Richard Fortey - Around the World in Eighty Trilobites

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Richard Fortey lecture from the Second Annual IISE-Linnean Society of London Legacy Lecture presented as part of the Darwin Distinguished Lecture Series. This lecture is sponsored by the Arizona State University International Institute for Species Exploration, College of Liberal Arts and Sciences, and the School of Life Sciences.

Transcript

Quentin Wheeler: [0:02] This is the Second Annual Linnaean Legacy Award and Lecture. And, for those of you just joining us, this is an annual event sponsored by ASU's International Institute of Species Exploration and the Linnaean Society of London. What we try to do through this is to gain attention and recognition for a scientist who has made outstanding contributions in the search for species in an exploration or bio-diversity.

[0:30] This year's recipient is Dr. Richard Fortey from the Natural History Museum in London. Richard studied geology at the University of Cambridge. He has spent an incredibly illustrious career and made the full use that one can of the incredible collections and libraries in the Natural History Museum in London. It is one of the best institutions of its kind on the planet.

[0:51] He's a leading paleontologist, he's one of the best communicators of science to the general public that we're fortunate to have. His research has focused on the systematics, evolution and modes of life of trilobites primarily, and studies of the Ordovician Palaeogeography, as well as the origin of the major groups of arthropods, which are the dominant creatures on the planet.

[1:13] He's a fellow of the Royal Society, a fellow of the Geological Society of London and a fellow of the Linnaean Society of London. He's the recipient of the Michael Faraday Prize from the Royal Society for Public Communication of Science, the Lewis Thomas Prize for Science Writing from Rockefeller University, and he was Collier Professor for Public Understanding of Science and Technology at the Institute of Advanced Studies of the University of Bristol.

[1:40] And just a partial list of his books, and I encourage you to do yourself a favor and read some of these, he's an incredibly gifted writer, include "The Hidden Landscape," which was named the Natural World Book of the Year in 1993. "Life: A Natural History of the First Four Billion Years of Life on Earth" was short-listed for the Rhone-Poulenc Prize in 1998. "Trilobite: Witness to Evolution" was short-listed for a Samuel Johnson Prize. "Fossils: Key to the Past" is a revered introduction to paleontology. "The Earth: An Intimate History," 2004, of which The New York Times said his writing is almost cinematic in style, concluding that it is the ultimate travel book that should be read by every person who wants to truly know and understand the place we live on.

[2:32] And most recently "Dry Store Room No. 1," which is said by the Evening Standard is a compendious and entertaining book, much of the narrative interest of the book is carried anecdotally by wonderful stories. Fortey gives us a vivid virtual tour of the museum's hidden stores and retired displays. It's a book filled with passion for nature and pride in an institution that has done so much to compile its inventory.
Fortey is a knowledgeable guy with a keen eye and gentle humor. Richard truly is a giant in the field and it's an honor to present this on behalf of the -- Art Institute and the Linnaean Society of London.

**Richard Fortey:** [3:19] Well, I'm deeply honored to receive this award and not a little surprised. I'm going to give my talk about trilobites. I've never done this talk before; it came as something of a surprise. You know, over the years I have spoken at countless scientific symposia and the scientists here will know that what you do there is give your new results and present the graphs.

[3:39] I've given talks in connection with my books quite frequently at literary festivals and the like. And what you do there is give a kind of encapsulation of what the book is about, maybe a few stories. But you, yourself, don't figure particularly prominently. So, it was something of a surprise to be asked to give an account of some of my adventures over the years looking for trilobites.

[4:03] Now, I really enjoyed the earlier session today. I thought it was fantastic. I feel now a little guilty because most of my stories, well, it's like having the color taken out. We've seen these marvelous fish, wonderful beetles, and of course, I work on fossils. So, I mostly work on rocks. And precisely the kind of habitats you've seen, lush jungles, damp rain forests, high plateaus covered in vegetation are exactly the kinds of places I don't go to.

[4:34] I go to places where you can see the rock. And, when I was asked to do this lecture, I went back into my own archive, my own past, and I took out the most disgusting old projection slides, some of which haven't seen the light of day for decades, and scanned them to produce the talk today. I was struck at just how uncomfortable some of these places had been. If they weren't cold, they were wet. And, if they weren't wet and cold, they were extraordinary hot and dry.

