BATH GEOLOGICAL SOCIETY

Journal

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50th Anniversary 1970-2020

SOCIETY ACTIVITIES 2020

LECTURE PROGRAMME

February 6th
AGM and a talk by Professor Toby Tyrell, Southampton University on the subject of 'Did Ocean Acidification kill off Calcifiers at the end of the Cretaceous'

March 5th
Thomas Land, Southampton University talked about 'Prehistoric behaviour; from dinosaurs to sea scorpions'

April / May - meetings cancelled due to COVID 19 Pandemic lockdown.

June 4th
Simon Kay, retired petroleum geologist; 'The history of Oil exploration in Southern England'

July 2nd
Dr Michael Oates, 'Ammonites from Mythology and Folklore to Geological relevance'

August 6th
Stuart Blake, Director of the Lochranza Centre; 'The Isle of Aran – one small island with many great stories'

September 3rd
Dr Doug Robinson retired from Bristol University; 'The Whin Sill and the geology of the Alston block'

October 1st
Jonathan Turner, Radioactive Waste Management; 'What is a geological disposal facility and what opportunities does it present for the geoscience community?'

November 5th
Dr Ben Moon Bristol University; Ichthyosaurs

December 3rd
Professor Tim Elliott, Bristol University; 'The Chemical Evolution of the Earth'

FIELD MEETINGS

Saturday, 29th February
Brown's Folly Nature Reserve
Leader: Graham Hickman, Bath Geological Society

Tuesday, 15th December
Bath Geological Society Christmas Social on Zoom,
Leader: Graham Hickman

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Cover photo: Alethopteris, Maurice Tucker. See article on pg. 35

Chairman's Report

When I took on the role of Chairman at the February AGM I had great hopes for a full and active programme during 2020. The year had begun like any other year; our first two lecture meetings were held as normal in BRLSI, Queen square. However, during March the UK became increasingly concerned by the spread of the new coronavirus (COVID-19). BRLSI closed their building to the public on March 17th 2020 and by March 23rd the government lock down began. This was an unprecedented event, something nobody had anticipated or planned for. With people being asked to stay home and only go out for essential grocery shopping or medical needs the country ground to a halt.

The Committee sprang into action informing members, and speakers, of the cancellation of the immediate upcoming programme. As the realization dawned that this was going to be more than just a few days or weeks, the Committee met via a phone conference call on April 22nd to discuss a way ahead. After testing the Zoom video application it was decided to continue the lecture programme using this virtual technology, a monthly Zoom licence was purchased and our speakers were approached to see if they would deliver their lectures remotely. Unfortunately all field meeting had to be cancelled. A monthly newsletter was started to inform members of developments and encourage member engagement. As I write this, in October 2020, the Society has issued 7 newsletters. We are very grateful to all the authors who made time to contribute articles enabling us to issue newsletters almost every month since the March lockdown.

Zoom lectures

In order to hold our lectures virtually we needed to ensure as many of our members as possible were able to use the technology. Therefore, on May 28th a Zoom test meeting was held with members to check setting and to familiarise everyone with the technology. The Zoom test proved a great success with many people seeing one another for the first time since March, the social aspects of this reunion cannot be emphasised enough. As the lockdown dragged on through April, May and June emotions fluctuated, it was nice to communicate with neighbours and see less traffic on the roads, but there was also frustration at seeing shops closed and holiday plans cancelled.

Simon Kay, our June speaker, was approached and agreed to present his talk over Zoom. After a trial run with just the Committee present, on June 4th our first ever Virtual lecture was given by Simon Kay. Simon presented his talk on the history of oil exploration in Southern England from the comfort of his home in Bradford-on-Avon. The feedback from members was positive and we have continued to deliver the lecture programme virtually for the remainder of the year.

In July, Dr Mick Oates presented his talk on Ammonites from his home in Barton upon Humber, North Lincolnshire. As members became more familiar with the workings of Zoom questions and answer sessions the end of the talks became livelier. During the part of the lock down a national 'clap for the NHS' was instigated every Thursday at 8pm and we had scheduled our Zoom calls to finish by 8pm allowing participation. However by mid-summer this ceased and following the talks some members stayed online to chat. Updates from Dr. Sam Medworth as an NHS insider were particularly interesting.

During normal times the Society takes a summer recess in August, but with a summer holiday season blighted by the pandemic and with most people home, the Committee decided to add a zoom lecture meeting on August 6th. Stuart Blake gave us a 'geological talk-tour' around the Isle of Arran from his home in Lochranza on the northern part of Arran. Talks of future holidays or field trips to Arran resulted.

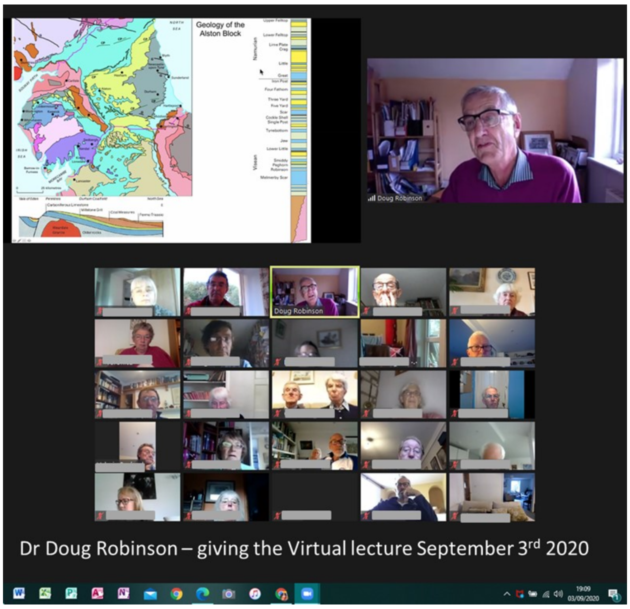
0n September 3rd our lecture was given by Dr Doug Robinson on the Whin Sill and the geology of the Alston Block, in the northern Pennines. Doug's work has now been published in the Proceedings of the Yorkshire Geological Society. The contact metamorphism showed that heat flow in Teesdale area lasted much longer than other areas and points to the source of the Whin Sill magma.

In October Jonathan Turner gave us a very thought provoking lecture about radioactive waste disposal and the design of deep geological disposal sites. The issue has as many social aspects to overcome as it has technical geological ones and Jonathan described the requirements for undisturbed burial design for 1 million years and to militate against future glaciations and earthquakes.

The Zoom lectures have been regularly attended by 25 to 35 people; this has enabled the Society to continue meeting and connecting with our members. Distant members have been able to join in and we were able to welcomed Elizabeth Devon, a former Chair and Committee member of the Society, who now lives in Northumberland. Other members such as Peter Larkin were able to listen to the lectures from the geotechnical vessel Omalius in the North Sea.

Whilst the lack of social interaction on virtual meetings is certainly a disadvantage, we have been given lectures by people who, ordinarily, would be too far away from Bath for this to be possible. Our lecture programme has been delivered at much lower cost than physical meetings and BRLSI have agreed to credit and carry forward the money we have spent on renting lecture rooms we have been unable to use during 2020. It is worth saying however that the speakers have a somewhat different experience presenting over Zoom. With the audience on mute there are none of the usual feedback signs such as laughter at the jokes or snoring to suggest the speaker needs to cough, or move on quickly! The speakers have also missed out on the customary pizza before the evening lecture, the warm welcome by

Polly Sternbauer and the tea and biscuits faithfully provided by Jan Williams.



Dr Doug Robinson – giving the Virtual lecture September 3rd 2020

The 50th Anniversary Celebration

At the onset of 2020 the Committee was preparing to organise a weekend event to celebrate the 50th anniversary of the Society. A date in October had been chosen and enquiries were being made for a venue and a line-up of mini talks. A grant of £350 was obtained from the Geologists' Association and local groups in the South-West were to be invited to celebrate our anniversary achievement. Unfortunately this has had to be postponed and we will endeavour to hold this event in 2021.

Field Trips

The only field trip we were able to run was to Brown's Folly on February 29th. All other trips in 2020 were unfortunately cancelled. A number of organisations have begun running field trips again and we are looking to run some trips in 2021 with social distancing measures in place.

The 2020 Committee

Chairman: Graham Hickman
Treasurer: Phil Burge
Membership Secretary: Polly Sternbauer
Meetings Secretary: Anne Hunt
Journal Editor & Zoom: Mellissa Freeman
Field Trip Secretary: Sue Harvey
Field Trip Safety: Bob Mustow
Webmaster: James McVeigh
Linda Drummond-Harris
Professor Maurice Tucker

I have been very grateful to the hard work and commitment of the Committee during this difficult time. Their efforts have resulted in the continued the programme of Zoom lectures, updating the website and producing the newsletter/journal. The Committee has worked hard communicating news and re-building the membership. The financial implications have been analysed and Zoom technologies grappled with. Under normal conditions the committee meets 3 or 4 time per year but under these situations we have met virtually about 6-7 times. The strength of a Society like ours is measured by those who volunteer their time and I am indebted by those on the committee.

The saying 'hindsight is 20/20' can certainly be applied to the year 2020. It's incredibly hard to predict the future, we are all in this together, if you have any comments or suggestions we would love to hear from you. On behalf of your committee thank you again for your support.

Graham P Hickman
chairman@bathgeolsoc.org.uk

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Arbroath to Auchmithie – Old Red Sandstone Extravaganza

By Charles Hiscock

Arbroath, a town about the same size as Chippenham, is situated on the north shore of the Firth of Tay 16 miles east of the city of Dundee. It is the largest town in the county of Angus and is famous for 'Arbroath Smokies', salted haddock which are then dried and smoked over a hardwood fire. They have been produced in the Arbroath area since the 18th century, having been started in the village of Auchmithie, 3 miles east of Arbroath and now, under EU rules, have to be made within 4 kilometres of Arbroath. Indeed, as one walks around the harbour area the smell of smoke mixed with fish is quite noticeable.

In the middle of the old part of Arbroath, on the highest point and dominating the sky line is the ruined abbey. Built from the local stone, it was founded in 1178 and dedicated to St Thomas Becket. It was not completed until 1233 and, in 1214 the founder, King William the Lion, was buried in the chancel. His tomb is marked by a tombstone in front of the high altar in the quire. As with all monastic establishments, the abbey was dissolved by Henry VIII, fell into ruin and was 'quarried' by the local inhabitants for buildings in the town. The abbey came to national attention in 1951 when, early one morning, the caretaker was surprised by four young men who told him that they had deposited the 'Stone of Scone' in front of the altar. The 'Stone' had been stolen from the Coronation Chair in Westminster Abbey earlier that year. The four men departed as quickly as they had appeared, leaving the surprised caretaker to report to the authorities. The 'Stone' was returned to Westminster but later repatriated to Edinburgh while a copy of the stone was made and can be seen in Arbroath Abbey.

The abbey has substantial remains of which the most obvious feature is the bright red sandstone and conglomerate, imparting an impressive presence to the ruins in bright sunlight (fig. 01, 02). The stone was quarried by the monks from the cliffs to the east of Arbroath which lie along the back of the beach and extend for many miles. This article describes the rocks and geological features which outcrop in the three miles or so from the eastern end of Victoria Park, the grassy area east of the harbour. The geological trail is part of the Whiting Ness (the headland at the east end of Victoria Park) to Ethie Haven SSSI, selected for its geological interest, coastal grassland, birds, flower and insect species. The tarmacked footpath passes along the top of the cliffs and allows the observer to see all the geological features described with the exception of a couple which are only visible from the beach.

Fig. 1: Arbroath Abbey

Fig 2: Arbroath Abbey

The headland at the east end of Victoria Park, Whiting Ness, displays the angular unconformity between the conglomerates and sandstones of the Upper Devonian Burnside Sandstone Formation 359-385mya and the fine sandstones of the Lower Devonian Arbroath Sandstone Member 398-410mya (fig. 03). The unconformity is irregular and reflects a period of non –deposition of about 40 million years. The Lower Devonian sandstone is tilted about 18 degrees south-east while the Upper Devonian dips 10 degrees south-south-east. On the wave cut platform below the Ness can be seen marks cut into the sandstone surface by the wheels of the carts the monks used to remove the stone to the Abbey (fig. 04).

Fig. 3: Whiting Ness unconformity

Fig. 4: Cart tracks in wave cut platform

A short distance east of the Ness, the unconformity is well displayed in the headland, marked by the irregular surface of the fine Lower Devonian sandstone and the base of the Upper Devonian conglomerate (fig. 05). As one walks along the footpath a significant geo (inlet) is reached where two levels of erosion mark two periods of sea level in the past (fig. 06).

Fig. 5: East of Whiting Ness

Fig. 6: Geo

The next feature is 'Needle E'e', (local dialect for Needle's Eye) which is a collapsed sea cave opened out by the sea during stormy periods. It lies about 23 feet above the present beach, having been formed when sea levels were that much higher (fig. 07).

Fig. 7: Needle's E'e

Fig. 8: Cross bedding, Maiden's Kirk

Another cove, formed when the sea level was higher than now, is 'The Mermaid's Kirk' where, high on the east side, cross-bedding in the Lower Devonian sandstone can be seen (fig. 08). Here a north-east trending fault has been opened up by the sea forming a geo approximately parallel to the line of the cliff. Access to the Kirk is hazardous so only the foolhardy attempt to get a photo!

Fig. 9: The Crusie

The Crusie is the next feature that the walker comes on, where joints in the Lower Devonian sandstone have been excavated by the sea to form caves. These have fallen in, forming the blowhole called The Crusie (fig. 09) on the right and a geo to the left of the observer. Another blowhole is seen some distance along followed by a geo called 'Dickmont's Den'. This is the largest of the geos, being 200 metres long and 100 metres wide, cut mainly in the Lower Devonian sandstone but with some Upper Devonian sandstones and conglomerates perched on the north-east wall (fig. 10). Beyond the Den and lying some distance from the cliff is The Deil's Head, a sea stack in the Lower Devonian sandstone which clearly shows the dip of the bedding (fig. 11), followed closely by a cleft parallel to the cliff line produced by erosion along a small seaward dipping fault line. Continued erosion along the fault line could eventually produce a sea stack similar to the Deil's Head.

Fig. 10: Dickmont's Den—fault controlled geo

Fig. 11: The Deil's Head

About 2 miles from the start, the walk drops down into Carlingheugh Bay providing excellent views of further structures. Two sea stacks project away from the cliff line, one of which gives a passable impression of The

Sphinx (when seen at the right angle and an eye of faith!) while alongside is an elongate stack with two mounds – The Camel's Hump (fig. 12).

Fig. 12: The Sphinx and Camel's Hump

Fig. 13: Dark Cave Fault (Lower ORS & Upper ORS

Across Carlingheugh Bay in the headland there is a fault, dipping at about 80 degrees, which separates the Lower Devonian (to the left) from the Upper Devonian (on the right). The movement along the nearly vertical fault downthrows the Upper Devonian in relation to the Lower (fig. 13).

Fig. 14: Baryte veins in LORS conglomerate, Auchmithie Harbour

There are many other features between Carlingheugh Bay and Auchmithie but the walk becomes more arduous so a return walk to Arbroath was undertaken and then a drive around to Auchmithie. The village sits at the top of the cliff but the harbour, now a ruin, is accessed by a rough steep road. The cliffs around the harbour are composed of conglomerates of the Lower Devonian Auchmithie Conglomerate Member 398-416mya, the only time conglomerates of this age are seen on the trail (fig. 14). The face of the cliff is cut by a nearly vertical fissure with two or three branches which have been infilled with barite veins (fig. 15).

