FOSSILS - Curated Transcript of BBC In Our Time podcast
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In Our Time is hosted by Melvyn Bragg. Melvyn's guests on this podcast are:

Richard Corfield, Research Associate in the Department of Earth Sciences at Oxford University,

Dianne Edwards, Distinguished Research Professor in Palaeobotany at Cardiff University, and

Richard Fortey, Senior Research Palaeontologist at the Natural History Museum

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Transcript:

[Melvyn Bragg] Hello. In the middle of the 19th century, the discoveries of the fossil hunters worried John Ruskin greatly. He wrote in a letter in 1851, "My faith, which was never strong, is being beaten to gold leaf. If only those geologists would let me alone, I could do very well. But those dreadful hammers I hear the clink of them at the end of every cadence of the Bible verses." The testimony of fossils has been remarkably eloquent when we've wanted to listen. And now, with mass spectrometers, electron microscopes and secondary X-ray detectors, these long dead organisms can speak to us of the past in ways they never could before. With me to discuss the place of fossils in history and the impact of the latest techniques in understanding them is Richard Corfield, Research Associate in the Department of Earth Sciences at Oxford University and author of a new book called "Architects of Eternity - The New Signs of Fossils". Also with us is Dianne Edwards, Distinguished Research Professor in Palaeobotany at Cardiff University, and Richard Fortey, Senior Research Palaeontologist at the Natural History Museum and author of "Trilobyte! - Eyewitness to Evolution".

[Melvyn Bragg] Richard Fortey, great breakthroughs in paleontology were happening in John Ruskin's time, as we've learned, but the evidence of some of the fossil record has been plainly on display for thousands of years. Can we start with the Greeks... what did they make of the fossils in the rocks?

[2:18]
[Richard Fortey] Well, there was a common belief that the remains of large fossil mammals that were eroded out of cliffs in the Greek islands were the evidence for the Gigantomachy, the battle between the gods and giants, with the gods triumphant. And other fossils were regarded as physical proof of the existence of gigantic heroes. There was very little in the way of what you might call scientific study of fossils, although, as usual, Aristotle had a few wise words to say. But the scientific appreciation of fossils was ignored, really, in classical times.

[Melvyn Bragg] But there was something from, as I understand it, and I've just been reading up at this obviously, from Pythagoras and Herodotus and Anaximander, that fossils were to do with water, that they'd come from water, is that right?

[Richard Fortey] Yes. I think it was recognized that water must have once occupied areas which it did no longer. But even in the Renaissance, there were scholars... Leonardo da Vinci for example, really recognized quite presciently that there were major inundations that must have covered the land. But his line really wasn't taken up until really until the 17th century.

[Melvyn Bragg] So the story is sort of very sporadic - a little Greek, less Latin, nothing much else until the Renaissance.

[Richard Fortey] Yes, it was a very late developing science, if you compare it with, say, astronomy or physics.

[Melvyn Bragg] Again, did Leonardo, just to tease out the history a little bit more, did Leonardo say anything which, as it was, set it on its course, or something you can draw on now as saying, "yes, he kicked that bit off"?

[Richard Fortey] Well, I think it was unpublished. It was in his notebooks and like many of his notebook writings, they seem prescient in retrospect, but were rather ignored at the time.

[Melvyn Bragg] What were they, though? What did he say?

[Richard Fortey] I believe he noticed that some of the shells were of similar types to things that could be found around the Mediterranean today and that therefore the disposition of land and sea must have changed.

[Melvyn Bragg] Is there any accounting for the lack of interest in what has become such a fascinating and interesting topic over the last, say, 150 years, Diane Edwards?

[Dianne Edwards] I personally don't know of one, but it does seem that things started happening in the middle of the 17th century. And an unsung hero of Paleobotany might be Robert Hooke, who's known as a physicist these days, but he was Polymathic. And he was the first person who actually looked at petrified wood - wood that's preserved as a rock - and worked out how it formed. He had a microscope and he also looked at decaying vegetable matter and said, "Well, not much of this is going to become fossil". And then this was taken up by later workers, so they had a very good grasp of what was going on then, but I think very many of them were reluctant on religious grounds to actually come out and say what they actually thought fossils were. But I think they believed it.

