Dinosaur diversity and extinction
## HORSHAM GEOLOGICAL FIELD CLUB
### OFFICERS AND COMMITTEE 2018/19

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Many thanks to the folk in Forest School office, who produce the printed version of Stonechat for us.
There rolls the deep where grew the tree.
O earth, what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea.

The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go.

But in my spirit will I dwell,
And dream my dream, and hold it true;
For tho' my lips may breathe adieu,
I cannot think the thing farewell.

Alfred Lord Tennyson, In Memoriam, Section 123
Editorial

Things change. The Tertiary has become the Palaeogene, so the K/T boundary is now the K/Pg boundary; the dinosaurs didn't all become extinct at that boundary, because the line that led to birds survived; and the boundary wasn't at 65 Ma anyway, but 66 Ma. The Earth is not flat, nor at the centre of the universe; the stars aren't on a crystal sphere and most of them probably have a planetary system; gastric ulcers aren't caused by stomach acid; phlogiston and the æther aren't real; and so on. But that's science for you: dogmas overturned by testable contrary evidence, and that's what our speakers give us in spades. Hurrah!

Also changed since the last issue of *Stonechat* are certain bones in the bodies of your Secretary and Editor/Treasurer: these understandably objected to their owners making unexpected, violent contact with hard surfaces and broke; but they are now back in action, having mended themselves (with help from the NHS, of course).

Unusually, but most welcome, there are two reports of field trips in this issue: one trip organised by Mike Webster to a site of 'abundant' trilobite fossils in Wales; the other from a Club member who joined a trip arranged by the Farnham Geological Society.

The Club's stand attracted interest again at July's Funday Sunday in Horsham Park. We now have 55 members – a record. There's a report on the Funday in this issue.

**Book sale:** Our Vice President, Frank Diggon, has (reluctantly, I suspect) decided to let go his collection of printed geological material, including books. They are now accommodated somewhere deep inside Peter & Dorothy Webster's house. Please give them a ring if you'd like to have a look and perhaps take some away (a donation to Club funds will be welcome, but is not mandatory!). If you don't know their number, ring Gill or email hgfc@uwclub.net.
Dinosaur diversity and extinction

Paul Upchurch

Report by Gordon Judge

To open his talk, Professor Upchurch spelled out the basics of dinosaur classification (see box). But our speaker's main concerns were to consider how sound the evidence is for the diversity of dinosaur species; and to update us on current thinking about their extinction.

The sampling problem

How should we measure diversity? The graph below, from our speaker's 2011 paper, shows the results of 3 different measures, from the early Late Triassic (Carnian, c.237 Ma) to the Late Cretaceous (Maastrichtian, c.66 Ma):

Dino **saur** basics:

1. **Three major groups:**
   - Ornithiscians – plant-eaters;
   - Theropods – bipedal, initially carnivorous, though some later broadened their diet;
   - Sauropods – large, long-necked herbivores.

2. Ornithischian ('bird-hipped') and saurischian ('lizard-hipped') dinosaurs:
   - The pubis bone in the pelvic girdle points downwards and forwards in an ornithiscian, relative to the ischium; in a saurischian, it points downwards and forwards.

\[
\begin{align*}
DBC &= \text{number of dinosaur-bearing collections (divided by 10)}; \\
DBF &= \text{number of dinosaur-bearing rock formations}; \\
TDE &= \text{number of species from each period found in the fossil record}
\end{align*}
\]

The TDE line is based on what the fossil record lets us see; but we are only *sampling* the true data, much of which remains inaccessible, and our samples are from discrete areas, not the vast regions in between them. So this sampling may well not be representative of its population. It can be biased, for example, by the amount of sedimentation laid down or subsequently eroded in a particular time period; or constrained by human factors such as funding or flavour-of-the-month selection of...
excavation site – the DBC and DBF lines on the graph attempt to capture such effects, and can be seen to correlate well with TDE’s line.

But this is not, the Professor insisted, good news: Since DBC and DBF are from necessarily limited data, good correlation of TDE with them means that it, too, might hide a sampling problem with the available fossil record. Fortunately there are ways of improving things . . .

**Rarefaction** Count the species for one time period $T_0$ at $n$ sites; then, for other time periods, say $T_1$, and $T_2$, do the same at the same number of sites – not more, not fewer, just $n$ sites each. You might have counted more species for $T_1$ and $T_2$ if you’d surveyed more sites, but at least your graph of diversity against time will be ‘fairer’.

**Residuals** For this, you need to have a range of results on observed diversity for which you know the number of sites searched in each case. Plot diversity against sample size (number of sites) and draw the ‘regression line’. If you now do a new diversity survey, using $m$ sites, you can use the line see how well your results match the ‘expected’ diversity for $m$ sites. If it’s significantly different, it implies that, *even after subtracting any sampling effect*, you’ve found a real difference in diversity. So a positive residual implies a reduced sampling effect.

**Evolutionary trees (cladograms)** This method can be used if one species is known to be closely related to another. If you’ve found species A in strata right through time period $T_1$ and in strata from the following period $T_2$, and you’ve found species B in time period $T_2$, then, if you know they had a common ancestor, that ancestor must have lived before period $T_1$; so you can conclude that species B must have been around in period $T_1$, even though you didn’t find it there.

**TRIPS** It’s an acronym for ‘True Richness estimated using a Poisson Sampling’ model – a seriously statistical technique which, to quote its creators, “assumes that species observed multiple times in a given time interval have a relatively high probability of fossilisation and [therefore] of modern-day discovery. The results estimate the number of species that might be missing, and hence the true number of species that might have existed.”

