Cymdeithas Daeareg Gogledd Cymru
North Wales Geology Association
NEWSLETTER
Issue 103 December 2020

Rounded clasts of rhyolite in ash-fall tuff from early eruptions (Yr Arddu) close to the Ordovician Snowdon Volcanic Centre. GPS receiver for scale. *Photo J.Wilkins*

Chairman's remarks

By Jonathan Wilkins

As I write this the Welsh Government have applied a national 'circuit-breaker' lockdown in all sectors which affect our Association, principally any optional travel and any meeting which is not part of a caring relationship. That will be old news by the time you read this, but the effects will still be with us. Please enjoy your walks for exercise, and look at any rocks or landscape features with particular, geological focus as you pass. It's all we are allowed, and we must give thanks that we live in an area of considerable natural interest and beauty. In all probability, you will also have foregone your annual vacations; if not then you were lucky indeed. The borders of Ireland (where I was heading to savour the Dalradian) have remained closed to visitors unless they were able to endure a fortnight's quarantine, and not just one, but two attempts at a week in the English Lake District have been repulsed! It remains to be seen whether a re-run of our 2020 holidays on our credit-notes will be possible in 2021.

I have spent a busy summer looking afresh at more local areas that I have visited before, but not yet studied in my usual fashion. In particular, a long-term interest in the intrusive igneous rocks of Snowdonia has been re-awakened by setting about writing up some history of their exploitation – and trying to figure out what the rock types are, since as with all rocks Snowdonian they have been somewhat modified by the Caledonian orogenic episode. I have therefore enjoyed a few fabulous days out in the hills around Ffestiniog and the Moelwyns, which I am sure were a huge, psychological benefit. I also have at hand a number of samples from which to make petrographic sections and continue investigations during the long days of enforced isolation.

I was very pleased to see the initiative by the Geologists' Association in London to make all of their back-catalogue of video lectures available for open-access on their web site. Normally they are hidden behind a rather insecure pay-wall, but that was taken away and the content augmented by a raft of invitations to virtual field trips talks and chats under the heading "Geology from your Sofa". In place of the usual Festival of Geology, there will be a virtual event on 7th November 2020 – details are on their web site under Festival of Geology. Having heard an effective preview last year of Phil Manning's talk on "The Day the Dinosaurs Died" I must say it was the first time I felt prickles on the back of my neck from a geology scenario. You will find all of this quite easily from the home page of the GA, and there is also a listing of other initiatives from other societies who are doing their bit to help.

For our own part, after a summer when members were at least able to go out and see rocks for themselves, we have to move with the times and try to put on more meetings through video-conferencing. Three presentations were made during the spring and I must commend the performance of Keith Nicholls, Gary Eisenhauer and Joe Botting who have braved the ether to entertain and inform us. I was able to join only one presentation due to hardware shortcomings, but I know that a good audience was able to see and interact with our speakers. In order to make the process easier, the Association will be taking up a license for the ZOOM platform so that we can operate without any of the limits on duration or number of participants that would apply to a 'free' or trial license. More on that shortly.

On my desk, in a 'reminder pile' are a couple of cuttings (or tearings) from the (Manchester) Guardian which caught my eye. National newspapers do sometimes report interesting, geological news, but these are not quite the run-of-mill dinosaur or meteorite finds.

Stonehenge continues to fascinate and inspire. Teams of workers including Rob Ixer (UCL), Richard Bevins (National Museum of Wales) and Joshua Pollard (Southampton) have tied down the origin of bluestones and rhyolites at specific, quarried outcrops, according to publicity dated March 2019. Now, in 2020 we hear that the iconic sarsen (a type of silcrete) uprights and lintels have been traced to outcrops at West Woods near Marlborough. The methods involved portable x-ray fluorescence analysis on in-situ material, and other, destructive methods on core material that was repatriated from the USA where it was part of a private collection of an employee of the company contracted to drill and install rock-bolts in one of the uprights that was re-erected in 1958 and found to be cracked. Another core section was subsequently discovered in Salisbury Museum, while the remainder is still 'lost'. The long, USA core was sectioned and subjected to petrographic and high-resolution, whole-rock ICP-MS and ICP-AES analyses to obtain a major and trace element signature with 1 part per million precision that was then compared with sarsens sourced from Devon, Wiltshire and Norfolk. Five out of six Wiltshire samples were rejected, as were all the samples from other counties. West Woods was apparently a hive of activity in the Neolithic, and it was even possible to show that some stones had originated from different locations at different phases of construction. All that on a mature sandstone with a silica cement, and consequently almost pure quartz! Chemostratigraphy with a truly satisfying outcome!

The other newspaper-tearing tells that the Earth has been simply quieter than usual during the 'Great Lockdown'. I know this for a fact, because the A55 is intrusively noisy and traffic levels are monitored easily from Deganwy. Records from seismic stations wordwide showed a reduction to as little as half that expected from 'normal' anthropogenic sources such as road traffic, and industry. The quietening was unprecedented within continuous records of seismicity, which reach back to the 1970s. Looking globally, it was possible to watch the spread of the coronavirus as successive areas locked down. The masking of microseismic events by human noise is an increasing problem (not unlike the cluttering of near-space by squadrons of microsatellites) and makes the sounds of creeping faults and intruding magma less easy to resolve. Yet more evidence that there is no longer such a thing as a 'natural' environment on Earth.

And finally, while we are on the subject of 'natural', it seems that the fashion for real rocks as kitchen worktops is passing! The other day I went to have a rifle through the skip at the back of our local 'granite' supplier, and I was horrified to discover that almost everything was a synthetic of some kind. Now, as geologists, we might argue that the natural variability of decorative rocks is part of their individual charm, or appearance, and what makes them special. Not so in the world of fitted kitchens, it seems. Now, perfection rules and natural materials are insufficiently perfect to satisfy, and the difficulties of producing blacks which are actually black without dye or laquer, or dazzling whites which stay white are so great that it is easier to start all over again by crushing pure quartz-based substances, adding the feature materials for decorative effect and mixing it with acrylic resin which is then cured under massive pressure to exclude any bubbles or flaws. Many manufacturers even produce ranges of polished, decorative concrete worktops. Maybe that is better than hacking mountains apart to make big sheets of polished rock, but it is certainly better than acrylic. Sorry to say, the amount of waste produced from the processing of these materials into bespoke pieces to finish kitchens is significant. At least a waste-stream of concrete or stone could be crushed for use as aggregates, or even lie inert in a landfill, but the idea that we now send massive, heavy chunks of plastic there instead is a worry. I did find a sheet of beautiful gneiss in store that was not plastic-based, and it featured pink garnets the size of a golf-ball, but it wasn't in the skip, so I hope that the customer appreciates the subtleties of Neoproterozoic tectonism in the fullness of time.

