The Black Country Geological Society

www.bcgs.info

Newsletter No. 279
June 2023

Contents:

To find out more about this photo - read on!

Copy date for the next Newsletter is Tuesday 1 August

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For enquiries about field and geoconservation meetings please contact the Field Secretary.
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, Twitter: @BCGeoSoc and Facebook.

Future Programme

Indoor meetings are normally held in the Abbey Room at the Dudley Archives, Tipton Road, Dudley, DY1 4SQ, 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.

Saturday 17 June *(Field Visit):* North Malvern – Tank Quarry and North Quarry. Led by Peter Bridges (EHT Champion for Tank and North Quarries). Meet to start at 11.00 at Tank Quarry Car Park, West Malvern Road, North Malvern, Worcestershire, WR14 4NA (GR: SO 768470). We will look at the Malvern Complex northernmost exposures and some exposures related to the East Malvern Fault (EMF). There are some steep paths and rough ground. Stout footwear is required. Either bring a packed lunch, or a proposed lunch stop is at The Nags Head, 19-21 Bank St, Malvern, WR14 2JG. **Essential that you inform the field secretary of your intention to join this visit** as we need numbers for lunch at the Nags Head (booking ahead is essential) and for handouts. Aim to finish around 4.00.

Saturday 22 July *(Field Visit):* Glacial Boulder Trail 8 - The Illey Valley Wilderness Trail. Led by Julie Schroder. Meet to start at 11.00 at Woodgate Valley Country Park car park, Clapgate Lane, B32 3DS. GR: SO 995 830. This is a pre-launch walk on the final trail in the Glacial Boulder series produced during the project 'Birmingham's Erratic Boulders: Heritage of the Ice Age'. The trail is 5½ miles, crossing 3 district boundaries, the M5 and the Midland watershed. It links some fine specimens of glacial erratic boulders, with opportunities to consider the underlying geology and the surrounding landscape. There is some rough ground, muddy in wet weather. Stout footwear is required. Bring a packed lunch or obtain food at the Black Horse Inn, Illey. The trip will finish around 4.00.

Monday 18 September *(Indoor Meeting):* 'The life and work of Sir Arthur Russell'. Speaker: Roy Starkey.

Monday 16 October *(Indoor Meeting):* 'Conclusion of the Erratics Project'. Speaker: Ian Fairchild.

Monday 20 November *(Indoor Meeting):* 'Origins of Starfish and their relatives'. Speaker: Aaron Hunter.

Monday 11 December *(Indoor Meeting):* Members meeting.

Other Societies and Events

Shropshire Geological Society

Thursday 22 June at 6.00 and Saturday 24 June at 10.30: Open Air Geology - Lyth Hill. Led by Albert Benghiat.

If you wish to attend then please notify Albert Benghiat: 07710 421 581, e-mail: SGS.chair@hotmail.com Further info: http://www.shropshiregeology.org.uk/SGS/SGSEvents.htm

Abberley and Malvern Hills Geopark 20th Anniversary – Geofest 2023

This year is the 20th anniversary of the Abberley and Malvern Hills Geopark. The annual Geofest is running from 27 May to 3 September. One of the main events will be a 20th anniversary celebration on 21st June. More on the Geofest Calendar here: http://geopark.org.uk/pub/category/geofest/

For further information go to: http://geopark.org.uk/ or contact the BCGS Field Secretary, Andy Harrison (details on p.2).

The Geologists' Association, Evening Lectures

Friday 7 July: BGS Geomaterials Collections: 200 years in the making. Speaker: Mike Howe. Hybrid Meeting (virtual and in person lecture).

Our hybrid lectures will be held both in the Janet Watson Lecture Theatre of the Geological Society, Burlington House, Piccadilly, W1V 0JU, & simultaneously over Zoom. Non-members are always welcome to attend for an introductory visit arranged by phoning (020 7434 9298) or emailing (sarah@geologistsassociation.org.uk) the Executive Secretary to book a place. The GA reserve the right to request a small charge for returning non-member attendance.

Manchester Geological Association

Saturday 25 June: Ingleton - Waterfalls Walk. Led by Lesley Collins, joint with Westmorland Geological Society. This is quite a demanding walk on a well-maintained path with an estimated 1000 (one thousand) steps. There is a charge for parking/entry to the walk.

Sunday 16 July: Force Crag Mine, Braithwaite, Cumbria. Leader TBA. An underground visit, joint with GeoLancashire.

For more information: http://www.mangeolassoc.org.uk/ or contact outdoors@mangeolassoc.org.uk

Warwickshire Geological Conservation Group

Thursday 15 June from 7.00 to 8.30: Evening Excursion to Roundberry Quarry, Tamworth. Led by Ray Pratt. No need to register. Details here.

There is a charge of £2.00 for non-members. For more information visit: http://www.wgcg.co.uk/ or email: WarwickshireGCG@gmail.com.

Mid Wales Geology Club

Tuesday 20 June: The Geology of Namibia. Speaker: James Creswell.

Further information: Tony Thorp tel. 01686 624820 and 622517 tonydolfor@gmail.com
Web: http://midwalesgeology.org.uk lectures start at 7.15 via Zoom.

Open University Geological Society, West Midlands

Sunday 25 June: Stiperstones Hills Shropshire. Led by Albert Benghait. Contact: Dave Green davepgreen@btinternet.com

Editorial

Our field trip season has begun with a successful visit to Roman Wroxeter. There is a detailed report by Andy for those who missed it and as a reminder for those who were able to attend. The next trip is to Malvern on Saturday 17 June, and it will be led by Peter Bridges, the EHT 'Champion' for this site. Much work has been done recently to improve some of the geological sites in the Malverns, and to further our understanding of the ever-complex geology of the Malvern Hills. Even if you've been before, don't miss this opportunity to learn more about the Malverns. I am greatly looking forward to the chance to take BCGS members round the Illey Wilderness Trail on 22 July. Having had some part in devising this route (Glacial Boulder Trail 8), I feel particularly enthusiastic about it. It is a lovely country walk linking some amazing erratics, and is full of surprises! There will be an August field trip, yet to be confirmed. We will keep you informed as soon as we can.

