Dorset GA Group

Newsletter Autumn 2021

https://dorsetgeologistsassociation.org/

Contents

Welcome to the Autumn Newsletter!

Owing to my recent eye surgery, this issue has been unavoidably delayed. I've received plenty of articles, not least because we have enjoyed a full field trip programme, ably organised by Val. We are sorry she is stepping down (see p.15). Word may have reached you that Alan is also stepping down as Chairman at the AGM, having made a huge contribution to DGAG for many years. It is vital that members come forward to fill these crucial roles to ensure the future of DGAG. Please consider volunteering for one of these soon to be vacant committee posts, you will be fully supported. The Newsletter would not appear of course without the support of contributors, for which I am very grateful. Rest assured that that if your report or article didn't make this edition, it will be in the next one. *Kelvin*

Anthony Brook was our scribe for the **Field Trip to Dartmoor 22nd May 2021.**

This was the first field trip since the lockdown due to Covid that I have attended. Unbelievably, in a month of near continuous rain, Alan had managed to arrange the trip on a day when there was only one brief shower! We had been armed with several pages of notes and factsheets by the Dartmoor National Park on the Geology, Landforms and Tor Formation.

Jointing in granite, Haytor Rocks

We began the day at **Haytor Rocks,** observing the megacryst granite with large phenocrysts of orthoclase feldspar up to 5cm in length. Alan explained how these would have formed when the magma chamber that produced the batholith would have remained at a constant temperature for a long period of time allowing the crystals to grow. It was explained that the Tors stand proud in the landscape because the jointing in them is less dense and so weathering is reduced. We walked around the Tor to a location where a finer-grained granite intruded the megacryst granite. However, a heavy rain shower meant a quick return to the cars and a long drive to the second locality.

Intrusive sill of Micro granite

At **Two Bridges Quarry** I missed what Alan had to say about the locality because of limited parking spaces in the car park. The locality shows heavily-weathered granite with areas where the feldspars have been completely decomposed and the quartz grains form an uncemented grit. There are several theories to explain this weathering and it is likely that all three played a role but to what extent for each is open to academic debate.

1. Weathering due to tropical conditions during the Palaeogene.
2. Pneumatolysis- hydrothermal action both during and after the granite was intruded…..

caused by the circulation of hot mineral fluids.
3. Weathering during the Pleistocene, caused by freeze-thaw action in periglacial conditions.

Two Bridges Quarry

Rotted Granite from Two Bridges

I wondered how much weathering of the granite had occurred since its exposure during the Permian as evidenced by pebbles and cobbles seen at Teignmouth. The batholith would have originally sat at some depth but with a lower density would have helped caused uplift, eroding the country rocks above. However since then it is thought it was covered by Mesozoic sediments that have since been eroded during the Palaeogene.

Lunch was taken at **Burrator Quarries,** where some members climbed up the path to see the magnificent views of the reservoir.
In the first quarry, where the cars were parked, Devonian country rocks were seen exhibiting signs of contact metamorphism. Alan showed a specimen of Hornfels with its splintery fine texture and later I collected a specimen of spotted Hornfels where new minerals grow due to the heat.

Spotted Hornfels

We then drove past the Prison at Princetown to the quarry at **Merrivale,** now disused. The quarry had produced dimension stone and the remains of the offcuts and waste rock were seen forming a dramatic scree slope from the road. The quarry itself was disused and flooded so we did not trespass into the restricted area. The granite here was not as megacrystic as at Haytor and specimens were observed with xenoliths of country rock, some with blurred margins, showing that they were melting into the granite and another with a feldspar phenocryst in the xenolith.

Waste rock scree at Merrivale Quarry

Around the site of the old cutting and polishing area were blocks of *Geo-Wrongs.* Specimens of Larvikite from Norway, often used as sea-defence rock armour, and red granites, which were clearly not from Cornwall.

The group at Merrivale Quarry

Dimension stone from Merivale

The last locality was to look at two tors; **Cox Tor** made from a basaltic sill in Carboniferous rocks and **Staple Tor** in the granite. The area was of interest because it displayed periglacial processes with clitter and block fields around the tors and earth mounds, probably caused by frost action. We gave our appreciation to Alan for organizing an excellent trip.

Pat Snelgrove follows up on previous Newsletter articles with:

More on the Wad Mines of Borrowdale, Cumbria

In my younger days when I could walk uphill and down dale all day long, we went on mine explorations with Ian Tyler (see earlier Newsletter) who at the time owned the mining museum in Keswick. However, our exploration of the Wad mines at Seathwaite was not one of them but we did have a copy of his mines guide for company.

He has written a number of fascinating books on the mines of Cumbria and we have several of them which are very readable and packed with information.
Back to the Wad!

Seathwaite, image from Google Earth©

Wad is a form of pure graphite and is also called Black Cawke, plumbago or black lead. Its structure consists of many flat layers of hexagons called graphene sheets. In each graphene sheet each carbon atom is joined by strong covalent bonds to 3 other atoms. The bonding between the layers is weak so the layers can easily slide over each other making graphite soft and slippery. The fourth electron is delocalised which allows graphite to conduct electricity. Graphite occurs naturally in this form and is the most stable form of carbon under standard conditions.

The Wad was found in the Upper Ordovician (Katian) Borrowdale Volcanics Series (BVS) in easily removed nodules in pipes of from 3ft to 9ft cross section in association with a highly altered diorite dyke bounded by two masses of blue dolerite. The BVS make up the highest and craggiest mountains, such as Scafell, Helvellyn and the Langdale Pikes in Cumbria. Numerous quartz veins traverse the formation but appear to have no direct connection with the graphite, although often coated with graphite. The pipes which extend to a depth of more than 100 metres are randomly distributed throughout the dolerite and to a lesser extent the diorite.

Helvellyn from Thirlmere

A theory on how the Wad was formed, can be found in the following article: L. Ortega et al. (2010), *The graphite deposit at Borrowdale (UK): A catastrophic mineralizing event associated with Ordovician magmatism*, Geochimica et Cosmochimica Acta, 74, Issue 8 pp. 2429-2449). The full article is available on-line. The next paragraph is my very limited summary.

Borrowdale looking south from Seatoller Fell

The volcanic-hosted graphite deposit at Borrowdale was formed through precipitation from carbon-rich fluids. The $^{13}C/^{12}C$ data indicate that carbon was incorporated into the mineralizing fluids by the assimilation of carbonaceous metamorphosed clay-rich rocks, such as mudstone or shale (metapelites) of the Skiddaw Group by andesite magmas of the Borrowdale Volcanic Group. The graphite mineralization occurred as the fluids migrated upwards through normal conjugate fractures forming the main subvertical pipe-like bodies. At the same time, the andesite and dioritic wall rocks adjacent to the veins were intensely hydrothermally altered. The initial graphite precipitation was probably triggered by the earliest hydration reactions in the volcanic host rocks. The structural features of the pipe-like mineralized bodies as well as the isotopic homogeneity of the graphite suggest that the mineralization occurred in a very short period of time.

