Dorset GA Group

Newsletter Spring 2020

https://dorsetgeologistsassociation.org/

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Welcome to the Spring Newsletter!

There are several longer articles in this issue, and so many thanks to all contributors. Our new Field Trip Officer, Val Fogarty, is working hard to put together a field-trip programme - so please support these excursions (Coronavirus permitting!). Details on p.18. The 2020 AGM minutes are now available from me by post or e-mail , just let me know if you'd like a copy. Can I remind you that membership renewals were due on 1st January 2020. Only paid-up members will receive the next issue of the Newsletter. *Kelvin*

Members enjoying a buffet lunch at the December Workshop

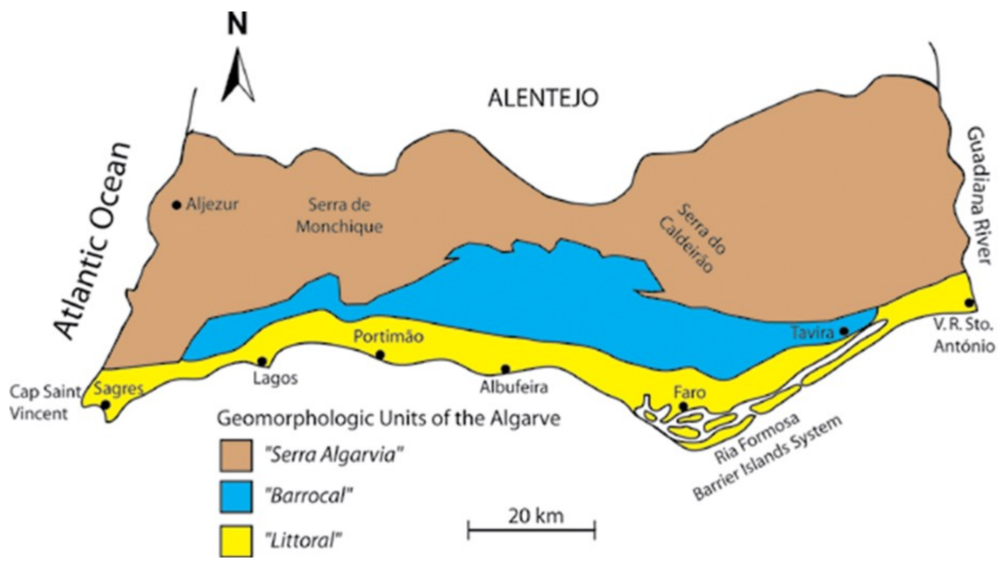
This issue's Special Insert sheet comes courtesy of Geoff Townson and the DBS Group. See page 17 for details

An introduction to the Algarve's geology

Mention the Algarve and you'll probably associate it with long sandy beaches, golf courses, lots of poured concrete and tourists. However in November, the sunbeds have been packed away for the winter and the temperatures are ideal to explore the region with bird reserves, cork trees and interesting and varied geology.

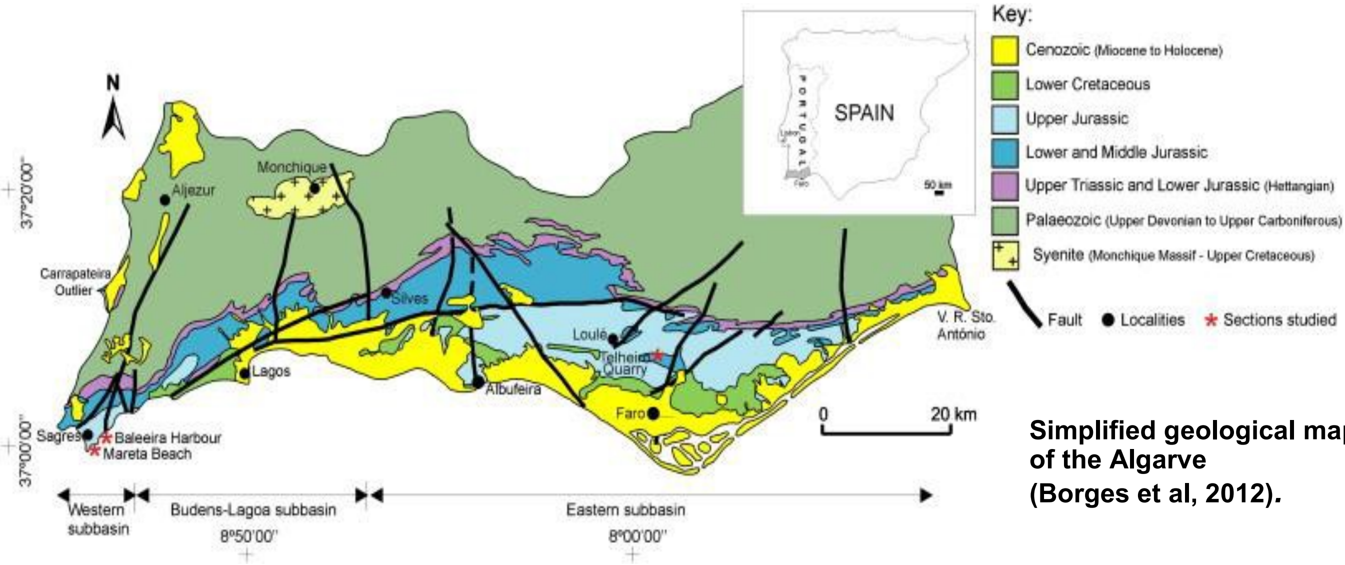
Geomorphology and geology

The Algarve, the southernmost region of the Portuguese mainland stretches from the estuary of the river Guadiana on the Portuguese/Spanish border over 150 km to Cape Saint Vincent, the most south-western corner of the European continent. The Algarve is separated into three different geomorphologic units as shown in the map below:



General location of the Geomorphologic Units of the Algarve (Dias, 2001).

The majority of tourist activities are concentrated in the small coastal area of the Algarve – the **Littoral**. The **Barrocal** area marks the transition between the coastal strip and the mountains of the Serra. The geologic formation mainly consists of Jurassic and lower Cretaceous limestone and schist and most of the Algarve's agricultural produce are grown on these fertile soils.
The Serra covers half of the total Algarvian territory of almost 5,000 sq km. The mountainous range of Devonian – Carboniferous rocks extend to the littoral part of the western coastline, exposed in Carboniferous shales of the cliffs. The Monchique Massif includes the highest peak in southern Portugal, Fóia (902 m), an intrusion of igneous rocks during Late Cretaceous times. Caldas de Monchique, a spa resort was already well known in Roman times because of its sulphurous water with a constant temperature of 32°C.



Simplified geological map of the Algarve (Borges et al, 2012).

