Home Counties North Regional Group Newsletter

Issue No. 9– September 2020

Opening words from the Chair HCNRG

Dear Home Counties North Regional Group Members,

Times flies so quickly and, before one realises, summer 2020 has passed by, I hope you are all well and getting on with the many, "new normal" ways of either working at home or in the office with social distancing.

The HCNRG Newsletter Editor Susan Lednarova is currently unavailable to produce Issue 9 because she is working outside the U.K. In consequence, I volunteered to produce this issue of the Newsletter and the Committee agreed. The Committee and I will continue to be maintaining HCNRG active and engaging with Members in these unprecedented times whenever we can.

Government lockdown restrictions have eased; Burlington House will have partial, phased reopening as of Monday 7th September, with the Library open on Thursdays only and strictly by appointment only. The Geological Society announced that they will try to increase opening hours over the coming weeks and months, including reinstating room hire from the start of October in line with recent Government guidance. I shall look forward to arranging another afternoon workshop at Burlington House when conditions are safe and allow this to happen.

In the meantime, I am delighted to deliver the next bimonthly HCNRG Newsletter, issue 9, to you to enjoy the knowledge and fascination of different facets of geoscience.

In this newsletter, we have articles written by both new and returning HCNRG FGS contributors; in addition, I have invited Derek Turner, Secretary of Bedfordshire Geology Group to write an article on their successful social distancing field trips. Articles in this newsletter include the Moine Thrust, Scotland – a new look based on current advanced research; Blue John, its occurrences, mineralogy, and history of mining in England; Corona virus - life in La Salvetat sur Agout, France; Geology of Montagnes Noires, France; Geology and palaeontology of Yanqing Geopark, China; South Georgia – geological survey and mapping, glacial geomorphology and glaciers; and last but not least - How microfossils helped in the Soham Murder investigation, England. As for myself, I wrote a short article on the geology of Bardon Hill Quarry in anticipation of a future HCNRG field trip, which hopefully will materialise in 2021; I have also included a quiz, with a prize for the winner.

My profound thanks go to all contributors; I am grateful for their generosity in spending the time to write with immense passion about the highlights and some of their best endeavours in the realm of geology. Whether it is as a personal hobby, a profession, academic research, observations on holidays or the report of a field trip, they share their best geology knowledge with no reservation; they are all geologists in their hearts.

I hope you will find this bimonthly newsletter enjoyable reading and look forward to hearing from you. Closing date for receiving articles for Newsletter issue No.10 is **Saturday 31st October 2020.**

The Committee and I wish you and your families the best of health, take care and stay safe.

John Wong Chair HCNRG

September 2020

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How microfossils helped in the Soham Murder investigation

Haydon W. Bailey* FGS & Liam T. Gallagher FGS

Network Stratigraphic Consulting Ltd., Harvest House, Cranborne Road, Potters Bar, EN6 3JF

***Retired**

At about half past ten on Wednesday, 25th of June 2003, a phone call came into the offices of Network Stratigraphic Consulting Ltd. in Potters Bar. A man's voice at the other end asked: "Do you know much about calcareous sponges?"

My response was brief "I know that they exist and that they're pretty rare. Why? What have you got?"

The voice, who by this time had introduced himself as forensic geoscientist Andrew Moncrieff, went on – "I have a report claiming that they are abundant in a chalk sample I have."

This time I was a little more definitive: "Someone is having you on – do you have any images?" He did, and he sent them to me; they were nothing like sponge spicules, they were prismatic calcite crystals from broken inoceramid bivalve shells, which do occur in certain chalk samples, unscientifically speaking, "by the bucket load!"

The conversation was the start of a manic three days which commenced with the arrival of a police car from Cambridge early on the same Wednesday afternoon, carrying a total of ten samples. Four were large enough to be processed for foraminifera and nannoplankton content, the other six were grains of chalk so small that they could only be analysed for nannoplankton. We were not told by the detectives delivering them where they were from, simply that they needed our results on the following Friday. We had two days to come up with some answers.

I carried out the foraminiferal analyses during the following day, Thursday, and my colleague, Liam Gallagher, worked his way through the nannoplankton analyses for all ten samples. We hardly spoke to each other all through Thursday. By close of play on the Thursday afternoon we were speaking again, and we had most of our answers. What we'd been presented with by the police were (See Figure 1):

- A solid chalk sample from a ditch excavated at a place called Blackdyke Farm, near to Lakenheath, Suffolk.
- Chalk samples from a roadway known as Common Drove, near Lakenheath – this was the site where the bodies of Holly Wells and Jessica Chapman had been found in August 2002. Chalk from the Blackdyke Farm ditch had been used to "pave" Common Drove during 2001 and 2002.
- Chalk/sand residue collected from the front suspension arm of the Ford fiesta driven by the suspect Ian Huntley.
- Several small fragments of sediment collected from the carpet in the driver's foot well of the Ford fiesta belonging to Ian Huntley
- Several extremely small fragments of sediment collected from the vacuum cleaner used by Ian Huntley to clean the carpet in the driver's foot well of the Ford fiesta.

When we compared our results on the Friday morning, a number of similarities became apparent and the geological puzzle started to fit into place. Firstly, both the foraminiferal data and the nannoplankton results from the Blackdyke Farm sample and the Common Drove samples gave identical results, indicating that the chalk originated from a single foraminiferal zone in the chalk (UKB3 of Hart et al., 1989) and a single nannoplankton subzone (UK1d of Burnett et al., 1998). These two units were of equivalent age and calibrated directly with the boundary level between the *Neocardioceras carcitanense* and *Mantelliceras saxbii* ammonite subzones within the upper part of the Lower Cenomanian. When we looked at the Clare Borehole, drilled 38 kilometres to the south of Lakenheath, the BGS recorded the same foraminiferal microfauna over a thickness of six metres of chalk. Furthermore, within these six metres there occurred two beds of chalk described as containing abundant inoceramid prismatic crystals. These beds were no more than two and a half metres thick. These were Andrew Moncrieff's misidentified "calcareous sponge spicules".

We could pin down the chalk from Blackdyke Farm and Common Drove stratigraphically to a single chalk unit, no more than two and a half metres thick. Given that in the Transitional Province of the Chalk (Mortimore et al., 2001) there is approximately 375 metres of succession, we had a pretty tight fix.

The foraminiferal fauna and nannoplankton flora identified from the Blackdyke Farm ditch and Common Drove was also recorded from the sample retrieved from the front suspension arm of the Ford fiesta driven by the suspect Ian Huntley. In addition, the same nannofloral association was recorded from one of the samples taken from the carpet in the driver's foot well of the Ford fiesta belonging to Ian Huntley.

Given that Ian Huntley had fully cleaned the Ford fiesta , even to the extent of putting a complete full set of tyres on the car, he had still left enough micropalaeontological evidence on the vehicle to indicate that it had probably been driven along Common Drove. In fact, in order to build up the pile of sediment on the front suspension arm, he must have done a U-turn on Common Drove and, in so doing, had "shaved" off chalk sediment from the artificial piles of chalk present along the sides of the Drove. These had been created when the chalk was originally used to pave Common Drove and had been bulldozed flat.

Liam Gallagher and I spent the morning of Friday June 27th writing our totally integrated report, which calibrated the precision of our results and outlined the evidence that Ian Huntley's Ford fiesta must have been driven along Common Drove. At this stage in the police investigation he was still denying that he had ever been to the location. The micropalaeontological evidence suggested otherwise.

On the Friday afternoon, having submitted our draft report we were asked to take it apart again so that we had separate reports for each of the foraminiferal and nannoplankton results, as these would now become integral parts of our witness statements. We were now regarded as witnesses for the prosecution.