[5:03] But nonetheless, and this is the message to everybody here really, mostly I've had a ball. I've also had the nine lives of well, I can't say every paleontologist, so I guess I should say every biologist having heard some of the previous stories.

[5:19] Along the way, various lives have kind of dropped off the list. But in spite of that, as one of my predecessors was saying, it's great to have done something which you've actually looked forward to doing everyday of your life.

[5:32] In one of my books, I described my sensation when I finally got my job at the Natural History Museum in London. I'd said it was like getting a piece of paper, a contract, which said "Amuse yourself for money." Well, I'm going to take you back to start with to where I became a paleontologist, which was almost by accident.

[5:55] Although again, this is something as it came from listening to our earlier speakers, most of them I suppose would confess to being born naturalists. I was one of those too, I went through from the age of, let's say, seven or eight, through the gamut of different organisms.

[6:11] Most people start with birds, and I was no exception. I did flowering plants. I loved, and still love, fungi, it's been my hobby for years. I've kept up my fungi. But for me, love at first sight happened, really, when I collected fossils. I don't know why that should be, why one thing rather than another. It's a bit mysterious.
And really, from a very early age, trilobites; for me, the older they got, the more interesting they got. And trilobites are just about the oldest large fossils, anyway that you can collect from the rocks, so they had an added glamor.

When I got the chance to go to the Arctic island of Spitsbergen, while I was still a student and this was the first ever geological map I made, I jumped at the chance. Now Spitsbergen lies at 80 degrees north. It's a small high Arctic island. It's as near as you can go on dry land in the North Pole. It's pretty remote. And I went there -- well, it was so long ago I can tell you that the Beatles' songs were hits for the first time.

It was a hard place to get to. You couldn't fly there as you can now. You had to go on a whaling vessel from Arctic Norway, from Hammerfest on about like this across the famous Maelstrom which is notorious as the roughest sea in the world. Most people spent most of the time at that point throwing up. I was lucky. I was quite a good sailor. You arrive in Spitsbergen at what is the probably the dreariest town in the world. [laughter]

I am sure whether this is a color photograph or not. [laughter] It's just a town of Barrensberg; and Spitsbergen is a strange island come by a treaty, which means the Russians can have a town on there and this is the Russian town of Barrensberg where they mine a little coal. But mostly I think it was used as a punishment posting for naughty Russians because when we landed there it was a very sorry place indeed. As we were shown around the town you could see drunk and depressed Russians being herded into doorways out of sight.

But then on to still more remote parts of Spitsbergen, and right at the northern tip we discovered Ordovician rocks. Ordovician, just to put it in context, is about 450 million years old, and before we had been there these rocks were completely unknown. So this was a 'tabula rasa' - we didn't know what we were going to find.

You'll see it's a pretty chilly place. There's a permanent ice sheet which occupies a large part of the central part of the island. This area is a big home for polar bears. We got around in small boats dodging between the ice floes. You can't see any rocks there and there were missed for years as people going along this strait couldn't see them from passing boats because they are really rather well hidden under a raised beach.

But here I hope you can see these dark rocks hearing out from underneath of the permanent ice and snow, and it was these rocks that yielded a wonderful selection of new fossils. As I had said this is polar bear country. we were constantly on the lookout for bears and we were provided with a gun to see them off. I was even issued a gun and we had rifle practice which consisted of putting a load of tins up on the shingle and taking potshots at the tins. And I missed every one.

I just said something about this and they said, "Oh, don't worry. When you are being chased by a polar bear your aim will improve immensely." [laughter] I never was -- in fact, I was one of the few people who's been to Spitsbergen twice and not actually seen a polar bear. In fact I am probably the only person who's been to Spitsbergen twice and not seen a polar bear. My theory is the place we were working in was so miserable that even the polar bears didn't want to go there particularly.