**Crunching the numbers**
The residuals method seems to show that there is only one period where the trend of dinosaur diversity increases significantly (positive residuals): from their appearance around 230 Ma to around 160 Ma, in the mid-Jurassic (see chart below). But is it correct?
In the mid-Jurassic, the supercontinent Pangaea split, freeing Laurasia from Gondwana. So a dinosaur lineage from earlier periods (such as the mid-Jurassic) might have become dispersed on what would become separate continents. The break-up sequence could leave evidence in the dinosaurs’ evolutionary tree: the more recently two areas had been in contact, the more closely we would expect their dinosaur species to be related. An analysis of several dinosaur evolutionary trees showed that the geographic distribution of their fossil remains and family relationships matches the timings of the break-up sequence; so these species must have been present since at least the mid-Jurassic, even if none of their remains have found from that time.

**Something going on?**

This led Professor Upchurch to realise that there was something important going on in the dinosaur world around the Early/Middle Jurassic. New discoveries bear this out: species once thought to have originated in the Cretaceous have now been found in this period. One is *Proceratosaurus*, an early tyrannosaur; so tyrannosaurs, previously thought to have been restricted to the Late Cretaceous of Asia and North America, are now seem to have their origins in the Jurassic. And around 15 years ago in north-west China, sauropod bones were found in two quarries near Lingwu. Dr Upchurch and a colleague went there recently to examine them and have named a new species *Lingwulong* (“surprising reptile from Lingwu”). ‘Surprising’ because (a) until then, its *Dicraeosaurus* group had been known only from South Africa and the Americas – it had been thought that a mid-Jurassic marine barrier stopped their radiation into eastern Asia; and (b) the deposits turned out to be 170–175 million years old, in the Middle Jurassic. It’s become the earliest known member of the neosauropods, previously believed to have originated in the *Late* Jurassic. This will affect the dating of other dinosaur lineages, too. So there was something important going on in the Early/Middle Jurassic!
Work done in 2008 by Bristol University and others shows a large increase in the rate of dinosaur diversification in the Early Jurassic:

And in 2016, workers at Reading and Bristol modelled differences between the rates of dinosaur speciation and extinction over time (right). The colours represent the three different dinosaur groups; zero on the graph implies no change in diversity. This again seems to signal a rapid dinosaur diversification rate in the Early/Middle Jurassic. (Beware: there are problems with this data – see below.)

And the possible causes of this rapid development? Ecological niches opened up by the end-Triassic mass extinction; an erect stance, which would have allowed their skeletons to support larger bodies and helped them run fast to escape predation; and other useful evolutionarily-acquired features such as hollow bones.

Professor Upchurch and colleagues ‘weighed’ around 450 dinosaurs (if you want to try this at home, see the June 2017 issue of Stonechat, available on the Club website). They found an ‘early burst’ of body-size increase in the Early/Middle Jurassic period (there it is again!), after which things settled down – there were no more body-size niches for the terrestrial dinosaurs to grab.

Decline or fall?
Our speaker believes the story of the extinction of the dinosaurs is not as straightforward as was recently thought. For a start, the Cretaceous/Palaeogene (K/Pg) boundary, when about 65% of species, including the terrestrial dinosaurs, died out, is now dated at 66±0.043 Ma, not 65 Ma. But was their pre-boundary demise gradual? The alternative ‘Tuesday afternoon’ scenario is that it was sudden – a step change in diversity.
North America has particularly good fossil-bearing sediments across the K/Pg boundary, but its latest-Cretaceous fossil faunas have virtually no sauropods, so using this data would create a geographical sampling bias. So this chart (left) shows the K/Pg boundary at 66.0 Ma and, for a number of other Dakotan dinosaur species (numbered vertical lines), the age of each specimen (black squares), together with the period of Deccan volcanism and mean annual global temperature (MAT). It shows that the time from which these finds began to peter out is just 170,000 years or so before the boundary. Absence of more data in this period could be the result of a sampling artefact; but the presence of this data seems to contradict the idea that there was a gradual decline in diversity over the vastly longer time of 10–15 million years.

Global data for longer periods has been analysed: the graphs (right) of both global and North American diversity show an increase (tending to the right) – again, not a decline – towards the end of the Cretaceous, and the almost vertical (at zero on the x-axis, not shown here) residuals shows that the global data is reasonably representative.

Disparity and TRIPS
Disparity is a measure of the difference in the number of body forms in populations having equal number of species: will this be less sensitive to sampling errors? A population with low disparity is more likely to be vulnerable to environmental change, so a ‘healthy’ ecosystem is one with high disparity. Results for North American hadrosauroid (duck-billed) and ceratopsid (beaked) dinosaurs seem to show a decline in disparity towards the end of the Cretaceous; but a little knowledge is a dangerous thing, and further studies have shown that North America is not representative of the global fauna of the time: globally, the hadrosaurs and ceratopsids were doing fine in terms of disparity.
Using the TRIPS method (see above), ‘species richness’ remains steady over the 15 million years or so leading up to the K/Pg boundary (the RH end of each graph) for dinosaurs as a whole (top), and for their three main groups.

But didn’t the impressive Reading/Bristol graph shown in ‘Diversification rate’ above show a fall in net speciation rate leading up to the boundary? Er, yes, but it hides a flawed methodology: half the available data was not used, and data for hadrosaurs and ceratopsids in the Late Cretaceous were excluded because they didn’t show the same pattern as the other data.

Pressure-pulse?
Some ten years ago, research on the main mass extinctions dismissed any correlation between diversity and meteorite impacts, and between diversity and flood volcanism. But there was a correlation between times when both events were present.

We know that the Deccan Traps had been spewing out hundreds of thousands of cubic kilometres of lava, with its attendant gases, for several hundred thousand years before the K/Pg boundary; and we know that a huge asteroid struck the Earth at Chicxulub at the boundary, 66 million years ago. If the dinosaurs’ eco-systems had been put under stress by the former, perhaps the global effects of the latter finished them off: long-term ‘pressure’, then a sudden ‘pulse’? The debate continues . . .