What we hadn't established at this stage was if Common Drove and the single origin chalk paving it, was unique. Could there be other similar driveways in the area which had comparable chalk "paving" and could have been driven over by the suspect. At this point we invited Christopher Wood to join our team. Chris was the retired BGS senior stratigrapher specialising in Chalk palaeontology. He now ran his own consultancy. Chris's unique memory banks for the Chalk of south east England meant that he was able to draw up a map showing the subcrop of our "chalk zone" across Cambridgeshire and Suffolk.

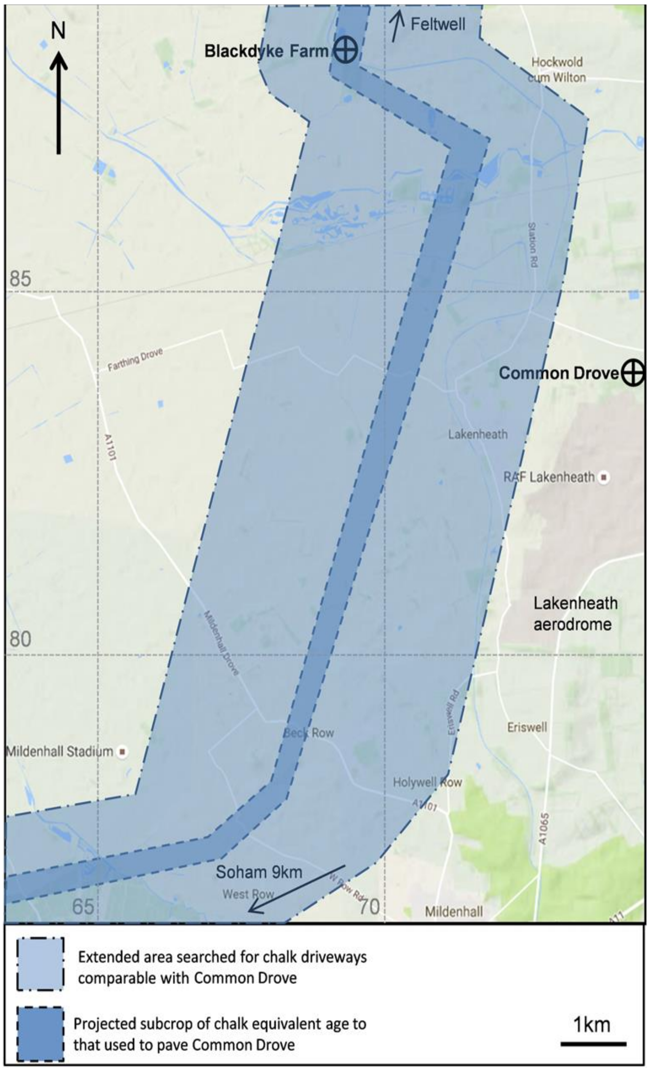

Figure 1

Using this map, he then illustrated a "band" a kilometre wide to each side of the subcrop. This became our next search area and detectives working on the case were asked to search the highlighted area and identify any driveways paved with chalk. Chalk samples were taken from these and brought back to our laboratory for analysis. Several were identified, but none yielded nannofloras or microfaunas comparable with those recorded from Common Drove. The "paving" history of Common Drove and the unique source of the chalk used to pave it meant that it was truly unique, and we could be sure that Ian Huntley's car had been driven along it.

All the evidence from the prosecution team had to be submitted to the defence team prior to the trial. When Huntley was presented with the micropalaeontological evidence placing him at the site where the bodies of the two girls had been found, he switched his story. He now claimed that he had driven along Common Drove in order to go plane-spotting at the nearby Lakenheath airbase. However, because he, and the defence team, were willing to accept our statements unchallenged, they were included in the case evidence, but we were never called to court to be cross examined.

Our evidence was just a minor part of a major investigation, which eventually built up enough physical evidence to fill two warehouses. The cumulative impact of the evidence was sufficient for Ian Huntley to admit killing the girls in his house, but he could not remember how or why prior to a jury verdict. Huntley basically looked for a manslaughter charge, however he was found guilty of the murder of the two girls Holly Wells and Jessica Chapman. He was sentenced to life imprisonment with the recommendation that he serve no less than forty years in prison.

Liam Gallagher and I had collaborated together for almost fourteen years by the time we carried out this work; this, and subsequent analytical studies for the Thames Tideway project, led us to the belief that, given a lump of chalk from the London Basin, using a combination of foraminifera and nannoplankton, we could place it stratigraphically to within 1.5 – 2 metres of the Chalk succession. The accuracy of the work we carried out on the Soham murder case led the lead forensic geoscientist Andrew Moncrieff to comment as he left our office for the last time, "when I carry out a murder I'll make sure I don't bury the body in the chalk!"

The forensic use of microfossils in serious crime investigations is probably more common than people realise. Frequently, it is more likely related to the use of plant spores and pollen rather than the calcareous microfossils used in the Soham case. Nevertheless, when used systematically such microfossils can be dramatically effective. For anyone interested in accessing further information regarding forensic micropalaeontology, a detailed version of this study was published in 2017 by The Micropalaeontological Society as: *Calcareous micropalaeontology in forensic investigations, with particular reference to the so called "Soham murder case"* (Bailey et al., 2017).

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Looking back during lockdown

Dr David Brook OBE FGS

It is now 16 years since I retired and about 10 years since I last carried out consultancy work after my retirement. I have not been totally inactive during the time since then as I have been involved with the HCNRG, the Harrow & Hillingdon Geological Society, the Harrow Natural History Society, the Geologists' Association and the London Geodiversity Partnership. However, I have gradually withdrawn from active participation in most of these groups so lockdown has not been too different from my normal life.

In thinking about what a retired geologist does in lockdown, one thing I have been actively doing is to reflect on my early years as a geologist with the British Antarctic Survey (BAS)and to look at how things have changed on the ground since that time. I have been aware of some of these changes through the activities and publications of the South Georgia Association (www.southgeorgiaassociation.org) and the British Antarctic Survey Club (www.basclub.org) as well as BAS.

I had travelled south on *RRS Shackleton*, leaving England in October 1965 and after stops in Montevideo, in Uruguay, and Stanley, in the Falkland Islands, we arrived in South Georgia in early November. The island had been mapped topographically and geologically during the South Georgia Survey expeditions led by Duncan Carse in the mid-1950s, with Alec Trendall (2011) as the geologist. Subsequently, Neil Aitkenhead and Phil Nelson had mapped the area around Cumberland East Bay, distinguishing contacts between the quartzo-feldspathic Sandebugten Series and the volcaniclastic Cumberland Bay Series on the Barff Peninsula.

After 3 days based at Godthul Harbour on the northern end of the Barff Peninsula to familiarise myself with the previous work, I transferred to the disused whaling station at Husvik, in Stromness Bay, to continue the geological mapping of the area between Cumberland West Bay and Fortuna Bay. I was assisted in the field by Alec Bottomley, a second-tour man who was an experienced member of the Craven Pothole Club. My mapping area was bounded on the south by the Neumayer Glacier and on the east by the König Glacier and it is the changes in these glaciers that are most noticeable. My field maps were enlargements to 1:50,000 scale of the 1:200,000 scale map of the island produced by the Directorate of Overseas Surveys (DOS). Once we started using them, we realised their inadequacy so Alec assisted greatly in the exercise by putting his cave survey skills to excellent use to produce a more accurate 1:50,000 map of the area.

Extract from the DOS map of South Georgia showing the area mapped by Aitkenhead & Nelson and that I mapped.

Revised map of the area between Cumberland West Bay and Fortuna Bay prepared by my field assistant Alec Bottomley.

