Newsletter No. 293
October 2025

Contents:

To find out more - read on!

Copy date for the next Newsletter is Monday 1 December

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For enquiries about field and geoconservation meetings please contact the Field Secretary.
Please notify Andy Harrison in advance if you will be attending these events.
To submit items for the Newsletter please contact the Newsletter Editor.
For all other business and enquiries please contact the Honorary Secretary.
For more information see our website: bcgs.info, YouTube, and Facebook.

Future Programme

Indoor meetings are now held in the Lamp Tavern, 116 High St, Dudley, DY1 1QT
7.30 for 8.00 o'clock start unless stated otherwise.
Visitors are welcome to attend BCGS events but there will be a charge of £1.00.

Sunday 19 October *(Field Meeting):* 50th Anniversary Part 2: Permo-Triassic and the Ice Age in the Black Country. Led by Graham Worton and Andy Harrison. Meet on Darby's Hill Road at 9.45 for a 10.00 start. Park opposite Oakham Primary School in the lay-by on the Birmingham side of the hill (GR SO966892, postcode B69 1SQ). We start at Darby's Hill viewpoint. Then we move down to St Brades Close and the Blue Rock Quarry / Portway Hill site. From there we take in a site new to most people (Barnford Hill park) and the Pudding Rock. Then we head over to Wordsley Ridge / Brierley Hill Road to look at the red sandstone and pebble bed exposures there. Finish in Old Wharf Lane Stourbridge, where we can see a huge new exposure in the red sandstones and the terrace of the River Stour. Bring a packed lunch, wear walking shoes and appropriate outdoor clothing.

Monday 20 October *(Indoor Meeting):* 'What Lies Beneath? Discoveries from Deep-Sea Drilling at Santorini Volcano (IODP Expedition 398).' Speaker: Ralf Gertisser, Volcanologist / Igneous Petrologist, Keele University. Since the 1960s, much of our understanding of the Earth's ocean floor has come from systematic scientific ocean drilling, carried out through long-standing international initiatives - most recently the International Ocean Discovery Program (IODP) - using iconic research vessels such as the *Glomar Challenger* and, more recently, the *JOIDES Resolution*. This presentation will focus on IODP Expedition 398, offering an inside look at the shipboard scientific operations aboard the *JOIDES Resolution* and sharing key findings that shed new light on the fiery geological history of Santorini and its neighbouring volcanoes. *(For more biographical details and the full talk abstract, see the Programme of Events on the website.)*

Monday 17 November *(Indoor Meeting):* 'Medicine and Geology - an Exploration'. Speaker: Albert Benghiat. Albert trained in medicine at Trinity College Cambridge and the Middlesex Hospital London. After a series of junior doctor training posts around the country he became Consultant Oncologist at Derby and subsequently Leicester. In retirement he studied geology at Leicester University and for a time was Associate Lecturer in Geology at the University of Derby until his recent move to Shropshire. This talk will recount the historical contribution of medical practitioners to the science of geology and go on to explore methodological similarities between the practice of medicine and geology.

Monday 15 December *(Indoor Meeting, 7.00 for 7.30 start):* Members' Evening and Christmas Social. This is our annual chance for members to share their geological experiences in a sociable atmosphere with a Christmas buffet provided by the Society. **Please contact Mark: honsec@bcgs.info if you can offer a short talk for this event.** Bring along any interesting geological specimens you would like to show us, or which you would like to be identified – there may be someone in our midst who can help!

Other Societies and Events

Warwickshire Geological Conservation Group

Thursday 20 November: 'Geothermal Energy'. Speaker: Chris Rochelle.

The meeting is at 7.30 in St Francis of Assisi RC Church, 110 Warwick Rd, Kenilworth, CV8 1HL.
For more information and booking visit: https://www.wgcg.co.uk/

Mid Wales Geology Club

Wednesday 15 October: 'The evolution of eyes and opsins - Pushing origins back in time'. Speaker: Tony Thorp.

Further information: Web: http://midwalesgeology.org.uk Lectures start at 7.15 and are a hybrid of in person meetings at Plas Dolerw, Newtown, SY16 2EH and via Zoom. Those wishing to join a meeting remotely should contact the secretary, Chris Simpson, at christopher_s@btinternet.com

North Staffordshire Group of the Geologists' Association

Thursday 16 October: 'Geohazards in the Peak District'. Speaker: Dr Vanessa Banks (BGS).

Talks start at 7.30 in WS0.06, Keele University. For more information: https://nsgga.org/

Woolhope Naturalists' Field Club - Geology Section

Friday 24 October: 'How geology influenced the railways of Herefordshire'. Speaker: John Lonergan.

Friday 14 November: 'Ongoing work after the publication of the Knighton Geological Sheet'. Speaker: Dr Arthur Tingley.

Meetings are in Hereford Town Hall, from 6.00 to 8.00. Non-members are welcome and pay £2. More info. at: https://www.woolhopeclub.org.uk/meetings

Geologists' Association Festival of Geology Saturday 1 and Sunday 2 November

Saturday 1 November, 10.30 - 4.30: Burlington House, London W1J 0BG. Talks throughout the day: 'Secret Lives of Dinosaurs', 'Early Evolution of Animal Life', 'How to build a Jurassic Coast';
Exhibits by societies, universities and museums; Rockwatch activities for the younger generation.

Sunday 2 November: Field Trips around London: The Natural History Museum's Evolution Garden; Trent Park; Canary Wharf. More details here: https://geologistsassociation.org.uk/festival/

Teme Valley Geological Society

Monday 27 October: 'Wilfred Thesiger's rock collection from Oman'. Thesiger's boyhood home was in the Teme valley near Knighton. Speaker: Dr. Alan Heward.

Monday 24 November: 'The Amber Spiderglass'. Speaker: Dr. Rachel Kruft Welton.

Talks take place in Martley Memorial Hall at 7.30. Non-members £3. For further information email: enquire@geo-village.org or visit: https://geo-village.org/

East Midlands Geological Society

Saturday 18 October: 'A tale of two Dorset field trips - vertebrate palaeontology and landslides'. Speaker: Dr Judith Nathanail.

Saturday 8 November: 'Geoscience for a sustainable future. Challenges and opportunities'. Speaker: Dr Karen Hanghøj.

Lectures are from 6.00 to 7.00, and are normally held in the School of Geography Sir Clive Granger Building on the Nottingham University Park campus. Non-members are welcome at all of our lectures and attendance is free of charge. Further info: www.emgs.org.uk

Manchester Geological Association

Saturday 18 October at 12.00: Broadhurst Lectures. This year there will be four talks:

Brian Jeffery on 'The Geology of Marple through the eyes of Samuel Oldknow and Nathaniel Wright'
Prof. Jonathan Mound on 'Space Weather and Forecasting Space Climate'
Dr Stuart Clarke on 'The Evolution of the Carboniferous Succession of Northern England'
Dr Graham Leslie on 'New insights into partitioned strain within the Carboniferous strata and Whin Sill of the Alston Block, northern England'.

Saturday 15 November starting at 1.00: It is planned to have three lectures on this day. Professor Hillary Kennedy (Bangor) will talk about coastal ecosystems and their role in climate change mitigation. 2 other speakers.

The Venue is The Department of Earth and Environmental Sciences at The University of Manchester, located in the Williamson Building, 176 Oxford Road, Manchester – opposite The Manchester Museum. Please contact us at info@manchestergeology.org.uk to book on to these events.

Shropshire Geological Society

Wednesday 12 November: 'The Stoer Group Stromatolites of NW Scotland'. Speaker: Dr Peter Gutteridge (University of Manchester).

