The Devonian System

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This talk is produces from Richard Edwards's notes that he produced when doing his talk on 14 Feb. Occasionally the text refers to pictures which are not present, I hope this does not detract from the write up too much.

Introduction

The Devonian System takes its name from Devonshire where the system was first recognised by Murchison and Sedgwick in 1836. The lecture begins with an account of the controversy which raged in the 1830 s concerning the age of these rocks, which reflected a more general uncertainty amongst geologists over the primacy of fossils or lithology in correlation.

The main part of the lecture is concerned with a modern interpretation of the Devonian System in the Welsh Borderland and SW England with particular reference to the palaeogeography.

The outline of the lecture

The Devonian controversy in the early 19th century

The Devonian System in England and Wales
Anglo-Welsh Basin
Cornubian Basin

Greywackes and the Transition Series

By the end of the 1820 s geologists had established in a general way the broad sequence of rocks from the Old Red Sandstone through to the Tertiary. However, the older, more complex, and apparently less fossiliferous rocks were assigned to the Transition Series. The most common rock type recognised within the Transition Series was a type of impure sandstone to which the term greywacke (derived from German mining term - grauwacke) was applied. Sometimes the names were used in a similar fashion to denote an ancient series of rocks, older than the Old Red Sandstone.

The Transition Series 1822

Maps shows the distribution of Transition Series rocks in England and Wales as mapped in 1822. The assumption was that they were all broadly the same age.

The protagonists

The interpretation of these older Transition Series led to some bitter controversies amongst the leading geologists of the day. In this lecture series we focus on how these rocks were mapped and interpreted in Devon and Cornwall and the accompanying disagreements about their age. The key characters were Henry de la Beche and Roderick Murchison.

De la Beche had been born into a wealthy family but at the time of this controversy he had fallen on hard times and was desperate to find paid employment as a geologist. He was especially anxious that his mapping in Devon should be regarded as of high quality in order to bolster his reputation.

Murchison was a wealthy man of military background who had been persuaded to channel his energy into the newly developing science of Geology. He was determined to forge a reputation as a leading geologist based on his work on the Transition Series in the Welsh Borderlands.

Murchison interprets the Transition Series in the Welsh Borderland

Murchison and Sedgwick had embarked on the task of mapping and establishing a stratigraphy for Wales and the Welsh Borderland. This led to Murchison defining the Silurian System in 1835. Of key importance was his recognition that Transition rocks could be traced without a major break downwards from the Old Red Sandstone. He followed William Smith in using the fossil content of the rocks as indicators both of age and for purposes of correlation. It was Murchison who proposed the title of Father of English Geology on Smith, but perhaps with the purpose of enhancing his own approach to geology.

De la Beche enters Devonshire

In 1832 de la Beche s comfortable life as a gentleman geologist was transformed by the collapse of his income from his estate in Jamaica. He badly needed a regular income and wished to continue his interest in geology. Through the intermediary of influential contacts such as Sedgwick he received a government grant of £300 to produce a geological map of Devon. At this stage the Transition Series was regarded as mainly greywacke with minor limestone bands and some carbon rich sediments with minor coal seams which were called Culm. De la Beche s task was to produce a geological map and work out the stratigraphy.

The problems of the Culm

The controversy which followed from de la Beche's mapping centred on the Culm and the use of plant fossils for correlation. De la Beche collected fossils from the Culm although they were rather poor specimens. He saw a resemblance to fossils of Carboniferous age but continued to regard the rocks as belonging to the Transition Series. At this stage in the development of Geology it was thought by many leading geologists in England and France that coal could be found in these older rocks. Murchison and Lyell were both vociferous in stating their views that coal was only found in rocks of Carboniferous age. This argument had huge economic significance because Britain produced about 53% of World coal production at this time.

De la Beche s interpretation

The slide shows a cross section drawn by de la Beche in a note to Sedgwick. The Culm is shown as being situated low down in the Transition Series and de la Beche considered the rocks were equivalent to the Cambrian which Sedwick had defined in North Wales. The synclinal structure was based on his correlation of two limestone bands which were later found to be of differing age.