Fig. 15: Baryte (Auchmithie Harbour

Depositional History

During the Devonian Period, Scotland lay somewhat south of the equator and the climate was hot and arid with seasonal heavy rain causing flash flooding on a huge scale. These temporal rivers carved their way across the arid landscape, leaving large masses of sand, gravel and cobbles which are now the Devonian Old Red Sandstone. During the drier periods the sands were blown by strong winds into dunes, forming the cross-bedding seen in exposures such as the top of the cliff at The Mermaid's Kirk. In the late Ordovician (480 – 440mya) and the Silurian Period ((440 – 410mya) a huge mountain range was being formed during the Caledonian Orogeny, of which the Scottish Highlands are just a small part. To the north east of the Arbroath area, these large rivers drained into the fault controlled lowlands of the Midland valley (bounded by the Highland Boundary Fault complex and Southern Uplands Fault) during the Lower Devonian Period, bringing the products of the erosion, the sands, gravels and cobbles, which can be seen along the coast. The conglomerates of the Lower Old Red Sandstone as seen in the cliffs at Auchmithie consist of rounded pebbles and cobbles of mainly quartzite with some limestone. At Whiting Ness near Arbroath, below the unconformity with the Upper Old Red Sandstone, the rocks are composed of red sandstone with interleaving beds and lenses of conglomerates containing small pebbles.

As has been said, the unconformity which is so well displayed in the cliff at Whiting Ness and about 200 yards east, marks about 40 million years of the Middle Old Red Sandstone period when either there was no deposition or rocks that were deposited have been eroded away. During this period, however, tectonic activity tilted the Old Red Sandstone beds to the south east and, at the same time, were subjected to wind and water erosion leaving a land surface which is now seen in the irregular contours of the unconformity.

Deposition of the Upper Old Red Sandstone began about 370 mya, consisting of sands, gravels and boulders transported by rivers flowing to the south east from much reduced mountains to the north west. Much of the conglomerates and breccias forming the Upper Old Red Sandstone are derived from the erosion of the Lower Old Red Sandstone. Later tectonic activity tilted the Upper sandstones to the south-southeast by about 10 degrees.

The sequence which can be seen along the trail is:

Upper Devonian	Burnside Sandstone Formation	consisting of red, orange or yellow sandstones, conglomerates and breccias mainly of Lower Devonian clasts
Lower Devonian	Scone Sandstone Formation - including Arbroath Sandstone Member and the Auchmithie Conglomerate Member	Cross bedded pebbly red sandstones with large white mica flakes and conglomerates with limestone and mudstone pellets. Conglomerates of well-rounded fine to coarse mainly quartzitic stones with beds of sandstone also containing limestone pellets.

The trail leaflet is well written with clearly annotated photographs, an excellent map and diagrammatic cross sections of features of the geology. The excellent footpath as far as Carlingheugh Bay is paved. However, because the trail continues across the beach at the Bay, stout shoes and care are needed from there to Auchmithie. The coastal trail provides excellent views of the geological features and also information for those with interests in natural history, local history and conservation. Some sections of the trail are fenced where the edge of the cliff is very close but much of it is open, leaving health and safety considerations very much to the walkers' common sense!

The leaflet "Arbroath to Auchmithie Geodiversity Trail" is published jointly by the British Geological Survey, UKRIGS Scotland, Tayside Geodiversity and Angus Council. I am pleased to acknowledge the source of the information in this article is drawn from the Trail leaflet.

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Footprints, lake sediments and replaced evaporites from the Triassic of South Wales: fieldtrip 23 April 2016

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On a bright sunny day with clear blue skies (23 April 2016) 32 members of the Bath Geological Society and other local societies met at Swanbridge on the Glamorgan coast of South Wales between Penarth and Barry Island to examine the Triassic deposits nearby.

The Triassic rocks exposed in south Glamorgan were deposited around the edge of an enormous lake or inland sea in which the Mercia Mudstone (formerly Keuper Marl) was deposited. The mudstone is mostly a red-purple silty dolomitic clay with nodules of pink-white gypsum (alabaster); it is exposed in a small bay on Barry Island, and also in the cliffs close to Penarth. In the subsurface of the Bristol Channel, there is a thick salt unit (the Somerset Halite) within the Mercia Mudstone, that was deposited in the lake when the water level was very low and very saline, and the climate was hyper-arid. The Triassic sediments in south Glamorgan overlie the Carboniferous limestone which locally created hills and cliffs around the Mercia Mudstone lake (Fig. 1). Wave-cut shore-platforms and wave-notches were cut into the limestone cliffs, and screes of Carboniferous Limestone debris were formed, locally reworked into beach gravel breccias where they

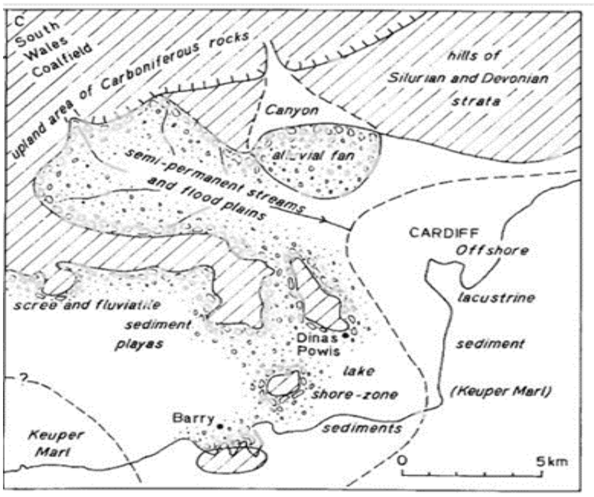

Fig. 1. Palaeogeography during Triassic times in South Glamorgan, South Wales (from Tucker 1978).

reached the shoreline of the lake. These features are well-developed and very accessible on Barry Island (see Tucker 1977, 1978).

After coffee and bacon sandwiches in the convenient café at Swanbridge for those arriving early, the group visited the exposures at Bendrick Rock and Hayes Point (Grid Ref: ST 140672). Here the unconformity with the Carboniferous Limestone is very clear and is extremely interesting since the upper surface of the limestone has split into very thin sheets. This exfoliation is a typical weathering feature of deserts, where the temperature change between day and night causes the rocks at the surface to split. There are also pebbles of limestone on the unconformity surface which have split in an onion-skin fashion (see Tucker 1974). The Carboniferous limestone here is full of fossils: mostly crinoids, with a few brachiopods and corals. The overlying Triassic consists of lenticular conglomerates and cross-bedded sandstones, some with a channel form, deposited by rivers in flood (Fig. 2). There are also thin, finer grained sandstones with

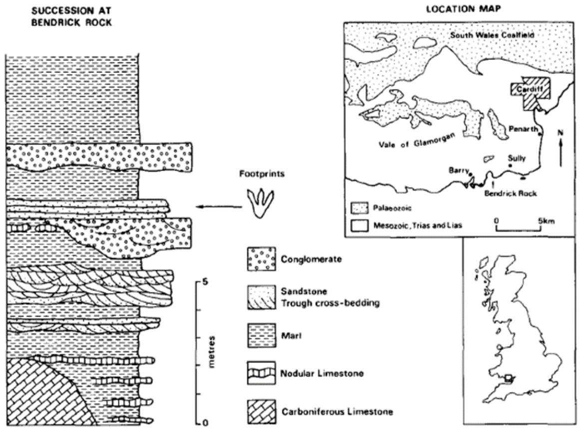

Fig. 2. Triassic succession at Bendrick Rock (Tucker & Burchette

ripples and mudcracks which were deposited by sheet floods coming from overflowing river channels, when there were flash floods. In actual fact, most of the deposits here are limestones (strictly calc-lithites) since most of the grains (sand to pebble size) are fragments (clasts) of Carboniferous limestone.

It is within the thin-bedded sheet-flood sandstones that dinosaur footprints were discovered in 1974 by Trevor Burchette and Maurice Tucker, then at the Geology Department, University College Cardiff.

Fig. 3a . Dinosaur footprints of Anchisauripus type from Bendrick Rock, now in the National Museum of Wales, Cardiff

Fig. 3b. Dinosaur footprint of Anchisauripus type from Bendrick Rock, now in the National Museum of Wales, Cardiff.

There are two sizes of footprint, one about 10 cm in length and the other up to 20 cm in length; both have 3 toes (Fig. 3 a and b).

There were many trackways composed of the smaller footprints on the top surface of a sandstone which had mudcracks and ripples. This surface, covering an area of some 25 square metres, is on display in the National Museum of Wales in Cardiff. Both sizes of footprint were assigned to the ichnogenus *Anchisauripus* by Tucker & Burchette (1977). Sadly, many of the footprints at Bendrick have been removed over the years by collectors and they have appeared for sale in rock-shops. The site is actually protected, being an SSSI, so it is illegal to take specimens from there. However, the party was lucky to find a good number of convincing footprints still visible on the bedding planes.

Along the coast at Bendrick there are palaeosoils developed within the succession and these show polygonal patterns of dolomite ridges, and nodules of dolomite. There are also numerous geodes ('potato-stones') composed of calcite in nodular dolomitic mudstone which were originally nodules of gypsum-anhydrite. The depositional environment was probably a saline sabkha which endured long periods of subaerial exposure, developed in the supra-littoral zone around the margin of the Mercia Mudstone lake. There are collapse features and disturbances too within the strata, which are likely the result of dissolution of evaporites (gypsum and/or halite) precipitated in the mud. Some of the dolomites could be dolocretes, precipitates forming close to the groundwater table, or in the capillary zone above.

After lunch, the group moved to Sully Island (Grid Ref: ST 169669) which can be reached at low tide by a rocky path across the foreshore (but only cross when the tide is falling!) from Swanbridge. On the cliff along the southern side of the island there is a spectacular outcrop of the marginal Triassic resting on Carboniferous limestone (Fig. 4).

Fig. 4. The cliff at the SE corner of Sully Island showing the marginal Triassic lacustrine facies resting unconformably upon, and onlapping, the Carboniferous limestone. The section is faulted, with the down-throw to the right / east. Lacustrine limestone occurs at the top of the cliff with nodular dolomitic mudstone below, much of which once contained evaporites (gypsum-anhydrite, possibly halite too). More clastic, shoreline facies occurs directly upon the Carboniferous bedrock, which formed an island at the time.

A well-developed lacustrine limestone is exposed at the top of the cliff, which was deposited in shallow-water in the marginal part of the lake, as shown by a range of sedimentary structures. Much of the red limestone is fenestral – that is containing small cavities (a few mm across) filled with calcite spar, called bird's eyes. This is the typical facies of a tidal flat or in this case, since the lake would not have had tides, a littoral flat – a planar area around the margin of the lake, at times covered by water and at other times subaerially exposed. The bird's eyes are cavities formed by the sediment drying out and the trapping of gas there. In addition, there are stromatolites, formed by microbial mats, and tepee structures resulting from cementation of the sediment surface and its expansion and buckling to form pseudoanticlinal features. Within the lacustrine limestone there are also palaeosoils, in the form of vertical calcite nodules – a type of calcrete, and below, layers of hematite-dolomite which represent a ferricrete (laterite). There are also local travertine-spring deposits, laminated calcite flowstone and large crystal pisolites, the result of freshwater, possibly warm, emerging from the Carboniferous limestone bedrock along faults (Leslie et al. 1992). Also of note and occurring below the limestone in nodular dolomite (probably a dolocrete), are numerous nodules of quartz, some with well-formed crystals inside. These are similar to the 'Bristol diamonds', geodes which are common in the Triassic of the Bristol area, and formed through replacement of anhydrite (Tucker 1976).

Back in Triassic times, some 200 million years ago, the Bristol Channel area was basically part of an extremely large lake extending down to Dorset with a shoreline in South Wales and the Bristol District where sabkhas and littoral flats existed and the various sedimentary rocks seen on this fieldtrip were deposited. There were hills around (now the South Wales coalfield and Mendips) composed of Carboniferous rocks, which supplied debris to the shoreline through flash floods descending down wadis and channels. The Middle East today has a similar climate, and many of the marginal lacustrine sediments are similar to those now being deposited along the Trucial coast of Abu Dhabi.

With clouds gathering and a cool wind blowing off the sea, the fieldtrip came to an end.

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Why is flint found in Islay?

by Isabel Buckingham

In 1979 an archaeological dig at a Bronze Age site on the island of Islay unexpectedly found a flint assemblage from a location where flint had been worked. As Ireland is the nearest land, they assumed that was where the flint and possibly the people had come from. Over the years a mix of random chance, observant crofters and deliberate searches has revealed more sites and information well summarised in ScARF South Hebrides Mesolithic Project.

While there was some contact with Ireland there are stylistic differences in the microliths and it is now known that the Mesolithic was found not only on the west and east coast of Scotland but inland in the Tweed valley, Aberdeenshire and to Orkney and Shetland. In Scotland stones are used locally and apart from an occasional high status object they are worked and used where found.

In Islay the sites are only in the Rinns on or near the west coast. Some sites show recurrent use and charcoal has given dates of 7250 +_45 BP, 7930 +-59 BP. These sites are near where flint is found in *diamictons* a convenient word that avoids stating whether this is till, or ice drop deposit. These deposits are only found on the Rinns which is part of the puzzle. High level glacial deposits to a height of <60m OD have yielded dates by Thermoluminescence of 53.9ka BP to 41.4 ka BP while those lower at Kilcairn gave >150ka BP. These flint and chalk erratics are totally absent from the more recent fluvo glacial deposits to the east on the Rinns or the low area joining Loch Indaal and Loch Gruinard which only became land about 2ka BP.

These are four possibilities:

Chalk exists in N Ireland but is largely covered by extensive Tertiary Basalt flows. It is only exposed along the coast. Did people transport this to Islay? That was the earlier assumption but the sea is stormy with strong tidal currents and the stylistic differences and other evidence make this unlikely.

Could chalk with flint have been plucked from N Ireland and moved north? Conventional thinking has the Irish and Scottish ice sheets joining and flowing to the edge of the continental shelf. The Donegal-Barra fan is interpreted as debris flowing from the ice. As the distinctive Ailsa Craig granite is found in the South West of England it is assumed the flow was southwards. However there is one possibility that this may have happened once.

Some chalk is still found in a tiny area of Skye. All striations show an east to west movement. Doubtless there were several cycles of erosion and deposition. Flint gravels are found near Buchan, and SW of Peterhead on hill tops up to 100m above sea level. They were worked in the Mesolithic, and suggest a widespread now remover Cretaceous cover.

Further east? Chalk fragments in a volcanic vent in Arran are well attested. There is the large Loch Gruinard fault on the east side of the Rinns which is a branch of the Glen More fault. It may be a half graben. There is a down throw to the east. Could Cretaceous rocks be found in the bed of Loch Indaal?

Fig. 1: Kilchairan storm beach

Attempts are boring have not yet given an answer, as 30m of estuarine mud overlies clay, but it is easy to see how glacial erosion would differentially remove a soft rock.

I searched and found water worn flint on Kilchiaran storm beach NR202601 (fig. 1). The island Heritage Centre at Port Charlotte has a large smooth lump of chalk with an embedded flint. Softer debris is pushed into the surface.

Present Situation:

I went with an open mind and two guides. I am familiar with the Uists but had not been to Islay before. The coast is a high energy environment and the present coast line seems to date from about 2,000BP when land was created between the Rinns and the remainder of the island. The date is from bore holes in the flat bog south of Loch Gruinard. There are strong tidal currents of <8 knots in the Sound of Islay and these flows create a standing wave off the Mull of Oa and the west entrance to Loch Indaal. There is a westward extending spit developed at the entrance to Loch Gruinard which is driven by tidal currents.

All west, north-west, and south facing beaches have well marked stone cobble storm beaches which are active and expanding. There are well developed and dynamic sand dune systems with some seaward erosion and active creation of fore dunes. There are blowouts and the creation of machair inland. These effectively hide what is beneath except along stream courses or where slippage has happened. Sphagnum Peat growth is active in the lowlands inland from Loch Gruinard, around Loch Gorm and blanket bog is found inland.

At a casual glance at the scenery shows all the features of moulding by ice and a further confusing mix of fluvo glacial features. Unravelling this is a work in progress, and I resorted to first principles.

The amount of crustal depression resulting from ice sheet loading is a function of ice thickness and the different density between ice and rock, which is normally about 1/3. Normally the amount of depression is highest in the centre of the ice sheet where it is thickest. The marginal depression extends to 150-180kms beyond the margin of the ice sheet depending on the plasticity of the rocks. Islay is an area of much faulted old rock and evidence is found at different heights in different locations.

