Reading Geological Society

Dorset Field Meeting Report

Thursday 16th May to Sunday 19th May 2024

Leader Ross Garden
(Reading Geological Society)

RGS visit to Dorset, 16th – 19th May 2024

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Thursday 16th May, 2024 Durlston Point, Tilly Whim and Swanage Bay

By Ailsa Davies

Introduction

We met late morning at Durlston Country Park, Swanage where Ross started the field trip by outlining the four days ahead looking at the geology of the eastern end of the Jurassic Coast. He followed this with an overview of the geology in the Swanage Bay area. Three sites were planned for the rest of the day; Durlston Head; the Tilly Whim Quarry and Swanage Bay.

Durlston Head

GR -SZ 03551 77270; 50°35′43″N , 001°57′04″W; W3W - celebrate.user.lamenting

Walking eastwards from the car park to Durlston Head we initially looked north to observe the topography and main stratigraphic units. The view was across Durlston, Swanage and Poole bays where we could see the rocks younging northwards from Upper Jurassic to Tertiary (Figure 1).

To the south of Durlston Head the Portland Group out crops; Durlston Bay itself comprises the Purbeck Group. Beyond Peveril Point in Swanage Bay we are into the Wealden Group which is about 716 m thick here; the thickest Wealden succession recorded in the UK. The succession here comprises two units; the Wessex and the Vectis formations. The Wealden progressively thins to the west.

Beyond Swanage Bay to the north is the chalk ridge of Ballard Down which is formed by a north facing monocline as seen later in the week at Lulworth Cove. This ridge is referred to as the Purbeck Disturbance and it extends westwards from Lulworth Cove to Swanage and eastwards to the Needles and the Isle of Wight and, which couldn't be seen on this misty morning. Further north, into Poole Bay, the succession is Cenozoic.

The Purbeck Disturbance is formed above faulted and eroded Jurassic sequences as was seen later in the trip. The main structure is referred to as the Purbeck fault zone and near Ballard Down the faults downthrow to the south. South of the fault zone the rocks a more complete succession out crops while to the north there is a major discontinuity between the Gault and Upper Greensand of the Cretaceous and the Oxford Clay of the Jurassic indicating that the northern area had been uplifted and eroded during the Upper Jurassic-Lower Cretaceous. This area was referred to as the South Dorset High. Cenozoic compression inverted the basin and and younger deposits such as the chalk were eroded south of the Disturbance.

Figure 1 View north from Durlston Head across Durlston Bay (Purbeck Group) and Swanage Bay (Wealden Group) to the chalk cliffs at Ballard Down.

Retracing our steps and heading further west to Tilly Whim Quarry we were followed by a pod of dolphins which caused much excitement!

Tilly Whim Quarry
GR - SZ 03036 76943; 50°35′32″N , 001°57′30″W; W3W - intricate.stale.pebble

Here we saw exposures of the Portland Stone Formation, which comprises two members:

- Portland Freestone Member
- Portland Cherty Member

It was the Portland Freestone that was quarried here although there are not as many quarries as on the Isle of Portland. The quarried stone was rowed out to sailing boats before being taken to the stone yards on Swanage Quay.

At the old tourist cave entrance we saw the Portland Freestone; a bioclastic limestone with little mud indicating a high energy environment. The shell fragments are grain supported with spary calcite cement; this and the lack of mud classify this as a grainstone. Vugs were evident in the limestone and we discussed their origin. Shells made of aragonite dissolve more readily than those of calcite creating vugs in the Freestone.

Further along the coast path, at the quarry, we saw the Portland Cherty Member which underlies the Portland Freestone (Figure 2). In addition to chert, this member has fewer identifiable shells and is finer grained than the Freestone. There was irregular bedding and a fair amount of bioturbation. Numerous burrows were seen. A few spicules were found by eagle eyed members although all could see the large ammonites, some on the level below (Figure 3).

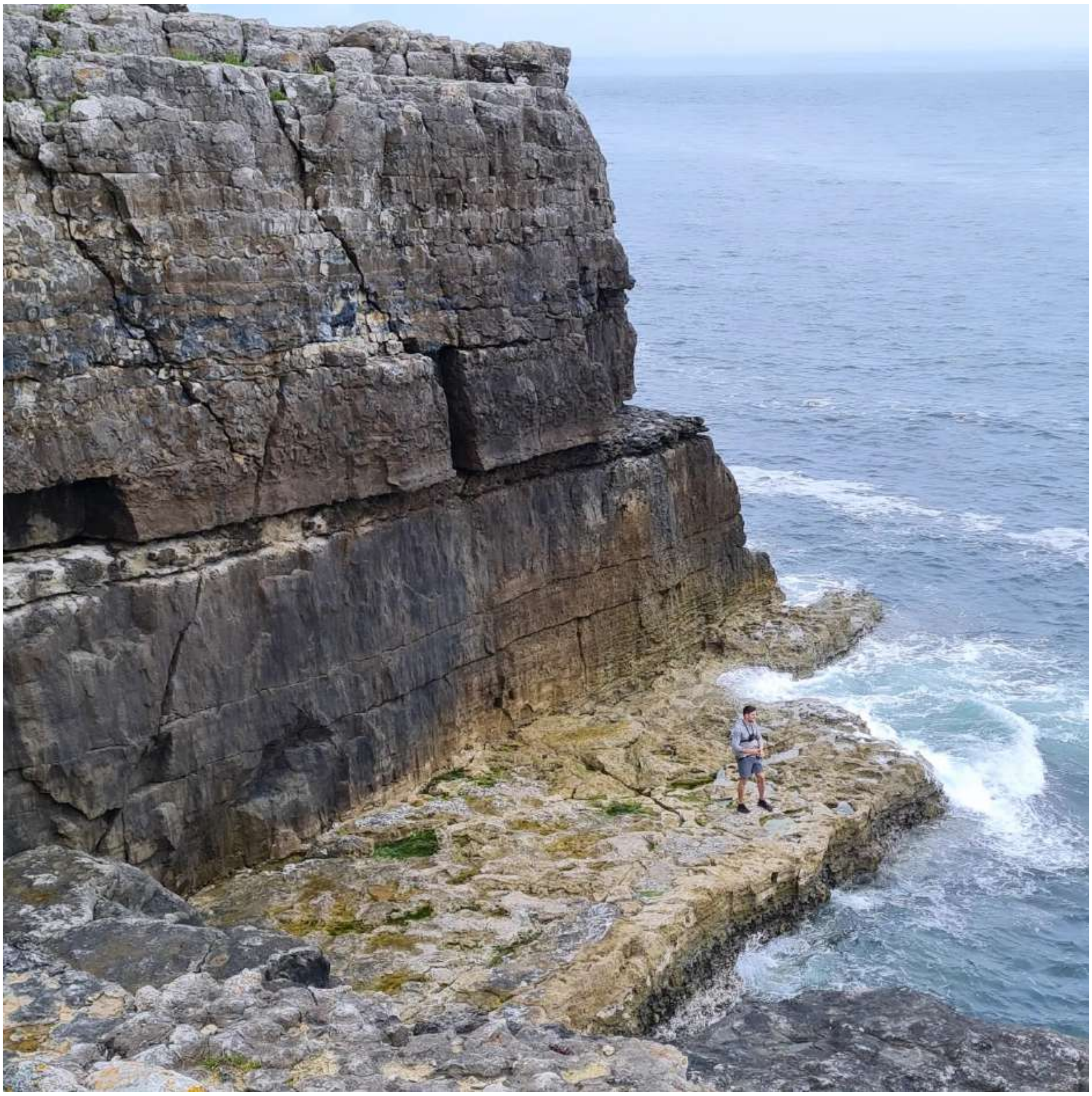

Figure 2 The Cherty Member of the Portland Limestone exposed in quarried terraces at Tilly Whim Quarry.