From time to time, if the wind changed, ice floes would blow in and cut us off. So we really were at the edge of the world. That's what you do if you are a paleontologist -- you sit...
down and break rock. A few years ago this used to be the punishment for criminals. But of course, when we break rock we find fossils. And there is no greater thrill -- well, actually, probably it's rather like seeing these fish at depth in coral reefs -- but to me there's no greater thrill than breaking up a piece of rock and seeing something come out that you see for the first time. You are the first eyes ever to look at these things. In the case of the trilobites, since they were the first organisms that had well developed fossil eyes, the eyes look back at you too.

So these rocks we collected systematically for weeks and weeks and weeks, breaking our way up through one section after another. Conditions? Well, a little primitive. Hurricane tents; you can see that these are actually camped out on the raised beach. Those of you with sharp eyes might just be able to make out on the top of that flagpole a Union Jack flag, which started off boldly waving at the strong wind. As the wind continued to blow incessantly for week after week, it gradually unraveled thread by thread. So at the end there was just a little limp kind of apology for a flag.

Most of the food we had came in these boxes, which then went back full of fossils; and pretty primitive diet, dried food mostly, the sort of things Captain Scott would have recognized. We have one glorious case of supplementary rations, which had things like Christmas puddings in it and tinned ham, and boy, did we look forward to having a little meal of ham after soaking these meat bars up for weeks and weeks.

This is a very exposed place, as you can see. So having a crap was a major event in your life. [laughter] You will be surprised to see that there is wood up there. That's because Spitsbergen lies at the very end of the North Atlantic drift or Gulf Stream, and wood gets carried up there on this and stranded on the beaches. I'm glad it did because we were able to use it to construct toilet arrangements.

Now, this photograph, unlike the ones I've shown you previously, was taken last year by another party that went and landed on the same shores. It's a tribute to our building I think, but you still see quite obviously how it worked. We called it the room with a view, [laughter] because we put the wood on three sides to keep out most of the Arctic wind and the fourth side was open to look out over the sea. So you could sit there contemplating the elements while doing your stuff, and it lasted obviously extremely well.

You can see one great thing about working this far north, and you will see there is absolutely no vegetation around at all. We're too for north for the mosquitoes or any of the other things that drive people nuts in the tundra. This really is as far as you can go. The drift wood also had another use, which was making cheery campfires. Here you can see us huddling up trying to have a good time and trying to make our whisky ration last a bit longer out in the strong wind.

The first of my nine lives, I might add, was falling off that boat I showed you earlier into the Arctic Ocean -- my stupidity entirely. Apparently you have four minutes before you are chilled too much to save yourself. I was yanked out in about one minute but I have still never being quite so cold in my entire life. I was quite lucky that somebody else was with me, of course.

Because of the wind, we used to tie spars and bury them underneath the gravel to keep the guy ropes of the tents taut when the wind blew. Mostly it was clear, but when the wind blew, it really did, and once or twice we had a blizzard that sealed us in the tent for days.
[13:58] This, if you want to know, is the best way to get to read all those very heavy Russian novels like "The Brothers Karamazov" or "War and Peace" and so on. If you're in a tent and there's nothing else to do, you can get through the longest novel there is.

[14:12] And there was our cook tent, with my friend David Bruton, who at that time smoked a pipe, contemplating our delicious supper. But what we were there for was, of course, to collect trilobites. These are rather black limestones, and some of you may be able to see some of these animals just appearing on the surface.

[14:31] If you are very lucky, you collected a whole one, which look something like that. I mean, that's a specimen just whacked out from the field. For those of you who don't know trilobites, they've got a head, a thorax and a tail, but they molted like all arthropods, so usually you don't get whole ones. You get bits of them, and when they're bits they look like this.

[14:52] That's just part of the head. That's an isolated tail. That's that nearly complete one. And there are various other bits and pieces you have to put together. So that would be a fairly typical plate to illustrate and describe a new species.

[15:05] That would be a much more typical fragment that you might just have to hammer out of the rock. These are occurring in limestones, so a lot of the work is actually digging out the things when you get home, excavating from the rock, which can take in some cases hours.

[15:17] But you'll see these things are very nicely preserved and show a lot of details, although sadly of course no color. Now, because this is a Linnaean lecture, I am going to talk a little bit about nomenclature, about naming things.

