Earth Heritage

The Geological and Landscape Conservation Magazine

Marine Protected Areas and Geodiversity

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Winter 2020

Creating Charles Lyell's World Online

Images from the GA's 2020 Photo Competition

A new global geopark and NNR

Tributes to Geoconservation champions

Earth Heritage

Cover: View of Barr Beacon, Walsall at Pinfold Lane Quarry, part of the Black Country, a new UNESCO Global Geopark. This site shows the contact between the Kidderminster Formation (previously known as the Bunter Pebble Beds) and the underlying Hopwas Breccia. More details on p.20. Photo by Graham Worton

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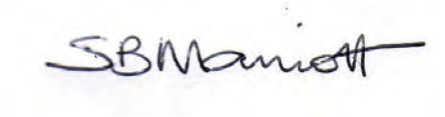
EDITORIAL

As with number 53, this issue of *Earth Heritage* has also been prepared in very challenging times. There are on-going restrictions on gatherings and shared travel due to COVID-19 that have impacted on conservation activities. *Earth Heritage* 54, however, is still a packed issue and contains reports of many geoconservation projects and how groups have adapted to lockdowns and 'firebreaks' and kept in touch virtually, some with acknowledged benefits that might not have been foreseen.

There is a report on the annual gathering of the Geological Society's Geoconservation Commission on the theme of Conserving Life—past, present and future. This was originally going to be held at the Museum of Archives in Dudley in the new Black Country UNESCO Global Geopark but was held virtually instead, complete with a virtual field trip to Saltwells NNR. One of the 'benefits' of virtual conferences is that they can reach a wider audience with participants who might not otherwise have attended.

The Glasgow Rock Doctors, an event that has been held annually for 30 years, also resorted to a virtual event. Although the Rock Doctors were not able to handle specimens as they normally would, the online platform meant that participants were able to submit images of their samples of rocks, minerals and fossils for identification. There was an added bonus that photos of exposures could be discussed to find out how geology influenced the landscape. The report acknowledges that, although specimens could not be examined at close quarters, the virtual event was more inclusive as people could join in at any time during the event from anywhere in Scotland and beyond.

As ever, we want to hear your views and to learn of new projects. It will be interesting to learn how you have coped with geoconservation projects during the continued restrictions and especially of any positive impacts. Please contact the most appropriate editor (left).



Susan Marriott - Guest Editor

The Shale Trail of West Lothian

The vast mining and industrial endeavour of 1850s oil shale exploitation in West Lothian is forming the basis of an inspirational new project taking physical form at the end of 2020. The Shale Trail, which promotes the industrial and rich geological heritage of West Lothian at a time when Scotland was the major oil producing nation in the world, will link communities to their industrial past and create a history trail. When complete, the Shale Trail will enable people of all ages to explore and learn about how geology and the past shale history in West Lothian have shaped local landscapes, our economy and today's natural environment. The 16 mile Shale Trail is supported by West Lothian LEADER Programme and National Lottery Heritage Fund. A full write-up will appear in the next issue of *Earth Heritage*.

Heath Brown, Shale Trail Heritage Manager

A key feature of the Shale Trail – West Lothian oil-shale 'bings' representing the waste derived from the extraction of oil from deep-mined Carboniferous shale beds. The bings have become a unique habitat, not found elsewhere in Britain or Western Europe, home to several nationally (UK) rare and protected plant and animal species. ©Tom Duffin.

The dramatic Great Orme's Head is seen here from Conwy Mountain across the Conwy Estuary. *Orme* is thought to derive from Old Norse for *sea serpent*, and from a distance the headland could be taken for the head of an ancient creature rising from the sea! For more information on how geoconservation, research and public safety are being approached, see the article on page 27. Photo by Stewart Campbell

ARTICLES

Marine Protected Areas and Geodiversity

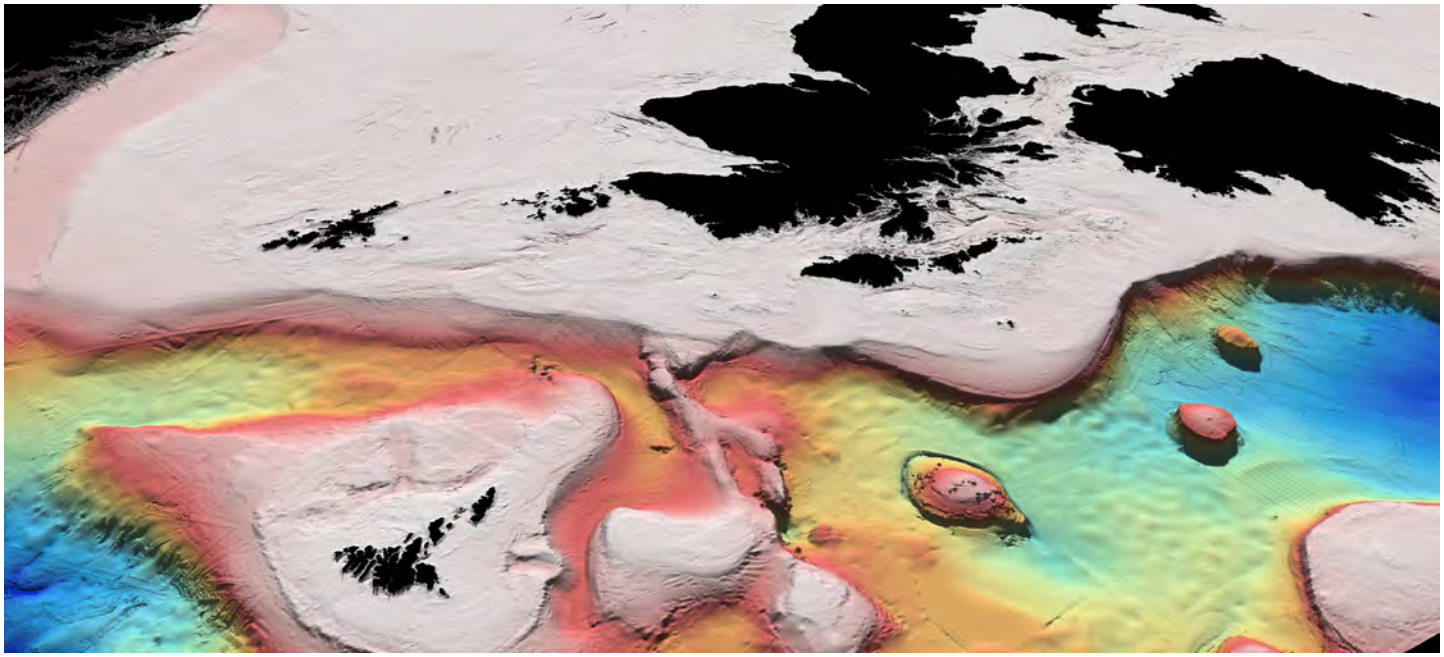
Sam Black, NatureScot

For a country of its size, Scotland has exceptional geological diversity extending from the tops of the highest mountains to the edge of the continental shelf offshore. All too easily forgotten, Scotland's geological formations below the waves are as striking and unique as those we are familiar with on land and they are an equally important part of our geological heritage. Not only is Scotland's marine geodiversity important from a scientific viewpoint, crucially it also contributes towards supporting some of Scotland's most iconic marine wildlife and provides multiple ecosystem services and benefits to society such as coastal protection, carbon storage and sediment supply.

The conservation of geodiversity is an important element of the Scottish Marine Protected Area (MPA) network. The Marine (Scotland) Act 2010 allows for the protection of:

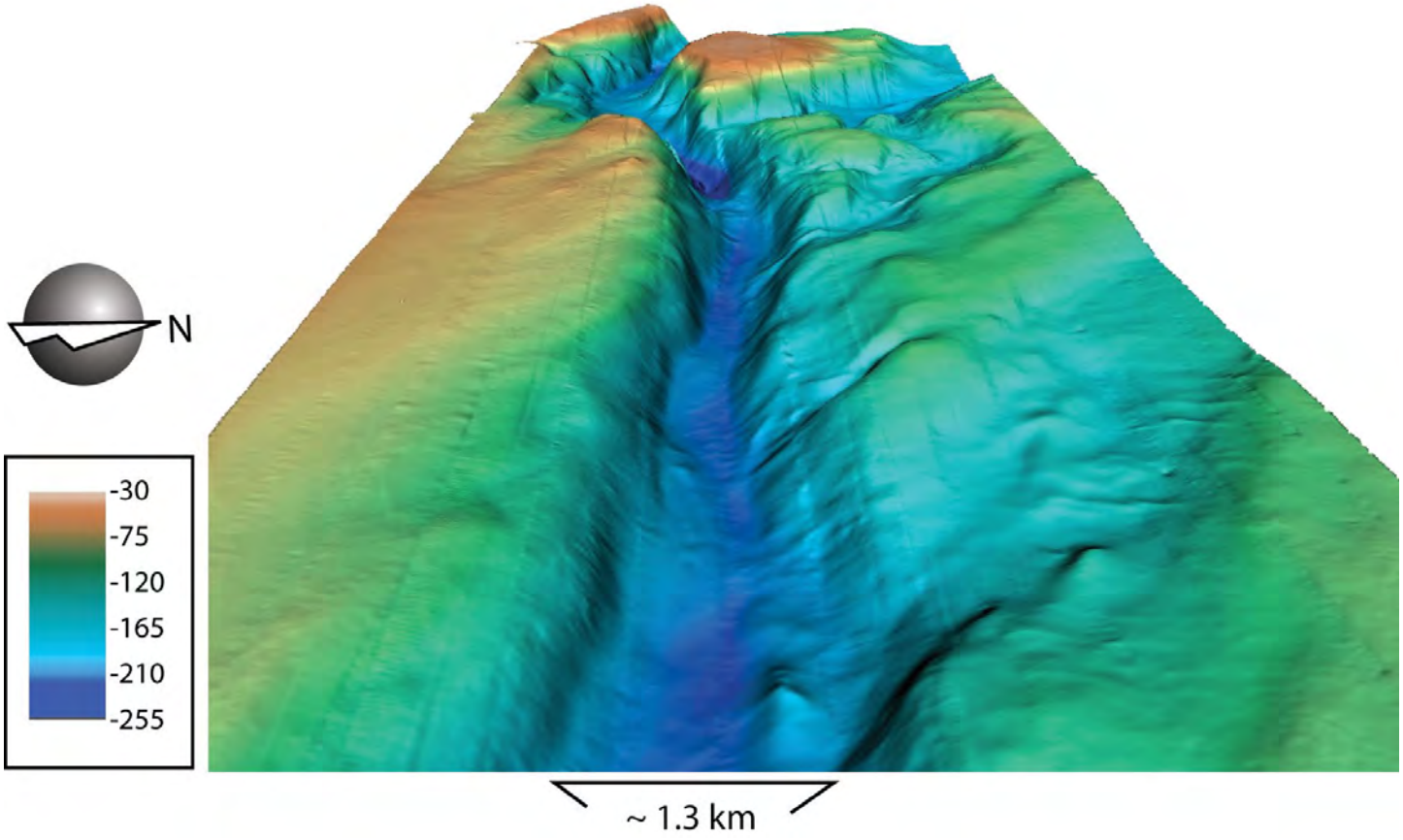
- areas of nationally and/or internationally important geological or geomorphological features;
- areas of exceptional and/or threatened geological or geomorphological features; and/or
- areas of geological or geomorphological features representative of key aspects of the marine geodiversity of UK waters.

Under this legislation, MPAs aim to bring geodiversity conservation and biodiversity conservation closer together. This is achieved by protecting geodiversity features for their stand-alone importance, or by protecting those features that overlap and support biodiversity features within a given area.



3D multibeam imagery of the Scottish continental shelf to the north and west of Scotland and Ireland. The image has been vertically exaggerated (by 5x) and was prepared by the British Geological Survey using EMODnet bathymetry data (https://www.emodnet-bathymetry.eu). © BGS.

A vertically exaggerated 3D depiction of the Southern Trench which lies off the Aberdeenshire Coast. The trench is on average ~ 200 m deep and is over 58 km in length. This feature is within the Southern Trench MPA alongside the highly diverse seabed habitat known as 'burrowed mud', found in the trench, and minke whale which concentrate in the area in large numbers to feed. © BGS.



An important part of this process has been the identification and prioritisation of those geodiversity features in Scotland's seas using the criteria set out above. So far, 35 key geodiversity areas have been identified which are split between eight different groups, many of which are now protected features within Scotland's MPA network. A link given in 'Further information' describes the selection process and an account of each geodiversity group.

The eight groups of geodiversity interests reflect common processes that have shaped the marine environment, some of which occur in both terrestrial and marine settings, whilst others are exclusively marine. Three salient examples are explained below:

The Quaternary of Scotland

During the Quaternary period Scotland experienced multiple glacial cycles, involving the growth and decay of ice sheets up to ~2 km thick. At their largest, these ice sheets extended from the Scottish mountains far out across the continental shelf and in places reaching its edge. The ice sheets carved out and deposited a range of features on the seabed, including streamlined bedrock, moraine ridges, iceberg plough-marks and sub-glacial tunnel valleys, such as the Southern Trench. Not only do these features create environmental conditions, where a range of marine habitats and species thrive, they also provide vital information about past ice-sheet behaviour. This helps us to understand possible effects of ongoing climate change, including the fate of marine-based ice sheets like those in West Antarctica today.

Marine Geomorphology of the Scottish Shelf Seabed

Given the dynamic evolution of Scotland's marine and terrestrial geology, there is a huge amount of sediment lying on the Scottish shelf seabed. In areas where current speeds are high the sediment is mostly swept away, leaving scoured rock floors or gravel wave fields which look like a ploughed field. However, in some areas dominated by strong tidal currents, large sand waves and banks can form such as those protected within the Clyde Sea Sill MPA, which extend across the entrance of the Clyde Sea. These marine landforms aid our interpretation of the interactions between currents and seabed sediments and can be locally important for biodiversity. In relatively shallow areas where stormy conditions are common, carbonate-rich sediments produced by biogenic habitats such as maerl beds, blue mussel beds and seagrass beds may be driven onshore to create spectacular white beaches and wildlife-rich coastal machair systems. An example of such a system is the Inner Hebrides Carbonate Production Area, which covers a large area of Scotland's western inner shelf seas and is a protected feature within the Sea of the Hebrides MPA.

Biogenic Structures of the Scottish Seabed

Scotland's seas are incredibly productive and biogenic structures in the form of sediment mounds and elevated features are common across the Scottish seabed. Created by marine animals and plants over time the structures can form large reef and sediment systems. Not only do these structures provide habitat for other species, they are also living libraries storing information of past environmental conditions such as historic sea-level rise, large oceanic currents and biological productivity through time. An iconic example of such a reef system is the cold water coral reefs which lie to the south-east of the Outer Hebrides that are a protected feature of the East Mingulay Special Area of Conservation. Sitting upon thousands of years' worth of skeletal remains of *Lophelia pertusa* and *Marepora oculata*, the cold-water coral reefs support a high diversity of over 400 species, including a sea sponge that was new to science when first examined.

Cold-water corals such as *Lophelia pertusa* have a wide geographic distribution and occur within a depth range of 200 m - > 2000 m. The *Lophelia* reefs present in the East Mingulay Special Area of Conservation are thought to have been present for thousands of years, possibly as far back as 11,000 years ago. © JNCC.

The shelf areas around the Inner and Outer Hebrides are important examples of non-tropical shelf carbonate systems. In these areas, storms drive carbonate rich sands and gravels shoreward to supply iconic white beaches and coastal dune and machair systems, such as Vatersay machair pictured here. © Lorne Gill, NatureScot.

Protection of geodiversity features

Human activities and development in the marine environment have the potential to impact upon geodiversity features at the seabed. The potential impacts from human activities may include:

- physical damage or loss through removal of material from the seabed, disturbance to the seabed or installation of infrastructure;
- loss of visibility (e.g. through burial);
- fragmentation of the interest and loss of relationships between interest features;
- disruption of natural processes (e.g. sediment cycling);
- loss of natural state through stabilisation of active landforms (e.g. through coastal defences).

The varying seabed features have differing types of resistance to these impacts. For example, Quaternary of Scotland landforms are relict and therefore cannot recover, but many are large enough to accommodate minor impacts without losing their integrity. Active smaller features like sand waves or biogenic structures can often recover, but this may be slow. Any management advice provided by NatureScot in relation to a specific activity or development will take the level of sensitivity of the feature into account, meaning that in some cases no additional management is required, whilst in others, specific measures are recommended to deliver protection.

The recognition of geodiversity interests within the Scottish MPA network alongside the conservation of biodiversity features allows an integrated approach for nature conservation purposes. They will not only conserve some of Scotland's unique geodiversity now and in the future but also help to maintain the range of ecosystem services and benefits these features provide for both nature and society.

Precious pockmarks: Scottish MPA geoconservation in action

The proposed Western Isles Transmission Link will be crucial infrastructure that unlocks the potential of the Outer Hebrides to provide renewable energy to the national grid. In a first for Scotland, potential impacts on nationally important seabed landforms will be avoided, thanks to engagement between the developer SHE Transmission, regulator Marine Scotland, and NatureScot.