Figure 3 Large ammonite on a bedding surface at Tilly Whim Quarry (ammonite 30-40 cm in diameter). Note the fine Thalassinoides burrows in the limestone

After lunch we moved on to Swanage Bay.

Swanage Bay

GR - SZ 03470 80464; 50°37′26″N , 001°57′08″W; W3W - skimmers.crafted.juggles

In Swanage Bay (Figure 4) we looked at Wealden deposits. The Wealden Group dips 10-12° to the north. The area between the Wealden and the Chalk is largely obscured by mudslides, which mask the Vectus Formation, a thin Lower Greensand succession, the Gault and the Upper Greensand.

Figure 4 *View at the northern end of Swanage Bay towards Ballard Down and the steeply northward dipping Chalk.*

Figure 5 *View to the SW down Swanage Bay towards Swanage showing the sands and mudstones of the Wealden Group.*

The Wealden succession at Swanage Bay comprises two formations:

- The lower unit, the Wessex Formation is partially obscured behind the sea walls at Swanage. The exposure to the north of the sea walls comprises interbedded sands and mudstones (Figure 5). The sands are fine to medium grained, with scour marks and cross-stratification. Some sands have parallel bedding and ripples. Locally pyritised, carbonised wood can be found. The mudstones have a variety of colours; red, purple, ochre and brown.
- The Vectis Formation out crops on the northern end of the bay

We started by walking northeastwards coming to a mud slip. To ensure we saw the section before the tide came in fully, we walked to the end of the exposed Wealden and then walked back down the stratigraphy.

The section comprises packages of medium to coarse grained, cross-stratified sandstones, units of finer grained, parallel bedded sandstones and thick intervals of mottled and variegated mudstones.

The medium to coarse grained, cross-stratified sands were 3-5 m thick with black carbonaceous layers. Linguloid ripples, tongue or randomly shaped, were found in a mud deposit slumped into a channel.

Carbonised wood material was common and included tree trunks 1-3 m in length and 10-20 cm in diameter. Some of the carbonised wood had bright yellow coloured jarrowsite precipitate. Jarrowsite is a hydrated sulphate deposit formed from oxidation of pyrite in the wood found at the site. Along with the wood, ferric iron concretions were found; tightly cementing the sandstones locally.

Bright yellow sands with banding was subject to great inspection (Figure 6). These were liesegang rings produced by the migration of meteoric water through the sands remobilising and then re-precipitating iron oxides.

Figure 6 Liesegang rings in a fluvial sandstone.

These coarser grained sandstone packages were interpreted as multistorey fluvial channel deposits.

The finer sands were commonly parallel bedded with mud flakes. Bioturbation was found in a sequence of mudstone / silt / fine sands. These were interbedded with sandstones with ripples. At the path down to the beach was a slumped section of interbedded sands and silts with common bioturbation (Figure 7).

Figure 7 Interbedded sands and silts deposited as deltaic units in lagoons and ponds.

The parallel laminated sands interbedded with mudstones were suggested to be deltaic units deposited in lakes and lagoons on a floodplain.

We also came across multi-coloured, predominately green and purple clays between the sand packages. These showed indistinct vertical structures picked out by brown mottling. Possible examples of slickensided fractures were seen in the mudstones. There were also some pale nodules in the mudstones which were probably calcretes. Mottled grey / brown mudstones were also interbedded with the fluvial sandstones and were possibly embryonic soils.

The variegated mudstones were interpreted as vertisols and gley soils demonstrating the transition between permanently saturated environment (gley) to periodically saturated (vertisols) soil environments. Smectite is formed in tropical environment from highly weathered rocks. This is a clay which swells and shrinks when experiencing wetting and drying episodes results in the shrinkage cracks in the soil and is an indicator of a vertisol.

After some discussion the conclusion was that the combination of channel and deltaic sands interbedded with thick paleosol indicated a fluvial floodplain with ponds and lagoons and fluvial channels. The wood indicates wild fires in the hinterland bringing down carbonised wood.

Friday 17th May AM, 2024 – Ringstead Bay to Osmington Mills

By David Ward. Photos from Ross Garden

Ringstead Bay to Osmington Mills

Ringstead Bay - GR - SY 74568 81376; 50°37′53″N , 002°21′39″W; W3W - curving.scoping.taken
Osmington Mills - GR - SY 73566 81651; 50°38′02″N , 002°22′30″W; W3W - dragonfly.mountains.skipped

We parked at Ringstead by the café, in bright conditions. The group walked to the coast, then turned W, onto initially a shingle beach with rock ledges for 300 m, then continuous boulder beds to trip the unwary.

Ross explained that we would walk to Osmington, progressing down the sequence, which starts in the basal Kimmeridge Clay and progresses down through the entire Corallian Group which comprises 4 formations; Redcliff, Osmington Oolite, Clavellata and Sandsfoot.

The section started in slumped clays of the basal Kimmeridge Clay with large, articulated oyster shells of *Ostria delta*. Relative to the underlying Corallian, the Kimmeridge Clay was deposited in deeper water away from coarse-grained terriginous input. However, water depth may not have been exceedingly deep.

Further on (c.300 m from cliff path) iron-staining was seen on the slumped material above calcareous sandstones. This was probably the Osmington Mills Ironstone, but it could not be seen clearly. The underlying calcareous argillaceous sandstones represent the Sandsford Formation, a marine deposit.

The low cliffs revealed ca 0.5 m thick limestones interbedded with mudstones. The grey fossiliferous limestones contain abundant white fossils of *Trigonia sp* and also about finger sized *Pinna* (Figure 8). *Trigonia* fossils are 3-8 cm across, show patches of white dots confined to one side of the fossils, they are known colloquially as “Osses Heads”. The shells are laid with the bedding, so not in life position. These are part of the Clavellata Formation.

Figure 8 Shelly limestone with abundant Trigonia (boot toecap for scale). 0

The limestones showed, in section, beds with raised “mounds” sometimes hanging down from the bottom of beds, sometimes standing up. They were ca 20 cm diameter and 10cm high. The RGS enjoys challenges of identification, but none were forthcoming for this feature. The sun was now breaking through low clouds, with the Isle of Portland in view, but with its top obscured by cloud.

Underfoot conditions were now severe – the “Beach” was taken up by a boulder bed, approximately average size of boulders 0.5 to 1 m across, making progress very slow and hazardous.

The prominent rock ledges were now sandstones, containing oysters, *Pinna* and *Trigonia*. On the bedding planes were trace fossils in abundance, showing interconnected structures up to 5 cm diameter – clearly burrows made by some considerable animal – these traces are of *Thalassinoides* and *Orphiomorpha*. While the “tunnels” are very common, it is extremely rare to see the animal that created them – if ever! The boulders on the beach all contain trace fossils.

The insitu rock here were sandy beds 10 cm thick, which dip gently towards S and E. In the centre of this structure, one bed was seen to be folded in an approx. E – W orientation and with a rounded top. It was suggested that this could have been a fold hinge, allowing the rock to dip. Associated with the structure there was lots of calcite veining along the crest of this feature and aligned with its length. Veining was probably related to the folding, presumably filling tension cracks.

Now in bright sunshine, The RGS adopted sensible precautions, with application of sun cream and various exotic hats by the members.

A 300 m further on, the outcrop was of massive, white very pure oolite, the Osmington Oolite with abundant bioturbation (Figure 9). The oolite is overlain by a rubbly bed containing (we were told, but not seen) sponge spicules of the genus *Rhaxella*. This was the Nodular Rubble Member of the uppermost Osmington Oolite Formation. The significance was that this was the same sponge spicule associated with the Cherty Member of the Portland Stone seen the previous day at Tilly Whim Quarry and later in the day on the Isle of Portland, however, here there was no chert.

As we had progressed down the section, the large fossils we saw in the higher part of the sequence were now replaced by smaller bivalves.

Figure 9 White oolitic limestine with prominent Thalassinoides burrows in the Osmington Oolite Formation (notebook for scale 21.5cm x 14 cm).