This was a brilliantly clear, concise and ordered romp through a complex subject, effortlessly delivered by an enthusiast for his subject. And it showed.

Having earned a PhD in Palaeontology and a BA (Hons) in Zoology at Cambridge, Professor Paul Upchurch is now Professor of Palaeobiology at UCL, researching the palaeobiology and evolution of dinosaurs, with an emphasis on the gigantic long-necked sauroptodons. He is particularly interested in using palaeontological data to study evolutionary patterns and processes.

Papers on the web:
2008 – ‘Dinosaurs and the Cretaceous Terrestrial Revolution’ (Lloyd et al):
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2603200/
2011 – ‘Geological and anthropogenic controls on the sampling of the terrestrial fossil record: a case study from the Dinosauria’ (Upchurch et al):
https://www.researchgate.net/publication/230808579_Geological_and_anthropogenic_controls_on_the_sampling_of_the_terrestrial_fossil_record_a_case_study_from_the_Dinosauria

Back
All terrestrial dinosaur lineages became extinct some 66 million years ago. Some blame the volcanic eruptions that formed the Deccan traps, others cite the Chicxulub asteroid impact. But could it be that, if the effects of the former had put them under ecological stress, the effects of the latter could then have finished them off – the “pressure-pulse” hypothesis? This unfinished report, filed by a Late Cretaceous correspondent, has just been discovered:

The pressure-pulse hypothesis
by Gordon Judge

I’m a dinosaur philosopher with a hard-earned PhD
In Palaeogeobioevolution.
I’ve studied dino species in their great diversity
And found a problem needing resolution.

We’ve colonised all niches in air and land and sea,
And modified our body plans to fit.
But no niche could protect us if some great catastrophe
Should happen to the Earth: we’d all be hit!*

This is the Late Cretaceous, and for some time now, the sky
Has had a reddish tinge. The air is hot
And smells of something strange. I cannot help but wonder why –
There’s something going on, I dunno what.

It’s putting heavy pressure on our staid old dino ways.
“Look out for ‘pressure-pulse’”, it’s often said.
Hey, what’s that bright fast-flying thing that looks like it’s ablaze?
Is that the ‘pulse’? If so . . . we’ll soon be . . .

* Except for the lineage leading to the birds, but our correspondent couldn’t have known that.

A group of chess enthusiasts checked into a hotel and were standing in the lobby discussing their recent tournament victories. After about an hour, the manager came out of the office and asked them to disperse. He said he couldn’t stand chess-nuts boasting in an open foyer.
Sunday Funday 2018
By Gordon Judge

As last year, the Club had a stand at this annual event in Horsham Park. And, as last year, the weather was hot and sunny. Fossils collected by Mike Webster and Beryl, and Geoff’s ‘Toye Collection’, were again unearthed and exposed to public view, along with display boards about the local geology. It seems that Horsham’s childlife has an appetite for fossils hidden in a ‘lucky dip’ bran tub, and for sharks teeth and volcanic eruptions, for these activities soon became extinct over the course of the afternoon. The geologically rare appearance of four lava-spewing volcanoes in the Park demonstrated, if nothing else, that you should never let your children have a say in where you live: in response to Craig’s invitation to select a suitable housebuilding site on one of them, several actually chose locations close to its rim . . .

As Beryl, who had organised our Park presence, noted: “The organisers allotted us a good site, alongside the path that everyone was using, with lots of people stopping to see what we were all about. Pity about the wall-to-wall sunshine, but if we had been under the trees in the shade we would have been a bit away from the action. As it was we were really busy all day. There were several enquiries about the Club which will hopefully lead to new members. Few had realised that the Club existed, so it was an excellent exercise in promoting our presence in Horsham. I think we more or less covered all aspects of geology: fossils, rocks and minerals, as well as local geological information and history. In fact there was something for anyone who showed an interest.”

Back
Bug hunt in Wales
Christine Stace

Being the keen fossil hunters that John and I are, we promptly signed up to go on the trip to Wales which Mike Webster was arranging. As it was a two-day trip over one weekend, I suggested to my better/other half that it would be a good idea to go up a few days earlier to have a little holiday in Wales and after many hours of research, I found a little house, attached to the farmer’s house just above Rhayader and very near to our trilobite hunt location. So we set off the Saturday before our fossil weekend in the rain.

When we arrived near our destination it was still raining and suddenly, way over in the hills in the low clouds and mist, we could just about see our holiday home. On the Sunday, we woke up to more rain and mist still surrounded by Welsh hills and Welsh sheep; but as we started to venture out into the unknown, the weather started to improve and so it continued, with wonderful daily sunshine and blue skies.

My research had found the Radnorshire Wildlife Trust Nature Reserve’s Gilfach Farm, so one day we went to visit and decided to do “a two to three mile walk” along the side of the river, across it and up to the old railway bank. It was the wrong time of year for birds, but apparently around November the salmon return to the river to come upstream, and if one is there at that time there is a wonderful viewing platform to watch the salmon jumping. On the old railway line (closed in the 1960s) there were numerous Sessile Oaks and also bilberry bushes. At one time, people would take the train to this area at the weekend to come and pick the berries. All in all, a wonderful day, although it has to be said that it felt more like four to five miles, as far as we were concerned.

My further research took us to the Elan Valley, another wonderful area and well recommended, with its six dams. From then on, we seemed to become experts in reservoirs and dams, going to another three or four nearby where at all locations there were picnic tables for us to sit by the water’s edge and eat our sandwiches. The other place to go is Gilgrin Farm just outside of Llandrindod Wells where large groups of kites gather to be fed every day. It is a magnificent site to see: the kites swoop down, pick up the meat more or less in flight and fly away with
the meat in their beaks. The only disappointing part of our week was that there was a full moon and so we were unable to see the stars in this well-known dark sky area in their full glory, as the sky was too light.

