opal is a mineraloid with numerous varieties. It is true that Australia is the worlds main source of opal, but there are other significant deposits in other countries, especially in Ethiopia, Nevada,U.S.A., and Mexico.
Opal may be a well known gemstone, but it is comparatively rare, and only well known because of it's beautiful appearance. It can be manufactured, but the quality obtained falls far short of natural opal.

It is often said that opal can be adversely affected by immersion in water. This is not true, and clean water and mild detergents will not affect opal. However opal is porous, and can be affected by strong common household chemicals such as bleach and cleaning fluids. The recommendation for cleaning is to use lukewarm soapy water and a very soft cloth.It must also be noted that opal has a hardness of 5.5-6.5 on the Mohs scale, but household dust has an average hardness of 7+, so care must be taken when choosing which cloth to use.

Bill Bagley

Reference:

Rey P. F. (2012) *Opalisation of the Great Artesian Basin (central Australia) : an Australian story with a Martian twist. Australian Journal of Earth Sciences, 68 (3), 291-314.*

Postscript

After writing this article I looked at my own collection, and discovered these three specimens, which strangely enough, don't fit neatly into any of the categories mentioned in the article.

Fig. 15 Pinfire Opal.

Opal, SiO_2 nH_20 is a hydrated amorphous form of silica, with a water content between 6% and 10%. Opal is non-crystalline, so it is classed as a mineraloid. Conditions during deposit can determine the gem quality of opal, for instance, if there is undisturbed deposition of identical sized minute spheres of silica, gem quality opal is formed. There is only a hint of "pinfire opal" in the green area of the specimen which was collected in Andamooka, Australia, by the club co-founder, Jim Nicholls.

Fig. 16 Rough Opal.

Opal is not a mineral, because it has a water content, and so it is classed as a mineraloid, It is classed as a hydrated amorphous form of silica, with a water content usually in the range of 6% to 10%, but it may have as much as 20%. Opal is composed of microscopic spheres of silicon dioxide molecules, which are deposited in closely packed planes. If the planes are very precise and regular precious opal is produced, however, most of the time slight discrepancies in how the spheres are deposited, result in "rough opal". This specimen is rough opal from Madagascar, with just a hint of regular deposition.

Fig. 17 Dendritic Opal.

Opal is a hydrated amorphous form of silica, and so it is classed as a mineraloid. This common opal variety is from the Norseman opal mine in Western Australia, and is locally known as gold lace opalite. The variety is described as being a yellow brown opal with black dendritic inclusions. This specimen is as the variety description, and was collected by Jim Nicholls, co-founder of our club while living near Norseman.

Fig. 15 *Pinfire opal collected by Jim Nicholls co-founder of MWGC.*

Fig. 16 *Rough opal from Madagascar.*

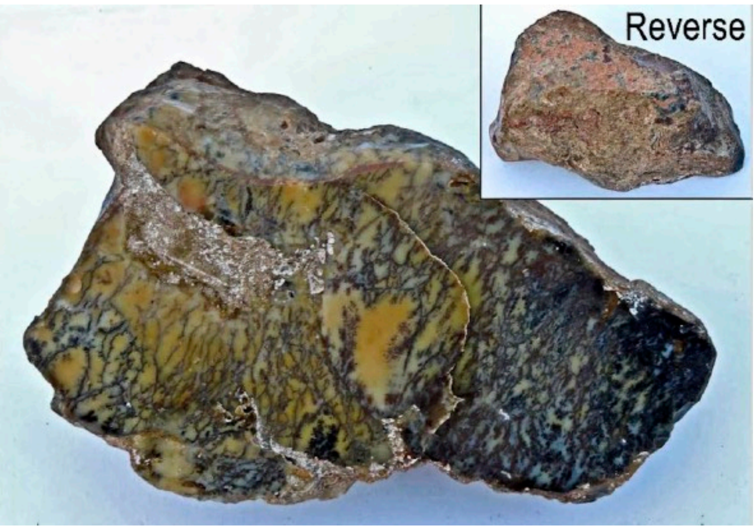

Fig. 17 *Dendritic opal found by Jim Nicholls while living near Norseman Australia.*