We now rounded Bran Point and were in site of the finishing point at Osmington Mills. Having progressed a considerable distance further along the beach (mainly by bolder hopping, or the "2 hands, 2 feet" approach) we found a major change in lithology – now, we were faced with cross-stratified brown-red sandstones of the Bencliff Grit Member. This is the uppermost member of the Redcliff Formation. We were assured that oil seeps were common in this area, but while we could smell a sulphury, oily odour, actual seeps of the black stuff were not observed.

The Bencliff Grit here contains large elipsoidal doggers, up to 1.5 m diameter (Figure 10). The cross stratification in the sands could be seen to pass into the doggers. As with all doggers, concretions and similar structures, a considerable debate, unresolved, was entered into by the members. But they made a fitting marker for the end of this section.

Figure 10 Elliptical calcite cemented sandstone dogger in the Bencliff Grit Member of the Redcliff Formation (notebook for scale 21.5cm x 14 cm).

The Coralline Group in Dorset is quite sandy in a number of units. Ross told us that Lydian pebbles (chert from the Carboniferous Limestone) were locally found in the basal unit of the Redcliff Formation a short distance to the west. This was significant when we considered the pebbles in the Wealden Group over the next two days.

A walk back over the headland to Ringstead was a minor challenge to the members and it was just a little unfortunate that the sun was now blazing down on the group but it provided great views of White Nothe the headland a short distance to the east of Ringstead.

White Nothe

View from: Ringstead Bay - GR - SY 74568 81376; 50°37′53″N , 002°21′39″W; W3W - curving.scoping.taken

We lunched at the Beach Café at Ringstead where an exercise was provided to sketch the structure between White Nothe and Holworth House. With guidance, it was possible to identify the out crops of the Kimmeridge Clay, the Portland/Purbeck, the Upper Greensand and the Chalk (Figure 11). The Gault was largely slumped, as at Swanage Bay. The section shows the Upper Greensand and Chalk successions (and the Gault), resting on the Kimmeridge Clay towards White Nothe, but overstepping onto the Portland and Purbeck

Groups towards Holworth House. This provided clear evidence for faulting and folding of the Upper Jurassic and Lowest Cretaceous succession prior to deposition of the mid and Upper Cretaceous.

Figure 11 NW-SE section from Holworth House (left) to White Nothe (right) showing northward tilted Kimmeridge Clay and Portland/Purbeck being overstepped by the southward dipping mid to Upper Cretaceous (Gault-Chalk)

Friday 17th May PM, 2024 – Isle of Portland

By Hilary Jensen; Pictures - Hilary Jensen and Peter Worsley

The afternoon session was on the Isle of Portland. This extends for about 6 km north to south and 2.5 km from west to east. It is surrounded by cliffs, precipitous in the west and east. At the southern end is Portland Bill and the Pulpit Rock. At the northern end, it is connected to the mainland by Chesil Beach which stretches 29 kms from Chesil Bay against the cliffs of Portland to West Bay in west Dorset.

Geologically, the Isle of Portland is on the southern limb of the Weymouth/Purbeck anticline (Figure 12), the sequence dips 1 – 2° southwards and is comprised of Kimmeridge Clay which crops out around the northern part of the island, overlain by Portland Sand Formation and Portland Stone Formation of the Portland Group and the Lulworth Formation of the Purbeck Group.

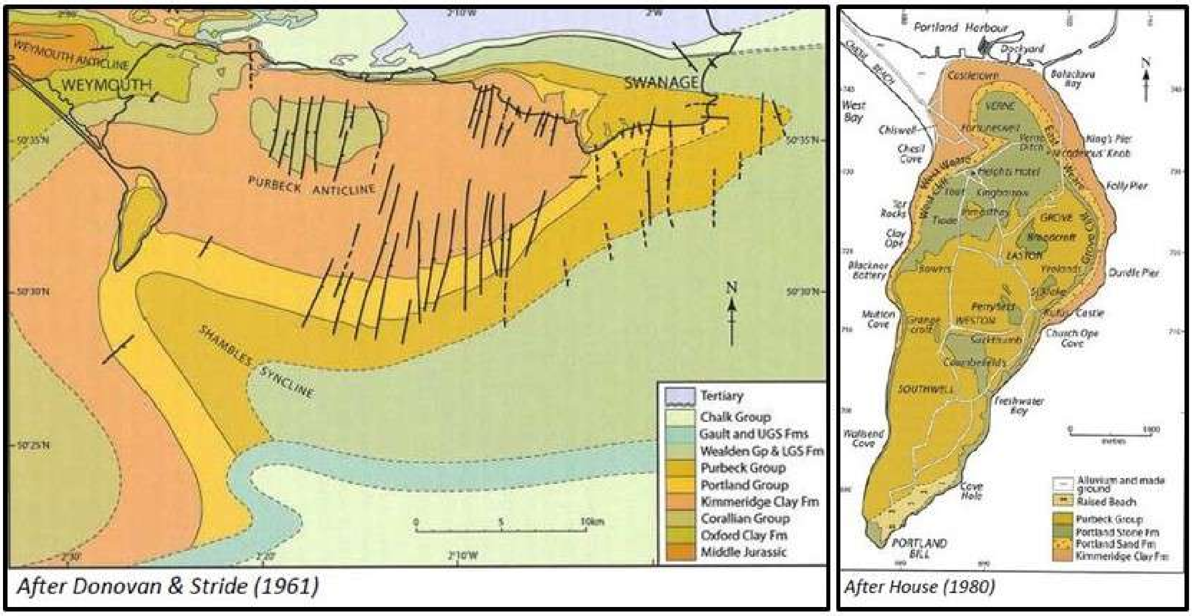

Figure 12 Geological maps of the Purbeck Anticline and the Isle of Portland.

Below is a simple stratigraphical column showing the groups, formations and members described below with current BGS names. The complete succession from deposition of Kimmeridge Clay in deep anoxic water, through the sands of the Portland Sand Formation and the limestones of the Portland Stone, through the lacustrine and lagoonal sediments of the Purbeck Group, represent a major cycle in Jurassic-Cretaceous stratigraphy.

Group	Formation	Member
Purbeck	Lulworth	
Portland	Portland Stone	Portland Freestone Member (Winspit Member of Townsend 1975) Portland Cherty Member (Dancing Ledge Member of Townsend 1975)
	Portland Sand	
Ancholme	Kimmeridge Clay	

Bower's Quarry, Weston to Blacknore

GR - SY 68665 72109; 50°32′52″N , 002°26′37″W; W3W - surpassed.fellow.lookout

The first site was Bower's Quarry (Figure 13). The group walked from there a few hundred metres to the cliffs just to the north of Blacknor Battery (GR -SY682724).

Figure 13 Entrance to Bowers Quarry and Mine on the Isle of Portland at Weston

The view to the north was of West Weare cliffs and Chesil Beach in the distance. We discussed the genesis of Chesil Beach. Its origin is likely due to the rise of sea level from a low stand at -120 to -130 metres OD at the peak of the Devensian ice age c. 20,000 BP. As the global ice retreated, sea level rose and fluvial sediments were swept up landwards, finally forming the present-day bar extending from West Bay in the west to the Isle of Portland in the east. The beach is 29 kms long, 200 m wide and 15 m high and is a dynamic system with the shingle size getting larger towards the east. At Chesil Bay, the cobbles are up to 5 cms in length; at West Bay there is pea-sized shingle. It has been more or less constant for the last 6,000 years of near stable sea level although there has been a net drift inland over salt marsh sediments. On occasions, there have been breaches in Chesil Beach but have anthropologically reconnected again.

The view of West Weare cliffs shows the Kimmeridge Clay at the base overlain by Portland Sand Formation and above which is the Portland Cherty Member (Figure 14), which we saw yesterday and examined at Tilly Whim caves. The overlying Portland Freestone had been extensively stripped by quarrying over the last several hundred years. The competent rocks of the Portland overlying Kimmeridge Clay make the whole coastline susceptible to landslip, demonstrated by the break of slope and the rotational blocks of Kimmeridge Clay in the lower part of the cliffs.