[Melvyn Bragg] Yes, but looking just one more thing before we get onto the 17th and 18th century, many men and women must have seen the fish in rocks and they could account for this, if they were very religious, by the flood. Were there any other subversive accounts that you can think of over those nearly 1,500-2,000 years?

[Dianne Edwards] I don't know of any. Perhaps you do, Richard? You [may have]...researched this?

[Richard Corfield] I'm just thinking about it. One of the interesting things about the history of paleontology is this enormous dead zone between the time of the ancient Greeks and the 17th century, which is when the ball started rolling and sort-of reached takeoff velocity in the 19th century, because Herodotus, Pythagoras, Empedocles and Anaxamander had noticed that there were invertebrate fossils on land the remains of what were clearly gastropods - types of molluscs - which were only known from ocean waters. And they were on land. And so they made this connection that there must once have been sea where now there was land, and Pliny, and one or two of the Romans, took it up. And then interest in paleontology just kind of dissolved for another thousand years, more than a thousand years until in the 13th century Risero D'Aretzzo came up with the idea of the Deluge. And of course this immediately gained currency, especially in a kind of clergy-driven environment of the day and stayed there until Leonardo da Vinci in the 15th century who...actually reconnected with the Greeks and was dissatisfied with the Deluge theory, what became known as the Neptunian theory. And there was know a kind of popular idea of the day, a pop culture idea for the explanation of fossils in the sort of Early Medieval period is that ... they were "sports of nature" put there by God as a bit of a joke just to keep people on their metal. But it was Leonardo who really reconnected with the Greeks and established fossils or paleontology on a firm scientific footing. His notes are in his thousands and thousands of words in mirror writing. And ...from then you had Agricola in the 16th century who actually coined the term "fossils" and that's where we have the term from and it started to develop from that. But really, as I've said, [the study of fossils] accelerated only in the 19th century.

[Richard Fortey] Agricola's interests, of course, were mostly mineralogical and he really set the science of mineralogy, which of course is part of geology, on a modern course and had relatively little to say about fossils themselves. But it was all part of a general revival in the interest of the earth as an object of scientific study which kind of set the scene for other scientific explanations to follow.

[Richard Corfield] You could argue that paleontology and geology at the time of Agricola in the 16th century hadn't really separated into two separate disciplines.

[Melvyn Bragg] Well, let's move forward quite steadily in this. In the 17th century we have Samuel Pepys praising somebody called Edward Cluid [?] in his diary. Now

...Diane Edwards, what was he praising about Cluid? What was Cluid's theory of fossils?

[Dianne Edwards] Well, Edward Lhuyd was the deputy curator or keeper at the Ashmolean Museum, which had a collection of both animal and plant fossils as well as well as minerals. And he produced the first catalogue for the Ashmolean. He was a very poor man. He came from Oswestry, in North Wales. He was a great naturalist, a linguist. But he needed money to publish this catalogue and so he enlisted the help of people like Sir Hans Sloane, Samuel Pepys, Isaac Newton, and they all got together and they paid for the publication of this small catalogue, which has the first illustrations of fossil plants, as far as I know, in it. And these are Welsh plants. And Samuel Pepys and Hans Sloane are said to have drunk a toast on the day that it went to press.

[Melvyn Bragg] What was his explanation of theory of how these fossils had arrived, where they'd arrived?

[Dianne Edwards] He thought they were freaks of nature.

[Melvyn Bragg] He thought they'd been put in place by God.

[Dianne Edwards] Yes. He had a colleague called John Ray, who was a great botanist and a chap interested in classification, and he predated Linnaeus in this. And John Ray knew what fossils were and they had long discussions on this, but Lhuyd never really came out and said that they actually were living organisms.

[Richard Corfield] He had a strange idea called the Spermatic Principle, which was that inside the tip of every male sperm there was a little homunculus, and that this could only come out when it was fertilized. And his idea was that fossils were kind-of "sports of nature" because the womb of Mother Earth had sort of semi fertilized this spermatic principle. And so this is where fossils had come from and why they were found in so often fragmented, because they were partially formed by, as it were, inadequate fertilization procedures.