Tectonically stable parts of the world, such as Bermuda are used to study sea level fluctuations and these show that sea level has only been higher by 2m in an interglacial 200kaBP and in the last interglacial at 5-6m. U-Th dates of fossil coral show that sea level was 121 +/- 5m lower during the last glacial maximum, rising to 60m about 10,000BP. The late glacial sea level rise was interrupted by two major freshwater pulses at 14,000 BP and 11,000BP giving the Lake Windermere Interstadial and Loch Lomond Interstadial when ice reformed during these Heinrich events.

The oldest lowest diamictons on the west side of the Rinns is up to 62mOD with the chalk and flint only in

Fig. 2: Icedrop deposit matrix sand not clay silt

Fig. 3: Ice striated mudstone.

the lower layers exposed at Kilchiaran NR204601. The gravel and sand beds had no visible orientation and occasional coarse sand lens. There seemed no fine material. I had no disagreement with an explanation that this was deposited in the sea below melting ice. (fig. 2) I managed to find water worn flint by searching the storm beach. Higher up in the same valley marked striations in Colonsay metamudstone were clear showing the east-west direction of ice movement (fig. 3).

Much of the deglaciation of west and central Islay seems to have occurred when sea level was at 22mOD. There is one marked east- west esker just north of Sutherland farm NR250655. Expensive outwash sands and gravels are exposed east of Saligo NR 213664 (fig. 4) and at NR231673 (fig. 5) where they have been worked. The sand martin burrows mark the sand lens. No flints are found. Studies in the area between Loch Gruinart and

Fig. 4: Fluvo glacial outwash 27m above sea level.

Fig. 7: NW dip in quarry behind Cnoc Iolairean

Fig. 5: Finer outwash about 300m east of previous

Fig. 8: Contorted beds with ice wedge and sand martin

Loch Indaal show that apart from one previous brief interlude the Rinns only became joined to the rest of Islay about 2,000BP.

Peat has developed over estuarine mud. There is a very strange arcuate moraine just inland at the head of Loch Indaal. It has an undulating top <29m at Cnoc Iolairean NR287635 (figs. 6, 7 & 8) which has conveniently been quarried for sand and gravel. The beds dip to the north west and are well bedded, with varied cobbles and very fine sand. The interpretation is deltaic forests. The lowest part is highly contorted, with sand martins using the silt parts. Could this have been affected by permafrost? The edge is overturned. Was there a tongue of ice in what is now Loch Indaal, or a large mass of ice pushed by a storm? Was this a "dead ice" feature? As no flint is found there either, the suggestion of Irish ice

Fig. 6: from Cnoc Iolair-ean looking east along ridge

seems less likely. *Hint in Google Earth use the previous date facility to* see *clearly.*

On the very unsatisfactory grounds that others theories are discounted, that only leaves the as yet unproven source of chalk as the now eroded deposits further east, possibly down faulted in Loch Indaal.

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Isabel Buckingham Remembered

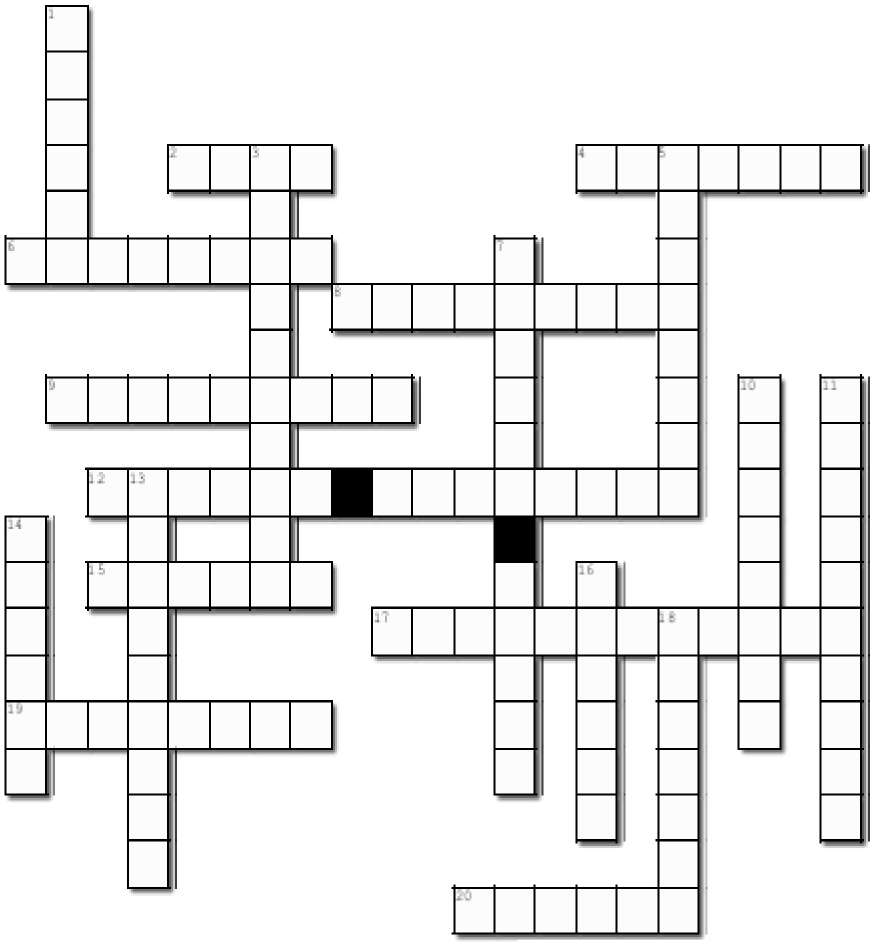
It is will great sadness we share the news that Isabel Buckingham passed away on 18th June 2020. Isabel will be sadly missed by all who knew her. Isabel was the Admin Secretary for the Bath Geological Society for four years until 2019 when she stood down due to illness. She was a very energetic and well organised individual. The Society benefited greatly from her contributions and enthusiasm. With a love for travel she has written many great articles for the Journal; the most memorable being on the German Geoparks visited in small plane with her husband Stewart in 2016. Living in Warminster Isabel led in a number of local field trips to Deadmaids quarry, Mendips and one examining the Geomorphology of the Warminster fault. With a lifelong interest in botany and geomorphology Isabel was also involved in many other local groups including the Warminster Branch of the Wiltshire Wildlife Trust where she was the Vice-Chairman. She was also a Volunteer Warden for one of the Warminster Flood areas.

Graham

Isabel Buckingham

Geology Crossword

Just a bit of fun - Complete the crossword puzzle below



Created using the Crossword Maker on TheTeachersCorner.net

Across

2. our home
4. Gas filled cavity in volcanic rock
6. Paleozoic; early, middle or upper.
8. uniformity in all orientations; having no order or preferred orientation
9. formation from the middle Jurassic
12. formerly Keuper Marl
15. supercontinent that existed during the late Paleozoic and early Mesozoic eras
17. laminated, calcareous microbial structure
19. dinosaur with three-toed limbs
20. extract stone (or other material) from here

Down

1. extrusive volcanic rock handy for removing dead skin
3. form of limestone deposited by mineral springs, especially hot springs
5. a fold with younger layers closer to the center of the structure
7. Yearly clean-up!
10. metamorphic rock with garnets & pyroxene
11. Microcrystalline form of silica
13. examples: gypsum, anhydrite, halite
14. most abundant mineral found on the Earth's surface
16. course grained igneous rock
18. Mountain building event

For answers see pg. 29

Reminiscences – Bath Geological Society

by Elizabeth Devon

I remember very clearly the first lecture I attended at the Bath Geological Society. It was a talk by Gilbert Green and, although I can’t recall the exact title, it was about the varying rocks at Weston super Mare and was very good indeed. It was then that I knew I needed the society’s help. I had recently been asked to set up an A level Geology group at the school where I was teaching. I had not taught A-level Geology before and, in fact had been out of teaching for a number of years when my children were small. I was not very familiar with the local rocks or the local sites.

That all changed as I started to attend the lectures and field trips regularly. All the members were helpful and friendly but I owe particular debts of gratitude to Charles Hiscock and Ron Smith who helped me enormously and gradually, my local knowledge expanded.

For many years my geological year was punctuated by the annual clear-up at Brown’s Folly Nature Reserve, the summer Rock It! event on the Bristol to Bath railway path with the Bristol NATS and the annual Geologists’ Reunion (now the Festival of Geology) which always used to be at University College, London. I have fond memories of all of these but especially of Jan with her Gryphaea ‘families’ at Rock It! Ask her about them.

‘Fig. 1: Rock it’ at Saltford, Charles Hiscock, 25.08.2003

Fig. 2: Bath Geological Society at the GA Reunion, Charles Hiscock, 08.11.1997

The lectures: there have been so many - - - but I shall never forget our Millennium lecture in the Assembly Rooms in Bath with Prof. Simon Conway-Morris. The big hall was full and it was an excellent, memorable event.

Field trips: far too many to mention but our regular field weekends to Hallsannery Field Centre will always stay in my memory. We always had wonderful long days in the field with Chris Cornford and then returned to the Centre for a wonderful dinner. I wonder if Charles' favourite armchair is still in the sitting room?

Fig. 3: Hallsannery weekend, Charles Hiscock, 07.06.1997

Our millennium field excursion was organised by Pat Bennett and involved a fabulous trip to the Greek islands. We studied everything from the major eruption about 3,500 years ago on Santorini, which destroyed the Minoan civilisation in the area, to the marble workings on Naxos, marble mines on Paros to the rich mineral deposits of Milos. It wasn't all spectacular geology - - there was a lot of sight-seeing and enjoyment of Greek food mixed in too.

In May 2007 we visited the Spanish Pyrenees, a field trip organised by Roger and Joy Lawley. We were based at Torla at the western end of the stunningly beautiful Ordesa National Park. The geological highlights of the week were seeing the deposits of not one, but two megaturbidites. They represented mega major catastrophic events; very exciting.

Fig. 4: Glastonbury Tor with H. Prudden, Charles Hiscock, 22.05.2004

Of course there were many, many local day field trips, far too numerous to mention. Geologists who formed a close association with the Society include: Geraint Owen from Swansea who led us to all the notable geological sites in south Wales, Hugh Prudden who took us to all in Somerset and Isobel Geddes who took us to all in Wiltshire.

Fig. 5: The Gower with Geraint Owen, Linda Drummond-Harris

Fig. 6: The Gower with Geraint Owen, Charles Hiscock, 29.09.2002

Mell asked me to write about things that came to mind when remembering the Society. I've mentioned quite a few already but also to be included: writing our 'Bath in Stone' book for Thematic Trails, Writhlington Batch open days, 'Geology on a Bicycle' on the Bristol to Bath Railway path with Simon Carpenter, ECOS Stones with Eric Robinson, Ploughman's Suppers and Garden Parties at our house and lots more . . . . Does anyone else remember the Bath GS T-shirts and the badges? What about the quiz night in 2004 with the Ammonites, Brachiopods, Graptolites and Trilobites? Sadly, I can't remember which team won. I could go on . . and on . . and on . .

Fig. 7: South east Wiltshire with Isobel Geddess, Charles Hiscock, 24.04.2004

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Early Fractures in Limestones: an example from Bermuda

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Fractures and joints are common features of all rock-types but the majority form during burial as a result of overburden pressure and response to regional and local tectonic stresses of compression and extension. With limestones however, fractures can form very early in the carbonate sediment's history, and close to the surface, although the actual processes involved are less certain. Fractures are important conduits for fluids flowing through rocks, including water, oil, gas and mineralising fluids, and some waters may lead to dissolution of the limestone and the formation of cave systems. This short article describes some prominent fractures formed in young (Pleistocene) limestones, up to several 100,000 years old, from Bermuda and reviews the possible reasons for their formation, which are not straightforward.

Geological background to Bermuda

The Bermuda islands occur upon a volcanic ridge formed through a mantle plume active in the mid-Tertiary, from 45-35 million years ago, which created a massive edifice (the Bermuda Rise) upon the Atlantic Ocean floor at a depth of 4000 metres. The seamount is oval in shape with a SW-NE elongation, about 100 km long by 60 km across, parallel to the Mid-Atlantic Ridge, which is located some 1500 km to the southeast. It is likely that the original volcanic complex rose to about 1000 m above sea level, by about 30 Ma ago, and since then it has been eroded down to create the extensive platform where shallow-water carbonate sediments have been deposited. There are no volcanic rocks exposed across the Bermuda pedestal but they have been proved in drilling, occurring at a depth of several 10s of m below sea level, beneath the carbonate cap.

Overall, the islands of Bermuda form a sort of rectangular shape, 23 x 4 km, with a long straight southeastern side, a shorter straight northwestern side at the NE end, and a short straight northeastern end (Figure 1); many of these shorelines have low rocky cliffs. The southwestern end is curved, as a result of longshore movement of lime sand, enclosing a large lagoon (the Great Sound). Reefs of coralline algae and corals are developed around much of the platform, very close to shore off the southeastern side, but much farther offshore on the NW side (Figure 1). There are 6 major limestone formations on the island, each deposited during an interglacial highstand, and separated by a palaeosoil. Most of the carbonates are aeolianite, that is lime sand derived from the beach, deposited by wind, with large-scale cross bedding. Shallow-marine to foreshore facies are far less common, and thin (a few metres); they are exposed at the base of several units, passing up into aeolianite which may reach several 10s of metres in thickness (Rowe 2020). These limestone packages were deposited from around 800,000 years ago during interglacial Marine Isotope Stages (MIS) 17(?), 11, 9, 7, 5e and 5a.

The young carbonates on Bermuda are cemented and many are extremely hard. The lithification took place soon after deposition, notably through the effects of meteoric (fresh) water, dissolving less stable (aragonitic) grains and precipitating calcite cement. Some foreshore-shallow-marine sediments were cemented by seawater.

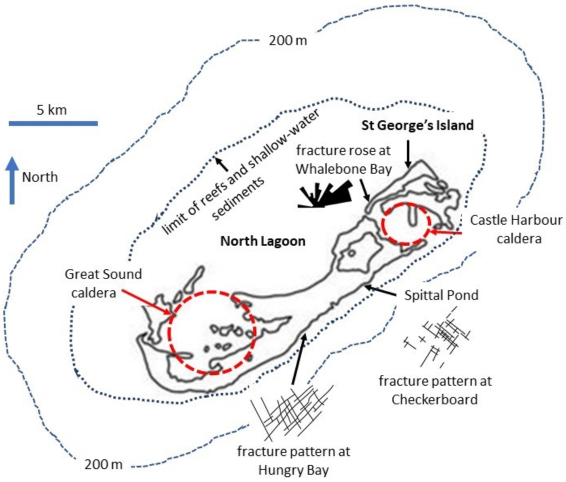

Fig. 1. The islands of Bermuda with the location of Spittal Pond and the fracture pattern there at Checkerboard Rock, as well as at Hungry Bay (from Scheidegger in Rowe et al. 2014) and Whalebone Bay (from Hartstock et al. 1997). Also shown are the locations of the 2 volcanic calderas, the outer limit of reefal and shallow-water carbonates, and the position of the 200-metre depth contour.

Fractured carbonates of Bermuda

At many outcrops on Bermuda, fractures can be observed in the limestones, but one locality where they are especially well developed is Checkerboard Rock at Spittal Pond Reserve (Figures 1, 2).
Here, the limestones belong to the Belmont Formation

Fig. 2. Prominent near-vertical SW-NE fractures with minor offset and cross-cutting NW-SE fractures in shallow-marine facies. Checkerboard Rock, Spittal Pond, Belmont Formation.