Whilst de la Beche toiled away in Devon his critics in the Geological Society in London were rubbishing his intepretation   although few of them had ever seen the outcrops he was describing.

De la Beche attacks his critics

De la Beche could not afford to return to London to face his critics but sent a cartoon to Sedgwick lampooning his enemies in the Geological Society. The title is Preconceived opinions versus facts. De la Beche is standing on the left pointing to his nose. This gentlemen is my nose. His adversaries respond My dear fellow your account of yourself may be very well but as we have classed you before we saw you as amongst men without noses, you cannot possibly have a nose .
The point De la Beche is making is that he has seen all the geological evidence whereas they are merely theoreticians speculating about rocks they have never seen.

Murchison and Sedgwick inspect the evidence

In July 1836 Murchison and Sedgwick took the night coach from London to Bristol and then headed for Bridgwater to start their fieldwork armed with Greenough s geological map of England & Wales and De la Beche s newly published large scale maps of Devon. By this time the fossils from the Culm had been confirmed by a specialist palaeontologist as being equivalent species as those from the Carboniferous in the Midlands.

Murchison was therefore convinced of the Carboniferous age of the Culm and believed that De la Beche had missed a major unconformity due to the absence of the Old Red Sandstone below the Culm.

At this point De la Beche was still using the greywacke lithology as his evidence for the much older, possibly Cambrian status of the Devon rocks.

Whilst Murchison and Sedgwick inspected his terrain poor de la Beche was mapping in Cornwall or possibly just watching the Cornish rain coming down?

Murchison s preliminary map

They firstly visited coastal exposures of the Culm which further convinced them of its Carboniferous age. They were often very critical of de la Beche s mapping for example at Combe Martin Murchison noted this part of De la Beche's map wretchedly worked out. However, De la Beche s large scale map allowed them to visit all the key exposures quickly.

If the Culm was Carboniferous and the other Devon rocks were Cambrian there must be evidence for a major unconformity and the search for this vital evidence became their main objective. However, all the exposures pointed to a gradual progression between Culm and Transition with no apparent break. Murchison had to concede on this point.

Following their reconnaissance visit they concluded:
The structure of Devon was broad trough occupied by the Culm of Carboniferous age
The rocks below the Culm seen as Silurian or Cambrian (note M starts to use the word Devonian, but as a sub-division of the Cambrian)

They reject De la Beche's structural interpretation on the basis that the limestones he correlated were in fact of different age.

In less than four weeks of fieldwork M& S had largely unpicked the work carried out by de la Beche over a period of three years!

However, the absence of an unconformity at the base of the Culm remained an unresolved problem.

Sparring partners

There followed a period of increasingly acrimonious exchanges between the two camps. The key differences between related to the probable age of the Culm.

M & S argued that the plant fossils should be the principal guide (using Smith s approach and these had been shown to have close affinities to Coal Measures rocks in other parts of England. The greywackes below were seen as probably Cambrian but the absence of an unconformity remained a stumbling block.

De L Beche was not prepared to accept the plant fossils as evidence of the age of the rocks. He believed that too little was known about the distribution of plants in the Transition Series and cited examples from France where plants had been described from the greywackes. De la Beche was still regarding lithology as a guide to dating rocks.

Geology of S W England (1838)

In 1838 John Phillips, William Smith s nephew, and a distinguished geologist and palaeontologist published a series of geological maps of Britain. He showed the Culm as being Carboniferous but coloured them as being equivalent to the Millstone Grit rather than Coal Measures. He was anxious not to suggest that a major coal field was located in Devon. The map showed that the consensus was swinging towards M&S.