The project includes installing power cables within the seabed from Lewis to the mainland, through the Wester Ross Marine Protected Area (MPA) which includes several geodiversity features. The cable route crosses seabed moraines from the area's last ice sheets, and remarkable post-glacial underwater landslides. NatureScot was able to advise that, due to the scale of these landforms relative to the cable installation, they would not be significantly affected.

In contrast, there were potential impacts on seabed pockmarks. These roughly circular depressions, mostly 20–140 m across, formed due to gas such as methane escaping from sediments. Their importance to science has recently greatly increased due to the contribution of such escapes to the planet's greenhouse gas levels.

Following advice from NatureScot, semi-automated analysis of seabed mapping revealed multiple pockmarks along the cable route. This has informed changes to the cable route to avoid pockmarks, which will help Marine Scotland ensure there is no 'significant risk of hindering the achievement of the conservation objectives' for the MPA.

Nick Everett, NatureScot

Further Information

Introduction to Ecosystem services: https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy/ecosystem-approach/ecosystem-services-natures-benefits

Information on the Scottish Marine Protected Area (MPA) network : https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy/ecosystem-approach/ecosystem-services-natures-benefits

The Identification, selection process, and prioritisation of geodiversity features in Scotland's seas: https://tinyurl.com/y68kwz2z

Pushing Geodiversity up the agenda in Wales…

Ken Addison, Chair of GeoConservation Cymru-Wales
kenneth.addison@spc.ox.ac.uk

Wales' geodiversity is world class, possessing rocks covering nine of Earth's eleven recognised principal stratigraphical systems, which provided early international standards of recognition and nomenclature, especially for the older Cambrian, Ordovician and Silurian systems of Wales. As well as underpinning our biosphere, geodiversity also provides the boldest structures of the Welsh landscape. Many ecosystems and habitats which are extensive in Wales, such as salt marsh, sand dunes, heathland, peat bogs, moorland and limestone pavements are indisputably biogeomorphic systems in their international recognition.

Integral links between geodiversity and biodiversity in the conservation of nature are recognised internationally. Yet the recognition of the significance of geological features and processes rarely

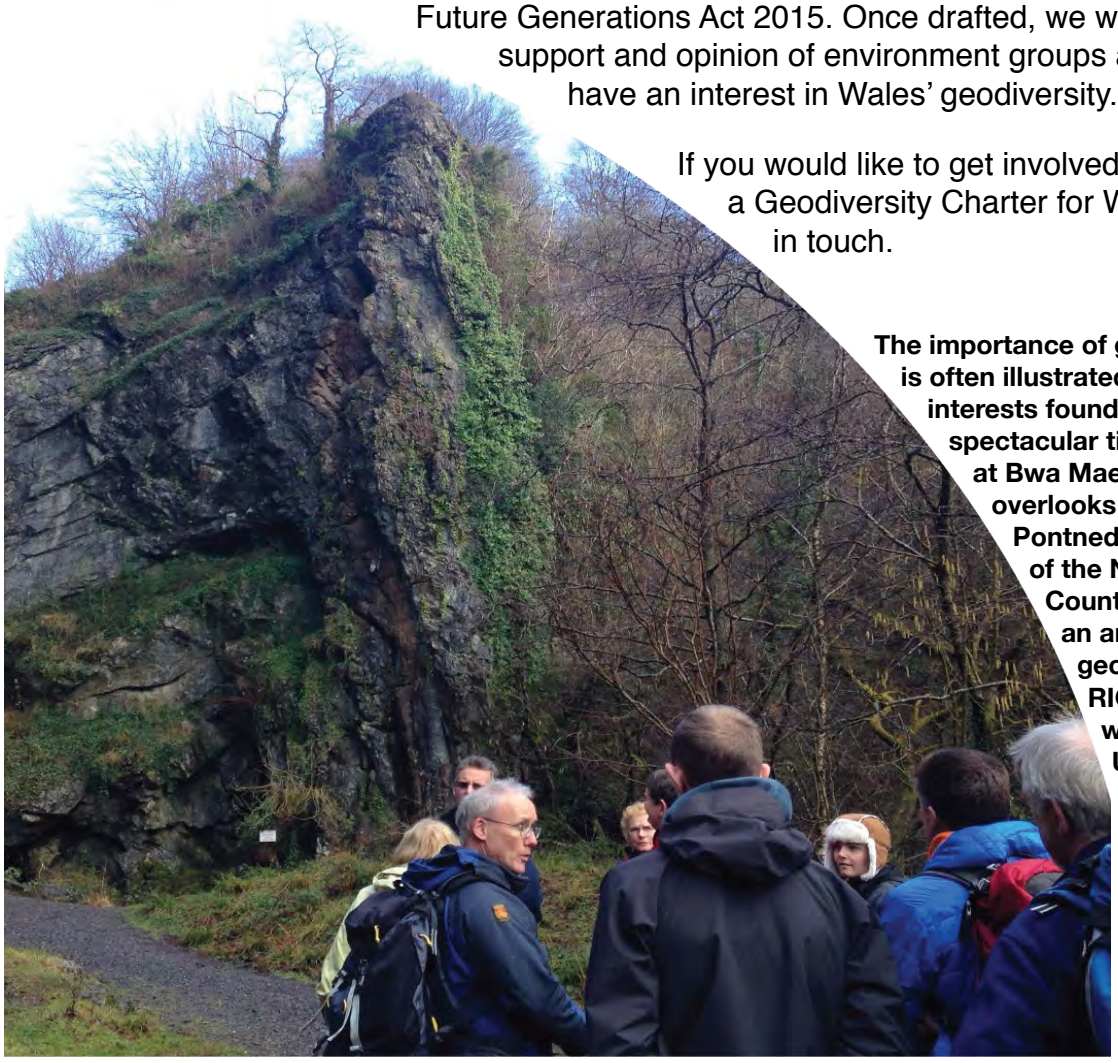
Yr Wyddfa/Snowdon is one of 76 National Nature Reserves in Wales that offer fantastic opportunities to explore spectacular landscapes underpinned by geodiversity. The glacial lake of Llyn Llydaw and surrounding moraines sit beneath the towering peaks of Lliwedd (L) and Yr Wyddfa (R) that record the explosive volcanic activity that occurred during Ordovician times. The 19th century crushing mill of Britannia Mine (just right of centre) on the shores of Llyn Llydaw illustrates how the geodiversity has also been exploited for copper. Photo by Ken Addison

continues beyond the preamble to many Welsh Government planning and policy consultations. By comparison, there is extensive use of the term 'ecosystems', 'biodiversity' and 'habitat'. This serious narrowing of the definition, recognition and application of geodiversity is pervasive, necessitating frequent re-statement, and equality for geodiversity with biodiversity needs to be recognised consistently across all Welsh Government policies and guidance.

Geodiversity has an essential part to play in addressing the challenges we face today, such as sustainable economic development, changes in climate and sea level, loss of biodiversity and improving people's health and well-being. Acknowledgement of the importance and value of geodiversity and the many benefits it provides to society has gained momentum over recent years with much of the impetus driven through the development of national Geodiversity Charters. Much of the pioneering work on the development of a national Charter was undertaken in Wales, but Charters were published by Scotland (2012, revised in 2018, see *EH*38), England (2014, see *EH*43) and Northern Ireland (2017) beating us to it.

GeoConservation Cymru-Wales has now picked up the baton and is co-ordinating the drafting of a Geodiversity Charter for Wales. Over the coming months, GeoConservation Cymru-Wales will be working with RIGS groups, UNESCO Global Geoparks, British Geological Survey, National Museum Wales and Natural Resources Wales to draft the Charter for submission to the Welsh Government. The Charter will reflect environmental and related objectives in Future Wales – The National Plan 2040, Environment (Wales) Act 2016 and the Well-being of Future Generations Act 2015. Once drafted, we will be canvassing the support and opinion of environment groups and stakeholders who have an interest in Wales' geodiversity.

If you would like to get involved in the development of a Geodiversity Charter for Wales please get in touch.



The importance of geodiversity in Wales is often illustrated by the array of interests found in any one locality. The spectacular tightly folded anticline at Bwa Maen near Dinas Rock overlooks the Afon Sychryd at Pontneddfechan. The site is part of the NRW-managed Waterfall Country Woodlands which is an area of rich industrial and geological heritage, with RIGS, GCR sites and lies within the Fforest Fawr UNESCO Global Geopark. The area is also famous for the production of the Dinas silica firebrick which was exported worldwide. Curiously firebricks in Russia are still called 'Dinas'. Photo Chris Byrne, NRW

Reflections from a Geoheritage Sabbatical in Scotland: The View from America

Brennan T. Jordan, University of South Dakota

In the autumn of 2019 I took a four-month sabbatical in Scotland, where I was hosted as a visiting scholar by Heriot-Watt University in Edinburgh. The focus of the sabbatical was on geodiversity, geoheritage, and geotourism. This article is a reflection on my sabbatical with perspectives on the geoheritage of Scotland, and on geoconservation efforts and opportunities in Scotland and the United States.

Scotland was a natural choice for a geoheritage sabbatical for several reasons: spectacular and diverse geology; the importance of Scottish scientists and Scottish sites in the history of geology; the presence of modern scholars who are leaders in the geodiversity, geoheritage, and geoconservation fields; and a level of governmental buy-in to the significance of geodiversity and Geoheritage most notably with Ministerial support for Scotland's Geodiversity Charter.

View into Coire an Lochain, below Cairn Lochan (1,216 m) in the Cairngorm Mountains. The corrie was carved by Pleistocene glaciation, with Younger Dryas moraines around and below the lakes. The late Silurian Cairngorm granite in the headwall is a manifestation of the Caledonian orogeny. The area lies in the Cairngorms National Park and the summit area is within the Cairngorms Site of Special Scientific Interest (SSSI). The official site management statement describes the Cairngorms as "the most important mountain area in Britain for biological and geological/geomorphological conservation." The geology and geomorphology of Cairngorms National Park are worthy of substantial geological interpretive resources. Photo by Brennan Jordan

Exploring Scotland's Geoheritage

The geology of Scotland is internationally appreciated for the enormous variety in a relatively small country. With a geological record that goes back to the Archean, Scotland's geology records, in its often-well-exposed rocks, three billion years of Earth's history (much of it as a part of North America, on the margin of Laurentia). However, enumerating the geologic wonders on display in Scotland is beyond the scope of this contribution.

I visited some of Scotland's geoparks and met with leaders of two of them. Scotland's two mainland geoparks, North West Highlands and Lochaber, both feature spectacular geology and scenery that provide outstanding opportunities to connect people with geology. Both also have modest but effective visitor centres and terrific in situ interpretive panels elucidating the geology for visitors and covering a wide array of geological topics. They occupy different communities and illustrate the diversity in roles that a geopark can play in its community, and vice versa. The Arran Geopark initiative is still in its early stages, but I was impressed with the innovative approaches employed in providing geoheritage interpretation on a limited budget.

For a travelling geoscientist, Scotland is a place to revel in the history of the science. James Hutton (1726–1797) is not only a significant figure for geologists, as the 'father of modern geology', but as a pioneer in our understanding of deep time he is an important figure in all sciences. 'Hutton's unconformity' at Siccar Point is a natural site of pilgrimage for geologists, and it is terrific that an interpretative panel and pamphlets at the site tell the story. The 'Hutton's unconformity' site on Arran is also highlighted by the aspirant geopark. Particularly accessible, barring recent developments, is the 'Hutton's section' site at the base of the Salisbury Crags in Holyrood Park in Edinburgh. It is unfortunate that access to the site has been affected by the recent closure of the Radical Road due to rockfall, particularly as the section is at the edge of the closure in an apparently safer location. The geoheritage community is actively lobbying Historic Environment Scotland, who manage the park, to ensure access to Hutton's Section in future management plans. In this regard the 2026 tricentennial of Hutton's birth may offer an opportunity to highlight and leverage Hutton's legacy and secure unfettered access.

What Can We Learn from Each Other?

There are important fundamental differences in land management between the United States and Scotland, but there are ways in which our geoconservation efforts can inform each other.

Scotland (and the U.K. in general) is way ahead of the United States in terms of a systematic approach to geoconservation. At the national level, the Geological Conservation Review process has been enormously successful, designating around 900 nationally or internationally significant sites in Scotland. Geoheritage inventories have also been conducted on a local scale and these inventories provide valuable guidance for the management of local geoheritage resources.

Geoheritage is not a widely recognized subject in the American geoscience community, and systematic geoconservation efforts, such as geoheritage inventories, are still in their infancy in the United States, the exception being the National Park system. Recent national initiatives in geoconservation have been driven by the U.S. National Committee for the International Union of Geological Sciences, which has created the U.S. Geoheritage & Geoparks Advisory Group. In 2013 the National Committee convened a workshop entitled 'America's Geologic Heritage' which functioned as an introduction to the concept of geoheritage as a management consideration and geoscience subject. At the time of this publication the National Committee is in the midst of a program, 'America's Geoheritage Initiative 2020–2021' which will culminate in a workshop, 'America's

Visitors at the Mather Point Overlook in Grand Canyon National Park, United States. The Grand Canyon is the iconic landmark of the U.S. National Park system and is recognized by visitors as a fundamentally geologic site. The Scottish landscapes that are a draw for many tourists also offer the potential to connect visitors to the geology responsible for the scenic views. Scotland's geoparks establish this connection, but more could be done in the national parks. Photo by U.S. National Park Service

Interpretive displays at the Yavapai Museum of Geology in Grand Canyon National Park, United States. The interpretive resources include three-dimensional representations, hands-on rock displays, and interpretive panels that tell the story of the Grand Canyon at different levels of complexity. Knockan Crag in the North West Highlands Geopark offers similarly high-quality interpretive resources. Photo by Michael Quinn, U.S. National Park Service

Geologic Heritage II'. It is anticipated that this workshop will result in more concrete action with regard to advancing systematic geoconservation efforts in the U.S.

The greatest strength that the U.S. has in geoconservation is an enormous amount of publicly owned land. The U.S. National Park system is frequently highlighted in international geoheritage discussions, but as important are public lands administered by the U.S. Forest Service, Bureau of Land Management and State Park systems. Significant geoheritage is found in all of these lands and Government ownership provides not only an avenue for conservation, but also a natural source of ongoing governmental funding for the provisioning of geoheritage interpretation, including visitor centres, displays, panels, and interpretive staff. The result is that the quality of interpretation available at U.S. National Parks is generally of a very high standard, The absence of such funding in Scotland means that geoheritage interpretation is supported by a mixture of lottery funding, non-profit organizations and private partnerships, with contributions from Local Authorities, government

agencies such as NatureScot, and with other valuable assistance from bodies like the British Geological Survey.

National Parks in Scotland are very different from their American counterparts, consisting mostly of private land, though the laudable Land Reform (Scotland) Act 2003 (Scottish Outdoor Access Code) assures public access to most points of interest. The two national parks, Cairngorms and Loch Lomond & The Trossachs, both encompass considerable geoheritage resources. However, the lack of a central funding mechanism means that interpretation resources are quite limited. The Balmaha visitor centre in Loch Lomond & The Trossachs National Park, provides some interpretation focused on the nearby Highland Boundary Fault. The VisitScotland iCentre at Aberfoyle represents another potential opportunity to provide geoheritage interpretation, but none is present. The geoheritage community could continue to engage national park authorities and other local stakeholders to maximize opportunities to promote geoheritage in both parks. There is also tremendous potential to promote geoheritage at cultural heritage sites. This is well done at the visitor centre for the Neolithic Calanais Standing Stones on Lewis. An example of where such an opportunity is missed is the Skara Brae site on Orkney.

Concluding Thoughts

The future of geoconservation is Scotland is bright, but it will rely on continued efforts from a wide array of stakeholders. The new Scottish Geology Trust may play a critical role in coordinating these efforts, and I urge widespread participation in, and support of, this organization.

Initial steps toward developing systematic initiatives in geoconservation in the U.S. are under way. Scotland, the U.K. and Europe more broadly, provide valuable models to inform the process in the U.S. I look forward to participating in this process, and I am grateful to all of those who spent time with me, discussing geoheritage, geodiversity, geoconservation, and geotourism in Scotland.

Skara Brae Neolithic archaeological site on the Orkney Mainland (a UNESCO World Heritage Site). Excavated stone house walls just inshore from Skaill Bay. The stone is of the Devonian Upper Stromness Flagstone Formation (an Old Red Sandstone unit), which is exposed on the shores of the bay immediately adjacent to the site (inset). This and related flagstone units are also the source materials for other outstanding archaeological sites in Orkney and Caithness and are valued building materials in modern communities as well. These rocks tell the story of arid lakebeds below the mountains of the Caledonian orogen, a story worth telling. Photos by Brennan Jordan

Further information

America's Geoheritage Initiative, 2020-2021:
https://www.nationalacademies.org/our-work/americas-geoheritage-initiative-2020-2021

Staffa: visitor access restoration in a sensitive setting

Emily Wilkins, Ranger, National Trust for Scotland

"Erosional forces which have fashioned the iconic island of Staffa and its famous Fingal's Cave present challenges concerning the provision of safe access for visitors. The National Trust for Scotland, in addressing recent storm damage to the walkway into Fingal's Cave, has adopted a carefully considered and sensitive approach to the task. This has ensured that rebuilding work has been undertaken sympathetically maintaining the visual integrity of this landscape jewel."