Apart from Andy's report, this issue brings you a fascinating article on quartzites by Ray Pratt, the latest up-date on the Erratics Project and more on the unusual subject of pebble shape from Mike.

Remember that we are still in need of more people to serve on the committee, especially to fill the vacant role of Meetings Secretary. We are a small team doing our best to keep everything going, but we need new people and new ideas to keep the Society alive and thriving.

Enjoy your summer holidays - and keep in touch with us on any geological exploits which you may like to share with other members. ■

Julie Schroder

Field Meeting Report

Saturday 1st April 2023, BCGS Field Visit – The Geology of Wroxeter Roman City: Led by David Pannett (Shropshire Geological Society).

Introduction

We met David in the site's English Heritage visitor car park at 10.30 on an overcast but mild day. David explained that, as a teacher, he has tried to get staff and associated archaeologists to provide interpretation for the building stones used within the site telling three basic stories: their geology and lithology; palaeoenvironments; local geography and landscape. ►

We started at a barn wall on Watling Street, then entered the site to undertake a mapping exercise looking at what building stones had been used and where. We learnt how this information closely correlates with the city's history and architectural evolution. Leaving the site, we visited churches in Wroxeter and Atcham, discovering their link to the city, before finally stopping at Acton Burnell to look at the Castle and its building stone link.

Examining the barn wall at Wroxeter

Geography, Setting and Geology

The Roman city is located at the junction of what was Watling Street and a major route leading south to the Wye Valley at the Roman fort of Caerleon (or Isca Silurum). Wroxeter sits on relatively flat and low-lying ground at roughly 60m, which slopes very gently north and west towards Bell Brook and the River Severn. The Bell Brook is approximately 280m north and flows westwards to intersect the River Severn, which flows roughly north to south approximately 300m to the west.

The city rests on a thick layer of river terrace deposits associated with the River Severn, forming a well-drained ridge and vantage point over the Severn floodplain. Alluvial deposits form the low ground to the west through which the Severn flows, and glacial till underlies the low-lying landscape to the east. The underlying bedrock is a brick red sandstone strata belonging to the Bridgnorth Sandstone Formation. A historical British Geological Survey (BGS) borehole located approximately 440m south-east of the site, confirms that the underlying river terrace deposits reach up to 24m depth. Underlying these deposits the 'hard red' Bridgnorth Sandstone was recorded to around 48m depth.

History

Wroxeter Roman City (or Viroconium) was the fourth largest city in Roman Britain and almost rivalled Pompeii in size. However, it did not suffer the same fate. Starting out as a 1st century garrisoned fort for a Thracian legionary cohort, the city later became a 200 acre fortified store and acted as a base for the 14th and 20th legions. At its peak, nearly 5,000 people lived in the city, which flourished with trades that included tanneries, leather works, bone works, pottery, glassware and metal jewellery. The city had many public buildings including a colonnaded forum, public baths and marketplaces. The Romans abandoned the city around the 7th century, flattening its earth defences and moved to Chester. However, the city continued to be used by Anglo-Saxons and those that followed. Today, only a small central part of the larger Roman city remains including a 7 metre high basilica wall, bath houses, markets and stores and a reconstructed town house. English Heritage currently own the site.

Building Stones

Our first stop was at a stone wall forming part of a barn on the opposite side of Watling Street from the car park entrance. The wall clearly illustrated the main rock types that had been used in the city construction and included some oddities from other sources. The local bedrock being too deeply buried beneath superficial deposits at this location meant that the building stones used had to be brought in from elsewhere. Typically, these sources were located close to the routes of Roman roads and may have been discovered when the Romans were looking for a source of roadstone to ►

construct byways such as Watling Street. Mapping the bathhouse and marketplace walls provided an insight into what each building stone had been used for and at what stage in the city's history.

Bathhouse and Basilica wall within the Roman City

The main building stone rock types included red, buff and pinkish grey sandstones.

The **red sandstone** was fairly uniform in grain size with grains stained from iron oxide and weakly cemented together with calcium carbonate cement. Pebbly horizons and conglomerates within the parent stratum indicate that it was a water-lain deposit placed under wet/dry semi-arid conditions such as those seen today on the drier slopes of the Atlas Mountains in Morocco. Upper Carboniferous in age, the parent stratum is the Salop Formation (formerly the Keele Formation). The source of this building stone has been identified from quarries at Pitchford, located approximately 6km south-west of the city. Its poor strength, due to weathering of the carbonate cement, meant it was mainly used for constructing walls, good examples of which can be seen around the basilica wall, bath houses, markets and stores.

The earliest construction seen within the city included using the Salop Formation building stone in conjunction with clay tiles. The clay was sourced from nearby glacial till deposits. Wall construction included using smarter looking stones to form a double skin and filling the space between with what was effectively rubble. The walls would be constructed in sections, one yard high, before a layer of tile was added, and this helped to provide some structural stability. After each layer of wall was completed, rendering using white lime mortar would be applied to the interior and exterior, which would be left to cure prior to the next layer being added. In places the original limestone render can still be seen on lower parts of the walls. The clay tiles also served to help keep the lime mortar in place and allow it to go off, before the next layer of wall was added. Holes located in the walls are testament to where scaffolding poles had been used during their construction.

Towards the southern end of the city complex are examples where the Salop Formation stone had been used without tiles. This represents later construction, likely during the late Roman period when potentially cash was running out and standards were falling. During this time some extensions and walls were built using recycled stone from earlier structures in the city.