Now on to the important part. Having left Rhayader, we arrived at our hotel, suggested by Mike, for our two-night stay from the Friday. Also staying there were Christine and Eddie and Beryl; Gill was unfortunately unable to come following her fall and broken wrists, so just a nice evening meal for the five of us. In the morning we set off in two cars to the Upper Gilwern Quarry following Mike’s very detailed instructions as to where to find the Shepherd’s Hut and quarry.

Having got very near to where the instructions told us to turn left and take an unmade road for about three miles(!), we noticed a group of people standing by their cars by the side of the road. We trundled along very happily, wondering when we would find Mike, Tracey, Sue and Natalie and finally met them at the gate. To my amazement I was opening the gate, not only for our two cars, but for another seven cars, the group having merrily followed us from their parking area.

I think we were all as surprised as each other. Our hopes of being an exclusive party of nine suddenly looked like becoming at least 20-plus: not what we had anticipated at all. Upon questioning they said they were a geological Open University Group. The owner of the Hut and Quarry came and the group were promptly given their marching orders – a relief to all of us, as we were all under the impression that we had sole and exclusive use of the quarry for the day.

Our fossil hunt began on yet another glorious day. The rocks of the hills are of Lower and Middle Ordovician age and the site has rocks from the Llanvirn Series of between 469 to 467 million years of age. The sheer number of trilobite fossils indicates a rapid burial and depth, probably from hot burning ash raining down from sub-aerial volcanoes followed by poisoning from noxious fumes. Palaeontologist Peter Lawrance has been studying this location for over thirty years and interprets this site as a near-shore shallow water environment used annually as a breeding and nursery colony for the trilobite *Oxyginus*.

We all found numerous body parts of all sizes and one or two complete trilobites, but looking at various pictures of trilobites, I would be hard put to name the ones we found. Mike Webster was the most successful finder, having learnt how to split the rocks correctly and finding whole trilobites when split. The less knowledgeable of us, just wandered around looking and we all found many pieces, both large and small,
together with enjoying yet another lovely day just sitting in the sun, having our picnic, chatting and at one time watching an unkindness of at least six ravens flying overhead.

All in all a very successful trip and worth repeating at some time, heightened by the lovely weather, of course. To end our trip, we finished up with all of us having dinner together at our hotel – the Shepherd’s Hut not really big enough to throw a cat around in let alone a sheep.

So to finish, our thanks to Mike for finding this quarry site and organising a very interesting, successful and enjoyable ‘Bug Hunt’ and who apparently found a very nice, large whole trilobite after we had left – yet to see.

Geology and transportation in the western Weald

John Lonergan

John began his detailed talk by delving below the familiar layers of Cretaceous clays and sandstones that make up the Weald to the Palaeozoic ‘basement’ rocks, which contains many deep faults:

Together with the disturbances that resulted from Africa and India colliding with Eurasia – the Alpine orogeny – repeated reactivation of these faults have controlled the geology and topography of our area.
The larger rivers, such as the Arun and Adur, pre-dated the Wealden uplift and have strongly influenced how transport routes developed.

**Horsham**

In prehistoric times there was little settlement in the Weald because of its forestation and heavy clays: most settlements were on the fertile coastal strip or the Downs.

Definite (dots) and probable (triangles) Late–Middle Palaeolithic hand-axe finds in Sussex

After the last Ice Age, sea level rose, causing rivers to erode sediments from their banks: valleys became less deep and hills less steep. Before that, transport would have been even more challenging. Worked flints indicate some human presence in the Neolithic, and tree cover had been cleared by about 1500 BC. After the Norman conquest, the Horsham settlement grew rapidly because of its position at the Western end of the Weald (avoiding the heavy clays of the Low Weald), which gave it good transport links, and its proximity to London. By the 1880s, Horsham had become a place of the well-heeled, and was used for Government functions such as the assizes, gaol and barracks. A brief decline when these were removed led to renewed growth when the railway arrived in 1848.

**The Roman legacy**

It wasn’t until the Romans’ properly-engineered roads (typically a gravel base below a layer of large stones, then a cambered layer of flints, topped by compacted slag,
gravel or cobbles – the upper layers being restrained at their sides by an earth bank – and drainage ditches along either side) that wheeled vehicles could pass one another easily. Their roads across Sussex were supply routes to Londinium.

They exploited the minerals of the Weald, especially for their iron industry (whose slag was used to surface roads); but this ended around AD 250 when the resources of the Forest of Dean proved more economical. After their troops left, the Roman transport infrastructure began to fall apart. Roads and bridges were now maintained by religious communities, who would also levy tolls on traffic.

We have little information about trans-Weald routes in the Mediaeval period, but what Wealden roads there were could only be used in summer: it could take up to two years to drag a large timber, destined for the Navy at Portsmouth, out of the Weald. By around 1360, most of the Roman network had disappeared:

Strategic routes, such as the road between Winchester and London, and roads from Canterbury to the south and to the Archbishop’s properties, remained. Wealden iron-making grew up again from the 16th century, eventually producing cannons for the military. Like the Navy’s timbers, these had to be dragged from their production site to rivers, then taken by sea to Woolwich for testing. Most traffic and shipping used coastal routes – until these were disrupted by the Napoleonic wars of 1803 to 1815 . . .

**Turnpikes**

From the late 1600s, Acts of Parliament granted groups of local worthies, set up as Trusts, the right to collect tolls from users of stretches of highway, and to raise loans secured against the expected revenues. The loans would be used to repair and maintain the road, while the tolls would be collected at toll gates, or ‘turnpikes’, the term becoming used also for the turnpiked road itself. Our speaker noted that
the quality of repairs was variable, with many turnpiked roads still being impassable in winter.