We look forward to seeing you at our virtual meetings in due course, and we also look forward to resuming real, face-to-face meetings in the fullness of time. If there is a new normal, let us hope that it is a better and more sustainable one that cares more for the Earth. Please look after yourselves and those dependent upon your care and attention.

To hammer or not to hammer ?

By Jonathan Wilkins

Working as I do in the business of analysing geological materials, and being one of the key contact points for the NWGA means that a tiny but steady trickle of 'found objects' arrive at my desk or email inbox for identification. The wonderful beaches which surround our coast are the source of many, but rivers play their part as well. For example, images of stripy, vitreous material from the Mawddach near Dolgellau were quickly attributed to iron/steel slag, but the green object which the finder insisted was peridot could not be discounted so easily, despite my protestation that there was no credible source of such a gem within Wales. Eventually the finder decided to send a piece in the post as he wasn't keen to make the journey in person, but the package was delayed while the Royal Mail pressed me to pay the surcharge for an item not

Fig.1 Plastic_stone - a piece of 'sea-glass' after an attempt at polishing.

carrying sufficient postage - putting a mineral specimen in a DL envelope with even a first class stamp isn't a viable option! So I was unimpressed to pay the fee and receive a piece of green bottle glass, an outcome which I had predicted but could not persuade the finder to consider. He never responded to my email of condolence, nor make up my investment in his nascent gemstone business.

Sometimes the joy comes from making a remote diagnosis, having decided what the object is and working out a way of proving it. One such was a turquoise-green mass about 5cm long, which I reckoned was melted plastics from a beach bonfire (Fig.1). The finder was persuaded to waft the item briefly over the flame of a gas stove, and was convinced by the smell of burning polymer that it was indeed man-made waste that had been abraded and polished by its time in the surf.

Most finds are 'meteorites' located by metal-detectorists, and they turn out (after painstaking work by x-ray diffraction) to be either slag, or smooth, rounded lumps of iron-ore. In fact, these finds are downright interesting because the slags usually comprise fayalite/magnetite mixtures which originate in copper refining, where silica is added to the molten 'matte' in order to react preferentially with the iron content of chacopyrite ores. Granulated copper slags are valuable because they are dense and free of crystalline silica, and therefore ideal as an abrasive powder for grit-blasting steelwork. Cathy O'Brien and I have scratched our heads over the abundance of this material on eastern Anglesey beaches, and its use as a stone substitute in repairing an ancient well. The production of copper ores from the Parys and Mona Mines was prodigious in the early 19th century, and I had not appreciated the extent to which those ores were smelted on the island. A great deal was indeed exported for smelting in Liverpool, but we are fortunate that very detailed accounts of smelting at Amlwch survive. The ores were given their initial roasting to drive off the bulk of the sulphur on the mountain, which is why areas of fabulous earth colours are so prominent, but the copper production was performed at Amlwch, in the area between town and harbour. At the end of the 18th century there were between 20 and 30 smelting hearths in use, fired with coal imported from Swansea or Liverpool, and the accounts suggest that production might run at about 2 tons of ore per day per hearth, but the actual rate of slag production is obscured by its recycling in the converting hearths. It must have been considerable, however, and just as in Germany, where the methods originated, the solidified slag must have been a useful building material. The production in eastern Germany of moulded setts from the slag was a significant source of paving material - particularly for the area around and between tramlines in the streets. It is frankly surprising that there is not more of it about on Anglesey.

Fig.2 A typical haematite erratic

Fig.3 Manganese_boulder. The Llandanwg 'meteorite'

The iron ores are a geological fascination, and it is my hypothesis that their abundance on the beach of Colwyn Bay probably makes them far-travelled glacial erratics from the Lake District coast where the carboniferous limestone is host to huge deposits of hematite which were mined until relatively recently for the iron industry of the Workington and Furness districts. Of course, there are also minor occurrences of similar origin around the Vale of Clwyd, such as Moel Hiraddug.

Recently a new type of 'meteorite' turned up from a beach near Harlech, and it had me stumped until I was eventually able to lay hands upon it. Pictures showed a dark, silvery-grey glacial cobble a bit more than a foot in length, rounded but of an elongated form displaying some slightly-folded 'bedding'. Oh, and heavy - like 20-25 kg heavy, in fact, and slightly magnetic. Wow! Janice, its custodian, was unable to break a piece off, or perform a streak-test to start the remote analysis (the streak of magnetite is black, of course, while hematite is red-brown). So the matter rested until the opportunity to visit our laboratory arose. When it arrived there was intense interest - at a sensible distance, of course, due to Covid-19 - particularly from my colleague Richard, whose Ph.D. was on meteorites. It was quickly decided that it was not a meteorite, but it was not obvious (to us) what it was. Well, the streak was black, but the rock was insufficiently magnetic for it to comprise magnetite throughout, and neither was it hematite. Running out of ideas, it was proposed and agreed that a sample be detached with a hammer so that rigorous investigation could start (everything we do in our laboratory starts with a powder).

Geologists get a bad rap for being so keen to hit rocks with their hammer, but the bottom line is that rocks are not always what they seem, and the weathered crust that presents itself is a disguise that must be removed. I am used to this, but I was utterly amazed by what lay beneath the silvery-black crust of this cobble. The weathered crust, which was not much more than a few millimetres thick in most places, covered a fresh rock not unlike a humbug, almost translucent in places and layered in pale grey and pinkish-brown colours with sparkly quartz in fractures. Inside and outside images are shown so that you can

Fig.4 Manganese ore inside the 'meteorite'

have a guess before I deliver my verdict (look away now etc). Ideas had been forming all the while, but the stripes reminded me instantly of banded ironstones, and a distant memory of a field trip during my MSc course in 1977 came to mind. Not banded ironstone, but sedimentary manganese ore from the famous Cambrian outcrops of the Rhinog Mountains. And manganese oxides and hydroxides are famously black pigments, while iron produces umbers and ochres. This time, instead of XRD investigation it was only necessary to do a bit of searching the Web for images of manganese ores from mid-Wales before we were able to declare an identification. If you are surprised that garnet is a key component, remember that rocks of the Welsh Basin have been

Fig.5 Slag_glass and 'peridot' fragments, Afon Mawddach.

metamorphosed to low greenschist facies, and the spessartine seems to arise from reaction between diagenetic rhodochrosite and clay minerals from the bedded mudrocks. They even have a posh name - coticules, coming from Belgian occurrences where they are used as superior whetstones.