[Melvyn Bragg] ...[It sounds] like the scenario for the next American blockbuster! [laughter]

[10:28]
[Richard Fortey] He did find the first trilobyte too, around ... the town of Flandilo, and he referred to them as "diverse flatfish".

[Melvyn Bragg] So in the 18th century, it's gathering force in this country, anyhow. ...The United Kingdom seems to be playing quite a big part; a lot of people are engaged in this. Richard Corfield, when do you think it comes of age? Does it begin to gather together in the 18th century? And who's pushing it forward then? What are they telling us? We've mentioned Linnaes, or Dianne has mentioned Linnaes already.

[Richard Corfield] I mean, without plugging without wishing to plug Oxford too much,... one of the foci for the coalescence of what I now call the "new science of fossils" was the [Oxford University] museum. But even before that, there were great paleontologists and geologists working in and around Oxford associated with the clergy, it has to be said. I'm thinking about Buckland and William Smith. And William Smith was the father of the geological map, which is an often denigrated part of paleontology and geology in the present day, but in fact is a way of seeing the way time passes simply if you walk across the landscape, because rocks of different age outcrop in different places and certain places in the present day. I'm thinking about the classical Bottaccione Gorge section in central Italy. You can simply walk up a road and walk through time. So these were the kind of ideas which were being established at the beginning of the 19th century.

[Melvyn Bragg] Richard Fortey?

[12:04]
[Richard Fortey] William Smith, of course, used this as a pragmatical guide to strata. He had himself no particular religious axe to grind. He was a practical man, a driver of canals and a surveyor. He used the strata as a very practical means and the fossils in the strata as a very practical means to know where he should drive his next canal. And the incorporation of his ideas about the succession of time into the scientific world was quite a protracted one. Who was this practical man to come along and tell us how we should think about the great workings of God? But the implications of the map and the succession of strata, of course, lie at the base of understanding geological time itself.

[Melvyn Bragg] Is this the time when the conflict is beginning to arise between the earth as dated as it were by the theologist Archbishop Ussher, 4004 BC, and the fossil paleontologist saying something else of a different order is going on?

[Dianne Edwards] It was probably much earlier than that. I think Lhuyd himself appreciated that sedimentation from looking at landfalls probably took a lot longer. They appreciated that it would take an awful lot of time to actually produce all these successive deposits with fossils in them, and that it was far greater than Archbishop Ussher would have calculated. So, yes, I think there was a gradual awareness throughout this period right from the end of the 17th century.

[Melvyn Bragg] Richard Caulfield?

[Richard Corfield] I think that it's sort of symptomatic of the tension which was existing between the clergy and a kind of nascent science which actually wanted to look in a different way, more or less objectively, as far as scientists are able to do that, at the evidence of the fossil record. But the recognition of absolute time is, of course, a 20th century invention - Ernest Rutherford and Frederick Soddy.

[Melvyn Bragg] And there's these Oxford laying-on-of-hands paleontologists, as you describe in your book very well. Let's just come to the end of this sort of very brief historical run through. Do you think it comes of age in the sense of gathering real force about the time of Huxley?

[Richard Corfield] I do.

[Melvyn Bragg] You do, Richard Corfield, could you tell us why you think that Huxley [was] Darwin's Bulldog and so on?