From the mid-18th century, the innovations of ‘Blind Jack’ Metcalf, Thomas Telford and John McAdam led to much more durable road surfaces similar to the Roman design, with good foundations, a graded and compacted stone base, a convex top surface and side ditches to aid drainage. From the early 20th century, a layer of hot tar was added and rolled into the top surface to bond and seal it. Stone chippings could then be added and rolled in. Later, the top layers of many main roads were replaced by a cambered reinforced concrete surface.

John ended his survey of Wealden transportation with a review of the artificial waterways proposed (though not always constructed) for our area. For a more detailed description, see the December 2015 Stonechat report of his talk that year.

After fielding questions from members, Beryl thanked John for such a well-researched and detailed talk.

John Lonergan is the Chairman and Field Trip Secretary of the West Sussex Geological Society and a Chartered Civil Engineer. He joined Belfour Beatty in 1986 and is now with WSP | Parsons Brinckerhoff and currently working on the Great Western Electrification Project.
A stroll around active volcanoes

Chiara Petroni

Report by Debbie Brand

At our October meeting we were joined by Dr Chiara Maria Petrone from the Natural History Museum’s Department of Earth Sciences, for a stroll around some of the world’s active volcanoes. This didn’t sound like the usual sort of evening ramble, but we were in safe hands with our knowledgeable guide, and so were able to take a close look at even the most dangerous of volcanoes.

Knowing the neighbours
Volcanoes are always a popular and interesting topic, both for people who live near them and those of us in quieter lands. Their constant presence and influence on their neighbours often leads to unique and varied perceptions of their characters. This can range from respect, to unease, and sometimes affection. Japan’s Mount Fuji (often referred to as Fuji-san) is viewed with respect by those nearby. The constantly active Stromboli is simply referred to by locals as iddu – ‘him’ in the Sicilian dialect. Popocatépetl in Mexico, which we heard about last year from Dr Petrone, has a legend associated telling of how Popo, a local warrior, went off to war, and his lover Iztaccíhuatl died while awaiting his return. When he discovered this, he froze and was turned into the mountain, while she became the extinct volcano nearby.

The Importance of being active

A volcano is usually considered to be active if there has been at least one eruption in the last 10,000 years. It can either be erupting or dormant, where it is likely to erupt in the future although not currently active. Extinct volcanoes are those considered unlikely to erupt again.
Some volcanoes occur as a one-off but dramatic event that takes everyone by surprise. These are called monogenetic volcanoes; they erupt only once. Parícutín in Mexico is a classic example – it appeared in 1943 over the course of a few weeks in a cornfield belonging to farmer Dionisio Pulido. The ensuing powerful eruption completely covered the town of San Juan Parangaricutiro, and activity continued for nine years until 1952. Hundreds of people were permanently relocated, although the volcano has been dormant ever since.

Others are known to be active, but are keeping quiet - for the moment at least... They are generally irregular and unpredictable. Both Fuji and Vesuvius are currently quiet (last eruptions were 1708 for Fuji and 1944 for Vesuvius), but each has the potential to endanger millions of people. Vesuvius has had lots of large Plinian eruptions (also known as Vesuvian eruptions after the 79 AD event that destroyed Pompeii); these are powerful gas-driven eruptions resulting in high ejected columns of ash, volcanic debris and hot gases. The last big Plinian event at Vesuvius was in 1631, but activity has continued ever since, varying from every few years to thousands of years between events. There is an evacuation plan in place for the 600,000 people living in the area at greatest risk from hazards like pyroclastic flows, fall out of ash and lapilli, and potential mud and ash flows after rainfall.

Then there are the restless ones; these are constantly active, sometimes for hundreds of years and are often well-known names like Etna and Stromboli, Mexico’s Popocatépetl and Merapi in Indonesia.

Lastly there are the very quiet ones, not known to be active until they erupt. The volcano of Chaitén in Chile was one such example; the first signs of seismic activity in 2008 were initially attributed to another nearby volcano. Within the next few days ash plumes appeared up to 17km high, followed by another bigger Plinian eruption and a 30km column of ash. There was however a quick evacuation response despite being unexpected, although high levels of rainfall during the first week re-mobilised the ash, creating a mud flow which destroyed 80% of the town. Other examples of sudden big eruptions include Pinatubo in the Philippines in 1991, Novarupta at Mount Katmai in Alaska in 1912 and El Chichón in Mexico in 1982. None of these had erupted before in recorded history, but these last three examples were the three largest eruptions of the last century. This rather worryingly suggests that the next large eruption could come from where we’re not expecting.
Keeping Track of the Troublemakers:
Many volcanoes around the world are closely monitored by observatories. Vesuvius had the first ever volcano observatory, the Osservatorio Vesuviano established in the early 1840s. Today there is also the Global Volcanism Program from the Smithsonian Institution. For those who are curious, or just nervous, its informative website (see web link below) shows all monitored activity around the globe, and has statistics and maps of past and present volcanic and earthquake activity, and sulphur dioxide emissions.

Predicting the future?
So the challenge for scientists is to understand how to forecast an eruption – mainly when, how big and what type of eruption is likely – this will determine whether to evacuate and how big an area is likely to be affected. At Merapi, the most active volcano in Indonesia, in 2010 there was a Plinian eruption that was much stronger than usual. 400,000 people were displaced, and nearly 400 died. But thanks to close monitoring which had picked up an increase in levels of activity over the previous month, alerts were issued and many people were evacuated away from the affected areas beforehand.

Earlier this year the Hawaiian Volcano Observatory (HVO) was in the news during the April eruption of Kilauea. It started with a decrease in the level of the lava lake in the volcano’s Halema‘uma‘u crater, followed by a crack opening on the eastern flank of the crater. Over the next couple of months there were a series of eruptions and up to 22 fissure openings. The caldera was completely altered; with the lava lake gone, the crater had dropped and changed shape. The HVO was able to provide detailed updates and communications for the local population and although many houses were destroyed nobody died.