[15:29] Some of the younger people here might not know that one of the great pleasures of being a systematic paleontologist or biologist is this business of being able to give things scientific names. We are the people who christen these animals, and if we've got it right, our names stay associated with them in perpetuity.

[15:46] This was my first ever trilobite that I named, and I called it Opipute inconnivus. It was a new genus and a new species. Now, Opipute means "one who ogles" in Greek. The reason it got that name is because it was a very unusual and peculiar trilobite, which is why it was worth a paper on its own.

[16:06] In it the eye, that's the eye, and there it is again, became enormously inflated. They had gigantic eyes that occupied most of the head shield. I was lucky enough to find a nearly complete one, except for the eyes, which enabled me to put together a reconstruction for the whole animal.

[16:23] Now, most trilobites lived all those hundreds of millions of years ago on the sea floor, but Opipute was the first of a number of trilobites I worked on, which took off from the sea floor and began to live an open oceangoing existence.

[16:38] Unlike many of their comparable crustaceans that live today, they developed gigantic eyes as they did so, with literally thousands of lenses, which are actually preserved on the fossil. Hence "one who ogles" and inconnivus means "without sleeping."

[16:54] So Opipute inconnivus was my first. I was very proud of the paper and very proud of the trilobite. Now, one dreadful thing that can happen to a paleontologist, or indeed to any zoologist, is that somebody else described the same damned thing or uses the same name.
Now, you might think Opipeuter is a very funny name, which wouldn't likely be used by anybody else. So at the time I first wrote it up, it hadn't been, but unknown to me while I was publishing Opipeuter, somebody in South America was describing a lizard with the same name, Opipeuter.

I didn't discover this for 30 years, so it took me 30 years to realize that my name Opipeuter wasn't actually going to be valid, which was a bit of a blow. But what you do? Then, well, you alter the name slightly, and I changed it to Opipeuterella, which is the valid name right now.

So that's an important trilobite for me. These are bits and pieces, but this was one of the most important discoveries I made, which was the trilobite's back to habitats.

These particular rocks showed that bottom-living trilobites weren't just one group of things, but lived in different habitats, some of which were low in oxygen.

This particular group, within the whole evolutionary radiation of a group of trilobites that are thought to become extinct at the end of the Cambrian, were here in the Ordovician, younger, producing lots and lots of species. It's a whole group I named this time, a family. I called them Balnibaridiae.

Now, those of you who know "Gulliver's Travels" may recall Gulliver visited the land of Balnibarbi on his travels, which was a country peopled by eccentric natural philosophers and crazy scientists. So again, I had quite an amusing time naming this particular group.

That was the ancestor of the whole group, which had this local evolutionary radiation of Spitsbergen. That was Balnibarbi syrinx, syrinx being a herald. This one, well, it's obviously related to the last one, but has this very wide brim, what do you think I called that? I called that one Balnibarbi sombrero.

Well, of course only one in 1000 people will probably ever come across Balnibarbi in the monograph, but nevertheless I can't tell you how enjoyable it is to indulge in this particular aspect of nomenclature.

Then we found little blind trilobites which had hung around for a long period of time with relatively little change. So we had in this Spitsbergen fauna, a fossil fauna, animals living at different ocean depths and also animals that had strange and extended ranges from ones previously known. It was all completely new information.

When I finished, after some years writing the monograph, they were in excess of 120 new species from this fauna, which was the richest one ever known from the Arctic island.

That was my first ever trilobite drawing. I put it in, not to show what a good artist... I've improved since then, but because this was the giant of the fauna, I gave it the name Gob, which is the name of an Anglo-Saxon giant.

If you take a very short name, then chances are somebody has already used it and you're not allowed to use the same name twice. I was amazed to find that nobody apparently had used this name Gob. I was pleased with that one, too.
[20:15] One of the other great things about all science, and particularly our sort of science, is serendipity. I dissolved some of these limestones in acid, partly to see what happened and partly to try and recover some insoluble kind of fossils that you can find in limestone.