X-ray diffraction was conducted in due course so that we could characterise the black and brown components properly, which led to further surprises. I expected that the black crust would comprise mostly the manganese oxides and hydroxides, but not a bit of it. The majority was a manganese garnet (spessartine) and quartz. The brown, striped part was a mixture of quartz, spessartine and rhodochrosite (manganese carbonate), while both contained a small content of pyrochroite (one of the earliest crystals to have its structure determined by x-ray crystallography, in 1919), which is manganese hydroxide. So, the black material is a patina resulting from the breakdown of the rhodochrosite, but as with iron oxides, the colour may be strong but the crystallisation is so poor that XRD hardly records any reflections. A whole article could be written profitably on the subject of manganese mining in mid-Wales, but that is for another time. Is there a message here? Just continue looking, and keep the interesting rocks flowing. One day a real gem may turn up!

The author is grateful for the support and forbearance of X-ray Mineral Services Limited and colleagues during the analytical work which has featured in this article.

Abandoned Lead and Zinc mining - Waen Glas and Pant Ddu mines Maeshafn, Flintshire

by Keith Nicholls BSc MSc PhD FIMMM MIQ MICE CEng

Fig.1 Collapsed stope or shallow surface workings on the Waen Las Vein, Big Covert, Maeshafn Lead mine,

Editor's note: This is an abbreviated version of Dr Nicholls' paper. The full version may be accessed online at either http://ampyx.org.uk/cdgc/newsltr/legacy_pb.pdf or www.tpwilliams.co.uk/nwga/nicholls_pb.pdf

Introduction

"Big Covert" is an area of private woodland (centred at NGR SJ199602) lying south of the Clwydian village of Maeshafn (Supplement Figure 1) close to the boundary between Denbighshire and Flintshire. The former Burley Hill Quarry (limestone) is located along the eastern boundary of the woodland. The area lies within the Clwydian Range Area of Outstanding Natural Beauty. The woodland is actively managed for forestry by a range of current owners, and is popular with locals for dog walking, exercise and other country-side pursuits. There are a number of public rights of way and access roadways in the woodland.

The general area is well known for its history of lead and zinc mining; and walking around the woodland it doesn't take the trained eye long to notice significant indications of former mining activity (See Supplement Plates 1 and 2 for examples). There is little indication to the general public of risks associated with the nature of the ground however, and particularly with respect to the extent to which the ground surface should be considered unstable.

Geology

There is relatively little drift cover (soils) overlying the solid geology (limestone bedrock), with the only extensive areas of soil materials comprising tipped mine waste and informal roadway made-up ground. The solid geology (see Supplement Figure 2) comprises Carboniferous Limestone, specifically the Leete Limestone Formation and overlying Loggerheads Limestone Formation. The eastern boundary (adjacent to Burley Quarry) is defined by a northerly trending fault which brings the overlying Cefn Mawr Limestone against the Loggerheads Limestone Formation. Davies et al (2004)[1] indicate the following chrono-stratigraphy for this part of the Carboniferous Limestone succession:-

Brigantian - Cefn Mawr Limestone Formation
Asbian - Loggerheads Limestone Formation
Holkerian/Asbian - Leete Limestone Formation

The British Geological Survey Lexicon (BGS 2020)[2] describes the Loggerheads Limestone Formation as follows:

"Thickly bedded, massive, pale grey shelly limestones (packstones and grainstones), locally mottled and pseudobrecciated, arranged in shoaling upwards cycles capped by calcretes, hummocky palaeokarstic surfaces and associated thin bentonitic clay seams (palaeosols) and rare coals. Locally dolomitised and with scattered chert nodules. The Loggerheads Limestone Formation records late Asbian platform carbonate deposition on the North Wales Dinantian shelf. Each cyclic sequence records a shoaling upwards unit developed in response to transgressive and regressive movements in sea level. Many regressions culminated in emergence of the platform surface and the formation of calcrete and karstic dissolution features. During these periods of emergence, wind-blown volcanic ash accumulated on the platform surface to form thin bentonitic soils."

The base of the formation is noted to be at the "Top of highest porcellaneous limestone of underlying Leete Limestone Formation." The Leete Limestone Formation is described as:

"Lithologically varied comprising diagnostic porcellaneous and fenestral limestones (wackestones and calcite mudstones) interbedded with dark, foetid argillaceous limestone (packstones), and pale skeletal peloidal limestones (packstones and grainstones)

including beds rich in oncoids. Thin grey and green mudstone beds and rare coals are present locally. Lithologies are arranged in shoaling-upwards rhythms, each capped by a porcellaneous limestone."

Mineralisation

Davies et al (2004) note the similarity of the style of mineralisation to that of the Pennine Ore-fields and suggest that they are of Mississippi Valley type, typically strata bound, epigenetic ore deposits (Paradis et al, 2007).[3] The mineralisation in the district is found most commonly in the upper parts of the Leete Limestone, and in the Loggerheads Limestone, and is typically associated with northwest orientated faults. The minerals found are generally sulphides of lead and zinc (i.e. galena and sphalerite) with accessory silver. Gangue minerals include calcite and quartz.

The mineralised faulted veins are also associated with generally northerly trending "cross-courses" - such as that which defines the location of the Burley Hill Quarry property boundary - but these are not normally mineralised to the same extent. Supplement Figure 2 shows the extent of local faulting identified on the current BGS 1:50,000 Geological Map together with the boundary between the Leete Limestone and the overlying Loggerheads Limestone as currently mapped. Burley Hill Quarry (BHQ) is seen to have been working the overlying Cefn Mawr Limestone.

Mining

The Mining history in the district is long and described in a number of references; primarily Davies et al (2004), and historical documents including Strahan (1890),[4] Smith (1921)[5] and Earp (1958).[6] The available information was usefully summarised by Campbell and Hains (1988).[7] Williams (1980)[8] gave very detailed information with respect to the area a short distance further north. There is however a dichotomy that needs to be considered with respect to interpreting modern as opposed to older geological texts. The

Fig. 2 Location Map and Aerial view of Maeshafn area

modern works benefit from a more refined geological understanding, and also from subsequent observations made during later mining activity and other excavations (such as, for example adjacent quarrying operations). The older texts however will be more closely associated with the original mining activity (most of which occurred in the late 19th and early 20th centuries). They may also have had access to original archive material lost to later workers.