The south coast from East to West

The nature reserve of the Ria Formosa in the east of this region from Faro to the Spanish border is a Quaternary barrier island/lagoonal system with wash-over fans, small inlets and back barrier lagoons. Most of the beaches are only accessible by ferry from the mainland. Further to the west – up to the outskirts of Albufeira - there are stretches of long sandy beaches and sand dunes against the backdrop of red and yellow Miocene sandstone cliffs. The soft cliffs, covered with pine trees have been shaped by erosion into karstic formations.

Piadade near Lagos

Sandstone cliffs near Albufeira

Rocha de Pena near Loule

The western Algarve between Albufeira and Lagos is rockier with Miocene limestone and marls dominating the coastline, interrupted by several large bays with sandy beaches protected by dunes, salty marshlands and lagoons.
Upper Triassic, Jurassic and Lower Cretaceous successions and unconformities are exposed in sea cliffs between Lagos and Telheiro, about 10km north of Cape Saint Vincent, these can be viewed from beaches and cliff tops. The cliff east of Mareta Beach at Sagres East exposes Middle and Upper Jurassic rocks, from Middle Bathonian to mostly Callovian grey marls. At the north eastern end of the cliff, the Callovian unconformity gives way to the more compact limestones and dolomites of Oxfordian to Kimmeridgian age.


Unconformities from Mareta Beach

Algarve Serra

The west facing Atlantic "Costa Vicentina" stretches for more than 60 km from Cape St. Vincent to Odeceixe. The rugged rocks of the steep coast are broken up by small sandy bays which are very popular with surfers. There are wide dune systems around Amoreira and Carrapateira, small estuaries and fluvial terraces.
The Monchique Massif consists of a pluton of alkaline igneous rocks (nepheline syenite) that intruded into the Upper Paleozoic rocks during the Late Cretaceous, estimated 72m.a. (Terrinha et al., 2006). Nepheline syenite has a high percentage of the mineral nepheline, alkaline feldspars, pyroxene and biotite and is fairly homogeneous and coarse-grained.


Syenite chemical weathering

On the side of the road leading to the peak of Fóia (902 m), there are clear examples of chemical weathering and a useful interpretation board. The weathering is more severe along the network of rocks in the rocks so rounded structures of various sizes are slowly forming in a process known as spheroidal weathering. Ball-like structures surrounded by concentric layers of weathered rock (like the fleshy layers of an onion) are clearly visible.


Spheroidal weathering

Seismic Activity

The Algarve has been affected by earthquakes, including the 1st November 1755 event also known as “the Great Lisbon earthquake”. Seismologists estimate that it had a magnitude in the range 8.5 – 9.0 with the epicentre about 200 Km west-southwest of Cape Saint Vincent where the Azores-Gibraltar transform fault forms part of the tectonic boundary between the Eurasian Plate and the African Plate. The combination of the earthquake, tsunami and subsequent fires when many residents were at church on All Saints Day almost destroyed Lisbon and estimates of fatalities range from 10,000 to 75,000.

Nearly all the coastal towns and villages of the Algarve were heavily damaged. The western city of Lagos became the capital of the historical province of Algarve in 1577 but was nearly destroyed with records claiming that 1080 of 1170 houses became unusable. Faro was protected by the sandy banks of the Ria Formosa lagoon and so in 1576 became the administrative capital of the region. *Hilarie Lewis*

References (which would also be useful to take on a field trip to the coastal region)

(from www.researchgate.net)

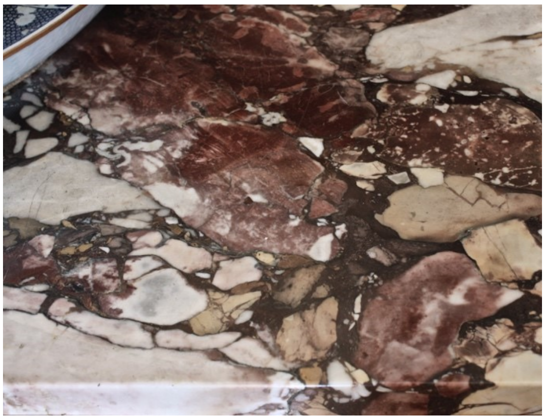
1)CIMP_Field Trip, Jose Tomas Oliveira, 2014

2) The Mesozoic Evolution of South-Western Portugal, field trip guide, Rui Pena dos Reis & Nuno Pimentel, 2012

Kingston Lacy Part 7: Interior Stone – Metamorphic

Apuan Alps Southern – Marble

Production and export of Oligocene-Miocene metamorphosed Seravezza and Stazzema areas' calcareous marble was maximised during the C19th. Matching or mixed clasts are along with the matrix, stained with oxides of iron or chlorite and most rarely with manganese piedmontite as below.



Breche violet of the Dining room table, is the French trade term for this most popular oxidised plumb red brecciated stone but it is not the true Seravezza Breccia Violetta, that is rich in piedmontite – see Saloon niches on next page.

Breccia di Seravezza Violetto, is today's update, for the N.T.'s. antiquated 19th C. term, Mischio di Seravezza. (It's also not as N.T. described - of *fleur pêcher* – the ancient Greek marble. Nor is this stone the repeatedly metamorphosed Italian Peach Blossom Marble, the *Fior di Pesco* of the Apuan Alps, which is used in the Drawing room doorway entablatures. (Both shown on next page.)

Here, close up, we can see the rich violet manganese colouration, generated by disseminated piedmontite and also the banded, elongate white brecciation, in a grey/ green and red matrix of chlorite and other iron oxides.

Central Dining room entablatures are of the true Apuan Alps Peach Blossom marble, that is still quarried other than at Seravezza. (The Classical Greek *Fior di Pesco*, from Eritrea Greece, is more crushed and striated, and can be seen at Chatsworth).

Rounded petal shapes and anhedral clasts, were repeatedly crushed and stretched, so that the crevices are filled, with secondary calcite. The veined, petal shaped texture, is considered to resemble peach blossom. (Colour tweaked brighter above to enhance clast crevicing).

In the Spanish room, generally grey and red matrixed, Apuan Alps metamorphosed marble pendants are set on Devonian Belgian Black limestone, both sides of *pietra jura* fire surround stone.

Mostly oxidised colours from these otherwise usually white Carrara marble quarries, recently revealed to be those from the historic 300 years' Fabricatti family quarries, are of grey to black graphite and red iron oxide disseminated mineral deposits.

Tuscany Marbles

Google's G M Fabbricotti Trade advert. Scroll down for fotogallery of this stone today.

Two Drawing room Siena Marble console tables of richly goethite egg yolk yellow *Giallo di Siena* have variable white calcareous shell remnant veining. They are of fine-grained Jurassic limestone metamorphosed during the Eocene. Still quarried today.

The three lighter yellow Siena Marble Dining Room doorways, and darker lower entablatures of the Drawing Room, are also of a rare and worked-out yellow Siena Marble but have a purplish or reddish veining in a very brecciated appearance.