[14:24]
[Richard Corfield] Well, to me...the Victorians had really recognized, or at least were recognising, a new theology, if you like, which was their interest in science, and the Oxford University Museum is nothing if it's not a temple to that particular Victorian theology. And, of course, Darwin had, in the 1850s, published Origin of Species by Natural selection and his great champion (because Darwin himself was quite a retiring [man] not to mention ... of ill health) [was] Huxley. ...And [Huxley] in fact encouraged [Darwin] to go further than he did.
I'm reminded of a line that Darwin had included in an early version of Origin of Species - "Natura non facit saltum" - nature does not make leaps. And Huxley said, well, why do you hobble yourself thus unnecessarily? Why does nature not make leaps? And of course, Darwin was a product of his times, as Steve Gould has noted, on more than one occasion, and liked the idea of gradual notions. It sort of fitted in with the mores of the age. But Huxley was a visionary in the sense that there was no need to hobble yourself to this kind of social context. And of course, it was a hundred years later that Steve Gould himself and Niles Eldridge came up with Theory of Punctuated Equilibrium, which vindicated Huxley's idea then, in fact, we now know that under certain circumstances, evolution can proceed in leaps. But from my perspective, the great debate of 1860, when Huxley had a run-in with the Bishop of Oxford [Samuel Wilberforce] - "Soapy Sam" he was called by the gutter press of the day for his slick tongue. And this was, in a sense, it's a kind of media fabrication, there's several different accounts of it. But it appears that the undergraduates of the day, then as now, like to see their academic elders, as it were, have a good verbal fisticuff. And they goaded Wilburforce into asking Huxley, who had not even intended to attend that debate that day, whether it was through his grandfather's or his grandmother's side that he claimed descent from an ape. This immediately showed that Wilburforce (a) had not understood very much about theory of evolution as promulgated by Darwin, and [(b)] understood even less about the nature and magnitude of geological time. And Huxley is reputed to have said, "The Lord hath delivered him into my hands" and standing up, said that "If the question was, would he rather claim descent from an ape, or be related to a man who used his mental intellects to ridicule reasoned scientific debate, why then he unhesitatingly affirmed his preference for the ape".

[Melvyn Bragg] Do you,... Dianne Edwards, think that Huxley is as key a figure in paleontology as Richard Corfield claims he is?

[17:06]
[Dianne Edwards] I wouldn't have thought that Huxley was a great paleontologist, but he certainly was a great advocate for the subject. He was not a paleobotanist, and my main interest is in paleobotany and paleobotany with Huxley and his cronies really wasn't considered at all. And most of the work then was being done on the continent, the great monographs were being developed in paleobotany at that time, and they were accumulating a lot of data. But it is interesting ... that I think the roots of modern paleobotany are in those people who were constructing monographs because they went a lot further than naming and describing their fossils.

[Melvyn Bragg] Right. Can we come to what fossils tell us now, Richard Fortey, can you just say briefly how a fossil is formed?

[Richard Fortey] To preserve a fossil, you need something with hard parts that is capable of being preserved in a sediment. The vast majority of fossils are of things like bones, leaves, skeletons, teeth, shells. They are deposited in a sediment which is covered by more sediment, which ultimately becomes rock. The rocks are then very often through earth movements, elevated above sea level, where you can wander along with your geological hammer, tap the rock, and take out the fossil. Just occasionally, you get very special geological circumstances that preserve whole faunas or floras. That is, you will get delicate soft tissues preserved. And these rare occurrences, of course, are immensely important in understanding the richness of life. Normally, fossils give us a partial view, the view of only those animals and plants with hard preservable parts, but they're not uncommon. There's a common misconception that fossils are rare things, but actually, as soon as you start looking for fossils, you will find them. The record of life is extraordinarily prolific.

[Melvyn Bragg] In your book "Trilobyte", you write about your researches into this evolutionary forerunner of the horseshoe crab. And you write, "I have pushed half Europe across half an Atlantic. I've closed ancient seaways and opened up others. I've been able to name an ocean greater than the Mediterranean and then condemned it to perdition". So what is it about the trilobite that enables you to act, as it were...a bit like God, really. I mean, can you tell us what a trilobite is and why it is so useful and enables you to write a sentence like that?

[Richard Fortey] Well, we're going back a very long way into the past. We're going back to 3-400 million years into the past. And this is a time when we know little, or comparatively little, about geography. Most people these days, most educated people, have heard of "Pangaea", the time when all the continents were conjoined in one great mass which then split apart to give us our present day continent. Well, with the trilobytes, we're going back to a time even before Pangea, when the continents were once again dispersed and we used the trilobites....

[Melvyn Bragg] ...Can you just tell everybody what a trilobite is?