(i.e. MIS 7, age around 200,000 years) and the most prominent fractures occur in the lower part, in shallow-marine facies; they are less common in the higher units, of low-angle beach facies and overlying aeolianite (Figure 3). Two sets of fractures are developed in the marine facies, roughly at right angles, oriented in approximate SW-NE and NW-SE directions (see Figure

1, measurements made from an aerial photograph). The SW-NE orientation is parallel to the rocky coastline, which extends in this direction for about 18 km. The fracture spacing is 40-60 cm, and fracture continuity extends for 10s of metres, with minor offsets. Most fractures appear close to vertical. In this upper intertidal zone exposure, the fracture pattern in the marine facies has been exploited by wave erosion-dissolution to generate a striking clints and grikes pattern (Figure 4), just as present on Carboniferous limestone surfaces in the Yorkshire Dales.

Fig. 3. Rectilinear fractures in foreground in shallow-marine facies, overlain by beach-foreshore facies, 1 metre thick (low-angle lamination dip to right, i.e. seawards) and aeolianite above (high-angle lamination dipping to left, i.e. onshore, 1.5 m thick), with fewer fractures.

Fig. 4. Fractures weathering to give a distinctive clint and grike feature.

The fractures are less common (and more widely spaced) in the higher aeolianite units (Figures 3, 4), which themselves are less tightly cemented and still quite porous. The fracture fills can be observed here and they are 10-15 mm wide and consist of cemented lime sand grains, with a central crack (Figures 5, 6). Elsewhere, there are calcite crystals within the fractures. and some contain laminated calcrete where there are palaeosoils not far above the bed. These features indicate that the fractures are dilational and suggest episodic opening. The fracture fills commonly stand proud of the adjacent rock (Figure 5).

Fractures are also documented from Hungry Bay, 5 km SW of Spittal Pond, and these have similar orientations to Checkerboard Rock, parallel and normal to the shoreline (Figure 1)(Scheidegger in Rowe et al. 2014). Fractures on the northwestern coast of Bermuda, in the vicinity of Whalebone Bay, St George’s Parish (Fig. 1), were described by Hartsock et al. (1997) in the Rocky Bay (MIS 5e) and Belmont (MIS 7) formations. They recorded the presence of a primary, dominant set of fractures oriented in a generally SW-NE direction (coinciding with the orientation of the 4-km-long straight rocky coastline there), but with several secondary, subordinate sets at large angles to this (see rose diagram, Figure 1).

Fig. 5. Three prominent near-vertical fractures in aeolianite facies with their more tightly cemented fills weathering out.

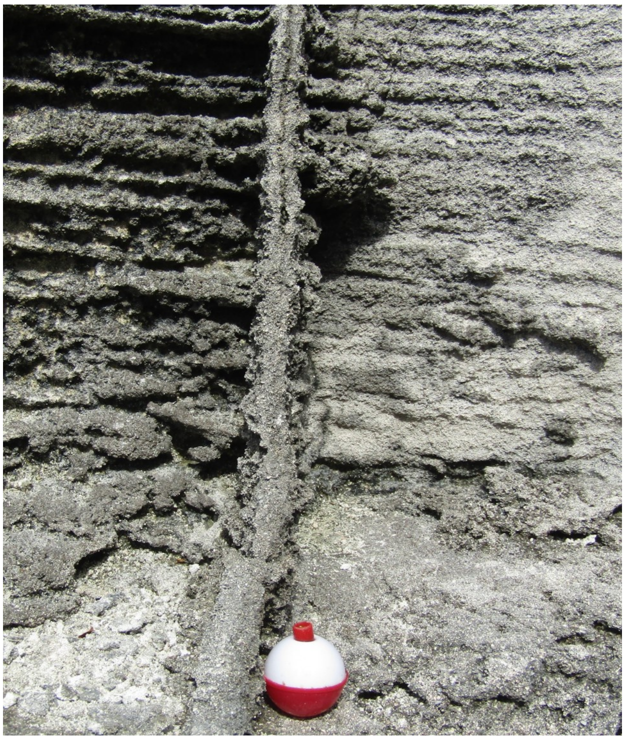

Fig. 6. Fracture cutting aeolianite with comminuted lime sand fill and calcite cement. Note central crack suggesting a later phase of movement (dilation). Fish float 4 cm diameter for scale.

Origin of fractures in young limestones

The fractures seen widely on Bermuda in the limestones occur within well-lithified carbonates, as young as 80,000 years, which have not been buried to any extent. Like many carbonate sediments they were cemented early, on contact with freshwater especially, and this could have taken place within 100s of years of deposition. Thus, competent rocks would likely have been produced soon after sedimentation, and these would have been liable to brittle failure if subjected to stress. Their near-surface location, the vertical to subvertical nature of the fractures, their orthogonal pattern and sediment-cement fills suggest the limestones were responding to strong horizontal tensile stresses.

Fractures in young (Quaternary) limestones have been described from many places in the Bahamas (e.g. Aby 1992; Whitaker & Smart 1997) and elsewhere, and in most cases they are oriented parallel to the local shelf margin, with another set at right angles. Fracture sets have commonly been exploited to form cave systems, including blue-holes. With many of these locations, the shallow-water to aeolian limestones are close (a few 100 m) to the shelf margin, which in many places is relatively steep, descending to 1000s of m. In the geological record, many steep-sided reefal platforms show a similar pattern of synsedimentary fractures parallel to the shelf margin, good examples being described from the Devonian in the Canning Basin of Western Australia and the Permian Capitan reef in Texas. Such fractures may be filled with contemporaneous sediment, giving rise to so-called neptunian dykes.

The formation of the margin-parallel (and normal) fractures in the Bahamas has been related to phases of sea-level lowstand, during glacial periods, when the platform would have become lithified as sea level fell. The cemented limestones would have been exposed up to 100 m above the lowered sea level for many 10s of 1000s of years, and then subjected to horizontal tensile stresses as hydrostatic pressure in the carbonates was lowered. On the southeast side of Bermuda, the drop-off to ocean depths, marked by a line of reefs, is only 100 m offshore (Fig. 1). Thus, the fractures in limestones along the SE side of the island, plus the linear nature of the coastline itself there (20 km long in the direction 050-230, Figure 1), is likely to be related to the presence of the nearby steep shelf. However, on the NW side of the island, in the St George's Parish area where there are also SW-NE fractures and a 4-km long straight section of rocky coast (Figure 1), there is an extensive shallow shelf lagoon extending for 10 km to the NW before the drop-off. Could this area have also been affected by the slope on the SE side of the island or is there another explanation? It is noteworthy that the NE end of Bermuda also has a conspicuous straight coast, at right-angles to the NW and SE coastlines, thus, also fracture controlled.

To account for the somewhat variable subordinate fracture orientations on the NW coast, Hartsock et al. (1997) suggested that the underlying topography of the upper surface of the volcanic edifice may have been influential. A volcanic caldera located beneath Castle Harbour, at a depth of 60 m below sea-level in the centre and 30 m at the margin, has been detected from seismic, and another larger one occurs beneath Great Sound (both shown on Figure 1). The interpretation is that massive dissolution of carbonates took place at the volcanics-limestone contact during sea-level lowstands, creating large cavern systems which collapsed and gave rise to the fractures in higher limestones. Such a process would certainly give rise to fractures in overlying carbonates but would probably not account for the clear SW-NE fracture-controlled coastline there.

The majority of fractures in rocks, generally, result from the effects of the regional stress field. However, in the case of the Bermuda Rise, this stress regime is complex, reflecting several processes including ridge-push forces related to sea-floor spreading at the Mid-Atlantic Ridge, relict thermal stresses from cooling of the volcanics and stresses from loading of the edifice (Vogt & Jung 2007; Rowe et al. 2014). However, it is difficult to see how these stresses would affect such near-surface limestones, and the compressive, shear fractures to be expected are not observed.

In summary then, the dominant orientation of the fractures on Bermuda, SW-NE, parallel to the southeastern shelf margin of the carbonate platform (plus their associated, orthogonal, NW-SE fractures), most likely relates to the tensile stresses affecting the lithified carbonates during sea-level fall and exposure, adjacent to a steep shelf margin. Other fracture directions may well be related to collapse of underlying caverns and topography of the volcanic subsurface caldera, but once formed, fractures will lead to further cave development through focussing dissolution. The regional stress regime is unlikely to be responsible for these early near-surface fractures.

The fractures on Bermuda, as elsewhere in similar limestones only 10s to 100s of 1000s of years old, clearly show that fractures can form very early in a sediment's history and near-surface. Synsedimentary – early diagenetic cementation to form brittle rocks is a major factor, as well as the proximity to a steep shelf margin, with major falls in sea level exposing the carbonate platform and changing pore-fluid pressures also involved.

Look carefully at fractures in sedimentary rocks and their orientations; they may be younger than you think!

Acknowledgement

I am grateful to Phil Burge for virtual discussions and comments on the MS.

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‘Blow, blow thou watery wells’ (with apologies to W. Shakespeare!)

By Charles Hiscock

On a cold winter’s day on the coast of Lincolnshire when a north east wind blows off the grey North Sea, the correct title of William Shakespeare’s poem from ‘As You Like It’ is very applicable. However, with apologies to Shakespeare, the first line of the poem came to mind on another visit to the Tetney Blow Wells and immediately became ‘corrupted’ to give the title of this article.

The village of Tetney is situated 6 miles south of Grimsby and 3 miles inland from the sea wall from Immingham south to the Wash that protects this low-lying stretch of coast. In an otherwise almost flat expanse (in spite of the caravan site nearby being called ‘Windy Ridge’) the superficial tidal flat deposits of clays and silts are intensively farmed as in fig. 1 which shows two clumps of trees and the distant Lincolnshire Wolds.

Fig. 1 Trees at Tetney Blow Wells and distand Wolds

The area of tall trees, mainly aspen and willow with a few oak and birch, surround a number of pools and marshy ground within which are the Tetney Blow Wells, major artesian springs with an interesting and surprising geological explanation. In an area of about half a square mile there are four large pools, each surrounded by marshy ground and reed beds filled with pale blue slightly cloudy water. Between 1948 and 1961 the wells were cultivated as watercress beds but there is little of this left except for watercress growing in the pools, waterways and some concrete. At one point in each pool a sluice siphons the water off into the Anglian Water Companies water supply, each sluice being clearly marked with a sign saying ‘Deep Cold Water. No swimming. Hazards include Entrapment. Drowning. Shock. Weil’s Disease’! (fig. 2).

Fig. 2 Safety sign by Well 3

The water flow from each pool is significant as judged by the current that noisily flows under the metal grids over each sluice and even after the very dry summer of 2018 the flow did not seem to have diminished compared with previous visits (fig. 3). These springs are not the only supplies of water to well up through the Pleistocene clays but they certainly are one of the most significant, so much so that the area was one of the first to be designated an SSSI by the Lincolnshire Wildlife Trust soon after its foundation. The Blow Wells are an important nature habitat particularly for birds migrating across the North Sea. During a visit in October 2018 numerous large flocks of the ‘winter thrush’, the Fieldfare, were seen around the trees feeding on the abundant hawthorn berries. In the warm autumn sunshine, numerous dragonflies and damselflies were skimming over the reed beds. In an earlier springtime visit the trees were alive with Chiffchaff, Willow Warbler, Blackcap and resident species such as Chaffinch, Goldfinch, and Greater Spotted Woodpecker while ducks and grebes were seen on the water. In the extensive reed beds Sedge Warbler and Reed Bunting are regularly seen. The meadow areas support profuse cowslips in spring and are cut later for hay to preserve the flowers.

Fig. 3 Blow well 4

The Lincolnshire Wolds lie in a north west/south east outcrop across Lincolnshire and extend in both directions across the Wash into North West Norfolk and across the Humber River, at Barton-upon-Humber, into Yorkshire where they become the Yorkshire Wolds (fig. 4).

Fig. 4 North East Lincolnshire

In the region of Tetney the Wolds ridge is about 13 miles to the west. It rises to about 165 metres, 550 feet, with the north easterly dip slope deeply incised with numerous ridges and valleys, mostly dry, some with streams but only 4 significant rivers; the Waithe Beck, River Lud, Laceby Beck and East Halton Beck. They are composed of a series of Cretaceous chalk formations which dip in an easterly direction from the top of the Wolds to beneath the Pleistocene tidal clays and silts of the coastal belt and the North Sea. Fig. 5 is a schematic cross-section of the geology in a SW to NE direction from Hemingby in the west to Saltfleet in the east. The western scarp which can be seen east of the A46 between Middle Rasen and Caistor (fig 6, taken at Claxby) is composed of a thick sequence of Jurassic Kimmeridge Clay which also dips in the same easterly direction under the chalk formations (fig. 5) and forms the water seal at the base of the chalk formations. The sequence of formations that form the Lincolnshire aquifers are –

Upper Creta-ceous	Flamborough Chalk Formation Burnham Chalk Formation Welton Chalk Formation Ferriby Chalk Formation
Lower Creta-ceous	Hunstanton Formation Carstone Formation Tealby Member of the Tealby Formation Spilsby Sandstone Formation

Fig. 5 NE .Lincolnshire chalk formations, (Whitehead & Lawrence 2006)

At Tetney, the chalk underlying the Pleistocene sediments is the Burnham Chalk Formation (84 – 94 mya) which has undergone much deformation. Cracks and joints have opened in the chalk thereby increasing its permeability and the upwards flow of groundwater. The wells are tapped for the local water supply but not all of the water is used for this purpose. Some, and water from the marshy areas around the wells, drains into rhynes (water-filled deep ditches as on the Somerset Levels) that empty into the Waithe Beck. This flows along the north west side of the Blow Wells area and then eastwards to join the Louth Canal to empty into the North Sea at Tetney Lock.

Fig. 6 Wolds, west scarp, Claxby, Kimmeridge Clay

As already stated, most of the valleys in the Wolds are dry as they do not contact the water table except in severe or prolonged wet weather when ephemeral springs occur. However, in the areas where the ground surface is permeable, groundwater rises through to the surface, in many cases as significant springs given the local name ‘blow wells’. The ones at Tetney are the biggest. The water which rises in the wells is derived from rainfall on the Wolds and can take years to decades to permeate through to the blow wells. The amount of water permeating is also affected by the thickness of glacial till draped over the chalk on the top of the Wolds which ranges from nil to a few metres in depth. Indeed, as one travels from Market Rasen through Tealby to Binbrook on the B1203, particularly in spring before the crops have grown and autumn after the fields have been ploughed, the chalk can be seen exposed in the valley sides. Near Binbrook in the central part of the Wolds, the Hunstanton Formation, previously called the Red Chalk (as exposed in the magnificent outcrop at Hunstanton in north west Norfolk) can be seen in the valley sides with white chalk above.

In an otherwise dead flat terrain, the Tetney Blow Wells provide an area of trees, marshes and reed beds with a rich flora and fauna. At the same time, large quantities of water are taken off for the water supply but, for the local population, it is a pleasant place for walking, exercising the dogs and enjoying the wildlife.

Reference: Whitehead, E J. and Lawrence, A R. 2006. The Chalk aquifer system of Lincolnshire. *British Geological Survey Research Report, RR/06/03.*

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Fun with Thin Sections

By Jonathan Slack

For the last five years, my wife and I have been walking the Southwest coastal path. We do this very slowly, making a trip a few times a year and have so far made our way from Poole Harbour to Land's End. Every so often she would point and ask me "what sort of rock is that?" Once we had got past the chalk and the Kimmeridge clay, I found it quite hard to answer. In theory I knew about sandstones, shales and limestones and about the different types of igneous rock, but the colour of rocks so often depends on lichens or iron staining or general dirt, so you need to look up close at a freshly exposed surface. Even then I still had some trouble and decided that I really needed to improve my identification skills.

As a retired biology professor I have spent a whole career looking at sections of animal tissues down the microscope. I knew that rocks become transparent in thin section and wondered if I could make my own rock sections to aid with identification. Having found out what equipment and skills are required to do this, I decided it would not be possible, but I did find someone willing to make them. Robert Gill of GEOSEQ will make you a slide from your sample for £14, including postage, and will also help you interpret it.