Colin MacFadyen, NatureScot.

The island of Staffa is a National Nature Reserve (NNR) and a Site of Special Scientific Interest (SSSI) for its breeding seabirds and maritime cliff vegetation. A popular tourist destination for over 200 years, visitors are attracted by the majesty of Fingal's Cave as well as the chance for a close-up encounter with puffins during the breeding season.

The island is formed of several 60 million year old basaltic lava flows which, in places, crystallised, as they cooled, into towering rock columns. The lowest and oldest lava flow in the sequence is the most spectacular forming Staffa's 'Great Face'. The rock columns are naturally split into sections by a number of horizontal joints and are freestanding. Given this geological control, erosion by the sea has resulted in the formation of a number of caves around Staffa's coastline, Fingal's Cave being the most famous. Broken-off columns provide a convenient if uneven surface (supplemented by concrete additions where necessary) for visitors to walk along below the columnar basalt cliffs and access the cave.

The Great Face at Staffa at the south end of the island, for many the approach to the island from Iona and Mull. The rock face is comprised of a thick lava flow consisting of a rubbly upper part and a lower part comprising regular mainly 6-sided columns. Fingal's Cave at the right of the image has been formed within the lower part of the flow. © National Trust for Scotland.

These forces of erosion are ongoing with the pounding of waves driving water under pressure between the columns, and into joints, forcing them apart. As a consequence whole columns may be lost to the sea during winter storms. During the winter of 2017/18 storms removed several large column sections supporting the walkway at a narrow point where it turns the corner into Fingal's Cave, leaving a gaping hole and necessitating its closure to visitors.

NNR guidelines state that reserves must be well managed both for wildlife and to give people the opportunity to enjoy and connect with nature. Fingal's Cave is an integral part of this experience on Staffa, with the sense of awe on entering the cave inspiring generations of musicians, artists and writers among other visitors. So we had to figure out a way to repair the access walkway while remaining in keeping with the aesthetics of the location, which proved to be quite a logistical challenge for such a hazardous worksite.

Thanks to advice of several engineers, and the works of a skilled and determined contractor, a design was formulated that would, in effect, rebuild some columns to provide a new robust section of walkway sympathetic to its surroundings. Due to the extremely exposed location it was not possible to erect a temporary structure to allow access to the cave. Another considerable challenge was the remote location of the island and the very exposed position of the walkway. Difficulties were compounded by all the materials and equipment having to be carried on site from the pier then across the uneven basalt causeway.

Construction work to restore access at the entrance to Fingal's Cave. Stainless steel rods secure shuttering for concrete, the lower sections of which have been carefully constructed to emulate the geometric forms of the basalt columns. The steel rods also provide a reinforcing element for the concrete © Colin MacDougall

The restored columns reforming the visitor path into Fingal's Cave. The concrete has been coloured to mimic the weathered basalt. © Colin MacDougall

The work involved new steps being cut into the rock closer to the base of the cliff which slightly altered the direction of the walkway to give more protection from the sea. Stainless steel rods were fixed into the rock to tie free standing columns together and make a structure strong enough to withstand the severe winter storms that had damaged the original path. Stainless steel rods were also used to hold wooden shuttering in place, to allow the pouring of concrete. The shuttering was carefully constructed to match the geometric pattern of the columns being rebuilt. To aid blending of the concrete with the setting it was dyed black to match the weathered and lichen-covered basalt. It was important to make the new access as unobtrusive and in keeping with the surrounding environment as possible. This more considered method of construction had not been used on Staffa before but it worked well and resulted in a structure that is less apparent than the original section of walkway.

Access to the cave was restored in October 2019, however the following winter storms again took their toll—cracks appeared in the next section of walkway slightly further into the cave as more supporting columns were swept away. It is clear that this is a long-term project to stabilise and protect the rocks in the area. This will be an opportunity to refine techniques with the ideal being to make the repairs indistinguishable from the natural character of the rock. Proposed future options include facing the walkway infrastructure with fallen stone gathered from elsewhere on the island - of course we will carefully avoid the boulder fields favoured by our nesting storm petrels!

A new UNESCO Global Geopark - the Black Country!

Colin Prosser, Natural England and member of the Black Country UNESCO Global Geopark Management Team

On 10th July 2020, after more than 10 years of work by the Black Country UNESCO Global Geopark Project Team, the Executive Board of UNESCO confirmed that the Black Country has been welcomed into the network of 161 UNESCO Global Geoparks spread across 44 countries. It was one of 15 new Geoparks from as far afield as Serbia, Canada, China, Finland, Indonesia, Nicaragua, Portugal, the Republic of Korea, and Viêt Nam that were admitted at the same time. This new status recognises the internationally important geology of the area, the historical and cultural links to the industrial revolution, the important green spaces that exist and the partnership work taking place to conserve, enhance and promote this heritage for visitors and local people alike.

UNESCO Global Geoparks are areas of international geological significance managed with a holistic concept of protection, education and sustainable development. They use their geological heritage, in connection with all other aspects of the area's natural and cultural heritage, to enhance awareness and understanding of key issues facing society. In doing so, they give local people a sense of pride in their region and strengthen their identification with the area, characteristics which are already strong in the Black Country after many years of activities and initiatives to promote and conserve the area's geoheritage.

View of Barr Beacon, Walsall at Pinfold Lane Quarry. This site shows the contact between the Kidderminster Formation (previously known as the Bunter Pebble Beds) and the underlying Hopwas Breccia.

All photos by Graham Worton

Close-up of the weathered rock face at Blue Rock Quarry, Sandwell. The exposures of the Carboniferous age igneous intrusion now form a nature reserve owned by the Wildlife Trust for Birmingham and the Black Country.

Singing Cavern is part of the remains of the limestone mining and quarrying industry in Dudley. Unweathered Silurian age fossils and ripples can be seen on the bedding planes. The cavern is accessed by canal boat, through trips organised by Dudley Canal and Tunnel Trust.

Ambassador Matthew Lodge, UK Permanent Delegate to UNESCO, Foreign and Commonwealth Office said, "*I am delighted that the Black Country has become the UK's eighth UNESCO Global Geopark, joining the UK's exceptional network of UNESCO designations. With geology stretching back 428 million years, and a landscape and heritage that shaped the modern world during the industrial revolution, it is right that the Black Country is given this prestigious UN status. Today's announcement ensures that this remarkable site will continue to inspire the million people who call the landscape home, as well as local and international visitors in the years to come. Congratulations to all.*"

The Black Country is blessed with some extremely diverse geology with the Silurian, Carboniferous, Permian and Triassic particularly well represented, and with internationally famous fossil faunas from the Wren's Nest NNR. Other key geosites include the recently declared Saltwells NNR exposing the coal so important in fuelling the industrial revolution, a suite of other protected geological and wildlife SSSIs and Local Sites, the museum collections at the Dudley Archive and Museum, and many other sites and buildings of historical and cultural importance. The links between remaining geological exposures and mines, the industrial revolution which generated them, the local communities historically arising from the exploitation of the area's geological wealth, and the opportunity to expand existing geological and cultural tourism, were central to the bid. So too was the area's urban setting which means that it is the most populated Geopark in UNESCO's Global Geopark Network.

The Black Country UNESCO Global Geopark Project Team, made up of the four Black Country boroughs (Dudley, Sandwell, Walsall and Wolverhampton) as well as others including Natural England, was delighted to finally achieve UNESCO Geopark status and the announcement received a great deal of media interest. The following quotes from the press coverage give a flavour of what achieving Geopark status means and of the opportunities ahead.

West Park, Wolverhampton, is a formal Victorian Park with a scattering of Devension Glacial boulders which were placed as part of formal landscaping. The close-up shows the plaque attached to the pictured boulder, describing its rock type, where it originated from and where it was found.

Tony Juniper, Chair of Natural England said, "*Today is a landmark achievement which recognises the internationally rich geology and cultural heritage of the Black Country. The move will benefit the environment and boost tourism, as well as providing more people with the opportunity to connect with the natural world. We will continue to play our part in making the most of the opportunities that this new Geopark brings, through conserving, recovering and championing the natural environment for the benefit of people and Nature alike, for generations to come.*"

Chris Handy, deputy chair and place lead for Black Country Local Enterprise Partnership said, "*We've long known that the Black Country is home to world-class sites of geological importance, sites that have played a key role in shaping our area both in terms of the places and the people. This news comes at a difficult time in the Black Country's history and beckons great times ahead, we look forward to working together to share and celebrate our Geopark with both the people of the Black Country but also the people we hope it will encourage to visit.*"

This new UNESCO Global Geopark status will bring an international profile to the area, providing increased opportunities for partnership work, education, and conservation, as well as facilitating social and economic benefits from increased tourism. A week-long celebration of the Geopark, much of it virtual, took place at the end of October. Exciting things are planned for the years ahead.

Further Reading

General information on UNESCO Global Geoparks: http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/
The Black Country UNESCO Global Geopark: https://blackcountrygeopark.dudley.gov.uk/bcg/

Saltwells: England's newest geological National Nature Reserve

Jonathan Larwood, Natural England

Saltwells in Dudley, West Midlands, has recently become England's newest geological National Nature Reserve (NNR), a declaration that has both recognised its important Silurian and Carboniferous geology, and a long commitment to managing its geological heritage. The NNR was declared and 'virtually' celebrated on the 23rd October 2020 and this article explores Saltwells' geology, the innovative management that has been undertaken, and the opportunities that Saltwells sets for the future.

National Nature Reserves – what are they?

National Nature Reserves emerged in the post-war years under the same legislation that established the early National Parks and Sites of Special Scientific Interest (SSSIs). They were created to protect some of our most important geology and wildlife, and provide 'outdoor laboratories' for research. Since then their purpose has widened. Not only do they protect some of our most sensitive natural heritage, they are places to develop and learn about conservation and for people to understand and connect with the natural world and how it is changing and evolving. From the Lizard in Cornwall to Lindisfarne in Northumberland today there are 223 NNRs in England; the largest the Wash (8,800 hectares) and the smallest Horn Park Quarry in Dorset (0.32 hectares). Perhaps the best known (and most reported to Earth Heritage readers) is the Wren's Nest NNR (not far from Saltwells) in Dudley, which is England's first geological NNR. About two thirds of NNRs are managed by Natural England, the remainder by approved bodies such as the National Trust, RSPB and many Local Authorities.

Why is Saltwells a geological NNR?

Saltwells has long been managed as a Local Nature Reserve, it is nationally important for its geology and is a key Geosite in the newly established Black Country UNESCO Global Geopark.

***Top*: Brewin's Canal Cutting SSSI and; *bottom*: Unconformity, Brewin's Canal Cutting SSSI. Photos by Jonathan Larwood unless otherwise stated.**

***Top*: High pressure hose treatment (copyright Dudley MBC) and; *bottom*: Doulton's Claypit.**

Saltwells NNR includes two geological SSSIs: Brewin's Canal Cutting SSSI and Doulton's Clay Pit SSSI. To the north Brewin's canal-side cuttings, and the disused tub-line cuttings that join it, expose marine Silurian rocks unconformably overlain by the Upper Carboniferous Staffordshire Coalfield. The sequence is tilted and intruded by a late Carboniferous dolerite dyke. To the south the disused workings of Doulton's Claypit SSSI continue the coalfield revealing a sequence through fossiliferous iron-rich mudstones and clays, cross-bedded sandstones and coal seams. Formerly the Thick Coal was exposed at the surface and removed as one of the most productive coal seams of the Industrial Revolution, the remaining Heathen Coal is today the only coal seam exposed in the Staffordshire Coalfield. Here clay was used for Royal Doulton sanitaryware giving the pit its name and the area is known as Saltwells as natural springs which emerge on the pit floor for a short time supplied saline mineral waters for the nearby Lady Wood Saline Spa.

This is a post-industrial landscape of coal mining and clay extraction. Today, as well as the disused Doulton's Claypit there are the transport routes—the remains of a tub-line that transported coal and clay to the canal network, early medieval coal bell pits and extensive spoil heaps. Oak woodland has established across the Reserve with spring bluebells, areas of heath and flower-rich grassland, and a network of ponds fed by the Saltwells spring which support a diverse invertebrate fauna including fifteen dragonfly species.

Managing Saltwells NNR

Dudley Borough Council has managed Saltwells as a Local Nature Reserve for many years, most recently guided by Senior Warden, Alan Preece, and his team supported by many volunteers including an active Friends group and the Black Country Geological Society. The canal sections are looked after by the Canal and River Trust who were granted 'approved body' status as part of the declaration of the Saltwells NNR.

***Top*: *Meganeura* fabrication (copyright Dudley MBC)**
***Middle*: *Meganeura* 'resting'**
***Bottom*: *Meganeura* 'flying'**

There is a network of well-maintained paths around the site with a new Black Country Geopark geology trail following the story of the Reserve's geological and industrial history. Key sections and views are kept vegetation free. Barges have been used to transport scrub away from the Brewin's canal sections and here volunteers have removed scree, vegetation, brushed clean exposures and created steps to the unconformity and dolerite dyke. Along the tub-line high pressure water hoses have been used to great affect to remove build-up of soil and create fresh exposures and, in Doulton's Claypit, trees have been cut back to open new vistas and reveal again the high sandstone faces that fringe the pit.

A £12,000 'Tesco bags of help' grant enabled the commissioning of local artist and sculptor, Luke Perry (www.ihsartworks.com), to develop innovative interpretation across the Reserve. At the entrance you are greeted by a 4 m cast metal core interpreting the geology beneath your feet. Throughout there are metal fern frond way markers and a sculptural surround for the interpretation panel that looks down into Doulton's Claypit. Here you find large *Meganeura* (the giant Carboniferous dragonfly) in flight across the ponds and resting on the rock faces—these galvanised steel dragonfly giants catch the sunlight across the pit and provide perches for Saltwells' present-day dragonflies.

What the future holds?

The next exciting moment for Saltwells NNR will be the arrival of a new warden's base. The foundations are in place and the building is being fabricated off site to arrive later this year. As well as garage and workshops, the base will include classroom facilities and exhibition space for the many visitors, groups and schools that explore the Reserve. Saltwells is an important destination in the newly established Black Country UNESCO Global Geopark (see this issue p.20), bringing new opportunities to connect to the other Geopark Geosites and tell a wider geological story, following the canal network across the Black Country, and maybe

one day (with the ambition to reopen the Wren's Nest canal) take a canal boat from Saltwells into the heart of the nearby Wren's Nest NNR.

The declaration of Saltwells NNR also marks a starting point for England's new NNR strategy which was launched in 2017. An ambition within this strategy is to tell the story of England's geological history through the NNR network. This will unfold through existing NNRs but where there are 'pages' missing new NNRs will fill the gaps. Saltwells is the first of these new NNRs, there will be more.

To conclude Senior Warden Alan Preece says:

> "*For Saltwells and its community, the National Nature Reserve designation is massively important. Saltwells is in the heart of an urban area and is used by people for so many different reasons. To know it is of national importance gives the community including residents, Counsellors and our partner organisations a real sense of pride.*
>
> *To know that this is because of its geology brings a whole other level of pride too, not just for Saltwells, but for the wider area. It feels like a big milestone in our journey because it links us directly back to the industrial heritage and the reason our community formed and also then forward into our future, as a central part of the newly designated UNESCO Black Country Geopark.*"

Further Information

National Nature Reserves
https://www.gov.uk/government/collections/national-nature-reserves-in-england

Saltwells geology trail:
https://discover.dudley.gov.uk/media/5104/saltwells-geosite-broadsheet-17-web-version.pdf

Final Press Release:
https://www.dudley.gov.uk/news/natural-england-declares-second-national-nature-reserve-for-dudley/

Reconciling geoconservation, research and public safety on the Great Orme's Head, North Wales

Cathy Hollis, University of Manchester; **Raymond Roberts** and **Stewart Campbell**, Natural Resources Wales (NRW)

More than the sum of its parts

Overlooking Llandudno and the North Wales coast, the Great Orme's Head is one of Wales' geological gems. A layer cake of superbly exposed Carboniferous sedimentary rocks towering 207 m above the sea, it provides an unrivalled opportunity for geologists to explore geodiversity laid bare. In addition to stratigraphical and mineralogical GCR sites notified within an SSSI, the site contains several RIGS (limestone pavement and soils), botanical features of national and European importance and numerous sites of historical and archaeological value (Roberts, 2003). The headland also offers stunning 360° views. However, its numerous tourist attractions, such as a Country Park, cable car, tramway, ski slope and internationally famous Bronze-Age copper mines, all bring different pressures and management challenges. In 2019, proposed engineering works to prevent rockfalls on a heavily used parking area threatened to obscure one of the Great Orme's key stratigraphical sections.