[Richard Fortey] A trilobite is a distant relative of the crustaceans and the insects, one of the jointed-legged animals. It was a marine creature with thousands and thousands of different species that were, if you like, one of the dominant life forms of the Paleozoic - of the period, beginning about 540 million years ago and going up to about 250 [MYA] - a long period of time. They had 300 million years of wandering about the oceans. Now, because they were so diverse and because they had species that were confined to particular ancient continents, you could use them, in a sense, almost like postage stamps issued by those ancient continents to define their limits. So I could use trilobites to draw out maps of the world. Starting with a trilobite in your hand, you finish up with something which embraces most of the world. We could recognize the existence of former oceans because they separated two great areas of different types of trilobite faunas. So, I mean, the point I was making there is that study of fossils may seem to some people slightly esoteric, but from such studies you can go to things which have global significance. Same points made by Richard in his book that starting with something as humble as a foraminiferum, you can study past climates, past atmospheres, major changes.

[Melvyn Bragg] Can we just stick to this idea of measuring time from fossils? I mean, how is it, Richard Corfield, ... possible accurately to measure time? You've spoken ... in your book, about half a million years and so on. Well, that seems a bit rough and ready. Can we just talk about how clear you get to measuring time, how near you get to measuring time accurately?

[22:10]
[Richard Corfield] Yeah, I think well, the thing to recognize is that there's two types of time in the fossil record. There's relative time, and that's the province of a subdiscipline of paleontology known as stratigraphy. And this is the way that rocks, as seen in the field or down core in an ocean core, are divided up. And there's various ways of recognizing the passage of time. Biostratigraphy is by recognizing evolution of different groups and different lineages of organisms within groups. And one of my favorite stories ...[?].concerns two fine Edwardian ladies, [Gertrude] Elles and Ethel Wood, who used a particular group...[?] of fossils called "graptolites", to divide time in the Lower Paleozoic 540 million ...to about 400 million years [ago]. And they worked with a guy called Charles Lapworth at the University of Birmingham and tramped all over Wales and the Welsh borderland recognizing that these tiny fossils, which looked like nothing more than a hacksaw blade in the rock, changed their form sufficiently quickly that you could, in fact, use these distinctive types of form to recognize different layers of time in the rock. And then you could go elsewhere, for example, to Sweden and Estonia, the Baltic provinces, and recognize the same succession of forms. And so it was possible to recognize the same slice of time in different parts of the world. And this is the recognition of relative time. The question of how you then make the transition from relative to absolute time is dependent on the discovery of radioactivity and the discovery of radioactive decay specifically, which is discovered by Rutherford and Soddy at the beginning of the 20th century. And they discovered that certain elements decay spontaneously, and I'm talking about uranium and thorium which were the elements that they were particularly interested in, into other elements and varieties of elements which are actually called isotopes. And this decay chain, if you like, has a constant statistical time associated with it and ends up at a stable end product, which is normally a variety of lead. And so this might be ... 400 million years [Note: The half life of direct decay from U238 to Pb206 is 4.47 billion years according to Wikipedia] for example, is a good decay constant for uranium to lead. And by recognizing the amount of, as it were, starting product in the rock and then the end product in the rock, the proportions of the two - uranium to lead - you actually know how long the rock has been there. And if you can bracket biostratographically dated rock, relatively dated rock, with absolutely dated rock, then you have the passage of time.

[Melvyn Bragg] Dianne Edwards, could I have your comment on this, measurements of time in these vast ways? What's your view of this?

[Dianne Edwards] Well unfortunately, it's only in recent sediments that we can actually date fossils themselves accurately. And this is where another element comes in, and this is carbon. And we can, I think, now how far can we go back with carbon?

[Richard Corfield] 70,000 years with accelerating mass spectrometry.

[Dianne Edwards] Yes, and this is where technology has improved enormously so that we can actually take very small fragments of fossils now ... and actually date them to a few tens of years almost. So this technology has made a big difference in actually dating fossils.

[Melvyn Bragg] And when you date them to within ...[a few 10s of years] ... what can you tell [about] them? ... What can you get from it? Can you give us an example of "yes, I know this happened 65,000 years ago at about this particular time, and from that I can conclude this about what life was like"...

[26:00]
[Dianne Edwards] Certainly using radiocarbon dating, we can find out a lot about the Quaternary period, which is the [present] period of ice ages where we have successor periods of very cold climates and warm climates. And we can take the interglacials, the warmest part of that, and we can actually look at cores through peats and sediments and take out plants from these and date them. And so we can actually find out how long it might have taken to become colder. This is refined by other isotope work, but that's something we can actually do by taking plant parts.