Sample of Wad

Seathwaite and River Derwent from Gilbert's level

Exactly when the deposits near Newhouse Gill at Seathwaite (NY 232 125) were discovered is not known but it was used by the monks of Furness Abbey in the mid sixteenth century to mark their sheep grazing on the moorland. The first diggings were just holes in the ground. Only two pipes, Gorton's pipe and Gilbert's level outcrop at the surface and were the first to be worked in the mid 16th century. The latter was discovered when an ash tree was uprooted by a storm. Other pipes were found by often fruitless trials by arduous pick and shovel underground exploration. The graphite did not require an expensive dressing plant, just a washing and separating floor. As it does not degrade it could be stored indefinitely without special storage facilities.

The Wad mines on the fell above Seathwaite

John Bankes marker stone near Gilbert level

The mining rights were held by the Crown. The first lease allowing commercial development was held by Ambrose Dormer son of the Lord Mayor of London (1541-42). Subsequently leases were bought and sold by a variety of investors until in 1607 Daniel Hechsetter's son and his German miners acquired a sub-let lease. Here there is a Dorset Connection as in 1625 their lease was acquired by Sir John Bankes. The lease, and other parcels of the Wad mines acquired later, stayed in the family until 1981 when the National Trust inherited the Bankes family estates including the rights to the Wad mines.

By the end of the 16th century, the main market for graphite was as a release agent to line moulds for cannon balls and musket balls. Thus, it was in great demand in the 17th and 18th centuries to support various naval conflicts between England, Holland and France. The price rose from £100 per ton to £1300 by the end of the 18th century. The mines were of such importance that guards were set to prevent theft. Miners were closely watched and searched when leaving the mine. One rogue was William Hetherington who pretended to be digging a copper mine (there were also copper mines in the valley), but had a secret concealed door from his mine that led through to Wad deposits he dug from underneath his neighbour's holding. After an armed raid on the mines in 1752 an Act of Parliament made it an offence to steal Wad punishable by whipping and a year's hard labour or 7 years transportation.

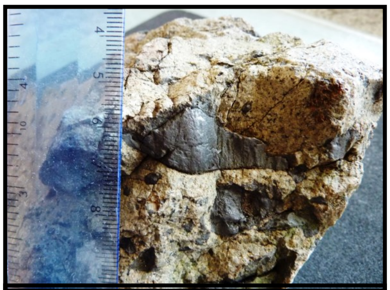
A classic coffin shaped mine entrance in the hillside

As the pipes were worked downwards, they were troubled by flooding. So, around 1620, the Old Men's Stage was driven by the German miners by hand to drain them. This process was repeated in 1798 when Gilbert's Stage was driven into the Grand Pipe, some 60 metres below the old level.

A possible drainage adit

The mines flourished until the late 1820s, but then began to decline. The last workings closed in1891.

The market finally collapsed when alternative casting methods were introduced. The other industry using graphite was in the manufacture of pencils. There is evidence that Flemish traders were supplying Michaelangelo's art school in Italy with graphite from Cumbria.



Sample of Wad in matrix

Graphite was first synthesized accidentally by Edward G. Acheson while he was performing high-temperature experiments on carborundum. He found that at about 4,150 °C (7,500 °F) the silicon in the carborundum vaporized, leaving the carbon behind in graphitic form. He was granted a patent for graphite manufacture in 1896, and commercial production started in 1897. Nowadays it can be synthesised from calcined petroleum, coke and coal tar pitch by high temperature treatment.

Report by *Roger and Janet Brown* on the DGAG Field trip Thursday 10th June to the Vale of Wardour. Leader: Steve Hannath, Wiltshire Geology Group.

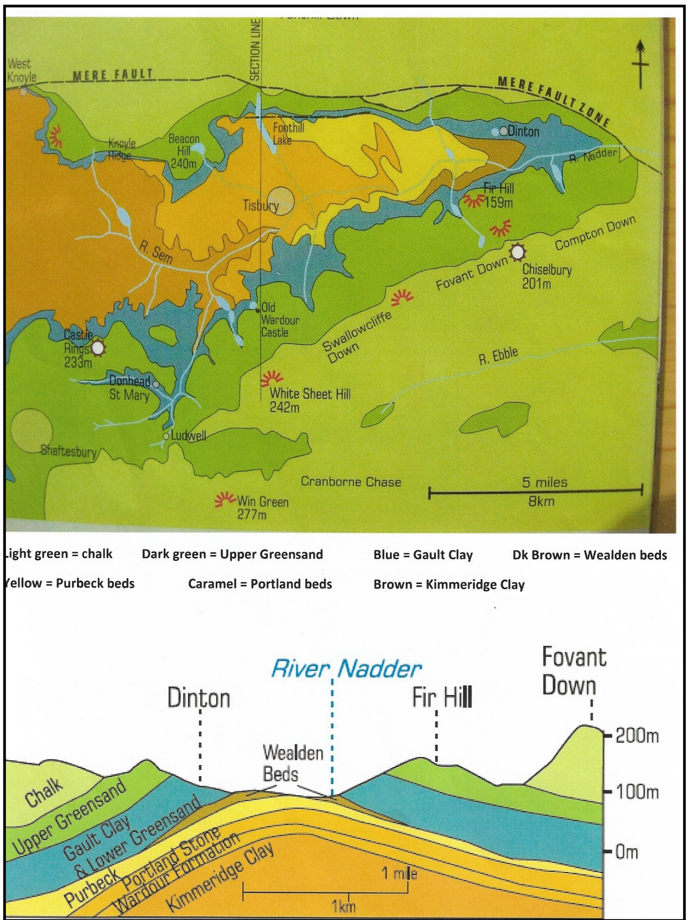


Fig.1 Geology of the Vale of Wardour

We gathered at the NT car park at Dinton, where Val welcomed us and Steve introduced himself. With the Vale of Wardour geological map in hand, he described the 5 mile/8km walk we were to embark on. There are not many exposures on the way, but the lay of the land dictates the stratigraphy. Explaining that he has an interest in history, too, he explained many points of interest on the way. Dinton itself has 8 NT places to visit – plenty of history here. We have included a precis of Etheldred Benett, a local geologist of great importance, at the end of the report. *(see Page 8)*

Fig.1 The stratigraphy of the area is topped with Chalk, below which is Upper Greensand, then Gault Clay Lower Greensand, Purbeck, Portland, Wardour Formation and Kimmeridge Clay. There is just a small outcrop of the Wealden Bed in Dinton. The Alpine Orogeny pushed the layered rocks up, then over time the anticline was eroded away and the river Nadder and its tributaries snaked their way through the landscape forming scarps and vales. Over 50 million years or so the Nadder carved its way through the Upper Greensand exposing the strata down to the level of the Portland Stone. At one time there were an incredible 250 mills along the length of the river, including 8 mills within a one mile stretch. A lot of land was owned by the church and run by abbots, and by the landed gentry.

Fig.2 Hyde House

Fig. 3 Philipps House

Figs. 2/3 Over the first of many stiles onto 250 acres of open parkland. First viewing one grand house, Hyde House, an old rectory, then the stately Philipps House built 1814-1817 using Chilmark Stone – the same stone used for most of Salisbury Cathedral.