I must confess that I was a little lost when it came to the geology. I found the identification and interpretation of complexly folded and faulted Andean volcaniclastic sediments of the Cumberland Bay Series a little difficult and my geological work was eventually incorporated in the work by Mike Skidmore (1972), the geologist who came after me in South Georgia and at Halley Bay.

The geomorphology was, however, of considerable interest, particularly the raised beaches and elevated rock platforms around the coast and the scree benches around 2 lakes alongside the Neumayer Glacier, one of which was dammed by the glacier and the other by moraine (Brook, 1971). Once again, Alec's surveying skills were put to full use while I struggled with the geology. The lake at the southern end of the Olsen Valley had more but narrower benches and assuming that they represented temporary still-stands during recession of the glacier, their formation had clearly ceased as the glacier no longer formed the dam. Gulbrandsen Lake on the other hand was still dammed by the glacier and it was quite possible that more benches would form as the lake level fell further.

Scree benches, lake at southern end Olsen Valley

Lake at southern end Olsen valley showing extent of Neumayer Glacier

Gulbrandsen Lake 16 November 1965

Gulbrandsen Lake 31 December 1965

As for the glaciers which formed the boundaries of my mapping area, the Neumayer Glacier terminated in a heavily crevassed floating zone with calving of small icebergs from the end-cliff, while the König Glacier just tailed off into a short zone of outwash gravels extending to the shore of Fortuna Bay.

Neumayer Glacier snout floating in Cumberland West Bay

König Glacier snout & outwash gravels at the head of Fortuna Bay

I first became aware of significant changes when I looked at the Environment management plan for South Georgia (EMP 2000), published in 2000. This clearly showed that the scree benches around Gulbrandsen Lake were much more extensive than they had been when I was there and that the lake itself had reduced considerably in size due to retreat of Neumayer Glacier. BAS have also produced a 1:50,000 scale map of the area around Stromness Bay, essentially the area I was working in, and I believe that Gubrandsen Lake is no longer marked on that map but Gulbrandsen Valley is so marked. The series of satellite images below illustrate the changes that have occurred this century and how the lake initially shrank before finally disappearing, while the glacier retreated, dramatically lengthening Cumberland West Bay.

Scree benches around Gulbrandsen Lake (EMP2000)

A much reduced Gulbrandsen Lake (EMP 2000)

Neumayer Glacier 2005

Neumayer Glacier 2009

Neumayer Glacier 2015

Neumayer Glacier 2020

These final two images show the retreat of the König Glacier from its position very near the head of Fortuna Bay. The glacier snout in 1965 was only about 2-300m from the shoreline but there is now a much greater spread of outwash gravels between it and the shore.

König Glacier & the head of Fortuna Bay 2015

Google Earth 2020 - König Glacier

Interestingly, while I was preparing this short piece about the changes in South Georgia glaciers since I had worked there in 1965, I came across the American Geophysical Union's Blogosphere (https://blogs.agu.org/fromaglaciersperspective), from a glacier's perspective and the two items below. This gives detail of the changes between 1999 and 2020, with an 8.8km retreat of the Neumayer Glacier and its separation from the König Glacier. I would estimate that since my time on South Georgia, the 2 glaciers have retreated by over 10km and 34-5km respectively. A sobering thought on which to conclude.

Neumayer Glacier 8.8 km retreat 1999-2020 Fjord Expansion

AGU Blogosphere: From a Glacier's perspective – Neumayer Glacier

Konig Glacier, South Georgia Separates from Neumayer Glacier in 2017

AGU Blogosphere: From a Glacier's perspective – König Glacier

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Yanqing Geopark – Palaeontology, Geology and a Petrified Forest

Rudy Domzalski FGS

The lockdown has provided an opportunity to go through my field notes and write a report of a geology trip in China in March 2016.

After a three-day conference on rock physics, a small number of attendees decided to go on a field trip in Yanqing Geopark led by Li Tang, coordinator of international affairs at the China Petroleum University (Beijing) as well as a geophysicist.

Yanqing Geopark is located to the northwest of Beijing and south of Inner Mongolia Autonomous Region.

The geological features in the geopark are mainly attributed to the marine and fluvial sedimentary deposition from 1.6 Ga to 140 Ma ago, followed by the Yanshanian tectonic movement about 80 Ma ago, a subducting plate moving northwest rotating China into Inner Mongolia (Wikipedia, 2020). This gave rise to the mountains and near vertical strata described in this paper. The field trip provided much evidence of tectonic and sedimentary processes as well as volcanic processes, and I have covered the main examples of these where I was able to take photos.

We set off early in the morning in a minibus from the conference hotel and headed north into the mountains towards Yanqing Geopark.

During the journey there was plenty of opportunity to see some of the geology and evidence of the tectonic uplift in the region from the mountains we were passing through (see figure 1).

Figure 1: View of mountains on the way to Yanqing Geopark: Evidence of the Yanshanian tectonic movement

The first stop was in a well-preserved park containing a forest of Jurassic petrified trees. We stopped to have a packed lunch in the car park before walking up a hill to the petrified forest. The tree stumps were preserved in enclosures to protect them from erosion as shown in figure 2.

Figure 2: Petrified Tree in protective casing

After the petrified forest we continued the journey to the Hongshiwan Dome. It is composed of Archean metamorphic rock (c. 2.5 Ga ago) and Mesoproterozoic Changcheng system marine sedimentary rock (c. 1.6 Ga ago). The dome is elliptical in shape with a length of about 8km and a width of 3km. The overlying strata inclines gently in all directions forming the dome. This dome was formed from the upwelling of a magma chamber underneath. Figure 3 shows part of one side of the dome. I did not get a date for this magmatic upwelling however from the Mesoproterozoic rocks which comprise the overlying layers of the dome, the upwelling must have happened after 1.6 Ga ago possibly due to the extensive tectonic activity the region has undergone in the last 100 Ma.

Next stop was at the monoclinal landform which is composed of red conglomerate and sandstone in the fourth member of the Lower Cretaceous - The Tuchengzi Formation (c. 140 Ma ago). The original horizontal layers have been uplifted and have become inclined, as shown in figure 4, due to the Yanshanian Movement. From the bottom to top, the sediment grain size is gradually fining upward suggesting a fluvial or flooding depositional environment. The complex erosion has permitted this rock formation to show its layering sequence

Figure 3: Side of Hongshiwan Dome

Figure 4: Monoclinal Structures

Further along there is a near vertical strata of mudstone which contains dinosaur footprints however when we got there it had been covered up to protect the footprints from erosion. There was further evidence of dinosaurs in the region as described in the museum visit.

After a short drive we found a local museum which had a small but excellent display of palaeontology and rocks of interest. Below are a few pictures of a dinosaur bone, a dinosaur egg and some rocks with mineral deposits as well as rocks which would be of interest as a building material, these are shown in figure 5. Unfortunately, I was not able to get a leaflet describing the minerals and rock types, however through a conversation with the curator I was told that there are copper deposits in the area.

Figure 5: Dinosaur bone, dinosaur egg and rocks sourced locally, as displayed in the museum

Further away from the magmatic upwelling and monoclinal structures there was more evidence of the marine environment and tectonic uplifting. Figure 6 shows the near vertical strata of dolomite which would have originally been deposited in a shallow marine environment before the tectonic uplift due to the Yanshanian tectonic movement. There are very thin layers of mudstone between the layers of dolomite, evident of fluvial deposits (Figure 7). This suggests that the area underwent marine regression and transgression. For every 10cm the marine sedimentary sequence represents about 1000 years. The dolomite belongs to the Gaoyuzhuang Formation of the Mezoproterozoic Changcheng System (c. 1.6 Ga ago).