Extensive workings in the area are known to have occurred in the 17th and 18th Centuries. Flintshire Records Office hold copies of a series of leases from throughout the late 18th and 19th Centuries ceding rights to mine "lead ore", "blackjack" (zinc sulphide), "smythom" (believed to be a synonym for blackjack), "boose" (mixed lead ore and gangue minerals), "calk" (barium sulphate) and "calamine"(zinc carbonate or silicate); from the mineral owner (typically the Grosvenor - Westminster Estate)[9] to various lessees in the area. The extant leases attributable to mining associated with what are known as the Waen Las and Pant Ddu Veins cover the period 1735 to 1891. Selected details from these leases are given in Supplement Appendix 2 Table 2.

The 1850 Geological Quarter Sheet records the presence of "Waen Las Mine" although the precise location is indeterminate at the original, as published, scale (See Supplement Figure 3). Strahan (1890) described the geology as understood by the geological survey responsible for production of the geological quarter sheet (79SE) published in 1892, following earlier editions in 1856 and 1886. The 1856 Edition (Supplement Figure 3) shows a number of veins (unnamed on the original) trending north-west to south-east. These were significantly modified in the 1892 edition and reflect both the greater knowledge of the mining activity, and the understanding of the mode of origin as faults (displacement of geological boundaries is clearly defined). This edition of the geological mapping appears to inform the location of the veins subsequently plotted and described by Earp (1958). Earp's description included enough detail to allow the veins shown on the 1856 mapping to be tentatively named, as in Supplement Figure 3.

It is also worth noting that there are also karstic features within the limestone and at least one location where early human (Romano-British) activity is believed to have taken place in association with later mining, as shown in Supplement Plate 3, described by Hesketh (1955)[12] and shown in summary (after Hesketh (1955) in Supplement Appendix 3 (Figure A3.1). In addition, there are a number of archive materials prepared by the cave and mine exploration communities available such as that relating to "Scouse Pot" - also included in Supplement Appendix 3 Figure A3.2. It can be noted that both these features show a combination of elements directed either north/south, or north-west/south-east, consistent with the generalised trends of faults and veins apparent in the bedrock as described previously.

Legacy Features

The method chosen to attempt to assess the extent of current legacy issues related to the former mining activity is to map the surface features that can be seen. These comprise numerous mine entries and subsidence related features including former active mine shafts, abandoned trials, spoil heaps, mine adit entrances and apparent "stope" collapses. The locations of these features were determined using GPS and have been collated in a gazetteer presented as Supplement Appendix 2, Table 2.

With the coordinates of the features available these can be plotted and compared with the available geological maps to allow interpretation of the likely origin of the features. This has been done using the freely available GIS Software "QGIS". Perhaps the most obvious features present are the vertical shafts, some of which have been formally capped, some have more informal capping and/or fencing arrangements, others are open but fenced. To date only a single open unfenced shaft (Supplement Gazetteer Reference 53) has been identified but given the extensive leaf litter and past informal capping practices, their further presence cannot be ruled out.

There is one clear mine adit entry associated with the former Waen Las mine (Supplement Gazetteer Reference 9). There are other less obvious features which may represent some form of "day-level" i.e. a pedestrian (likely crawling room only) entry for workers, but probably not a main access for goods and materials. In a number of locations apparent stope collapses are apparent. These are locations where mining has taken place beneath ground surface in a mineralised vein, and the workings themselves have either broken through to surface from beneath, or following cessation of mining activity, ground has collapsed into the open void beneath.

In some cases, the feature at the surface is a cleft or linear depression in the hillside and the mode of origin is unclear. It may represent differential weathering out of the mineralised vein by natural processes, or it may be a man-made feature associated with shallow quarry type workings of the vein at surface. It may also represent a subsidence feature associated with collapse of a stope from below, as described previously. In each of these cases the feature is noted simply as being a "Stope/vein". Supplement Figure 6 shows a stylised (and not to scale) representation of a “typical” early 19th Century lead-zinc type mine layout showing the relationship between these features and the ore body being worked. Supplement Figure 7 illustrates how these features would be anticipated to fit into the broader mining related landscape.

Web-based sources (particularly Coflein, 2020)[10] give some historical details of the mine and (Supplement Gazetteer Items 40 and 41) are derived from this source. This web page also holds a number of photographs believed to be of workings in the attributed to workings in the Pentrehobin Vein and Taylor’s Vein.

There are two clusters of features (labelled C1 and C2) toward the north of the area that do not appear to relate to any previously recorded mine workings. C1 lies relatively close to the extensive workings associated with the Maeshafn Vein and may be workings in a splay off that vein. Alternatively, both clusters C1 and C2 may be the first formal record of workings along mineralised faults which are recorded in this location on the most recent BGS mapping (see Supplement Figure 2). There is a single feature which