Wednesday 10 December: 'The Castle Bank Fauna near Llandrindod Wells'. Speaker: Joe Botting (Amgueddfa Cymru – National Museum Wales).

Meetings commence at 7.00 for 7.15. Lectures are now being held in hybrid form, in person at the Higher Education Centre, Shrewsbury College, as well as by Zoom. If you wish to attend please contact Albert Benghiat: 07710 421 581, email: SGS.chair@hotmail.com
Further information: https://shropshiregeology.org.uk/

Editorial

A big thank you as usual to our regular contributors: Andy gives us a comprehensive report of our April field visit to see the Arden sandstone in Warwickshire, Mike Williams brings us two geological postcards from his holiday adventures around the fringe of the British Isles, and Mike Allen treats us to a very accessible lesson on the meaty subject of crystallisation.

Some of you may be aware that there has been some BCGS activity connected with the National Trust property of Wightwick Manor in Wolverhampton. This has revolved around a restoration initiative from the Wightwick Manor garden team to revitalise the superb collection of glacial erratic boulders on display in the orchard there. So far, this has resulted in some illuminating historical research and a session spent with pressure washers to give the boulders a much needed face lift, all under the watchful eye of the Head Gardener and the Collections Inventory Officer at the Manor. This work ►

has been in progress intermittently for several months, and in this issue, I am pleased to be able to bring you the story so far.

We look forward to two more guest speakers before Christmas, and our Christmas Social on the 15 December – and remember**, please contact Mark: honsec@bcgs.info if you can offer a short talk for this event.**

Finally - **don't miss the next event on our calendar!** This is the second part of our special 50th anniversary pair of field trips, in which Andy and Graham have recreated, as far as possible, the Society's first two field trips in 1975. This time join us on a roller-coaster ride from the Permo-Triassic to the Ice Age. ■

Julie Schroder

Field Meeting Report

Saturday 5 April: BCGS Field Visit to Rowington & Henley in Arden, Warwickshire – Looking at the Arden Sandstone. Led by Stuart Burley.

Members may remember that Stuart Burley gave a talk to the Society in January 2023, entitled *'A very British summer in the late Triassic: the Arden Sandstone Formation of the English West Midlands and the dawn of the dinosaurs'.* A former lecturer at Keele University, Stuart is the current chair of the Warwickshire Geological Conservation Group (WCGC). We had a good turnout from BCGS and WCGC members for this event, and met Stuart at the St Laurence Church car park in the village of Rowington for a 10.30 start. Throughout the day, conditions were cool and clear with some patchy clouds and a strengthening wind.

St Laurence Church, Rowington

After a health and safety briefing, Stuart explained what the day would involve. Firstly, there would be a short walk south out of Rowington to the Grand Union Canal. Here we would look at two outcrops as an introduction to Arden Sandstone. Walking back to the village, we would stop at St Laurence church for refreshments, and have an introduction to the Reverend Peter Brodie and his work on this stratum. This would be followed by a short drive south-west, along the Old Warwick Road (B4439) to the village of Shrewley and a cutting on the Grand Union Canal that represents the British Geological Survey (BGS) type location for the Arden Sandstone. We would then have lunch at the Fleur de Lys pub, in Lowsonford, before heading to Henley-in-Arden to visit St Nicholas Church and the site of the Beaudesert (motte and bailey) Castle Mount in the afternoon.

Mercia Mudstone Group Stratigraphy

Formerly known as the Keuper Marl, the Mercia Mudstone Group is around 400m thick and covers the late Triassic from the end of the Norian (210Ma) back to the Ladinian (240Ma). The stratum is sandwiched between the Lower Triassic Sherwood Sandstone Group at its base, and the late Triassic ►

(Rhaetian Stage) Blue Anchor Formation/Penarth Group above. The BGS describes the Mercia Mudstone Group as 'red, less commonly green-grey, mudstones and subordinate siltstones with thick halite-bearing units in some basinal areas'.

The Mercia Mudstone sequence stratigraphy is split into the Sidmouth Mudstone at its base, the Arden Sandstone in the middle, and the Branscombe Mudstone in its upper parts. The mudstone units are named after the villages in Devon where they were first identified, i.e. Sidmouth and Branscombe. In England, this stratum stretches from the Wessex Basin up through the Midlands and into the Cheshire/Staffordshire Basins. It is a truly global stratum and extends beyond the UK to China, S. America, India and Spain.

Base of the Arden Sandstone, near Rowington Hill Bridge on the Grand Union Canal

The Arden Sandstone sits centrally within the Mercia Mudstone Group and gets its name from the Forest of Arden, Warwickshire. It occurs as a discontinuous layer, reaching up to 10m thickness, interspersed with large pockets of the evaporate minerals, halite or gypsum. Typically comprising greenish-grey and purple mudstone and siltstone and greenish-grey rippled sandstone with thin and localized pebble beds, this stratum dates to the Carnian Stage (approximately 227Ma to 237Ma). Its deposition occurred during a major change in global climate, known as the Carnian Pluvial Episode (CPE), from around 234Ma, which lasted roughly 2 million years.

Rowington Hill Bridge, Grand Union Canal Cutting

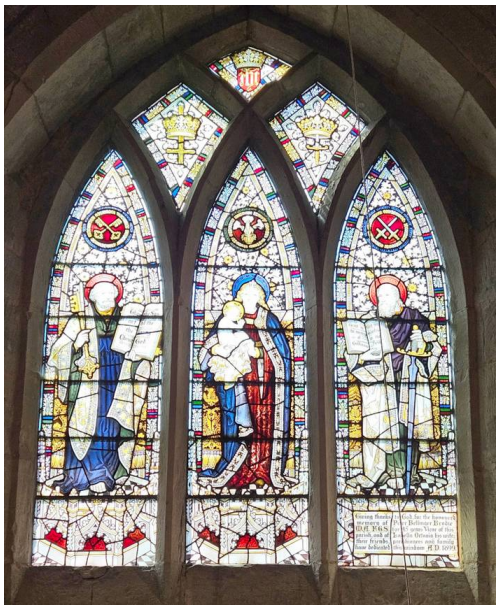
Our first stop, below Rowington Hill Bridge on the Grand Union Canal, provided two outcrops of the Arden Sandstone on the canal's north and south side. The southern outcrop, high up on the canal side, represents the base of the Arden Sandstone *(see photo above and on front cover).* Between the outcrop and the towpath, Stuart assured us that there was around 3m of red Sidmouth Mudstone. Now overgrown with vegetation, Stuart and WCGC members had cleared some vegetation away in 2022.

In the first outcrop, the overlying Arden Sandstone appears very different from the lower red-brown Mercia Mudstone. Greenish-grey in colour and coarse-grained it contains broken (brecciated) fragments and ripples with an east to west orientation and is dolomitic in places.

The second outcrop *(see photo, right)* on the canal's north side, represents sandstone beds sitting above those on the south side. These beds comprise greenish-grey coarse and thickly-bedded layers, around 1m thick, showing cross-bedding. Their nature has been interpreted as resulting from deposition during an episodic high energy event lasting no more than a day. ►

Cross-bedded sandstone, nr. Rowington Hill Bridge

St Laurence Church and Reverend Peter Brodie



The commemorative window for Rev. Peter Brodie, in St Laurence Church, Rowington

Returning to Rowington, we headed to St Laurence Church for tea and coffee. Here, Stuart introduced us to the Rev. Peter Brodie (1815-1897), who is remembered in a stained glass window on the church's south side, with the following inscription:

"Giving thanks to God for the honoured memory of Peter Bellinger Brodie M.A. F.G.S for 45 years Vicar of the parish and of Isabella Octavia his wife; their friends, parishioners and family have dedicated this window A.D. 1899."