[Richard Fortey] I beg your pardon. In terms of our own history, of course, this is vital because man, our own species, was spreading out and retreating from the advancing and retreating ice sheets. And probably glacial history, as revealed by the fossil chronometers, is one way of unpicking our own early history in Europe and Asia and so on.

[Melvyn Bragg] You think we were determined by ice?

[Richard Fortey] Well, some people maintain that Neanderthal man, for example, now recognized as a separate species, was cold adapted, a specialist for coping with icy conditions. So our own history has been uniquely bound in with climatic oscillations in, geologically speaking, the relatively recent past. For us, people around this table, a million years is not very much time,

[Melvyn Bragg] ...I gather we've had ten ice ages in the last million years... But can I come back to this time? Can I come back to this idea with you, Dianne Edwards? [Can you discuss the idea from] Car Woese who is said to have discovered that there's a clock in every cell.... And it tells us how long it's been since that cell moved away from its common ancestor. And therefore that gives us an entry point to notions of time, which is very illuminating. Now, can you just unravel that a bit, please?

[Dianne Edwards] Well, this is based on the sequences of nucleotides and the rate at which these bases change through time. And if we assume that they change uniformly through time, then we can look at examples of living organisms which one would suspect have evolved at different periods in the past and actually calculate at what time they diverged.

[Melvyn Bragg] How does it work in a cell? It seems extraordinary. Every cell has this clock in it. I mean, clock is a very graphic word. Can you just spell it out a bit more?

[Dianne Edwards] Well, everyone knows about DNA, and we all know that DNA is composed of chains of nucleotides, and these are his clocks. If we actually change a base, then the protein that's created or the enzyme that's created from that sequence of bases might change and therefore have an influence in either the development or the appearance of an organism. And so by knowing the timing of the changing of these bases, then this is your clock.

[Melvyn Bragg] Anything to add Richard Fortey on that?

[Richard Fortey] Well, one of the extraordinary discoveries of the last few years is that we share common genes right down the evolutionary tree. It's the final confirmation that evolution must have happened, if you like. We have genes in common with the humblest bacterium. So common ancestry, which was one of the great debating points in the 19th century, is no longer in doubt. And we can scale the changes that have occurred to the genome. This is what this clock is. Changes have been cumulative. The genome, by and large, has got bigger. Complex changes have been acquired. And you can trace this almost like a genealogy. So it's another way of getting at time. And in this case, it gets to really deep time, because these divergences at the cellular level happen not merely hundreds of millions of years ago, but at thousands of millions of years ago.

[Melvyn Bragg] I was going to try to tackle deep time, so here we go. [With] deep time, we're talking about 2500 million years ago, which is, frankly, as far as I'm concerned, inconceivable, but that's what you're talking about. now. Can you tell us how fossils can give us real insights... into deep time and what's going on there, Richard Corfield?

[30:33]
[Richard Corfield] ...An easier way of thinking about the passage of time is to remember that the earth is 4.5 billion years old and that 2.5 is approximately halfway between the formation of the Earth and now. And then if you scale that by thinking that fossil life on Earth started 540 million years ago, 0.54 billion [years ago], then it gives you an idea of where we are in time. ...And the problem, of course, is that the fossil record at timescales of 2.5 billion years is not very helpful at all because it's at a time before shelley fossils had evolved. In fact, the shelley fossils on which most of 20th century, and certainly 19th century, paleontology was based, in fact, turn out to be very unhelpful when you're contemplating deep time, which, incidentally, is a phrase originating from the American writer John McPhee. ([Deep time is] almost a paleo cliche these days, but it was John McPhee who coined it.) Richard's right, you know, ... when he talks about the molecular clock. Technically it's known as ribosomal RNA. So [as] I'll explain in just a second, [it] is the only way of getting at these events the divergence, for example, of the most fundamental differences between animals, the protostomes and the deuterostomes, which occurred way, way back about 2.5 billion years ago. You can only get at this through looking at cellular clocks. And the cellular clock works in much the same way as the uranium clock, which I talked about earlier. Statistically, mutations will accumulate at approximately constant rate given enough time. And if you look at certain parts of the cell which are highly conservative i.e absolutely vital for the functioning of all life, which is what this ribosomal RNA is, then you know that we have it today, and that the very earliest organisms, bacteria and pre-bacteria, must have had it too. Because this rRNA, as it's colloquially known, is part of the mechanics by which the DNA is translated into the functional chemistry of the cells, the proteins. So rRNA clocks are a different way of addressing deep time and a more flexible way than fossils.