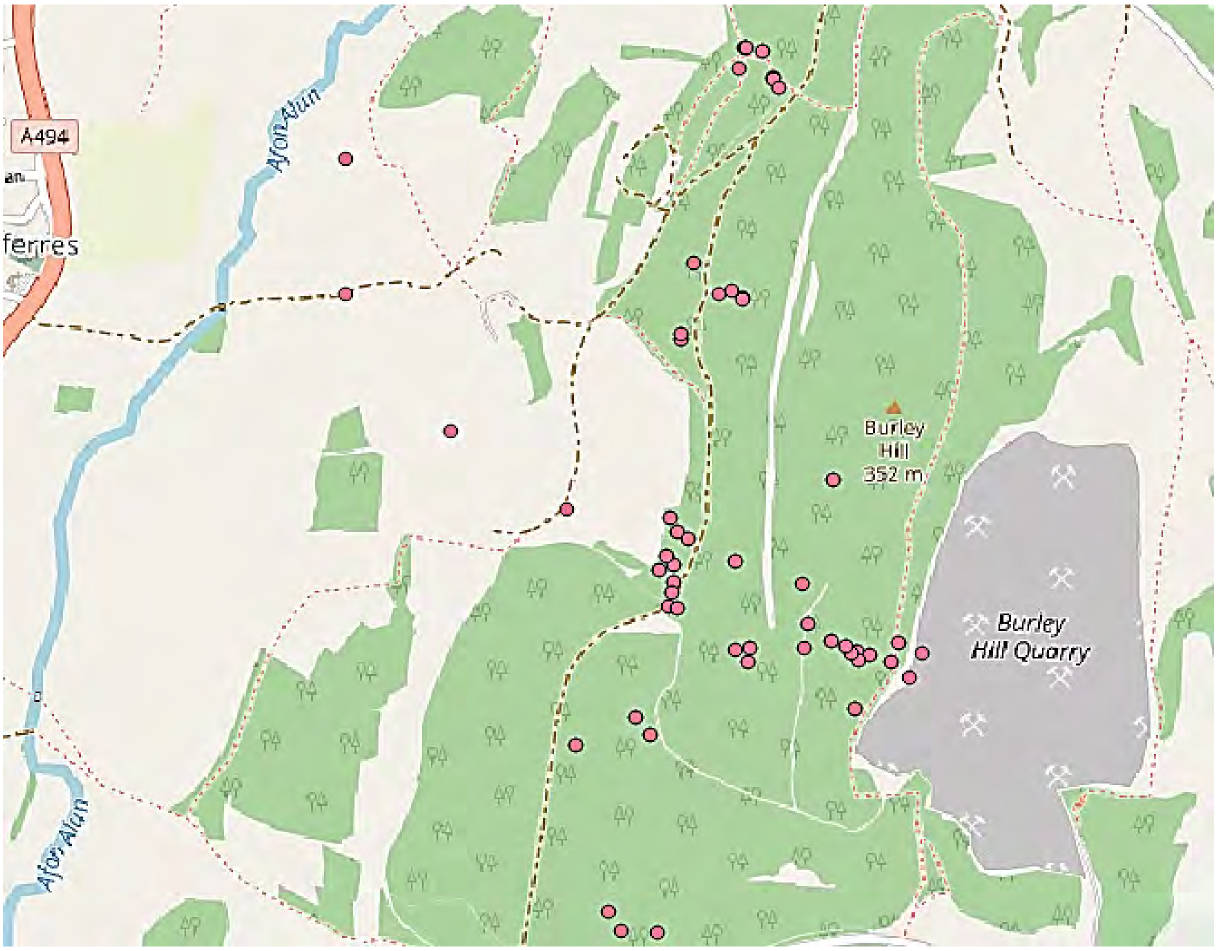

Fig. 3 Identified features marked on recent base map (Open Street Map)

Waen Las Bach Vein. Ford (2008)[11] records the presence of a drainage adit portal adjacent to the River Alyn (Supplement Gazetteer Item 42).

Fig.3 (Supplement Figure 8) shows the locations of the features identified plotted on an Open Street Map base plan using QGIS. Fig.6 (Supplement Figure 9) shows this same data interpreted with respect to the recorded workings. The main features to note include a swathe of mining related features associated with what can be termed Waen Las (western) and Pant Ddu workings (eastern) along the swarm of veins including the Waen Las itself, the Waen Las bach, Pant Ddu and Goodwin Veins. To the south of these workings two separate groups of features can be defies categorisation within this framework. Located at SJ19987, 60226 this apparent shaft has been identified by the presence of what appears to be a timber and concrete shaft cover. It is possible that this feature (Supplement Plate 6) has been misinterpreted, with one alternative explanation being its use as a mountain bike jump ramp.

Fig.4 1850 Geological Quarter Sheet (79SE). Veins names follow Earp (1958). Copyright BGS (1850) **1** Jamaica Flat. **2** Maeshafn Vein. **3** Waenglas Vein. **4** Waenglas Bach Vein. **5** Goodwin Vein. **6** Pant Du Vein. **7** Pentrehobin Vein. **8** Taylor's Vein. **9** Belgrave Vein. Note the presence of "Waen las mine"

Legacy Issues

The extent of the legacy issues relates to the nature of the particular mining activity undertaken at specific locations. Risks associated with mine shafts are obvious, as they can extend to considerable depth below local ground level. Whilst most of the shafts associated with lead zinc working are likely to be of relatively small diameter - they are sufficiently large to allow an individual to fall. It should also be noted that whist a capped shaft is not necessarily safe from collapse. Shafts can collapse because they have been built in a manner that relies on the adequacy of for example original timber strut-work or masonry lining. Adits can be particularly problematic because they are by necessity at shallow depth where they intersect the ground surface. They can have little in the way of intact rock cover, and without support the portal and immediate adit extents are often unstable.

The prospect of instability associated with the open stope workings affecting ground surface is more difficult to predict. The stability of the "overhand" cover i.e. the rock above the miner's head will depend, amongst other things, on how close the top of the stope came to ground level. As it approaches ground surface it is to be expected that the strength of the ground deteriorates, as does the quality of the ore being worked. Obviously several of the stopes along the Waen Las and Pant Ddu workings have daylighted with the formation of crown holes. All ground within these areas of workings that has not already collapsed should be considered susceptible to future collapse on the precautionary principle. Similarly areas C1 and C2, and in the vicinity of Taylor's Vein and the Pentrehobin Vein should also be considered at risk.