Not only was Rev. Brodie vicar of St Laurence Church, he was also a passionate geologist and fossil collector who studied at Cambridge (from 1834) under Professor Adam Sedgwick. He wrote several papers on the Arden Sandstone and others on Trias/Lias fossil insects. He reportedly collected over 25,000 fossils, including fish and reptile remains from the Arden Sandstone outcrops at the Shrewley canal cutting, which he logged in the 1860s to 1870s. His work on the Arden Sandstone revealed an explosion of life and recorded evidence of clam shrimps, sharks, fish and reptiles, including Rhynchosaur footprints.

Shrewley Canal Cutting

Our second stop of the morning was at the Shrewley canal tunnel and cutting on the Grand Union Canal, immediately south-west of Shrewley village. The cutting is roughly 150m long and at its eastern end enters a 370m long tunnel, which is wide enough for one boat at a time. Historically, leggers were employed to propel boats through the tunnel as it was too narrow to include a towpath. Built around the late 1790s and over 130 miles long, the Grand Union Canal connects London with Birmingham and operated for only a few decades before the London to Birmingham railway arrived in 1846. Today, looked after by the Canals and Rivers Trust, and representing the type location for the Arden Sandstone, the cutting is one of six SSSIs in Warwickshire, specifically dedicated to geology.

The transition from the red-brown Sidmouth Mudstone into the greenish-grey Arden Sandstone in the Shrewley Cutting

The outcrop shows nicely the transition from the red-brown Sidmouth Mudstone into the greenish-grey Arden Sandstone. A fine gritty conglomerate at the contact transitions into a green sandy mudstone, equivalent to what we saw at Rowington, with rippled and cross-bedded sandstone layers above that. These also exhibit polygonal desiccation cracks. Rev. Brodie's logs contain very accurate descriptions for the Arden Sandstone at this location and clearly show where he found many of his fossil specimens, and ripple marks. ►

Henley in Arden Mount

After lunch, we headed to Henley-in-Arden. Parking next to St Nicholas Church, Stuart pointed out how, like St Laurence Church, its construction is from Arden Sandstone, the upper sandstone beds of which were worked for building stone. Oddly enough, very few buildings in Henley-in-Arden are built from the Arden Sandstone and are instead constructed from brick. A clue as to why may come from St Phillips Cathedral in Birmingham, which originally was constructed from Arden Sandstone. Unfortunately due to pollution, the stone has had to be replaced over time because it does not weather well.

From the church, we headed west up the grassy slopes of the Mount and the historical site of the Beaudesert (motte and bailey) Castle. Originally dating to around 1046, the castle would have had great views over the Warwickshire countryside. It is likely that the former castle was also built from the Arden Sandstone. However, nothing remains today and mystery surrounds what happened to the castle and the stone used to build it. All that remains today are the earthworks that surrounded it. As a sort after building material, it is likely that the sandstone was taken and used in local churches and important houses in the local area.

St Nicholas Church, Henley-in-Arden

From the Castle Mount, we admired the western view. The low-lying landscape before us rises to a roughly north to south trending ridge known as the 'Great Divide'. This forms a continuation of Central England's watershed as it leaves the Midlands, with rivers to the east draining towards the River Trent and the North Sea and those to the west into the Rivers Avon and Severn and out to the Bristol Channel. Glacial and glaciofluvial activity sculpted the landscape during the Pleistocene and since. Glacial outwash channels cut through the 'Great Divide' in several places and one occurs near to Rowington.

View west from the Beaudesert Castle Mount, Henley-in-Arden

Palaeoenvironment and Palaeogeography

The most striking difference between the Mercia Mudstone and Arden Sandstone is the colour difference which is simply down to the oxidation state of the iron they contain. Exposure to oxygen within an oxidising semi-arid environment gives the Mercia Mudstone its red colouration. However, more reducing conditions, within a low oxygen environment are what give the Arden Sandstone its greenish-grey colour. ►

Grand Union Canal Cutting, Shrewley

Today, such conditions can be found in North Africa where semi-arid environments occur with lakes and seasonal rivers draining relatively higher ground. Red sediments form around the lake shores where they are exposed to oxygen. However, below the waterline where oxygen-deprived, reducing conditions occur, dark mud, rich in organic matter accumulates. The organic matter comes from algal mats, plant and other dead fauna deposited within the lake. Rivers and streams wash in sandier and coarser sediments and large sediment dumps from flash floods occur periodically. Its greenish-grey colouration, laminated muddy layers, cross-bedding, rippled sandy layers, fossil fauna and the presence of halite and desiccation cracks indicate that the Arden Sandstone formed under similar conditions. The lakes were discontinuous within a semi-arid landscape and subject to expansion and contraction as they periodically dried out and refilled. Halite indicates that the lake water had a variable salinity and as the lakes contracted, during drier spells, evaporite deposits formed on the lake shores. From the Rev. Brodie's work, we know that the lakes teamed with life and included fish, sharks and clam shrimps. Amphibians and reptiles, such as Rhynchosaurs and other tetrapods, have also left their mark as remains and footprints on the lake shore where they once walked.

More information about the work of the WCGC at Shrewley and the Arden Sandstone can be found in their 2023 Spring newsletter available on their website: www.wgcg.co.uk/about-wgcg.

Stuart has also written an article with Jon Radley from Warwick Museum in 'Earth Heritage' magazine. This was the basis of this field event and it is entitled:

• Stuart Burley and Jon Radley, 'Geoconservation partnerships enable restoration of Arden Sandstone outcrops in the English Midlands', Earth Heritage 57, Summer 2022: https://www.earthheritage.org.uk/downloads/

I would like to thank Stuart for a very enlightening and enjoyable day exploring the Late Triassic and look forward to our next outing with the WGCG. ■

Andy Harrison

From Orkney to New York in search of Dinichthys - the giant of its day

The Orkney Islands have long been famous for strata of Middle Old Red Sandstone age containing an abundant fauna of fossil fish. Many specimens of this fauna are to be found on display at the Fossil and Heritage Centre located on the island of Burray some 10 miles to the south of Kirkwall, the capital of the archipelago, and connected by a series of bridges to Orkney's Mainland. ►

The Orkney Fossil and Heritage Centre, Isle of Burray, Orkney

Thanks to these displays, plus interpretive scenes at the museum, an insight can be gained into a period when vertebrates in the form of fish appear in increasing numbers, leading in Devonian times to a truly great explosion in evolutionary development at a critical period in the history of vertebrate life. There is a fascination with the number of large fish which quickly appear in the fossil record and in particular **Dinichthys**, the apex predator and giant of its day.

Head of Dinichthys on display at AMNH, New York

Thanks to the possession, for some 50 years, of Edwin H. Colbert's seminal work 'Evolution of The Vertebrates', plus a personal visit several years ago to the American Museum of Natural History in New York, a more detailed picture of this animal emerges. **Dinichthys** is found in the Upper Devonian (Famennian) Cleveland Shale formation, today considered a Konservatte Lagerstatten containing completely preserved body fossils. Dinichthys and the closely related **Dunkleosteus** and **Eastmanosteus** are thought to have reached lengths in excess of 30 feet. These enormous fish with huge skulls and strong jaws equipped with cutting plate teeth, predated on other fish and cephalopods.