This so variably red, mauve and violet veined Siena Marble stone was quarried on Convent of Montarrenti land and so is named Convent Siena Marble or *Broccatello di Siena.*

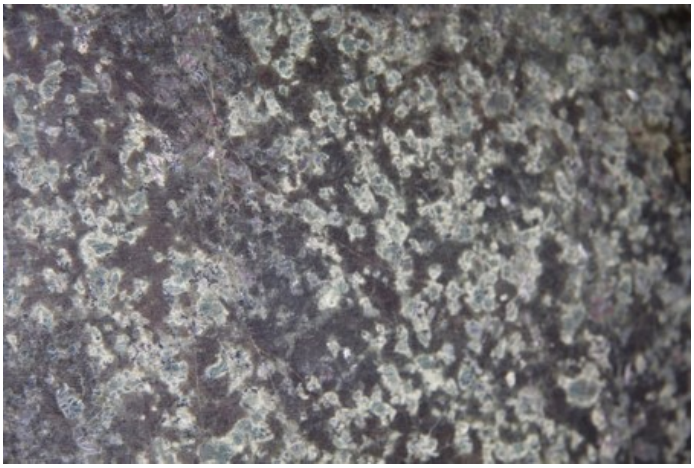
Liguria and Tuscany Serpentinites

William Bankes's C19th masons were limited for Italian serpentinites to those from Levanto and or most likely Polcevera at Genoa, Liguria. Ophiolitic serpentinites and other altered Pyroxenes have been long quarried in Liguria's techno-stratigraphic units and many textures have probably been all worked out. Best known Genoa textures are well brecciated while classic commercial *Rosso Levanto stone* is typically a very heavily white calcite veined Magnetite rich bastite serpentine which causes it to appear a darker green and when hematite rich water, percolates through it, the stone becomes deep red. Traded *Rosso Levanto* is typically a heavily white veined mix of both colours. Tertiary lithification.

The central panels of the two marble stands are also of clearly brecciated Convent/ *Broccatello* Siena but the red and green stones are of serpentinite. William Bankes's C19th masons were limited for Italian serpentinites to those from Levanto and or most likely Polcevera at Genoa, Liguria.

Ophiolitic serpentinites and other altered Pyroxenes have been long quarried in Liguria's technostratigraphic units and many textures have probably been all worked out.

These bronze statuette pediments are a 'serpentinite' but not clastic Verde Antico as is N.T. Guide described. It is a polished version of V*erde di Prat,* a long-used, local high-status decorative dressings building stone used around this town in northern Tuscany. Observable veining here may be of calcite but also of talc or hydromagnesite and commonly risked a veining network weakness to long-term weathering if used as a building stone.



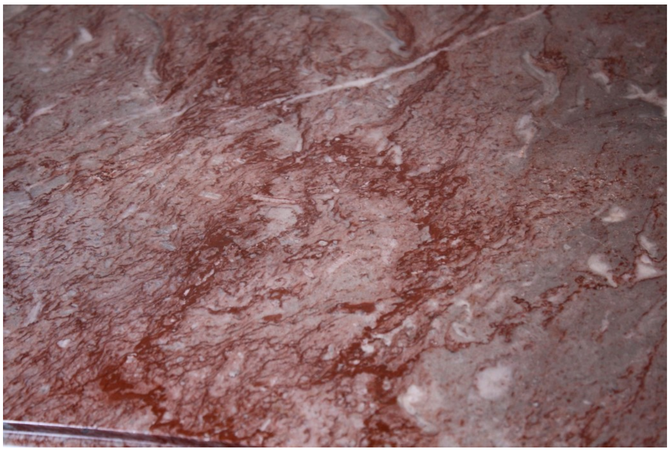
Verde di Prato – as above in this zoomed macro image, illustrates well the Tertiary serpentinised enstatite-rich peridotite (probably Late Jurassic/Cretaceous harzburgite) in which relict enstatite crystals now form the texture of this stone. Fine reticulated veining can just be discerned centre left.

This stone is most probably a Connemara Marble, from the Clifton area of western Galway and much more darkly banded with Serpentine minerals than usual. Connemara serpentinite textures are very variable, and the predominant colouring is often of lighter greens and even yellows. A Precambrian metamorphosed impure limestone was available in time for Bankes's use at Kingston. (First floor landing).

French Haute Pyrenees – and Languedoc

From Italy, we go to the French Pyrenees. Incredibly large sharp-edged Lower Cretaceous tectonic breccias, of the Haute Pyrenees, are known as the Breche Grande Antique. Blocks, of just two cubic feet or so, are set as plinths, to the four Dining Room door frames.

Repeatedly fragmented and slightly metamorphosed red breccia in grey matrixed Haute Pyrenean Sarrancolin but with white calcite infills and veining, is seen in two top passageway tables leading to the attic stairs.



In this example from one table, only light metamorphism is revealed, despite repeated orogenic alteration events, by the remnant fossils' evidence easily seen centred here. This stone is still actively quarried.

Good but small, top landing, examples of the world-famous red Devonian crinoidal limestone *Rouge Languedoc* including stromatactis sponge cavities filled with layered grey and white calcite. (Layering remains open to agreed petrological explanation). Still actively quarried in south-west France. *Peter Bath*

References:

1) Price, Monica, Decorative Stone - The Complete Sourcebook. Thames & Hudson Remaindered New & Used via Amazon. Also USA edition; with title reversed in paperback.
2) Rogers, Patrick: The Beauty of Stone - The Westminster Cathedral Marbles. Only from the Cathedral shop.
3) Sebba, Anne, The Exiled Collector – William Bankes and the Making of an English Country House. John Murray New & Used cloth & paperback.
4) Monica T. Price & Lisa Cooke - The Corsi Collection of Decorative Stones - website: *http://www.oum.ox.ac.uk/corsi/*
5) Kingston Lacy – The National Trust (1994).
6) Caroe, M. B. "Kingston Lacy, Dorset: an architectural case history." ASCHB Transactions 10 (1984).
7) References to William Rayner artificial stone are available via various websites.
8) A Colour Atlas of sedimentary Rocks – Adams et al.
9) A Colour Atlas of Carbonate Sediments and Rocks Under the Microscope – Adams et al.
10) http://dorsetbuildingstone.weebly.com/portland-limestone-ndash-wilts-chilmark.html
11) http://dorsetbuildingstone.weebly.com/portland-stone---dorset.html
12) Rogers, Patrick: The Beauty of Stone - The Westminster Cathedral Marbles. Only from the Cathedral shop.
13) Dorset Building Stone – website: http://dorsetbuildingstone.weebly.com

A New DIGS Site in the Rodwell Cutting, Weymouth

Part 1: The story so far

Rodwell Cutting is on the former Weymouth-Portland railway line between Wyke Tunnel in the north and Buxton Road Bridge in the south. The cutting is some 400m long and up to 10m deep and was excavated, partly by blasting, in 1863-4, providing material to construct the Marsh Embankment north of the tunnel. The railway was closed for passenger and goods traffic in 1965 but continued to be used by the Admiralty until 1970. It is now followed by the Rodwell Trail, a tarmac-surfaced pedestrian and cycle route (NCN Route 26) well-used by the local community and visitors. The cutting is through strata of the Corallian Group on the southern limb of the Weymouth Anticline, extending from the Nothe Clay in the north to the Sandsfoot Clay in the south and including the Osmington Oolite and Clavellata beds. The new DIGS site is in the southern part cutting, located by OS map ref. SY 675781 (Figure 1).