So, I bought some slides of igneous rocks from him and set about learning how to distinguish the different mineral crystals. I have an old Zeiss microscope (vintage 1977), which, although designed for biology, does have the rotating stage and polarising attachment which are essential for petrological work. Compared with biology, the "thin" sections of petrology are actually rather thick. A biological section would be 6-10µm thick, while the standard thickness of a rock section is 30µm. With sections this thick it is fortunate that the magnification used tends to be rather low, otherwise a lot of the section would be out of focus. The most useful objective lenses are the lowest powers: x2.5 and x6.3. For even lower power, I use a dissecting microscope with a transmitted light base and simply place the polaroid filters on either side of the slide.

To take photographs I needed a camera. So I bought an old Canon SLR, without the lens, from eBay, and I had an adapter made for my microscope by GT Vision Ltd. This setup has worked reasonably well, although it is not as slick as the professional imaging setups I used to work with.

Identifying minerals

I have focused most attention on igneous rocks. By the time we got to South Devon, we were encountering some of these in the field. The first thing I had to get used to looking at thin sections was that there are numerous tiny crystals at every possible orientation. The optical properties of a crystal differ depending on the orientation and so you have to look at several crystals of the same mineral to decide what it is. How do you know it is the same mineral? This is very much an art but you do get used to it after a while. The identification of minerals in thin section depends on a variety of features: colour, crystal shape including twinned structures, "relief" (i.e. refractive index), cleavages, and, especially, the colour when viewed between crossed polaroids.

Most minerals are colourless in thin section but some are coloured. Moreover for some of these the colour changes in plane polarised light (i.e. using just the lower polarising filter) as the crystal is rotated. This colour change is called pleochroism and can be very useful for identification. To illustrate this, a crystal of biotite, a dark form of mica is shown in Fig.1. The two views are taken in plane polarised light but with the specimen rotated 90°. The first view shows a dark brown colour while the second is almost colourless. This indicates a high degree of pleochroism, which, together with the characteristic cleavage pattern definitively identifies this crystal as biotite. The dark patches in the crystal are common in biotite and are halos of radioactive transformation around small inclusions of zircon. Zircon is a complex silicate of zirconium, often containing radioactive elements such as uranium and thorium, and

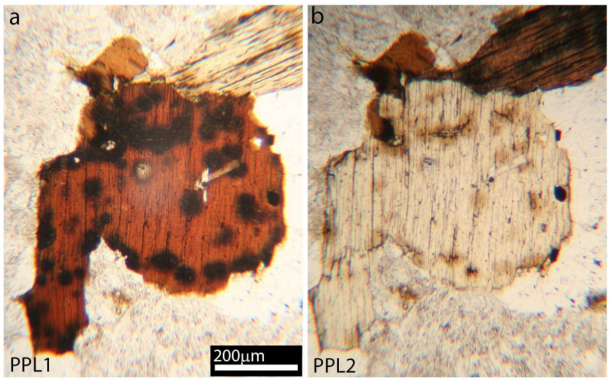

Fig. 1 Pleochroism of biotite in plane polarised light (PPL). a) Maximum colour orientation: the crystal is dark brown. It also shows prominent dark patches due to the effect of radioactive elements in minute zircon inclusions. b) Rotated 90°. The brown colour is almost gone. The second crystal at the top is now brown.

the halos represent the effect of the emitted particles on the surrounding mineral.

The appearance of mineral crystals between crossed polaroids is a real joy to observe, as the colours and patterns are often strikingly beautiful, arguably as beautiful as the frog embryos I used to look at. Most mineral crystals are anisotropic, which means that the refractive index differs depending on the path taken through the crystal by the light ray. When plane polarised light enters an anisotropic crystal, it is divided into two rays with their vibrations at right angles. Because of the different refractive indices of the crystal in different directions, one ray will be a little faster than the other so they emerge from the crystal out of phase. If a second polariser, at 90° to the first, is placed above the specimen, it captures just one vibration plane of both rays. If there is no phase shift between them no light will be transmitted and the specimen will appear black. If there is a phase shift then the interference of the two rays will generate a colour.
This effect is known as birefringence. As the specimen is rotated the birefringence changes from none (black, or extinction) to maximum (a specific colour) every 90

degrees. This does not occur for minerals of the cubic crystal system, such as garnet, which are isotropic and so appear black in all orientations. For anisotropic minerals, the difference of refractive index, and thus the resultant colour, does differ depending on the orientation of the crystal. Each type of mineral has a maximum birefringence colour which is characteristic of the largest possible difference, assuming that the section thickness is the standard 30µm.

The birefringence colour is one of the most valuable diagnostic features for identification. As the degree of birefringence increases so the colours recur, so we speak of first order yellow, second order yellow and so on. The first three cycles are apparent in Fig.2a which shows a wedge-shaped piece of olivine. Because the degree of birefringence is proportional to the thickness of the crystal, in a wedge you see the full succession of colours in order. The sequence of colours is known as Newton's scale, and is presented as the Michal-Lévy chart in all books on optical mineralogy. Usually it is not difficult to decide to which order a particular colour belongs, partly because you can often see the adjacent colours due to variations in thickness, and partly because they become pearlier in appearance after the third cycle. In Fig.2 three minerals are shown in addition to the olivine wedge. Quartz has a maximum birefringence of a creamy white colour. Augite, a complex silicate belonging to the pyroxene group, appears blue but has a maximum

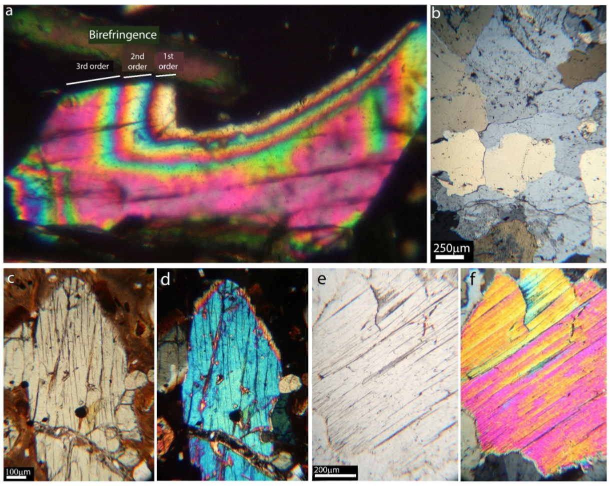

Fig. 2 Birefringence in crossed polarised light (XPL). a) A wedge of olivine showing a progression through three cycles of interference colours with increasing thickness. b) Quartz crystals in a granite. These occupy the central part of the image and vary from grey to buff to a cream colour (maximum birefringence) depending on orientation. c,d) Augite from an andesite, viewed in PPL and XPL. This appears blue but the maximum birefringence of augite is higher. e,f) Muscovite from a granite, viewed in PPL and XPL. This is second order pink, but again, can be higher.

birefringence of second order pink. Muscovite, or white mica, which is a sheet silicate, has a maximum of third order pink.

The most common mineral in most igneous rock samples is feldspar. There are several types of feldspar and to understand them it is helpful to consider first the chemical structure of quartz. Quartz consists of an endless three-dimensional arrangement of silicon atoms each surrounded by four oxygens in a tetrahedral arrangement. Because each oxygen is shared between two silicons, the overall ratio of silicon to oxygen in quartz is 1:2, hence the conventional chemical formula SiO_2. The structure of the feldspars is like quartz except that about one in four silicons is replaced by aluminium. Aluminium is trivalent while silicon is tetravalent, so in the feldspars some additional cations (positive ions) are needed to ensure electrical neutrality. If the cation is potassium ion we have an orthoclase feldspar, if it is some mixture of sodium and potassium ions, we have an alkali feldspar, and if it is some mixture of sodium and calcium ions we have a plagioclase feldspar. Mixtures of potassium and calcium ions are not found.

It is possible by optical methods to be quite discriminating about identification of which particular subclass of feldspar is being observed, but in Fig.3 I show just two common appearances typical of alkali and plagioclase feldspar. Both show a low level of maximum birefringence which is first order white. The most characteristic difference between them is the twinning behaviour. Twinning of crystals occur when they grow on either side of a mirror plane giving multiple crystals related by mirror symmetry. Alkali feldspars tend to show simple twinning, while plagioclase tends to show lamellar twinning, visible between crossed polaroids as multiple stripes of black and white. For both types of twinning, as the microscope stage is rotated, the black areas change to white and the white to black, because their orientation relative to the light beam is changing. Feldspars in igneous rocks are often "altered", meaning that they have suffered some chemical degradation or transformation over the millions of years since the crystals were formed. This is apparent in Fig.3 as the buff-coloured or grey opacity seen as irregular patches.

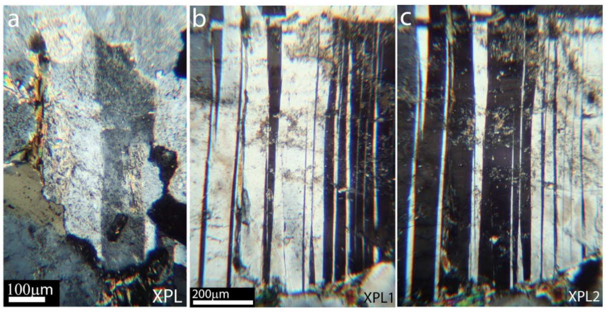

Fig. 3 Feldspars viewed in crossed polarised light. a) Alkali feldspar from a granite showing simple twinning. b,c) Plagioclase feldspar from a gabbro showing lamellar twinning. There are two crossed polaroid views, 90 degrees rotated. Both these specimens are slightly "altered", or degraded, which is common for feldspars.

In some areas of Cornwall the alteration of feldspars in granite has progressed so far that a large proportion of the rock has become kaolin, or China clay.

Rocks

Having learned to identify some minerals down the microscope I was beginning to be able to identify some rocks from their mineral composition. One of the most characteristic igneous rocks, familiar to those of us living in the South West, is granite (Fig.4). This forms the moorlands of Devon and Cornwall and outcrops along much of the Cornish Coast. Granite is actually pretty easy to identify without a microscope because of its characteristic jointed structure and the fact that the crystals are large and visible to the naked eye or a hand lens but it looks much nicer down the microscope. Granite is classified as an "acidic" rock i.e. high in

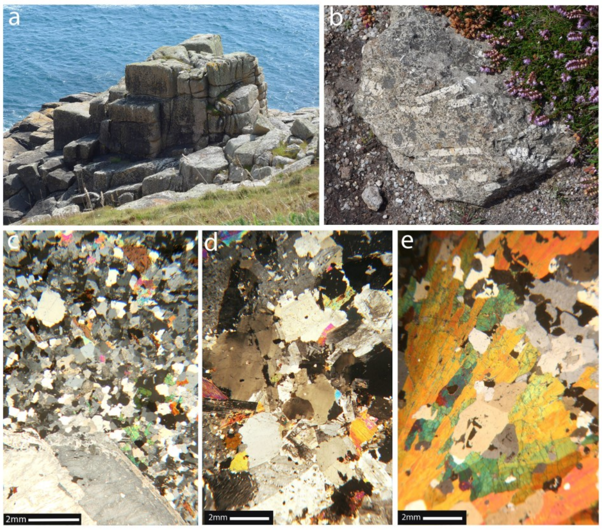

Fig. 4 Granites. a) A granite outcrop on the Cornish sea coast. Note the vertical and horizontal jointing. b) A granite near Land's End containing huge feldspar crystals (phenocrysts). c-e) Low power sections of three different granites from the South West. c) From Dartmoor. At the bottom, there is a large alkali feldspar phenocryst showing simple twinning. Most of the small crystals are quartz, appearing black grey or white, there is also some green tourmaline and brown biotite. d) From Bodmin moor. Here the crystals are larger. They are mostly quartz and feldspar with a few brightly coloured crystals of muscovite. e) From Penwith. This granite has an unusually high content of tourmaline, which appears as the yellow, green and orange crystals.

silica, and plutonic, i.e. cools slowly below the ground so crystals have time to grow large. It is normally composed of quartz, feldspars and micas. The South West granite outcrops also often contain tourmaline.

Geology textbooks all contain a classification of igneous rocks based on the silica content and grain size. Among the plutonic rocks, diorite contains less silica and more plagioclase than granite together with some pyroxene and amphibole. Gabbro has a lot of plagioclase and pyroxene, and maybe a little olivine. Peridotite, characteristic of the mantle region below the Earth's crust, consists largely of olivine and pyroxene. The minerals dominating the low silica, or "basic", rocks: pyroxenes, amphiboles and olivine, are referred to as mafic minerals because of the high content of magnesium and iron (Fe). These minerals are intrinsically dark coloured and because of them basic igneous rocks are dark in colour or contain a preponderance of dark to light coloured crystals. The mafic minerals are all silicates. Olivine consists of isolated SiO_4 groups with Mg and Fe ions to balance the electric charge. Pyroxenes have chains of linked SiO_4 groups, and amphiboles have double chains. Fig.5 shows samples of diorite, gabbro and peridotite

Igneous rocks that solidify at the surface, otherwise known as volcanic rocks, usually have a very small grain size because the crystals do not have much time to grow while the lava is cooling. However, often volcanic rocks show a porphyritic structure in which small crystals are embedded in an amorphous matrix. In such cases the crystals represent those minerals of higher

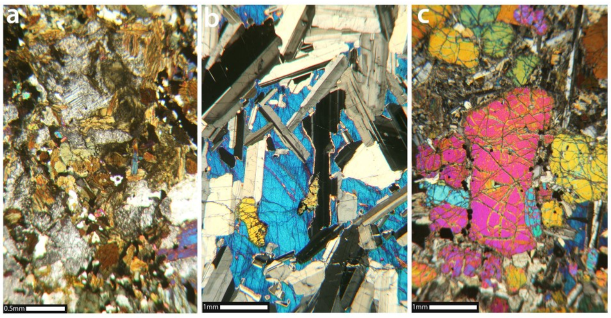

Fig. 5 Some other igneous rocks. a) Diorite from the Malvern Hills, containing plagioclase (stripy), pyroxene (blue), some quartz, and some opaque material, probably magnetite. b) A gabbro from Ardnamurchan, Scotland, containing plagioclase and pyroxene (blue). c) A peridotite from the Isle of Rhum, mostly consisting of olivine. b) and c) are not my own collection, but were purchased from GEOSEC.

melting point that can start to crystallise while the lava is still molten. Tuffs, formed by ejection of material from volcanos, can be identified because they contain pumice fragments as well as the usual components of the lava.

If the crystals in a tuff are oriented this indicates that the material was moving fast just before solidification, so it is probably a rock formed from a pyroclastic flow, called an ignimbrite. We often go to the Bodrum peninsula in Turkey (Fig.6a,b). This picturesque area suffered extensive volcanism about 10 million years ago and most of the scenery is formed from lavas and tuffs. The rocks are classified as andesites, which means an intermediate silica content, similar to diorite, and a small grain size. Fig.6c shows a porphyritic andesite from a volcanic plug near the town of Turgutreis, which contains crystals of augite and biotite. In the village of

Fig. 6 a) Gümüşlük bay on the Bodrum Peninsula, Turkey, showing the volcanic scenery. b) A striking volcanic plug above Turgutreis, Bodrum Peninsula. c) Low power section of andesite from near the plug. Crystals are embedded in a black matrix, and include plagioclase (stripy), biotite (dark brown) and augite (blue). d) A spherulite, formed of radiating crystals, in a green tuff commonly used for building in the ancient world.

Gümüşlük, where we stay, there are many masonry blocks left over from Roman and Byzantine times still lying on the surface. A popular stone used in those days was a greenish tuff which is relatively soft and easy to work. This contains radiating spherulites probably composed of quartz and feldspar (Fig.6d).