Fig.5 Entrance to Big Covert cave

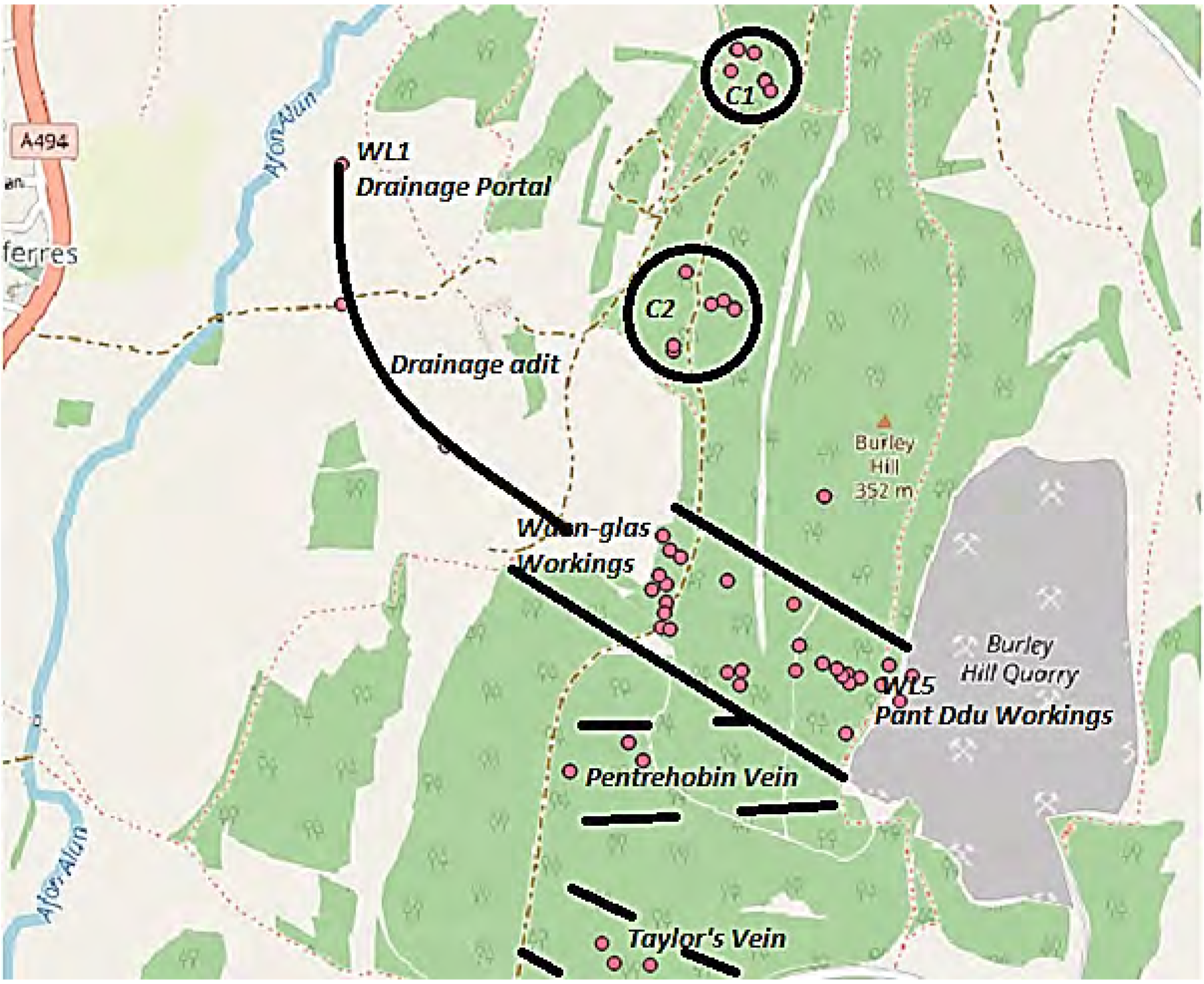

Fig.6 Interpreted figure based on previous figure showing locations of identified features with respect to recorded mining history. Note two sets (C1 and C2) of previously unrecorded mining activity.

The extent of any historical treatment offered to any of the shafts, adits and mine voids remains uncertain. Anecdotal evidence (Ford, 2008) suggests that forestry operations in Big Covert may have infilled old open workings by bulldozing operations during 1966. It is apparent that some of the land-owners and/or occupiers have undertaken some fencing of the more obvious mining related features. However, other than a single "Beehive" type shaft cap (Supplement Gazetteer Item 14, Plate 7), many features are unfenced, with no public warnings as to the nature of the ground and the extent of historical mine workings.

Those using the woodland for leisure pursuits should be aware of the potential for leaf litter to be covering mining related features that are open to the surface. It is hoped that any owners undertaking forestry related operations should be aware of the generalised risks from mining in the area, but it is worth noting that there is specific concern with respect to vehicle traffic using the established roadways in and around locations C1 and C2, within the areas of Waen Las and Pant Ddu workings, and around the Taylor's and Pentrehobin Veins. There is no readily available published record of any specific remedial works having been put in place to counter the risk of mining related surface instability affecting any of the major roadways.

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Anglesey Geology - in search of a new orthodoxy

By T.P.T.Williams

In 1995 the late Prof. Dennis Wood gave a public lecture entitled 'Edward Greenly and the Geology of Anglesey'. The venue was the Main Arts Lecture theatre in the then University College of North Wales, now Bangor University. The capacity of this theatre must number in the hundreds and every seat was occupied. The present writer can vouch personally for the extraordinary fact that when ushers had to prevent further late arrivals from entering due to the over-crowding, some few mild altercations occurred.

The point of recollecting this event is to emphasise the extent of public interest in Anglesey geology. Dennis's outreach work was legendary and for years he led groups to the classic areas where he would hold forth with superb clarity on the often difficult subject matter, as well he might, being the principal professional heir to Robert Shackleton's canonical reorganisation of Edward Greenly's 1919 synthesis.[1] This reorganisation held sway as established orthodoxy for some forty years from the early 1960s.

Greenly envisaged Anglesey's sedimentary rocks as forming a succession in the Precambrian, ranging from the South Stack (SS) series and Holyhead Quartzite as youngest down to the widespread exposures of his Gwna Group as oldest, with the Coedana Granite intrusive in this 'bedded series'. Shackleton applied recently developed 'way-up' techniques to establish that the succession in Holy Island younged upwards, and therefore that Greenly's order must be inverted, with the Holy Island Group now the oldest and the Gwna presumably at the top. There the matter rested in comfortable stability for decades, with the notable exception of Dennis's work interpreting Shackleton's

Profs Robert Shackleton (centre) and D.S.Wood (right) *en route* to the Skerries in 1995, courtesy of Trinity House's R.Biddlecombe. (left) *Photo T.P.T.W*

scheme within the emerging plate-tectonics paradigm, involving a destructive margin running roughly on the line of the Menai Straits fault. Attempts at radical revision of this succession (Barber and Max[2]) and novel palaeontology (Muir[3]) seemed to find only limited support, if any. This situation was rudely upset in 2004 with the announcement by Collins and Buchan[4] of U-Pb zircon dates from the South Stack rocks of the Holy Island Group, in the range 511-491 Myr. The implication of this work within the context of Shackleton-Wood orthodoxy was shattering. Apparently almost all the supposed Anglesey Precambrian 'bedded succession' must be latest Cambrian or Ordovician !