Figure 7: Mudstone exposed between the dolomite layers

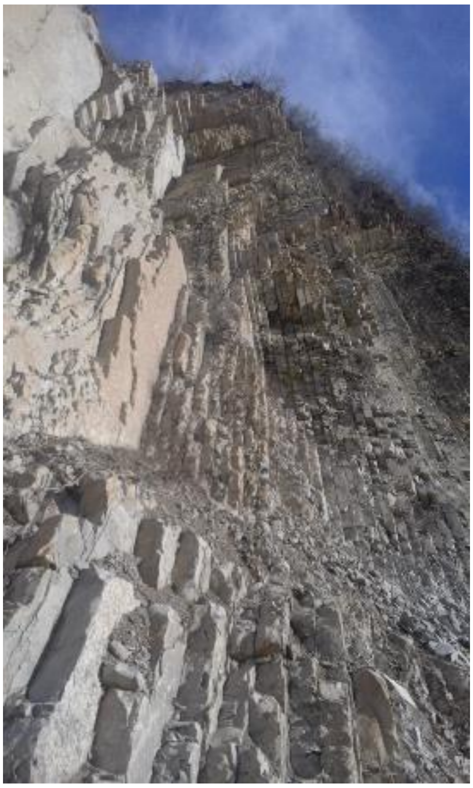

Figure 6: Near vertical dolomite strata

The final outcrop I will describe is of the near vertical strata of Precambrian Wumishan Formation (c.1.4 Ga ago) Again it is a dolomite outcrop formed in marine conditions and has been uplifted by the Yanshanian tectonic movement. The outcrop is about 100m high and the weathered surface is a greyish, white as shown in Figure 8.

Figure 8: Near vertical dolomite

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A new look at an old thrust belt

Roy P Dunn BSc FGS

The author has been researching the Moine Thrust Zone since 1981, and has spent numerous field seasons mapping 65km+ in considerable detail. This is not intended to be an exhaustive review, see Olroyd and Dewey papers for more on Moine Thrust research history.

The Moine Thrust Zone, one of the premier deeply eroded mountain belts has a complex and as yet, not completely unravelled history. It is laterally discontinuous and numerous unanswered questions remain concerning its formation, age, and physical extent offshore.

Without delving too deeply, this thrust belt has been a problem since Victorian times. Science politics, government surveyors with big egos (Murchison & Geikie) with expansionist ambitions for their own systems; and amateur (academic) geologists (Lapworth & Nicol) carrying out detailed mapping coming up with opposing theories, coming down to "how do you get metamorphic rocks parked on top of non metamorphic rocks?"

Was there a "great dislocation", or could you develop a gneiss on top of an unmetamorphosed quartzite and limestone?

Things were a little complicated as there appeared to be no discontinuity between the non metamorphic and metamorphic lithologies in some localities, no change in bedding or foliation. The published literature suggests that the Geological Survey camp was winning. Perhaps with our hindsight it is easier to accept tens of kilometres of lateral translation on thrust faults, than it is to consider some as of yet undetermined mechanism to produce gneiss on top of quartzites and limestones in-situ. There was no driving force for mass lateral translations of material, although the Alpine mountain chain in Europe was a possible hint that such a movement was possible.

In the early 1880's Geikie was seeking to put to death the ridiculous idea that he and his mentor (and predecessor Head of the Geological Survey of Great Britain) Murchison had been wrong about the absence of a great discontinuity separating the Eastern Gneisses (or granulites as they were sometimes known) from the unmetamorphosed limestones and underlying quartzites. He sent his most accomplished geologists to the key areas starting at Durness and Loch Eriboll (Fig 1), and over the years working their way SSW. Callaway, read a paper at the Geological Society in 1881 concerning the Durness Limestones as they were to become known, and the newer gneisses and Lapworth published several papers in 1883 highlighting the disposition of all lithologies, and the difficulty of having gneiss on top of non-metamorphic rocks. The detailed Geological Survey mapping started in 1883, and Peach et.al. almost immediately made the leap to understanding large displacement lateral (reverse) faults with crumpling in the form of folding and duplexes in the footwall beneath. Geikie's 1884 paper in Nature conceded he and Murchison had been wrong, and other existing authors had been correct.

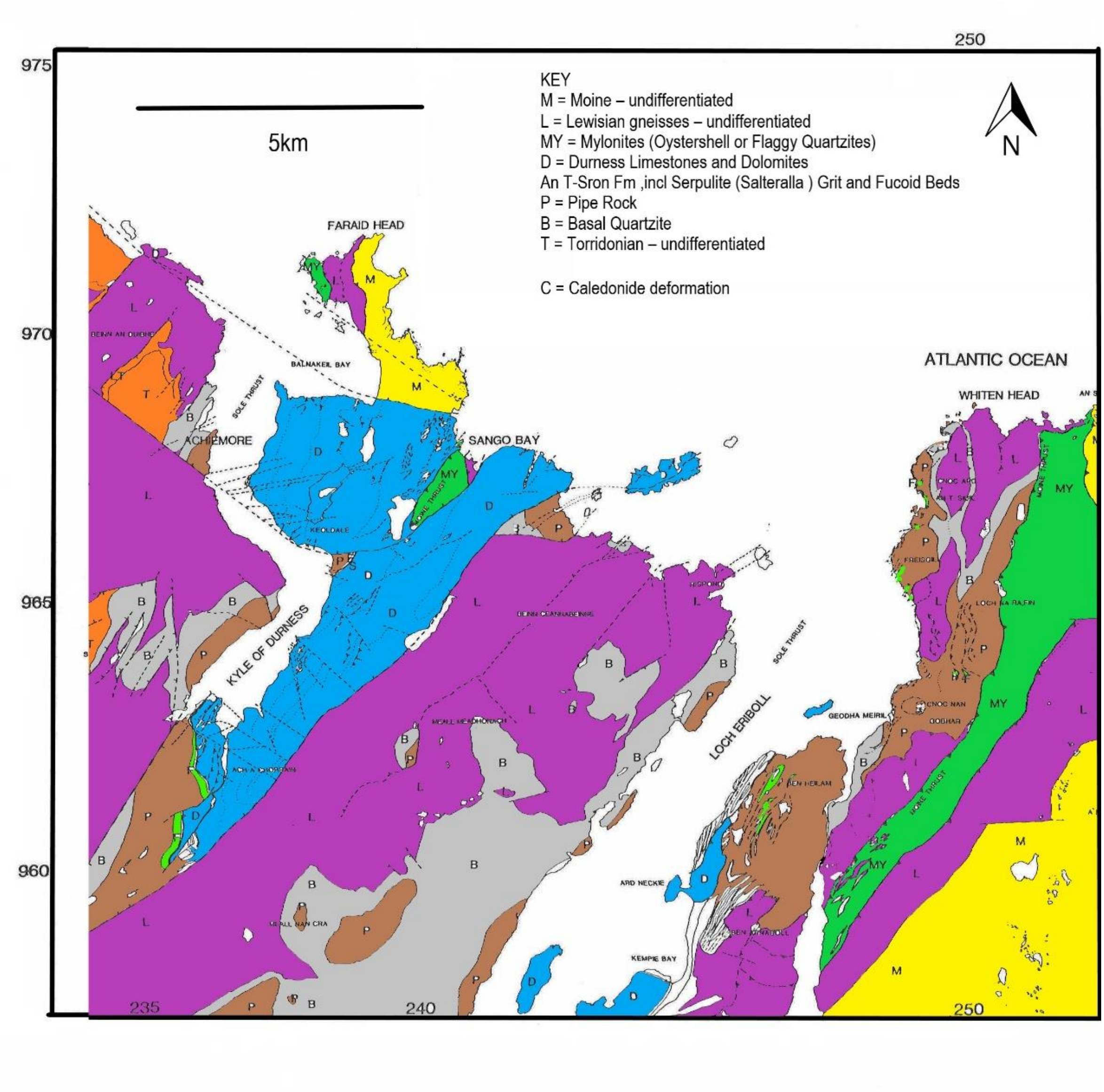

Figure 1. Geological map of the Northern most part of the Moine Thrust Zone

Eventually the structure of the whole thrust belt from the northern Scottish coast, down to Skye was confirmed and resulted in the groundbreaking Geological Survey Memoir by Peach & Horne (1907)

This classic thrust belt is still the subject of intense debate, and appears to break many of the rules constructed by geologists over the years. Figure 2 indicates older Basal Quartzite imbricates above younger Pipe Rock duplex (78% shortening), with a central area with nappes, rotated blocks, down cutting faults and regular thrust orientation faults. So younger over older and right way up, more or less follows thin skinned thrust belt rules. However, to take this photograph one has to stand on a duplex with an extensional floor thrust, which does not obey general thrust rules.