Murchison & Sedgwick announce the Devonian System

In 1839 Murchison (with Sedgwick as nominal co-author) published a key paper entitled "Classification of the Older Stratified Rocks of Devon & Cornwall"

The paper had two objectives:
i) To claim priority for the trough structure of the Culm (not acknowledged by De la Beche)
ii) To suggest that the greywackes below the Culm were equivalent to the Old Red Sandstone
Murchison proposed that these sediments belonged to a distinct System which he called the Devonian

The Devonian System (2017*)*

Murchison defined the Devonian System on the basis that a distinctive fossil assemblage occurred within limestones. However, Devon and Cornwall represent a poor area for pinning down exact points of stratigraphy. The sediments, mainly mudstones and slates, are poorly fossiliferous and complex deformation has made sedimentary sequences difficult to unravel. Stratigraphers and palaeontologists have therefore turned their attention to Devonian sequences in continental Europe for the fine tuning.

Decisions on where boundaries should be made are decided by an international panel. Reference sites are proposed which must fulfil certain requirements such as complete sequences without any faulting and must contain a range of fossils which can be correlated with other areas. Usually the appearance of a key fossil marks the definitive moment in time

These markers in geological time are informally known as 'Golden Spikes". The spike for the start of the Devonian is marked by the appearance of the graptolite M. uniformis and the section occurs at the village of K?? near Prague, Czech Republic. This followed a long controversy and the final decision was not made until 1972! Note graptolites were pelagic organisms which had wide geographical distribution
Brits get a look in so the Golden Spike for the base of the Ordovician occurs at Dobbs Lyn, Moffat in the Scottish Borders and for sub-divisions of the Silurian System.

Whilst looking at the Geological Column note the number of Systems which have been devised by British geologists. Most of them.

Old Red Sandstone continent (Laurussia)

During Devonian times Britain lay on the edge of a great continent, termed Laurussia or sometimes the Old Red Sandstone continent. This continent formed as a consequence of the merging together of a number of smaller continental plates culminating in the Caledonian orogeny. Thus northern Britain was characterised by a mountain chain which formed the main source of sediments in the Anglo-Welsh Basin in late Silurian times.

Distribution of Devonian in southern Britain

The map shows the distribution of Devonian rocks in southern Britain. In the lecture I will focus on the well exposed continental sediments of the Anglo-Welsh Basin and the marine sediments of the Cornubian Basin. However, note that sub-outcrop extends across much of southern England and has been recorded in 32 deep boreholes. These reveal a varied range of lithologies but allow a tentative boundary to be drawn between continental and marine facies.

Late Silurian/early Devonian geography

The geography of Britain in Late Silurian and early Devonian times is shown in the maps. In Pridoli times the conditions in Wales and its borderlands had become a shallow alluvial plain, uplifted in the early stages of the Caledonian orogeny. Devon and Cornwall formed a landmass, feeding sediment northwards. However by Lower Devonian times a series of extensional basins had developed in Cornwall and Devon with a progression from continental to shallow marine conditions.

In Lower Devonian a southward progressing front provided the main source of sediment.

The greening of Britain.

Early plant life is detected in rocks of Ordovician age which contain spores. We can reconstruct the pre-Devonian environment as having fungae , lichens and bryophytes but these were confined to damp environments. Cooksonia, the first vascular plant with a plumbing system, is recorded in rocks of late Silurian age and has been described by Professor Dianne Edwards as “the grandmother of all agriculture”. Plants now had the physiology which enabled them to migrate away from water courses. First descriptions of the plant were made in 1937 by William Lang from Perton Lane in the Woolhope Dome area. Cooksonia grew to ankle height.

Zosterophyllum evolved from Cooksonia in Early Devonian times. In contrast to Cooksonia, which died after releasing its spores, it had a growing tip on its central stem, whilst spores were produced on side branches. This plant grew to knee height.

Prototaxites

A terrestrial fossil fungus dating from Late Silurian to Late Devonian (430 – 360Ma). It formed trunk-like structures up to 1m wide and 8m tall. On a microscopic scale they are formed from narrow tube-like structures which weave around one another.

The true nature has been a matter of debate since first described in 1843. In 2001, after 20 years of research American Francis Heuber classed it as fungus on the basis of morphology.

Carbon isotopes suggest that Prototaxites did not use photosynthesis. It is suggested that it fed from the surrounding substrate with a wide ranging network of mycelia.