The **buff coloured sandstone** was very variable and comprised homogenous sandstone with gritty and pebbly horizons formed under shallow water conditions with the sand grains being sourced from a desert environment. Iron leaching from overlying stratum occasionally turned this stone a ruddier colour. The parent stratum for this building stone is Ordovician aged Hoar Edge Grit, which was identified as having been sourced from the Acton Burnell area, situated nearly 8km to the south-west of Wroxeter. This stone was much easier to carve and stronger that the Salop Formation stone. It forms a later buttress wall surrounding the bathhouse and in some later extensions to the bathhouse. Again, used in the later Roman period, this building stone was likely to have been falling out of fashion as the city fell into disuse.

The **pinkish-grey stone** comprised gritty quartzite with the iron oxide leached out to form a ganister. This stone had been deposited in low oxygen shallow deltaic swamps and belongs to the ►

Carboniferous Pennine Middle Coal Measures Formation. In places ironstone concretions could be seen associated with this stone. The nearest source for this building stone on Watling Street, is at Red Lake, Ketley, located approximately 11.5km to the east. Its hard nature meant this stone was used for specialist construction such as doorsteps, sills and jambs.

Also included in the wall were lumps of tufa, which had been brought in from Wenlock Edge. The tufa was used as a source for making the lime mortar used to render the finished walls.

The building stone blocks vary in size from around 200mm to just over 0.50m. The bigger blocks were typically used at the base of walls and structures such as colonnades to provide a solid foundation. Smaller stones were used for the body of the main wall as they were easier to carry and manoeuvrable. A clue as to how the larger blocks were moved can be seen as neat rectangular holes cut into the stone, known as lewis holes. The holes splay out inside to allow a three pronged device, called a lewis, to be inserted. The two outer prongs of the lewis were flat wedges, so that when the middle prong was added they filled the hole and provided a strong anchor. Once the lewis was inserted, the blocks could be lifted up and carried.

Other Upper Carboniferous stones and glacial erratics, also seen in the barn wall, are believed to have been brought in much more recently from Eaton Constantine, about halfway between Shrewsbury and Telford. These building stones are believed to have been introduced by the owners of the Raby Estate when they constructed various farm buildings. Wroxeter Roman City lies within this territory.

Outer wall to St Andrew's Church, Wroxeter

Post-Roman Times

Once the Romans abandoned the city and retreated from Britain, they left some of the buildings intact along with the street grid. The city remained inhabited by the local population and traders until the Anglo-Saxons arrived sometime in the 5th Century. The city was finally abandoned sometime during the 6th century, possibly due to plague or when the region was taken over by the pagan Anglo-Saxon King Penda of Mercia. From Anglo-Saxon times onwards, the former Roman town was messed about and pillaged for its building stones. The Anglo-Saxons used river transport, as opposed to roads, where possible and had a ready source of building materials to hand. They 'mined' the city walls and drainage systems to recover the clay tiles made by the Romans. Building stones were generally re-used to construct new buildings in the surrounding towns and villages, particularly churches.

At St Andrew's Church, Wroxeter, and St Eata's Church, Atcham, we saw many examples of stones that had been taken from Wroxeter city and incorporated into the walls. Chisel marks, carvings and lewis holes were a good give away as to the building stones' origins. Where lewis holes were shallow, this meant that the stone had been dressed. The larger building stones from Wroxeter generally typify Anglo Saxon architecture. Later structures - into the 13 century - tended to employ smaller stone sizes, because this was all that was left. The Victorians introduced many exotic stones like alabaster to old buildings (such as St. Eata's) during the 1800s for decorative appeal on alters, floors and tombs. In more recent times, as the original sandstone has weathered, conservation works have replaced blocks with newer looking matching sandstones to save these historic structures. ►

Acton Burnell Castle

Our final stop of the day was Acton Burnell where the Romans sourced the Salop Formation bedrock. Here, we visited Acton Burnell Castle which was built between 1284 and 1293 by Bishop Burnell, Edward I's Lord Chancellor. Parliaments were held here twice, in 1283 and 1285, but by 1420 the castle was abandoned. Today the structure remains as an impressive example of a medieval fortified manor house.

The castle is constructed from the same Salop Formation strata as seen at Wroxeter, however, here the stone has been locally quarried as opposed to having been taken from earlier structures such Wroxeter. In places the original lime cement rendering could also be seen on the walls.

We finished our tour around 4.00 at Acton Burnell after a very enjoyable day with good weather. I would like to thank David for his time and another very interesting visit and we look forward to the next one. ■

Andy Harrison

Birmingham's Erratic Boulders: Heritage of the Ice Age

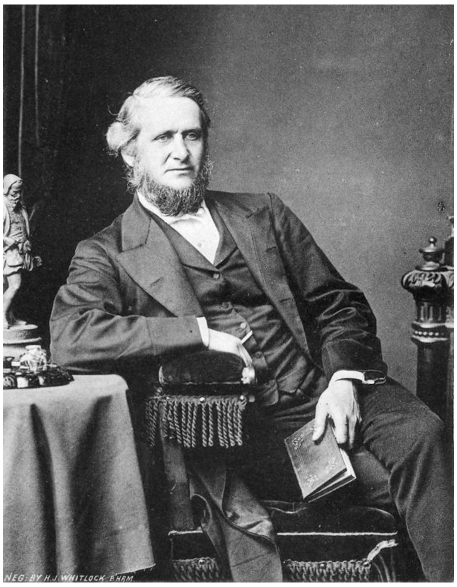
More trails, dates and the story of the Reverend Henry W. Crosskey

Erratic boulder trail leaflets are still being produced as fast as we can manage! The first guided walk on Trail 4 (Woodgate Valley) took place on 29 May, and Trail 5 ('Three Hills Challenge - Calcot, Romsley and Frankley Hills' for cyclists and 'Around Frankley' for walkers) is ready for publication but is just awaiting the removal of a boulder from its current position to a space in New Frankley. There have been numerous unforeseen administrative obstacles in the way of this, so we just have to be patient. At the Frankley Carnival on 24 June the project team will be there with leaflets and activities, and information about all our Trails and other Project activities.

