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Tetrapod World: early evolution & diversification

Newsletter No. 14, January, 2018

It's over a year since I distributed the last Newsletter, and I thought it would be good to summarise the main results of the project. Much of this is already known, but I hope you'll still find this gives a more coherent picture.

In the past I've restricted news to two sides of A4, to make life easier for anyone that wants to print off a hardcopy, but this one, most likely the last for this project, exceeds that.

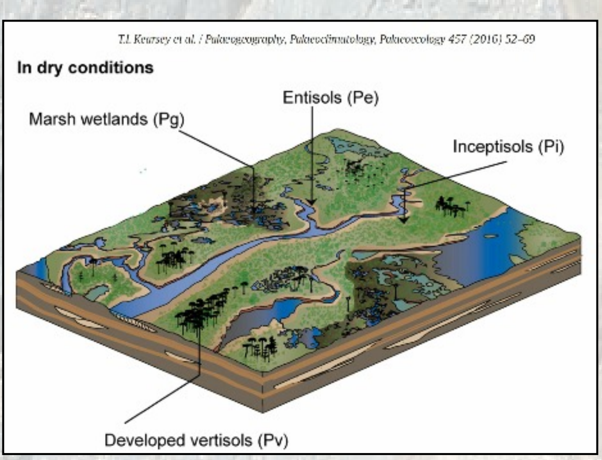
Environment

In the earliest Carboniferous, Europe and North America were close together not far from the equator, and sliding past each other, resulting in volcanic activity and mountain-building. There's a diagram illustrating this on the final page.

All our sites were close to the sea, but while those in Scotland, particularly the more western ones, were subject to some marine influence, with occasional marine incursions, those in the east were less so, being much more continental flood plain.

The landscape was low-lying, with streams, rivers, lakes and ponds, and extensive vegetation on the land surfaces of these flood and coastal plains, although little of this would have been very tall. Large trees seem to have become extinct at the end of the Devonian, and taken some time to reappear. The climate was generally monsoonal.

The low-lying coastal and flood plains were subject to marine incursions primarily generated by storm surges associated with monsoon conditions. The marine influence is quite cryptic and in the more easterly sections, including Burnmouth and in the borehole that we drilled in 2013 a few miles west of Berwick upon Tweed, is largely identified from distinctive burrows with some macro- and microfaunal fossil evidence. Here the storm surges would have advanced up rivers, increasing the area affected.

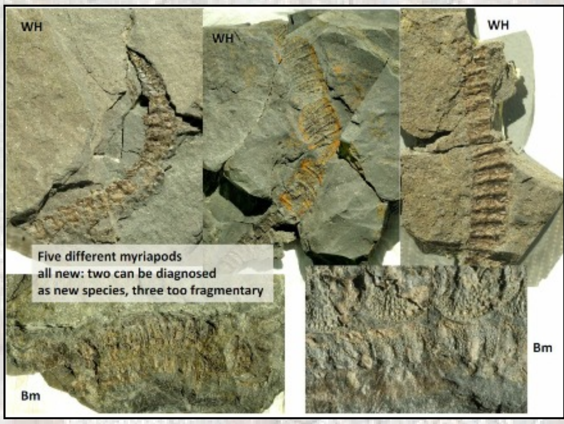


In Northumberland, the sedimentology and the fauna indicate a more marine-influenced setting with the most westerly sites closest to the sea. Marine conditions were probably established from time to time in Northern Ireland, as shown by the presence of stromatolites. Heavy seasonal rainfall alternated with very dry periods, during which intense evaporation resulted in water bodies becoming hypersaline lakes, where layers of evaporites were deposited, or dried out completely.

At Burnmouth in particular, there are also numerous palaeosols (fossil soil layers). These come in various flavours – waterlogged, dessicated, or alluvial soils, for example. Many of those at Burnmouth are reddish layers with snaking, branching, greenish root traces visible. Palaeosols were also found in the borehole core .

Invertebrates

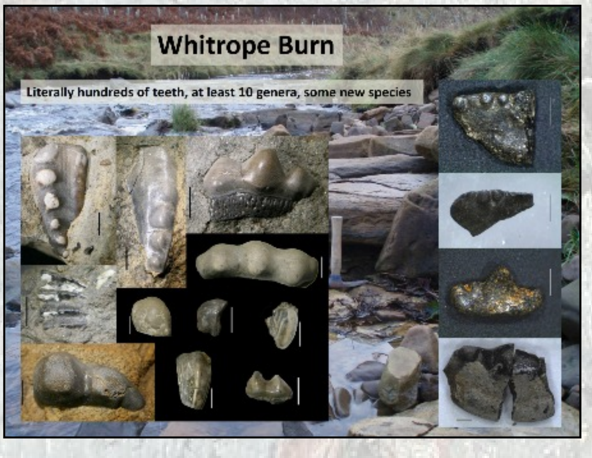
We have found five myriapod (millipede) specimens, all new to science. Sadly, only one of these is sufficiently complete to name. A paper describing it is in press.