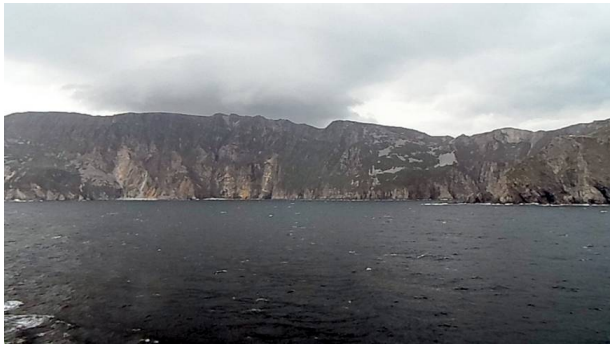
Belonging to the class Placodermi (or Gnasthostomes), they are distinguished by one of the great events in the story of vertebrate evolution; the development of jaws. First appearing in late Silurian times, they achieved their most spectacular form in the arthrodires or armoured, joint-necked fish, achieving a dominance which in some respects meant they were the most successful of all vertebrates. But this was short lived and by the Hangenberg anoxic event (358.9 Ma) the arthrodires were extinct.

During their period of dominance Dinichthians probably only had other members of their species to fear. Equipped with 8 - 10ft of boney plates covering the head and thoracic shield, the rest of the body appears to have been unprotected. A hinge mechanism between the head and thoracic shield allowed the upper head to be raised as the lower jaw dropped, achieving a very wide gape and an almost instantaneous bite achieved by jaw plates shaped to form scissor-like cutting edges. It is perhaps here in this mechanism that the evolutionary 'dead end' for these animals is best expressed as it should be noted that the Placoderms are the one class of extinct vertebrates; all other classes are represented by living species. ■

Mike Williams

A Postcard from the Megacliff of Slieve League, County Donegal, Ireland

Located 30kms from the port of Killibegs these 601m high cliffs are formed of Dalradian quartzites and gneiss belonging to the Slieve Tooey and Slieve League formations, which have been correlated with strata in both Scotland and Newfoundland, forming part of the International Appalachian Trail. ►



601m cliffs of Slieve League, Donegal, from the sea

Believed to have developed over some 100,000 years by glacial corrie wall creation coupled with periglacial action, these rock formations were invaded by the sea in Holocene times and although exposed to severe wave action have only been slightly modified at their base.

Although best viewed from the seaward side, these cliffs also have summit access via a narrow road leaving the village of Teelin (Teileann), which is close to The Wild Atlantic Way, a 1600 mile coastal road route running from Inishowen in the north to Kinsale in County Cork.

Leo's Tavern, Meenaleck, County Donegal

This route achieves one of its finest incarnations around the coastline of Donegal visiting many beautiful sandy bays and coves formed from the local granite, but best of all it passes close to Leo's Tavern, Meenaleck, Crolly, the family home of the internationally famous band Clannad and even their more famous sibling Enya. So, reflecting on Enya's 1988 hit song 'Orinoco Flow', follow her call to 'sail away' and go with the (Orinoco) 'flow' enjoying the 'craic' over a Guinness! ■

Mike Williams

The Glacial Erratic Boulders of Wightwick Manor
and the Manders of Wolverhampton

Introduction

In 2010 a BCGS field trip to Wolverhampton included the array of 19 glacial erratic boulders on display at the National Trust's Wightwick Manor, home to the Mander family and situated close to the Tettenhall Wood district on the western fringe of Wolverhampton. A photo in my collection records the event. Almost every boulder bore a metal sign indicating its rock type and a general sign explained the glacial origins of the boulders, but this visit begged many questions about this magnificent collection. The Trust's Wightwick Manor guide book of the time simply stated that: *"the boulders... were deposited in the area by a glacier in the last ice age. They were laid out as a feature in 1957"*. But why were they displayed here? Who was responsible? Who had provided the geological information for the signs? Were they discovered in the grounds of the Manor or had they come from elsewhere?


BCGS members admire the erratic boulders of Wightwick Manor on a field trip in 2010

These questions lay dormant until it came to my notice in 2024 that the garden team at Wightwick Manor, led by James Carnell, were looking for some help to refresh the boulders and update the interpretation. A start had been made by geology lecturer Clive Roberts who sadly passed away ►

The Wightwick Manor erratic boulders and signage installed in the late 1950s. BCGS visit, 2010

before the project was completed. Clive had also been a volunteer at Wightwick Manor. Given my earlier interest in Wightwick Manor's boulders and my later involvement with the glacial erratics project in Birmingham, I was keen to follow this up. The BCGS committee became involved and it wasn't long before a meeting was arranged with James Carnell, (Head Gardener), Stephanie Wilkes (Wightwick Manor Collections Inventory Officer), Graham Worton (BCGS and Black Country Geopark) and me, and this took place in November 2024.

On a site walk Graham showed us that hundreds of small glacial erratics could be found in the Manor grounds, many of them incorporated into walls around the property. These are evidence of significant deposition in this area during the glacial period and these small glacial erratic stones were almost certainly found within the grounds. But was this the case with the array of 19 large boulders? It gradually became apparent that answers to my questions about the 'human' history of this display would be found closely interwoven with several generations of the Mander family and their homes. Here we'll step back to meet some of the significant characters in this glacial erratic saga.

The Mander Family of Wolverhampton

The Mander family has played a significant part in the history of Wolverhampton through many generations. Their prowess in the world of manufacturing dates back to the 18th century, but most significant was the establishment of the 'Mander Brothers' company in 1845 by Charles Benjamin Mander (1819 - 1878) and his brother Samuel Small Mander (1822 - 1881). Their business was the manufacture of varnishes, paints and inks and they became leaders in their field for many decades. As liberal non-conformists the Manders became well-known for their philanthropic civic enterprises, and their growing wealth also enabled them to improve their own living conditions.

Boundary wall at Wightwick Manor containing numerous glacial erratic rocks

In the early 1860s Charles Benjamin Mander took possession of 'The Mount' in the fashionable district of Tettenhall Wood, Soon after, in 1865, Charles Benjamin's brother and business partner, Samuel Small Mander made his home just a little further to the north-east along Tettenhall Wood Road with the building of Glen Bank.

We can surmise that around this time both brothers were taking an interest in the subject of geology. The clues are sparse, but there are records which show that Charles Benjamin was a member of the 'Dudley and Midland Geological and Scientific Society and Field Club' (forerunner of BCGS) in 1864 and 1865, and his brother, Samuel Small, was listed in the Society's journal for July 1864 as a member of the 'Field Club Only' section of the Society.

Another important - and relevant - theme running through the history of the Mander family from the mid-19th century is a strong connection with the Arts and Crafts movement which became influential ►

in the fields of art and architecture through the second half of the 19th century. The movement was inspired by the philosophy of John Ruskin who wrote copiously on the subject of the dehumanising face of industrialisation and he advocated a return to nature to find inspiration for beauty and attention to detail in art and architecture. He was a force behind the architectural Gothic revival in the late 19th century and was a pioneer in advocating conservation of the natural world and man-made heritage. These values became integral to the life-styles of the Manders involved in this story.

Ruskin was influential in the founding of the National Trust and the Society for the Protection of Ancient Buildings. He was also directly responsible for founding the Guild of St. George in 1871, which promotes itself as: *'The charity for arts, crafts and the rural economy'.* This brings us back to the glacial erratic story with the introduction of a living member of the Mander family, Sir Nicholas Mander of Owlpen in Gloucestershire. Sir Nicholas has written a three volume history of the Mander family, and in keeping with the Arts and Crafts influence of his forebears, he is a member of the Guild of St. George. His inaugural address in 2022, gave further clues to the geological interests of of his ancestors. The subject of his address was 'John Ruskin' and he linked Ruskin with his own family thus:

"His aesthetics - with that of William Morris - inspired the building of a group of family houses still appreciated and visited today, and influenced their collecting habits in art - as well as their interest in geology, represented by giant specimens of erratic boulders, all identified and labelled, in my great-great-grandfather's garden."