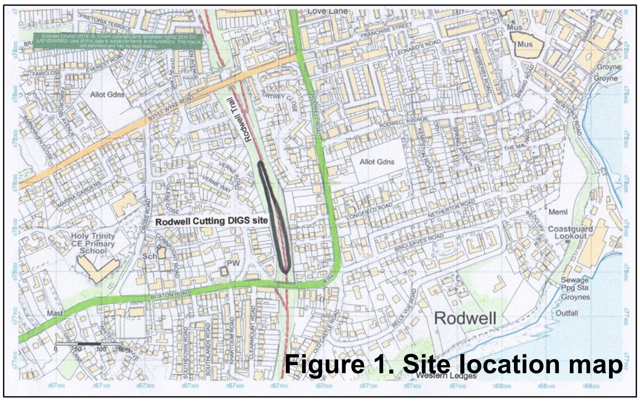


Figure 1. Site location map

Excavation of the cutting severed groundwater flow to springs to the east, including the Rodwell, which means either reedy or red spring. These springs formerly provided a water supply for local residents and a long-established brewing industry but were largely replaced by water piped from Sutton Poyntz in 1856. The catchment area of the springs is a small hilltop area occupied by houses with relatively large gardens and school grounds west of the cutting.

Groundwater now issues as a ‘dripping well’ from limestones overlying clay beds along a 100m section within the DIGS site on the western side of the cutting. On contact with air groundwater rich in calcium and bicarbonate loses carbon dioxide and a hard deposit of calcium carbonate (tufa) forms, petrifying leaves and twigs and obscuring limestone surfaces. Such deposits are uncommon in southern England. A small stream flows northwards in the side ditch for a short distance towards the preserved platforms of the former Rodwell Station, where it sinks into railway ballast overlying sandy strata.

Previous geological studies

Blake and Hudleston described the strata in the cutting in the mid-1870s, when there were few or no trees and probably little ivy. They compared their observations with equivalent strata exposed along the coast between the Nothe and Sandsfoot Castle. The coastal exposures, now partly obscured due to buildings and sea defences, constitute Sandsfoot GCR site and contain the Western Ledges (Figure 1).

The coastal section was also studied by Sedgwick in 1828, Buckland and De la Beche in 1836, and Woodward in 1895 and was considered to be the type locality for the Corallian in south Dorset. Exposures in the cutting were re-appraised by Arkell (1936) and those on the adjacent coast were described by Cope (2016). Cope, applying informal unit names, observed that the surface of the Nodular Rubble unit of the Osmington Oolite was a wave-cut platform with infilled borings overlain in turn by the basal Sandy Block unit of the Clavellata Formation and the Chief Shell Beds unit, represented by two argillaceous oolitic limestones with *Myophorella clavellata* in life position.

Blake & Hudleston (1877) recognised fifteen units in the cutting, and their record is summarised in Table 1 with the substitution of modern fossil and formation names. They placed the boundary between the Osmington Oolite and Clavellata formations between their beds 7 and 8, but Arkell (1936) considered that the boundary should be placed between their beds 2 and 3. Blake & Hudleston had come to the conclusion that “these Corallian beds cannot be trusted to be constant any further than we can see them”, but Arkell broadly disagreed.

Table 1. Strata previously recorded in the Rodwell Cutting

<table>
<tr><th>Age</th><th>Formation</th><th colspan="3">Strata descriptions (after Blake & Hudleston, 1877)</th><th>Thickness (m)</th></tr>
<tr><td rowspan="15">Corallian Group (Oxfordian faunal stage of the Upper Jurassic)</td><td rowspan="2">Clavellata
(Arkell)</td><td>1</td><td colspan="2">Blue CLAY (possibly part of Sandsfoot Clay Member)</td><td>-</td></tr>
<tr><td>2</td><td colspan="2">Hard blue impure LIMESTONE in six courses, with numerous casts of Trigoniae bivalves (e.g. Myophorella clavellata), Pleurotomariae gastropods (e.g. Bathrotomaria reticulata), etc.</td><td>3.66</td></tr>
<tr><td rowspan="4">(Blake & Hudleston)</td><td>3</td><td colspan="2">Rubbly very slightly oolitic LIMESTONE, beds separated by marly partings (0.2m thick)</td><td>2.13</td></tr>
<tr><td>4</td><td colspan="2">Oolitic MARL, very fossiliferous, particularly Myacites bivalves (e.g. Pleuromyra uniformis). Fine grained pisolite?</td><td>1.22</td></tr>
<tr><td>5</td><td colspan="2">Grey rubbly LIMESTONE, scarcely oolitic</td><td>0.46</td></tr>
<tr><td>6</td><td colspan="2">Stiff MARL, very oolitic towards base, hard ferruginous bed in centre</td><td>1.45</td></tr>
<tr><td rowspan="9">Osmington Oolite</td><td>7</td><td colspan="2">Hard ferruginous OOLITE</td><td>1.22</td></tr>
<tr><td>8</td><td colspan="2">MARL with flaggy calcareous grit</td><td>0.91</td></tr>
<tr><td>9</td><td colspan="2">Strong semi-oolitic FLAGSTONE with calcareous markings</td><td>0.30</td></tr>
<tr><td>10</td><td colspan="2">Blue CLAY with oolite grains at the base</td><td>1.12</td></tr>
<tr><td>11</td><td colspan="2">Solid, shelly and oolitic light-coloured LIMESTONE, with the echinoid Echinobrissus scutatus (Nucleolites clunicularis)</td><td>1.12</td></tr>
<tr><td>12</td><td colspan="2">Light-coloured MARL, becoming oolitic below</td><td>0.61</td></tr>
<tr><td>13</td><td colspan="2">Rough shaly OOLITE in two blocks</td><td>1.22</td></tr>
<tr><td>14</td><td>MARLS</td><td rowspan="2">(possibly part of Bencliff Grit Mbr)</td><td>1.83</td></tr>
<tr><td>15</td><td>Fine grained calcareous GRIT</td><td>0.61</td></tr>
</table>

Revealing the strata and registering the site

Until recently, the strata were largely obscured by vegetation, principally ivy beneath a sycamore canopy. Preliminary clearance of ivy at ground level was carried out for the 'Dripping Well Project' on behalf of the Friends of the Rodwell Trail and Sandsfoot Castle (FoRT) with permission from the former landowner, Weymouth and Portland Borough Council (WPBC). The long-term plan was to improve geological interest, drainage and biodiversity in the cutting. During the course of this initial work it became apparent that significant exposures remained.