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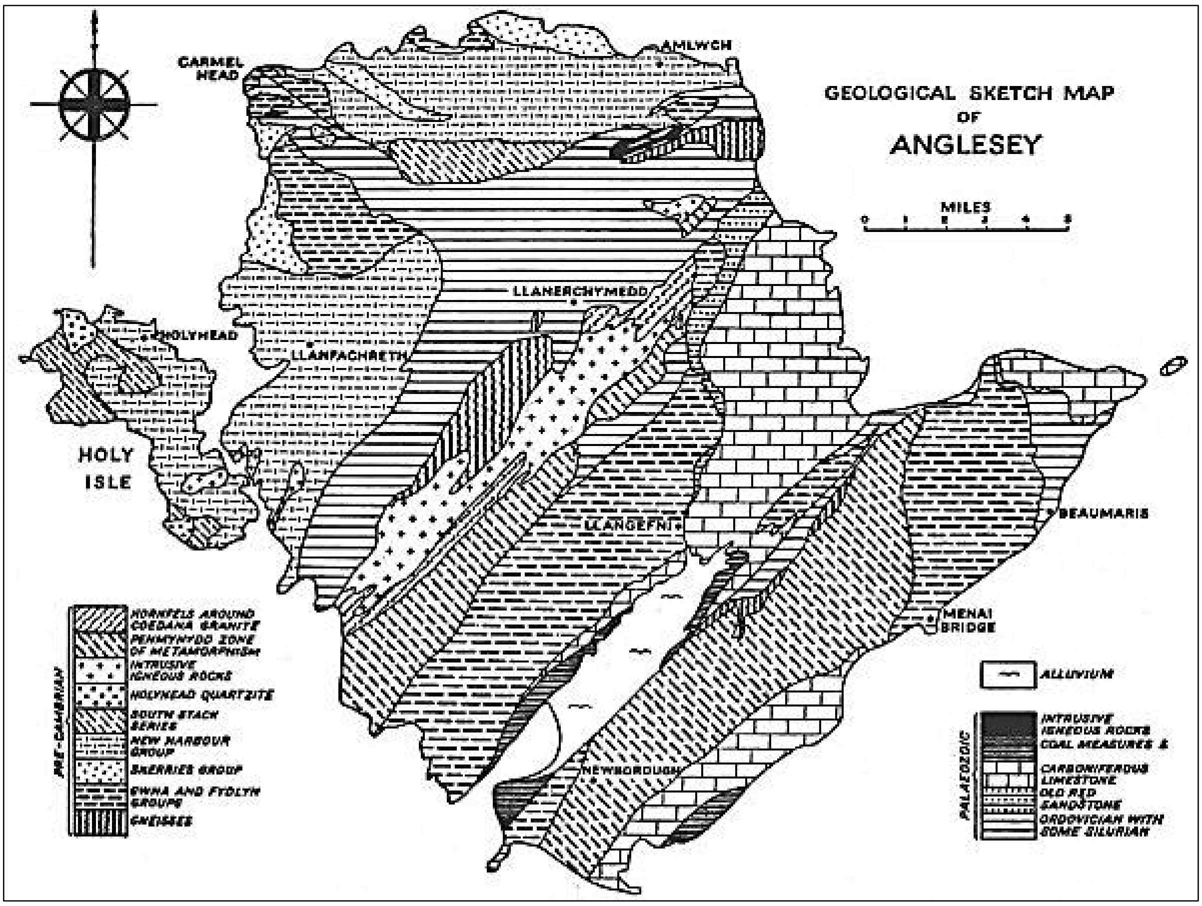
[1] E. Greenly *Geology of Anglesey* 1919

[2] A. J. Barber and M. D. Max 1979 *A new look at the Mona Complex (Anglesey, North Wales).* Journal of the Geological Society, 136, 407-432

[3] D. Muir, G. M. Bliss, P. R. Grant & M. J. Fisher 1979 *Palaeontological evidence for the age of some supposedly. Precambrian rocks in Anglesey, North Wales;* Journal of the Geological Society 136, 61-64

[4] Alan S. Collins and Craig Buchan 2004 *Provenance and age constraints of the South Stack Group, Anglesey, UK: U-Pb SIMS detrital zircon data;* Journal of the Geological Society, 161, 743-746



This paper was the herald of a succession of new results. In 2011 Dr J. Horak of NMW, in collaboration with Prof. J. Evans of NERC Isotope Geosciences Laboratory, Nottingham published[5] the results of a remarkable application of strontium geochemistry to the large limestone olistoclast in the Gwna melange of Gadlys Quarry, Cemaes Bay in N. Anglesey, deriving an early Neoproterozoic Cryogenian (*c.*800 Myr) or Tonian (860 Myr) date for these rocks.

In 2012 Dr J.Treagus et al[6] published a study of the junction between the Upper South Stack (Rhoscolyn) and New Harbour (NH) formations on Holy Island, characterised by a distinct band of volcanic tuff. Sandstones and conglomerates at the top of the Rhoscolyn Formation are followed, without any break, by tuffs and then mudstones of the NH formation. In light of the work of Collins and Buchan the clear implication was that the New Harbour rocks are younger than 500 Myr and thus Ordovician.

In 2014 a valuable publication appeared by Drs Margaret Wood and Stewart Campbell in collaboration with Prof. Brian Windley of Leicester University and others. Entitled *Footsteps through time,*[7] it presented the results of a group of Japanese geologists led by Profs. Shigenori Maruyama and Yukio Isozaki, in collaboration with Windley, concerning the geology of Anglesey. Along with this sumptuously illustrated book appeared a series of papers by members of the Japanese collaboration, most notably for our present purpose the presentation of a very extensive series of zircon dates from Anglesey rocks.[8] Some idea of the extent of this work is seen from the partial summary table below.

Reaction to these developments and their presentation to the public have been curiously incoherent. As in every area, the first point of call for information has become the World Wide Web and Anglesey geology is no different. Yet any quick trawl will reveal an inconsistent mixture of pre-2004 orthodoxy and bland acceptance of the new results, with little or no critical discussion of any problems or contradictions. Moreover, some of the most important recent work is difficult to access and poorly

5 Jana M. Horak & Jane A. Evans *Early Neoproterozoic limestones from the Gwna Group, Anglesey;* Geol. Mag. 148 (*1*), 2011, pp. 78–88

6 J. E. Treagus, S. H. Treagus & N. H. Woodcock *The significance of the boundary between the Rhoscolyn and New Harbour formations on Holy Island, North Wales, to the deformation history of Anglesey;* Geol. Mag. **150** (3), 2013, pp. 519–535.