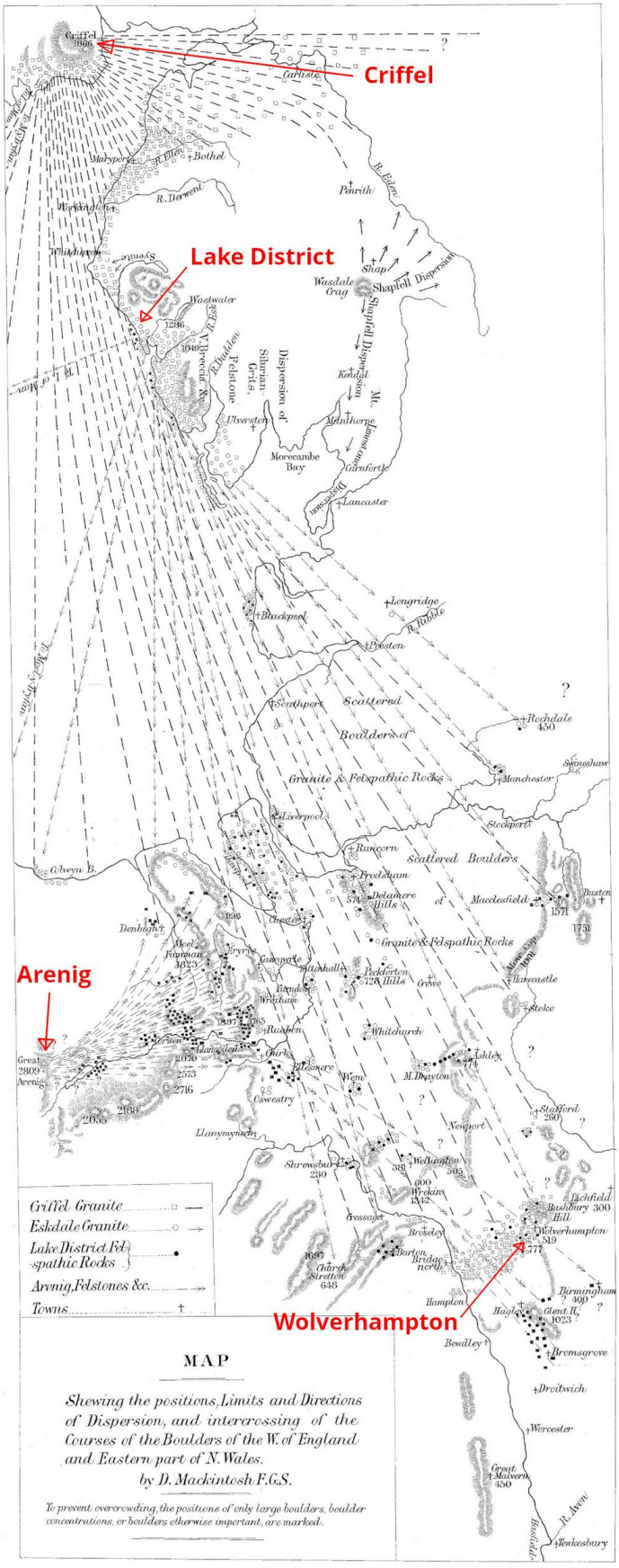
The great-great grandfather in question was Charles Benjamin of the Mount. But what of the erratic boulders? There is, so far, no direct evidence of their acquisition by Charles Benjamin, but from this lead and a few further clues and we can surmise a sequence of events, based on the accident of nature that Wolverhampton proved to be a fertile hunting ground for glacial erratic boulders.

The science of glaciology and Victorian Society

One of the hot topics of geology in Victorian times was the subject of glaciology and the search for evidence of glaciation in the landscape. Glacial erratic boulders provided readily visible clues and they were profusely strewn across the Midlands. There was mounting evidence from the area of two different ice advances, later known as the earlier 'Anglian' advance peaking around 450,000 years ago and the most recent 'Devensian' advance which peaked around 22,000 years ago. Erratics from Birmingham southwards to Bromsgrove were mostly found to be made of felsic tuff from the Arenig Mountains in Wales belonging to the earlier ice advance, whereas the far more numerous erratics found in the Wolverhampton area were hard granitic rocks, mostly from Criffel Mountain in Dumfries and Galloway (Scotland) or from Ennerdale and Eskdale in the Lake District. They were very different in appearance and texture from the underlying rocks which are mostly formed of a crumbly red sandstone. Wightwick Bank cuts through the grounds of Wightwick Manor and provides an excellent exposure of the local Early Triassic Wildmoor sandstone bedrock which formed in braided river systems within a desert environment around 250 million years ago.

Wildmoor Sandstone, Wightwick Bank. (Wightwick Manor's 'Mathematical Bridge' visible on the left)

The Wolverhampton erratics were found no further south, marking Wolverhampton as the terminus for the Devensian advance in the Midland area. The ►



1879 Erratic boulder distribution map by D. Mackintosh

Wolverhampton line is shown graphically on a comprehensive erratic boulder map produced by a dedicated field researcher, Daniel Mackintosh in 1879[1] *(here annotated for easier navigation).*

With local evidence of more than one ice advance, it is no surprise that Birmingham became a centre for glacial research. The British Association for the Advancement of Science (BAAS) created an 'Erratic Blocks Committee' centred in Birmingham with a dedicated Secretary in the person of Henry William Crosskey, a local Unitarian minister. With requests sent out to geological societies and institutions to report glacial erratic findings, the Mander brothers would have been aware of their significance through their membership of the Dudley and Midland Geological Society.

Apart from their scientific significance, it became fashionable in certain quarters of Victorian Society to have a private 'bouldery' consisting of glacial erratics found on their land or acquired by having them brought from their glacial resting places in the local area. Amongst the cognoscenti, this would also have been a gesture to save the boulders from destruction in the wake of urban development. Thus, it seems, was the origin of the erratic boulders at the Mount. Once again evidence is sparse, but the earliest reference I have found comes in a footnote to a paper on Glacial Erratics by Daniel Mackintosh[2] (of erratic boulder map fame) for the Quarterly Journal of the Geological Society in 1874:

"Mr. Mander, of Tettenhall Park, has formed what may be called a Bouldery; and the largest granite boulder it contains was dragged from Trescott by a great number of horses."

This confirms that a bouldery had been created at one of the Mander properties by this time, though Mackintosh could be referring either to Charles Benjamin's home at the Mount, or Samuel Small's at Glen Bank. Both properties were in Tettenhall. The same author inadvertently provides the answer in the 1879 ►

publication[1]: *"One boulder in the late Mr. Mander's bouldery, Tettenhall, required fifteen horses to drag it from Trescott".*

Reference to the 'late' Mr. Mander by 1879 places this bouldery very definitely at the Mount: Charles Benjamin died in 1878, and his son, Charles Tertius had inherited the property.

A final Victorian reference indicates that the glacial erratics at the Mount had become well known amongst the geological community, when a 'Long Excursion to the Birmingham District'[3] was organised under the direction of Professor Charles Lapworth (then Professor of Geology at Mason College which later became the University of Birmingham). This took place over one week during the summer of 1898. Other participants included Jerome Harrison (FGS), W. Wickham King (FGS), and Professor W.W. Watts. This 'excursion' was a wide-ranging field trip from Birmingham to Nuneaton, then the Lickey Hills, Sutton Coldfield, Wolverhampton, Kidderminster, the Abberley Hills, and Dudley, and included a pre-arranged visit to 'The Mount' in Tettenhall preceded by a visit to West Park Wolverhampton where a collection of erratic boulders had been installed when the park opened in 1881. The 1898 excursion report by Professor Watts states:

"An early start was made on Monday, August 1st, for Wolverhampton, and a visit was made, under Mr. Jerome Harrison's direction, to the West Park, in which the Corporation have preserved a couple of large boulders - one from Criffel, and the other from Arenig or the Lake District. The party next drove to Tettenhall, where they were hospitably entertained by Mr. C. T. Mander at breakfast, after studying a fine collection of boulders amassed by that gentleman's father. The majority of the boulders had come from Lakeland and South Scotland" but there was at least one "Welshman" in the collection. ('Welshman' was a term used by some to describe the felsic tuff boulders from the Arenig mountains in Wales.)