The dramatic Great Orme's Head is seen here from Conwy Mountain with the Conwy Estuary and Morfa Conwy in the middle distance. The sedate Victorian watering town of Llandudno lies partly on a low-lying tombolo that separates the Great Orme from mainland North Wales. *Orme* is thought to derive from Old Norse for *sea serpent*, and from a distance the headland could be taken for the head of an ancient creature rising from the sea! The Welsh name, Pen y Gogarth, aptly describes a 'stepped or terraced headland'. Photo by Stewart Campbell

Happy Valley lies on the east side of the Great Orme close to Llandudno Pier. Its public gardens lie within a former quarry gifted to Llandudno by Lord Mostyn to celebrate the Golden Jubilee of Queen Victoria in 1887. Happy Valley also hosts a mini-golf course, ski-slope, toboggan run and the Great Orme Cable Car. The Happy Valley car park (above), adjacent to Llandudno Pier, provides essential parking for these heavily used attractions, and lies at the gateway to Marine Drive—a spectacular anticlockwise, one-way route around the perimeter of the Great Orme. In 2019, small rockfalls from the rock face at the rear of the parking area necessitated closure of this much-used facility to ensure public safety and prompted urgent consideration of remedial engineering work. Photo by Raymond Roberts

Geology

Imposing coastal cliffs, numerous inland outcrops and quarry sections provide almost three-dimensional exposure of the Carboniferous limestone that makes up the Great Orme's Head. These rocks were deposited during the Mississippian subperiod (*c.* 359–323 Ma) on a shallow-marine shelf known as the North Wales Shelf (Adams & Cossey, 2004). The richly fossiliferous Lower Carboniferous rocks preserve detailed evidence of the depositional environment on this shallow, sub-tropical shelf and record changes in relative sea level during an important period of Earth history—a transition from a warm global climate to the onset of the Gondwanan glaciation. The distinctive stepped topography of the Great Orme reflects a series of sedimentary cycles. In addition to representing virtually the whole Lower Carboniferous succession in North Wales (Adams & Cossey, 2004), the Great Orme is also important for understanding a range of processes that occurred after the rocks were deposited. These include plate-tectonic processes associated with the Variscan (Hercynian) mountain-building period which resulted in large-scale folding and faulting, including formation of the Great Orme syncline—a spectacular downfold with an axis trending north-east to south-west. The Great Orme's rocks also host important mineral deposits. Most notable are the dolomite-hosted copper minerals that have been mined extensively since Bronze-Age times. The copper mineralisation is thought to have resulted from percolating hydrothermal fluids that were poor in sulphur. Dolomitisation is thought to have occurred during multiple events from immediately after deposition until late Carboniferous to early Permian times (Juerges *et al.*, 2016). Precisely when the copper minerals were formed (and subsequently altered) is uncertain, but a Mesozoic age has been suggested (Bevins & Mason, 2010). The mechanisms by which dolomitisation of the limestone beds occurred is currently the subject of ongoing research at the University of Manchester.

Key site for geological research

Over the last 10 years, researchers from the University of Manchester have conducted several projects on the Great Orme's Head to gain a better understanding of how the limestones were deposited and subsequently altered during burial (diagenesis). One of the most important post-depositional processes that occurs in limestones is dolomitisation (see below) and geologists from Manchester are continuing to focus their research on the heavily dolomitised Pier Dolomite Formation (PDF) at the base of the Great Orme.

The PDF forms the basal (*c.* 140 m) of the Great Orme's Lower Carboniferous sequence. These brown dolostones contrast markedly with the largely un-dolomitised grey limestone beds of the Great Orme Limestone that dominates the coastal cliffs elsewhere around the headland. The PDF crops out in several places around the margins of the Great Orme syncline but is best exposed around the south-eastern margin of the headland. Although it crops out around the western tollhouse, Loreto Convent and the site of the former Gogarth Abbey Hotel, it is best exposed and most accessible behind the Grand Hotel, around Llandudno Pier and at the back of Happy Valley car park.

Juerges (2013) studied the PDF in detail. She suggested that dolomitisation had occurred during multiple expulsions of fluid. These fluids are thought to have moved up and along faults associated with the Dinorwic/Aberdinlle fault system during burial and uplift of the North Wales Shelf in the late Carboniferous. However, the zebra dolomite textures associated with high-pressure fluid flow, during uplift and exhumation of the platform, were not studied in detail. Ongoing research is therefore looking at them more closely as part of a wider project, which has been designed to evaluate fully the geo-mechanical controls on the formation of zebra dolomite textures (McCormick, in prep). Because zebra textures are often associated with dolomite-hosted mineral deposits, the results of the project could have far-reaching implications for our understanding of fault-controlled emplacement of dolostone and low-temperature, sedimentary-hosted mineralisation (e.g. lead-zinc systems).

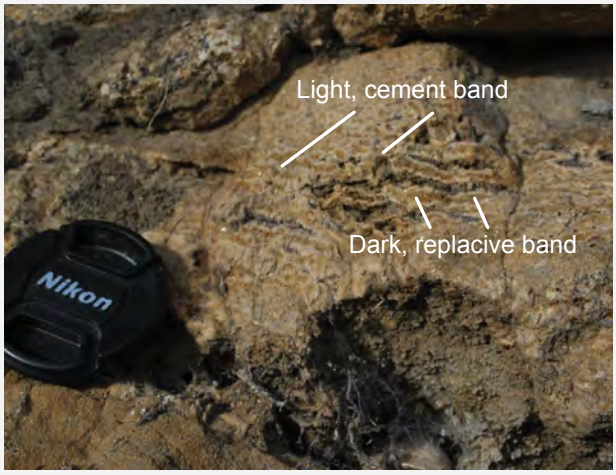
Potentially damaging engineering works

Following a series of minor rockfalls onto the Happy Valley car park from the quarried limestone cliff behind, Conwy County Borough Council (CCBC) closed the facility in late summer 2019 and employed engineers to assess options to make the area safe. The car park is an important asset for CCBC, generating significant income and providing much-needed capacity, especially at the height of the tourist season. As a result, proposals were quickly formulated to remove much of the vegetation

The PDF comprises the oldest rocks exposed on the Great Orme's Head. Happy Valley car park, pictured here before recent engineering works, provides a particularly accessible dip section through the PDF and good examples of zebra textures (see following inset box). Heavily used locations such as these have the potential to generate conflicts between managing the site for safe public access and maintaining the integrity of the geological exposures. This part of the Lower Carboniferous GCR feature is therefore one of the key localities for NRW photo-monitoring and this composite image of the whole section was produced in advance of proposed engineering works by the University of Manchester. Photo by Cathy Hollis

Dolomitisation – zebra texture

Dolomitisation occurs when limestone is recrystallised and chemically altered from calcium carbonate ($CaCO_3$) to calcium magnesium carbonate ($CaMg(CO_3)_2$). How this process occurs has been studied by geologists for decades but remains enigmatic. The PDF on the Great Orme is recognised by its darker, browner colour (compared to the more ubiquitous grey limestone), its crystallinity and some unusual striped textures known as zebra dolomite. Zebra textures are typified by alternations of dark, replacive dolomite and white dolomite cement (below). They are intriguing because they are usually associated with dolomite that has been formed by fluids that have moved up faults at high pressure and temperature. Potentially these textures could provide information on how dolomitisation occurs. Their localised occurrence emphasises the importance of conserving key outcrops. Prior to recent engineering works, exposures through the PDF at the rear of Happy Valley car park showed a series of small, often elongated cavities (vugs) in which zebra textures were well developed (bottom, left). Locally, the dolomitic fill in the zebra textures has been dissolved by weathering (bottom, right). Photos by Cathy Hollis



overhanging the quarried cliff and to cover the rock face entirely with protective wire mesh (rock netting) bolted right down to the tarmac surface of the car park. This would allow visitors to use the car park without risk of further rockfall. However, it would significantly reduce access to this critical research and teaching site. From a geoconservation perspective, an alternative approach would be required.

Consequently, a series of site meetings was held between NRW, CCBC and its contractors and key research staff from the University of Manchester Geology Department to see if a compromise solution could be reached. Establishing that the Happy Valley car park rock exposures were currently the subject of high-level scientific research, and that they form a frequently used teaching locality, proved to be critical factors in the discussions. After assessing options, it was agreed that wire netting would not cover the entire rock exposure; rather, it would terminate 1.5–2 m above the tarmac surface of the car park. This would leave a continuous rock-exposure height of 1.5–2 m along the entire length of the dip section, with the benefit of maintaining safe access for teaching, research and the general public. It was also agreed that prior to any remedial engineering works, the Manchester researchers could log and photograph the sections in detail, marking the position and orientation of critical faults (the potential sources of dolomitising fluids). CCBC and its contractors also generously allowed researchers access to the sections during the engineering works. While contractors were removing excess vegetation and de-scaling the rock face prior to installing the rock netting, it was possible to

Following an agreed approach, NRW issued an assent to CCBC for vegetation clearance on the upper parts of the cliff face prior to rock netting and bolting. This was an excellent opportunity for rescue sampling—particularly of the unusual zebra textures in parts of the site previously out of reach or obscured by vegetation. Contractors took care not to remove specified plants, including the sea cabbage or sea kale (*Crambe maritima*), that form an important element in the biodiversity of the Great Orme's Head SSSI. Photo by Stewart Campbell

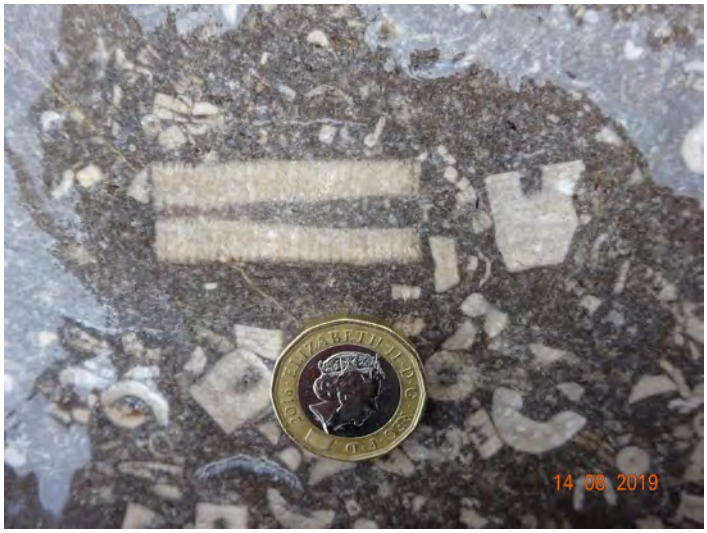
The Happy Valley car park exposures through the PDF are seen here after completion of the engineering works. The lowest 1.5–2 m of the PDF above the tarmac surface remain un-netted along the entire length of the dip section, making it available for teaching and research. A continuation of some beds in the PDF also occurs seaward, below road level. Photo by Stewart Campbell

gain samples, especially of zebra textures, from hitherto inaccessible parts of the face. This enabled a total of 36 samples to be taken systematically across the outcrop using a rock hammer, including 5 samples of zebra dolomite. These will be analysed in the context of the wider variability in rock texture by microscopic examination and geochemical analysis.

Living with nature

The Marine Drive provides the principal access route around the perimeter of the Great Orme's Head. This popular and scenic road is bordered in many places by towering cliffs and steep rock cuttings and, inevitably, there have been rock falls and even fatalities. Indeed, in 1993 after prolonged heavy rain, 24 virtually simultaneous landslides rendered Marine Drive unusable for many months (Wood & Campbell, 1995). With public safety and the prevention of accidents paramount, there will always be pressure for remedial engineering works in such heavily used and inherently hazardous locations. The construction of gabions and retaining walls and the use of rock netting/bolting are consequently recurrent geoconservation issues on the Great Orme's Head. The case of the Happy Valley car park exposures clearly demonstrates the importance of early dialogue between parties. In this case it has ensured that public safety and geoconservation requirements can be reconciled. Important parts of the PDF at Happy Valley therefore remain accessible for research.

Adjacent to Llandudno Pier and below Happy Valley, exposures of the PDF occur in coastal sections (right). Although the PDF is generally poorly fossiliferous in comparison with other limestone formations on the Great Orme, wave-washed sections here provide fine examples of crinoid debris (below). Photos by Stewart Campbell



There is a high level of rock exposure on the Great Orme's Head. However, there is a long history of quarrying and the Marine Drive and many other roads, car parks and lay-bys have been cut into the bedrock leading to local instability. The challenge for site managers and NRW geologists is to retain access to key geodiversity features while maintaining public safety. Photo by Raymond Roberts

Acknowledgements

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NRW is extremely grateful to **Cathy Hollis** and **Cole McCormick** (University of Manchester) for their rapid response to this geoconservation issue and their readiness to provide advice and undertake rescue logging, sampling and photography of the Happy Valley car park exposures at very short notice. Their help has ensured that parts of this key stratigraphical exposure remain accessible for teaching and research. **Charlotte Williams** (NRW) kindly co-ordinated NRW's formal response to the works and provided specialist biodiversity advice.

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A New DIGS Site in the Rodwell Cutting, Weymouth - The story so far

Geoff Pettifer, Dorset's Important Geological Sites Group

Rodwell Cutting is on the former Weymouth–Portland railway line, in Weymouth, between Wyke Tunnel in the north and Buxton Road Bridge in the south. The cutting is some 400 m long and up to 10 m deep and was excavated, partly by blasting, in 1863–4, providing material to construct the Marsh Embankment north of the tunnel. The railway was closed for passenger and goods traffic in 1965 but continued to be used by the Admiralty until 1970. It is now followed by the Rodwell Trail, a tarmac-surfaced pedestrian and cycle route (National Cycle Network Route 26) well used by the local community and visitors. The cutting is through strata of the Corallian Group on the southern limb of the Weymouth Anticline, extending from the Nothe Clay in the north to the Sandsfoot Clay in the south and including the Osmington Oolite and Clavellata Formation. The new DIGS site is in the southern part cutting, located by grid reference SY 675 781.

Excavation of the cutting severed groundwater flow to springs to the east, including the Rodwell (which means either reedy or red spring). The catchment area of the springs is a small hilltop area occupied by houses with relatively large gardens and school grounds west of the cutting.

Groundwater now issues as a 'dripping well' from limestones overlying clay beds along a 100 m section within the DIGS site on the western side of the cutting. On contact with air, groundwater rich in calcium and bicarbonate loses carbon dioxide and a hard deposit of calcium carbonate (tufa) forms, petrifying leaves and twigs and obscuring limestone surfaces. Such deposits are uncommon in southern England.

Previous geological studies

Blake and Hudleston described the strata in the cutting in the mid-1870s, when there were few or no trees and probably little ivy. They compared their observations with equivalent strata exposed along the coast between the Nothe and Sandsfoot Castle. The coastal exposures, now partly obscured due to buildings and sea defences, are within Portland Harbour Shore SSSI.

The coastal section was also studied by Sedgwick in 1828, Buckland and De la Beche in 1836, and Woodward in 1895 and was considered to be the type locality for the Corallian in south Dorset. Exposures in the cutting were re-appraised by Arkell (1936) and those on the adjacent coast were described by Cope (2016).

Blake & Hudleston (1877) recognised fifteen units in the cutting (Table 1). They placed the boundary between the Osmington Oolite and Clavellata formations between their beds 7 and 8, but Arkell (1936) considered that the boundary should be placed between their beds 2 and 3. Blake & Hudleston had come to the conclusion that "*these Corallian beds cannot be trusted to be constant any further than we can see them*", but Arkell broadly disagreed.

Southern end of main exposure on 16 March 2018. Rubbly argillaceous limestone overlying clay or marl (possibly units 3–7 of Blake and Hudleston). Blake & Hudleston placed these strata at the base of the Clavellata Formation, whilst Arkell considered them to be the uppermost beds of the Osmington Oolite Formation. Photo by Geoff Pettifer

Discovery of the Clavellata Formation on 25 February 2019. A thin layer packed with *Myophorella clavellata* bivalve shells extending to the left of the DIGS volunteer's hand. This exposure is in the upper part of the cutting above the water table and therefore is not obscured by tufa. Photo by A. Holiday

Close up of the Clavellata Formation. Taken on 14 November 2019 after further clearance work. The Myophorella clavellata fossil at the far left retains both valves, indicating that it has undergone very little or no transport from its original growth position. Photo by Geoff Pettifer

Age	Formation		Strata descriptions (after Blake & Hudlestone, 1877)		Thickness (m)
Corallian Group (Oxfordian faunal stage of the Upper Jurassic)	Clavellata (Arkell)	1	Blue CLAY (possibly part of Sandsfoot Clay Member)		-
		2	Hard blue impure LIMESTONE in six courses, with numerous casts of *Trigoniae* bivalves (e.g. *Myophorella clavellata*), *Pleurotomariae* gastropods (e.g. *Bathrotomaria reticulata*), etc.		3.66
		3	Rubbly very slightly oolitic LIMESTONE, beds separated by marly partings (0.2 m thick)		2.13
		4	Oolitic MARL, very fossiliferous, particularly *Myacites* bivalves (e.g. *Pleuromya uniformis*). Fine-grained pisolite?		1.22
	(Blake & Hudleston)	5	Grey rubbly LIMESTONE, scarcely oolitic		0.46
		6	Stiff MARL, very oolitic towards base, hard ferruginous bed in centre		1.45
		7	Hard ferruginous OOLITE		1.22
		8	MARL with flaggy calcareous grit		0.91
		9	Strong semi-oolitic FLAGSTONE with calcareous markings		0.30
		10	Blue CLAY with oolite grains at the base		1.12
	Osmington Oolite	11	Solid, shelly and oolitic light-coloured LIMESTONE, with the echinoid *Echinobrissus scutatus* (*Nucleolites clunicularis*)		1.12
		12	Light-coloured MARL, becoming oolitic below		0.61
		13	Rough, shaly OOLITE in two blocks		1.22
		14	MARLS	(possibly part of Bencliff Grit Mbr)	1.83
		15	Fine-grained calcareous GRIT		0.61

Strata previously recorded in the Rodwell Cutting (Blake & Hudleston, 1877)

Revealing the strata and registering the site

Until recently, the strata were largely obscured by vegetation, principally ivy beneath a sycamore canopy. Preliminary clearance of ivy at ground level was carried out for the 'Dripping Well Project' on behalf of the Friends of the Rodwell Trail and Sandsfoot Castle (FoRT) with permission from the then landowner, Weymouth and Portland Borough Council (WPBC). The long-term plan was to improve geological interest, drainage and biodiversity in the cutting. During the course of this initial work it became apparent that significant exposures remained.