The Frankley Hill boulder gets a facelift

Trail 6 is a cycling trail around Bromsgrove and Tardebigge, nearing completion and due to be launched on 15 July at Bromsgrove Carnival *(see front cover photo for a fine Arenig boulder by a pool above Tardebigge Reservoir).* This leaves just Trail 8 - the Illey Wilderness Trail in the main trail leaflet series for the team to get together in time for its launch in Woodgate Valley Country Park on 12 August. There will be a pre-launch field visit for BCGS on 22 July to give this route its first public test. Do come and join us for this unusual field trip! ►

Work is now well advanced to produce 5 information boards to be installed at strategic sites: Cannon Hill Park, University of Birmingham, Masefield Square, Woodgate Valley and New Frankley. Work is also in progress to create a fully accessible and inclusive trail to visit some of our most accessible and high-profile erratics. There have been two very helpful training sessions to point us in the right direction to create this trail.



Rev. Henry W. Crosskey

Along with the essential work for the project, Trail 5's connection with the erratics of Frankley Hill and their significance in late 19th century glacial research, inspired me to complete an article - long intended - on the story of the Reverend Henry W. Crosskey and the Erratic Blocks Committee. He was chairman of this committee for 20 years, and the interweaving of Crosskey's geological activities with his pastoral and social work makes a fascinating story, especially his passionate involvement in the finding, recording and preservation of erratic boulders. He would surely have approved of the aims of this project! The article is too long for this publication, but we hope you will be inspired to look at it here: https://erraticsproject.org/Henry_Crosskey/

We will soon be seeking help in preparing the Illey Wilderness trail leaflet, the nearest route to our Black Country base in Dudley. We hope you will be able to get involved! ■

Julie Schroder (BCGS rep. Erratics Project steering group)

For more information:
https://erraticsproject.org/
https://www.facebook.com/birminghamerratics
https://www.twitter.com/erraticsproject
https://www.instagram.com/erraticsproject

The Enigma of Quartzites

Quartzite is a hard, blocky rock which exhibits irregular sharp fractures and tends to shatter. It is usually white to grey in appearance. Colours are caused by staining and impurities. Red colour is commonly due to varying amounts of haematite. Quartzite is one of the most physically durable and chemically resistant rocks found at Earth's surface. Where present it commonly forms ridges and scree. Soil cover is either thin or absent. Some quartzites contain just enough weather-susceptible nutrient-bearing minerals such as carbonates and chlorite to form a loamy, fairly fertile though shallow and stony soil. The term quartzite has a different meaning to some than to others. In the USA a quartzite is a metamorphosed sandstone generally formed during regional metamorphism. Elsewhere it can be applied to diagenetically altered (pure) sandstones. Commonly the prefix of meta or ortho is used to distinguish between the two.

Metaquartzites are commonly associated with mountain-building events at convergent plate boundaries. Here the sands deposited on continental margins become metamorphosed into quartzite by the intense pressure of a plate collision and are often associated with deep burial. We should therefore expect to find quartzites within all ancient continental collision plate boundaries. ►

The Shropshire Stiperstones forms a prominent ridge

Definitions and Characteristics

Orthoquartzite: Some rocks show the macroscopic characteristics of quartzite, even though they have not undergone metamorphism at high pressure and temperature. These rocks have been subject only to the much lower temperatures and pressures associated with diagenesis, however diagenesis has cemented the rock so thoroughly that microscopic examination is necessary to distinguish it from metamorphic quartzite. Thin sections may reveal quartz overgrowths.

The classifications of Folk (1954) and Pettijohn (1954) classify sandstones containing 95% or more quartz to be orthoquartzite. McBride (1963) classifies sandstone with 95% quartz or more as quartzarenite. Orthoquartzite (in the narrowest sense) is often 99% SiO_2 with only very minor amounts of iron oxide and trace resistant minerals such as zircon, rutile and magnetite.

As a general rule at least ninety percent of a quartzite rock is quartz. Although few fossils are normally present, the original texture and sedimentary structures are preserved. ►

Weathering of variations within the quartzite highlights the sedimentary features

This inverted image shows a conglomerate with a channel feature above

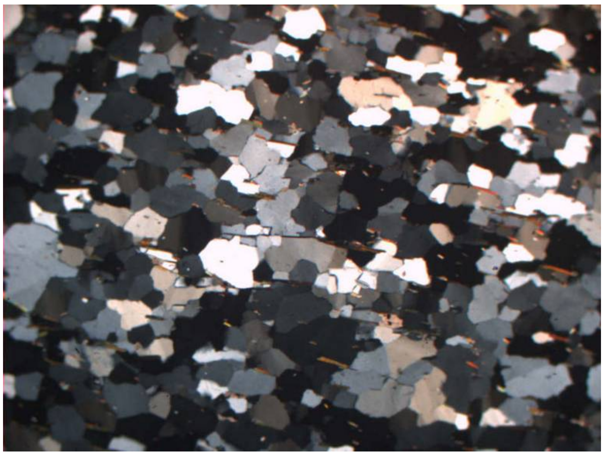
The Shropshire Stiperstones quartzite

Quartz arenite and orthoquartzite are both composed of greater than 95% detrital quartz. The terms *orthoquartzite* and *quartzarenite* effectively mean the same. However, the use of the term quartzite implies metamorphism to many and could cause confusion whereas the term quartz arenite is universally accepted as being a sandstone of sedimentary origin. The typical distinction between a true orthoquartzite and an ordinary quartz sandstone is that an orthoquartzite is so highly cemented that it will fracture across grains, not around them.