Fig.4 Lake on Gault Clay

There are five local quarries – Tisbury, Wardour, Chilmark, Chicksgrove, Wockley, which all quarried Portland Stone. Some now just quarry on demand, or are closed. Chilmark (Tisbury) Stone is still quarried at Upper Chicksgrove Quarry, a SSSI. The stone is mainly used for restoration work.

Fig.4 Walking on, we passed a large lake, indicating that it had formed in a hollow over the impermeable Gault Clay.

Fig.5 Along the River Nadder, a pause at the first mill site. The mill had been burnt down in1904. Local Fullers Earth was used at the wool mills, where cloth was repeatedly pounded to scour and shrink it.

Fig.5 The River Nadder

Fig.6 View across Nadder valley over the wheat fields.

Fig. 6 View across the Nadder valley

Fig.7 Through Fovant Wood, part of which used to be MOD land. The remaining bunkers there are now used to store expensive wine at an even temperature. On up Fir Hill on the Greensand escarpment.

A walk along the steep holloway revealed banks of Upper Greensand. A cockle bed is exposed, packed full of small oyster – like fossils. The Greensand marks the top of the building stone level, forming the cliff along the upper edge of the wood. The Upper Greensand is recognisable by the abundant dark grains of glauconite in the sandstone that gives it a distinctive greenish grey colour. Fossil burrows are also common features. Hurdcott Stone – Upper Greensand is still quarried near Burford St Martin, 6 miles east of Tisbury. It was used as a damp-proof course in many older buildings.

Fig. 7 Cockle bed in the Upper Greensand

Fig.8 Further on by the edge of Fovant Wood there is a good view looking towards the Fovant Badges. From the Fir Hill escarpment we looked south across the Upper Greensand sloping at 20° and dipping under the Chalk of Fovant Down. The Fovant Badges showed up well, cut into the Chalk face. The badges are the regimental emblems cut by troops stationed here during WW1 . One new badge, of a poppy, has been added recently. To highlight the Chalk, it had to be imported from Dorset. The badges have to be refreshed every 20 years.

Fig. 8 The Fovant badges

Figs.9/9a. (see page 7) The next stop was Compton Chamberlayne Church. We spotted a lot of Greensand stonework in the walls. It had weathered badly, with the harder fossils standing out. The windows and door frames were finished with the harder local Chilmark Stone, as were the quoins.

Fig.9 Compton Chamberlayne Church

Fig.9a Upper Greensand ashlar block

Fig.10 Graffiti in Upper Greensand

Fig.10a The old estate bridge

Figs.10/10a. We passed under an old estate bridge made mostly again of Upper Greensand. The roof from it was long gone. Interestingly, there was a lot of engraving/graffiti carved into the sides, one by a WW1 soldier. The large estate once belonged to William Becksfield, said to be the richest commoner in England.

Fig.11. A walk by the vast water meadows. These were managed by the estates. Channels were cut into the low-lying land, and locks were used to flood the meadows in the early spring. When the water retreated, the soil was nutrient-rich and lush grass grew. The sheep were then brought down from the higher ground which they had grazed on and fertilized all winter. This was called the Early Bite. The higher ground fields were then ready for the first crops to be sown. The channels in the meadows can still be traced. This system of farming ended when the Industrial Revolution arrived.

Fig.11 Steve explains the farming system

Fig.12 Dinton Cottage and Mill

Fig.12. Dinton Cottage and Mill. The last mill along the walk. There has been a mill at this site since 1086. The one we see today was built in 18th century, with the mill cottage being added in the19th century. The mill is now a Grade 2 listed building.

We ended by thanking Steve for a lovely walk through The Vale of Wardour and for organising a superb pub lunch afterwards.

Roger and Janet also wrote the following article.

Etheldred Benett 1776 – 1844 of Pyt House, near Tisbury

Ethelred Benett:

"First Female Geologist"

'A Lady of Great Talent and Indefatigable Research'. Etheldred was born into a wealthy family. She is regarded as the first female geologist, collecting and studying fossils in south-west England. The rocks at Upper Chicksgrove were of particular interest to her and she made one of the very first bed by bed stratigraphical descriptions. It is signed by her and is now in the Geological Society of London Library. The Geological Society, however, at the time, banned her because she was a woman. Most of her collection ended up in Philadelphia. Tsar Nicholas of Russia gave her an honorary doctorate from the University of St. Petersburg, not realising she was a woman. As she was a lady of means, she could hire fossil collectors and afford to buy prepared specimens.

She had the largest collection of anyone at the time and is credited as developing geology as a science. Etheldred met up with all the great geologists of the day – Mantell, Buckland, De La Beche, Murchison and Lyell. She presented William Smith with one of the better-known fossils from the Vale of Wardour, 'The Tisbury Coral'. Her speciality was the fossils of the Mid-Cretaceous, Upper Greensand, focussing on sponges and molluscs. She studied Conchology. Latterly, Etheldred was the first to look at micro fossils. Many types of fossils were found and identified by her, as well as some rare fossils with soft parts preserved.

THE HOT ROCK SLOT

LAYERED MAFIC INTRUSIONS

"Iconic" is an overused word these days, but if you were asked to name an iconic intrusion the chances are that you would come up with one of the large, layered mafic intrusions such as Bushveld, Skaergaard or Great Dyke. These bodies are truly spectacular; not only are some of them absolutely vast (the Great Dyke is 500km long) but many have wonderfully complex internal variation, with a prominent role played by layering. In some intrusions this can be mapped out as a kind of stratigraphy and, as we'll see, there are many parallels between igneous layering and sedimentary bedding.

Layered mafic intrusions (LMIs) form where large volumes of basaltic magma pond at depth within the Earth's crust. The largest intrusions may take over a million years to crystallise fully. Their complex internal structures are made possible by the low viscosity of basaltic magmas and the wide temperature intervals over which they crystallise. Layering is also characteristic of large syenite intrusions since alkaline magmas also have these attributes, but I'll leave those rocks for another time.

There is a huge volume of scientific literature devoted to layered intrusions, mainly because of the valuable evidence they provide for interpreting the processes of magma crystallisation and differentiation. The origins of layering are still hotly debated; one recent review lists 25 mechanisms! Over the last 50 years the Bushveld intrusion alone has been the subject of over 1700 scientific papers.

3-D forms of layered mafic intrusions:

The characteristic forms adopted by LMIs are lopoliths, funnel intrusions and funnel dykes. **Lopoliths** are essentially giant sills, of which the Bushveld intrusion of S Africa is a classic example at *ca*. 8km thick and 300km across. **Funnel intrusions** are smaller, up to 20km across, and have inverted cone shapes, with inclined, inward-dipping lower contacts; they probably form as thick cone sheets in which the central core is pushed far up. **Funnel dykes** are giant dykes with Y-shaped profiles; their lower, planar parts (?feeder dykes) may be up to 1km thick and their upper parts are like long funnel intrusions. The Great Dyke of Zimbabwe is a good example. Layering also occurs in some smaller basic intrusions such as ring intrusions, sills and plugs.