Sharks and Rays (Chondrichthyans)

Before the start of this project, the number of early Carboniferous chondrichthyans from the UK was very restricted, but we have found hundreds of specimens, representing at least 20 recognisable taxa, and so far two new to science (in press). Most of these came from the bed of a stream in the Borders Region called Whitrope Burn.

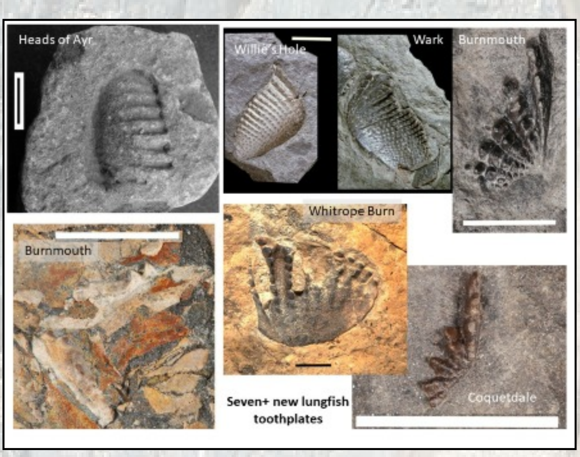
They are all preserved as isolated teeth. 14 came from fish with crushing dentition that looked more like modern chimeras, while six are more typical pointy shark's teeth. We think they lived in lagoons, at least partially open to the sea, and we did find a single rock layer at Whitrope Burn containing crinoids. These are related to starfish and sea urchins and are definitely marine, so at least that layer was deposited under open sea.



Lungfishes

Previously, there were two securely-dated lungfish tooth plates from the entire world in this time period. In 2015 we published descriptions of seven new taxa of lungfish in the scientific journal Palaeontology, and quite a few more have come to light since.

Although we do have numerous isolated lungfish bones and one articulated partial skull, most of our lungfish are known only from their tooth plates. The patterns of rows of teeth and the angles with each other are all very characteristic, and allow us to give them separate names, even though we don't know what the fish themselves looked like. No doubt some future palaeontologists will find body fossils with the tooth plates intact, to fill that gap in our knowledge.



Judging by some of the isolated bones we have found, some of these were two to three metres long.

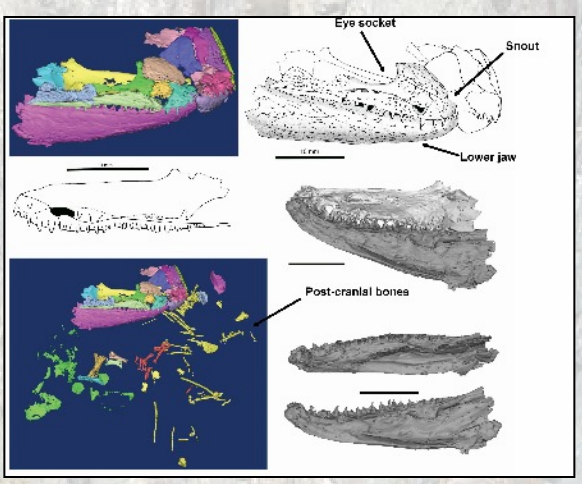
Other Fishes

We have lots of specimens of ray-finned fishes (most modern fishes are ray-finned) which are being worked on, but nothing has been published so far. The same applies to a group of extinct fishes called rhizodonts (the name is derived from the Greek meaning rooted tooth) of which we have many from Burnmouth, some of which were also two to three metres long. A paper describing some of these has recently been submitted for publication.

Tetrapods

In the period covered by this project, the Tournaisian, there was previously only one tetrapod known from around the world, as well as lots of isolated bones and trackways from Nova Scotia. In 2016 we published a paper in the scientific journal Nature Ecology and Evolution describing five new taxa of tetrapod, and there are plenty more out there. All our specimens are very fragmentary, and these five are the only ones for which we actually have enough data to describe and name them, and start to work out their relationships to other tetrapods.

We have another seven taxa of tetrapod for which the material is insufficient to identify them, although it's enough to say they're distinct from each other and the ones we have described.



The specimen above was discovered quite by accident. A student was studying some lungfish bones that were sticking out of a piece of rock and asked for the block to be micro-CT scanned so he could see what they looked like inside. To everyone's amazement, the scan revealed the front part of a tetrapod skull, along with a scattering of post-cranial bones!

It is still completely invisible to the naked eye, being inside the rock, and is likely to remain so, as it's far too fragile to excavate. We named it *Aytonerpeton microps* after the parish of Ayton, in which we found it. "Erpeton" means "crawler", and "*microps*" means "small face."

We named another of our tetrapods *Ossirarus kierani*. *Ossirarus* is derived from Greek, implying scattered bones, and *kierani* honours Betty and Oliver Kieran, representing the Burnmouth community, who have supported us and encouraged local interest and cooperation from the start.