A DIGS field party surveyed the site in May 2018 and the group subsequently agreed to seek registration of part of the cutting as a Local Geological Site. Relevant forms were compiled in accordance with GeoConservation UK guidelines. A site management plan was drawn up and the site was accepted by WPBC in January 2019, prior to the transfer of land ownership to the new Dorset Council on 1 April 2019. DIGS volunteers cleared further vegetation and carried out ditch clearance between February and April 2019 (Photos 1 and 2). Most recently, on 14 November 2019, further vegetation was removed from around the Clavellata bed (Photo 3), ivy strands were pulled up above the main dripping well exposure and some signage was replaced.

Photo 1. Southern end of main exposure on 16 March 2018. Rubbly argillaceous limestone overlying clay or marl (possibly units 3-7 of Blake and Hudleston). Blake & Hudleston placed these strata at the base of the Clavellata beds, whilst Arkell considered them to be the uppermost beds of the Osmington Oolite (see Table 1).

Photo 2. Discovery of the Clavellata bed on 25 February 2019. A thin layer packed with *Myophorella clavellata* bivalve shells extending to the left of the DIGS volunteer's hand. This exposure is in the upper part of the cutting above the water table and therefore is not obscured by tufa.
Photo: A.Holiday

Photo 3. Close up of the Clavellata bed shown in Photo 2. Taken on 14 November 2019 after further clearance work. The *Myophorella clavellata* fossil at the far left retains both valves, indicating that it has undergone very little or no transport from its original growth position.

Importance of the site

This is the only DIGS site in the Corallian on the southern limb of the Weymouth anticline. The strata span an important boundary between the Osmington Oolite and Clavellata formations and can be compared with those of similar age along the coast at Portland Harbour, the Fleet and in the Osmington area. The site is a valuable educational resource for students from primary school age up to university level. It is easily accessible along the Rodwell Trail, and the lower exposures and dripping well are highly visible.

The petrifying springs continue to flow, albeit at a much reduced rate, during prolonged dry periods such as May-July 2018. They demonstrate geology (or hydro-geomorphology) in action and this was further emphasised during the 'beast from the east' event, when ice formed over the tufa (Photo 4). The springs also support masses of liverwort on the rock face and watercress in the pool below.

It is unlikely that they would qualify as 'Petrifying springs with tufa formation (*Cratoneurion)*' in terms of the EC Habitats Directive as they were formed relatively recently and therefore do not support a range of distinctive bryophytes. Further advice will be sought from Natural England at a later date, however.

Photo 4. Northern end of the main exposure on 1 March 2018 during the 'beast from the east' event. Icicles have formed where a spring issues from flaggy oolitic limestones underlain by grey clay within the Osmington Oolite Formation (possibly units 8-10 of Blake and Hudleston). Local lads walking home from school had fun smashing the largest icicles and were surprised when they regrew overnight!

Future site management

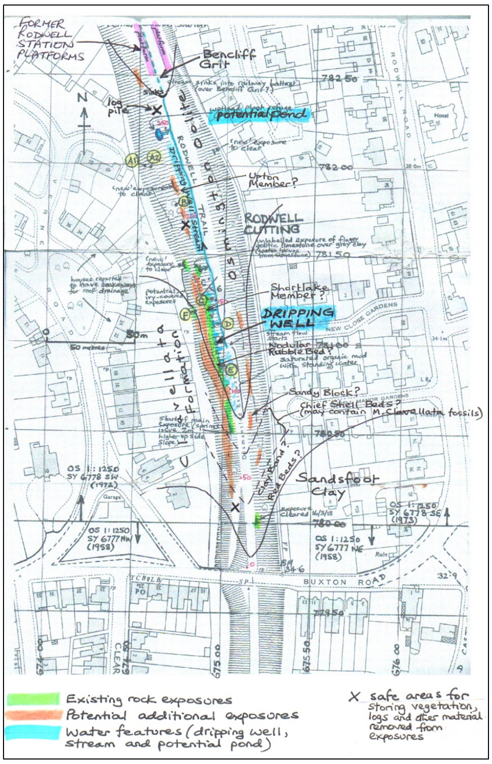
Existing and potential rock exposures and water features are located on Figure 2, which forms part of the site management plan. The letters in circles refer to the locations of rock specimens collected during the initial investigation of the site, prior to its adoption by DIGS. Locations D and E are shown in Photo 1 and Location C is shown in Photo 4. The rock exposure in Photo 2 is adjacent to location F. Future goals include connecting exposures and keeping them clear of excessive vegetation, without compromising slope stability, extending the stratigraphic range of the exposures, in particular the boundary between the Osmington Oolite and Clavellata Formations, and constructing a more accurate geological map and associated cross-sections. Faulting might help to explain the presence of the dripping well, but the exposed strata do not appear to have been displaced in this way. The published Geological Map indicates an inclined subsurface fault beneath the Western Ledges that does not extend up into the Corallian, but this fault is not identified on Cope's seismic profile across this area.

Photo 5. Clearing the stream course below the dripping well on 29 April 2019. Working space is restricted along the trail! Tufa supporting masses of liverwort obscures the rock face. Liverworts are primitive plants whose ancestors arose some 400 million years ago. Watercress is now flourishing in the embryonic water feature below the springs.

It will also be necessary to keep the stream course clear of debris using hand-held tools such as draw hoes (Photo 5). Stream flow will be monitored and compared with readings from a local rain gauge. We also hope to create a small seepage-fed pond in a silt-filled depression. A few laurels and large unstable sycamores will be removed, and this would have a secondary aim of increasing native plant diversity. On-site re-use of materials will include construction of access paths and placing branches to create working platforms and log piles for the benefit of wildlife. Soil removed will be incorporated into the log piles (see Figure 2). Care will be taken to preserve areas for wildlife, and trees and dense vegetation will not be removed or disturbed during the bird breeding season (March-August). These tasks will be carried out in partnership with FoRT and Dorset Council. In due course an information board will be created and installed, with the aim of increasing public perception of the ways in which different components of the local earth system interact. The story of this site will continue to unfold.