Rhythmic and cryptic layering:

According to the classical model developed by L.R. Wager and others, layering is primarily the result of **fractional crystallisation**, whereby early-formed crystals separate from the liquid e.g. under the influence of gravity and, in so doing, progressively deplete the magma in the chemical components of those crystals. Rocks formed by the accumulation of crystals are termed **cumulates**. Most minerals that crystallise from mafic magma are denser than the liquids from which they crystallise so they will tend to sink; in LMIs, therefore, cumulates that form by gravitational separation accumulate from the bottom up. (Flotation cumulates rich in low-density feldspathoid minerals occur at the tops of some syenite intrusions.)**Rhythmic layering** is clearly visible in outcrop and is defined by alternating layers with different mineral proportions (e.g. Figs. 1–3). Small-scale rhythmic layering may reflect variations in convection current velocity in the magma chamber causing variation in crystal settling rates.

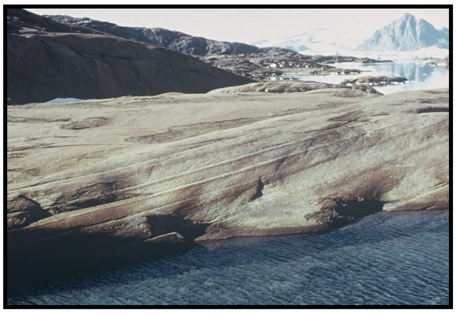


Fig.1 Layered gabbros, Skaergaard, E Greenland. Photo: W.J. Wadsworth

Fig.2 Alternating layers of pyroxenite (dark) and gabbro, Tugtutoq Giant Dyke, E Greenland. Photo: B.G.J. Upton.

Fig.3 Rhythmic layering in the Hovden Gabbro, Norway. Photo: G. Droop.

Large-scale rhythmic layering (e.g. in the Rum intrusion, Scotland – Fig. 4) may be due to periodic replenishment of the magma chamber with new batches of magma, or periodic convective overturn interspersed with long periods of stagnation.

Fig.4 Large-scale rhythmic layering on Hallival, Rum, Scotland. Photo: W.J. Wadsworth.

Cryptic layering is the progressive change in the chemical composition of rocks and minerals with position in the intrusion (usually structural height) indicating a change in magma composition as crystallisation progressed. (More on this below.)

In lopoliths, funnel intrusions and the upper parts of funnel dykes, rhythmic layering seems to develop parallel to the bottom contacts, much as one would expect from the development of cumulates by crystal settling. However, in the vertical part of the Tugtutoq Giant Dyke, E Greenland, the layering dips at about 30º (Fig. 2) towards the centre of the dyke, and this has been interpreted as the accumulation of crystals at the angle of rest. However, layering parallel to high-angle contacts has been described from some intrusions, indicating the influence of processes other than crystal settling, e.g. flow segregation or fluctuations in nucleation rate.

Cumulate mineralogy and rock-types:

The mineralogy of LMI cumulates reflect the minerals crystallising early out of basic magma, *viz*. olivine $(Mg,Fe)_2SiO_4$, chromite $(Fe,Mg)Cr_2O_4$, orthopyroxene $(Mg,Fe)SiO_3$, augite $Ca(Mg,Fe)Si_2O_6$, plagioclase feldspar $(Ca,Na)(Al,Si)AlSi_2O_8$, ilmenite $FeTiO_3$ and magnetite Fe_3O_4. Common cumulate rock-types include:

Gabbro: augite + plagioclase (± olivine ± orthopyroxene)
Norite: mainly orthopyroxene + plagioclase
Troctolite: mainly olivine + plagioclase
Peridotite: mainly olivine ± pyroxenes
Pyroxenite: mainly orthopyroxene or augite
Anorthosite: mainly plagioclase
Chromitite: mainly chromite.

Textures and structures of cumulates:

Cumulates generally consist of close-packed, euhedral or subhedral crystals of early–formed minerals surrounded by sparse poikilitic or interstitial **intercumulus minerals** representing crystallisation from trapped liquid (Figs. 5 and 6). Monomineralic cumulates (e.g. the anorthosite shown in Fig. 7) are thought to form by continued growth and compaction of cumulus minerals after settling and concomitant expulsion of liquid from the crystal mush. In large intrusions where temperatures remain high for long periods, monomineralic cumulates tend to become texturally equilibrated, developing ‘soap-bubble’ textures with straight grain boundaries meeting at angles close to 120º (Fig. 7).

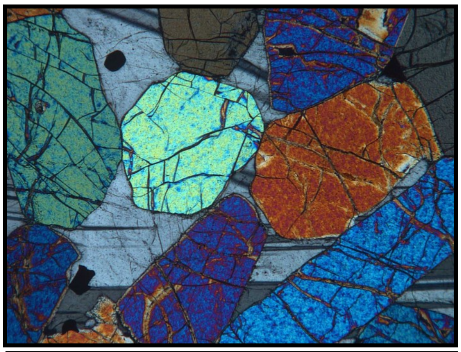


Fig.5 Photomicrograph showing cumulus olivine grains and intercumulus plagioclase in troctolite from Rum. Crossed polars. Field of view 2 mm across. Photo: G. Droop.

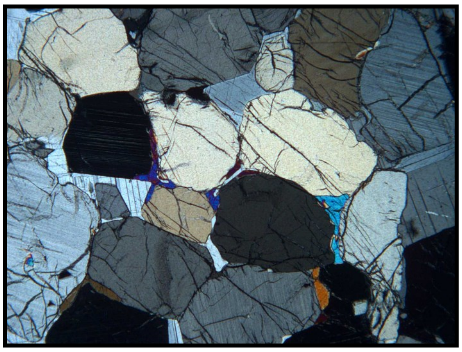


Fig.6 Photomicrograph showing cumulus orthopyroxene grains and intercumulus augite and plagioclase in pyroxenite from the Stillwater intrusion, USA. Crossed polars. Field of view 2 mm across. Photo: G. Droop.

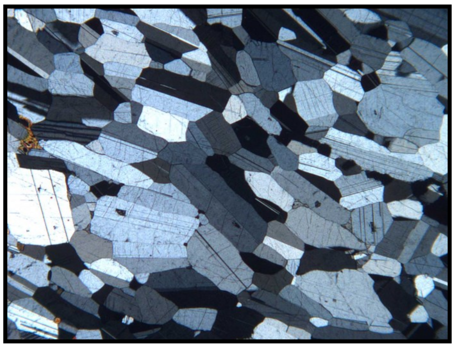


Fig.7 Photomicrograph showing aligned cumulus plagioclase grains in anorthosite from Rum. Crossed polars. Field of view 2 mm across. Photo: G. Droop.

Cumulus minerals may be aligned (Fig. 7) due to settling and/or compaction, or to flow alignment, or to preferential growth on certain crystal faces.

Fig.8 Rhythmic layering in the Huntly Gabbro, Scotland. Note the graded layer which shows that the layering is inverted (younging indicated). Photo: G. Droop.

Igneous layered cumulates commonly exhibit ‘sedimentary structures’ analogous to those commonly found in clastic sedimentary rocks, including graded layering (Fig. 8), trough layering (Fig. 9) and ‘cross bedding’, confirming the importance of the process of sedimentation from currents in a highly fluid medium (silicate liquid in this case, as opposed to water in the case of clastic sediments). Load structures may form whereby dense crystal aggregates attempt to sink through less dense ones; Fig.10 shows an example in which a mass of dense chromitite and troctolite cumulate has partly detached itself from the base of a layer and has begun to sink through a less dense plagioclase crystal mush. ‘Syn-sedimentary’ faults and slump folds have also been described from some LMIs.