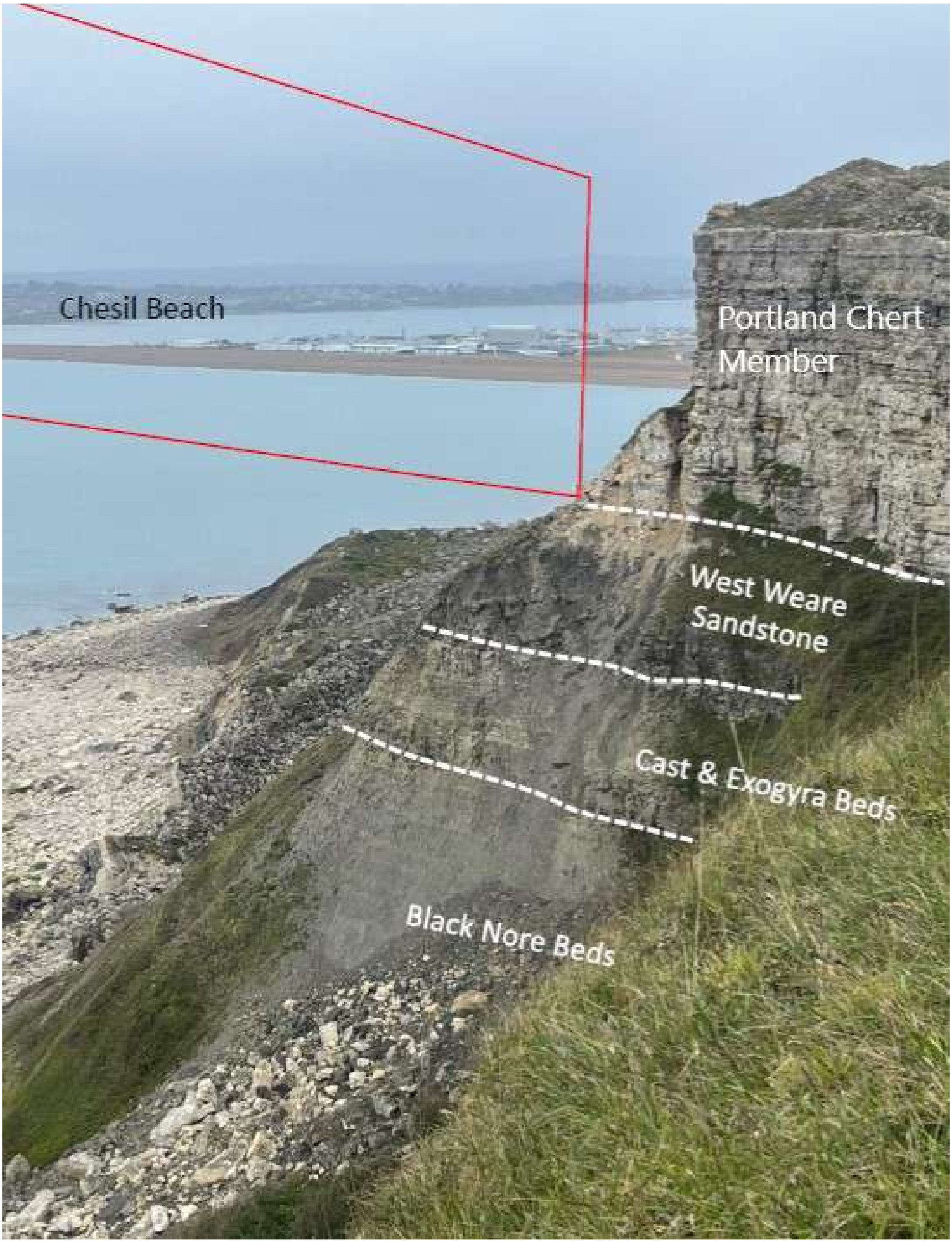

Figure 14 View to West Weare Cliffs and the eastern end of Chesil Beach. The cliffs show the upper part of the Portland Sand and the basal part of the Portland Limestone Formation.

Continuing to the outcrop of the Portland Freestone Member, examination with a hand lens showed it to be oolitic and spiculitic with two sponge species, *Pachastrella* and *Rhaxella*, the former associated with a higher energy deposition conditions. It also includes vugs and a lot of shell fragments. Ooids were identified. In a simplified model of the Portland Stone sedimentology in the context of a carbonate ramp, the Portland Cherty member is interpreted as representing the outer ramp facies in a depositional zone of medium to low energy whereas the Portland Freestone was deposited in shallower water settings with oolitic shoals (Figure 15).

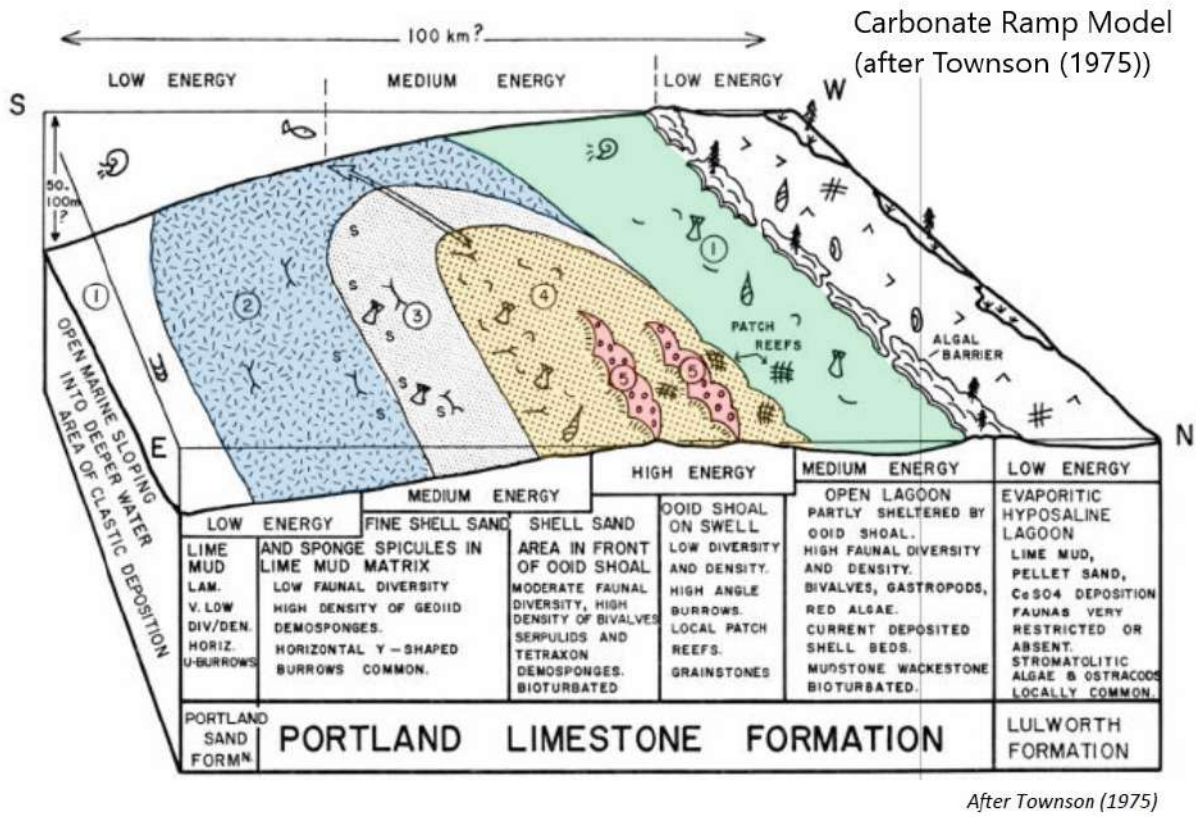

Figure 15 Townson's model (1975) of carbonate ramp limestone formation.