Warnings are unfortunately not always possible though. On 3rd June this year the Volcán de Fuego in Guatemala had a very sudden pyroclastic flow, one of the deadliest volcanic hazards. This was a very active volcano, almost constantly active at a low level; but with no
warning and almost no evacuation time, the sudden flow completely destroyed a town nearby and more than one hundred people died.

Dr Petrone’s previous talk focussed on Popocatépetl, the most active volcano in Mexico and showed us how by learning about the past activity we can understand current and potential future events. We heard about the latest methods of diffusion chronometry that look at the crystal composition of minerals formed beneath a volcano (see Stonechat June 2017). The minerals give us information if we listen and learn. Scientists’ understanding of the volcanic plumbing system has changed a lot over the last decade or two; we now know that there is often a complex network of reservoirs and layers of magma.

The talk ended with a note from Etna herself: a physicist colleague of Dr Petrone’s had taken the seismic signal of Etna and translated it into music – we heard the intriguing voice of the volcano expressed with jaunty strings, gradually building up with an orchestra of pipes and clarinet, before slowly fading out. We then ended our ‘stroll’ with effusive applause and plenty of questions.

Dr Chiara Petrone has a PhD from Florence University and is currently a Research Leader at the NHM, with a mission to investigate the relationship between the timescales of pre-eruptive magmatic processes and the dynamics of a volcano’s plumbing system. She hopes to determine whether Popocatépetl’s current moderate explosive activity will culminate in a Plinian eruption.

Web ink: Smithsonian Institution’s Global Volcanism Program: https://volcano.si.edu/
Out of 9 million specimens held at the NHM, some 250,000 are echinoderms, so curating this collection is no small task. In that context, some members of the club had previously met Tim whilst at the Museum for a ‘back-room’ visit, and that had sparked an interest in hearing a talk from him. He currently has a finger in many pies: for example, he participates in a good number of research projects on echinoderms with co-workers from around the world; he has edited the latest, now the 8th, edition of *British Mesozoic Fossils* (now with a lurid red cover!) and has written the app “Fossil Explorer”. Quite a diverse background.

He made an interesting aside regarding our local geology: writing a piece for a field guide for Wealden fossils, he had contributed a single page on echinoderms, contrasting that with several chapters for the corresponding Yorkshire Lias publication.

Tim then launched into a detailed description of echinoderms, their construction, their appearance and their various modes of life. He pointed out that echinoderms have more in common with us than they do with, for instance, snails or brachiopods. The fossil remains of an echinoid such as we find locally in the Chalk is not an exoskeleton, not a shell, per se, but can be likened to a skeletal structure. He gave a rather graphic and amusing analogy, in comparing the outer ‘shell’ of a sea-urchin, an echinoid, to that of the human skull: we have soft bits inside, hair outside, but in the case of the echinoid for ‘hair’ think ‘spines’.

We were then introduced to the 5-fold symmetry and plumbing systems of echinoids, and the facility of a starfish to recover from the trauma of ripping away a leg or two. One interesting point was the description of the manner in which some crinoids can stick to a substrate, such as a rock. It is usually suggested that this involves a sucker mechanism, but actually crinoids secrete a gum-like protein, which in turn can be dissolved should the creature wish to move. Apparently they are not entirely static, affixed to a rock.

The second part of the talk became more specific to the Yorkshire Lias. Tim described the location of the outcrops, the difficulties of access, and the cold, unlike Dorset where it is easy to wander onto the beaches. Tim’s discussion of the relevant fossils to be found in that part of the
Lias was in considerable and interesting detail, but too complex to relate here. Tim pointed out that much work has been done from about 1820 to around 1890, but that little has been done since. But systematic research is currently underway, and new fossil types are being discovered as modern work is proceeding. He showed images of superb specimens: two of these excellent and prize items had been gifts to the Museum by Yorkshiremen, no less! Tim acknowledged that perhaps reputation of Yorkshiremen as skinflints might be modified. (I’m a proud exile from God’s Own Acre.)

In conclusion, yet again, as on many occasions previously, the Event’s Secretary, namely Beryl, has found an excellent and lively speaker to come to talk about their work, one who is both knowledgeable and working at the rock-face. This was a most informative talk given by a consummate enthusiast for his topic.

Dr Ewin is a senior curator at the Natural History Museum, with specific responsibilities for the fossil echinoderm collections. He actively researches fossil echinoderms and plants, and manages staff who cover the collections of Bryozoa, Corals, Cephalopods, Brachiopods and other smaller invertebrate groups. In addition, he is active on the committee of the Geological Curators Group.

Book and app:
Fossil Explorer app: free to download – see http://www.nhm.ac.uk/take-part/identify-nature/fossil-explorer-app.html

Peter Webster adds: Tim’s talk about the Yorkshire Lias reminded me of that Spring Bank Holiday week in the late 1970s, when the HGFC went camping and fossilling in the East Riding. Who could forget the near neck-breaking descent some took to the beach? Our then leader had enthusiastically but completely erroneously suggested that this was a short-cut. Then, hours later we were staggering back up that mighty cliff, successfully laden with a rucksack or two of Lias beach material. However, there was a unique Eureka Moment! A founder member, Derek Brown, now sadly departed, was the proud owner of an absolutely pristine-new geological hammer, recently acquired for this trip. On reaching the beach, someone, I think Frank, picked up a spherical cannonball of the black Lias rock from the beach debris. It was chosen completely at random, about 20cm in diameter. The suggestion was made, “Here Derek, try your
new hammer on this!”. Derek duly obliged, more in hope than expectation. One quick blow, quite literally, a clean break, the rock split, and the remarkable result can be seen in the photograph above.

Custody of the said stone has now passed to us where it lives in an old sock for its protection. It appears regularly at our talks to the primary school children and causes a real ‘wow’ of amazement.