[20:30] To my amazement, when we started examining the washings of the limestone solution, we found other things sitting on the sieve. Some of them were little objects like this, which are trilobite larvae. Trilobite size, I should explain, are as big as your hand in the case of Gog, up to this sort of size.

[20:50] This little thing is a pinhead-size. It's a millimeter long. This is the first really good ontogeny we have for organisms preserved as fossils. Well, actually now they're known back beyond 500 million years, but at that time, 450 million years.

[21:03] So you can actually trace the development of individual species from little, pinhead-sized larvae through to adults. That's got all kind of zoological interest, not just to do with the trilobites themselves.

[21:15] But, even funnier, in the same sieve samples, there were some really weird little organisms. This one is one of the strangest. You see, it's got a little spiral in the middle, and then grows out into a tube this way. But it also grows, apparently, into a tube this way. So it's growing, simultaneously, two ways at once. That's extremely hard to interpret, if you're a zoologist, as to which kind of group of organisms it belonged to.

[21:45] This is something, again, I had nomenclatorial interest. I wanted to call this animal Trumpetites - well, for obvious reasons, I hope. But, at the time, scientific editors were a bit stuffy, and that sounded a bit too vernacular, so I was forced to rename it Janospira after Janus, the god that looked both ways. Anyway, in my mind, it's always Trumpetites.

[22:05] I wrote a short paper on it describing it as new fossil in search of a phylum. About 10 years later, somebody else wrote a paper saying, found - a phylum for Janospira, who proved - I think satisfactorily - that this was a very anomalous and peculiar kind of mollusk.

[22:21] So you never know what's going to turn up, which is a wonderful thing about paleontology. So we had larvae, and then we had fragments of a phosphatic material, which at the time were the earliest fragments of vertebrates known. So this took the history of the vertebrates - of course, including ourselves - right back to the early part of the Ordovician.

[22:42] Somebody was saying that getting fossils into "Science" or "Nature" - you can't get a trilobite into "Science" and "Nature" but you can get a vertebrate in. That was my first ever "Nature" publication, this early vertebrate.

[22:54] At that time, they were thought to start towards the end of the Ordovician. Now they're known from the Cambrian. But, at the time, it was a very important and completely unexpected discovery.

[23:03] So I determined, in the kind of way that you do when you're young and optimistic, to try and chase this early Ordovician horizon all the way around the world. I couldn't understand why, if we'd found 100 more species in Spitsbergen, why there weren't very many known elsewhere in the world.
[23:19] The "elsewhere in the world" that occurred to me first was in my own home country, Wales. Wales it was that actually gave the name to the Ordovician system - the land of the Ordovices. It's been studied there for - well, practically 200 years, and yet, evidence of the rich diversity we'd found in Spitsbergen was lacking. Why?

[23:41] Where those white patches are are where the rocks of the right age occurred. Now, the message here is that until you go and look, you don't find. In fact, people just hadn't spent enough time whacking the rocks in this bit of Wales.

[23:54] Well, some of the cliffs are pretty hairy. That's almost as exciting as working in Spitsbergen, although very dramatic. It turned out that the real good pay dirt occurred inland. Here we are, bashing rocks again. Actually, one of the minor delights of putting this tour together is observing the author's own ontogeny.

[24:13] [laughter]

[24:15] Thin as a laugh, I was described as when I was young. You'll see the profile gradually changing.

[24:22] But what we did find in these rocks were trilobites, not quite to match the ones in Spitsbergen, but a rather large number - even closer to home - of species that had never before been recognized. Some had been. This particular trilobite was collected by the father of the Silurian system, Murchison, in 1839. So that's a familiar one.

[24:46] But this very pretty beast, with its unique fringe which no other arthropod really has, was a completely new form that we found in Wales. The interesting thing was that all of these forms, of which there were 20 or 30, were completely different from the ones we found in Spitsbergen with the exception of one or two linking species.

[25:07] So we had a geographic story that was beginning to emerge. One of the things we found were a whole series, not just one, of these pelagic, these free-swimming trilobites with big eyes. And I've just lined them up across here so you can see them. That's Opipeuterella there, but there are a number of other things that were more or less convergent upon it which had different evolutionary origins. All of the cenotians were becoming much more interesting. Not only were the sea floors occupied by different sorts of trilobites, and different ones in different areas, but the water column was occupied by them as well. Fascinating.