We viewed the Portland Freestone Member yesterday at Tilly Whim near Durlston Head, and various differences were noted - here there are larger shell fragments and ooids and there was more chert. Townsend (1975) associated these differences to differing energy levels and deposition of higher energy facies on 'structural swells'. However, it was pointed out that Townsend's original SW-NE oriented swell did not match our understanding of the structural of the area. An obvious cause of this difference was not forthcoming, but tentatively ascribed to the formation of the Purbeck Anticline.

A discussion was started about the formation of chert. Chert occurs in large nodular masses elongate in the plain of bedding. The silica source was the opaline silica spicules in sponges, which on death was unstable and dissolved; the concentration of silica in pore waters increased and silicification took place. The chert was formed relatively early after deposition and has preserved the shells of bivalves and gastropods prior to dissolution of aragonitic shells by meteoric pore-waters seeping down from the Purbeck lagoons.

Ross pointed out examples of the gastropod the Portland Screw; *Aptyxiella portlandica* preserved in the chert but dissolved in the adjacent limestone. He said that examples of this chert had been found as pebbles in the upper Purbeck Group at Friar Wadden north of Weymouth and in the Wealden at Stair Hole at Lulworth Cove.

We walked inland to view the Portland Freestone member. This has been used for many famous buildings – for example, the Palace of Westminster (1347), the Tower of London (1349) and parts of Buckingham Palace (1854). In Reading, Portland Stone was used in the construction of High Bridge across the Kennet in 1788, Simeon Monument in the Market Place (1804), the Maiwand Lion plinth (1910), Shire Hall in Forbury Square (1911) and Reading Cenotaph (1932).

Figure 16 Mine entrance into the Portland Freestone in Bower's Quarry.

The freestone is known as "Whitbed" by quarry workers and Figure 16 shows that it was mined as well as quarried. It is a massive, thick, bedded, oolitic, fossiliferous limestone. On the carbonate ramp model, this represents a depositional environment of higher energy. On Portland, the freestone is capped by a shelly, highly fossiliferous limestone, from which the shells have been dissolved out leaving bivalve and gastropod moulds, these are the Roach beds, also widely used as building stone.

The Portland Freestone is overlain by the base beds of the Purbeck Group, characterised by two dirt beds separated by algal limestones. The depositional environment was of shallowing seas passing upwards into lagoonal and lacustrine settings; the dirt beds are interpreted as soil horizons. Elsewhere on Portland, plant remains and tree stumps have been seen on past field meetings. Figure 17 shows the quarry faces with an interpretation of the strata (SY 681719).

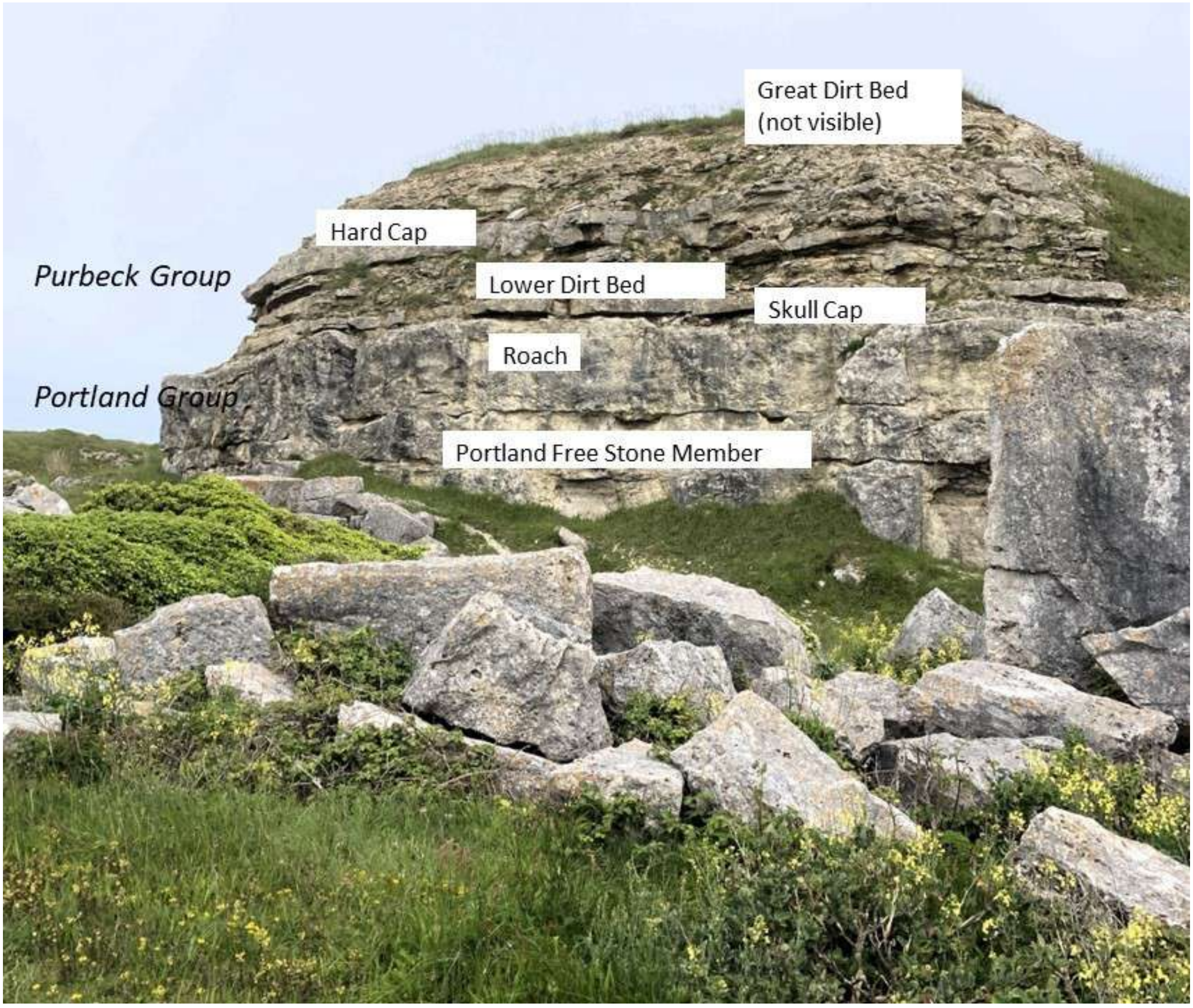

Figure 17 Portland-Purbeck boundary near Blacknore.

Portland Bill

GR - SY 67564 68451; 50°30′54″N , 002°27′32″W; W3W - pilots.undercuts.weeds

The next site was at Portland Bill to view the Quaternary raised beaches. Two raised beaches are present, the lower of the two, at about +7m OD, the east beach, was not visited by the group on this occasion but Figure 18 shows the section. This is dated at MOI Stage 5e, c.120,000 BP (SY678684).

Figure 18 The lower raised beach at Portland Bill.

The higher beach is much degraded and disturbed by the quarrying in the area and extends across the cliff top to the NW of the lighthouse as shown in Figure 19 (SY675684). There used to be visibility of good sections of this but sadly they are now behind a re-constructed security barrier. The raised beach sequence is on thin-bedded basal Purbeck limestones at a height of approximately +14m OD and consists of approximately 2.5m of cemented beach material with well-rounded clasts. It has been possibly dated at c. 210,000 BP, MOI Stage 7. The raised beach deposits are overlain by loess in part, above which are solifluction deposits (head) separated by a weathering horizon. The head is crudely stratified, formed under subsequent periglacial conditions. This is dated to c. 210,000 BP and is at a height of +14m OD. We were able to examine the clasts and although mostly flint, there were some rounded clasts of granites and quartzite suggesting derivation of material from Devon.