The excursion report formed the basis of a publication by Lapworth entitled 'Sketch of the geology of the Birmingham District with Special reference to the Long Excursion of 1898'[4]. In this, the visit to Wolverhampton and the Mount was expanded:

"To the north, west, and south-west of Wolverhampton the erratics are to be numbered by the thousand, and some of them bear striations which they probably received while still in situ, and before removal from their native places. About thirty or forty years ago Mr. Mander, of The Mount, Tettenhall, Wolverhampton, preserved many fine local erratics from destruction by removing them to his grounds, where he formed them into a 'bouldery'."

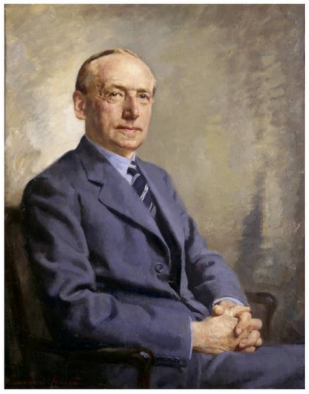
Wightwick Manor, July 2025

There the boulders remained through generations of the Mander family until the Mount was sold by Sir Charles Marcus Mander in 1952. It was converted to become 'The Mount Hotel' which is still functioning today, and this 'erratic' story now moves through the Mander family branch of descendants from Samuel Small Mander.

Long before 1952, Samuel Small Mander's 'Glen Bank' home had been demolished and the site is now occupied by the Nuffield Hospital. His son, Samuel Theodore, had bought part of the Wightwick Manor estate including the old 16th -17th century Wightwick Manor, just a short distance to the south-west of the Mount. In the grounds he created a new home which was completed in 1887, and he transferred the old name of 'Wightwick Manor' to his new home. The architectural style of the Wightwick Manor ►

we know today was heavily influenced by the Arts and Crafts movement. The old Manor buildings remained as outhouses, and it is likely that they were preserved by Samuel Theodore with the Arts and Crafts ethos of conservation in mind. It is interesting to note that the Mander properties of The Mount, Glen Bank and Wightwick Manor all took advantage of a high ridge of Triassic Wildmoor sandstone which stood high above the industrial heart of Wolverhampton.

Sir Geoffrey Mander and the Erratic Boulders at Wightwick Manor



Sir Geoffrey Mander 1938
© National Trust[5]

Sir Geoffrey Mander inherited Wightwick Manor following the death of his father in 1900, and extended the collections, preserving the Arts and Crafts theme for which Wightwick Manor is well-known today. Sir Geoffrey was a Liberal MP from 1929 - 1945, and was the incumbent owner of Wightwick Manor when the property was donated to the National Trust in 1937. The family continued to live there and it was during Sir Geoffrey's time that the Mount was sold. Fortunately, and in keeping with the family tradition of conservation, Sir Geoffrey stepped in to save the Mount's erratic boulder collection, and it was during the year of the house sale (1952) that the 19 erratic boulders in the current collection were transferred from the Mount to Wightwick Manor.

Since the recent renewal of interest in the glacial erratics by the National Trust's Wightwick Manor team, correspondence has come to light which shows that the erratic boulders had been set out in 1957 in the orchard, in the curved array which exists to this day. However, Sir Geoffrey didn't stop there. The Wightwick Manor archives reveal an interesting letter from J.F.A. Stark, a geology lecturer at Wolverhampton and Staffordshire College of Technology. Addressed to Sir Geoffrey Mander and dated November 1958, it is in response to a query from Sir Geoffrey about the nature and provenance of the erratic boulders. This letter reveals that Stark had visited the boulder collection with Fred Shotton, Professor of Geology at the University of Birmingham, and had collaborated with him on the analysis of the boulders. This had included taking samples and making thin sections, and attached to Stark's letter was a list identifying the boulders from 1 – 19. However, it seems that Sir Geoffrey was unsure which way round the boulders had been numbered! Shotton's reply was not immediately illuminating:

"It may sound rather silly but I confess that I cannot answer confidently the question of which end of your line of boulders is No.1." But he goes on to offer a solution: *"However, I think you can clear this up very quickly for I enclose seven chips which are numbered according to the list you got, and if you compare these with the boulders, I think it will be immediately apparent that they only fit one way round".*

The problem was solved and Sir Geoffrey's initiative resulted in 19 metal signs (placed in the correct order!) for each of the erratic boulders, plus the general notice about their glacial origins *(see photo on p.12).* Sir Geoffrey died in 1962, leaving this glacial boulder legacy which could be traced back to his great uncle, Charles Benjamin Mander of the Mount. The boulders and their signage have remained safely in situ since then, but there is no doubt that they are ready for a face-lift and rehabilitation as one of Wightwick Manor's precious and more unusual collections.

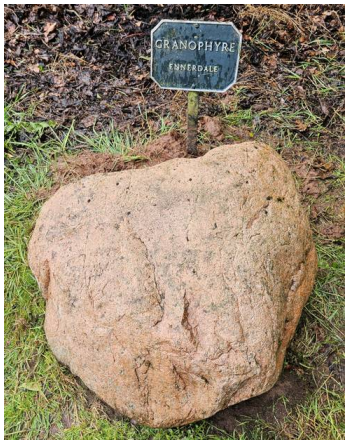
Raising the Profile of Wightwick Manor's Erratic Boulders

At the meeting in November 2024, I suggested that a first step to the revival of the erratic boulders would be to clean them with a pressure washer. I had access to the portable pressure washer ►

owned by the Lickey Hills Geo-Champions and was aware of the difference this process has made to enhance the geological features of sites around the Lickey Hills and many of the erratic boulders in the Birmingham Erratics project. This was agreed in principle, but the boulders are a 'collection' in the care of the National Trust. The National Trust is accustomed to renovating man-made stone heritage, so the idea of 'heritage' natural boulders under their care being sufficiently robust to withstand pressure washing was treated with some caution, and it took a few months to get the necessary permissions.

The team and boulders just after pressure washing

A small team was assembled including two BCGS members with their own portable pressure washers, and the boulder cleaning day was set for the end of May this year. Graham was on hand to re-organise the interpretation signs, some of which had got out of order over the years. The final result was spectacular, and much admired by all those involved. From 19 rather uniform grey rocks encrusted with lichen and dirt, the erratics now show their individual characteristics. This makes their geological features easier to discern, and quite simply makes them more appealing to look at. The pink colouration of the Ennerdale granophyres is particularly striking.



Pink Ennerdale Granophyre after cleaning

Cleaning the erratics is just a start and there is a lot more work yet to be done. The signage uses old-fashioned terminology and the interpretation needs to be up-dated. However, the signs are part of the heritage, and it is planned have them cleaned and restored. The next step will be to combine the new findings with the work already done by Clive Roberts, and support the Wightwick Manor team in producing some new interpretation for visitors to Wightwick Manor. A leaflet has been suggested, and, perhaps, an information panel installed beside the boulders. Then there is the wider Geopark consideration of the Ice Age story all around Wolverhampton, including the remarkable collection of erratic boulders in West Park.