[33:08]
[Richard Fortey] I think it would be wrong to give the impression that there were no fossils in these early periods of time. In the Pre Cambrian, there are fossils that go back, well, to 2.5 billion years. They're very simple fossils. They're mostly mat like forms called stromatolites that form strange cushions. And from inside the stromatolites, in exceptional circumstances, you can find the fossils of bacterial and even algal cells that give us a real record of this very early history of life.

[Melvyn Bragg] Can I ask a final question for you, Richard Fortey, about this deep time? Henry Gee, talking about this concept, said that it's sort of cocktail party talk. I think that was actually his phrase on a radio program. These are merely isolated points which can't be connected. What are we finding out about deep time from fossil evidence..?

[Richard Fortey] Well, I think Gee's assertion is absolutely absurd. The story of paleontology over the last 20 years has been of progressively investigating deeper levels of time, and, in the right circumstances, finding out extraordinarily intimate details of events that happened a long time ago. Just because something is distant doesn't mean to say it's unapproachable. That is, we can still find a geological record of something which enables us to study it. ...Of course, there are gaps, and those gaps have to be filled in by other means, such as molecular means, such as Richard was describing, but it's very hard to grasp 2,500 million years, all of us find a problem with that. But that's not the same thing as saying it's impossible to find out about it. It would be like saying, oh, we can't find out about the origin of the universe because it happened so long ago and so far away. Of course, you can ask the right questions, the right scientific questions, and you can find out a surprising amount.

[Melvyn Bragg] Well, let's come back to what most paleontologists do, which is go out and look for fossils. And I'd like to talk to [Dianne Edwards] now about the place in Aberdeenshire, the Rhiney Clert. Can you tell us why that is so important and what it gives?

[35:11]
[Dianne Edwards] Well, this is one of these rare events where whole ecosystems are preserved. I work on the earliest land plants and these are the plants that transferred terrestrial environments and also changed the atmosphere. And in Rhynie in Aberdeenshire, we have, 400 million years ago, a hot spring deposit. The hot springs would have been very similar to those in Yellowstone today. And so plants that are growing around the hot springs were actually flooded by this water, which was rich in silica. The silica preserved around the plants. And so not only do we have the plants themselves, but we have the animals that lived in the debris, we have spiders sitting in sporangia eating mites, we have algae growing in the pools, we have shrimps in the pools. We can see the development of soils. It's an absolute godsend to paleobotany. It's, well, I think probably the most single most important paleobotanical site that we have in Britain, and in the world.

[Melvyn Bragg] So this is 400 million years ago. So we're getting rather familiar with this now, after deep time, and just down the road, really. Can you give us some examples of what you can draw from this clearly intensive and unique site? What sort of information does it give you that you can give us pictures of what's been going on there?

[Dianne Edwards] Well, those plants were quite unlike anything we have today, except for one group. And so if we didn't have this fossil record, we would not know what the earliest land plants were like. The molecular people can tell us when they arrived, but we do need the fossils to tell us that they were just collections of stems. But recent research has shown us that we can look a little at the physiology of these plants. We can see how they were growing, we can see that they suffered major water stress from the way the cells are constructed. We can even say something about the carbon dioxide concentration of the atmosphere by looking at the ways in which they were taking up carbon dioxide. These things had very few pores in the surface to absorb carbon dioxide. And this fits in with the models that suggest that carbon dioxide concentration then were 10-15 times higher than they are today. And so we can use these plants not only to reconstruct the affidities [?], we can actually look at their ecology, their reproductive biology, and even the ways in which ultimately, plants can relate to the drawdown of CO_2 in the atmosphere, in the Paleozoic.

[Richard Fortey] And in the Rhynie Chert as well there are animals which show that certain elements of the ecosystem were already present. ...There were almost certainly predatory spiders. There were mites that served to break down plant tissue. So we have the beginnings of a terrestrial ecology - even then, right at the beginning - that we can still recognize today. So these kind of insights into geological past are truly wonderful and indispensable, really.