Figure 19 The degraded upper raised beach at Portland Bill with rounded flint and 'exotic' pebbles. In the background are the quarry workings of the Portland Freestone.

The final question gave food for thought – why does the Isle of Portland exist from a geomorphological viewpoint? A question we took away with us.

Acknowledgement – RGS Dorset Field Guide by Ross Garden, RGS Newsletter May 2011 report.

Saturday 18th May AM, 2024 – Kimmeridge Bay

By Roger York

Kimmeridge Bay
GR - SY 90825 78679; 50°36′28″N , 002°07′52″W; W3W - slouched.stored.dial

We arrived at the car park at Kimmeridge Bay prepared for a wet and dull day but the rain held off and the day remained dry and brightened.

Ross gave us an introduction and description of the shoreline and the oil field. The oil field was positioned on what from the bay looks to be an anticline but, in fact, the beds are flatter and dip slightly to the SE and it is the shape of the bay makes the bedding appear anticlinal. An E-W oriented anticlinal structure does exist beneath the field and oil production is from the fractured limestone of the Middle Jurassic Cornbrash. The oil has been pumped with the single 'nodding donkey' for over 60 years and still gives about 65 barrels of oil every day. The field is structurally discrete from the larger Wytch Farm oil field near Poole but in both cases the oil comes, not from the Kimmeridge Clay but from the Lias. In the North Sea, the

Kimmeridge Clay had been more deeply buried (often to greater than 4 km) but here it had not been buried deeply enough for oil to form.

Figure 20 Kimmeridge Bay (with nodding donkey just visible).

Ross led us east round the bay to the path under the cliffs (Hen Cliff) below Clavel Tower. The rocks at the bottom of the cliff are the Maple Leaf Shales with the first stone band being the Cementstone (Figure 20). Above this are the Hen Cliff Shales. We were warned to be careful and wear hard hats here as there are frequent (very small) showers of shale fragments (and one occurred).

The beds here are cyclic with A clay; B bituminous clay; C oil shale; and D coccolith limestones (mainly converted to dolomitic limestone). The cycles are expressed by sea level changes and explained by Milankovitch cycles. These are often incomplete at Kimmeridge, frequently being ABAB cycles as seen in Hen Cliff between the upper Cementstone and the Yellow Ledge Stone Band.

The beds dip to the east and we reached the Yellow Ledge Stone Band (with its attendant cormorants) where a normal fault dipping about 45º to west, had a downthrow of about 50 cm (Figure 21). Ross had already explained about ‘relay’ faults on the large scale but here was an illustration of ‘relay’ faults on a small scale in this fault zone (Figure 22).

Figure 21 Fault at Yellow Ledge with downthrow to west of about 50 cm.

Figure 22 Small scale relay faulting in larger fault zone.

The path was very close to the cliff and in places we needed to clamber over the fallen dolomitic blocks. These often showed lenticular fractures across the middle of the bed (Figure 23) which are explained as tension gashes caused by the reduction in volume of the replacement of some calcium by magnesium (from limestone to dolostone).

Figure 23 Tension gashes in dolostone.

Saturday 18th May PM, 2024 – Worbarrow Bay

By Angela Snowling

The aim of the afternoon session was to explore how the Wealden varied at this location compared to the outcrop at Swanage seen previously.

Worbarrow Bay
GR SY 87067 79752; 50°37′02″N , 002°11′03″W; W3W - icon.roadblock.charities

The pre-reading material for this section across Worbarrow Bay is covered by in the field guide; page 17 (the soils above the Wealden sandstones), page 60 a west to east cross section along the coast, page 63 types of fluvial channel reflecting difference in accommodation space and connectivity, page 64 the lithological column with a record of the types of formation and thickness.

Ross noted key geographical features in the bay starting with the Purbeck at Pondfield Cove and Worbarrow Tout to the east and ending at Worbarrow Bay to the west, where we started the beach traverse. Looking beyond Worbarrow Bay to the west he noted; the Purbeck Disturbance at Lulworth Cove, Bacon Hole and Mupe Bay (see the following day's reports), and the Isle of Portland (see previous day's afternoon report). There is no Portland succession at Worbarrow Bay, but it out crops on Gad Cliff a short distance to the east towards Kimmeridge Bay. The Worbarrow section contrasts with that at the Isle of Portland. At Worbarrow Bay, the beds are dipping moderately steeply northwards, whereas at Portland the units dip 1-2° southwards. This reflects the folding across the Purbeck Anticline (Figure 12).

The Wealden here is thinner (429 m) than at Swanage - representing a 60% reduction in thickness. The Wealden is not present on the coast beyond Durdle Door to the west but is present in land in the anticlines at Chaldon Herring and Osmington. Only the Wessex Formation is exposed at Worbarrow Bay. It comprises interbedded sandstones and mudstones. The latter are commonly obscured in landslips and are less well seen than at Swanage Bay but include the red and purple mottled paleosols as seen to the east. The sandstones include fluvial and lacustrine deposits. A notable feature not clearly seen at Swanage is the presence of the Coarse Quartz Grit towards the top of the exposed section. This is a distinctive granular conglomerate.

Dips are steep in the Wealden beds (between 30-50° towards the north) and the chalk at the NW end of the bay dips at 55-75° to the north. Landslips at western end of Worbarrow Bay include material from the Lower Greensand, Gault and Upper Greensand and Lower Chalk, which lie unconformably above the Wealden as seen between Holworth House and White Nothe on the previous day.

Ross posed the following questions for the walk along an 800 m stretch of the Wealden from the entrance to the bay westwards. Hand lenses were needed to examine grain size and shape as well as the nature of the cements.

- What is the lithological distribution along the section i.e. fluvial sandtones, lagoonal sandstones, mudstone, paleosol?
- What proportion of paleosol do you estimate in this section compared with that seen at Swanage Bay?
- What is the proportion of sandstone to mudstone?
- What proportion of the sands are fluvial vs lacustrine/lagoonal?
- What criteria would you use to differentiate these depositional environments?
- How laterally continuous do you think the sands are?

Figure 24 Clean, pale coloured fine-grained lacustrine/deltaic sandstones overlain by iron rich, orange coloured fluvial sandstones. The foreground is in slumped paleosols and there are paleosols above the fluvial sandstone.

Figure 25 Chemical 'Liesegang' staining in sandstone.

Figure 26 Example of iron rich band, commonly seen at the contact of coarser-grained (higher permeability) fluvial sandstones and finer grained (lower permeability) deltaic sandstones.

Figure 27 Example of rafted lignite log towards the top of a fluvial sandstone, with abundant lignite in the sandstones below

Figure 28 Channel point bar deposits capped by a thin, discontinuous floodplain mudstone. This channel sequence is incised by a younger coarse-grained and gritty fluvial sandstone with an irregular, erosively scoured base.

Figure 29 Example liesegang iron staining in a fine-grained sandstone. There was much discussion as to the character of the banding and the ferruginous 'stones'.

Figure 30   Chalk and Upper Greensand pebbles from the sections above the Wealden.

Figure 31 Iron-staining and carstone formation in fluvial sandstones below the Coarse Quartz Grit

Answers to questions and further discussion

Q1a. Compared to Swanage what proportion of the total exposure is comprised of paleosols?

- Ross estimated about 30% paleosols here compared to 70% at Swanage.

Q1b. What proportion of the Wealden sequence comprises sandstone and mudstone?

- Based on published logs for Worbarrow Bay this was about 50:50%.

Q2a. Why didn't the leaching from the iron rich band above percolate into the clean sand below (Figure 24)?

- This could be explained by the lower permeability of the finer grained lacustrine sandstone below the coarser grained, higher permeability fluvial sandstone.

Q2b. Was the Liesegang-type of chemical leaching effect similar to that found in Swanage (Figure 6, Figure 25)?

- Yes, in parts, but care was needed as in other areas it was simply an iron-rich or iron-cemented sand (Figure 26).

Q3. What evidence is there of fluviatile structures?