A DIGS field party surveyed the site in May 2018 and the group subsequently agreed to seek registration of part of the cutting as a Local Geological Site. A site management plan was drawn up and the site was accepted by WPBC in January 2019, prior to the transfer of land ownership to the new Dorset Council on 1 April 2019. DIGS volunteers cleared further vegetation and carried out ditch clearance between February and April 2019. Most recently, on 14 November 2019, further vegetation was removed from around the Clavellata bed, ivy strands were pulled up above the main dripping well exposure and some signage was replaced.

Importance of the site

This is the only DIGS site in the Corallian on the southern limb of the Weymouth anticline. The strata span an important boundary between the Osmington Oolite and Clavellata formations and can be compared with those of similar age along the coast at Portland Harbour, the Fleet and in the Osmington area. The site is a valuable educational resource for students from primary school age up to university level. It is easily accessible along the Rodwell Trail, and the lower exposures and dripping well are highly visible.

The petrifying springs continue to flow, albeit at a much reduced rate, during prolonged dry periods. They demonstrate geology (or hydro-geomorphology) in action and this was further emphasised during the 'beast from the east' event (2018), when ice formed over the tufa. The springs also support masses of liverwort on the rock face and watercress in the pool below. It is unlikely that they would qualify as 'Petrifying springs with tufa formation (*Cratoneurion*)' in terms of the EC Habitats Directive as they were formed relatively recently and therefore do not support a range of distinctive bryophytes. Further advice will be sought from Natural England at a later date, however.

Clearing the stream course below the dripping well on 29 April 2019. Working space is restricted along the trail! Tufa supporting masses of liverwort obscures the rock face. Liverworts are primitive plants whose ancestors arose some 400 million years ago. Watercress is now flourishing in the embryonic water feature below the springs. Photo by Geoff Pettifer

Future site management

Future goals include connecting exposures and keeping them clear of excessive vegetation, without compromising slope stability, extending the stratigraphic range of the exposures, in particular the boundary between the Osmington Oolite and Clavellata formations, and constructing a more accurate geological map and associated cross sections. Faulting might help to explain the presence of the dripping well, but the exposed strata do not appear to have been displaced in this way. The published geological map indicates an inclined subsurface fault beneath the Western Ledges that does not extend up into the Corallian, but this fault is not identified on Cope's (2016) seismic profile across this area.

It will also be necessary to keep the stream course clear of debris using hand-held tools such as draw hoes. Stream flow will be monitored and compared with readings from a local rain gauge. We also hope to create a small seepage-fed pond in a silt-filled depression. A few laurels and large unstable sycamores will be removed, and this would have a secondary aim of increasing native plant diversity. On-site re-use of materials will include construction of access paths and placing branches to create working platforms and log piles for the benefit of wildlife. Soil removed will be incorporated into the log piles. Care will be taken to preserve areas for wildlife, and trees and dense vegetation will not be removed or disturbed during the bird breeding season.

These tasks will be carried out in partnership with FoRT and Dorset Council. In due course an information board will be created and installed, with the aim of increasing public perception of the ways in which different components of the local earth system interact. The story of this site will continue to unfold.

Note from Alan Holiday, DIGS chairman.

Geoff has taken on the designation of this new DIGS site with great enthusiasm and great credit should go to him for seeing this through. Other members of the group have been involved in the conservation activity. The site has generated interest among passers-by as they see the work being done and it raises awareness of local geology.

Northern end of the main exposure on 1 March 2018 during the 'beast from the east' event. Icicles have formed where a spring issues from flaggy oolitic limestones underlain by grey clay within the Osmington Oolite Formation (possibly units 8–10 of Blake and Hudleston). Local lads walking home from school had fun smashing the largest icicles and were surprised when they regrew overnight! Photo by Geoff Pettifer

Further Reading

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Blake, J.F. & Huddleston, W.H. 1877. On the Corallian rocks of England. *Quarterly Journal of the Geological Society of London*, 33, 260-405.

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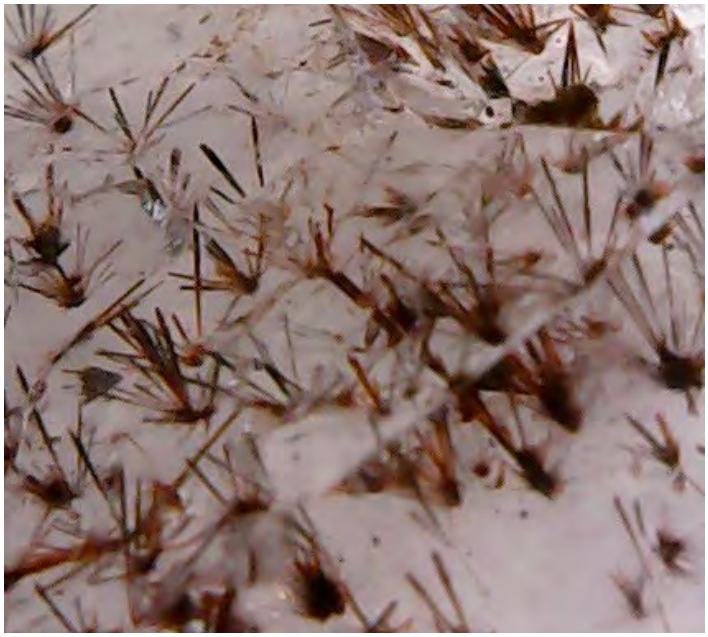
Zooming in with the Rock Doctors

Neil DL Clark & David Webster, Geological Society of Glasgow

Top: As in pre-pandemic events hand specimens of rocks, minerals and fossils were forthcoming for the Rock Doctors to identify. However, the identification of specimens, such as these manganese dendrites, were this year undertaken by virtual means. Photo by kind permission of V. Christison.



Left: Microscopically sized rutile held within a crystal of quartz: one of the many images submitted for identification at the long-running Glasgow Rock Doctors event. This unprecedented virtual gathering has been incredibly successful, which offers an insight into future Rock Doctor events though virtual meetings with people and rock specimens have their limits. Photo by kind permission R. McKenzie.

The Glasgow Rock Doctors has now been an event in Glasgow since 1990 with the help and support of the Geological Society of Glasgow. Over the past 30 years there have been many rocks/minerals/fossils looked at, pondered over, and frequently identified with a good degree of certainty. This year, however, as we are all aware, has been quite unprecedented. For the first time, the Rock Doctors has had to be an online event with prior digital image submission as well as hasty identifications on hazy screens during the event. Identification was successful for the most part but depended on the quality of the digital image submitted and the angle at which the photograph was taken. During the event on the 9th June 2020, those who submitted their images were able to chat with the Rock Doctors about their find and were in turn quizzed about it and sometimes asked to show their finds to the camera to allow the Rock Doctors to view the piece from a variety of angles. For the first time, it was possible for the public to discuss more than just hand-held samples, as they were able to submit images of landscapes that they were interested in finding out more about as well. This also allowed the Rock Doctors to discuss how the geology defines the landscape and elaborate on the potential for interesting rocks/minerals/fossils in a particular area.

Pipe Rock, quartzite of Cambrian age, at Loch Dubh in the Northwest Highlands with its well-defined layering and jointing was one of the identification tasks for the Rock Doctors. The submission of images was a departure from previous Rock Doctors events allowing, for the first time, discussion and identification of geological landscape features. Photo by kind permission of C. Williams.

With screen sharing, it was possible for everyone who joined the event to see the variety of submissions and take part in the discussions. Images taken by one attendee were of microscopically sized minerals held within a crystal of quartz. They were interested to know what these inclusions seen by their grandchild might be. Another had seen some interesting rock formations in the North West Highlands of Scotland near to Loch Dubh, north of Ullapool. Another had not submitted images but was able to show some samples they had to hand from the quarries near to Elgin. Most of the samples identified were of smaller hand-sized samples that were part of the enquirers' collections; specimens that had been left to one side unidentified since they were collected. These included the roots of Carboniferous lycopods, gastropods, ammonites, corals, pitchstone pegmatite, dendrites and much more. There is always a challenging variety of specimens offered forth at these events and it constantly keeps the geologists on their toes as well as giving them an chance to share their knowledge with the public, who are most appreciative of the opportunity to meet a real geologist (even though it was virtually this year).

The public were able to join at any time during the one and a half hours of the event and we had over 25 people attending at any one time from all over Scotland … and perhaps even beyond. It was an opportunity that some may not have been able to have in the past, as they would perhaps not have travelled the distance to a venue in Glasgow but were able to take part in the online event. Those taking part were of all ages and all levels of geological experience—including the occasional geologist attempting to catch the Rock Doctors out!

All things considered, despite the pandemic, it was reassuring that there was a means of communicating our enthusiasm for the topic, and helping others to appreciate it more, without the inherent risks of the one-to-one contact at close quarters of previous events. As the online event allows a more inclusive interaction with the public, we certainly hope to do this in the future, but nothing really compares with handling the material and examining it at close quarters (roll on the old 'normal').

Geoconservation and the GA—our response to Covid-19

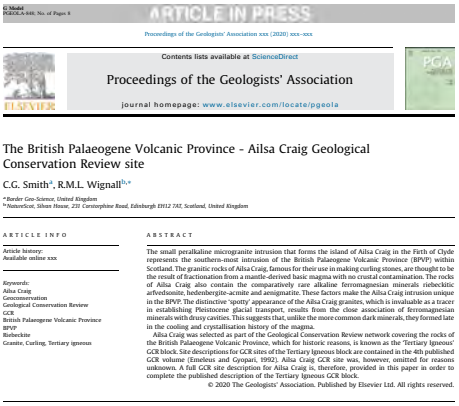
Colin Prosser, GA Chair of Conservation and Natural England

The period of national lockdown and ongoing requirements for social distancing and associated restrictions on sharing transport and gatherings of more than 6 people have had an undoubted impact on everyone's ability to carry out conservation activity in the field. Having said this, the GA has done its best to retain an active interest in geoconservation and to continue to contribute in some form or other wherever possible. Most importantly we have continued to publish, with partners, this magazine (*Earth Heritage*) as a means of providing a focus for the geoconservation community and as a vehicle through which to share news and good practice.

Specific activity during this period has included:

- Reviewing the impacts of lockdown on geoconservation, including the status of geoconservation activity across the country (see *EH*53, pp. 12–16).
- Maintaining an interest in geoconservation matters in the outside world—the GA has responded to a government consultation and made representations over the closure of a show cave over the last few weeks.
- Running a virtual meeting room/breakout session on geoconservation as part of the Festival of Geology (November 7).
- Offering our support and congratulations to the Black Country on becoming a UNESCO Global Geopark: we visited key sites within the Geopark, including the newly declared Saltwells National Nature Reserve, as part of the GA Annual Conference in 2018.
- Participating in virtual meetings with a geoconservation theme.e.g.
  - The Geological Society's virtual Geoconservation Gathering meeting: October 2020 'Conserving life past, present and future'
  - Oxford Geoheritage Virtual Conference, May 2020
  - Provision of a virtual lecture to the West Sussex Geological Society on the Piltdown National Nature Reserve, October 2020
  - Ensuring that the Curry Fund keeps running in order to provide a potential source of funds for projects including geoconservation activity
- Agreeing a format to publish descriptions of new Geological Conservation Review sites as stand-alone papers in the PGA: three such papers relating to sites in Scotland have been written and published online to date.

The site description for the Ailsa Craig GCR site has been published on-line in the PGA during lockdown (below) and is due to appear in hard copy in the near future. The paper describes the granite rocks found on the island of Ailsa Craig (top, © British Geological Survey) which are also used to make curling stones (middle, © Dr Graeme Adam).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The British Palaeogene Volcanic Province - Ailsa Craig Geological Conservation Review site

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ABSTRACT

The small peralkaline microgranite intrusion that forms the island of Ailsa Craig in the Firth of Clyde represents the southern-most intrusion of the British Palaeogene Volcanic Province (BPVP) within Scotland. The granitic rocks of Ailsa Craig, famous for their use in making curling stones, are thought to be the result of fractionation from a mantle-derived basic magma with no crustal contamination. The rocks of Ailsa Craig also contain the comparatively rare alkaline ferromagnesian minerals riebeckitic arfvedsonite, hedenbergite-acmite and aenigmatite. These factors make the Ailsa Craig intrusion unique in the BPVP. The distinctive 'spotty' appearance of the Ailsa Craig granites, which is invaluable as a tracer in establishing Pleistocene glacial transport, results from the close association of ferromagnesian minerals with drusy cavities. This suggests that, unlike the more common dark minerals, they formed late in the cooling and crystallisation history of the magma.

Ailsa Craig was selected as part of the Geological Conservation Review network covering the rocks of the British Palaeogene Volcanic Province, which for historic reasons, is known as the 'Tertiary Igneous' GCR block. Site descriptions for GCR sites of the Tertiary Igneous block are contained in the 4th published GCR volume (Emeleus and Gyopari, 1992). Ailsa Craig GCR site was, however, omitted for reasons unknown. A full GCR site description for Ailsa Craig is, therefore, provided in this paper in order to complete the published description of the Tertiary Igneous GCR block.

Images from the Geologists' Association 2020 Photo Competition

Gerald Lucy, Geologists' Association

This annual competition, open to non-members as well as GA members, had a submission dealine in September with results announced and a display of the winners at the Festival of Geology (7th November 2020, which was online this year) as well as featuring in the December issue of the GA Magazine.

Ammonite Pavement, Lyme Regis, Dorset
James Codd

Lyme Regis requires no introduction as a valued fossil locality. It enjoys geoconservation protection from designation with the 'Axmouth to Lyme Regis Under Cliffs SSSI', which has multiple geological and biological interests (www.gov.uk/government/publications/devons-national-nature-reserves/devons-national-nature-reserves#axmouth-to-lyme-regis-undercliffs)

Standing Gneiss, Isle of Lewis
Gary Eisenhauer

Devonian flagstone fence stones, Yesnaby, Orkney
Gary Eisenhauer

Illustrative of the frequent overlap of archaeological and geological interests, this Lewisian stone circle (above left) at Calanais is made from the rock of the same name (Lewisian Gneiss). Gary clearly likes his island geology in vertical mode, as he has also produced this view of Devonian flagstone fence posts (above right) in the protected area at Yesnaby, Orkney.

Bubbling hot mud, Yellowstone National Park, USA
Peter del Strother

A close-up view of a small area of a very large national park. This is the oldest national park in the USA, having been signed into law by President Ulysses S. Grant in 1872. It is renowned for its geothermal features, as well as its scenery and wildlife.

The Green River, Harpers Corner, Dinosaur National Monument, Colorado–Utah, USA
Graham Roberts

This American National Monument is a park with numerous fossil-bearing sites that has yielded, amongst others, Allosaurus, Deinonychus, Abydosaurus and various sauropods. These come from Jurassic fluvial deposits. As Graham's photo shows, the Green River is responsible for spectacular modern geomorphology.

Chevron folding at Millook Haven, Cornwall
Steve Dumpleton

The folding visible in the coastal sections of North Cornwall is of world renown. The cliffs at Millook Haven are part of the Millook to Foxhole Point GCR site, lying within the Boscastle to Widemouth SSSI (multiple interests), the Pentire Point to Widemouth AONB and the Heritage coast of the same name.

Whaleback folds and the Whin Sill, Cullernose Point, Northumberland
Nicole Barnes

This locality lies within the Castle Point to Cullernose Point SSSI, designated for its importance in demonstrating features associated with the intrusion of the Whin Sill, with the development of a number of rock types from an originally homogeneous body of molten rock, including granitic material from late-stage fractionation.