Geoff Pettifer

Figure 2. Important rock exposures and water features of the DIGS site



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3) Proceedings of the Dorset Natural History and Archaeological Society, 57, 59-93. British Geological Survey. 2000. 1:50,000 scale geological map of West Fleet and Weymouth (Sheet 341 and part of 342).
4) Wright J.K. & Cox B.M. 2001. British Upper Jurassic Stratigraphy (Oxfordian to Kimmeridgian). Geological Conservation Review, Vol.21, Ch.2 (Sandsfoot. ID 828). JNCC, Peterborough.
5) British Geological Survey. 2011. Geology of south Dorset and south-east Devon and its World Heritage Coast. Special Memoir. NERC.
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THE HOT ROCK SLOT

PERIDOTITES

Although they are relatively uncommon in the Earth's crust, peridotites are the most abundant silicate rocks, volumetrically speaking, of which we have direct evidence, comprising as they do the bulk of the upper mantle. They are of fundamental importance to geological processes in and on the crust through (i) their melting behaviour (as they are the principal source of basaltic magmas and of a variety of rarer magma types), and (ii) their physical properties, notably density and viscosity; the latter control the buoyancy of mantle plumes and the thickness, stiffness and buoyancy of the lithosphere, and hence many of the features of plate tectonics including the topography of the Earth's surface.

Definition and classification:
Peridotites are defined as rocks consisting mainly of olivine ($(Mg,Fe)_2SiO_4$) +/- pyroxene(s). The word 'peridotite' comes from the french word 'peridot', a term for gem-quality Mg-rich olivine (forsterite). Peridotites are ultramafic, which means that their ferromagnesian minerals make up at least 90% by volume. Minerals that may be present in minor amounts include plagioclase feldspar, spinel, garnet, hornblende, phlogopite, chlorite and serpentine. Peridotites are classified on the basis of the proportions of the principal ferromagnesian minerals:

Dunite: Olivine (e.g. Figs. 1 and 2)
Harzburgite: Olivine + Orthopyroxene
Wehrlite: Olivine + Clinopyroxene
Lherzolite: Olivine + Orthopyroxene + Clinopyroxene.

Both igneous and metamorphic olivine-rich ultramafic rocks can be referred to as 'peridotite' and the distinction between the two is not always easy. Nor is it particularly useful, as most peridotites have undergone some solid-state modification either in the form of deformation or fluid-driven conversion of some or all of the olivine to the low-temperature hydrated mineral serpentine (approx. $Mg_3Si_2O_5(OH)_4$).

Fig. 1. Hand specimen of a dunite nodule from Lanzarote. Note the pale olive-green colour of the fresh, unweathered, gem-quality olivine. Specimen is 10 cm long.

Photo: G. Droop

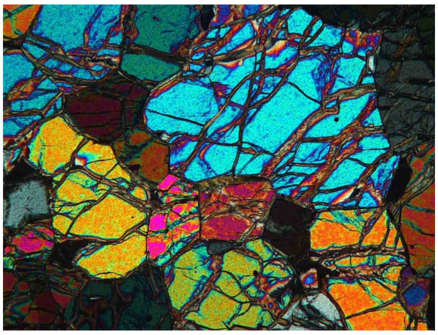

Fig. 2 Photomicrograph of dunite from an unknown locality, showing the bright interference colours and high relief typical of olivine. Crossed polars. Long axis of field of view = 5 mm. Photo: G. Droop

Fig. 3 Large-scale cumulus layering in the Rhum intrusion, NW Scotland. The mountain is Hallival. The 'benches' are of olivine gabbro and the more deeply eroded layers are of peridotite.
Photo: W.J. Wadsworth

The identities of any minor minerals present can provide useful information on the conditions under which the peridotite crystallised/equilibrated. This is particularly true of the aluminous minerals plagioclase, spinel and garnet. Experimental studies have shown that garnet-bearing peridotites are stable at greater pressures (hence depths below the Earth's surface) than spinel-peridotites, which in turn are stable at greater pressures than plagioclase-peridotites. At depths greater than *ca*. 440 km, olivine itself becomes unstable, transforming to ringwoodite, a denser mineral with a similar chemical composition and a spinel-type crystal structure. Compared to most other types of silicate rock, peridotites have bulk chemical compositions characterised by high MgO (30-40 weight %), low SiO_2 (38-45 wt.%), and low CaO, Na_2O, K_2O and Al_2O_3. Peridotites also tend to contain higher amounts of the trace elements chromium and nickel than other rock types, locally forming economic mineral deposits.

Igneous origins of peridotite:

In theory, there are three igneous processes by which peridotites can originate: (i) direct crystallisation of peridotite magmas; (ii) formation of cumulates during the fractional crystallisation of large intrusions of basaltic magma; (iii) formation of refractory residues during the partial melting of 'fertile' peridotite source rocks.

There is little evidence for the first of these processes as very few crustal peridotite bodies appear to have crystallised directly from peridotite magma, and no lavas of peridotitic composition are being erupted at the present day. The clearest examples of peridotitic magmas are komatiitic lavas (see *Hot Rock Slot*, Winter 2018), but these were restricted almost entirely to the Archaean when the Earth's interior was much hotter than today.

Fig. 4 Cumulus layering in the Ben Buie intrusion, Mull, W Scotland. The top layer is plagioclase peridotite and the lower layer is olivine gabbro.
Photo: G. Droop

On the other hand, there is a wealth of excellent field and petrographic evidence for the formation of peridotites as cumulates in the lower parts of large basic intrusions such as Rum and Mull in W Scotland (Figs. 3 and 4). Settling of early-formed olivine crystals from magma produces layered rocks in which large, well-formed 'cumulus' olivines are packed together and separated by small, cuspate patches of interstitial late-crystallising minerals (Fig. 5).

There is also good experimental and geochemical evidence supporting the formation of peridotites during partial melting: modest degrees of partial melting of …..

….lherzolite (‘fertile’ peridotite) at *ca*. 1300-1400ºC yields basaltic magma (~10-20%) plus a refractory residue of harzburgite (‘depleted’ peridotite) (80-90%); this process thought to be important at mid-ocean ridges and in plume heads, with the depleted harzburgites adding to the lithospheric upper mantle.

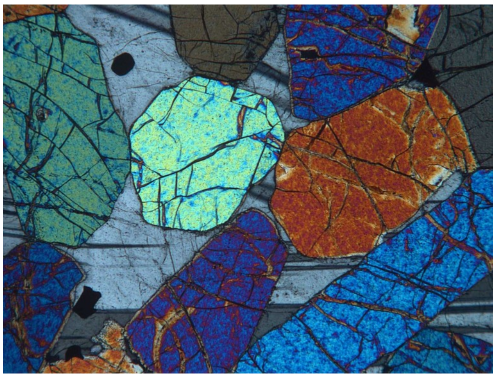

Fig.5 Photomicrograph of an olivine-rich cumulate from Rhum. Note the close-packed, ‘cumulus’ olivine crystals (mostly bright interference colours) and minor interstitial plagioclase (greys, with lamellar twinning). Crossed polars. Long axis of field of view = 2 mm. Photo: G. Droop.