Fig.9 Trough layering in gabbro, Skaergaard.
Photo: W.J. Wadsworth.

Skaergaard: cryptic layering as evidence of fractional crystallisation:

A few LMIs preserve evidence of *in-situ* fractional crystallisation, i.e. they each result from a large body of magma crystallising to completion in a closed magma chamber, without replenishment or volcanic tapping. Skaergaard is the most famous, and I’ll use it as an example, but the Kiglapait intrusion in Labrador is another case.

Skaergaard is a Tertiary funnel intrusion, 11 km in diameter, cutting gneisses and basalts in E Greenland (Fig. 11). It was tilted after intrusion. It consists of (i) the Marginal Border Group: an early sheet of olivine dolerite bounded by a chilled margin representing the original magma composition; (ii) the Upper Border Series (UBS): coarse unlayered gabbros that crystallised at the top of the magma chamber by cooling through the roof; (iii) small bodies of granite that might represent late-stage differentiates; (iv) the Layered Series (LS): cumulates, mostly gabbros, rhythmically layered on a small scale, which crystallised at the base of the magma chamber.

Fig.10 Hand specimen showing a load structure at the base of a layer in the Rum intrusion. Squares 1cm across. Photo: G. Droop.

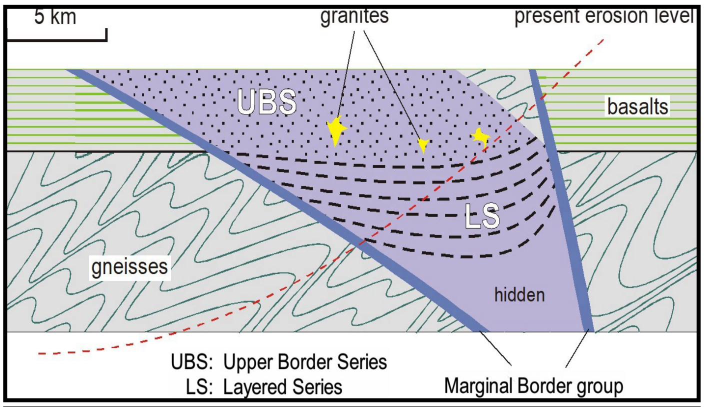


Fig.11 Schematic cross-section of the Skaergaard intrusion. Image: G. Droop.

Cryptic layering occurs in the LS, with rock types changing from olivine gabbro at the exposed base through olivine-free gabbro to diorite at the top. (The UBS shows corresponding changes from the top down.) Quartz joins the assemblage at the top of the LS in the diorites. The reason for this is that settling out of early-formed olivine, pyroxenes and plagioclase (all of which have lower SiO_2 than the liquid from which they crystallise) caused the remaining liquid to become more siliceous, eventually reaching quartz saturation.

The compositions of the minerals also change: (i) Olivine and pyroxenes become more iron-rich. This is because these minerals have lower Fe/Mg than coexisting melt, so the Fe/Mg ratios of the remaining melt and later mineral precipitates progressively increase. (ii) Plagioclase becomes more sodic (i.e. albite-rich). This is because plagioclase has lower Na/Ca than coexisting melt, so the Na/Ca of the remaining melt and later plagioclases increase.
The Skaergaard intrusion thus preserves clear evidence of *in-situ* differentiation of a single body of basic magma by the process of fractional crystallisation.

Economic importance:
LMIs are significant sources of chromite, platinum-group elements, base metal sulphides, magnetite and ilmenite. Chromitite cumulates (e.g. Fig. 12) account for a high proportion of the world's Cr reserves. Most mined platinum comes from a single, thin (≤4m) laterally extensive layer of norite cumulate within the Bushveld intrusion called the Merensky Reef. The origin of the PGE enrichment in this layer is still debated but may have something to do with the separation and accumulation of dense droplets of immiscible sulphide liquid from the silicate magma.

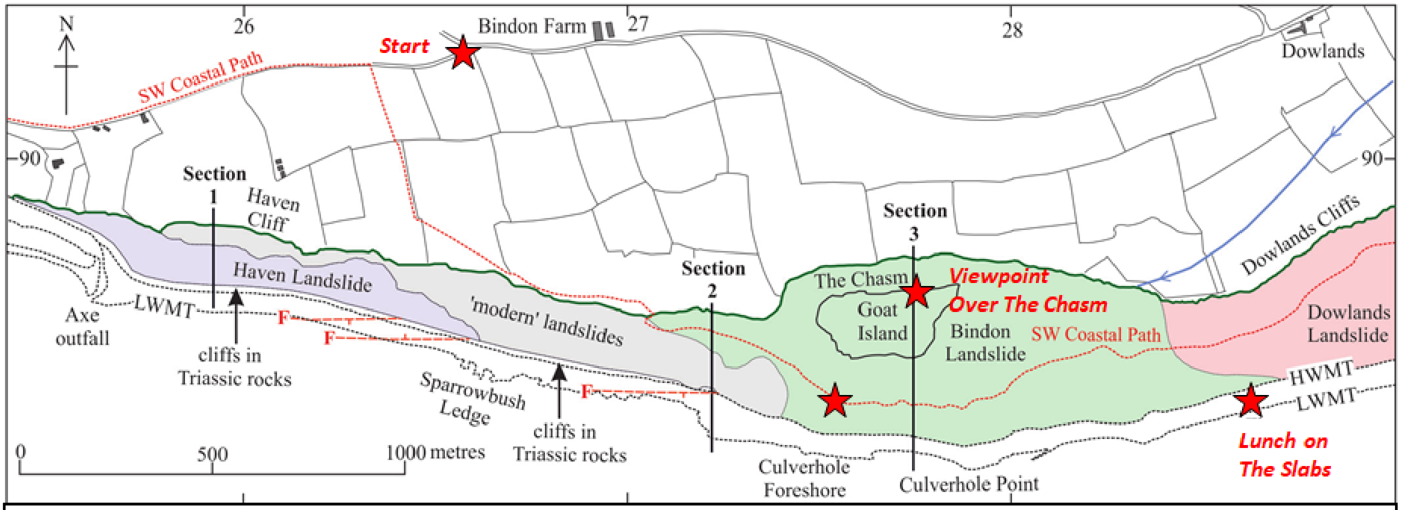
Fig.12 Chromitite layers (black) in anothosite in the Bushveld intrusion, S. Africa. Photo: W.J. Wadsworth.

Fig.13 Rhythmic layering in the Duntulm Sill, Skye, Scotland. Photo: L. Cody-Rapport.

Layered mafic intrusions in the UK:
Scotland is undoubtedly the best place to see LMIs in the UK, with excellent examples provided by the Ordovician 'Newer Gabbro' suite in NE Scotland, notably the Insch, Huntly (Fig. 8) and Belhelvie intrusions, and the Tertiary central complexes of the Western Isles, especially Rum (Fig. 4) and the Cuillins of Skye. Some of the late Palaeozoic sills of the Midland Valley (e.g. Lugar & Saltcoats) are differentiated and have basal olivine-rich cumulates, as does the Tertiary Shiant Is Sill in the Hebrides. Spectacular rhythmic layering occurs in the sill at Duntulm Castle, Skye (Fig. 13).