Metamorphic rocks

Having become moderately familiar with igneous rocks I have tried to extend my attention to metamorphic rocks. These contain many more different minerals and are very complex indeed. The composition of a specific metamorphic rock depends on what it was before metamorphosis (the protolith), and on the degree of pressure and temperature to which it has been subjected. For a particular protolith, a plot of pressure against temperature can be divided into zones of different composition called facies. Metamorphic rocks often have a layered structure arising from the compression they have suffered. This layering is clearly apparent in Fig.7a showing a mica schist from South Devon which has distinct layers dominated by quartz and muscovite. It arose from a Devonian shale which was metamorphosed in the late Carboniferous when the granite intrusions of the area were formed. Igneous rocks can also undergo metamorphism, and Fig.7b shows a hornblende schist from Cornwall which arose from a basaltic protolith and is largely composed of hornblende, which is a type of amphibole, and pyroxene. A mineral often found in metamorphic rocks is chlorite. Contrary to its name, this does not include chlorine, but is a complex sheet silicate formed from various mafic minerals by chemical alteration. Chlorite and another metamorphic mineral, zoisite, are unusual in that they show an anomalous birefringence colour, not part of the normal Newton's scale. This appears as a strong Prussian blue colour (Fig.7c) which is very characteristic and aids identification.

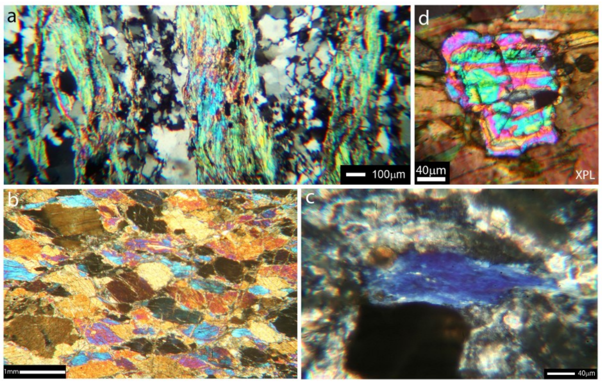

Fig. 7 Metamorphic rocks. a) A mica schist, showing alternating bands of quartz crystals (black, grey or white), and muscovite (multicoloured, and at this magnification appearing as fibrous swirls). b) A hornblende schist, with brown crystals of hornblende and blue augite. c) A clump of chlorite in an altered basaltic rock, appearing a "Prussian Blue" colour due to anomalous birefrin-gence. d) A crystal of epidote in a biotite gneiss.

Gneisses are rocks of high metamorphic grade, also with a layered structure, usually arising from granites or diorites. Fig.7d shows an epidote crystal from a granitic gneiss rich in biotite. Although found in Devon close to the mica schist, this was a beach cobble, so its exact location of origin is unknown.

I still find the identification of metamorphic rocks difficult, as the appearance of the rocks can be very diverse and the minerals present in a specimen often don't seem to correspond to any particular facies! However, as always, the specimens are very beautiful and can show an infinite variety of shapes and colours.
In the last few years I have had a lot of fun collecting samples and making a provisional decision about what they are from their hand lens appearance. I then have some of them sectioned and attempt to identify the constituent minerals to see if I was correct in the preliminary identification. I have improved my skills to some extent but also learned to be cautious as the range of rock types is very large and the superficial appearances can be very varied. In the future I will aim to explore the metamorphic rocks in more detail and try to become familiar with the range of minerals they contain and the various facies they display. I also feel I should try to understand more about the crystallography of minerals, as this is the real key to making sense of what you see down the microscope. If any member of the Society would like to help me with interpretation of the sections I should be most grateful. Please get in touch at j.m.w.slack@bath.ac.uk.

Sources

As a complete newcomer to this area I have needed all the help I could get. In terms of books, I have found "Minerals and the Microscope" by H.G.Smith to be the most useful. This is old (4th edn 1956) and out of print, but second-hand copies are available. It explains the principles of optical mineralogy pretty clearly and describes the appearance of a wide range of mineral. Because of its antiquity it does not have colour illustrations. For these I have turned to "A Colour Atlas of Rocks and Minerals in Thin Section" by MacKenzie and Adams, which provides a basic set of pictures taken in plane polarised and crossed polarised light. Useful illustrations are also to be found in "A Key for Identification of Rock-forming Minerals in Thin Section" by Barker. This presents a dichotomous key for identification of minerals similar to those used for identifying plant or animal species in biology. I find the key quite hard to use as it depends a lot on identifying cleavage patterns, which of course vary with orientation, but the pictures are good and show a wider range of minerals than MacKenzie and Adams. As far as websites are concerned, Robert Gill of GEOSEQ has a useful site with descriptions of several common minerals. There is also a remarkably comprehensive set of sections presented by Alex Strekeisen, an Italian geologist who has compiled a very extensive website illustrating almost everything.

Websites:
http://www.alexstrekeisen.it/english/index.php
http://www.geosecslides.co.uk/

Books:
Smith, H.G.(revised Wells, M.K.), *Minerals and the Microscope*. London: George, Allen and Unwin. 4th edn.1956.

MacKenzie, W.S. and Adams, A.E. *A Colour Atlas of Rocks and Minerals in Thin Section*. London: Manson Publishing. 1994.

Barker, A. *A Key for the Identification of Rock-Forming Minerals in Thin-Section*. London: CRC Press. 2014.

Quiz:

By Sam Medworth

We live on the southern slopes of Bath, roughly halfway between Combe Down (of Oolite fame) and the river Avon. Sheet 265 of the BGS 1:50000 maps shows this as "Lower and Middle Jurassic in a foundered area", and I can confirm this from my own experience, having dug up pieces of chalky white limestone as well as clay from the Fuller's Earth formation; rubbly limestone, Midford Sandstone, and Oolitic limestone which may be builders' rubble or may have slipped down from higher up the hill. Over the 35 years that we have lived here, I have collected a number of fossils and thought members might like to see some pictures. I decided to present them as a quiz. The winner will be the first person to email the Chairman with the correct genus name for each.

1.

2. Split in half lengthways

3.

4.

5.

6.

7.

8.

9.

10.

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Crossword answers:

Across: 2. Bath; 4. Vesicle; 6. Devonian; 8. Isotropic; 9. Cornbrash; 12. Mercia mudstone; 15. Pangea; 17. Stromatolite; 19. Theropod; 20. Quarry

Down: 1. Pumice; 3. Travertine; 5. Syncline; 7. Browns Folly; 10. Eclogite; 11. Chalcedony; 13. Evaporate; 14. Quartz; 16. Gabbro; 18. Orogeny

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Dinosaur Snippets

by Phil Burge

There was a time when I had an interest in Russian literature. I read a lot, including reading War and Peace twice (honestly). However, I had trouble with the names of the dramatis personae to such an extent that I merely recognised the shape of the name rather than try to read the name fully each time it appeared. Accordingly, I could not tell you a single name from any of the many books that I read. The same problem applied to my studies of palaeontology and particularly of the dinosaurs. The names are simply too long to remember! Time for a reinvigorated attempt at learning something about dinosaurs – including the names.

With all the recent advances in understanding of dinosaur morphology, colouration, brain case analysis, evolution and the frequent announcement of new dinosaur species you may be wondering as to whether a dinosaur snippet falls into this category of a new discovery – perhaps a new trace fossil, a minutiae of scale patterns or perhaps a new species of dinosaur.

Or you may have realised, almost instinctively that snippet refers to a short item of interesting news. There has been a lot of dinosaur news recently and here follows a few snippets.

Dinosaur clade diagram

The standard view of the dinosaur phylogeny shows the development from the Archosaurs and splitting into the Ornithischians (bird hipped) and Saurichians (lizard hipped) with evolution of the Theropods (meat eating) and birds. In this model the birds developed from the lizard hipped dinosaurs.

A paper published in 2017 by M Baron et al in Nature throws this view on its head. The researchers looked at 457 anatomical characteristics across 74 types of dinosaur and from this a revised cladogram was developed. This places the Theropods closer in phylogenetic terms to the Ornithischians than the Saurichians.

To take one characteristic, Ornithischians and Theropod fossils show hair-like integumentary structures whereas those of Suarischians do not – as far as the fossil record currently shows. By way of an example, a paper published in 2013 entitled "An unusual basal Therizinosaur dinosaur with an Ornithischian dental arrangement from northeastern China" published in PLOS One, examines a fossil Theropod *Jianchangosaurus yixianensis*, which shows booth feathered features and dental characteristics associated with herbivores.

Apart from anything else this changed view of dinosaur phylogeny poses interesting questions about convergent evolution of certain characteristics (meat eating for example) within the Dinosaurs.

Footsteps

In March 2020 it was reported (BBC) that researchers from the University of Edinburgh had discovered a "dinosaur stomping ground" on Skye, this discovery adding to the known understanding of the ecosystem of the Middle Jurassic. Footprints included those of the

Fig. 1 Footprints from Skye, *Stegosaur Deltapodus*.

Stegosaur Deltapodus, a three toed Theropod.
In 1954 dinosaur footprints were found on a cave ceiling in Lower Jurassic rocks in Queensland. Initial interpretations suggested that these footprints were those of a quadruped Theropod – odd as Theropods were bipedal. The caves are closed but luckily researchers were able to go back to the original field notes and drawings housed under the stairs of the offspring of the geologist who first found the prints. From these, the researchers were able to conclude that it was not one dinosaur but two and indeed they were Theropods.

Fig. 2 Australian cave footprints

Much like buses, dinosaur footprints are found in threes. Another cave story, this time on the ceiling of the Castelbouc cave in France. These footprints are up to 1.25 metres long and probably belong to a new species of large herbivore, Titanosaur. The tracks were made around 166 – 168 million years ago. (From Nature 2nd April 2020).

Fig. 3 French cave footprints

Recent finds

A fossilised duck billed dinosaur has been discovered in a Moroccan mine and named A*jnabia odysseus,* family Lambeosaurinae, and dating to the end Cretaceous. Specifically phylogenetic analysis paces this specimen within the Arenysaurini clade which is a clade previously only known in Europe.

This specimen is a mere three metres long while some duck billed dinosaurs reached lengths of 15 metres. Duck billed dinosaurs arose in North America and then spread to South America, Europe and Asia. How did they get to Africa which was isolated by deep seas during the late Cretaceous? The lead researcher from the University of Bath, Nicholas Longrich describes this find as somewhat improbable and the species name gives a clue as to how the research team believe the dinosaur made its way to Africa – by swimming from Europe. (From Cretaceous Research, November 2020).

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Breathing new life into old rocks
The Stonar School Geological Collection

By Simon Carpenter

Introduction

In October 2019, the writer became custodian of the Stonar School Geological Collection including a substantial number of minerals and fossils collected by the late **Philip Werran Curnow** (1912 –1992), a former teacher of archaeology and geology at Stonar School near Bath. The Stonar Collection had been mothballed in 2004 when the school Geology Department closed. The following account describes the ex-Stonar school collection, provides biographic detail on Philip Werran Curnow and outlines how the collection will be refreshed so it can continue to be used in future as a geology resource for the community.

Figs 1 & 2: *The state of the Stonar School Geological Collection before it was collected by the writer in 2019. The metal filing cabinets contain part of the Philip Curnow Collection. (photo credit: Claire Sparrow, Stonar School).*

Background

Stonar is a day and boarding school for nursery to sixth form. It has an equestrian centre and is located in the Wiltshire countryside close to Bath.

In the summer of 2004, the Stonar School geology department closed. The geology collections associated with it were no longer required and were stored first in one of the school laboratories and then moved to an outside barn. During the period of storage in the barn, the metal filing cabinets holding some of the Curnow Collection began to rust. It seems that the collections remained in this poor state for some considerable time before they were collected by the writer in October 2019 (Fig 1 & 2).

The writer was first made aware of the risk to the geological collection at Stonar School by former Head of Geology at the School and Chair of Bath Geological Society, Elizabeth Devon, following her retirement in 2003. Many people gave rock, fossil and mineral specimens to the Stonar School geological collection including Elizabeth Devon, the late John & Pat Bevan-Jones, the late George Hibberd, Charles Hiscock, the late Ron Smith, Christopher Steane, the late Pat Bennett and Malcolm Tucker. Geology students at the school and members of Bath Geological Society also added to the collection, but the biggest contribution came from Philip Curnow.

At about the same time, another fossil collection belonging to George Cross, a Bath Geological Society member (Carpenter, 2004) was also looking for a new home, following the collectors death. The Cross Collection including many local fossils was eventually acquired by Gloucestershire Geology Trust, but in 2019, the writer discovered that the Trust had disposed of the entire collection without attempting to rehome it. This unfortunate situation illustrates just how vulnerable private collections are, without the protection and protocols normally associated with accredited museums. The Cross Collection with a large number of local fossils, would have been an ideal 'handling' resource for Somerset Earth Science Centre.

Both the Cross and Stonar Collections suffer from lack of associated documentation, something that is difficult to correct or improve retrospectively. Because of the lack of information and limited research potential, most of the Stonar School Collection will be used in 'handling' collections. There are few museum-grade mineral and fossil specimens within the collection. When discussing this with friend and geologist, Alan Bentley, it was interesting to hear his thoughts on geology collections and in particular those intended to inspire and enthuse. Alan Bentley says, 'Ideally, specimens intended to demonstrate the geology or palaeontology of a location need the best possible examples, plus meticulous recording of the era/stage, lithostratigraphic unit, horizon, Zone, subzone and locality (plus date of collection if the source is at risk of disappearing). This often means repeat visits to a locality over several years. Specimens for teaching about their own composition (petrology) do not necessarily need all that, unless they are rare, specialist or unique. But they do need to be decent specimens and in the case of minerals, tolerably large to handle so as to sense the weight, density and texture (the rule of thumb used to be the size of a cricket ball - not always possible admittedly), clean of all surface grime and showing some sharp crystal faces, cleavage or other characteristic form. Boring-looking rock specimens can be enhanced by having one polished face, or accompanied by a thin-section microscope slide'.

Philip Werran Curnow

Philip Curnow whose private collection was donated to Stonar School following his death in the summer of 1992, taught archaeology and geology at Stonar School. There are no field note books associated with Philips collection and we know precious little about his interests and activities other than his passion for Cornish geology (Elizabeth Devon, personal communication). His wife, Margaret Curnow, was deputy headmistress of Stonar School until her death in July 1990. Philip was elected a Fellow of the Geological Society of London on 21 June 1950 (no.7039) but was removed from the list at the Council Meeting of 8 January 1964 – although no specific reason is given (Richard Ashley and Caroline Lam, Geological Society of London, personal communication). On Philip Curnow's admission form to become a Fellow of the Society, his student profession is crossed out and followed by, 'As from Aug 1st – Curator of Geology, Bristol City Museum'. At this time, Philips address is, 31 Sciennes Road, Edinburgh EH9. He had just completed an Honours degree course in Geology at Edinburgh University, with his final examination in July 1950. With a new role beckoning at Bristol City Museum, it is likely he moved from Scotland shortly after becoming a Fellow to take up his new post in Bristol.

Further research by Richard Ashley shows that Corporal Philip Werran Curnow was awarded the Distinguished Flying Medal for his conduct as a radio operator/air gunner during bombing missions to Norway on the 9th July 1940.

The Philip Curnow Collection

Philip's Collection contains both minerals and fossils. The dates on specimen labels suggests his most active period of collecting occurred during the 1960s. Back then, access to quarries to collect fossils and minerals was less problematic than it is today; there was certainly less concern over health & safety. Many of Philips geological specimens from the Mendip Hills in Somerset, for example, come from Carboniferous Limestone quarries where access today is almost completely forbidden on safety grounds. The fossils in the Curnow Collection are almost exclusively invertebrates and include some interesting and diverse material including well-preserved Silurian, Carboniferous and Jurassic corals. Local fossils are represented by ammonites, bivalves, gastropods, brachiopods, sponges and plants. There are a small number of vertebrate fossils including some shark teeth from the Blackheath Member of Abbey Wood, London and some fragments of Late Triassic bone bed conglomerate from the Westbury Formation of Aust, South Gloucestershire. The collection has been obtained mostly from UK fossiliferous locailities, but there are also a few exotic/foreign specimens in the collection. At the time of writing, the full extent and detail of the collection is not yet known.