Granite tors on Stowes Hill, Bodmin Moor, Cornwall
Richard Furminger

Tors are classic features of the upland granite scenery in Cornwall and Devon. Right-angled joints formed as the granite magma cooled, chemical weathering of the feldspar crystals along the joints, and finally frost action, have produced these remarkable shapes. Stowes Hill lies within the Bodmin Moor section of the Cornwall AONB.

Conserving life - past, present and future

Hannah Townley, Natural England

The Geological Society of London's Geoconservation Commission held their annual gathering on the 7th October 2020. Originally a face-to-face meeting was planned in Dudley at the Museum & Archives, followed by a field trip to see the geology of the newly declared Saltwells NNR. This year, like many other events, the meeting was held virtually due to Covid-19 restrictions.

The event was well attended and included members of the Geological Society of London's Geoconservation Commission along with geoconservationists and stakeholders from the British Isles, with a few from further afield.

This year the conference title and theme concerned conserving life (*Conserving Life—past, present and future*) as part of the Geological Society's Year of Life. A total of nine speakers from across the UK delivered presentations on a range of geoconservation topics. The gathering provided insights into how different aspects of the UK's palaeontological resource can be conserved and used, with plenty of food for thought for the attendees, especially around engagement with volunteers and the public.

Conserving sites

Michael Dempster (Northern Ireland Environment Agency) told us about the conservation of palaeontological ASSIs (Areas of Special Scientific Interest) across Northern Ireland giving examples of site-based challenges and opportunities, from the highs of discovering fossil millipede trackways on site, to the lows of illegal fossil collecting and damage to important geological exposures.

Colin MacFadyen (NatureScot) described the Skye Nature Conservation Order (NCO) put in place to address the issue of unconsented and damaging fossil collecting activity. The NCO has helped raise awareness of the collecting issue and offers scope for engaging with the local community, visitors to the island, scientists and amateur fossil collectors, although some of this has been put on hold due to Covid-19. Further details can be found on the NatureScot website and in *EH* issue 52.

Tim Astrop (Brymbo Heritage Trust) told us about progress with the Brymbo Fossil Forest Project which conserves and promotes a 314 million-year-old in situ fossilised Carboniferous forest and the Trust's engagement with volunteers. See issues *EH* 26, 43, 45, 46, 51 and 53 for the Brymbo story since its discovery in 2003.

Conserving collections and public engagement

Chris Reedman (Jurassic Coast Trust) described the Jurassic Coast Collection, which aims to improve access to important fossils from the Jurassic Coast and to emphasise their unique role in the story of the World Heritage Site. See *EH* issue 53 for a fuller description and images of fossils from the collection.

Liz Hide (Sedgwick Museum of Earth Sciences, University of Cambridge) presented about museum collections, public engagement and social change. She said, "Museums bring rocks to the people", as museums are usually located in towns and cities and can provide experiences of the natural world to those who cannot get out on site easily. She challenged us to think about what we could do to

Recently discovered millipede trackway, the earliest evidence of land animals from the Devonian of Northern Ireland. Photo by Michael Dempster/NIEA

Further Reading

Conference programme and abstracts: https://www.geolsoc.org.uk/expired/10-gsl-geoconservation-gathering-2020

help our volunteers, rather than thinking 'what volunteers could do for us'.

Jonathan Larwood (Natural England) told us about England's National Nature Reserve (NNR) strategy and ambition to tell England's geological story through new and existing NNRs. He illustrated his talk with case studies on Wren's Nest NNR, Horn Park NNR, Swanscombe Skull Site NNR and the new Saltwells NNR (see page 23), telling us about their site management and how they can be used as outdoor laboratories, for engaging volunteers and the public.

Using the palaeontological resource

Matthew Pound (Northumbria University) described his work on the Brassington Formation, the most extensive Miocene sedimentary succession onshore in the UK, which occurs as inliers in the karstic surface of the Carboniferous in Staffordshire and Derbyshire. The deposits formed in a sub-tropical, seasonally wet climate, dominated by lacustrine and fluvial environments. The pollen, spores and macrofossils provide a unique insight into the response of ecosystems to climate changes that accompanied the Middle to Late Miocene cooling.

Lesley Dunlop (Berkshire Geoconservation Group, Oxfordshire Geology Trust & Northumbria University) emphasised the importance of site networks. Using examples from the Berkshire and Oxfordshire Local Geological Sites (LGS) networks she explained that linking several LGS together (through interpretation, trials or field visits) can give a much larger picture of environmental and landscape change.

Graham Worton (Dudley Museum and Black Country UNESCO Global Geopark) told us about the effects of the development planning process on geological sites in the Black Country. Building relationships with planners and using their language with them can have many positive benefits, for example influencing development design and layout, choice of materials, and physical and intellectual access to geological sites.

A virtual trip to Saltwells

Graham Worton completed the day by leading us on a virtual fieldtrip to Saltwells NNR (see page 23). Like all traditional field trips we started in the car park, before following the geological trail along the old mineral tub-line. The first stop was to view Doulton's Claypit with spectacular cliffs showing a section through the rocks of the Middle and Lower Coal Measures. Continuing along the tub-line you reach rocks of Silurian age and can see the unconformity between the Silurian and Carboniferous rocks at Brewin's Canal Section SSSI. Despite many calls from the Zoom chat facility, we did not see the inside of the Saltwells Inn, the traditional end to many field trips.

***Top*: A view of Kenslow Top Pit that shows the Kenslow Member with overlying glacial till; one of the sites investigated by Matthew Pound that provides an insight into Miocene ecosystems and climate changes**

***Left*: Some of the fossil wood from the Kenslow Member**

Both photos © Matthew Pound.

Conclusions from the day

There was a general sense of the success of the day. The presentations linked well and connected how we conserve palaeontological heritage on site, linked sites to collections and wider public engagement, and the wider application of palaeontological heritage in planning and understanding environmental change. Attendees agreed that it was good to meet virtually as it widened the audience, and in the future having talks available virtually, even when face-to-face meetings are allowed, would allow greater dissemination of ideas from conferences.

Well done to all the conference organisers, session convenors and speakers who contributed to this interesting and informative event.

Creating Charles Lyell's World Online

David McClay, Philanthropy Manager, Library & University Collections, University of Edinburgh

Sir Charles Lyell (1797–1878) was fundamental in establishing the popularity and credibility of geology as a science in the nineteenth century, especially in disseminating James Hutton's theory of uniformitarianism. Through extensive field work, travel, popular lectures and bestselling books, he became internationally famous and respected by many scientific communities. His *Principles of Geology*: being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation (1830–33) was in print throughout his life and was regularly revised to incorporate new evidence and arguments.

Lyell's extensive published writings, specimens and archives are essential in understanding and appreciating his contemporary impact and enduring relevance. The University of Edinburgh has recently brought together the majority of Lyell's extensive archives: his notebooks, letters, lectures and various papers. Assembling this collection has been achieved in several stages.

Sir Charles Lyell. Engraved portrait by Thomas Herbert Maguire, 1849 © University of Edinburgh

Founding the Lyell archives

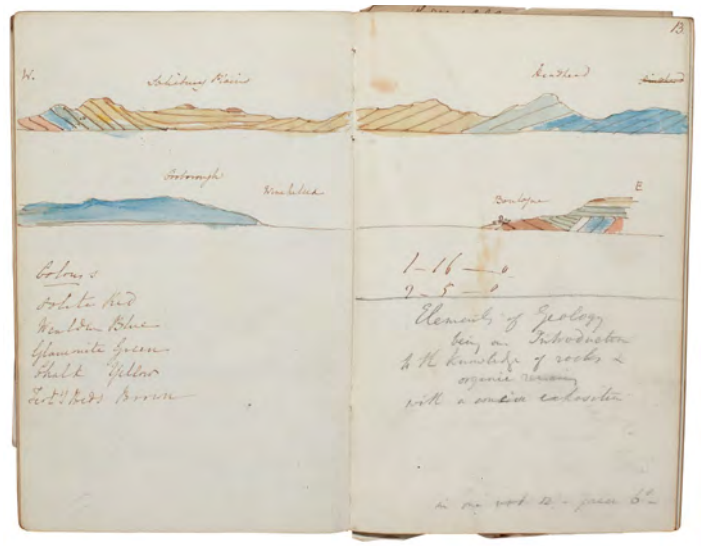
The foundation Lyell collection was generously donated to the University in 1927 by Lady Lyell of Kinnordy. These archives include field and lecture notes, correspondence and press cuttings. Areas of geological focus include Forfarshire, Madeira and the Canary Islands, Mount Etna and New Zealand. The correspondence, from 1831–1873, extends over more than 6,500 folios and offers fascinating detail, not only on Lyell, but a lively selection of influential and curious members of nineteenth century society. A small but important Lyell specimen collection came with the papers and consists of around one hundred stone artefacts (axes, spears and arrow heads), three meteorites, 25 fossils and 25 rocks. Some of the specimens are significant because they were used to illustrate his books. The collection includes flint tools which relate to his research for his Geological Evidences of the Antiquity of Man (1863).

The 1927 donation was not motivated by a particularly significant Lyell and Edinburgh connection. However, by the early twentieth century the University's geological credentials had been well established. Sir Roderick

Murchison had founded Edinburgh's chair of geology in 1870, the first appointment being Sir Archibald Geikie.

Lyell's notebooks

Having a longstanding Lyell archive, the University of Edinburgh was particularly keen to acquire his notebooks when they became available in 2019. These 294 pocket notebooks, which, apart from a few missing ones, form a long and uninterrupted series of continual thought and study from 1818 to 1875. They vary from approximately 70 to 270 pages, and are crammed with extensive notes and memoranda on geology, natural history, social and political subjects, with many hundred accompanying sketches and diagrams. They are fascinating and invaluable.



***Top*: Sir Charles Lyell notebook, illustrating Salisbury Plain and draft title of his Elements of Geology. © Sotheby's**
***Bottom*: A selection of Lyell's notebooks. © University of Edinburgh.**

Lyell's habitual use of notebooks was a key part of his working method and integral to his geological research and publishing. In addition to gathering the raw materials for much of his printed work, they offer the most immediate insights into his life, reading, draft and copy correspondence and, most critically, his immediate and developing thoughts.

The notebooks had remained in Lyell family possession until the death of Charles, 3rd Baron Lyell (1939–2017) when they were valued at £1,444,000 and provisionally sold to an overseas buyer. An Export Bar was applied, having been designated as of national significance and if at all possible they should be kept in the UK. Thanks to a negotiation, based on the tax advantage of a Private Treaty Sale, a revised purchase price of £966,000 was set. Between June and October 2019 over 1,100 donations reached the funding target. Whilst the University of Edinburgh, the National Heritage Memorial Fund and the John R. Murray Charitable Trust made vital major donations, it was also the coming together of many individuals, societies and grant giving bodies, including the Geologists' Association, that helped achieve the goal of saving the notebooks. A notable feature of the fundraising campaign was the wide international response and generosity.

Completing Lyell's archives

The University of Edinburgh, with the addition of the notebooks, has now established itself as the archival centre for Charles Lyell. When government ministers, specialist advisors and

the Treasury decided to accept the bulk of Lyell's remaining archives under the Acceptance in Lieu of Inheritance scheme, they decided to allocate them, for free, to Edinburgh.

This varied collection arrived in August 2020 and perfectly complements the rest of the archives. Highlights include a further 1,200 letters to and from Lyell and between his family members. Special correspondents include Charles Darwin, Joseph Dalton Hooker, Leonard Horner, Thomas Huxley, Sir Roderick Murchison, John Murray III, Herbert Spencer and George Ticknor.

The collection's scientific, personal and publishing papers include much material on Lyell's and his wife's experiences in America, journal articles and offprints of scientific papers, reviews, speeches and lectures notes. The varied items relating to his publications include drafts of his literary works, including an early autobiographical manuscript, partial book manuscripts including the Principles of Geology, annotated revision copies of his works and illustrations, lithographs and maps.

Further recent opportunities to add to the collection have included a Lyell family album of letters and photographic portraits and foreign language editions of his books. Again the support of organisations such as the Friends of the National Libraries and the Friends of Edinburgh University Library have made these acquisitions possible.

Charles Lyell's World Online

With this extensive Lyell archive now assembled at the University of Edinburgh, focus has turned on how to make the most of this collection and share it as widely as possible. Our Charles Lyell's World Online project is an extensive programme of conservation, preservation, digital photography, cataloguing, transcription and online access and engagement. Conserving and preserving the physical collection is essential to allow traditional in-person consultation and research, as well as displays and exhibitions. However, the full potential of the collection will only be achieved through an additional online version of the Lyell archive.

With high quality digital photography of the notebooks, along with the most significant parts of the remaining archive collection, we will create the basis of a fascinating online resource. These images will be made more accessible and understandable by transcribing the text and contextualising with information and interpretation around the biography, bibliography, chronology and science. This online resource, which is freely accessible, will be useable by a wide range of people, from specialist historians and scientists, to the casual and inexperienced browser or student.

In addition to describing and making accessible the collections held at the University of Edinburgh, the Charles Lyell's World Online will also seek to act as a hub for other relevant Lyell and contemporary resources, whether that is further archives, texts or specimens.

By investing in the archive in this way the true value of the collection will be realised for current and future generations and made publicly available for all, creating a far greater knowledge and appreciation of Lyell's life and world, a time in which the Earth Sciences came of age.

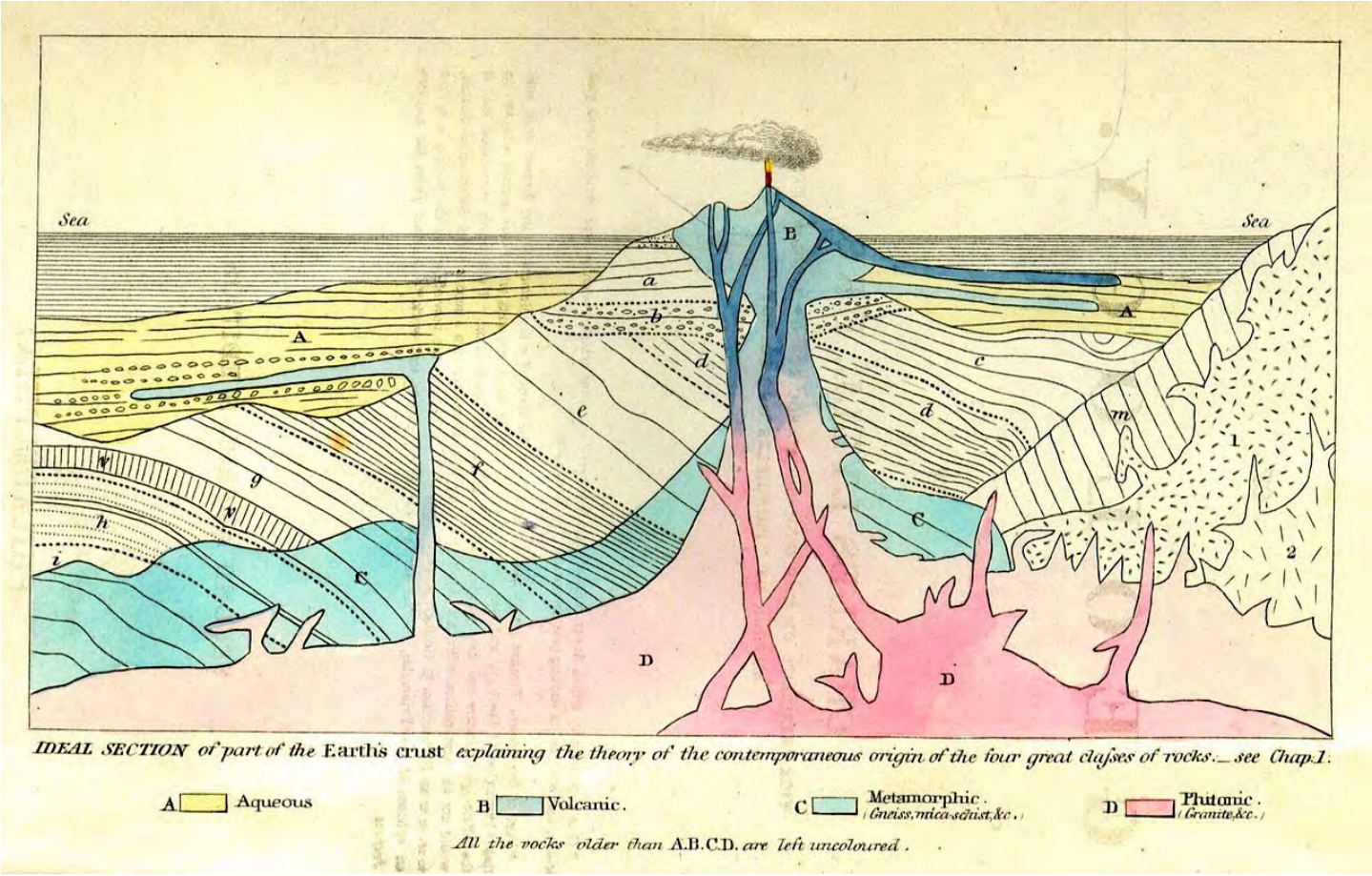


Illustration in Sir Charles Lyell's *Elements of Geology* (1838) 'Ideal Section of part of the Earth's crust explaining the theory of the contemporaneous origin of the four great classes of rocks' © University of Edinburgh

Further Reading

To learn about the archives and our developing plans and progress there are a website and blog:

Through Lyell's Eyes: https://www.ed.ac.uk/information-services/library-museum-gallery/crc/the-sir-charles-lyell-collection

Library Lyell website: http://libraryblogs.is.ed.ac.uk/lyell/

Tribute to Matthew Parkes

Sarah Gatley, Geological Survey Ireland

We were all deeply shocked to hear the news of Matthew's sudden death on 23rd October 2020, and the task of paying tribute to him is as monumental as his stature and the impact that he had on the geological community throughout his career.