The fragmentary nature of the fossils we've found is unfortunate, because although we've shown that Romer's Gap didn't exist, this was the period during which the largely aquatic tetrapods that survived the end-Devonian extinction evolved to become fully terrestrial, and we still have few specimens to show us how that change took place.

Plants

We don't have much intact plant material, but we do have vast numbers of plant spores, which our team in Southampton have been studying in depth, dissolving the rock in hydrofluoric acid to leave the spores visible. This is how we know that the land surfaces were covered with vegetation, and that most of this was sprawling and low-lying with few big trees.

Plant spores are readily identifiable and their parent plants existed for finite periods of time before becoming extinct. This has enabled the Southampton team to identify the Devonian/Carboniferous boundary at Burnmouth, something not previously known. This allows us to calculate that the earliest tetrapod fossils we have from Burnmouth lived only about a million years after that.

We also have lungfish fossils from the same bed as the tetrapod, and this throws up an interesting point. There is a theory that after a mass-extinction, such as at the end of the Devonian, the surviving taxa tend to be rather small; the so-called Lilliput effect. This does seem to be true, in that our earliest tetrapod specimen (not *Ossirarus*) is pretty tiny, but it's not true of the lungfish, which are quite a respectable size. So it may be that the Lilliput effect is real, but applies differently to different groups.

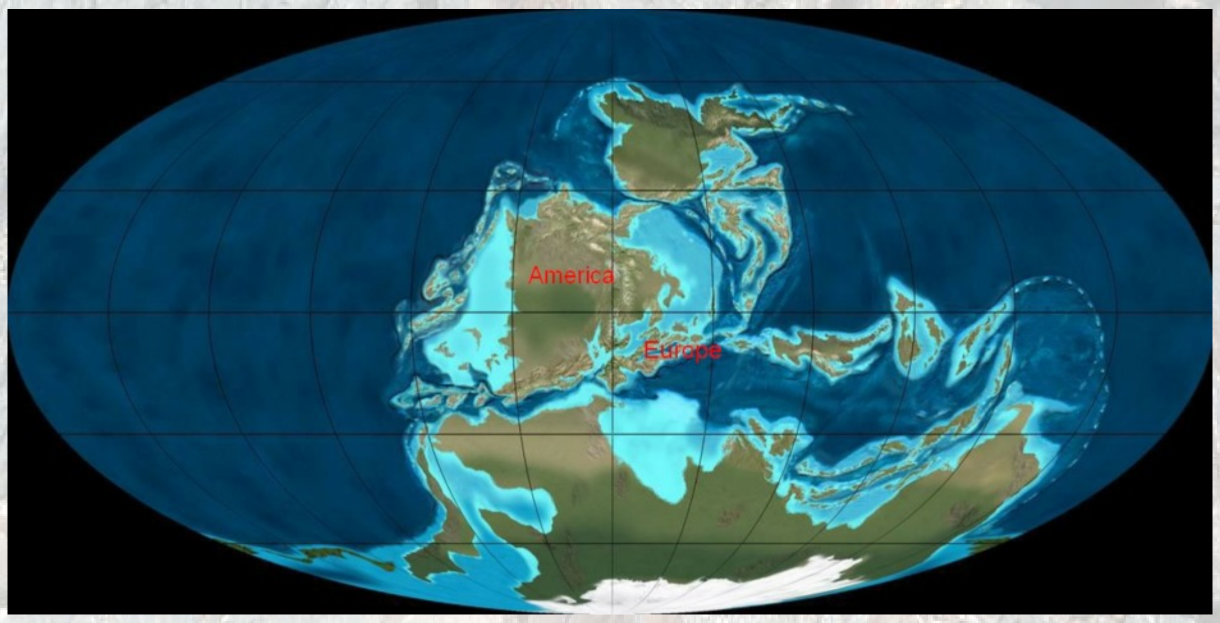
Conclusion

We think this project has been a fantastic success and has answered many of the questions we were asking when we started out. Although the funding has run out, there is still masses to do. I don't know what everyone else has on the go, but Jenny Clack in Cambridge has four papers in preparation, and I have the impression the same goes for many of our other collaborators.

We've shown that Romer's Gap was a collecting anomaly, we think brought about by no-one looking in the right rocks. The Tournaisian continental deposits in the UK tend not to have any component useful enough to make quarrying worthwhile; no coal, no oil, not much decent building stone, and so on, as a result of which, no 19th century industrialists bothered to quarry the stone. With no-one digging the rocks up, no fossils came to light, and eventually, the palaeontologists started to assume there was nothing there to find, so there was no point looking.

It was only as a result of Tim Smithson's 25-year persistence, studying his geological maps and visiting the Borders Region for odd weekends to look at the rocks that we started to realise there really were fossils there to find, and that understanding was greatly enhanced when he involved the late Stan Wood in the search.

By showing that Romer's Gap was an artefact, we hope to encourage palaeontologists around the world to start looking at Tournaisian continental deposits, to show us a much fuller picture of the world as it was then. The more you look, the more exciting it gets!



The continents as we think they looked during the Tournaisian