top third in the water. After death the top would break off to fall horizontally in the sediment, leaving the diamond shaped base to become fossilised in situ. Also found were *Liostrea* species and a few pieces of fossil wood on which oysters were attached. While looking at the cliff and the faults, it was noticed that two Ravens were rolling and tumbling in flight at the top, to be followed by a Peregrine Falcon which dived steeply towards the beach, no doubt hoping for a raven for afternoon tea. Without success, however!

Image 15: Bivalve 'Pinna' in cross section

We returned to the causeway and then walked to the west over the ledges of Southerndown Beds in which were large numbers of small chert pebbles derived from the Carboniferous Limestone as it was eroded away. Above the chert beds are the ledges of Blue Lias limestones and shales in which fossil oysters and ammonites (*Arietites* species?) up to 30 cm in diameter are visible.

We had started off in very unpromising conditions but intrepidly stuck to the itinerary, to be rewarded by sunny weather, excellent exposures and plenty of interesting features, all very clearly pointed out and described by Dr Geriant Owen. Our Chairman at the time, Maurice Tucker passed a vote of thanks to Dr Owen, expressing the gratitude of the members for giving up his time to lead us on a rewarding trip.

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BOOK REVIEW by Isabel Buckingham
The Story of the Earth in 25 Rocks
by Donald R. Prothero
Pub Columbia university Press 2018 as hard back or e book

Donald Prothero taught palaeontology and geology at various institutions in California and has previously written about fossils.

By choosing 25 different rocks he tells the stories associated with their place in the development and understanding of geological ideas theories and understanding. Some names are familiar such as James Hutton and William Smith, others less so such as James Croll who's C19th work on the earth's elliptical orbit, wobble and albedo was almost forgotten then developed by Milankovitch who survived two World Wars. This is well written and researched although I could quibble about details.

New ideas are not often welcomed and their acceptance can be a long uphill struggle. The problem of how to date meteorites led Patterson to work on lead products and find a very recent increase. The wrath of companies who added lead tetraethyl to car fuel to try and discredit him and it is to the credit of Caltech that he was allowed to continue when his integrity was questioned.

This is a good read if you accept the USA bias. Stories of the individuals and interwoven with the clear explanations of the development of the understanding.

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Lulworth Cove Field Trip – April 2017
Graham Hickman

The party gathered in the Lulworth Cove car park, excited by the day ahead and the glorious spring weather. Professor Maurice Tucker, from the University of Bristol and Bath Geological Society, addressed the attendees and described the programme for the day.

Figure 1 – Lulworth Cove Overlook. Maurice described the geological history of the area.

The plan was to spend the morning on the West side of Lulworth Cove and work our way around the bay in the afternoon to Mupe Bay.

Figure 2- Lulworth Cove is a classic geological section of the Jurassic Coast World Heritage Site.

During Carboniferous to Devonian times there was an ocean to the south, with limestones being deposited on southern flank of an ancient landmass. This ocean closed during what is described as the "Variscan orogeny" as the Gondwana and Laurasia tectonic plates collided to form the supercontinent Pangea. The Permian period was tectonically quiet, then during Triassic times Pangea being splitting. Old faults were reactivated to form the Wessex basin. East- west faults allowed subsidence and the deposition of several kilometres of Jurassic and Triassic sediment. During the Early Cretaceous period further tectonic movements resulted in uplift, erosion and tilting. During the Late Cretaceous global sea level rise returned the area to fully marine conditions with the widespread deposition of Chalk. Finally as the Alps formed in Europe the area experience compressive forces again with thrust faults and folds being reactivated.

Figure 3 - Stair Hole. The Lulworth crumple zone

The group next visited Stair Hole (Figure 3). Here the rocks are steeply inclined and small tight folds are easily seen. This is known as the 'Lulworth Crumple' these high frequency faults and folds have developed on the northern limb of a major monocline, reactivation of deep normal faults has led to local compressional features. The Portland Beds form a strong barrier to erosion from the sea, while the Purbeck beds are softer and more easily eroded. It has been suggested that some of the features we see may have been karst caves; when sea level rose 15,000 year ago the sea has eroded them to become arches.

Figure 4 - Maurice standing on the Cinder Beds.