It is often difficult or impossible to differentiate quartz arenite from metaquartzite. The transition of sandstone into quartzite is a gradual process. H.M. King in Geology.com states: "A single rock unit such as the Tuscarora Sandstone of the central Appalachians might fully fit the definition of quartzite in the parts of its extent where its quartz grains have been metamorphosed into a durable interlocking mass. It would be better called 'sandstone' in other areas". https://geology.com/rocks/quartzite.shtml

A specimen of metaquartzite showing its conchoidal-like fracture and granular texture. By Gabriel Haute Maurienne, Wikimedia Commons

A **Metaquartzite** is a non-foliated metamorphic rock composed almost entirely of quartz. It is formed when a quartz-rich sandstone is altered by the heat, pressure, and chemical activity of metamorphism. The distinction between an orthoquartzite and a metaquartzite is the onset of recrystallization of existing grains. The dividing line may be placed at the point where strained quartz grains begin to be replaced by new, unstrained, small quartz grains, producing a *mortar texture*[1] that can be identified in thin sections under a polarizing microscope. With increasing grade of metamorphism, further recrystallization produces *foam texture*[2] characterised by polygonal grains meeting at triple junctions, and then *porphyroblastic texture*[3] is characterised by coarse, irregular grains, including some larger grains (porphyroblasts) *https://en.wikipedia.org/wiki/Quartzite*. During the change from a granular to a crystalline texture shell material will be destroyed, but the rock may retain some original sedimentary features. To be classified as a quartzite by the British Geological Survey, a metaquartzite must contain at least 80% quartz by volume. ►



Quartzite under a microscope

A specimen of the Bo Quartzite collected near South Troms, Norway, observed through a microscope in thin-section under cross-polarized light. The quartz grains in this view range in colour from white to grey to black depending upon their optical orientation. The important thing to notice is how they fit together in a tight interlocking network. The interlocking nature of the grains gives quartzite its incredible durability.

Photo by Jackdann88, Wikimedia Commons

Occurrence

A search for quartzites suggests they have a wide global distribution but the occurrence seems to be restricted to narrow periods of geological time within the Precambrian and Lower Palaeozoic. The youngest are the orthoquartzites of the English Midlands which are Ordovician in age. The lack of post-Ordovician quartzites suggests:

- perhaps something was fundamentally special at the time of deposition and diagenesis, creating environmental conditions conducive to the formation of orthoquartzite.
- lithology naming and use of the term quartzite has been inconsistent, e.g. in the Alps metamorphosed sandstones have been referred to as meta psammites.

The English Midlands provide us with some splendid examples from a Cambrian marine transgression over rocks of the Ediacaran Period. (This spans 96 million years from the end of the Cryogenian Period 635 million years ago, to the beginning of the Cambrian Period 538.8 Mya. It marks the end of the Proterozoic Eon, and the beginning of the Phanerozoic Eon.) We see a basal Cambrian orthoquartzite in Nuneaton, Malvern and the Wrekin. There is some doubt as to the exact age of these orthoquartzites. The Stiperstones Quartzite was considered as Cambrian but is now listed as Ordovician.

All the above examples have been laid down on the quiescent Avalonian margin of the Iapetus ocean. They all show sedimentary structures and trace fossils consistent with their being laid down in a very shallow marine environment.

There is an additional orthoquartzite at the Lickey Hills just SW of Birmingham, which was also considered as Cambrian but is now been dated as Ordovician. The Lickey Hills deposits suggest a shoreline too far to the east to fit with the rest of the evidence for the modelled Ordovician shoreline.

Provenance

In order to become a quartzite the original sandstone should contain 80-95% quartz. Such a source rock would be an acidic igneous rock, probably from a denuded ancient shield. The eroded material would be transported to the sea by rivers of sufficient length to deliver a mature deposit, e.g. 'Gilbert-type' deltas produce large volumes of prograding sand deposits which, when worked by tidal currents and possibly longshore drift, could produce quartz-rich beach and near shore deposits. Alternatively or in combination, a sea transgressing onto an ancient land surface could create such deposits. The deposits would be worked in a high energy shallow marine setting where winnowing action could ensure a well-sorted clean sand. The key factors are that sediment supply would need to have been high and basin subsidence ongoing to provide the accommodation space for the thicknesses of the deposits we see today.

Sand to Quartzite

Orthoquartzite

For a sand to transform to an orthoquartzite requires pressure solution of the quartz to take place. The pressure temperature (PT) conditions required to transform sandstone to quartzite depend on a number of conditions. ►

Conditions assisting conversion from sandstone to orthoquartzite

1. Well sorted sediment with 80-95% quartz.
    - Granitic arenaceous source, big rivers with prograding Gilbert type deltas and longshore drift; onshore desert conditions (with a constant supply of windblown sand); high energy marine depositional setting (winnowing) with good sorting; high depositional rates; subsiding basin creating accommodation space.
2. Angular to subangular fine quartz grains.
    - Smaller grains give a larger surface area with more opportunity for grain to grain contact and pressure solution.
    - Larger grains will require higher PT conditions
3. A thin film of water around the grains enables earlier onset of pressure solution.
4. A small amount of clay material within pores can act as a catalyst to the onset of pressure solution.
    - Clay coating of grains will prevent pressure solution occurring.
5. Silica entering solution at the point of contact crystallises out on the quartz grain surface within the pore space. This is an effective means of transfer of silica within the pore.
6. Ability of the sands to dewater thus maintaining normal hydrostatic pore pressure.
    - Prevention of fluid escape from the constricting pores will create overpressure and reduce effective stress. This will inhibit pressure solution and the onset of transformation from sandstone to quartzite.
7. As beds compact, grains redistribute, porosity decreases and pressure solution commences, the beds will get compressed vertically, and extend laterally

Conditions preventing or inhibiting conversion from sandstone to orthoquartzite

8. Rapid deposition (storms) i.e. poor sorting.
    - In a high energy marine environment seas will normally redistribute such deposits, making them a rare feature. However if the storm first created a scour prior to deposition then the feature may be preserved as a sandstone within the quartzite.
9. Rounded and/or larger grains. These give low point to point contact and a decreased surface area for pressure solution to commence.
10. Grain coating, pore fluids such as oil, gas, salt.
11. Clays, volcanic ash, organic inclusions.