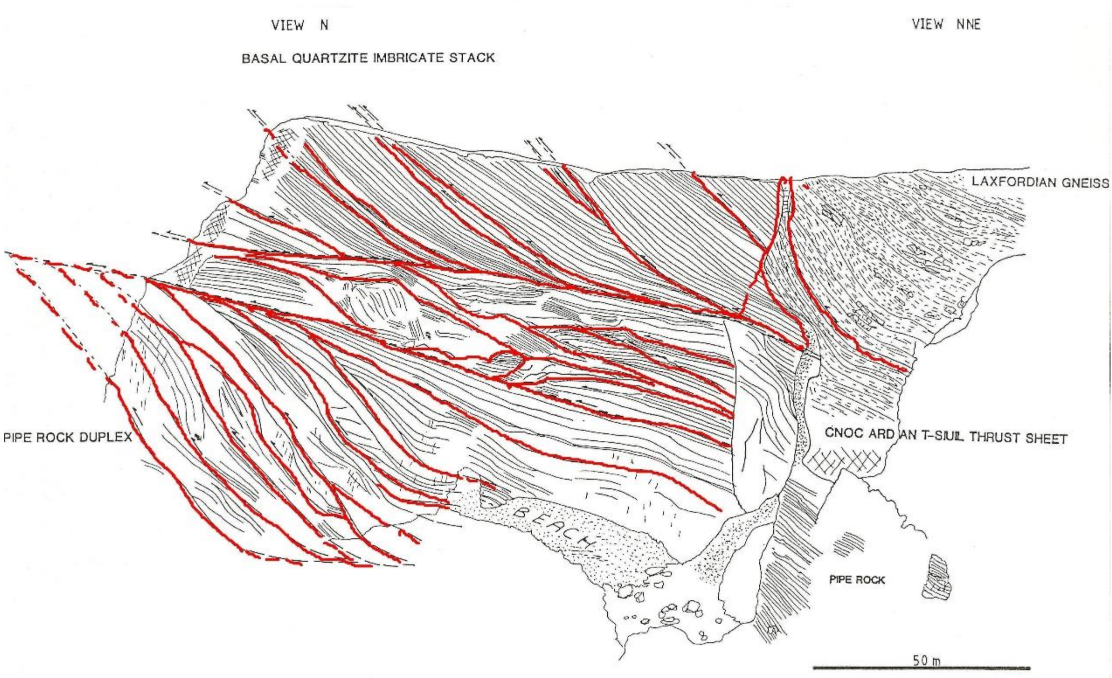

Figure 2. Duplexes and imbricates at Mol Mohr, NE, Loch Eriboll

The present study attempts to reconcile some of these issues, determining many parameters experimentally, rather than using numerous published parameters from other studies. A five-degree hinterland or decollement slope is presumed for much of the thrust belt in this northern area based on mapping foreland on the western shore of Loch Eriboll. This is based on measured thrust ramps in the Cambro-Ordovician metasediments, and average ramp angles in the Moine as well as spacing of ramps and flats in the presumed Laxfordian type gneisses involved in the thrust belt.

Peach & Horne originally thought the thrust belt propagated hinterlandward, (towards the east) then in the 1980s post Elliott & Johnson 1980, everything was foreland propagating, thin skinned, propagating towards the west, though thick-skinned maybe hinterland propagating, but definitely could be out of sequence thrusting at any time.

The main overriding thrust sheet (the Moine Sheet) is carried piggyback style on a sequence of foreland propagating, quartzite and carbonate thrust sheets and duplexes but is itself breached by a second reactivated Moine Thrust which effectively decapitates a Cambro-Ordovician duplex. This second Moine Thrust then potentially cuts down tectonic section near Sango Sands in Durness with much thinner quartz mylonites than at Loch Eriboll to the east. The presumed top to the Durness Durine formation is currently a tectonic surface (the base of the Mylonites, Moine Thrust s.l.) so may have been much thicker but removed tectonically as the initial overriding thrust sheet bulldozed an Ordovician or Silurian surface.

The Moine Thrust Zone typically includes brittle deformed foreland sequences adjacent to the sole thrust, a belt of complication with hinterland, lateral and foreland dipping duplexes, imbricates, fault propagation folds and syncontractional extension up to the Grampian and Scandian deformed Moine Thrust Sheet with ductile deformation features, riding in places on 600 meters of mylonitic Oystershell phyllonites and mylonites.

A transect across northern Sutherland from East to West follows a transition from higher metamorphic facies to weakly metamorphosed metasediments. At the same time there is a transition from basement involved thrust sheets to weakly metamorphosed quartzites, dolomites and limestones and more rare siltstones.

So simple story, perhaps?

The Moine mylonites, where the lithology was first described by Lapworth are of uncertain origin, they are believed to have a combination of Lewisian Gneiss, Basal Quartzite, Moine Pssamites protoliths. Dewey et.al. 2015 suggested that the Moine Thrust fault, may be linked at depth to the Great Glen Fault, which has a sinistral and a dextral movement history. The Moine Thrust may also be a remnant of the Grenvillian Orogeny (1Ga) formed at depth, then reactivated 520Ma later in the initial stages of the Grampian Orogeny.

The Moine psammites and pelites have deposition ages ending around 1000-870 Ma and pre-Caledonian deformation ages 850-790Ma. These Moine rocks only occur east of the Moine Thrust. To the west of the Moine Thrust, the Lewisian basement (with its own history of multiple reworking) has a carapace of unconformable Torridonian s.l. red beds with a Cambro-Ordovician metasedimentary sequence. Some authors suggest that there is some equivalence between the Moine and the Torridonian though this remains controversial.

Temperature control on deformation has been undertaken by various means, as traditional index metamorphic mineral assemblages are not present.

- C-axis fabric skeletons can describe quartz fabrics stabilizing at various temperatures, and also record the amount of rotation
- Quartz grain boundary deformation mechanisms, bulging recrystallization, 280-400°C; sub grain rotation, 430-530°C; and grain boundary migration 540-570°C.
- Illite Crystallinity; x-ray diffraction of clay grains that are believed to be the product of recrystallization around 2µm diameter, the less the spacing between the clay layers, the higher the temperature during recrystallization.

All three are used in the current study, to provide a range of temperature controls. With temperature controls, ultimately come deformation models.

An inverted geothermal gradient is located in the Balnakiel region near Durness, indicating shear heating from the over-thrusting Moine mylonites and psammites sheet, whilst a regular geothermal gradient warmed the sequence from below. A continuous lateral thermal gradient is seen from west to east, with increasing grade toward the Grampian Hinterland as would be expected. There is also a lateral geothermal gradient along the thrust belt strike, being slightly cooler in the south than in the north. Back in Durness, if you take the temperatures from the less deformed rocks we can infer maximum depths of burial of about 11 km.