The Purbeck formation records a transition from shallow marine conditions to muddy alluvial rivers in the Wealden, this is the transition from the Jurassic to Cretaceous Periods. One bed of note is the Cinder Beds (Figure 4), so called for their slightly blue

Figure 5 - West Cliff Lulworth Cove – examination of the Unio Member.

appearance. However, it has nothing to do with volcanic ash or cinder. The beds have their colour from an abundance of oysters Praeexogyra *distorta.*

The group made their way back from Stair hole into Lulworth Cove and started walking along the beach to the west cliff. Here a close up view could be had of the uppermost beds on the Purbeck formation. The glauconitic sandstone Unio Member (Figure 5) named for the presence of the bivalve Unio valdensis. Normally glauconite is indicative of sub-oxic marine conditions, however the presence of freshwater bivalves, crocodile and turtle bones suggests an origin as a lake or lagoon deposit.

Figure 6 – intra clast conglomerate with lime clasts

Figure 7 –West Cliff Lulworth Cove – the Broken Beds.

Further along the west cliff, near the base of the Purbeck, is an interesting conglomerate with lime clasts incorporated into the rock and interpreted to have been derived from a period of desiccation. Conditions where the lagoon dried, lime mud became exposed, flacked, cracked and then redeposited. (Figure 6).

Further along the west cliff, a complex set of strata were observed called the Broken Beds (Figure 7). These are 4 -5m in thickness and consist of folded, floating and brecciated beds. These beds occur in the monocline crumple zone but their origin is not simply from later fracturing. Further East the Purbeck section can be shown to have evaporates, such as anhydrite and halite, in the subsurface (Figure 8). At this location the dissolution of the anhydrite is believed to have resulted in a collapse breccia.

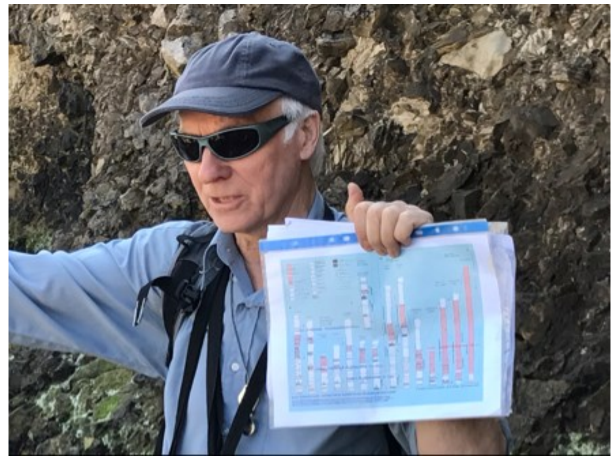

Figure 8 –West Cliff Lulworth Cove – Maurice explains the Broken Beds. Pink shading are evaporites in the subsurface.

After lunch the group made their way across the back of Lulwoth Cove noting the presence of Greensand and the Lower Chalk and the absence of Gault Clay. The Greensand being rich in bivalve fossils and serpulids worm tubes. The Chalk contained pale brown nodules and shell fragments of the bivalve inoceramus.

After climbing the cliff on the East side of Lulworth bay, the group was pleased to see the MOD gate open allowing access to the Lulworth Range. From the cliff top path the fossil forest could be observed. Unfortunately following a cliff fall in 2015 the stairs down to the ledge were still closed. Although some wood however has been silicified, the majority of what is preserved of the fossil forest is the stumps, mostly empty moulds, preserved by 'stromatolitic' microbial mounds (Figure 9).

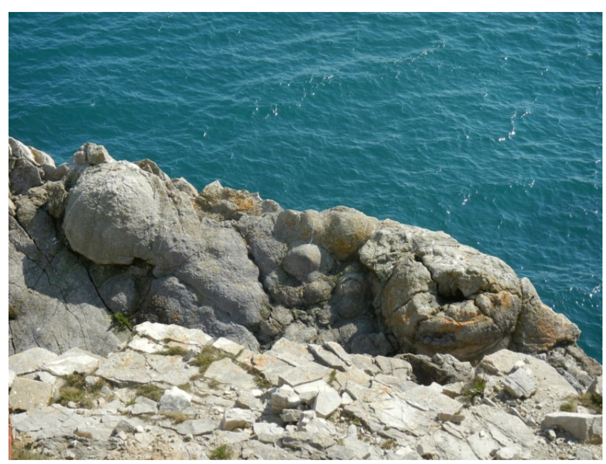

Figure 9 – Fossil Forest

The group walked on until we reach the overlook to Mupe Rock (Figure 10), where we observed the scenic but inaccessible stacks. The stack in the foreground having a Purbeck cap overlying the Portland Broken Beds and Portland Freestone.