Matthew's last role was as Assistant Keeper for Earth Science at the National Museum of Ireland, where he demonstrated his wide-ranging expertise in Irish palaeontology and geology, collections and displays. He also pursued his other passions, including the promotion of Ireland's geological and mining heritage, through his publications and outreach activities.

Matthew's reputation as the Go-To-Man for Irish geological heritage was established during his time in the Geological Heritage Programme in Geological Survey Ireland from 1998 to 2005.

Probably one of his greatest legacies is the national programme of County Geological Audits, which Matthew initiated in 2004 with the publication of counties Sligo and Carlow. He continued to have a central role in each County Audit to the present day, and is the author of several follow-up books and exhibitions.

He was also instrumental in securing Ireland's only Geological Monument, the Valentia Tetrapod Trackway in Kerry, through the purchase of the site by the Irish Government.

With a love of quarries, Matthew was always closely associated with the industry. Amongst his many publications, the 'Geological Heritage Guidelines for the Extractive Industry', was a collaboration between the Irish Concrete Federation and Geological Survey Ireland (GSI).

A prolific author of academic and other papers, Matthew's ridiculously long list of offices held, includes:

- Chairman of the Mining Heritage Trust of Ireland;
- Editor of Earth Science Ireland;
- Editorial Board of the Royal Irish Academy's Irish Journal of Earth Sciences;
- Chairman of the Geological Curators' Group;
- Librarian and Expedition Fund Committee member of the Speleological Union of Ireland;
- Irish representative of ProGEO, the European organization for geological conservation;
- Founding member of the Institute of Geologists of Ireland, involved in several working groups, including the Ethics Committee.

Matthew was a long-serving member on the Geological Society's Geoconservation Committee and helped organise the 2018 Annual Gathering in Dublin, bringing speakers from across the island of Ireland. He was also involved with international conferences, most notably 'Natural and Cultural Landscapes - The Geological Foundation', held in Dublin in 2002.

Perhaps Matthew's lasting legacy was going to be the new major GSI-National Museum exhibition in Collins Barracks; he will live on through its realization.

Matthew had fingers in so many pies (and such a huge network of friends and colleagues), it is impossible to cover them all, but those of you who worked with him, or just talked with him, know that he was passionate, prolific, indefatigable, always good humoured and unfailingly generous with his time and assistance; and I feel honoured to have been one of those people. A kind and gentle, gentleman. And he loved cats.

I am sure that you will all join with me in extending our sincerest condolences to Matthew's wife Michelle, and to their families and friends.

Alan Cutler MBE – A tribute to a pioneer in local Geoconservation

Graham Worton, Keeper of Geology, Dudley Museum at the Archives and Coordinator of the Black Country UNESCO Global Geopark

On the 17th May 2020 the Geoconservation community lost one of its great and most respected champions, Alan Cutler. His passion and commitment over more than 40 years has had an enormous impact on the promotion and conservation of geology, especially in the Black Country and in terms of supporting local geological conservation groups nationally.

Alan Cutler (left) with Graham Worton at the Murchison Speech re-enactment in the Dudley Caverns, 2006. Photo by Phil Riley

Born in Stourbridge in 1948, Alan grew up in the heyday of thriving Black Country industry and his pride in the area and desire to conserve its amazing heritage for future generations shone throughout his life. Alan was not, however, formally trained as a geologist, and settled into the local metals industry after studying physics. It was whilst furthering his own education at night classes in geology that he became inspired, in 1975, to establish an amateur local geological society—the Black Country Geological Society (BCGS). From then on his impact on the subject as a passionate advocate and campaigner grew, leading to local and eventually national recognition.

He joined the Geological Curators Group (GCG) and the History of Geology Group of the Geological Society and quickly took an interest in the plight and potential loss of geological sites and museum collections. The BCGS became a means of promoting local geology and attempting to halt its ongoing loss, with early activity including intervening at local museums to 'rescue' and improve local geological collections, campaigning for the protection of local geological sites, and holding public lectures and field excursions to connect local people with their landscape and its heritage.
A pivotal moment for geoconservation in the Black Country came in 1985, when Alan was particularly influential in bringing the Geological Curators Group to Dudley for its AGM. This resulted in the establishment of the post of Keeper of Geology in Dudley Museum in 1987; until that point all local geoconservation was being done by volunteers in their spare time. This appointment led to the creation, over time, of a local geology network of schools, engineers, academics, planners, families and individuals that together have created award winning geological galleries and held nationally renowned geological events and festivals attended by thousands of local families and enthusiasts.

Local and regional geodiversity partnerships flourished in the early 2000s with Alan coordinating meetings and with the support and encouragement of Natural England. These led to a more structured approach to geoconservation with a greater capacity to do good things—and ultimately to develop the landscape-scale geoconservation/promotion work that has now become the Black

Alan pictured at Shire Oak Quarry, one of the many local geosites in the Black Country, with extensive exposures of Triassic Chester Formation overlain by Quaternary glaciofluvial sands and gravels. Photo by Graham Worton

Alan played important roles in many local partnerships, including the successful Black Country UNESCO Global Geopark bid. Photo by Colin Prosser

Country UNESCO Global Geopark, announced in July 2020. A success that would not have been possible without the 1985 GCG meeting and the changes that emerged from it.

Alan was a gentle man with a cheeky smile who had fantastic natural skills in negotiation and persuasion. He was trained in graphic design, conference organisation and exhibition work, so he knew how to present a concept and advocated for geology in many meetings and arenas. In particular, he was doggedly determined to get geology explicitly referred to in planning and nature conservation policy (in the same way that archaeology and biodiversity are).

In addition to advocacy and persuasion, he co-authored, with Colin Reid and Peter Oliver, the Geological Handbook and Field Guide to the Wren's Nest National Nature Reserve (1990) (which has been reprinted and revised and is still used today), co-produced geological leaflets and guidebooks under the banner 'Scorching deserts and icy wastelands', and contributed papers at national and international conferences.

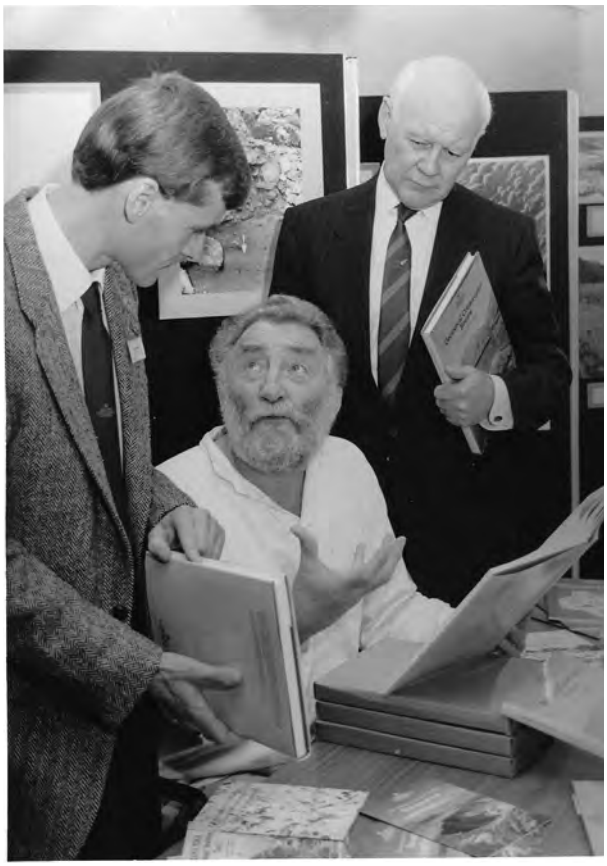
His enthusiasm and reputation led to him chairing various geodiversity and biodiversity fora, being a board member of the Black Country and Birmingham Local Nature Partnership, serving as treasurer to UKRIGs/GeoconservationUK and even to being employed for a while as a geological conservation adviser with Natural England. He was rightfully awarded the MBE in 2017 for his tremendous, and mostly voluntary, contributions to geology and conservation which he typically and modestly described in a local newspaper as "a rather pleasant hobby".

A Tribute to David Quentin Bowen

Stewart Campbell, Natural Resources Wales & **David Bridgland**, Geologists' Association

The leading Quaternary geologist and geomorphologist, David Quentin Bowen, died on October 5th 2020. In addition to a prodigious scientific and research output, David had a longstanding commitment to and involvement with nature conservation, particularly geoconservation. In the 1980s, he started devoting considerable time and energy to the Geological Conservation Review (GCR) programme of geosite selection and publication. Starting with his appointment to the Nature Conservancy Council's (NCC) Advisory Committee for Wales (1986–1991), he provided critical independent quality assurance for Welsh geosites being issued from the Geological Conservation Review Unit (GCRU) in Newbury (and latterly Peterborough). This interest would culminate in his co-authorship of the first volume to be published in the GGR series in 1989—*Quaternary of Wales* (Campbell & Bowen, 1989). David's involvement with this publication was significant; his considerable scientific and political weight helping to garner support for a massive publication programme that might otherwise have faltered in its early days.

With the dissolution of NCC in 1991, three new nature conservation agencies for Great Britain were created: Countryside Council for Wales (CCW), Scottish Natural Heritage (SNH) and English Nature (EN; now Natural England), together with an overseeing and co-ordinating body—the Joint Nature Conservation Committee (JNCC). From the inception of these organisations, David was an important advocate for geoconservation, serving as Vice-Chairman of CCW 1991–2001 and, during the same period, as a member of JNCC's governing Committee. During this time, he had oversight of research programmes and geoconservation initiatives at the highest level, including JNCC's GCR publication programme. Together with the late Sir John Knill he developed a business case to allow completion of the GCR volumes series—at a time when the programme was seriously under threat. Perhaps the greatest expression of David's input was publication of *An Introduction to the Geological Conservation Review* (Ellis *et al*., 1996) of which he was a co-author. This was an important publication both practically (providing an explanation of how the GCR exercise had been undertaken and showing its wider relevance) and politically—providing a much-needed 'statement of intent' and context for the remaining subject volumes of the GCR that would be published.

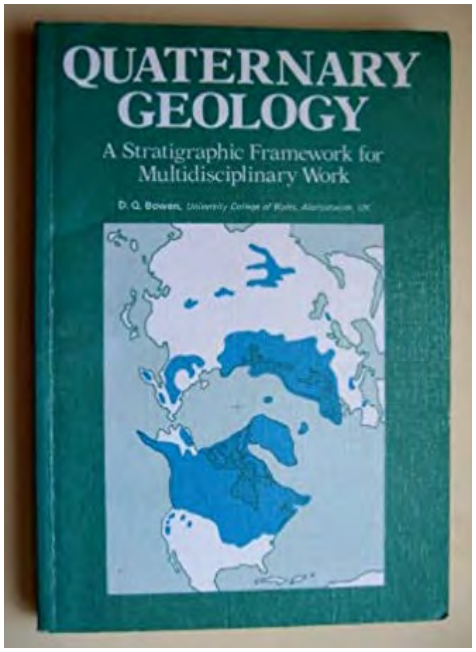


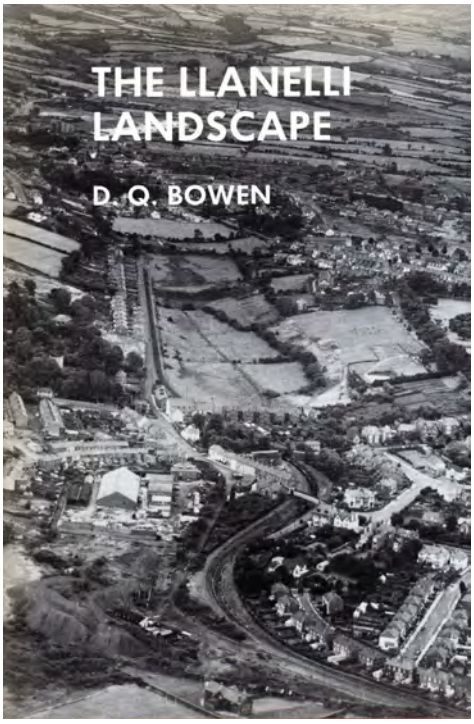
Quaternary of Wales **– the first volume to be published in the GCR series – is launched at Museum of the North in Llanberis on 31.10.1989. Left to right: Stewart Campbell, David Bellamy & David Bowen (photo by Kerry Roberts, courtesy of the Chronicle Group). See *Earth Science Conservation*, 27, 15 (1990).**

In academia more widely, David will be remembered fondly by the very many undergraduate and graduate

students he inspired, mainly at Aberystwyth and Cardiff universities but also, for a few years, at Royal Holloway (University of London). He will also be remembered as the founder and first editor of the journal *Quaternary Science Reviews* and for an outstanding 1978 textbook *Quaternary Geology: A Stratigraphic Framework for Multidisciplinary Work* (Pergamon), still on the shelf of numerous Quaternary scientists. He was President of the Quaternary Research Association (1978–1980) and an honorary life member of the International Union for Quaternary Research (INQUA).

As a passionate Welshman, David's greatest enthusiasm and oratory were inevitably reserved for Wales—its language and cultural legacy, its magnificent glaciated landscape and geological heritage, and its heroic pioneering geologists, such as O.T. Jones, T. Neville George and Eric Brown. It was perhaps in this context that David championed the cause for the first turlough discovered in Wales (Pant-y-Llyn in Carmarthenshire) to be registered and documented as a GCR site and then notified and protected as an SSSI (Campbell *et al.*, 1992), notwithstanding the many difficulties involved. He was the Chairman of the Llanelli Millennial Coastal Park (1996–2001) and published *The Llanelli Landscape -The Geology and Geomorphology of the Country Around Llanelli*, in celebration of the town of his birth (on St Valentine's Day in 1938) in which he spent his youth. David's legacy to geoconservation is assured.





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William Sawney Bisat (1886-1973) – the goniatite man

Nigel Price, student, the online Postgraduate Diploma in 'The Geology of Northern England', University of York.

William Sawney Bisat was born in 1886 in Doncaster. Schooled at Doncaster Grammar, he was good at Science and English winning school prizes and sporting colours. He left to start work at sixteen—his father having died the year previously and the family needed his income (Stubblefield, 1974). After a brief period in the family business of bookselling and printing he joined Harold Arnold and Sons, a large, successful Doncaster based civil engineering contractor. He continued his studies at Doncaster Technical College and progressed quickly to be junior site engineer for the construction of Leighton Reservoir near Masham (Baldwin, 2004).

He had become interested in geology through joining the Yorkshire Naturalists' Union and working with two amateur geologists—George Grace and Henry Culpin, active collectors of Coal Measures fossils. At the age of 20 he read his first paper to the Doncaster Scientific Society on fossils of the Magnesian Limestone.

W. S. Bisat circa 1950. (Baldwin, 2004, p.373, fig. 1.). Reproduced with the permission of the Geologists' Association.

Early Days

At Leighton, a huge trench was dug for the cut-off wall—a deep barrier underneath the dam to prevent groundwater getting into the excavations. This passed straight through what Bisat was to call the Colsterdale Marine Beds and he spent his spare time collecting specimens here, along the seven-mile supply railway that he was responsible for surveying and constructing and in the stone supply quarries, including Clints Quarry. Here he worked with Wheelton Hind, an amateur expert on Carboniferous goniatites and bivalves, and with Hind's help produced his first work on the Carboniferous (Bisat, 1913). He identified two marine bands and used these to divide the lithological sequence of the area. His expertise was already becoming apparent with the precise identification of many species.

His Seminal Work

Hind died in 1920 and Bisat, as his literary executor, was passed his papers. Bisat had become more competent and more meticulous than Hind and corrected a major error of Hind's through identifying that the goniatite *Eumorphoceras pseudobilungue* from the Pendle

Clints Quarry, Leighton Reservoir. Massive coarse-grained Lower Brimham Grit (Kinderscoutian, R1). British Geological Survey, National archive of geological photographs P005511. Reproduced with the permission of the British Geological Survey ©UKRI 2020 All rights reserved.