I started this article with questions, but the answers simply seem to generate more questions! I wonder about the boulder at the Mount which *"required 15 horses to drag it from Trescott"*. That did not get moved to Wightwick Manor! Then there is the *'Welshman'* at the Mount mentioned by Professor Watts in the 1898 report. There is no such boulder amongst the 19 at Wightwick Manor. Is it still at the Mount, or lost? Given the interest of both Mander brothers (Charles Benjamin and Samuel Small) in geology, was there also a 'bouldery' at Glen Bank? Then in more recent times, what happened to the *"seven chips"* which Professor Shotton sent to Sir Geoffrey? They have not (yet) been found at Wightwick Manor.

There is still more geology to take into account at Wightwick Manor! In addition to the glacial boulders there are some natural stone artefacts which were rescued by Sir Geoffrey Mander from the Houses of Parliament during renovation work in the 1930s, with some additional ones following World War 2 damage to the Parliament buildings. But that is another story... ►

If you would be interested to help with any aspect of this on-going geological research at Wightwick Manor, please let me know at the usual address: newsletter@bcgs.info ■

Julie Schroder

Acknowledgements and references

1. 'Results of a Systematic Survey, in 1878 of the Directions and Limitis of Dispersion, Mode of Occurrence and Relation to Drift Deposits of the Erratic Boulders of the West of England and East of Wales'. D. Mackintosh read: March 1879, Quarterly Journal of the Geological Society (QJGS)

2. 'Additional Remarks on Boulders with a particular reference to a group of very large and far-travelled erratics in Llanarmon Parish, Denbighshire'. D. Mackintosh 1874, QJGS

3. 'Long Excursion to the Birmingham District, July 28th - August 3rd 1898'. W.W. Watts. Proc. Geologists' Association, Vol. XV

4. 'Sketch of the Geology of the Birmingham District'. Prof. C. Lapworth. Cornish Brothers Ltd. 1907

5. Portrait of Sir Geoffrey Mander by Clarence A.B. White, 1938. © National Trust, Wightwick Manor

Wolverhampton History and Heritage website: http://www.historywebsite.co.uk/
My thanks to the National Trust team at Wightwick Manor for providing access to archive letters

Mike's Musings No. 59 – Crystallisation

In his 1962 account of the first ascent of the Carstensz Pyramid, nowadays known as Puncak Jaya, *(Fig. 1),* located on the island of New Guinea and the highest point in Australasia, Heinrich Harrer records that his native porters (members of one of the many 'Stone Age' tribes inhabiting the island), could not comprehend that the ice they encountered for a first time at great altitude was the same material as the water they lived with daily (in considerable abundance) in their tropical world of torrential rainfall and fast flowing rivers. They had no concept of **freezing** and **melting**, so were doomed to disappointment when the marvel of the solid ice they carefully wrapped up and stored in tins to take back to show their fellow villagers several thousand feet lower down in their jungle homes, would simply reveal itself as liquid water.

Fig. 1: Puncak Jaya, (the Carstensz Pyramid) 4884m
Photo by Alfindra Primaldhi, Wikimedia Commons

This strange phenomenon, the equivalence of ice and water, is simply due to the different **states of matter** that we, with a little education, are now all, perhaps unconsciously, familiar with; at least with the three 'common' states (also known as **phases**): **solid, liquid, and gas**. The more familiar phases of water, for example, are shown in Figure 2, and this shows the various processes by which they transform between phases. Figure 3 shows that these phases are largely controlled by the temperature (pressure, as we shall see, is also important in geological contexts), passing from solid (ice) to liquid (water) to gas (vapour) as temperature rises. It also shows that phase changes occur not smoothly, ►

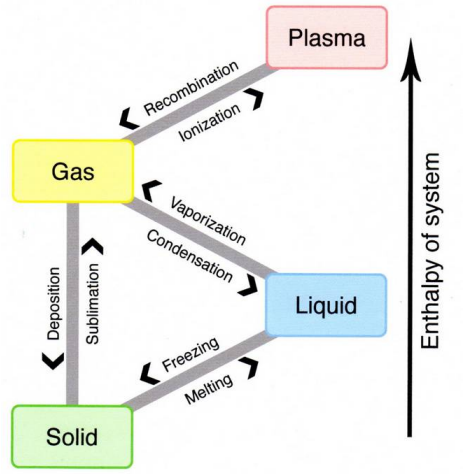


Fig. 3: The most common 'States of Matter' and their inter-relationships

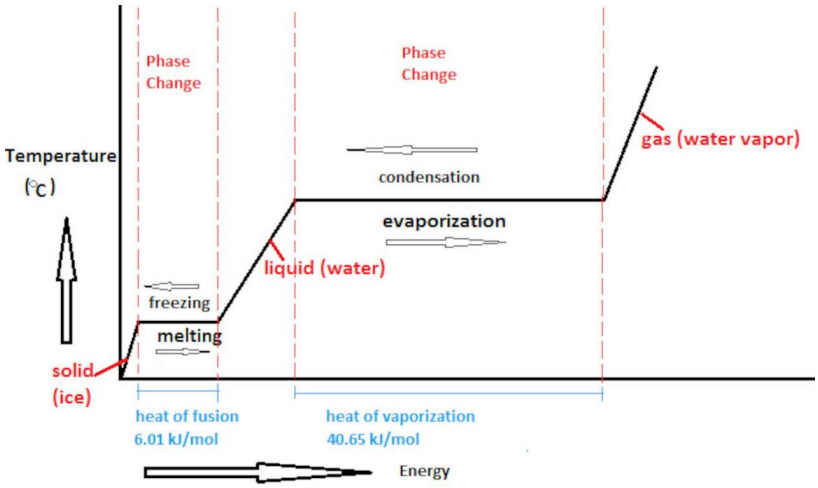


Fig. 2: The phase changes of water with rising temperature Illustration by Cawang, Wikimedia Commons

but with hiatuses during which energy needs to be added to the system without the temperature changing in order to bring about the rearrangement of the atoms to implement a change of phase.

In fact when I Googled 'states of matter' I was dismayed to discover that I, like the 'Stone Age' inhabitants of New Guinea, was likewise unaware of most of the further esoteric states that exist in the world of physicists and astrophysicists, such as plasmas, Bose-Einstein condensates, superfluids, quark-gluon plasmas and degenerate matter (etc.)! Fortunately, for the purpose of this Musing, we can overlook our (collective?) ignorance of everything except solids and liquids, as I consider, in simple terms, their relevance to geology.

I have mentioned before *(Musing No. 38)* the triumph of the Vulcanists over the Neptunists in explaining the formation of igneous rocks by crystallisation from a molten state, but in fact even the Neptunist concept of rocks being formed by evaporation from a liquid solution holds true of certain sedimentary rocks (notably chemical precipitates such as beds of salt or gypsum), even if it isn't applicable to the igneous world. What both, of course, have in common is the formation of solids as their constituents transform from a liquid state. This transition is due to the more rigid ordering of their atomic structure, which we call **freezing**, and is a reversible process, which we call **melting**, when the transformation is from a solid to a liquid state.