Stratigraphic summary

The diagram shows how conditions of sedimentation changed in Devonian times both regionally and with time. Things to point out:

I) Subdivisions of the Devonian
ii) Sediment in Anglo-Welsh Basin dominated by muds in Pridoli and sands in Lower Devonian
ii) Townsend Tuff
iii) Marine conditions through mid Devonian in Devon/Cornwall
iv)Acadian unconformity

The transition from the Silurian to the Devonian marks the end of the marine phase of the Anglo-Welsh Basin which had been a zone of rapid subsidence and deposition of both sediments and volcanics since Cambrian times. Now the evidence suggests a profound pause with a stable landscape persisting for tens of thousands of years. Deep weathering of this landscape resulted in the development of thick calcrete horizons. These are especially well developed in Pembrokeshire.

Environments of deposition

Before looking at the rocks which represent the Lower Devonian in the Anglo-Welsh Basin let's look at their environment of deposition. Three zones can be distinguished:

Zones of calcrete accumulation in inter-fluves.
Minor streams draining from and eroding the calcrete.
Major south flowing streams draining an area outside the immediate area.

Anglo-Welsh Basin (Herefordshire)

One of my favourite views in Herefordshire from Froome Hill. The low-lying ground in the middle ground underlain by Silurian mudstones (Pridoli).) Analysis of the heavy mineral fraction within the mudstone indicate a source of metamorphic rocks in the Scottish Hihglands. The scarp formed by Devonian Freshwater West Formation dominated by sandstones. In the distance the Black Mountains (Lower Devonian).

In Herefordshire the transition from Silurian to Devonian is marked by both calcrete development and by the change to coarser sediments as sandstones start to dominate over mudstones.

Transition from Silurian to Devonian

As we saw in Pembrokeshire the change from continental Silurian (Pridoli) to Lower Devonian is marked by a series of calcrete horizons which mark a long period of stability in the landscape. The Bishops Frome Limestone (now Chapel Point) is the most important horizon, marking the transition.

Freshwater West Formation (St Maughan s Formation) 700m

We now see much coarser sediments with sandstones forming 35% of the succession. Current bedding suggests that the sands were transported from the north and northwest. The heavy mineral fraction contrasts with the underlying Pridoli mudstones where metamorphic minerals predominated. Now the heavy minerals suggests sedimentary and volcanic sources, probably from the adjacent Welsh massif.

Fining upwards cycles can be recognised at varying scales. Inspection of Cradley Stone in Malvern buildings shows how some fining up leads to horizons which are susceptible to weathering (inset).

Senni Formation 300m

Until recently this formation was thought to be restricted to Black Mountains. However, recently John Davies has suggested that the ORS sediments in S. Herefordshire designated by BGS as Brownstones should be re-classified as Senni Formation.

I) Flaggy sandstones with low angle current bedding suggesting sluggish flow rate overlying calcrete.
ii) Soft sediment deformation structure caused by escaping water.

Brownstone Formation- Ross 1200m

This formation is characterised by 1200m of coarse pebbly reddish-brown sandstones. Good examples can be seen in Ross-on-Wye and Goodrich Castle. The coarse nature of the sediment reflects the emerging landmass to the north and west as the deformation front of the Acadian orogeny moved southwards.

This deformation culminated in a phase of uplift so that the area became a positive feature rather than a zone of deposition. Thus there are no Middle Devonian sediments in the Anglo-Welsh Basin.

Acadian orogeny (Caledonian)

The orogeny south of the Iapetus suture is referred to as the Acadian - named after a former French Province, now Nova Scotia.

Two phases. Uplift in Pridoli already mentioned. The second phase resulted in gentle folding producing the Ludlow anticline (image). The folds have NE trending axial planes.

Acadian faulting took place along pre-existing faults and many new faults were initiated. Most Acadian faults were normal including Church Stretton fault.

Ludlow anticline

The geological map shows the Ludlow anticline which is plunging towards us. Dark blue shows Aymestry Limestone Formation. Low relief in middle ground underlain by Moors Cliff Formation. The lower part of Clee Hill underlain by Freshwater West Formation.