Ages of deformation are also being further constrained. Early attempts used time consuming bulk wet chemistry to gauge ages via radioactive decay of Uranium to Lead. Laser Ablation Inductively Coupled Plasma Mass Spectrometry is a newish technology in geology, enabling thumb sized polished, solid samples to yield dates from calcite with Uranium and Lead isotopes, or potentially Rubidium and Strontium. Garnets growth rings can be precisely dated, indicating multiple deformation or temperature events from a single grain.

Published dates put the start of movement on the Moine Thrust at 450 Ma (Bird et.al. 2013) based on Late Ordovician garnet around Northern Highland Terrane indicating Proto Moine Thrust develops at depth, and suggest final movements and cooling of the Moine sheet at 428-413 Ma. Dallmeyer et.al. 2001, however the undeformed Loch Borralan pluton in Assynt was dated at 429+/- 0.5Ma by Goodenough et. al. 2011.

The famous Lighthouse Duplex west of Ben Heilam on the East coast of Loch Eriboll was sampled and the slickensides on the linking faults do not yield Grampian or Scandian ages but ages more akin to post Pangea collapse and ultimately creation of the West Orkney Basin. Samples taken from the Durness area reveal Grampian and Late Scandian ages, but are not accurate enough for publication.

The controversy continues, as the author has located syn-contractional extension adjacent to the Sole Thrust in the Kyle of Durness, a theoretical but little reported feature of thrust belts in mountain wedges, and pseudotachylytes within the thrust zone, and the foreland is deformed by thrust related features.

If we take our transient 11 km depth of burial at Durness, and a longer 15 km formation depth for the Quartz mylonites from the Grampian or Grenvillian Orogenys we start to get some control on the deforming mountain wedge. The wedge was approximately 172 km from the projected toe down to the mylonites at a depth where they are believed to have formed. If you turn the volume of the wedge into a flat bottomed block down to 15 km depth, and assume its top was at approximately sea level before the final Scandian deformation the block must have been 140 km in length. Against this we have to consider was the wedge on average 11 km deep at Durness, and deeper but eroded faster without any modern vegetation cover to protect it even at low altitudes? Were standard Silurian geothermal gradients higher than present day gradients, so heating would have been greater than today, so our 11 km depth may be an overestimate?

So, if you put all of this together, we can approach a wedge model that suggests the backstop to the Moine Thrust was 311 km from the current outcrop of the Moine Thrust when it started to climb for the presumed formation depth of 15 km. This would accommodate the width of any Grampian terrane but with the sinistral and dextral movement on the Great Glen Fault, the backstop collision may have originally been NNE or SSW of the current position of the Northern Highland Terrane relative to the Grampian Terrane.

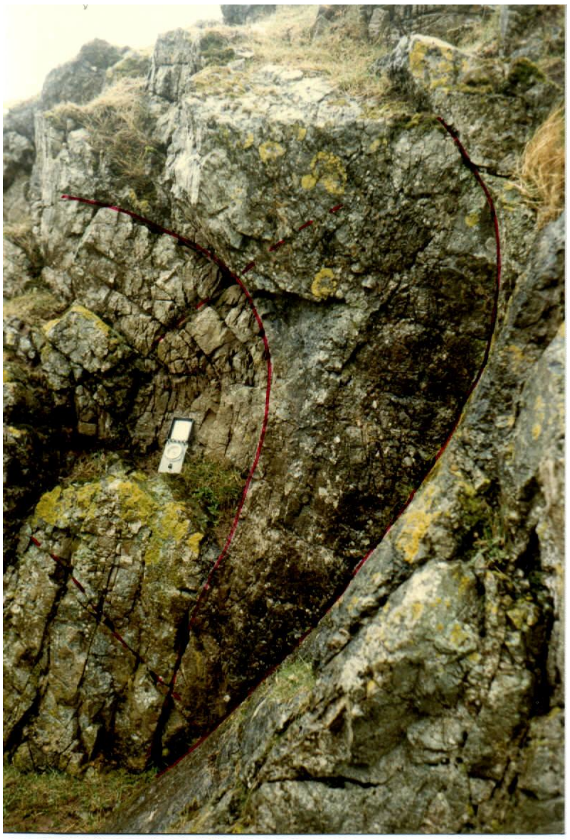

Figure 1. Nappe like fold in the Durine formation, part of the undeformed foreland. View (SSW) along thrust belt strike. Compass clinometer for scale.

In conclusion the Moine Thrust zone is almost certainly the transition between a thin skinned (foreland propagating) thrust belt and a thick skinned basement involved thrust belt. It has out-of-sequence faulting and reactivation of existing faults. It may date back to Grenvillian times (1Ga) when it was an aseismic mid crustal fault, but have been reactivated in the Caledonian Orogeny several times, and link at depth with the Great Glen Fault, and possibly other transcurrent faults.

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Corona virus – Life in La Salvetat sur Agout, southern France, and the geology of the Montagnes Noires

Doris Southam FGS

I travelled to France in mid-July when the lockdown in the UK eased. The flight with Ryanair was just like any other flight, packed in like sardines, but everybody had face masks, the stewardesses gave out drinks, although it said that they would not come round!!! At the airport in Beziers, I had my certificate that I had not been in contact with an infected person and my address here in France, The customs official did not look at it, nor when I asked whether he wanted it, he waved me away!! So, if anybody on the flight had developed any symptoms, they would certainly not been able to do any tracing! Very casual!

In La Salvetat sur Agout in southern France, I cut 50 cm high grass around the house, so I can walk in passages without necessarily being attacked by ticks (we have quite a few deer here, and I was warned that with the heat and lovely weather, it is tick galore infestation! I took the honey from my beehive, that is quite an operation and sticky as well! Labour intensive, as my equipment is hand-me-downs from my brother! Unfortunately, I can't take the honey to London, not in the hand luggage and in the hold it gets too expensive, so I distribute it here to my friends, who are eagerly awaiting their share !!!.

There has been no case in the village here, as far as I am told, and people wear facemasks, in the shops and in the café inside but not on the balcony, We have market day on a Thursday and a Sunday, when there are quite a few people ln the market place, and the shops, also tourists from the coast who come up for the week end. So, I avoid shopping on those days. With the good weather, we meet each other mostly outside in the gardens anyway. The only place, in the balcony of the local cafe, where we are about 1 m apart from each other, but the windows of the balcony are open, I wear my mask when I finish drinking the expresso! On the whole, outside in the open, people are quite casual.

Geology of this area:

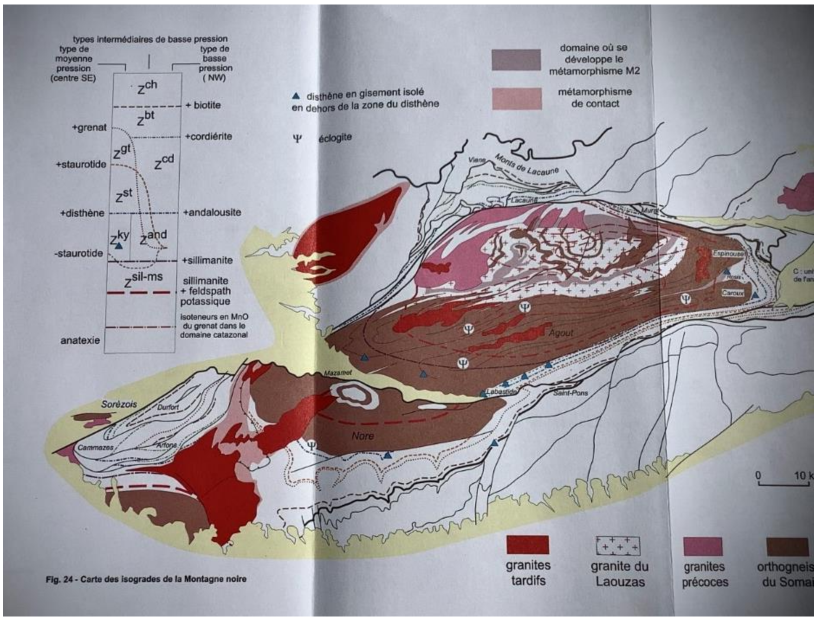
The Hercynian (Variscan) Orogeny was a major and prolonged episode, mountain building that began from the Late Devonian and continued throughout the Carboniferous, affecting a broad belt along an approximately WSW to ENE line from what are now south-western England and north-western Europe and southern Europe and the Iberian Peninsula, and eastern North America, caused by northward thrusting and plutonism along a discontinuous front.