Unknown factors

- Impact of grain frosting
- Impact of rock textures
- P/T relationship with **time** for a sandstone to transform to orthoquartzite
- Acidity of the groundwater
- Are the silica cements of the same type as that of the silica grains? The P/T relationship at the time of crystallisation of quartz within a granite would be very different from that existing at the time of pressure solution during diagenesis, particularly in the pore space environment with pore water and traces of other minerals. Chalcedony and opal are the low temperature SiO_2 variations.
- If silica enriched water from pressure solution will commence at burials reaching 70°C this suggests about 1750m depth (assuming 4°C per 100m). At this depth the overburden pressure would be around 396 bar in a tectonically relaxed basin. The commonly held belief for Lickey ►

Quartzites is a burial of 1000m which would equate to around 40°C and an overburden pressure of about 286bar. These temperatures and pressures seem extremely low suggesting time and other factors may be required. *(An elevated geothermal gradient could have existed at the time of deposition of the Lickey deposits as seen by the interbedded tuffaceous sandy clays in Barnt Green Road Quarry.)*

- Is the temperature gradient that important? We see evidence of the fact that rocks that start to fold under the pressure of ice movement, (rock creep). Glacial till cobbles show indentations (pressure solution?) where they have been in contact with other cobbles. Friction causes heat, therefore the temperature at the point of grain contact may be greater than the regional temperature gradient. On one hand silica enriched fluids are generally associated with volcanic centres / high heat flow e.g. silica terraces. On the other hand flowing water will slowly erode rocks creating gullies and flow pathways.
- Under regional metamorphic settings it is possible that once silica enters solution (at depth) then, due to buoyancy pressure, it can permeate along hydraulic pathways into overlying shallower rocks with sufficient porosity and permeability, where it could precipitate out. To do this it must drive out the existing fluids. The affinity of the rock to the silica-rich invading fluid must be greater than to the pore fluid (seawater?) being displaced (wettability).

Metaquartzite

Intermediate to high grade regional metamorphism associated with convergent plate boundaries, provides a mechanism to generate sufficiently high pressures and temperatures for the re-crystallisation of the quartz and subsequent tectonic elevation. Metaquartzite is a metamorphic rock with a crystalline texture. During transformation to quartzite the impurities become concentrated along hydraulic pathways creating a striking visual effect *(see photo below)*.

Uses

Quartzite has been used since prehistoric times for stone tools. It is presently used for decorative dimension stone, as crushed stone in highway construction, and as a source of silica for production of silicon and silicon compounds. ►

Polished metaquartzite

(with apparent stylolites)

During transformation to quartzite the impurities become concentrated along hydraulic pathways creating this visual striking effect.

Photo by James St. John, Wikimedia Commons

Conclusion

The term 'quartzite' has not been used in a consistent manner around the world nor through time. Quartzite as a product of metamorphism (metaquartzite) has probably been used more consistently through time and internationally, although the use of meta psammite has been common in alpine studies, and metasandstone (BGS). Quartzite as a product of diagenesis, (orthoquartzite), has been called quartzarenite, psammite, silica cemented sandstone or simply sandstone. Commonly the prefix (meta or ortho) is simply not used. In addition, the classification schemes as defined by Folk, Pettijohn and McBride based on a 95% quartz content, have not been consistently applied. A number of the quartzite exposures of the Lickey Hills and the Nuneaton Ridge do not conform to this classification scheme, having significantly less quartz than the required 95%. It is clear that when reading papers relating to orthoquartzite exposures the reader needs to be aware that conformity to definitions may be somewhat relaxed. ■

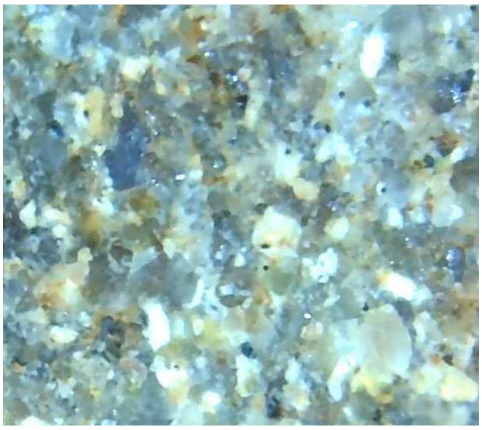
Ray Pratt

[1] **Mortar texture:** This consists of larger mineral fragments set in a groundmass of crushed material derived from the same crystals.

[2] **Foam texture:** This is a non-standard reference to a texture in metamorphic rocks in which some minerals (quartz for example) meet two other grains of the same mineral at 120 degree angles - the soap-bubble-like angle. This angle develops because it minimizes surface energy, which can happen during metamorphic re-equilibration.

[3] **Porphyroblastic texture:** Relatively large single crystals which formed by metamorphic growth in a more fine-grained matrix.