Major fault shown on map is the Leinthall Earls Fault, a normal fault formed in a later extensional phase.

Huntsman Hill Conglomerate

The start of Upper Devonian sedimentation is characterised by a spectacular conglomerate, The Huntsman Hill Conglomerate, in which rounded clasts of quartz predominate. The remaining part of the succession consist of a fining upwards sequence of sandstones.

Pembrokeshire

View of Marloes Sands. Silurian in foreground?

Pembrokeshire- location map.

Localities visited.

Picture of Brian Williams explaining an aspect of calcrete formation - gilgae structures formed by wetting and drying of soil.

Ritec Fault

In Pembrokeshire during the Lower Devonian sedimentation was dominated by fluviatile environments with sources of sediment derived from the north, very similar conditions to those in Herefordshire. However, subsidence on the north side of the fault during sedimentation led to marked variation thickness. As a consequence Lower Devonian on the N side ranges up to 4437m whereas on the S side the thickness max is 1422m.

During the later Variscan orogeny the Ritec Fault changed from a normal fault to a thrust.

Environments of deposition

We have already discussed the broad picture of sediment environments in the context of Herefordshire. The Pembrokeshire coastal exposures provide a superb opportunity to observe the detailed sedimentation within a meandering river system.

We begin by studying the outstanding exposures of calcrete at Llansteffan and then look at the detail of deposition within a point bar setting on a meandering river.

Chapel Point Limestone

Calcrete is the product of soil formation under particular climatic conditions. The gradual change from soil to a type of limestone is driven by a number of factors:

Climate where evaporation is a key process
Plants plant roots play an important role
Ground water rich in calcium carbonate

At Llansteffan it is possible to trace the development of calcrete within a soil horizon. Initially calcium carbonate rich ground water percolates along plant rootlets. These vertical structures can be clearly seen. In some cases the very large structures have been attributed to fungi rather than plants. The horizontal layers are conglomerates with closets formed from fragments of limestone these will be explained later.

Super-mature calcrete

At Llansteffan six calcrete profiles are recognised. Here we see both super-mature and immature profiles.

Point Bar sedimentary sequence

In a meandering river erosion is concentrated on the convex part of a bend whilst deposition takes place on the point bar (see top image). A cross section though a point bar (bottom image) reveals the complex stack of sediments which build up from a coarse lag deposit at base to silts in the upper horizon. Each stage of accumulation is characterised by specific sedimentary structures.

The succeeding slides relate this model to the Freshwater West Formation at the locality of Freshwater West.

River channel within Freshwater West Formation

Note clear channel profile. Also the first indications of the newly formed channel.

Location: Freshwater West: channel fill

The cycle of sedimentation begins within the main channel with an erosional base and depostion of a lag gravel with clasts formed from collapsed bank material – evident as conglomerate.

The main channel sequence is dominated by coarse sands with trough cross bedding. The latter results from deposition on undulating dune surface.

Location: Freshwater West: lateral accretion

Now we consider deposition within the point bar. Sediment varies from medium to fine grained sand. Structures characterised by climbing ripples.

The lower image shows low angle accretionary bedding.

Fine sandstone with Beaconites burrows

Rootlets not evident here but instead we find evidence of burrows termed Beaconites. Recent studies suggest that these were made by primitive millipedes that burrowed down to the water table to hibernate or moult during periods of drought.

Ridgeway Conglomerate Formation

An upward coarsening sequence of red sandy mudstones, fine to coarse grained lithic arenites and conglomerates. The class in the conglomerates include quartzites, greywackes, siltstones and vein quartz. At higher stratigraphic level phyllite class can be seen which reveal a source of metamorphic rocks.

The age of the Ridgeway Conglomerate Formation is uncertain, possibly late Lockovian. It is interpreted as forming in an alluvial fan with the source being south of a major fault in the Bristol Channel area.

Palaeogeography in mid-Devonian times

Central and northern Britain are an eroding landmass with no deposition taking place. Map shows position of coast, zone of shallow water and marine basin underlain by oceanic crust (shrinking Rheic Ocean).