A field trip to the roots of the Hercynian mountains
by Beryl Jarvis

In praise of field trips in general . . .
Here in the South East we are fortunate in having quite a few geological clubs and societies, as well as having London and the Geological Association not far away. Many have programmes that include field trips. We are lucky having an enthusiastic Field Trip organiser in Mike Webster who knows the Wealden district and sites really well and has together with Peter Austen, introduced many members to our local quarries and pits and more. Further afield, trips recently have been to Dorset with our president Bob Chandler, and in the past we’ve been to Devon, Cornwall, Wales and Iceland amongst other places. Mike’s autumn trip to find trilobites in Wales was a new departure – see report on page 11. I hope that some of our members who haven’t thought of going on a field trip might be persuaded to dip a toe in.

Over the years as well as a variety of trips with Horsham I have been on many trips with other geological Societies including Farnham, West Sussex (based at Worthing) Harrow and Hillingdon, Reading and the GA. We have been to locations in the UK as well as abroad. All have been really worthwhile and interesting and welcoming. Some field trip leaders produce a well-researched Field Guide. All have a real interest in the area that they take us to.

Numbers on field trips are generally between 10 and 25, the accommodation usually arranged for us and we all have meals together. Sometimes there is a talk in the evenings about the geology to be explored the next day. Although we mostly arrive individually we usually share just a few cars each day when visiting sites. Longer trips usually have a free day for sightseeing etc. For trips abroad travel arrangements are made for you generally through a travel company who arranges flights, tickets, local transport, accommodation etc, and
insurance is available. As to who goes on them... the people are as varied as those in our club. Some know a lot, some know a little but all are interested to find out more. Clubs welcome non-members.

... and one in particular
This was a three-day May field trip in 2017 to visit the south west coast of England between Torquay and Start Point and inland to Dartmoor. It was organised by Farnham and led by Dr Mark Eller. This was quite an active trip with quite a lot of driving between sites and between 2 and 3 miles walking a day including treks down narrow Devon lanes to reach the locations and lots of clambering over rocky outcrops on the beaches. Mark had produced a fantastic Field Guide and his patience in explaining everything we saw was commendable. We were based at an hotel in Ashburton The aim was to see what had happened in this area during the Devonian, Carboniferous and Permian periods, a time when the Rheioc ocean gradually closed and two great land masses, Laurussia on its northern shores and Gondwana on the southern, met head-on. This collision produced the extensive east/west Hercynian mountain range, (equivalent to the Himalayas) and the new supercontinent was Pangea.

**Laurussia** (also known as Euamerica was a minor supercontinent created in the Devonian as the result of a collision between the Laurentian, Baltica, and Avalonia cratons during the Caledonian orogeny, about 410 million years ago.

The area that we visited had been on the southern shores of Laurussia, a passive margin. As the Rheioc Ocean started to close, the oceanic crust was subducted south under Gondwana as Gondwana moved northwards. This put our area under tension so E/W rifting occurred forming a succession of half-grabens in a back-arc extension situation with some associated volcanism. When the two land masses
finally collided and only a sliver of oceanic crust was left, the extensional faults reversed and changed to compressive faults as Gondwana continued to push northwards. The Laurussian sediments were buried deep and metamorphosed to varying degrees as the continental crust thickened and formed the Hercynian mountain range in the Late Carboniferous. A series of thrust nappes formed as the push continued from the south. The remaining sliver of ocean crust (mentioned earlier) got caught up in an early thrust northward and was pushed up over the continental crust (obducted) to become the Lizard ophiolite.

This all happened during the Devonian and Carboniferous periods. By the early Permian our area was in the middle of the supercontinent and just north of the equator. Erosion of the Hercynian Mountains happened big time in the hot dry climate: wadis, flash floods and alluvial fans disrupted the landscape. Continued oxidisation coloured the landscape permanently red. As the area became unroofed decompression occurred and huge tongues of granitic magmas moved up through the crust. These cooled and crystallised to form the Cornubian batholith. There is considerable mineralisation within the surrounding country rock. It took 30 million years for all these multiple granite intrusions to be emplaced!

**Day 1**

Our first day was spent identifying the various sediments deposited over the Devonian period. We concentrated on locations between Torquay and Brixham. This area is in the South Devon Basin formed over one of the earlier half grabens. In the Early and Mid-Devonian, limestone reefs formed in shallow seas over the highs of Torquay and Brixham. Most living creatures would then be found in the sea, and they were abundant. At Daddyhole Cove (an important Geopark) and Brixham Quarry we saw rocks full of corals, crinoids, brachiopods etc. and really impressive stromatoporoids. At Babbacombe we saw Late Devonian thick dark black mudstones. These we

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**Stromatoporoids**

Stromatoporoids grew by secreting calcareous sheets and are preserved as rather conspicuous fossils. Some formed domes in excess of 5 meters in diameter. This growth process resulted in layers (laminae) parallel to the substrate, and rod-like pillars perpendicular to the laminae. The layers closest to the surface of the skeleton probably contained living tissue; layers away from the surface appear to have been back-filled with calcite. The surface of the skeleton, where most of the living tissue resided, has raised structures called mamelons, presumably serving as sites for excurrent openings.
understood were the result of an exponential increase on land of seed-bearing trees that produced thick layers of black anoxic sediments in the seas. This caused the sea life to die in several extinction events in the Late Devonian. We found a couple of outcrops of basic igneous dolerite at Babbacombe that had been produced during the rifting caused by extension.

Other sediments that we saw were Permian. The erosion and weathering of everything deposited after the late Devonian including any Carboniferous sediments and the whole of the Hercynian mountain range had produced distinctive red mud, sand and silt deposits lying uncomfortably on the Devonian beds. We saw Permian flash flood and alluvial fan conglomerates containing Devonian limestone clasts at Oddicombe Beach. At Saltern Cove and Brixham Quarry (Berry Head) we were introduced to neptunian dykes where fractures in the grey Devonian limestones had an infill of red Permian muds and calcite.