Lickey Hills Barnt Green Road Quarry (BGRQ) Quartzite



This quartzite sample from BGRQ in the Lickey Hills (left) would be more accurately described as a lithic arenite.
On the right is a x5 magnification of the same sample showing feldspars (white), and dark lithic grains.

Mike's Musings No. 45

Some thoughts on Pebble Shape - Part 2

In Part 1, some basic methods of measuring particle 'shape' were established, and the main factors influencing shape development considered. We now look at some practical discussions drawn from the literature specific to 'pebbles'.

It appears that discussions about pebble shape have a longer history than I have suggested so far. The oldest reference I have come across dates from 1834 when Palmer[1] discussed the role of wave action in sorting beach pebbles both by size and shape. A contribution by Cornish in 1898 suggested that the size and shape of beach gravels depend on the natural fragmentation of the source outcrop, modified by wave action.

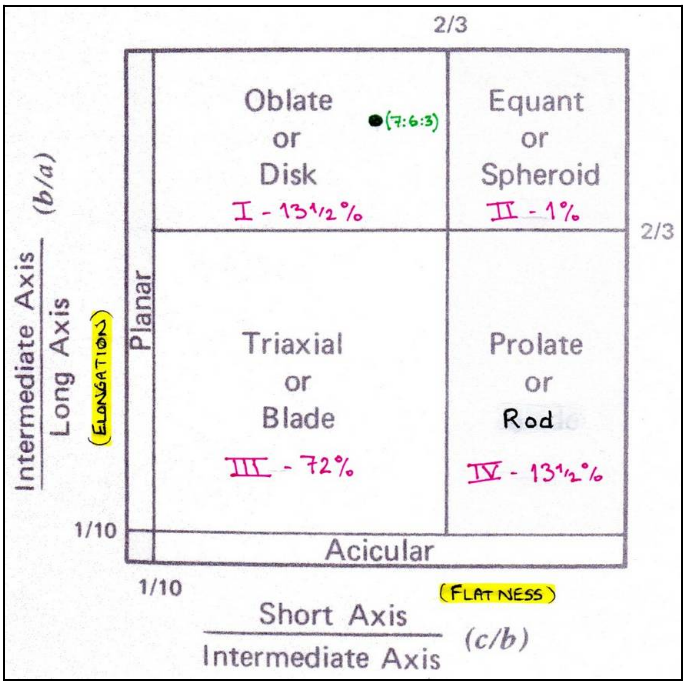


Figure 1: A Zingg diagram

The question of pebble shape first caught my interest in an article that wondered why it is very rare to find near-spherical pebbles on the beach. The enquirer provided some statistical measurements derived from a 'random' collection of beach pebbles (but not so random as to exclude all pebbles that were deemed to be 'not well-worn'), and concluded that the 'ultimate stable configuration' seemed to be flattened ovoids with average dimensions of the three principal axes (a,b,c or x,y,z) in the proportion of 7:6:3. This point on a 'Zingg diagram' is marked on Figure 1, and falls fair and square in the oblate (or disc) zone.

Simple mathematical probability (apparently... my maths is too poor to comment!) shows that isotropic pebbles subjected to 'random erosion' will fall within the four 'Zingg fields' (I – IV) in the following proportions: I - 13.5%, II - 1%, III - 72%, IV – 13.5% [Fig. 1]. Clearly, then, there seems to be a strong bias shown by the beach pebbles with a 7:6:3 shape, which are much flatter (oblate) than the maths predicts.

The original enquirer suspected that the erosion process on beaches was undoubtedly complex, but would nevertheless be statistically regular (as regular as the swash and backwash, to-ing and fro-ing of pebbles by wave action?) and suggested that at least part of the explanation might be that a 'chance asymmetry' led to a profound bias in the ultimate shape of a beach pebble. Other sources have come to the conclusion that wave abrasion is crucial to the final pebble shape, and that original shape and internal fabrics are of secondary importance at best. This is supported by Lord Rayleigh's observation that he was able in the laboratory to produce flattened pebbles similar to those on beaches from *rock fragments lacking internal planar structures.* ►

Further comments centre on the fact that beaches often have several different 'regimes' - flatter and steeper areas (either side of berm crests [Fig. 2]) brought about by differential tides and varying wave strengths dependent on climatic factors. This results from a contrast in the way pebbles on a beach interact with one another. On flatter slopes they predominantly tend to slide over one another, whilst on steeper slopes there is a greater tendency for pebbles to roll about, particularly pebbles which are 'rounder' in shape. Gravity and buoyancy may also play a part in favouring, or otherwise, a sliding over a rolling motion, also influenced by pebble shape.

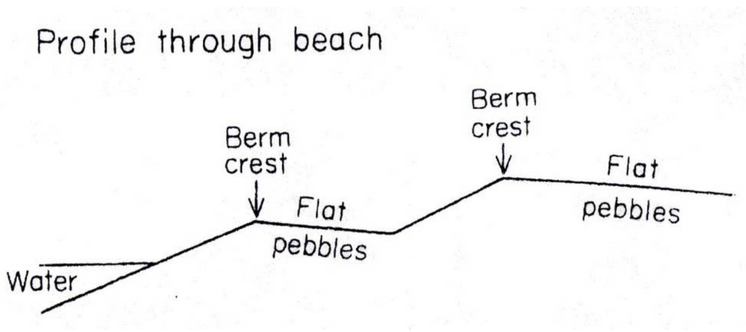


Figure 2: Beach Profile showing 'Berm Crests'

The rollability factor might also deplete a beach of pebbles of rounder shape during the early stages of beach development, particularly in higher energy (stormy?) environments, which would again result in a population of 'over-flattened' pebbles on any particular beach. (Incidentally, rollability is a dominant factor in the case of one familiar lithology where sand-sized grains are involved - oolitic limestones; but this case is somewhat irrelevant as the shape of these grains are a product of accretion, not erosion!)