[Melvyn Bragg] Is it true, Dianne, just to finish with this particular part, would you say that that is an "infinite resource" up there in Aberdeenshire, that you will just discover more and more about it, the more you can bring to bear in it through modern technology of examination?

[Dianne Edwards] I don't think technology has helped us very much with the Rhynie Chert. What I would like to know is whether or not these plants were acting as Yellowstone plants do today in accumulating heavy metals from this environment with modern technology, with lasers and various kinds of analysis. I could do that. But no, we've been doing the same sort of thing with the Rhynie Chert. It's a very small exposure. It's just one field. We are still finding out new things about the plants. For example, if we look at a fern today, there are two parts to its life cycle. There's the fern that we know and grow, and then there's a very tiny, very delicate part, which is the sexual part of the life cycle, which is a separate plant. And it's been a very long standing controversy since the last century in botany as to what this tiny, delicate part was when plants first came out onto the land, and lo and behold, for the first time, we actually have the first part, the sexual part of the life cycle of these fern ancestors in the Rhynie Chert. So we're still discovering... but ideally, what I would like to find is a Rhynie Chert in the Ordovician, for example, when we know plants first got onto the land, that's around about 450 million years ago. There [with fossils from the Ordovician period] we just have the spores of the plants, and the plants themselves have completely disappeared, we have no fossils. So we need more Rhynie Cherts, but they're a long time coming.

[Melvyn Bragg] Briefly, Richard Corfield, can you ... tell us what is new about paleontology now? You talk about the new signs of fossils...

[39:47]
[Richard Corfield] I personally think that we actually used a lot of new technology to investigate paleontology today. I mean, we've talked a bit about ribosomal RNA techniques - this thing that Carl Woese developed as recently as 1977. Mass spectrometry has been around somewhat longer. This is this technique for recognizing these different varieties of elements known as isotopes. And we've talked about the spontaneous decay of uranium to lead as a chronometer of deep time. But in fact, we can also use a different variety of isotope - the so-called stable isotopes which do not spontaneously decay - to investigate the temperature change in ancient oceans as long ago as 400 million years, in fact. At the time of the Rhynie Chert, we now know something about the way the temperature changed in those oceans and those atmospheres through looking at isotopes. And through another suite of isotopes, the carbon isotopes, we've been able to track carbon dioxide changes very well in fact, over the last hundred million years, which is between now to well into the time of the dinosaurs. And in fact, it's through the use of carbon isotopes in the geological record. This aspect of the "new science of fossils" where we take an organism which I'm particularly fond of, the planktonic foraminifera, and we digest them, break them down into their component atoms and measure the [carbon isotope ratios?]... that we're able to know that the greenhouse effect actually exists. There's no debate that the greenhouse effect exists, the debate in the present day is how fast our greenhouse gas concentration in our atmosphere is changing. And one of the things that we've been doing in Oxford is to look at a time which appears to be a mirror image of our current greenhouse plight which occurred 55 million years ago when the Earth warmed by eight degrees centigrade. And this is twice the temperature difference between now and the last Glaciation. And it's only through these new techniques applied to the science of fossils what I call the "new science of fossils" that we can actually address climatic, for example, questions.

[Melvyn Bragg] Richard Fortey, do you see many benefits coming from applying the latest technology to paleontology?

[Richard Fortey] Well, curiously, it serves to invert a classic phrase we used to say, the geologist's dictum, was "the present is the key to the past". And it seems that for the future, "the past may yet prove to be the key to the present" as we investigate global warming.

[Melvyn Bragg] Global warming, of course, you said very briefly, you said this is rather good for you. It releases more sites?...

[Dianne Edwards] I'm not sure I did say that. Global warming certainly could be good for plants. And we can use plants to track global warming in the past. And this has been done. I think one of the breakthroughs for paleontology has been this discovery that these pores in the surfaces of the leaves can actually change and the higher the carbon dioxide concentration the temperature, the fewer the pores.

[Melvyn Bragg] I'm afraid that's all we have time for. Thank you for listening.