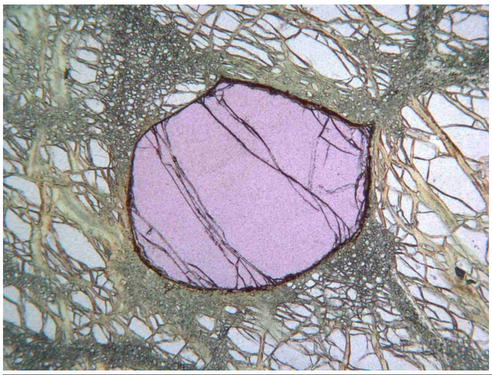

Fig.6 Photomicrograph of a garnet peridotite nodule from the Bultfontein diamond pipe, S. Africa, showing a pyrope garnet crystal (centre) surrounded by partially serpentinised olivine. Plane-polarised light. Long axis of field of view = 5 mm. Photo: G. Droop.

Fig.7 An exposed surface of garnet lherzolite at Almklovdalen, W Norway. Crimson garnet and bottle-green clinopyroxene (Cr-diopside) are set in a rusty-weathering matrix of olivine and minor orthopyroxene. Photo: G. Droop

Other ways in which peridotite bodies can form:

There are two further processes by which crustal peridotite bodies can form, both amply supported by field evidence. The first of these is the transport of nodules of ~unmodified mantle rock during eruption of deep-seated mantle-derived magma (e.g. Fig. 1). Nodules sampled from diamond-bearing kimberlite pipes are extremely important as they provide the only direct evidence we have of the composition of the upper mantle at depths greater than 100 km. The majority of peridotites from kimberlite pipes are garnet lherzolites (Fig. 6) implying that this is the dominant type of peridotite at those depths.

Lastly, an important non-igneous process by which crustal peridotite bodies can originate is the tectonic emplacement of fault-bounded slices of upper-mantle rock during plate convergence. A good example of this is the obduction of huge slices of oceanic lithosphere as ophiolites (e.g. the Troodos ophiolite in Cyprus and the Semail ophiolite in Oman), the lower parts of which typically consist of variably serpentinised dunites and harzburgites. Tectonically emplaced non-ophiolitic peridotites (‘Alpine’-type peridotites) are also found in the most deeply exhumed parts of mountain belts; good examples include the Almklovdalen Peridotite (which preserves garnet lherzolites, Fig. 7) in the Norwegian Caledonides, the Lherz Peridotite (the type locality of lherzolite) in the French Pyrenees, and the Ronda Peridotite of S Spain.

Peridotites in the UK:

Within the UK, large masses of extensively serpentinised peridotites crop out in the Lizard, Ballantrae and Shetland ophiolite complexes (e.g. Fig. 8). Cumulus peridotites occur within the layered basic intrusions of the Tertiary Volcanic District of NW Scotland (Skye, Mull, Rum) and the Caledonian ‘Newer Gabbro’ intrusions of NE Scotland (Insch, Huntly, Belhelvie). Mantle-derived peridotite nodules (mainly serpentinised spinel lherzolites) have been reported from alkali basalt vents and dykes of Carboniferous age …..

Fig.8 Exposure of serpentinised layered harzburgites in the Shetland Ophiolite at Hagdale, Unst. Photo: G. Droop

...in the Midland Valley of Scotland. Small bodies of ultramafic rock, including spinel peridotite, form a minor component of the Lewisian Gneiss Complex in NW Scotland. I can supply precise locations for anyone wishing to see examples of these British peridotites for themselves and I can also supply a few locations in W. Norway and the Alps.

Giles Droop

Geomagnetism and the South Atlantic Anomaly

We all know that the Earth has a magnetic field, but:

- Why does it have one?
- Is it something we can rely on?
- Why does it not line up perfectly with the spin axis of the Earth?
- Has the Earth always had a magnetic field?
- Is it important to life on Earth and our current use of technology?

To start let's look to the rocky planets and our moon. Mars and the Moon both have an iron core but do not have a measurable magnetic field - there are magnetized areas on their surfaces, though, and these might have resulted from a time when they had a magnetic field. Mercury has a small magnetic field, but it is Venus that gives a real clue as to why the magnetic field on Earth exists. It seems most likely that Venus has an iron rich core (probably very like the Earth's because it is just a little smaller and has a similar density of 5.2 vs 5.5 g cm^{-3}). The important difference is that Venus, with no measurable magnetic field, hardly spins on its axis (there are only 1.92 Venus days in a Venus year). The higher rate of spin of the Earth is important, as we will see later.

The outer planets have magnetic fields - Jupiter's dipole field is about 20000 times stronger than that of the Earth - and the dipoles of Saturn, Neptune and Uranus are all stronger too. It is thought that they generate their fields from a similar dynamo effect (that we will come on to), but that the electrical currents associated with the dynamo, and which produce the magnetic field, flow in highly compressed elements or chemical compounds - for example on Jupiter when the hydrogen at depth is hot (>10000K) and at 200 Gpa (2000000 bars) it undergoes a phase transition and becomes metallic and electrically conductive.

The early descriptions of the magnetic field (that of Gilbert in 1600 "*On the Magnet and Magnetic Bodies, and on the Great Magnet the Earth"*) provided a useful description but did not explain the mechanism. It was following the observation of Hans Christian Oersted in 1819 (of a compass needle deflection when an electrical circuit was switched) that real progress was made in understanding the connection between electrical currents and magnetism by, for example, André-Marie Ampère, Carl Friedrich Gauss, Jean-Baptiste Biot, Félix Savart, Michael Faraday and James Clerk Maxwell. It was during this period that the understanding of how a dynamo works was developed. It works because a small residual magnetic field in a machine that could be moved, or better rotated, could produce a current that generates a larger magnetic field and then could be used to produce electrical power for external circuits (this is known as "self-excitation" and the pre- alternator electrical generators in cars used this and were correctly called dynamos, but the bicycle "bottle dynamo" that is turned by contact with the tyre was not - it is a "magneto" because the magnetic field is produced by a permanent magnet and also it is an alternator not a dynamo). Compared to the strengths of magnetic fields used in electric motors, the Earth's magnetic field is very small (~50nT vs 1T), yet this small field is very important in protecting the Earth from energetic charged particles - see the video which has a link at the end of this article.

There is evidence from very old zircon crystals that the Earth had a strong magnetic field 4.2 billion years ago and used a dynamo effect to create it with a different mechanism (possibly using the precipitation of magnesium oxide within the Earth) from that giving us the present magnetic field, This early magnetic field would have provided a strong shielding effect from charged particles from the sun and space. The early magnetic field almost collapsed about 565 million years ago before becoming stronger as the solid inner core started to form and the present mechanism developed - see https://phys.org/news/2020-01-evidence-strong-early-magnetic-field.html

Further insights and discoveries were needed beyond the basic electromagnetic theory to understand why there is a magnetic field for the Earth. The first of these was in 1919 when Joseph Larmor proposed that a dynamo mechanism could be used to describe the formation of sunspots. This was followed in 1926 by Sir Harold Jefferies' demonstration, from seismic results, that the Earth had a liquid core and in 1934 Inge Lehmann (a Danish seismologist and geophysicist) demonstrated that there was a solid core within the liquid core. A further insight was provided (Sir Geoffrey Ingham Taylor 1922) by understanding the way in which fluids circulate when subjected to the Coriolis effect (which results from the rotation of the Earth); these are known as Taylor Columns.