Despite Lord Rayleigh's intervention, it seems intuitively probable that 'starting shape' is a factor of some significance in determining the subsequent 'shaping history' of a piece of rock, and judging by published discussions I'm not alone in thinking this. My observation is that most lithologies come with a 'starting shape bias' due to some inherent planar fabric: bedding in sedimentary rocks, cleavage or foliation in metamorphic rocks and some degree of crystal alignment - flow texture - in some igneous rocks. Some commentators have also pointed out that even apparently structureless quartzite pebbles, composed almost entirely of quartz crystals, may have an inherent internal fabric produced by a generally preferred alignment of the longer optic 'c' crystallographic axis. In reality, there are few lithologies that are likely to be truly isotropic. It seems probable that an initial flatness in a pebble will be further accentuated through rolling, and particularly sliding interactions, resulting in a tendency towards the 'over-flattening' reported at the outset (7:6:3 axial proportions). ►


Figure 3: A selection of pebbles from Nash Point, Glamorgan Coast...


Figure 4: ...and the beach from whence they were collected

Figure 5: Nash Point pebbles in close up

Flint and similar forms of cryptocrystalline quartz are perhaps the 'most isotropic' pebbles we find on many of our beaches. Indeed, the flint pebble has been compared with the loess particle (silt-sized quartz grains). Both are about as isotropic as things come and both undergo considerable breakage before reaching their 'mature sedimentary state'. Thus, it has been suggested that pebbles and silt particles are ideal for shape-study analysis, while sand grains 'carry too much of their igneous history' to be of real value.

Returning to the original question, amidst all the literature it seems that the occurrence of spherical beach pebbles is indeed vanishingly rare, for all the reasons so far explored. But why, then, should there be any beaches where such shapes predominate? Perhaps we can draw conclusions from one instance where such a condition has been reported. Just north of Nash Point, on the west coast of Glamorganshire, a small patch of beach about 10m², nearly all the pebbles are near-spherical, ranging in size from around 3-15cm in size [Figs. 3-5]. The near vertical cliffs are composed of regular couplets of hard limestone and soft shale (Lower Lias) with equally regular orthogonal joints [Fig. 6]. The bed thickness and joint spacing evidently conspire to produce a fairly dominant supply of cubic rock fragments which, despite their weathered shape, do not get carried very far (the site is close to a 90° change in cliff direction), so perhaps two opposing currents cancel each other out, limiting or containing pebble transport, resulting in this unusual phenomenon.

Figure 6: Bedding and jointing in the cliffs supplying the beach with pebble material

I have recently come across a similar condition operating on sandstone cliffs at Kilmurry Bay on the Dingle Peninsula. Again, a combination of bed thickness and joint spacing in a limited location seems to produce a fairly regular supply of regular cuboidal blocks that deliver very well rounded, if not quite so spherical, large pebbles (strictly cobbles and boulders) to the nearby storm beach [Figs. 7/8]. Perhaps then 'original shape' *can* be a dominating factor, even if this is not always the case.

I fear I have allowed myself to become obsessed with beach pebbles, so moving on I will mention a couple of broader investigations. ►

Figure 7: The Storm / Boulder Beach at Kilmurry Bay, Dingle Peninsula…

Figure 8: …and the nearby cliffs from which the boulder beach is supplied

A study by Dobkins and Folk of pebbles on a Tahitian beach (that's the kind of field project one would happily volunteer for!) consisting essentially of just one fairly isotropic lithology (basalt) concluded that the beach pebbles were consistently flatter than those found in the streams that carried them to the shore. They attributed this to a difference in the mode of transport of pebbles in different environments:

Saltation: (the bouncing of pebbles carried along by flowing currents) favours spheroids
Rolling: (the 'turning over' motion of a pebble on its axis) favours rods
Sliding: (the 'slipping along' of a pebble on its surfaces) favours discs

whilst immobility favours the pebble remaining the shape it began with!

The last factor explains why larger pebbles will resist motion the most, requiring higher energy environments for substantial re-shaping. This also controls the degree of sorting achieved in any sedimentary deposit. The other three factors helped to explain their observation that *river pebbles* tend to have *higher sphericity* but *lower roundness* values than beach pebbles - 'flatness' being the principal difference. They also noted a difference between *low energy beaches where the **smaller** pebbles were flattest* and *high energy beaches where **larger** pebbles were flattest.*

Figure 9: The Funzie Conglomerate, East coast of Fetlar, Shetland

Another study by Sames, on quartzite and chert particles, likewise came to the conclusion that *fluviatile* environments produced pebbles of *lower roundness* (more angular) while *littoral* environments produced pebbles of *higher roundness* (smoother, with fewer surface irregularities).

Finally, pebble shape variations have been studied in the context of tectonic deformation. A notable example is the case of the kilometre-thick lower Silurian Funzie (pronounced 'fenny') Conglomerate, exposed on the east coast of Fetlar (Shetland) [Fig. 9]. The conglomerate consists largely of quartzite pebbles set in a phyllite matrix and has the useful property that many of the pebbles weather out for easy handling [Fig. 10]. Measurements of pebble shape and subsequent 'Zingg-style' analysis (presented by Flinn in a slightly different manner and based on certain assumptions) reveals that flattening deformation (discs) was most intense close to the thrust contact with an adjacent serpentinite, whilst elongation deformation (rods) was increasingly dominant further away. This may sound rather esoteric: suffice to say that such studies help to unravel the detailed history of tectonic events. ■

Figure 10: Funzie Conglomerate: a selection of 'stretched pebbles' extracted from the Fetlar cliffs

Mike Allen

1. As numerous sources have been used in the compilation of this article, I have not provided any further references than the names in the text. All references are acknowledged, and full details can be provided on request.