The Montagne Noire is part of the West European Variscan Belt. In the French Variscan segment, a collisional orogeny, characterized by a major horizontal thrusting, progressive crustal thickening and southward migration of deformation of metamorphism during the Devonian and Carboniferous (Demay, 1948 and other authors). Later stages in the orogenic evolution of the belt involved intense granitic magmatism (Duthou et al, 1984) and regional low pressure/high temperature metamorphism associated with uplift and erosion.

This metamorphic core complex is one of the first well-described Variscan regional examples of late orogenic crustal thinning subsequent to orogenic shortening and thickening (Echtler and Malavieille, 1990). It is variously described and extensively written about as: The Variscan Montagne Noire in southern France: a dextral sigma clast in a transpressive suture (Mementi, Valbolne, 2004).

A Transpressional Model (Michel Demange, 1999), an attempt at explanation of the Domes : Viscous Collision of Channel explains double domes in Metamorphic Core Complexes (Patrice F Rey, et al, 2011).

In a regional context, the central part of the Montagne Noire (classically called the Axial Zone) is an isolated crystalline complex, elongated east-northeast - west-southwest. It is composed of presumably Proterozoic or early Palaeozoic gneisses, mostly migmatised and intruded locally by late Variscan anatectic granites (Bard and Rambeloson, 1973; Demanche, 1975, 1982). In the south, this domal structure is tectonically overlain by polyphase low-grade metamorphic structures.



Source of diagram - BRGM Service Geologique National, France

The granitic intrusion uplifted the whole area, which was estimated by some at 8000 m at one stage. Now we just reach approximately 1000 m. But there are interesting features, such as herring bone deformations in gneiss, at 1000m high (Lac de Vesol).

The cover above the granitic batholith is metamorphic, up to garnet grade, (at least in the area where I looked). Unfortunately, not big enough to make jewellery.

Of course, these scientific considerations, mentioned above, have little to do with everyday experience of the whole region, a complex amalgamation of autochthonous and mini bits of crust or islands (not known where they come from), pushed northwards by the migration of the African continental plate:

La Salvetat on a high plateau, (700 m) in the centre of the Montagne Noire, is now a forested hilly area (after forestation in the 1950's) , with hot springs just 20 minutes away, (a Spa), testimony to thermal activity still operating. There are numerous artificial electricity lakes, sheep grazing, supplying milk to Roquefort, (and I just learned, the sheep are also sold to Greece, to provide the Feta cheese!!) . Over the mountain pass to one side, the descent is to the northeast through the ragged Gneissic Mountain belt, The Carroux , passing the Gorges de l'Heric, (Orthogneiss with Augen, a spectacular walk). Further down that area before coming to Le Lac Du Salagou, situated among red rocks (argillaceous rocks with a very high content of iron), one passes a quarry with a big slap of rock with crinoids (I discovered some years back a very prolific fig tree on the site!), over a high plateau of volcanic rocks, past Le Cirque de Moureze, (karstic landscape), there is also a disused bauxite quarry.

Towards the southwest, towards Carcassonne one encounters a karstic landscape, lakes, and Minerve, situated on a rock, carved out by two rivers in a limestone landscape, with a 2 to 3 metres thick deposit of alveoline limestone, and a spectacular unconformity between the gneiss and the limestone. (and again, two very prolific fig trees, in the dry river bed !!!) I also came across a disused quarry with overturned flute marks.

The entire area, down to the Mediterranean (60 km) is so rich and varied, (not to forget the vineyards, and their "tasting" facilities), that there is never a boring moment, especially when you travel with the local geological maps in your glovebox!

Birkbeck College organized a few years ago a field trip for second year geology students and alumni to this area, so there is really enough to see.

There is a very detailed field guide, (available in the Geological Society's library!) with suggested itineraries, to the whole region, in French (this is, most probably because there is a very famous geology department at the University of Montpellier), I use this guide when I have guests interested in the local geology. **But helas, no guests this year, everybody is weary of the Virus.**

Bedfordshire Geology Group social distancing field trips

Derek Turner, Secretary, Bedfordshire Geology Group

Bedfordshire Geology Group has started some of its outside activities again. Aware that some members might justifiably question why they should pay their membership fee if no events are taking place, the committee decided to proceed with a planned visit to Barton Hills on a Saturday in June followed by a midweek visit to Broom Quarry South in early August.

Barton Hills is a National Nature Reserve, a few miles north of Luton, famous for its chalk downland wildflowers. Little chalk is exposed but the site has a spectacular dry valley system, powerful and easily-visible springs and extensive views across the Gault Clay vale towards the Greensand Ridge and beyond. A complication arose because the site- a well-known beauty spot- had become extremely popular as lockdown rules eased and the weather was dry, warm and sunny. Fortunately, I knew a public-spirited farmer who allowed us to gather in her farmyard and this allowed us to approach the site from a less busy direction.

We expected that with some members self-isolating, fewer than 6 people would want to attend but interest rose steadily and we ended up with 10. This meant that as well as adhering to the social distancing guidance for a group of 6 or fewer people walking outdoors, we had to split into two groups, each led by someone familiar with the site, that set off separately and kept apart at each of the information and discussion stops. Most of the paths we used were wide but we occasionally had to wait while others passed through gateways and also to see the springs which bushes encircle and are a magnet for inquisitive children as well as geologists. Those who attended were all pleased that they came and thought that the arrangements that we made were satisfactory.

Broom South is a few miles from Biggleswade and the latest quarry in the valley of the River Ivel to be exploited for its sand and gravel. The owners, Tarmac, have an extensive health and safety policy which one of their staff took us through in detail outside before ensuring we had the correct hi-vis safety gear which involved a brief visit indoors. We had all taken our face masks and donned them for this and used the sanitising fluid on the way in and out to clean our hands. The staff member accompanied us as we made our leisurely way around the site, essential as the quarry operates continuously. Only 4 of us had turned up on the day and keeping our distance was easy as we made our way through the areas that had been worked and between heaps of stone where we searched for fossils and erratics.

With Covid 19 likely to be around for many months and possible years and pushing the prospect of having more indoor meetings far into the future, Bedfordshire Geology Group has proved that there is no reason why outdoor events should not take place as long we adhere to official guidance and take sensible precautions. Those members who attended were all pleased with the opportunity to get out and see some geology in the field again.

Minerals [Blue John] and Me

Stuart Wagstaff FGS

There is always an event in your life which has an effect that controls the path which you follow. For me it was minerals.

When I was seven years old, my friend gave me some quartz crystals which was completely mesmerised by and amazed that such beautiful things could be produced by nature. From that point on, our holidays in Wales, were dominated by opportunities to find minerals. At that time, I never gave it a thought that people could actually find minerals as a job! It was not until my teen years, when I visited Derbyshire on a geography fieldtrip, that I was completely hooked. The geology, forces of nature and the occurrence of minerals drew me in further. Most impressive of all being the mineralogy of Treak Cliff Cavern, famed for its production of Blue John, a very aesthetic variety of Fluorspar/Fluorite.