The Cornubian Basin

Gurnards Head: Upper Devonian marine sediments with pillow lavas. Also the site of an Iron Age fort. Pub recommended.

Marine Devonian in SW England

To the south of Pembrokeshire occurred the coastline of the ORS continent. A shallow marine shelf basin (pale blue) merged southwards into deeper marine basins.

In contrast to the NE-SW trending structures which are characteristic of the Caledonian orogeny the influential structures in Cornwall and Devon are mainly NW and E-W trending which are believed to be reactivated basement faults which were first formed in the Cadomian orogeny.

These faults played a major role in the development of the Devonian and Carboniferous sedimentary basins across the region. They were later reactivated during the Variscan orogeny.

Extensional basins of Devon & Cornwall

Extensional movements and differential subsidence/uplift on E-W (Cadomian) and NW SE basement structures led to the development of sedimentary basins and rift-related basic volcanism. The area was occupied by six sedimentary basins with sediment supplied by nappe structures moving northwards. A range of clastic sediments and basic volcanics fill the sedimentary basins.

The map also shows the location of the Lizard Complex which contains NE-SW fabrics.

The Trevone Basin

I have selected the Trevone Basin for more detailed study. The map shows location and the defining structures. Defined on east by the Cambeak/Cawsand fault and to the north by E-W trending normal faults. Subsidence took place through Middle and Upper Devonian with accumulation of 6000m of predominantly marine sediments over a period of about 37 million years (390 327 Ma). Note St Austell granite dated at 281Ma. Thus the history of the evolution of this part of the orogenic zone extends over more than 100 million years.

Half-graben model of Trevone Basin

Recent research has led to the construction of a model which shows the Trevone Basin divided into two zones on either side of an E-W trending normal fault which is an extensional reactivation of a thrust.

The Pentire Formation is restricted to the footwall of the fault and has a more limited succession which includes significant vulcanicity. The Trevone succession is much thicker and comprises mainly marine sediments.

Stratigraphy of Trevone/Pentire

Fossils traditionally used to work out stratigraphy are rare in rocks of Devonian age in Cornwall but in recent years progress has been made using goniatites, clymenids (ammonoids),conodonts and thin-shelled finger print ostracods. The latter are crustaceans that live in the upper part of the sea floor (benthos). They are typically very small, just a few mms in length. They provide valuable information about age and environment.

Points from the stratigraphic table:

Contrast in periods of deposition both within and without basin
Trevone Basin mainly marine apart from Meadfoot Beds which are regarded as forming in shallow water conditions: mudstones,siltstones and sandstones with cross bedding predominate.
Pentire sequence contains basaltic pillow lavas.

Trevose slate

Trevose slates were deposited in a marine environment with 4000m of hemipelagic mudrocks deposited. Barred basin environment has been proposed with rapid subsidence and fill. Horizons of pyritised black shale indicate anoxic conditions. Note relevance to causes of mass extinction.

Marble Cliffs Trevone Bay
Limestone turbidites near top of succession suggest an intra-basin carbonate rise.
Note – a rare occurrence of carbonate rocks in Cornwall.

Purple slates

The Polzeath Slate Formation is characterised by its purple colour which represents a widespread change in sedimentary conditions across NW Europe.. The red pigment indicates a deficiency in nutrients from the Caledonian source areas, specifically organic matter, nitrates, iron, and phosphates.

Pentire Point

Now we have crossed over the Camel estuary where we are within the Pentire succession. Initially dark to mid-grey mudrocks followed by a sequence of extrusive volcanic rocks. Fine grained alkali basalt flows, water-lain tuffs and pillow lavas predominate. These volcanics are highly vesicular.

The pillows are interpreted as the toes of pahoehoe flows rather than deep water pillows.

Palaeogeography of Britain in Late Devonian

Main points:

I) The Upper Devonian geography of Central England & Wales does not at first sight differ markedly from Lower Devonian apart from early signs ofVariscan orogeny such as Lizard ophiolite.
However…….
Major changes include…..