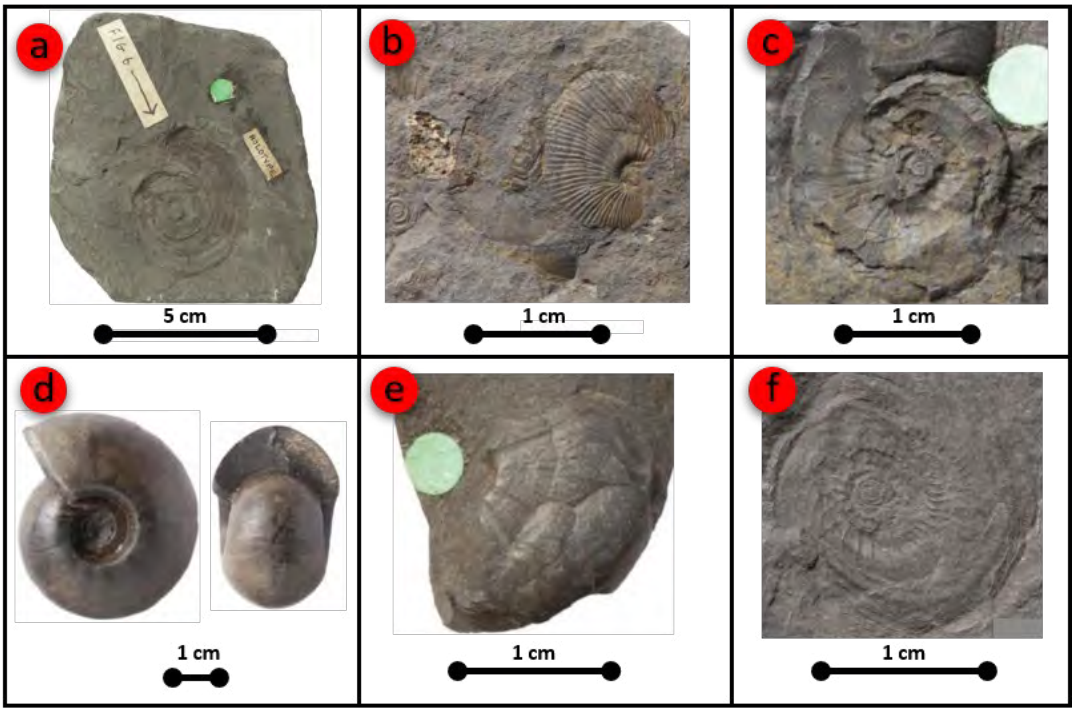
Grit was not the same as *Reticuloceras bilingue* in the Yoredale Series 3,000 feet further up the succession (Baldwin, 2004).

Bisat continued to develop goniatite faunal zones and produced his definitive paper on the Carboniferous goniatites of northern England (Bisat, 1924). He made this contribution with the insight that there had been a prior tendency to place under one species, groups from different horizons with some but not all matching characteristics. He identified these as different species, whilst accepting variety within the same horizon as intra-species variation. Bisat was able to distinguish the evolutionary development of species using the key features of shell shape, suture pattern and mouth outline by noting that although each of these features changed through the lifetime of a particular species, the evolutionary stage of a particular feature was independent of the other two in the adult stage.

This was no small feat considering the crushed nature of most of the specimens and the variation in morphology within one species' own growth stages. Bisat named 26 zones and six lithological divisions and 'transformed' the Carboniferous through adding stratigraphic precision—causing the redrawing of maps of Carboniferous Europe (Ramsbottom and Saunders, 1985).

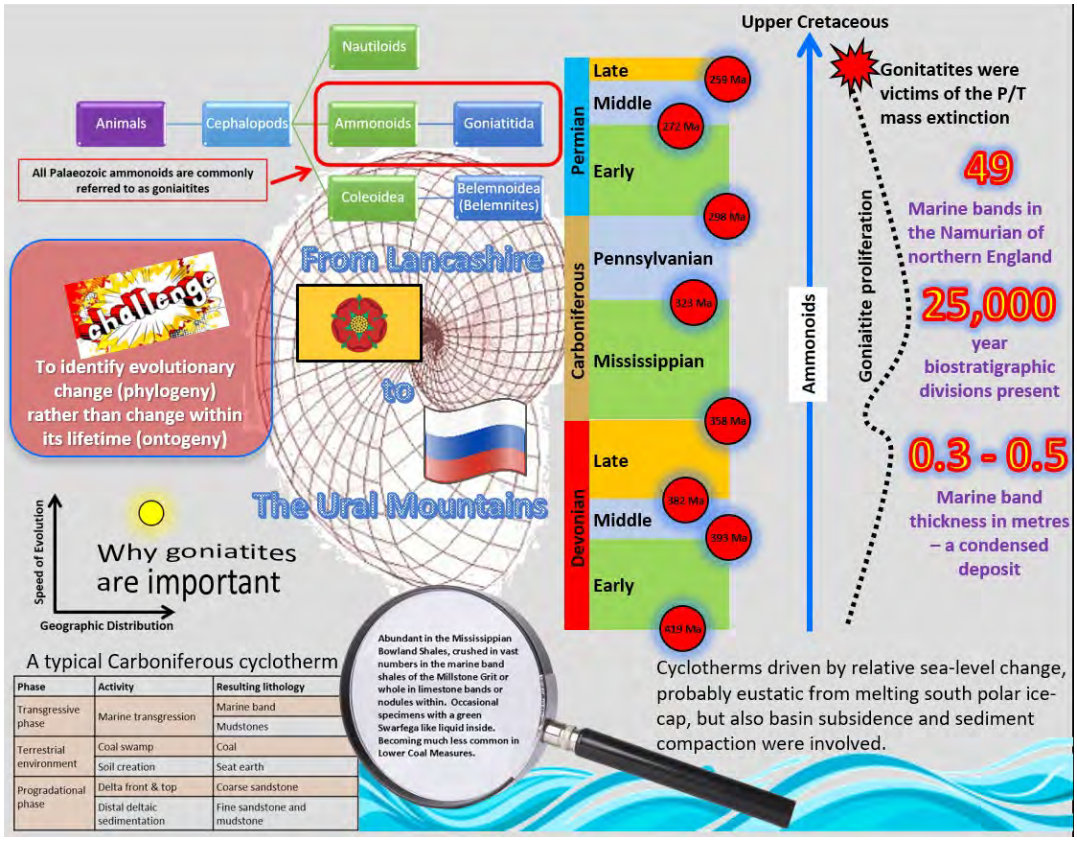
In 1926 Bisat was invited by Schmidt (working on the Carboniferous goniatites of Germany) to view key locations in Westphalia and in the following year presented a paper at the first international conference on Carboniferous stratigraphy covering both his British zones and their European counterparts (Stubblefield, 1974). He regrouped the stratigraphic divisions into nine 'genus zones' effectively introducing stage naming for a large part of the Carboniferous, using local names such as 'Kinderscoutian, R1' (Baldwin, 2004). Bisat extended his work into the English and Welsh Coal Measures and abroad, finding correlations with fossils in Westphalia and Missouri (Stubblefield, 1974).

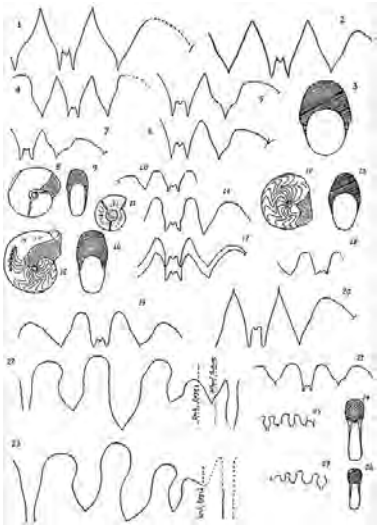
Bisat refined his zonal scheme over the next 30 years, producing some 22 papers on the Carboniferous. By way of example, his Lower Reticuloceras (R1) age strata which had three zones in 1928 was extended by 1943 to six zones, Bisat having recognized eighteen species of which

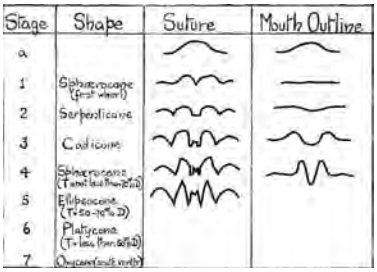


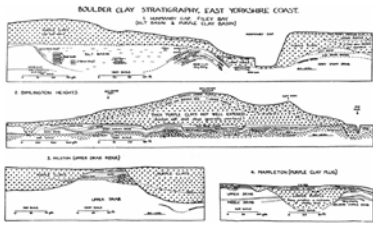
Top: **Typical goniatites of the Namurian; a. *Reticuloceras reticulatum*, Millstone Grit Group, b. *Cravenoceras nititoides*, Millstone Grit Group, c. *Reticuloceras todmordense*, Millstone Grit Group, d. *Cravenoceras leion*, Pendelian, e. *Reticuloceras dubium*, Millstone Grit Group, f. *Eumophoceras pseudobilingue*, Yeadonian, Bowland Shale Formation. (JISC GB3D Type Fossils, 2019). Online project partners, Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.**

Bottom: **Infographic of the goniatite and its environment. Image by Nigel Price.**









***Left*: An example of Bisat's work demonstrating his identification skills and methodological approach. These are his drawings of structural elements of goniatites from the Beyrichoceras Zone of the Visean. He obtained examples from over ten national sources and has identified sixteen species in what was the period of greatest goniatite evolutionary activity (Bisat, 1934, Fig. 1–27). By permission of the Council of the Yorkshire Geological Society.**
***Top right*: Development stages of the family Glyphioceratidæ. Reproduced from Bisat, 1924, p.68, by permission of the Council of the Yorkshire Geological Society.**
***Bottom right*: Sections from Bisat's work on the Pleistocene. (Reproduced from Bisat, 1939. Plate 17 after p.149). By permission of the Council of the Yorkshire Geological Society.**

thirteen were new. He was always keen to advance others' knowledge and he used more than a dozen friends to collect on his behalf.

In the 1920s the Geological Survey were mapping the Lancashire and Yorkshire coalfields. Although the Survey officers were competent surveyors, they just did not have Bisat's ability to identify goniatites, so the amateur was called upon to help (Baldwin, 2004). Whenever Bisat travelled from York or Manchester Stations, he would phone the local Survey office and they would rush down to the waiting room with the latest specimens for him to identify (Stubblefield, 1974).

The Pleistocene

Bisat remained at Arnold's for all his working life, finishing as chief engineer and company director. Work took Bisat to Hull and there he took on a secondary interest in the Pleistocene of East Yorkshire, mapping 35 miles of coastline, drawing the sections on rolls of graph paper. He appreciated the need for standardisation of colour descriptions and adopted that of the West Riding wool trade. Through this work he improved the classification of these Pleistocene deposits and his efforts were key to determining certain strata as pre-Ipswichian rather than Devensian (Bisat, 1939).

Recognition

Bisat received honorary degrees from Leeds and Durham and many prestigious awards including the Murchison award and the Lyell Medal and he was elected a Fellow of the Royal Society. Unassuming, he created his own award to be presented by the Yorkshire Geological Society and called it The Phillips Medal, which is now their most prestigious award. To mark the 175th anniversary of the Yorkshire Geological Society, they established the W S Bisat Medal, to recognise outstanding contributions to any field of applied geology.

Goniatites' importance and where to see them today

The infographic provides some clues and background to the importance of goniatites. W S Bisat donated his collection of 893 goniatites to the British Geological Survey and they are catalogued in the BGS PalaeoSaurus Online Collections Database. Specimens are also held in the British Museum of Natural History. However, anyone living over Carboniferous rocks can go and find them. Two sites of international importance are SSSIs—Park Clough near Marsden in West Yorkshire has the type section of the Marsdenian and the *Reticuloceras gracile* marine band with abundant goniatites and bivalves, whilst Stonehead Beck in Gill Beck SSSI in Cowling, Lancashire is the type location

for the boundary of the Chokerian with seven marine bands in a 40 m shale sequence. Additionally, Crimsworth Dean SSSI near Hebden Bridge has several marine bands and is the proposed type section for the upper part of the R1 Stage (highest Kinderscoutian). A classic locality is Ratten Clough in the Cliviger Valley just north of Todmorden with good exposure of the *Cancelloceras cancellatum* marine band and the *Gastricoeras subcrenatum* marine band at the top of the Namurian.

Conclusions

W. S. Bisat took the unpromising family of goniatites within the Ammonoid order, studied their form and development to an extent where they became an invaluable tool in determining the chronostratigraphy of much of the Carboniferous, in strata that posed challenging lithostratigraphic correlation. Bisat caused the geological maps of the Carboniferous throughout Europe to be redrawn in the 1930s and when in 1939 the Director of the Geological Survey of Great Britain was asked who had done most for the Geological Survey since the war he simply answered, “Mr Bisat” (Baldwin, 2004).

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William Macfadyen and 70 years of geoconservation

Colin Prosser, Natural England

Just over 70 years ago, on 3rd July 1950, and at the age of 57, William Macfadyen, or 'Mac' to his colleagues, decided to take on a new challenge. After an extremely eventful life involving being badly injured by machine-gun fire and winning a Military Cross in WW1, re-enlisting and serving his country again in North Africa and Italy in WW2, and spending most of the rest of his life employed as a petroleum geologist and hydrologist in the Middle East and North Africa, he joined the newly formed Nature Conservancy (NC) and played a major role in shaping nature conservation in Great Britain.

Having completed a degree in chemistry when invalided out of WW1, he then studied geology as a prelude to many years working in hostile environments in Egypt and what are now Somalia and Iraq. He therefore brought a great deal of experience and expertise to the role of the Nature Conservancy's first Chief Geologist, qualities that were extremely useful in turning the recently enacted National Parks and Access to the Countryside Act (1949) into practical delivery on the ground.

Down to business

Mac was extremely methodical and thorough in his approach and soon threw himself into what would be a ten-year career in geoconservation. Given his age and the relatively late stage of his career, his work rate was impressive. Travelling by car and working alone he covered the length and breadth of Britain. By the end of 1951 he had visited 301 sites, including 37 in Scotland, and by the end of 1955, five and a half years into his time with the NC, he reported that he had inspected 558 sites, 345 in England, 69 in Wales and 144 in Scotland, and that they were all notified or in the process of being notified as SSSIs. Visiting and assessing these sites involved much more than just driving around the country. He needed site-based records and data and started a card-index system. He had a card for each site, on which he gave a description of the site, including its exact location, listed key references and provided details of the date of his inspections, land ownership and usage and general condition. He also photographed each site he visited and indexed the photographs accordingly.

Mac's pioneering work set the framework for geological conservation and undoubtedly influenced how scientific and conservation evidence was collected and managed to support SSSI notification, safeguard and management. As part of his 'journey' into nature conservation he recognised many things which still ring true today. For example, that:

- sound science, accurate site documentation, record keeping and first-hand knowledge of a site was essential to inform SSSI notification and safeguard;
- notifying SSSIs soon led to site management casework and that dealing with this reduced the time available to continue his notification programme;
- he could not be an expert on everything, leading to him establishing an external geological advisory committee to support his work;
- things always take longer than you expect: he planned to publish books describing all geological SSSIs across GB before he retired, but only ever finished and published the book for South

***Top*: William Macfadyen shortly before joining the Nature Conservancy © Natural England**

***Bottom*: William Macfadyen at Swanscombe Skull Site NNR in 1959 © Natural England**

Further Reading

Prosser, C.D. 2012. William Archibald Macfadyen (1893-1985): the father of geoconservation? *Proceedings of the Geologists' Association*, 123, 182–188

Prosser, C. 2019. Pioneering geoconservation work archived. *Earth Heritage*, 52, p4

West England, Geological Highlights of the West Country, which took him until 1970 (10 years after he retired and at the age of 77); and

- geology and wildlife are intrinsically linked—he was regularly asked to apply his geological expertise to wider issues relating to wildlife conservation, especially on NNRs.

His legacy

Mac retired in 1960 and relinquished his role to George Black who filled it until 1985. Mac undoubtedly set very high standards and left a major legacy to nature conservation. Almost single-handedly he notified well over 600 SSSIs across England, Scotland and Wales (most of which are still SSSIs today) and he was involved in the declaration of at least 3 geological NNRs. Importantly, he left an archive of detailed records and photographs of the SSSIs he visited in the 1950s, which the government conservation agencies still use today in assessing change and responding to planning applications and reports of damage etc. He also demonstrated the benefits of working with external specialists and of putting the science that underpins the SSSI series into the public domain. These ways of working are still used today, for example relevant specialist geoscientists are still consulted to inform decision making and evidence is placed into the public domain through publication of the Geological Conservation Review, the site-based scientific description and interpretation that underpins all geological and geomorphological SSSIs today.

Mac died in 1985, but his work, started 70 years ago, still influences and supports the conservation and management of SSSIs today. He was the first professional geological conservationist anywhere in the World and as such is an important part of Britain's conservation history.

The island of Ailsa Craig (image © British Geological Survey), 16 km off the Ayrshire coast, is largely comprised of an unusual and distinctive microgranite which is used to make world-renowned curling stones (inset image © Dr Graeme Adam). Ailsa Craig is a Geological Conservation Review (GCR) site, the scientific description for which was published on-line in the PGA during the lockdown (see article on page 41 for more details).

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