There are not many LMIs in the rest of the UK. The gabbros of the Lizard and Shetland ophiolites are locally layered, as are the gabbro sheets at Rhiw on the Lleyn peninsula and the Carrock Fell Gabbro in the Lake District. *Giles Droop*

Alan Driscole **reports on the field trip to Goat Island, the Chasm, Sheepwash and the Slabs, Undercliffs National Nature Reserve led by** *Geoff Rowland.*



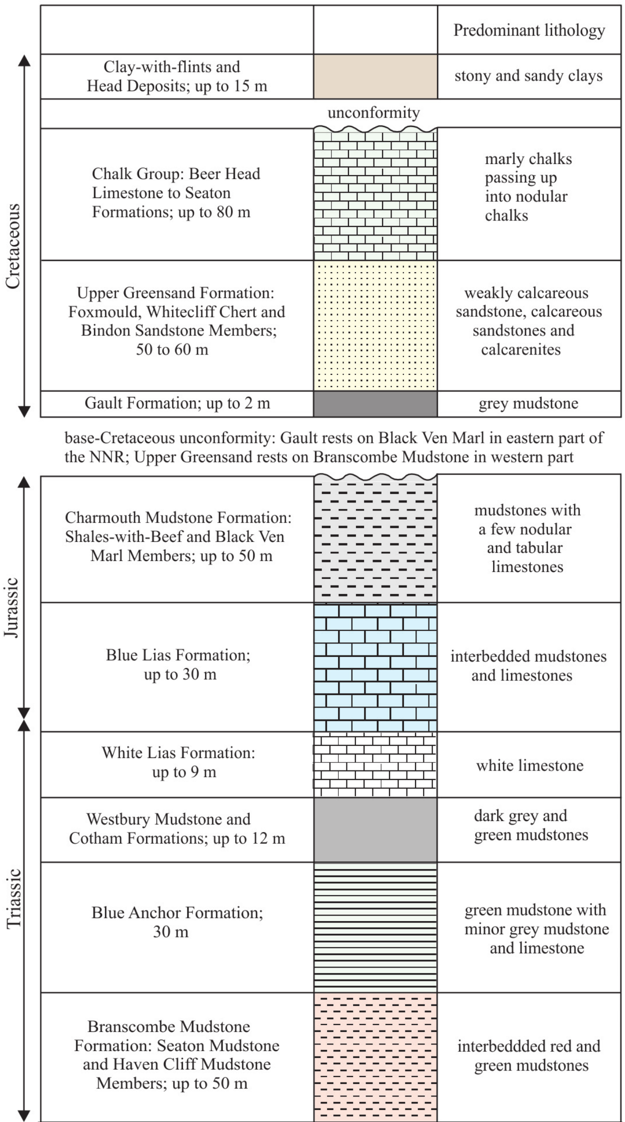
1. The coast between Axmouth and Lyme Regis includes several landslides. The Bindon Landslide (1839) is the most spectacular and the best documented. ***From Geoff's trip handout***

A bit of a misnomer; Goat Island is neither an island or is known to have been the home of any goats. Rather it is a large block that forms the core of the Bindon Landslide; the most impressive and best-documented of several landslides along the seven-mile stretch between Axmouth and Lyme Regis. This area of rugged coast, preserved as the Undercliffs National Nature Reserve, covers not only the landslips, but underlying rocks of late Triassic and early Jurassic (Liassic) age locally exposed at beach level.

The 304 hectare Undercliffs NNR is important, not only for it's geology and geomorphology, but for its wildlife and we were fortunate to be led by Geoff, a volunteer for Natural England. Geoff has spent many hours maintaining the reserve and access and consequently knows it like the back of his hand, including the little-known byways (definitely not highways) off the South West Coastal Path.

Sixteen of us met with Geoff on a slightly overcast but pleasant Saturday morning. The plan was to take the SW Coastal Path into the Undercliffs and cross the Bindon Landslide with a couple of detours to view the Chasm along the north side of Goat Island and descend to the coast at The Slabs, to take lunch on in-situ Blue Lias with a spectacular ammonite pavement (Fig. 1). Lifted from Geoff's handout, Fig 2 summarises the stratigraphy of the area, with the Triassic and Lower Jurassic, tilted to the east unconformably below marine Cretaceous. The gap between the Lower Lias (early Sinemurian; 199 Ma) and the Gault clays (mid Albian; 110 Ma) represents approximately 90 million years.

As we were joining the Coastal Path we were reminded of the arduous nature of the terrain to expect along the Undercliff (Fig. 3). In fact, this section of the path (which used to pass below Goat Island) was recently lost to landslips and is impassable.



2. The Gault and overlying Foxmould are believed to be the surface on which the Bindon Landslide moved. Below the landslides the upper part of the Blue Lias Formation is exposed on the coast at The Slabs. ***From Geoff's trip handout*** **.**

3. A warning of things to come! Steep ups and downs, tree roots, slippery stones (rounded Cretaceous cherts) and the occasional hole and fence all made for a challenging trek. We were fortunate that Geoff could get permission to leave the path to view The Chasm and The Slabs.
Picture by Richard Hallett

4. Viewpoint over the Bindon Landslide. This point marks the western end of the landslide, with a steep descent followed by ascent onto Goat Island.
Picture by Alan Driscole

5. The meadow on the edge of Goat Island, looking down to the sea.
Picture by Saleem Taijbee

The new section runs along the top the Undercliff, on private land, but we could see slip faces in the hillside by the path where the land continues to move. At a viewpoint on the western edge (Fig. 4) it was possible to see the rugged, heavily wooded nature of the Bindon Landslide. There followed repeated descents and ascents as we crossed the western part of the landslide onto Goat Island, entering a meadow full of wild flowers (Fig. 5); the result of hard work rather than nature.

From here we left the Coastal Path to view the Great Chasm and discuss the geomorphology, geology and history of the Bindon Landslide. With the help of his model (Fig. 6), Geoff described the geology of the area, with the easterly tilt of the Triassic and Jurassic during the early Cretaceous resulting from uplift to the west centred on the Cornubian Massif during early opening of the northern Atlantic Ocean. Following exposure and erosion the Cretaceous marine transgression reached east Devon by the mid-Albian.

6. Overlooking The Chasm, and with the benefit of his custom-made model, Geoff describes the geology of the Undercliff, with Triassic, Jurassic and (further to the east) Lower Cretaceous tilted east below the Upper Cretaceous.
Photo by Mimi Spencer

7. The Chasm. The steep slope in the fore-ground forms the northern edge of Goat Island. Goat Island is effectively a detached but internally undeformed block of Upper Greensand and Chalk that has moved seaward over a slip-plane in the Gault Clay. The Chasm results from the movement of the Bindon Landslide away from the in-situ Cretaceous (in cliffs to the left). ***Photo by Alan Driscole***

8. The Chasm and in-situ Cretaceous. This picture clearly shows the in-site Chalk and Upper Greensand on the northern side of The Chasm and the size of hole; infilled by fully grown ash trees! ***Photo by Richard Hallett***

The Gault Clay, overlying the unconformity, and the Foxmould sandstone are believed to form the base of the detached block of the landslide. Soft, weak and impermeably Gault clays, overlying permeable and (especially after sustained heavy rain) water saturated sandstones and a gentle structural dip towards the sea provided the ideal conditions for slope failure.