Much of the collection is without identifying numbers or codes (Fig. 3 & 4). The written information in each specimen tray is also limited. For example, a fossil coral specimen in the Curnow Collection may simply say 'Jurassic' and 'Bath area'. Scientific names are used when known, but regrettably, detailed stratigraphy, a desirable requirement for most research collections, is missing.

There had been index cards with details of specimens and localities when the collection was owned by Stonar School (Elizabeth Devon, personal communication), but at the time of writing, these remain missing.

The School Collection

The School Collection, other than the Curnow material, had been catalogued under the headings, rocks, fossils and minerals. The collection catalogue, created when the collection was still in use by Stonar School, refers to groups of rocks, fossils and minerals and describes various 'shelves', 'drawers' and 'cabinets' where they were stored and displayed. Unfortunately, as the collection was moved, a large number of geological specimens were separated from their card trays and labels. As many of the specimens were without any codes or numbers, re-uniting some material will be very difficult.

Fig. 3 & 4. Much of the information accompanying the geological collection is missing

A future for the collection

The Stonar School Collection has a few rare and interesting fossil specimens including the crab, *Plagiophthalmus oviformis* Bell from the Wilmington Sand Member of Wilmington Quarry, Devon, collected by Philip Curnow and an 'ex-Stonar School' specimen. This fossil was donated to the Natural History Museum, London (Fig.5), on Saturday 2nd November 2019 by Simon Carpenter. A small collection of sponge fossils from the Faringdon Sponge Formation have also been identified as a donation to Oxford Museum where they will be used to make up a small handling collection in Philips name for use in their schools outreach.

The bulk of the Stonar School Collection will be offered as reference and handling material to local museums, schools and field study centres. When fossils or minerals are surplus to requirement, the agreement is, that they

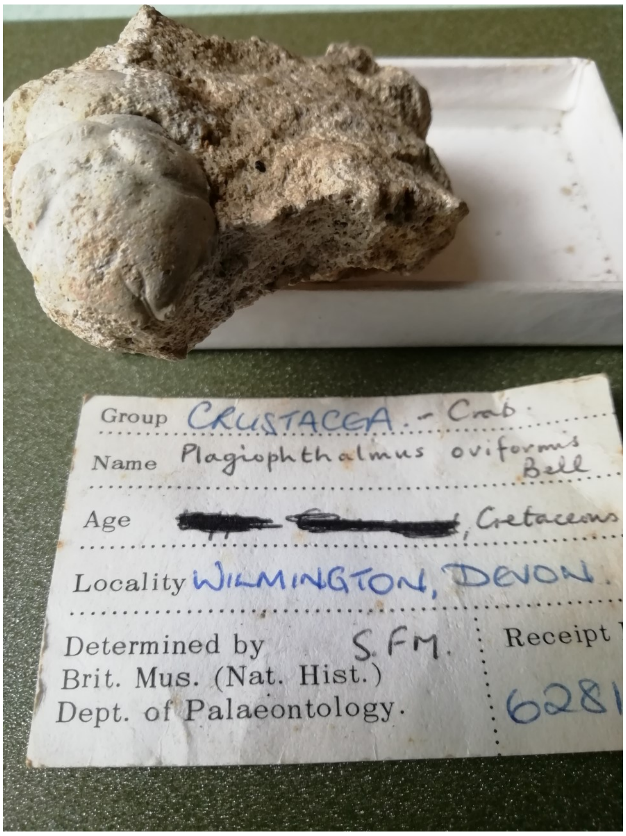

Fig 5. The fossil crab, Plagiophthalmus oviformis Bell. From the Stonar School Collection and collected by Philip Curnow. The original specimen label is missing. The accompanying form is a Natural History Museum, London determination slip. (photo credit: Simon Carpenter)

can be given away at public events or sold to raise funds to support geological charities.

It is likely that the collection is widely dispersed. All organisations accepting 'ex-Stonar School Collection' specimens will be encouraged to acknowledge this on specimen labels and documents.

At the time of writing, Somerset Earth Science Centre are interested in taking some of the Stonar material to improve their handling collections. The Centre, based at Moons Hill Quarry, Stoke St Michael work closely with schools, colleges, universities and community groups across Somerset to improve their understanding of the Natural World and in particular, the Earth Sciences. A small collection of graptolites, collected by Philip Curnow has also been donated to Bristol City Museum.

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Thanks

I would like to start by offering my sincere gratitude to Stonar School for relinquishing care of their geological collection so it can be refreshed and used with the geological community elsewhere. Elizabeth Devon, former Head of Geology at Stonar School alerted me to the threats facing the School geology collection and has helped provide information about the collection and collectors. I am indebted to Richard Ashley for finding out more about Philip Werran Curnow. Before this writing project began, we knew very little about Philip, so it is has been very exciting to discover that he was a Fellow of the Geological Society of London and a past Curator of Geology at Bristol City Museum. I would also like to thank Alan Bentley, friend and geologist for helpful comments and discussions during the course of this project and for assisting in the identification of the fossils and minerals. Finally, I would like to thank the many people who gave their rocks, fossils and minerals to Stonar School and in particular, the contribution made by Philip Werran Curnow.

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'Breaking news – meteorite impact causes devastation near South Gloucestershire village'

By Charles Hiscock

In this internet age we are also constantly being bombarded by news flashes from across the world onto our mobile phones, computers and tablets. The news may be a few seconds old when it reaches us. Some of it will be 'fake news', a scourge of modern media that leaves us wondering if we can believe some, or all of, that which we see or hear. The constant information and warnings we get about 'fake news' prompted me to wonder what it would have been like if instant communications had existed in the Triassic Period. More precisely, 214 million years ago! Hence the title of this short article (and no, it is not 'fake news', it is true – but a bit delayed and embellished!).

In 2009 I was invited by Mark Mitchelmore to have a tour of Churchwood Quarry about a mile north of the village of Wickwar. Mark Mitchelmore was a geologist for Cemex UK, the owning company and operator of the quarry. On a fine day in September we walked around the perimeter of the quarry on the excavated level at the top of the marine Lower Carboniferous Clifton Down Limestone (340 mya), the material that was processed in the quarry and sold as aggregate for the road and house building industries. However, the Clifton Down Limestone is overlain by first the Triassic Dolomitic Conglomerate, a scree and alluvial fan deposit laid down by the erosion of the Carboniferous mountains, which grades upwards into a fine yellowish sandy matrix. This, in turn, grades into the desert sediments of the red Mercia Mudstone Formation. The break at the top of the Clifton Down Limestone represents an unconformity with a gap of about 74 million years.

In 1973 A. Kirkham was in Churchwood Quarry when he discovered 'unusual green spherules up to 1mm diameter within erosional troughs along the unconformable top of the marine, Lower Carboniferous, Clifton Down Limestone'. The spherules were found initially in a 'cross bedded deposit of hard and soft silty marls occurring discontinuously at similar stratigraphic levels along much of the western face of the quarry'. Subsequently, the spherules were analysed, photomicrographed and dated to 'between Late Carboniferous and Late Triassic although Triassic is more likely'. He also considered the origin of the spherules, suggesting that 'they were created as molten ejecta associated with a meteorite impact'. (Kirkham 2003 – abstract below)

Glauconitic spherules from the Triassic of the Bristol area, SW England: probable microtektite pseudomorphs

A. Kirkham

KIRKHAM, A. 2003. Glauconitic spherules from the Triassic of the Bristol area, SW England: probable microtektite pseudomorphs. *Proceedings of the Geologists' Association*, **114**, 11–21. Marine Lower Carboniferous Limestone is unconformably overlain by Triassic desert sediments at Wickwar, Bristol, SW England. Deposited by fluvial activity along the unconformity are pockets of partly cross-bedded marly limestones containing abundant glauconitic spherules with distinctive internal architectures, such as spheres within spheres. They are accompanied by shocked-quartz and probably pseudomorph altered glass spheres representing former microtektites created by a meteorite impact with Earth. Their possible link with mass extinction events are considered.

In the late 1980's Gordon Walkden was working in the Carboniferous quarries of the Bristol area on the lizard and small dinosaur remains that had been discovered in the Triassic fissures in the quarries. He made a visit to Churchwood Quarry but it proved unrewarding for the fossil remains but he did collect 'a lump of pink rock with green balls in it'. He called it 'a pretty curio with no immediate explanation. It just went into a drawer to await developments'. Ten years or more later, when working on a thin section of the Cretaceous/Tertiary impact deposit from Haiti, the penny dropped. He realised that those little green balls he had collected from Churchwood Quarry were the same, or similar to the KT boundary deposit. (Walkden 2004)

I had read the both articles shortly after publication so, in 2009 when I visited the quarry, I asked Mark Mitchelmore about the spherulitic deposit. He said that most had been quarried away in the intervening years but, with a bit of luck, we might find some small pieces. We walked around the south west face of the quarry on the top of the limestone until reaching the graded face of the Mercia Mudstone. Within the red rock were small pieces of yellowish sandy rock more akin to the fine sandy deposits at the top of the Dolomitic Conglomerate. However, it was not plain sailing and we had to search a lot of the material before pieces were discovered containing the tell-tale little green balls. Mark told me that the original deposit was loaded with them but the pieces I was able to collect contained more sparse numbers. The photographs in the journal reports showed the green spherules to be abundant almost to the exclusion of other materials. Nevertheless, the specimens that we collected were good quality and show the spherules very clearly, figures 1 and 2. During lockdown I rediscovered my specimens of the green spherules which I collected that day and they inspired me to write this article.

Gordon Walkden's scientific sleuthing on the green spherules eventually led to the conclusion that they had been formed by the impact of an asteroid at Manicouagan in northern Canada where a 100km crater

Fig. 1 Green spherules

Fig .2 Close up of green spherules

exists from an impact that occurred during the Triassic. By dating techniques it was possible to place the age of the deposit at 214-215 mya.

Fake news? Well, up to a point because the impact was 2000 km away from Britain (since the Triassic, that distance is now 4400 km due to plate tectonics and the opening of the Atlantic Ocean). Not just up the Triassic road from Wickwar but the result of the impact, as we see, did leave its mark on the south Gloucestershire village, albeit in a way not obvious or devastating to the locals! There was no Atlantic Ocean in between us and Canada and the terrain at the time was an arid, windswept desert making it an ideal place for the landfall of an asteroid with the minimum of disruption to life on earth. There was been no major extinction recorded at that time in the Triassic. The impact caused melting of the rocks and ejected it into the atmosphere. It was only over a long period that the finest ejected material slowly returned to earth but the coarser particles rained down across the planet a short time after impact. They were then washed from the surface by heavy rain storms into playa lakes, pools and wadis where they aggregated into shallow deposits (Curtis 1982).

At the quarry, these lagoons formed in the undulating topography of the Carboniferous limestones and concentrated the spherules in lenses. While looking for the spherule samples, I found some well-preserved fossil ripples in Mercia Mudstone, indicative of the shallow lagoonal conditions, figure 3.

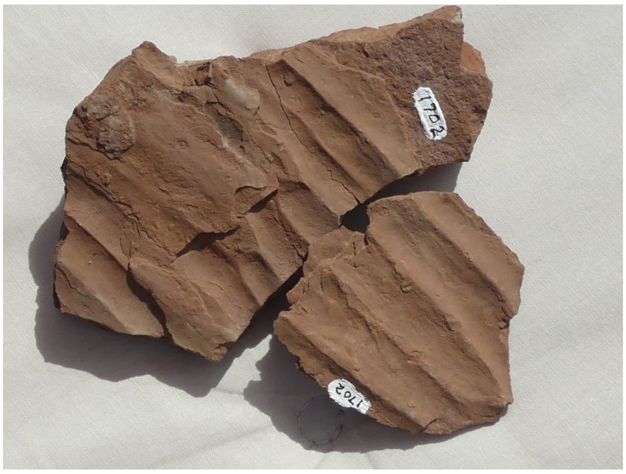

Fig. 3 Ripples in Mercia Mudstone

In 2020 the only evidence of the effect of the impact about 214 mya, 20,000 km from Wickwar, lies in various museum collections and the scientific papers written about it. Nevertheless, it is a sober reminder that these events do happen albeit rarely and that, maybe sometime in the future there will be a similar deposit of little green balls over the village of Wickwar. Now, that would be true news!

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Equatorial Rain-Forests in Bath: Fossil Coal-Measure Plants from Twerton - Radstock

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Introduction

This article discusses the Carboniferous rocks in the area of Bath – particularly the Coal Measures which were exploited in the 18th and 19th centuries in the area between Twerton and Newton St Loe. Evidence for the former coal mining activity is scant in western Bath but fragments of shale with fossil plants, as well as pieces of coal, siderite and sandstone derived from the old tips can be found. There is plenty of evidence of mining farther south / southwest in the Radstock area and coal tips are still present and accessible for collecting fossils.

Carboniferous rocks in the Bath region

One is accustomed to Jurassic sedimentary rocks in the Bath area but it is also possible to see Carboniferous rocks, and not just in the pavements of Bath either, which are of Pennant Sandstone in many places. This very hard, weather-resistant Upper Carboniferous stone was exploited at Willsbridge, just 8 km northwest of Bath, and farther afield (e.g. Hanham, Downend, and Temple Cloud). If interested, you could visit the old Pennant Sandstone quarries and exposures on your way to Longwell Green in the nature reserve of the Siston Brook valley at Willsbridge Mill (Grid Ref ST666 708) or the fine exposures along the old railway line, now a cycle track, just past Bitton towards Bristol. These outcrops are of Downend Sandstone, the lower part of the Pennant Sandstone Formation, a clean quartzitic-lithic-micaceous arenite with largescale cross-bedding and channel structures, deposited by major rivers flowing from south to north, 310-15 Ma ago. However, samples of other Upper Carboniferous coal measure facies, along with plant fossils, can be collected from old coal tips in the region. The nearest site, perhaps surprisingly, is near Twerton and a little farther afield to the south old tips can still be seen in the region of Radstock. The Radstock Museum of Somerset Coalfield Life (radstockmuseum.co.uk) has many spectacular fossil plants on display as well as artefacts from the mining activities and a reconstruction of a coal mine; it is well worth a visit.

Coal mining history and geological context

Coal has been mined in the Somerset coalfield since Roman times, but it was not until the late 1600s that is became a major industry with more than 60 pits working over the next four centuries. Peak production was in the late 19th and early 20th centuries but from then on it steadily declined until Nationalisation in 1947 when there were only 12 pits left. The last two, Kilmersdon and Lower Writhlington, near Radstock, closed in 1973. At the surface there are two small areas of Upper Carboniferous rocks in the Somerset coalfield, in the vicinity of Pensford and around Nettlebridge; otherwise they occur below the Triassic and Jurassic cover. Some workings were at depths of many 100s of metres, down to 1000 m below the surface. The coalfield has a broad synclinal – basinal structure, with the youngest strata in the middle, but it is quite deformed with large E-W and N-S faults and two major E-W thrust systems: the Farmborough Compression Belt and the Southern Overthrust. These important structural features divide the coal basin into 3 parts, the Pensford and Radstock synclines in the north and centre of the coalfield and the Nettlebridge area to the south. The coals worked in the Pensford and Radstock areas were mainly from the Upper Coal Measures, especially the Farrington Group (Westphalian D), above the Pennant Sandstone. The deformation of the coal measures took place during the Variscan orogeny towards the end of the Carboniferous as a result of the final closure of the Rheic Ocean to the south. Uplift and erosion during the Permian were followed by further desert erosion, arid-zone rivers and lakes (playas) during the Triassic (Bunter Sandstone, Mercia Mudstone and Dolomitic Conglomerate), depositing the 'Red Ground' of William Smith (New Red Sandstone). Marine transgressions during the Rhaetic and Jurassic deposited the sedimentary rocks we are familiar with around Bath: Blue Lias and Charmouth Mudstone, Midford Sands, Inferior Oolite, Fuller's Earth and Great Oolite.