Figure 10 – Mupe Rock

As the trip drew to a close the group thanked Maurice for a very informative and enjoyable field trip.

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"Directional Drilling – From Geometry to Geology"
By Phil Burge

Introduction

Within the upstream oil and gas industry there has been, and to some extent remains a tension between the drillers and the geologists. The former are driven by a "can do" attitude where the aim is to drill and complete the well as quickly as possible (within the necessary bounds of safety and well integrity), while the geologists would like to extract as much information as possible about the formations being drilled, which requires time and adds to costs. Horizontal drilling and geosteering has brought the two disciplines together such that drilling performance and well productivity are increased by geological interpretation in real time.

Old time drillers attempted to keep the wells vertical. This is not easy, creating problems as wells tended to intercept or end up draining a neighbouring property, intentionally or otherwise! Directional drilling, pioneered by John Eastman began in the 1930's. Enabled by simple surveying tools providing inclination and azimuth data and using mechanical properties of the drillstring, drillers could drill away from the rig location in a preferred direction. These methods were used until the 1970's and early 1980's when bent sub motors and then steerable downhole motors provided greater control of the well path.

Steerable motors in conjunction with Measurement While Drilling tools (MWD) allowed more complex directional wells to be drilled leading to horizontal drilling and multilateral drilling. In the mid 1990's Rotary Steering Tools (RST) were developed. These tools greatly increase the efficiency of directional and horizontal drilling in particular, allowing geologists to target more complex reservoirs and drillers to plan more complex well paths.

Introduced in 1939, mud logging was the main information gathering method. Samples of drilled cuttings were examined at surface, indications of hydrocarbons noted and a log of the formations drilled compiled. The mud loggers worked closely with the wellsite geologist. Geological and formation fluid data lagged drilling by some time as mud loggers and geologists had to wait for samples to appear at surface.

Beginning in the 1920's through the work of the Schlumberger brothers, and developed continuously ever since, electric logging, or wireline logging has been used to gather geophysical information providing detail on rock and fluid properties. Electric logs are deployed into the well by wireline and as such the data is collected after drilling an interval of the well.

From the early 1980's electric logging sensors were, along with existing directional sensors added to Measurement While Drilling (MWD) tools. The initial benefit of MWD was in improved directional drilling performance. As geophysical measurements became more reliable and sophisticated, FEMWD (Formation Evaluation MWD) began to add to or in some cases replace electric wireline.

A real game changer was the combination of RST (a drilling tool) and FEMWD (a geophysical measurement tool) and the development of remote real time data centres. Real time geophysical data is now interpreted away from the wellsite and decisions on steering the well and are made by collocated multi discipline teams. The history of these developments are shown in the time line in **Figure 1.**

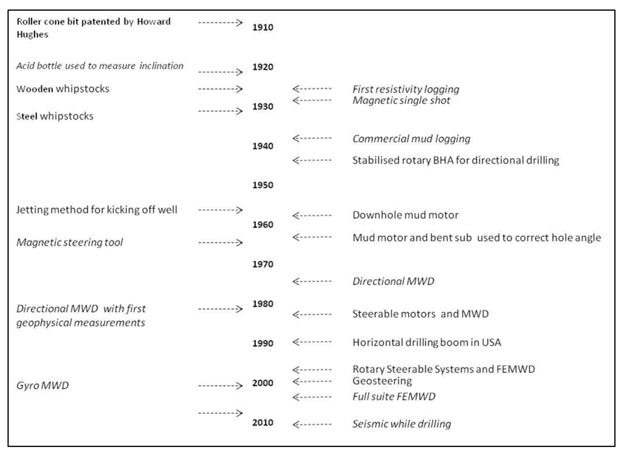

***Figure 1:** Time line of major drilling and measurement technologies. Measurement technologies shown in italics*

The industry has moved from drilling based on geometry to drilling based on geology and from interpretation days or hours after drilling to seconds. The consequences in terms of performance and productivity have been game changing.

This paper will review the development of directional drilling and data collection technologies in the context of the geology.