I'm sure many of you, if not all of you, are aware of this mineral, but it has been a fascination of mine ever since my first trip and I have been lucky enough to enjoy the countryside and the mine on many occasions. As a member of several mineralogical societies/clubs, this has provided opportunities for adding to my collection of this beautiful mineral.

From this interest, below is a very brief summation of its occurrence, its formation and some photographs of specimens in my collection.

Blue John is a form of fluorite composed of Calcium Fluoride (CaF_2). This particular variety is characterised by its blue/deep purple colour which is commonly inter banded with clear and yellow fluorite. Blue/dark purple is a relatively rare colour for fluorite and there is much debate as to where this colour originates (oil from the shales above or rare earth metals / radioactive isotopes, none of which have been concluded). Due to the cubic crystal structure, blue bands are seen as intricate zigzags through the mineral and occurs in renowned 'veins' formed through successive phases of mineralisation.

The mineral is thought to have been mined as early as 1709 and discovered whilst searching for Lead and Zinc deposits which occur in the area. However, it is known that the Romans had worked this mineral as a carved cup has been discovered in a Roman grave. The mineral is known to have been used as a decorative stone from about 1770 where it was used in fireplaces, vases and jewellery

It has been known by several names through its history but thought to have adopted its name 'Blue John' through its analogy with its French colour description 'bleu et jaune' (blue and yellow).

From the early 1700's several mines were opened up on the side of Treak Cliff Hill in Derbyshire to work this mineral along with several open cast excavations on the side of the hill (shown in the photograph below). Two of the mines can still be visited today; Treak Cliff Cavern and Blue John Mine, the former of which has the most impressive displays of Blue John and can be seen center left in the photograph.

Treak Cliff Hill showing former mine workings

The mineral occurs within the Carboniferous Limestone which, at the time, formed a series of Reefs along the northern margin of a lagoon stretching across most of the Peak District. About 5 to 10 million years later, at the end of the Carboniferous Limestone age (Brigantian), the area was raised above sea level and was subjected to erosion and the formation of karstic features. About 1 million years later, the area began to sink again and the karst features were broken down into boulders which slid down the former reef slope (what we see as Treak Cliff today). Over the next 10 million years, during the Namurian times, shales and the Millstone Grit sandstones were formed and deposited over the top of the boulder beds. These deltaic deposits were thought to have attained a thickness of about 1500m burying the limestone deep into the crust. As the temperature and pressure increased, this caused reactions within the sediments and trapped water releasing chlorine, fluorine, sulphate, calcium, zinc, lead and barium. These fluids permeated though the voids within the boulder beds which were then trapped by the shales above. These saturated waters then deposited the minerals we see today.

The mineral veins are generally defined by their pattern of colour bands and traditionally there were fourteen named veins some of which can be seen in the photos above and below. The main commercial veins occur in Blue John Cavern and Treak Cliff Cavern although several other mines were sunk; notably Old Tor Mine (now sealed up). The named mineral veins include Twelve Vein, Five Vein, Bull Beef Vein, Dinging Room Veins, Winnats One Vein to name but a few. Mining still continues today albeit on a small scale from Treak Cliff Cavern. The mine is restricted in the amount it can extract and this is generally turned into ornaments and sold often demanding a high price.

If you are ever in Derbyshire, Castleton is well worth a visit.

Specimens of Blue John

Geology of Bardon Hill Quarry, Leicestershire; and a Quiz competition

John Wong FGS, Chair HCNRG

In the early autumn of 2016, I led a field trip for the Amateur Geological Society to Bardon Hill Quarry in Leicestershire, which 4 HCNRG Committee members also attended.

A few months ago, just before the full nation-wide lockdown, members of the HCNRG asked me to arrange a field trip to Bardon Hill Quarry, I am hoping that, when the pandemic restrictions ease further, especially social distancing, it may be feasible sometime in the summer or autumn of 2021 to arrange such a field trip.

In the meantime, below is a brief summary of the geology in the quarry, and a simple quiz competition open to every HCNRG FGS member; the winner will receive a BGS geology map of the Bardon Hill area. The quiz question is in the last paragraph of this article.

Bardon Hill Quarry produces over three million tonnes of asphalt-coated roadstone and aggregates per year, which is approximately 15% of the annual production in the U.K.; the quarry is located at the highest elevation in Leicestershire, 964 feet (293m) above sea level; on a clear day at the top of the quarry on the summit of Bardon Hill one can see the Malvern Hills in the distance, as well as the Shropshire Hills and the Peak District. The quarry floor in 2016 was at 165 feet (50m) above sea level and it was thought that it would reach a depth below sea level by the end of the decade. Bardon Hill is a Site of Special Scientific Interest; apart from the volcanic and plutonic igneous petrology, the structural geology resulting from the Caledonian Orogeny and the Triassic paleo-topography, the area is also home to the rare Charnwood red spider.

The geodiversity in the quarry includes volcanic rocks formed by late Precambrian ocean island arc volcanism and Triassic sedimentary rocks formed within an arid desert environment. The stratigraphy is complex; the geology is significant because the quarry has a variety of Precambrian outcrops *in situ* whereas other areas in England have very few exposures of Precambrian rocks on the surface. Andesitic igneous rocks in the quarry were from a volcano formed above a subduction zone where the andesitic magma intruded into overlying Precambrian water-laid volcanic tuffs of the Bradgate Formation; its eruptions were similar to the Soufrière Hill volcanic eruption on the Caribbean island of Montserrat in 1995.

Large-scale folds and a large number of faults, which formed later during the Caledonian Orogeny in the Silurian and Devonian, can be seen in the quarry walls.

The Caledonian Orogeny tectonism was followed by intense subaerial erosion creating deep valleys and gorges. During the Triassic Period, steep valleys were filled with silt and mud of extensive seasonal desert lakes, which formed the Mercia Mudstone Formation with thick wadi channel deposits. The base of these mudstones shows a heterolithic unconformity on a buried paleo-landscape of Precambrian basement rocks which contain volcaniclastic horizons (see photograph attached).

The various types of igneous rocks *in situ* include volcanic fine-grained microcrystalline andesite, dacite, andesitic–dioritic porphyries, phyllites in the fault zones, dioritic and granophyric dykes, intrusive monomictic breccias also known as Bardon 'Good Rock', and rocks which have spherillitic textured glassy margin representing the chilled andesite.

Epiclastics include various Triassic fluvial mudstones and volcanoclastic sediments, and pyroclastics include submarine volcanic tuffs, hyaloclastic breccias are all present in the quarry.

Now the Quiz question - **What is the AOD depth of the Bardon Hill Quarry floor at the present time (September 2020)?** Answer can be in metres or in feet AOD; the HCNRG FGS member who gives the nearest AOD will win a BGS geology map of the Bardon Hill area. Please send you answer on email to homecountiesnorthregionalgroup@gmail.com , closing date is Friday 30th October 2020.

Bardon Hill Quarry southwest face, while the background may resemble late Precambrian Torridonian Sandstones lying on an irregular unconformity over the Paleoproterozoic Lewisian gneiss, it is, in fact, the Triassic Mercia Mudstone Group sediments lying on a burial Triassic landscape, the basement rocks consist predominantly of a variety of late Precambrian felsic igneous rocks, mostly andesites.

Thank you to all the article contributors

A very big thank you from the HCNRG Committee to all the article contributors.

In the absence of HCNRG lecture meetings and field trips/workshops, the production of additional newsletters is an attempt to provide HCNRG members with something in lieu of the HCNRG activities that cannot be held. We shall look forward to your support to the HCNRG, always appreciate.

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