The Chasm remains an impressive valley approximately 1,200 metres long and up to 120 metres wide, marked by steep-sided slopes along the northern edge of Goat Island and by cliffs along the north of The Chasm, which is filled with mature ash trees (Figs. 7 & 8); sadly, suffering the effects of ash dieback. Following weeks of heavy rain, the rapid collapse of a large area of farmland over Christmas 1839 caused a sensation attracting many sightseers (including Queen Victoria) and the geologists William Buckland and William Conybeare.

As a result, the Bindon Landslide is well documented, with contemporary drawings showing collapsed and rotated blocks of land within The Chasm (e.g. Fig 9). Seaward movement of the landslip pushed up an area offshore to form a small natural harbour, but which soon washed away. For more detail on the history of the Bindon Landslide and recent theories on its development, the work of Ramues Gallois and Richard Edmonds is recommended.

9. The Chasm and Goat Island. Drawings made shortly after the landslide show how farmland slipped and rotated into the hole vacated as Goat Island slipped seaward. ***From Geoff's trip handout***

From The Chasm we made our way back to the Coastal Path (Fig. 10). A few more steep descents and ascents, marking the eastern edge of the Bindon Landslide, brought us to the Sheepwash. Built around 1800, long before the landslide and when the area was farmland, the Sheepwash is constructed mainly of Greensand cherts and was used to wash sheep in fuller's earth and lime before shearing to increase the value of the fleece. From here we left the path again, clambering over a low fence and down a slope, sometimes on our backsides, to the beach, where we could see slipped Gault Clay and Upper Greensand overlying the Blue Lias.

10. The Undercliff on the Bindon Landslide. A typical section of undulating path, with a luxuriant flora . ***Photo by Alan Driscole***

11. The Slabs. The lunch break and a chance to view large ammonites (*Coroniceras*) and nautiloids in the Grey Ledge bed (top Blue Lias Fm). ***Photo Mimi Spencer***

Our lunch stop, which Geoff had ensured coincided with a low tide, was on The Slabs, with limestones and shales at the top of the Blue Lias Formation exposed in a small ENE-WSW trending anticline. The upper-most bed of the Blue Lias, the Grey Ledge, showed abundant large ammonites, plus the occasional nautilus and driftwood - (see Figs. 11 & 12).

12. The Slabs. More large *Coroniceras* in the Grey Ledge. ***Photo Saleem Taijbee***

After lunch we retraced our steps to the Coastal Path and then headed back west, stopping briefly for the group shot (Fig. 14). Our thanks go to Geoff for leading such an interesting trip and arranging access off of the main path to view The Chasm and The Slabs. My thanks to Mimi, Richard and Saleem who have contributed photos for this report.

13. The Group! ***Photo Richard Hallett***

Finding a Field Trip Officer

When I was asked to be the Field Trip Officer, I accepted for one year only. That was to help out Kelvin and Alan who had always been so very helpful to me as I tried to learn some of the basics of geology. I had never looked at a rock or a fossil until I retired in September 2014 and joined Sherborne u3a Geology group which I now run! The leader back then was Chris Wilson and he moved to the Lake District within three months of me joining! Luckily Alan took us out on field trips throughout 2015 and my interest grew.

So, in September 2015 I joined Lyme Regis u3a and did a year course with the wonderful Geoff Townson who inspired me even more. After that I joined DGAG in 2016. On each trip I would ask lots of questions and many of you answered me with enthusiasm. It only seemed right to accept the post of Field Trip Officer to pay back for all the kindness. It had been vacant for several years and Kelvin had been doing it along with his role of Secretary, Newsletter Editor, Events Officer and Sales! The question is who is going to take it on now? It would not be fair if Kelvin had to do this role again. Perhaps you could consider it? Even if it is only for 1 or 2 years? If I could do it with so little knowledge, I am sure you could too.

The role is very interesting and I have enjoyed it. I was worried that I did not have enough contacts to do the role properly. However, with the advice and support of DGAG members and especially members on the committee, I had fun planning a full itinerary of events throughout the year including the recent residential trip to the Black Country. I have got to know many more of you and enjoyed your company. My one year did turn out to be two years because everything was put on hold in 2020!

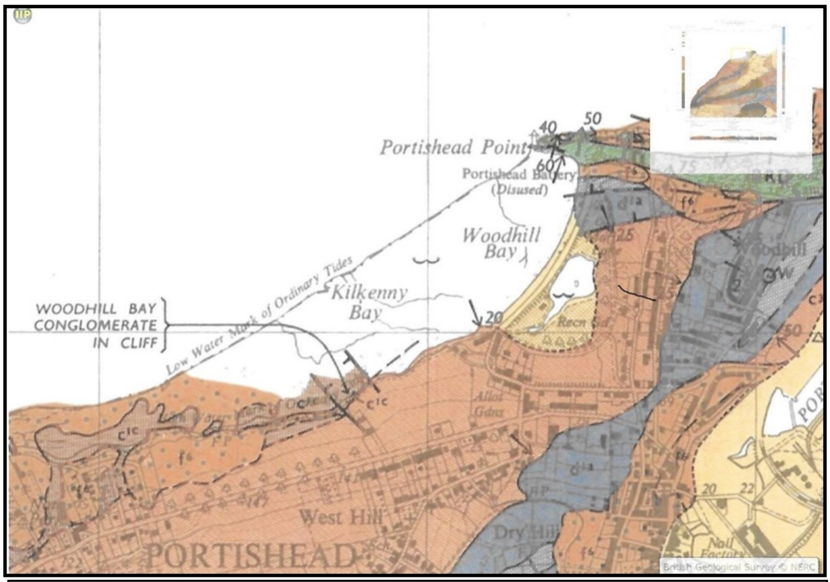
I was a biology teacher and I love Marine Biology. However, I lived and worked in Wolverhampton so I didn't get much chance to do much during my career. Now I live in Dorset I can get to the coast within an hour and volunteer at the Wild Seas Centre at Kimmeridge Bay. I hope to do more of this in the next few years. I won't bore you with details of the crab survey that I am running but I find it fascinating.

Please seriously consider taking on the role of Field Trip Officer, starting in January 2022. I can recommend the role and I am sure you would enjoy it. If you want to chat it through with me do give me a ring. *Val Fogarty*

Charmouth Heritage Coast Centre are on the look out for any new volunteers to assist in the centre and on fossil hunting walks with both the public and schools. In a normal non-pandemic year there are lots of marine events too such as rock pooling and citizen science seashore surveys. If anyone is interested please contact Alison Ferris at: info@charmouth.org

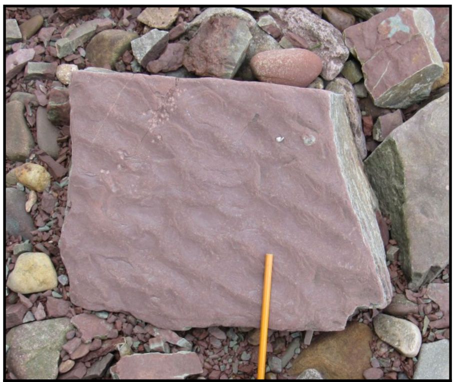
Roy Musgrove reports on :Powys to Portishead: Field trip 26th June 2021 and wider comparisons (Part 1).