- Figure 24 shows evidence of a lacustrine sand body cut into by an overlying fluvial unit. In Figure 27 a channel bar comprising laminated, fining-upwards sandstones grading upwards into interbedded sands and silts. In the latter there is little evidence of large scale cross–stratification there although some bioturbation exists. In other areas along the exposure there is some evidence of deltaic-like structures. See counts of point bars, channels etc. in the notes page 64.

Q4. What does the lenticular character of some sandstones infer about the extent of the sand bodies and the environment at the time?

- Ross explained this was due to a channel incision into the floodplain mudstones and lacustrine deposits. The inference was that the channels would have had limited lateral extent perpendicular to palaeoflow.

Q5. Can the Coarse Quartz Grit be used as a marker bed? See page 47 of notes.

- Although similar lithologies were found in the Wealden at Swanage this was debated due to the high energy of the paleoenvironment and deposition in fluvial channel fills. The pebbles are predominantly of sub-rounded white quartz with suplimentary arenite and dark clasts. The poor rounding suggests rapid transporation from the sediment source area and deposition without repeated recycling and rounding of the material. This is consistent with the fluvio-deltaic setting indicated by the sedimentology.
  Ross indicated that the small black pebbles were of two principal types; radiolarian chert from the Culm Measures and tourminalite (schorl), both from the Cornubian Massif to the west. The quartz pebbles included examples of luxullianite also from Cornubia. This contrasted with the pebbly material found in the Corallian near Osmington which was lydite from Carboniferous limestones (investigated by Ross as part of his thesis).

Q6. What paleoenvironment existed at the time of deposition of the pink/purple mudstones and paleosols?

- It was warm, humid conditions with intense chemical weathering, particularly in the floodplain depositional areas of east Dorset

Q7. How were the lignite rafts produced?

- Wildfires were thought to be the main source of the carbonised wood. This suggests that there where upland areas adjacent to the floodplains that were prone to fires. The wildfire products where then transported downstream in subsequent floods onto the floodplain.

Sunday 19th May AM, 2024 – Lulworth Cove

By Sarah Cook

Stair Hole

GR SY 82237 79901; 50°37′07″N , 002°15′09″W; W3W - splendid.irrigated.mystery

The morning started with a walk to Stair Hole to view the Lulworth Crumple (Figure 32). The seaward side of the Crumple comprises the uppermost Portland Limestone and the fold is accommodated in the interbedded limestones and mudstones of the Purbeck Group.

Figure 32 The Lulworth Crumple, folding in the steeply northward dipping limestones and mudstones of the Purbeck Group

Behind the coastline at the back of Lulworth Cove is a large fault which during the Late Jurassic and Early Cretaceous was a normal down to the south throwing fault that in Alpine times was reactivated as a reverse fault. The crustal compression at this time created anticlinal folding with dips close to the fault becoming vertical. Away from the fault the dips flatten out.

One of the themes throughout the fieldtrip was, ‘why does the Wealden Group vary so much in thickness over this area? Along the Dorset coast it varies from 650 m at its thickest to 167 m at Lulworth Cove. Changes in facies seen during the fieldtrip suggest changes in accommodation space due to subsidence during deposition might have caused thickness changes between areas. It is also possible that bed slipping during Alpine folding might have contributed to the reduction in thickness by squeezing out the less competent layers and so reducing the thickness. At Lulworth Cove, there is evidence from the presence of Portland and Purbeck Group chert and Kimmeridge Clay phosphate clasts within the Wealden sediments that indicate faults were active in Wealden times. This suggests that accommodation space changes due to faults active during Wealden times may be more likely to have caused the thickness changes. However, the significant change in Wealden Group thickness may be the result of a more complex combination of several processes.

Lulworth Cove

GR SY 82695 80011; 50°37′10″N , 002°14′46″W; W3W - mammal.rashers.baguette

We walked eastwards along the coastline down through the stratigraphy. We stopped and looked at the bioturbated and shelly Holywell Chalk (Figure 33) which has the greenish grey Plenus Marl at its base, a good seismic marker used in offshore oil and gas exploration. This was underlain by the Zigzag Chalk which overlies the green/grey Upper Greensand (Figure 34) with small, sand size, black glauconitic grains within it as well as *Exogyra* fossils.

Figure 33 Bioturbated and nodular Holywell chalk.

Figure 34 Highly glauconitic sand with abundant Exogyra and 'glauconite-poor' burrows from the uppermost Upper Greensand.

We then passed further down the stratigraphic sequence to the Wealden sediments. This sequence was vertically bedded and included the Coarse Quartz Grit (Figure 35) which comprised granule and pebble sized clasts and was often heavily iron stained making it very distinctive. We had seen similar rocks elsewhere along the coast and concluded that such a distinctive rock type would be deposited in a short timeframe and may be correlatable across a wide area.

Figure 35 Granules in the Coarse Quartz Grit of white quartz, grey arenite and black Culm chart and tourmalinite

A bit further down the beach we saw a good example of a beach rock cemented onto steeply northward diping Wealden sandstones (Figure 36). It contained chalk and flint clasts originating from the Upper Cretaceous indicating that it must be a younger rock and not part of the Lower Cretaceous Wealden succession.

Figure 36 Iron cemented beach rock with rounded pebbles of flint and chalk.

Fossil Forest

GR SY 82980 79671; 50°36′59″N , 002°14′31″W; W3W - truckload.breakaway.says

Our next stop was the highlight of the day, the Fossil Forest which comprises limestones, evaporates and mudstones of the Lulworth Formation at the base of the Purbeck Group. Today nothing remains in situ of the original silicified tree trunks at this location as they were largely removed by Victorian fossil hunters, however some pieces of fossilised wood have been returned and are on display at the steps down to the site (Figure 37).

Figure 37 An example of silicified wood from the Lulworth Formation.

In Purbeck times, the trees are thought to have grown on low lying land adjacent to marine lagoons. The Great Dirt Bed representing the soil layer the trees grew in has weathered out, (Figure 38). Subsequently, conditions changed and the trees were inundated by the lagoon and died. The lagoon was hypersaline, and when the trees fell into the lagoon they became silicified, probably due to extreme seasonal pH changes (pH >9.4) which caused silica in the general environment to dissolve and then silicify the woody material. The root balls of the trees, when swamped by the lagoon, were coated in algae which preserved their shape (Figure 39).

Figure 38 Algal limestone above the Great Dirt Bed comprising rounded micritic limestone pebbles in a carbonaceous matrix.

Figure 39 Algal mounds developed over the root balls of fallen trees.

Evidence of the extreme conditions in the lagoon are casts of salt crystals (hoppers) preserved in the lagoonal sediments, desiccation cracks and tepee structures (Figure 40) and the overlying Broken Beds (Figure 41). The Broken Beds are intervals of jumbled bedding which may be up to a few metres thick, bounded above and below by normally bedded rocks. The brecciation of the limestones comprising the Broken Beds was caused by competent beds of limestone being interbedded with layers of anhydrite, with the anhydrite, on burial being replaced by calcite which causes a reduction in volume of 20% (Smyth, J & McCormick, T, 1995). This volume reduction caused the fabric of the rocks to become unstable and the beds collapsed forming the Broken Beds.