Day 2
On the second day, we visited the adjoining older basin to the south, the Looe Basin between Brixham and Start Point. Here we saw how the sediments had been altered during the Carboniferous era by having been subjected to increased temperatures and pressures during burial. We went to Man Sands, Blackpool Sands, Lannacombe Beach and Prawle Point to see how metamorphism had increased in grade and altered the mudstones as we moved south, from shales and slates through phyllites to schists. At Prawle Point the minerals in the metamorphic rocks had changed completely to greenschist which took its pale green colouring from epidote and chlorite, and also contained albite, mica and lots of long amphibole crystals. These rocks had probably originated as Devonian volcanics.

Day 3
On the final day, we went inland to look at the roots of the Hercynian mountains, the granites. We visited Hay Tor, a small-scale 18th century quarry and the granite railway that had employed horse-drawn trucks to take the quarried granite on part
of its journey to the coast and eventually London. The granite composition showed how fractional crystallisation and richer compositions at the various stages of magma intrusion had produced a porphoritic texture near the upper margins as it cooled with large three-inch feldspar crystals in a smaller grained matrix of quartz and mica. This ‘Giant Granite’ showed that Hay Tor and the surrounding area were very near to the top of the original magma intrusion. Boron which was also in the melt but not involved in granite formation was available to form large chunks of tourmaline. Other incompatible minerals not needed moved through cracks and fissures that had formed in the granite and surrounding rock as the melt cooled and produced veins containing minerals such as tin, copper, lead, arsenic, tungsten, silver and gold. At the same time groundwater circulating through the top of the batholith in places was altering the feldspars to form kaolinite.

We went to Bag Tor and Birch Tor where you could see where tin had been mined from before the 1700s. The shafts were now water-filled and fenced off for safety. Looking at the quarry faces at Burrator we could see the contact between the granite and the slates of the country rock and saw how the slates had been altered to hornfels. In places chunks had broken off and been incorporated into the melt. We made a stop at Two Bridges quarry where we saw how the feldspars in the granite had been altered to kaolin and had been washed away leaving a coarse quartz/mica rich gravel. Finally we saw the enormous Lee Moor quarry at Blackaton Cross where kaolin was currently being mined. Kaolin (China Clay) amongst other things is primarily used in paper manufacturing process, but mining for it produces an enormous amount of waste – 90% – which ends up as vast spoil heaps.

We saw far more than I have mentioned: more sediments, fossils, minerals, rocks, varieties of folds faults thrusts and only hope that what I have understood is correct! You had better not quote me! It was a great trip and as always will encourage me to do more reading. Many thanks Mark!

Where on the face of the earth can we find a spot on which close investigation will not discover signs of that endless cycle of change, to which this earth has been, is, and will be subjected?

Charles Darwin, The Voyage of the Beagle
Club Programme 2019

Wed. Feb 13  The Chalk Cliffs and Shore Platforms of Sussex. Dr David Robinson, University of Sussex
Wed. Apr 10  To be arranged – watch the Club website!
Wed. May 8   AGM
Wed. Jun 12   The Last British Ice Sheet. Dr Bethan Davies, Royal Holloway
Club meetings
Unless otherwise stated, all evening meetings are held at Forest Community School, Comptons Lane, Horsham at 7 for 7.30pm. To ease the Treasurer’s mind, we ask for a nominal contribution of 20p for coffee and biscuits.

Field trips
Field trips require appropriate clothing: waterproofs, stout boots or Wellingtons. All geological sites are potentially dangerous and members are reminded that they attend field trips at their own risk. Any children attending are the sole responsibility of parents or guardians. It is always advisable to telephone a Committee member, if you are coming on a field trip, in case there are any last-minute changes.

Equipment for Field Trips
Some UK sources of tools, clothing and other equipment for field trippers are:
UK Geological Equipment (Freephone 0800 0336 062)
Order online at http://www.ukge.com
Geo Supplies Ltd (0114 245 5746)
Order online at http://www.geosupplies.co.uk
Geology Superstore (0800 977 8539)
Order online at http://www.geologysuperstore.com

Geological Maps and Area Guides:
British Geological Survey (0115 936 3241)
Order online at http://www.bgs.ac.uk/catalogue/home.html
Geologists’ Association (020 7434 9298)
Order online at https://geologistsassociation.org.uk/shop/

Free tide Predictions:
Tides4fishing (auto-corrects for BST)
For any date (select date on calendar, and select place using map):
http://www.tides4fishing.com/uk/england
UK Hydrographic Office (manual correction needed for BST)
For six days ahead:
Edited by
Gordon Judge
gordon.judge1@virgin.net

[Credits: Upchurch/Researchgate (diversity and residuals graphs); NHM (Proceratosaurus); Lloyd/Proc Biol Sci/NIH ('Increasing diversity' graph [simplified]); Sakamoto/PNAS ('Net speciation rate per Myr' graph [simplified]); Brusatte/Cambridge Philosophical Society ('Dinosaur species occurrences', 'Residual global diversity' and 'Diversity/disparity' charts [both simplified]); John Lonergan’s slides (Weald section & Roman roads map); chobham.info (Gough map extract); Susan Rowland/Philimore (Roman roads); Matt Pope/reseachgate.net (hand-axe find sites); Alan Rosevear/Flickr (turnpike map); Volcanodiscovery.com (Halema’uma’u crater); blackwellpublishing.com (echinoid section); newscientist.com (human head section); sciedirect.com (collision of Laurussia & Gondwana); Wikipedia (Laurussia); Beryl Jarvis (Rheic Ocean/Laurussia sketch), OUGS (Berry Head); dartmoor.gov.uk (Hay Tor); forum.ukuleleunderground.com (dinosaurs & ark cartoon)]