The present understanding and mathematical model of the dynamo theory stems from the work and ideas of Walter Elsasser from 1941 who proposed that the magnetic field resulted from electric currents induced in the fluid outer core of the Earth.

So how does it work?

Firstly there is movement by convection in the outer liquid core and this is caused by a difference in the temperature between the solid core and the mantle. There might also be other factors contributing to this flow (the outer core has a slightly different chemical composition to the inner core and energy is also provided by gravitational contraction).

Next the convective flow of conductive material moves through the magnetic field which exists in that region of the Earth. The flows are deflected by the Coriolis force in the case of Earth and rotating planets. In the case of Venus, the Coriolis force is effectively absent because of its very slow rotation and this is the reason for the lack of a detectable magnetic field.

It is the Coriolis force that tends to direct the magnetic orientation to be roughly along the spin axis of the Earth by the mechanism of Taylor Columns and this can be in the direction it is today or reversed as it was 750000 years ago.

The mathematical solution of the equations is not simple and, like some of the models used for weather forecasting, any solution requires very lengthy runs on supercomputers. These computations have been made using the best estimates of the properties of the fluid outer core and they are in line with observations and have also demonstrated how a field reversal comes about.

It seems, from the evidence that the magnetic poles move quite rapidly, that the Coriolis effect and the Taylor Columns are not sufficiently strong to overcome the random effects on flows that occur during convection and this complicates their interaction with the magnetic field. Because of the chaotic condition, magnetic fields can occur in directions different from the spin axis. This breakdown in direction can occur in localised areas and can proceed to a highly complex situation before a new stable pattern arises. This might well then be recorded in the magnetic signatures in the rocks as a field reversal. The South Atlantic Anomaly is in one of these areas where the changes in the field are such that the local field opposes the more general field and reduces the radiation shielding there.

It is not the only anomaly and how these anomalous areas are being investigated is shown in the excellent 15 minute video at: https://www.youtube.com/watch?v=QiheGigtnws&list=LLmUwLUQW5mrYagq4v6lI3tQ&index=2&t=29s The video also gives information as to why the Earth's magnetic field is important to life on the surface of the planet and to the reliability of the technology that we have become dependent upon. *Leon Sparrow*

Report on the December Workshop and the AGM

Good discussions…..

Thirty or so members attended the December Workshop at Broadmayne. There was a good selection of members' displays and sales were healthy too. Thanks to Michael King and Mike Le Bas for generous donations from their libraries. It is always a good social occasion and, as usual, the buffet lunch went down well.

…..and sales!

The AGM drew similar numbers and proceeded smoothly. Alan Holiday gave a talk on 'Coastal Defence in Weymouth Bay' to conclude proceedings. I haven't included the minutes in this mailing, partly to conserve paper but also space, it's turned out to be a very full issue! Please let me know if you would like a copy of the minutes before I send them out ahead of next year's AGM. My thanks to all who contributed to both events, in whatever way. *Kelvin Huff*

Dorset Building Stones Group

This informal group has been running for about 3 years now, compiling a considerable body of work on its website. Members might like to visit the site and select a few churches and buildings to visit on a fine day! The Building Stone ID Flowchart included with this issue has been compiled by Geoff Townson using the Dorset Building Stone website:
https://dorsetbuildingstone.weebly.com
It is based on the contributions by (A-Z): Sheila Alderman, Pete Bath, Alan Holiday, Kelvin Huff, Geoff Rowland, Pat Snelgrove, Jo Thomas & Geoff Townson.
Currently, the group have a big project underway with Wimborne Minster, currently being studied by Pete Bath, Pat Snelgrove, Geoff Townson and Jo Thomas. This will be published on the website in due course. Pete's Kington Lacy series, serialised in this Newsletter, may eventually appear in booklet form, in association with the National Trust. Watch this space! The DBS group would welcome the participation of any member in its activities. If you are interested, please let me know. *Kelvin Huff*

Book review: Fossil Collecting on the South Dorset Coast by Steve Snowball and Craig Chivers. Pub: Siri Scientific Press, 2020. Price: £18-99.

The first thing to say is that the book is beautifully illustrated with over 300 colour photographs, diagrams and paleo-art. It follows the previous guide on west Dorset and has a similar format. Emphasising responsible collecting, it is much more than a fossil collecting guide, even though the geology will be familiar to many. Sections on general geology, stratigraphy and landscape are followed by excursion guides from the Fleet in the west to Ringstead Bay in the east. Basic access information is given, although I would have liked to have seen some location maps, grid-references plus more logistical information such as parking and toilets. It's probably too 'nice' to use in the field but used with the G.A. Guide written by John Cope, it's great preparation for a trip and an accessible read. *Kelvin Huff*

DGAG Field Trips and allied events 2020

Please note that some events may have to be postponed owing to Coronavirus restrictions.

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

Wednesday April 8th: DGAG Lecture: 'Carbonate concretions in the Dorset Jurassic'. **POSTPONED**

Saturday April 25th: Fieldtrip to Portishead. **POSTPONED**

1st-3rd May: Lyme Regis Fossil Festival

May 9 - May 17 : GeoWeek 2020 **See** https://www.bgs.ac.uk/geoweek/ for details.

Wednesday 20th May: Fieldtrip to Vale of Wardour. **POSTPONED**

Saturday June 6th: Fieldtrip to Dartmoor, including Hay Tor. Leader: Alan Holiday

Saturday June 20th: Undercliff Walk. Leader: Geoff Rowland

August (tbc) : Fieldtrip to Bincombe and Sutton Poyntz. Leaders: Alan Holiday and Kelvin Huff

Saturday 5th September: Hampshire Fossil and Mineral Fair, Lyndhurst.

Friday 11th– Monday 14th September: Black Country Residential Fieldtrip

Saturday 24th October: Holiday Rocks, Broadmayne.

Saturday 28th November: DGAG Annual Dinner, Weymouth

Saturday 12th December: Winter Workshop, Broadmayne.

Website: https://dorsetgeologistsassociation.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

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

March 29th (Sunday) Sidmouth and Budleigh Salterton. **POSTPONED**

June 14th (Sunday) Chichester Harbour. Leader: David Bone.

July 5th (Sunday) Studland. Leader: Kelvin Huff.

August 23rd (Sunday) Geology and Archaeology in the Landscape, Wiltshire. Leader: Dick Millard

September 6th (Sunday) Horn Park and area. Leader: Bob Chandler

Reminders: Contributors' deadline for the Summer Newsletter is: **Monday, June 22nd 2020.**

Committee news:

We **still** need an Events Officer!

Kelvin

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