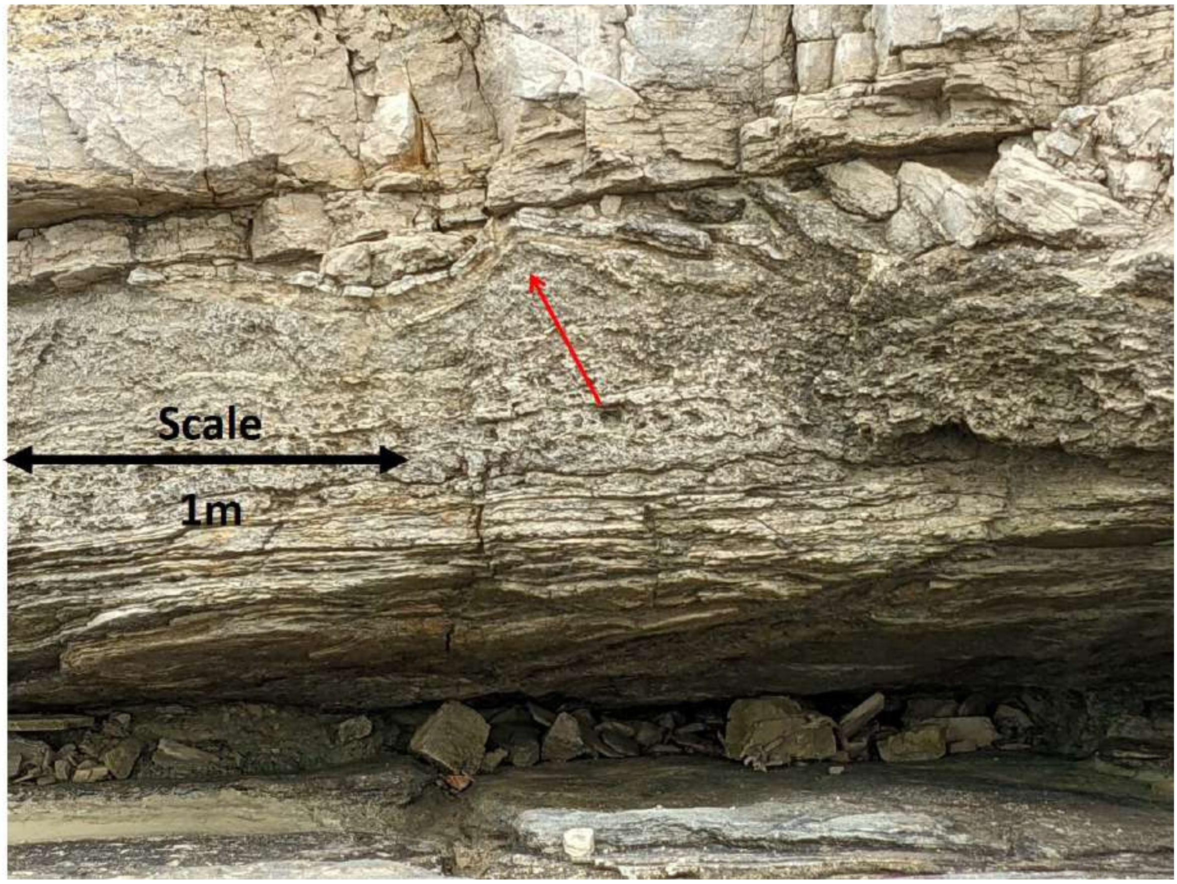

Figure 40 Tepee structure in algal limestone above the Great Dirt Bed.

Figure 41 Broken Beds – brecciated, laminated algal and evaporitic micritic limestones.

Sunday 19th May, 2024 – Mupe Bay

By Jim House

During lunch at the site of the Fossil Forest several members of the party investigated the loose rocks on the floor of the quarry. Several discoveries were made, including samples of halite pseudomorphs combined with pellets which were interpreted as faecal droppings. This initiated a discussion on the nature of the environment that produced pseudomorphs i.e. hypersalinity, evaporation, the burial of halite crystals, and the subsequent loss of the halite – leaving the pseudomorphs behind.

After lunch members of the party climbed the many steps out of the Fossil Forest quarry and walked eastwards along the coastal path to the site of an old gun emplacement on the edge of Bacon Hole – so called because the rock strata look like 'streaky bacon' – well maybe.

Looking into Bacon Hole from the cliff top it was possible to see the steeply dipping strata in the bay, these are upper Portland Freestone, overlaid by the basal Purbeck Beds with the Broken Beds on top (Figure 42). The northern cliff of Bacon Hole shows alternating light and dark rocks which give the location its name, these are alternating layers of mudstone and limestone of the upper Lulworth and Durlston formations in the Purbeck Group.

Figure 42 *Bacon Hole looking east, with Mupe Rocks in the bay and the 'streaky cliff' to the left. Also note the extensive exposure of the Wealden beds across Warborrow Bay in the distance visited on the previous day.*

The view and weather were both excellent and it allowed Ross to give an overview of the sites that had been visited during the previous three days and how the geology fitted together.

The party then continued along the coastal path to the edge of Mupe Bay. After the group photo some members elected to head back, but the majority went down onto the beach via the stairs at the SW end of Mupe Bay (Figure 43).

Figure 43 Members of the RGS observe the information sign with the casual ambivalence of seasoned pro's .

At beach level, to the right of the stairs (south) are the limestones of the Purbeck Group but the party did not go this way due to the rocky nature of the foreshore and the risk of rockfalls. To the left of the stairs (north) are beds of the Wealden Group.

There was a discussion on how historically the Cinder Bed at the base of the Durlston Formation was considered to mark the boundary between the Jurassic and Cretaceous in Britain, but it is now considered that the boundary lies towards the base of the Lulworth Formation at the base of the Cypris Freestone.

The contact between the upper Purbeck Limestones and the lower Wealden sands and muds was partially covered by slumped material at this point, so it was not possible to clearly see the boundary. The Wealden deposits in Mupe Bay dip steeply to the north and have a thickness of approximately 229 m (Arkell, 1947), which is 40% greater than that seen in Lulworth Cove some 1.5 km to the west. However, it is only half as thick as the exposure encountered the previous day on the eastern side of Worbarrow Bay, some 2.5 km to the east, which is 429 m thick. There was a discussion on the significance of this rapid thinning to the west, and explanations on the possible paleoenvironments which could give rise to the thinning, including; the gradual increase in accommodation space in the depositional basin towards the east, while the area around Lulworth Cove had less accommodation space.

The lowest exposed part of the Wealden, just to the north of the stairs, is a Wealden oil sands. Members of the party collected samples of black, fine-grained sandstone heavily impregnated with sweet smelling fresh oil, suggesting an active oil seep. While an examination of the cliffface also revealed large black boulders in a matrix of finer grained sandy material. These have been interpreted as boulders of oil-impregnated sand that have been reworked in a Wealden channel. The boulders being derived from the Wealden itself.

A discussion about the origins of the oil and its geochemistry took place. Both the fresh oil and the oil in the boulders has been geochemically identified as coming from the Lower Jurassic, Charmouth Mudstone (Lias). And how Cretaceous burial of the Lower Jurassic down to approximately 2 km would have been sufficient to reach temperatures in the 70 – 90° C range, which would have enabled thermal maturation to take place. After looking at the oil sands the party went on to the explore the rest of the Wealden beds.

Figure 44 Members of the party examine the Wealden oil sands, note the presence of large dark boulders in the upper centre of the image.

The Wealden beds were examined and showed a similar mix of depositional environments to those seen the previous day in Worbarrow Bay, including lagoonal/deltaic deposited sands with parallel laminations, and coarser grained fluvial sandstones with mudclasts and pebbles.

The Gault and Lower Greensands are very poorly exposed in Mupe Bay, so after traversing the Wealden beds the party turned around and walked back along the beach to the stairs and the long climb up and over Bindon Hill to Lulworth. The transition from the Wealden and Gault beds to the Greensands and Chalk is clear to see from the change in vegetation and topography. The dip of the chalk at Bindon Hill is almost vertical and creates a very impressive out crop.

Once in the village of Lulworth Cove the party all got together again and gave a hearty thank you to all those involved in organising such an excellent field trip.

It was then time for an ice cream or two, before heading home (Figure 45).

Figure 45 The RGS members in Purbeck.
From left to right: Ross Garden, Angela Alexander, Roger York, Carole Gregory, Ailsa Davies, Jim House, Hilary Jensen, David Ward, Sarah Cook, Mike Jones, Philip Snowling, Angela Snowling and Peter Worsley

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