The context of Portishead's well-known outcrop is perhaps best appreciated by reference to a geological map. An anticlinal ridge with most of its NW limb beneath the Severn lies NE/ SW, with the fold axis plunging NE. Like some of the smaller scale folds at the coast, it appears to close under the town and has faulting at the "nose". The coast lies almost parallel with the fold axis and going SW along the exposure is against dip, with the rocks ageing as you continue. The site is an SSSI and hammers are taboo.



1. Location map, (*Contains British Geological Survey materials © UKRI [2004]"*

We descended a ramp from The Esplanade to the foot of the sea wall and made our way to the first outcrops at the south-west end of Woodhill Bay. Initially we met conglomeratic sandstone in fairly thick beds, but as we went further interbedded mudstones soon appeared, along with much cross-bedding and current bedding (3). A slab of sandstone with scallops (2) was produced by current bedding because the scallops were symmetrical whereas flow scallops are steeper upstream than downstream. Other distinctive features seen included a dense patch of mica flakes and some levels of bioturbation by bottom-dwelling creatures.



2. Slab of sandstone with symmetrical ripples. (Photo: Kelvin Huff)

This is due to the elevation of the Wales/Brabant Ridge in the late Silurian and early Devonian having initiated deposition in continental conditions by very dynamic river systems flowing from the north. The conglomerates were deposited in channels which migrated sideways with some frequency and were braided. The finer sediments were laid down in shallower water between channels and in slacker flows. Having regard to the presence of Marine Devonian rocks not far away it is probably true that they also occupied the lower parts of their courses in this area and flow no doubt sometimes slackened on approaching the sea. The variety of beds and lenses of different sediments was quite dramatic. The sandstone is said to contain clasts of Mona complex metamorphic and igneous rock, and there was discussion as to how this came about with the Wales/Brabant ridge lying between Anglesey and Portishead. This will be returned to later.

After a while we came to a vertical offset in the rock face which is marked on the map as a fault (4). There was a thin breccia along the fault plane and the right hand side is downthrown about 10 m.

3. Typical conglomeratic sandstone and mudstone Portishead Formation.

4. Fault downthrown approximately 10m on right hand side.

Beyond this is an unconformity, with Triassic conglomerate (5) on top of the Devonian. The absence of obvious fragments of Carboniferous limestone left some unconvinced that the overlying rock wasn't slumped Devonian, but we accepted that the location has been studied in great detail over the years, and the capping was Triassic. The presence of the famous "Woodhill Fish Bed" was indicated by a primitive blue graffito of a fish!

5. Angular Unconformity: Triassic on Devonian

The fossils from here have enabled the Portishead Formation to be dated to the Fammenian stage at the very top of the Devonian. The exact junction with the overlying Carboniferous is concealed under the valley crossed by The Esplanade, so it cannot be determined whether it is conformable or not. The beds have been folded during the Variscan Orogeny and it was noted that the direction of pressure (from the south) was shown by the southern elevation of anticlines being steeper than the northern, as with the water pressure in scalloping.

The next feature seen was a second fault beyond which the unconformity ceases, and eventually we came to an iron ladder leading up the cliff and a path back to the cars, where we stopped for a quick lunch. Further down the coast towards Clevedon are outcrops of the Black Nore Sandstone, but we didn't go that far.

6. Closing Anticlinal Fold in the Lower Limestone Shales.

In the afternoon we returned to the coast at the north-east end of The Esplanade. Here the rocks exposed are The Lower Limestone Shales at the bottom of the Carboniferous. These shales and limestone are stained iron-red and are arrayed in narrow folds (6), some of them closing inland. The fossils are overwhelmingly crinoid fragments.

The post-depositional changes in the limestone along Portishead Point (aka Battery Point), resulted in cavities or vugs forming, in which "spar" formed from calcite was deposited (7). Despite the depredations of collectors, one example was found in the cliff. It was also pointed out that the last fold on the foreshore had its steeper side to the north, and no-one could come up with the explanation for this. It was also noted that the intertidal muds were displaying desiccation cracks, with a grid of cracks to be commented on by future geologists when lithified!

7. Post-depositional cavity with spar (Photo Kelvin Huff)

This marked the end of the field trip although some of us went out along the rather slippery rocks of Battery Point, without finding anything further worthy of comment. The top of the point has a layer of Blackrock Dolomite on the top surface, which elsewhere in the district underlies the Blackrock Limestone. Alan was thanked for a most interesting and enjoyable day.

Part 2 will look at the equivalent strata in South Powys and the area in between.

DGAG Field Trips and allied events 2021-22

N.B. All events and field trips are subject to current Covid rules and restrictions

To book a place on our field-trips, contact Val Fogarty using her details below. £2.00 day trip fee.

October 9th: Fleet Lagoon Walk. Leader: Geoff Rowland.

November 6th or 7th: Wimborne Minster Building Stones, with Pete Bath. (GA Festival of Geology)

If any member has any ideas for field-trips please let Val or any committee member know.

As temporary Events Officer I have booked Broadmayne Village Hall for the following events:

October 23rd: Holiday Rocks Speakers: Alan Holiday on Northumberland plus others needed please!. Let me know if you are attending.

December 11th: Winter Workshop Let me know if you are attending and/or need a table for displays.

January 8th 2022: A.G.M. Post-A.G.M. talk by Bob Chandler

Please note that the above meetings may be by Zoom or as physical events. Members will be informed by email nearer the time. (KJH)

https://dorsetgeologistsassociation.org/
https://dorsetbuildingstone.org
https://dorsetrigs.org/

DIGS (Dorset's Important Geological Sites)

The group welcomes anyone wishing to help with conservation work on Local Geological Sites. Please contact Alan Holiday if you are interested. Working parties go out on both weekdays and weekends.
alanholiday@btinternet.com

Wessex OUGS events have resumed

Saturday 16th October - David Bone, Chichester Harbour, etc.

Saturday 13th November - Beaminster area. Bob Chandler

Saturday 22nd January - A.G.M plus a talk.

Please contact Jeremy Cranmer on: wessexdaytrips@ougs.org or telephone 01305 267133 to book a place.
£2.50 day trip charge.

Can we help answer your geological questions?

Either post them on our website's contact form or send them, maybe including photos, to me at the email below.

Reminders: Contributors' deadline for the Winter Newsletter is: **Wednesday, December 1st, 2021.**

Committee news:

We **still** need an Events Officer.
Kelvin

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Secretary, Newsletter Editor, Events and Sales	Kelvin Huff	01305 265527	kelvinhuff30@gmail.com
Treasurer and Membership Secretary	Alison Neil	01305 832937	alison.neil@madasafish.com
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