The coal mines in the Pensford sub-basin, including those around High Littleton, Mearns, Camerton and Paulton, were well known to William Smith from his survey of the coal reserves there, which first brought him to this region in 1791. However, remarkably, the stratigraphy of the coal measures in this area was actually described and illustrated in a cross-section by John Strachey in a paper published in 1721 in the Transactions of the Royal Society. Strachey's section was based on his knowledge of the coal seams and associated strata, their thicknesses and directions of dip, in many pits from Bishop Sutton to Farrington to High Littleton. It is clear from his paper that Strachey had grasped the concept of stratal continuity, dip and strike, and identifying particular beds by their contained fossils, as well as the effect of stratal displacement by faults. From 1795-98, William Smith was employed by the Somerset Coal Canal Company as a surveyor and engineer to plan the routes of the canals from Camerton and Radstock to Midford, which were then to continue as one to the Kennet & Avon canal, joining it at Dundas. It was during these years, especially surveying the Triassic and Lower to Middle Jurassic strata along the canal routes, that Smith realised the significance of sedimentary strata, their continuity, along with their specific fossils for correlation such that the new discipline of **stratigraphy** was born.

Coal mining in the Twerton - Newton St Loe area

Back in the 18th and 19th centuries there were several coal mines in this area just a few km from Bath city centre, between Twerton, Corston and Newton St Loe (Fig. 1). There is a small area of Pennant Sandstone at the surface in the Corston area (see the BGS app *iGeology*) which might have alerted early prospectors to the possibility of coal in the vicinity. Indeed, coal had been worked in open quarries to the west of Corston in the early 1700s. The first coal mines were established in the 1730s near the Globe Inn on the A4 (the Globe pits) and at Newton which lasted until 1845. Conveniently, the Globe pit, near the 17th century Globe Inn, provided coal for the coking ovens which were necessary for the brewing of beer (encouraged by the Government of the time to reduce the amount of gin being consumed by the general populace). Also, it was often better for one's health to drink beer than water in those days!

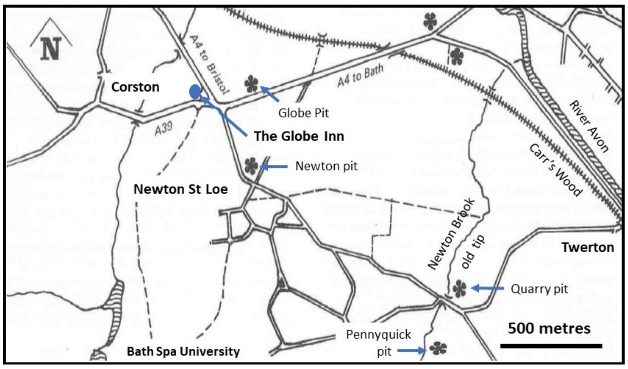

Fig. 1. Map showing the location of the coal mines in the Newton St Loe, Twerton and Corston area (modified from Davies 1977).

There were two pits in Twerton; one known as Quarry pit, started in 1834, was located at the junction of Newton and Whiteway Roads. In 1841 a new mine was opened at Pennyquick, a km to the south which lasted until 1877. Much of the coal extracted from these mines was high grade and it provided coking coals for the local industry in Bath, including brass-making at Saltford and Keynsham and, later, fuel for the cloth industries in Twerton itself, Widcombe and Lyncombe.

The coal mines provided employment for around 100 men and boys judging by the returns on the 1841 census, with most living in Corston and Newton. Although a dangerous and tough environment working in cramped spaces with the danger of rock-falls and explosions, as well as floodings, the coal miners were generally better paid than agricultural workers. In the early 1800s a hewer in the mine working a 6-day week would be earning up to 18 shillings whereas a farm labourer in Somerset would be receiving around 7 shillings.

The coal measures in the Twerton-Newton area are on the very eastern edge of the Bristol & Somerset Coalfield and on the northeast side of the Pensford Syncline and they occur unconformably below the Triassic-Jurassic strata (Fig. 2). The coal beds belong to the Upper Coal Measures, i.e. the Westphalian C (Bolsovian sub-stage), and are within the Downend Member of the Pennant Sandstone Formation. The rocks appear to be quite faulted and locally folded, as recorded in the mine records, and the general dip is towards the NW at quite high angles (Fig. 3). Figure 3 is a delightful sketch cross-section by M. Harvey, Manager, of the mine workings at Newton St Loe dating from 1844, showing the surface buildings, the dipping coal seams named and the pattern of tunnels, along with notes on the particular use of the coal from each seam. Many of the shale fragments that can be collected from the vicinity of the Twerton pits are shiny and sheared, the result of the strong deformation of the strata. The coal seams in these pits are relatively thin, mostly 40-70 cm, but they are at quite shallow depths. In the Pennyquick mine 13 coal seams were encountered, but many of these were less than 40 cm so that only 3 were worked at depths of 110, 120 and 210 m, with thicknesses of 0.7, 0.6 and 1.5 m, the last being known as the Great Seam (!).

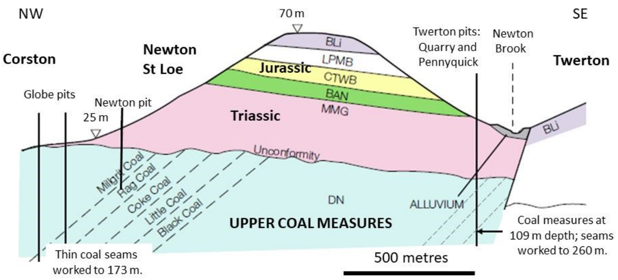

Fig. 2. Cross-section from Twerton to Corston showing the geology and the location of the coal mines. BLi = Blue Lias, LPMB+CTWB+BAN = Rhaetic, MMG = Mercia Mudstone, DN = Downend Formation (modified from B&NES 2010).

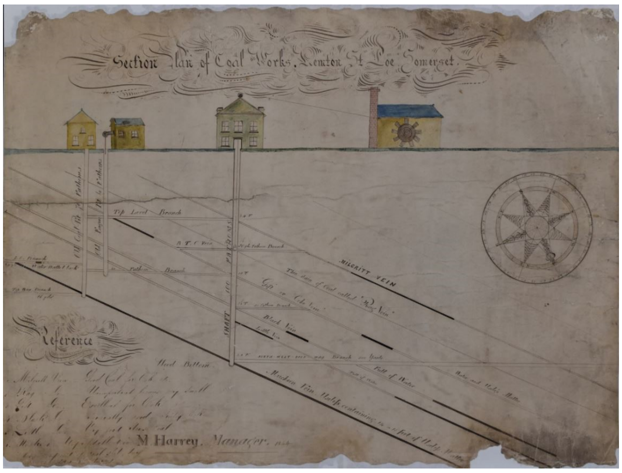

Fig. 3. Cross-section of the coal workings at Newton St Loe showing the steep dip of the beds and access tunnels. From the Bath Record Office.

Between 1808 and 1813, on the other side of Bath a trial shaft was dug at Batheaston (ST782 675) in the hope of reaching coal, with the now-famous Father of English Geology, William Smith, involved as a consultant. However, this venture was not successful; the coal measures are absent, having been eroded away during Permian uplift, and beneath the Triassic 'Red Ground' occurs the Lower Carboniferous Cromhall Sandstone and then limestone. In addition, the shaft flooded several times during the digging and this affected the flow of water at the Roman Baths to everyone's consternation (Kellaway, 1991).

Evidence of coal mining at Twerton

The coal mines around Twerton, as elsewhere, naturally produced a lot of waste material but unfortunately (for fossil hunters that is!), and as is the case in many places in the UK, these tips have been removed or flattened and grassed over. In fact, in the 18-19th centuries it was a requirement that land disturbed by coal mining be returned to its original state when the mining activity ceased. Hence, in the Twerton-Corston-Newton area there is little evidence of the pits and opencast sites. With material from the pits near the A4 and the Globe Inn it is thought that some of this was used to construct the embankment of the GWR railway line across the Avon floodplain towards Saltford, built by Brunel in the late 1830s. The waste rock from the Quarry pit at Twerton was landscaped to form Pennyquick Park, adjacent to Newton Road, towards Whiteway Road.

Fig. 4. Coal measures mudstone with abundant plant fragments, including a leaf (pinnule) of a pteridosperm (seed ferns). Twerton.

In spite of most evidence from the coal mining industry being lost in this western area of Bath it is possible to find pieces of coal measures rock hereabouts. One location is along the footpath in a wooded area that runs south from the A4 to Whiteway Road, following the line of the Newton Brook on the eastern side; look along the footpath itself and in the adjacent bank, above Newton Brook, opposite Bath Mill. This path can be accessed through Carr's Wood, which runs alongside the main GWR railway line (itself parallel to the A4) with two fine neo-gothic Bath-stone tunnel entrance arches built by Brunel in the late 1830s. Here can be found pieces of coal, black mudrock with coaly streaks (referred to as 'scares' by miners) and carbonaceous shale, which may contain plant fragments (Fig. 4) or show shiny polished surfaces. Round to egg-shaped nodules of siderite are present (Fig. 5); these consist of very fine crystals of iron carbonate ($FeCO_3$), they weather orangey brown on the outside but have a steely grey colour when fresh.

Fig. 5. Siderite nodule, distinguished by a brown colour and feeling heavy in the hand, formed within muddy anoxic sediment during very shallow burial. Twerton.

There are also pieces of sideritic mudstone with rootlets and some nodules contain fossil insects. Siderite is a common mineral in coal measures strata and forms in an anoxic freshwater environment, such as marshes and waterlogged soils. There are fragments of sandstone, fine-grained, thin-bedded samples with cross laminae and generally larger pieces of more massive coarser sandstone derived from a thicker bed. Sandstone was likely deposited in streams, on floodplains, in deltaic channels and in shallow bays.

Coal measures fossil plants

Of the common fossil plants there are many fragments of seed ferns (pteridosperms) to be found on old coal tips, including conspicuous delicate leaves (pinnules) of *Neuropteris* (Fig. 6) and *Alethopteris* (Fig. 7).

Fig. 6. Leaf of a seed fern, probably Neuropteris. Twerton.

Fig. 7. A large piece of the seed-fern Alethopteris (pteridosperm). Radstock Museum.

These actually look like modern ferns but in fact they are not (they produce spores rather than seeds) and they became extinct in the Jurassic. One of the most common fossil plants seen in mudrocks is *Calamites* (Fig. 8), a pteridophyte, i.e. a spore-bearing vascular plant, rising to 25 m in height. *Calamites* is the term for the stem, which has transverse markings of leaf nodes and longitudinal furrows and ridges. Its leaves, *Annularia*, are small, lance-shaped and arranged into rosette-like whorls (Fig. 9). This is a relative of the present-day horsetail, *Equisetum*, which can be found in many damp places near streams and in woods, indeed commonly where the coal tips are! Another common pteridophyte is the tree-like *Lepidodendron*, which grew to a height of 40 metres in the swamps and had a horizontal, forked root-system, referred to as *Stigmaria,* off which extended numerous thin rootlets (Fig. 10). The stem is recognised by its rhomboid-shaped leaf-scars (Fig. 11) contrasting with another common pteridophyte *Sigillaria*, with its squarish leaf scars.

Fig. 8. A stem fragment of Calamites (pteridophyte), a relative of the modern horsetail. Kilmersdon tip.

Fig. 9. Leaves of the horsetail, Annularia, with a distinctive radiating pattern. Radstock Museum.

Fig. 10. The root system (Stigmaria) with thin rootlets of a lepidodendron tree. Radstock Museum.

Fig. 11. Piece of a lepidodendron tree with leaf scars. Radstock Museum.

Fossil plant sites in the Somerset coalfield near Radstock

There were numerous old coal tips (locally called batches) in the Somerset coalfield but many have been removed or reclaimed and some are now covered with trees and bushes; nevertheless, there are still a few places left to seek out fossil plants. The old tip for the Kilmersdon pit is just west of Haydon (Grid ref ST682 536) and the tip for the Lower Writhlington pit (ST703 553), 1.5 km ENE of Radstock, are both still accessible. There is also the spectacular batch at Midsomer Norton (ST654 553) which from a distance looks just like a volcano (Fig. 12).

Fig. 12. The impressive batch, old coal tip, at Midsomer Norton.

The Writhlington and Kilmersdon tips mostly consist of debris coming from the roof shales above the No. 10 coal seam (also called the Big, Brights or 21-inch seam) in the Farrington Group of the Upper Coal Measures, which was exploited by the pits in the last 20 years of their operation. Numerous fossil plants have been recorded from these tips and a list is given in Allen (1977). However, perhaps the most exciting fossils to look out for here are the insects, much sought after by Victorian collectors. Dragonflies are particularly special with one found with a total wing-span of around 50 cm; it was discovered on a slab of shale from the Tyning tip and named as *Boltonensis radstocki*, after the palaeontologist who first described it and its location. In addition, cockroaches, grasshoppers and spiders have been found in the shale of these tips near Radstock, showing that the coal measures environment was not very different from tropical swamps today. It can be difficult to distinguish insect wings from fern pinnules, however, a case of clever camouflage!

For the Kilmersdon tip, take a footpath west from Haydon opposite the post-office or there is a public footpath out of Radstock south along the Wellow Brook (1.5 km) which crosses the SW side of the tip and there are good exposure for searching out fossils. Much of the material there is black shale and coaly shale, which commonly have compressed plant fossils. In addition, siderite nodules are present, and these may contain fossils too. Pieces of *Calamites* are common, as well as a variety of seed ferns.

The Lower Writhlington tip is accessible from the south side of the old Radstock to Wellow to Midford railway line which is now a cycle path. Coming from Upper Writhlington, off the A362, take the minor road north to Lower Writhlington, pass St Mary's Church and cross the bridge over the Wellow Brook to get to the old railway line. The tip is a conspicuous discrete steep hill with many pieces of coal measures rock lying around near the base. Coal was recovered from this tip in the mid-1980s. Also look out for the WWII pill-boxes. From the summit of this tip there is a good view to the NW and the Tyning tip, on the north side of the old railway track, where there are also exposures and plant fossils.

The Midsomer Norton Batch is very accessible, but much of the shale has disintegrated into very small pieces. Large slabs of thin sandstone and sideritic mudstone can be picked up with plant fossils. Climbing to the top though is an effort and risky!

Concluding remarks

It is always interesting to find fossils and think about how things were millions of years ago, but it is almost even more exciting to find fossils lying about which are from rocks not exposed at the surface but coming from 100s of metres below ground. The pieces of Upper Carboniferous mudstone with fossil plants shown in the Twerton area and tips near Radstock are the evidence of hot and steamy equatorial forests and swamps that existed 300 million years ago with a quite different flora from that of today, and also testament to the hard work of a long-gone generation of coal miners, who worked in terrible, unpleasant, confined and dangerous conditions.

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Bath Geological Society 50th Anniversary 1970-2020

By Graham Hickman

2020 is an important year for the Bath Geological Society as it represents our 50th anniversary since the inaugural meeting on 25th September 1970 at Bath University. The Society is indebted to the officers and committee members who have enabled the programme of monthly lectures and fieldtrips over the years. When circumstances allow the Society plans to hold a special event to celebrate.

Chairs of the Society

Graham Hickman	2020-present
Richard Pollock	2018-2019
Maurice Tucker	2015-2017
Richard Pollock	2012-2014
Elizabeth Devon	2008-2011
Vicki Griffths	2006-2007
David Workman	2002-2004
John Parkins	1998-2001
Charles Hiscock	1992-1997
Eddie Avent	1989-1991
Allan Comer	1988
Joy Coppin	1987
Bob Whitaker	1984-1986
Ron Smith	1982-1983
Edna Parmenter	1980-1981
George Cross	1977-1979
Bob Whitaker	1975-1976
John Andrews	1973-1974
Bob Whitaker	1971-1972

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Roger Southgate	2006-2009
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Laurie Lloyd	1994-1998
Sonia Chant (Vince)	1984-1993
Allan Comer	1978-1983
T. Grant	1975-1977
M. Carter	1973-1974
David Robertson	1971-1972

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Vicki Griffths	2003-2005
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Ann Davison	1971-1976

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