7 S. Campbell, M. Wood, B. F. Windley *Footsteps through Time;* Anglesey County Council 2014

8 Hisashi Asanuma, Wataru Fujisaki, Tomohiko Sato, Shuhei Sakata, Yusuke Sawaki, Kazumasa Aoki, Yoshihiro Okada, Shigenori Maruyama, Takafumi Hirata, Tetsumaru Itaya, Brian F. Windley *New isotopic age data constrain the depositional age and accretionary history of the Neoproterozoic-Ordovician Mona* Complex (Anglesey-Lleyn, Wales); Tectonophysics 706–707 (2017) 164–195

No. of concordant zircons	Source rock type	Location	Formation	Lowest Age Myr	Greatest Age Myr	Comment
5	Pelite	Church Bay	Gwna	596±10	1681±93	
16	Psammite	Aberffraw	Gwna	571±20	2701±38	
56	Psammite	Bodorgan	Gwna	878±43	2883±109	
54	Sandstone - date by ^{206}Pb-^{238}U 550±24 Myr	Llanddwyn Island	Gwna	468±8	2634±94	Lowest age due to lead loss ?
48	Sandstone	Beaumartis	Gwna	566±16	1649±56	
28	Pelite	Holy Island	New Harbour	520±33	2050±98	
45	Pelite	Cemlyn	New Harbour	515±13	2057±67	
32	Pelite	Cemlyn	New Harbour	548±9	634±8	
68	Sandstone	Holy Island	South Stack	545±10	2905±70	
42	Sandstone	Rhoscolyn	South Stack	522±16	2669±88	
55	Sandstone	Rhoscolyn	South Stack	522±9	2896±55	
25	Psammitic schist	Aberffraw	Penmynydd zone	584±30	1974±80	Penmynydd Zone now Central Shear Zone
70	Psammitic schist	Gwalchmai	Penmynydd zone	1157±122	2818±47	
49	Psammitic schist	Gwalchmai	Penmynydd zone	591±15	2137±113	
44	Paragneiss	Llys Dulas	Coedana complex	612±22	1898±87	

Asanuma et al's 2017 table of zircon dates from various Anglesey formations

publicised. At the same time, Greenly's Skerries formation has been rather arbitrarily subsumed in one or other of the NH or Gwna groups. There has apparently been little discussion of the basis for this decision.

In some respects professional opinion is itself divided. The Windley-Japan group consider that the rocks of the western part of Anglesey formed in an obductive and subductive accretion, combined with under-plating of the Holy Island, NH and Gwna rocks onto the accreting margin in such a manner as to reverse their order of deposition, i.e. the oldest, Gwna comes out 'on top' while the youngest, SS rocks are now 'at the bottom'. According to Wood and Campbell's description[9] of this model, the preferred date for the NH rocks is 530-520 Myr and they were deposited before the SS series. There is thus clear dichotomy of opinion between the Treagus and the Windley-Japan schools as to the status of the NH.

Nor is there agreement any longer regarding the Gwna Group. The work of Horak and Evans includes the comment 'early Palaeozoic age for the basal part of the succession, the SS and the overlying NH, is now incompatible with the Gwna Group constituting the top unit of this succession. This suggests that the Gwna Group does not belong to the Monian Supergroup and that the stratigraphy of the group requires re-examination'. Long ago, Greenly himself distinguished two very distinct types of limestone within his Gwna, the 'Cemaes' type analysed by Horak and Evans and a 'Llanddwyn' type. As Wood and Campbell say, 'the currently classified Precambrian Gwna … can in fact be divided into three distinct accretionary entities, [only] the youngest of which is Cambrian in age'.[10] If we still believe Muir's palaeontology[11] of 1979, Llanddwyn Gwna would appear to be of the latter age while that of Horak and Evans belongs to a distinct and earlier period. The evidence of the Asanuma zircon dates for Gwna rocks is not inconsistent with this view.

Clearly there is much to do if we are to recover a stable orthodoxy comparable to that of Shackleton and Dennis Wood. If a modestly well informed onlooker may make an observation, it would be that the NH urgently needs attention. Questions spring to mind from the most cursory glance at Greenly's map, notably the great extent of spilitic intrusions within the NH on the mainland and their essentially complete absence on Holy Island; Greenly distinguished two distinct NH facies, his Soldiers Point type east of the Holy Island Namarch fault and his Llwyn formation to the west. Is the latter, corresponding to the area studied by Treagus et al, indeed younger than 500 Myr while on the opposite mainland the NH rocks are from an older 530 Myr horizon characterised by much more basaltic intrusion? Zircon dates within the Soldiers Point facies are not available apparently. It will be apparent from the table that Asanuma only offers dates obtained within the Llwyn NH of Holy Island and the so-called Amlwch Beds to the north of the Carmel Head thrust

[9] S. Campbell, M. Wood, B. F. Windley *op.cit.* p.42

[10] *ibid* p.18

[11] D. Muir, G. M. Bliss, P. R. Grant & M. J. Fisher *op.cit*

plane. It is not certain exactly how the latter correlate with the NH south of the thrust.

Again, if we are to lose the Skerries group, is it to be subsumed in the NH or the Gwna ? Having seen at first hand the extraordinary conglomerates of the Skerries Islands, this observer doubts they can be other than latest Gwna. Their limestone, quartzite and above all jasper pebbles all appear to conform to Gwna type. The problem of the origin and age of the granitoid and quartz-porphyry boulders found, in Anglesey, only in the Skerries conglomerates on the Islands, remains unsolved but their absence in known NH rocks, together with the absence of spilite pebbles in the conglomerate, speaks against it being of intermediate NH or younger age. Of course, the adjacency of latest Gwna and earliest NH would make the question somewhat academic. Perhaps something may be gained by a new study of the curious 'nip' of supposed Skerries-type rock within the mainland NH at Penial, Llanfwrog? Noone has looked at it since Greenly.

Finally, how do the strange Carreg Onen slates, Trefdraeth conglomerate and Baron Hill rocks, long taken as representing a slight Cambrian presence on Anglesey, fit into any new scheme? They seem to have been forgotten in recent discussions. But the questions they pose still remain, along with many new ones !

Dates for the Diary

Wednesday December 16th from 7.30pm - Virtual Xmas get together over Zoom. We will be holding our usual Xmas get together this year, only due to circumstances, it will unfortunately be held remotely. However, it will comprise a series of short 10-15 minute presentations as in previous years and contributions are welcome from the members. If you have any questions or a short presentation you would like to give then please let me (Gary) know at g.eisenhauer@btinternet.com

Saturday 30th January at 10am - Virtual AGM over Zoom, followed by a talk TBC at 11.30am.

Links for these events will be sent out in due course. And as an aside, the Geologists' Association 'Virtual' Festival of Geology is being held on Saturday November 7th and depending on when the newsletter goes out this will be either a sneak preview or old news. But I have an entry in the GA photography competition this year which has been 'highly commended' and will be on displayed on the website (along with the other winners and entrants) of said festival. I have attached the image and details below, in case you are interested in including it in the newsletter.

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