In the igneous realm, when dealing with the very high temperatures of magma cooling to form igneous rock, it sounds odd to speak of minerals crystallising due to **freezing**, but this is the same process as water turning into ice. Magma is in effect a 'chemical soup' of many elements in disassociated liquid form, such that the **freezing** process is a rather more complicated affair. Magmas will vary widely, but the transformation into igneous rock will essentially be the same in all cases. Every mineral has its own specific temperature of ►

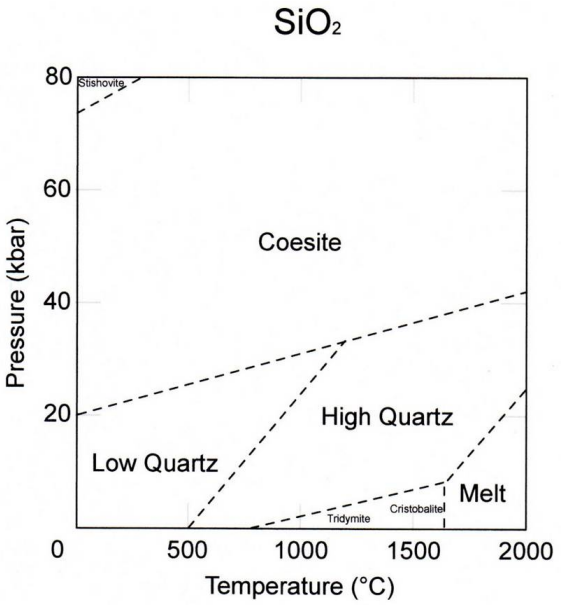


Fig. 4: Pressure - Temperature diagram for the various polymorphs of SiO_2

formation, or put another way, its own **freezing point**. Olivine, for example, **freezes** at 1205°C in its iron form (Fe_2SiO_4), and at 1890°C in its magnesium form (Mg_2SiO_4), and all temperatures in between for MgFe forms (which hints at the complexity of Mother Nature and the almost infinite possibilities from a given initial magmatic composition).

But the ability of a particular mineral to crystallise depends on many factors. The most obvious requirement is that the magma contains the necessary chemical elements. You cannot form quartz unless both silicon and oxygen are present in the parent magma. But like olivine, quartz comes in many forms (although these all have the same chemical composition: SiO_2), controlled not just by temperature, but also highly dependent on the other main factor: **pressure.** Different minerals, and indeed different forms of the same mineral, only exist within particular ranges of temperature and pressure, giving rise to the concept of the **stability field.** This may be diagrammatically displayed in the form of a **pressure-temperature** (P-T) diagram *(Fig. 4),* which shows the stability fields for SiO_2 (various forms of quartz). Coesite and stishovite are high pressure forms that were first recognised in the Barringer meteorite impact crater *(see Musing No. 53, October 2024, Newsletter No. 287).* Coesite sometimes occurs in ultra-high pressure metamorphic rocks, and stishovite has been found in minute quantities in some diamonds, but when subjected to 'normal' conditions at the Earth's surface they both revert to stable lower pressure forms of quartz.

For a cooling magma all the various complexities of mineral form and their respective chemical composition and stability fields combine to determine the order in which minerals crystallise out of the parent magma. Yet other factors are also involved such as mineral **immiscibility** (like oil and water - not all minerals always want to co-exist within the same rock), and **mineral concentrations**, but we have enough complexity to think about without adding more to this list! It will also be obvious, I hope, that once minerals begin to crystallise out of an initial 'chemical soup', the chemical composition of the remaining 'soup' changes. This leads to a process known as **magmatic differentiation**, but before we consider the significance of this, let us look further at the order in which minerals form as magma cools.

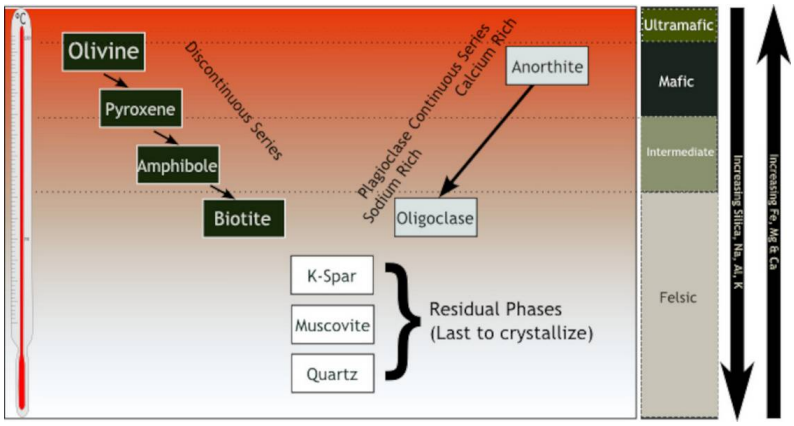


Fig. 5: Bowen's Reaction Series

From both observations of naturally occurring rocks and experimental work on basaltic magmas (one of the more common and widespread types) the Canadian petrologist Norman L. Bowen (1887 – 1956) was able to determine that the common **rock-forming** minerals *(see Musings 20 & 21, April & June 2019, Newsletters 254 & 255)* typically crystallise in a specific order when magma cools *(Fig. 5).* Two concomitant sequences (a so-called continuous series: the plagioclase feldspars from anorthite to oligoclase, and a discontinuous series: olivine – pyroxene – amphibole – biotite) develop at higher temperatures (with their **higher freezing points**) before the **lower freezing point** minerals (albite / orthoclase feldspars – muscovite – quartz) form at successive lower temperatures. As these minerals aggregate to produce a final rock type it should be noted that the composition of the magma is continually changing (as explained above), and slight variations in each 'crystallisation sequence' dictate the detailed final rock type (bearing in mind the chemical composition of every magma is unique, with many other chemical elements present beyond those which form the main rock-forming minerals). ►

It is of further interest to note that this so-called **Bowen's Reaction Series** *(Fig. 5)* is allied to the concept of the **Goldich Dissolution Series** that describes the relative stability of these minerals, which are largely in the reverse order! This effectively explains their relative liability to weathering (with quartz excepted: it is more inert by virtue of its relatively simple chemical composition). **Felsic** minerals decompose more readily, while **mafic** minerals become increasingly more inert, partly as their iron content increases, which may seem odd since everything containing iron seems to rust so readily; but rusting is less destructive than decomposition! The overall explanation for this is that minerals forming at lower temperature are more stable at the similar conditions found on the Earth's surface.

The actual development of a crystal is commonly a two-stage process. It begins with **nucleation**, whereby atoms begin to cluster and arrange themselves into the particular pattern appropriate for the mineral that is going to crystallise. This creates areas within the magma where these atoms become more concentrated and begin to form stable **nuclei** which, when they reach a critical size, promote the complementary process of **crystal growth**. The critical size depends on both chemical and thermodynamic factors such as temperature and solubility of the chemical species which control the rate and amount of precipitation from the magmatic solution. The rate at which cooling takes place also influences the resulting **texture** of the rock, such as the way in which different minerals interact with each other and whether the rock is fine or coarse-grained.

Fig. 6: Three examples of the celebrated 'Rhomb Porphyries', rare rocks from the Oslo Fjord region

One fairly common texture is described as **porphyritic** *(Fig. 6).* This is where large, often well-shaped (**euhedral**) crystals (**phenocrysts**), occur within a fine grained or glassy matrix. These crystals are usually of minerals that form early on in the crystallisation sequence and therefore have more freedom to grow. This process often happens when rising magma is cooled in two stages, first slowly at deeper levels and second more rapidly closer to the surface. An alternative mechanism involves early stage phenocrysts denser than the magma containing them settling out at the base of the magma chamber (cumulates) and then later getting caught up in a sudden and rapid eruption during which the remaining magma cools rapidly as a fine-grained groundmass, usually of later forming minerals.

Once all the major rock-forming silicate minerals have crystallised out from a parent magma, the remaining liquid contains a much greater proportion of volatile (**low freezing point**) constituents. This usually includes water and metallic constituents, referred to as a **hydrothermal fluid**, which leads to the deposition of more valuable (to us humans) **ore deposits**. Since these final fluids are much more mobile ('runny'), they are able to invade the cracks and fissures which open up in the rocks surrounding the igneous intrusion in the form of **mineral veins** *(Fig. 7.)* But, the details of mineralisation are another matter altogether! ■

Mike Allen

Fig. 7: Rare-Earth Element Mineral Veins in the Ulefoss Mine, Fen District, Norway