Late Devonian flora

During the Devonian plants continued to grow larger, to develop roots and move beyond the limits of river banks. By mid-Devonian both leaves and roots had developed.

By the end of the Devonian the first forests had developed. In 2007 the accolade of World’s first tree was awarded to Wattieza, following discovery in New York state . Dated at 385 Ma.

Here I have chosen to focus on Archaeopteris, which is more widely distributed and known in more detail. It ranged in age from Late Devonian to early Carboniferous (383 – 323Ma).

A. is known as the first modern tree because of bearing buds, reinforced branch joints and branched trunks, more similar to modern seed bearing trees than other spore bearing taxa.

The tree grew to 30m in height with leafy foliage. The large fronds were thickly set with fan shaped leaflets. The trunks of some species exceeded 1.5 m.
The first seed bearing plants also developed in the late Devonian. An example is Elkinsia, a seed-bearing fern from late Devonian described from USA.

One consequence of the flourishing of plant life was the increase in oxygen content and decrease in VCO2 content of atmosphere – more conducive to animal life on land.

Also impact on rate of erosion.

Evolution of atmosphere

The graph shows the increasing content of oxygen in the atmosphere from Silurian times and peaking in the Carboniferous. At the same time carbon dioxide dramatically decreasing. These changes are a consequence of flourishing land plants.

How is oxygen in past climates detected? The global geological cycle of C and S involving exchange of reduced C&S between rocks, atmosphere and oceans controls levels of oxygen in atmosphere. The main information about oxygen in atmosphere comes from C & S isotopes.

Tiktaalik

In 2004, following 6 years of research on Ellesmre Island in the Canadian arctic, a team led by Neil Shubin, found a skeleton of a transitional animal between a fish and a land-living animal. There are a number of differences between Tiktaalik and most other fish. Lungs! Live -fish were first described from South America in mid 19th century. Fossil examples described from Gaspe peninsula, Quebec in rocks dated at 380Ma.

Wrists and push-ups

A key anatomical development evident in the skeleton of Titaaliks limb is the basic design of an arm and hand. We can recognise the basic plan of humerus, radius, ulna. This structure enabled Titaalik to effectively do push up and so drag itself along a mud bank, thereby escaping predators and finding new sources of food.

Late Devonian extinction

*Y*ou can see from the graph that the Late Devonian marks one of great five mass extinctions in the Phanerozoic. However, it had less severity than the others.

Families 19%
Genera 50%
Species 70 – 80%

In contrast to the Late Cretaceous event which seems to have been one dramatic episode the Devonian was marked by 4 extinctions at widely separated intervals. One of the most marked was the Kellwasser event at the Frasnian/Fammenian boundary. Named after the type locality in Germany.

The Kellwasser event

The Kellawasser event occurred at the Frasnian/Fammenian border. The following became extinct at this point in time: certain types of brachiopds, trilobites, conodonts. This event also witnessed the demise of coral reefs which had flourished for 100 million years. Animals which thrived in cool waters seem to have survived which suggests a period of global cooling. In contrast animals whose habitat was warm tropical waters fared badly.

Causes of extinction

A number of explanations have been proposed for the extinctions:

I) Fluctuating temperatures in the marine environment. Examination of the slide shows marked sea temperature changes at this time. Early K event marked by rise in temperature whilst upper K shows drop in temperature. Both events coincide with rising sea level.
NB Temps obtained from O2 isotopes from biogenic apatite

ii) Anoxic conditions indicated by black shales. Enhanced burial of organic carbon is shown by positive carbon isotope excursions during the anoxic phase (see diagram). C13 is depleted in terrestrial plants where photosynthesis is important. Increase in vegetation led to draw down in atmospheric and oceanic CO2 levels and culminated in significant climate cooling. These short term cooling episodes were superimposed on a longer term warming beginning in middle Devonian, with up to 8 degrees warmer temperatures in latest Frasnian.

Anoxic conditions possibly caused by intensified nutrient content which may be due to a development of land plants, phosphorus from volcanic activity, enhanced weathering due to early Varsican uplift.

Iii) No evidence for meteorite impact large enough to cause extinction.

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