[25:37] The only things that were in common between Wales and Spitsbergen were the very deep-water ones that were adapted to low oxygen. I show you this fragment, this head particularly, because one of the Welsh ones had this unique bulb right in the middle of the head. Very extraordinary structure, the explanation of which eluded me for many years until I was doing field work in Thailand. And when I was doing field work in Thailand I was offered, as one of the dishes in a restaurant, the chance to eat limulus, the horseshoe crab.

[26:06] Most of you will be well aware of limulus in North America, but the thing about it, it's supposed to be the trilobite's closest living relative. And I dissected it once upon a time, and I couldn't think what the hell you could eat on a limulus. They're extremely un-fleshy things.
So I immediately accepted the opportunity to eat this, if only to find out what a trilobite tasted like. I said, "Yes, please," wondering what would come to the plate. What they actually did was open the carapace of the limulus up and inside its head were yolky eggs.

Now, those of you, and I'm sure it's most of you, who are familiar with crustacean eggs will know they're carried under the thorax, usually in a special basket. Not so in limulus, they're actually inside the head cavity in an exactly homologous position to where that bulb is on the trilobite, this strange bulb on this particular and unusual trilobite. So it seems to me very likely that this particular structure was the first example we have of a brood chamber in an arthropod to carry this particular trilobite's load of eggs. That's rather a bleached-out one of a relative of this deep-water trilobite we found from Wales.

So onward 'round the world. I got very cold in Spitsbergen and froze to bits, but now it was the turn of the desert. I don't know if any of you have been to Eureka, Nevada. The same Ordovician rocks carried on right down into the western part of the US. I made several visits there to this wonderful loamy town, which is sort of a bit of a ghost town, but now having a bit of a revival. But we would mostly be working miles out from that, camping out. And I must say that Great Basin country, I absolutely adore it. For me, it's one of the most beautiful places I've ever worked.

There I am, early on in my ontogeny, I think it was my pseudo-hippie phase; here I am twenty years later, looking at the same rocks but doing what I'd been doing for twenty years, which is pummeling to find trilobites.

The great thing about Eureka, Nevada and the surrounding area was that the trilobites, at least some of them, were like the shallow-water ones we had in Spitsbergen, even down to the same species, so I was able to correlate in to a part of North America, which had never been done before. And again, the surprise was, nobody had found these animals before in the US.

The reason for that is quite a simple one: there's an awful lot of rock, and there are terribly few specialists. If you've heard that message earlier today, you won't be surprised. And some of these are rather pretty, although fragmentary. This is one of the Nevada trilobites, that's another one. This was a singular beautiful one I found up on the Cherry Creek range thousands of feet above sea level.

And that reminds me of escape number two, or life number two, because this is very high up, the Great Basin's high, and if you go on the mountain ranges, still higher. And my companion from the University of California at Riverside, Mary Droser, said "Well, Richard, the great thing about working this high up is you're too high for the rattlers." Hardly had the words escaped her mouth, there was a very loud rattling noise, and the answer was, "Well, occasionally they go up high." To get a breath of mountain air, or something. I don't know. [laughter]

And then I went to the ultimate outback. Now, of course, I suppose people in the west of the US still like to think of themselves as cowboys and a bit tough, in Nevada. Believe me, that's nothing compared with the center of Australia. This is on the join between Queensland and the Northern Territories. It's the most remote area I've ever been to, bar none. I can probably include Spitsbergen in that. You can drive for hours and hours and see not a sign of human habitation.

But I show this sign in particular, I'm not going to show you many trilobites from this area, because this is a pub. This is the Pub Betoota. And if you look at a map of Australia, even
quite a small one you will find Betoota marked, even though it consists of only this pub, because there's nothing else out there to mark on the map.

[30:05] Now the terrible thing was that the landlord of the Pub Betoota had an argument with one of his clients, who was an inebriated ranch hand, which resulted in the death of the client. He was stabbed to death. So, of course this man was going to be arrested. And that was obvious because the other people had to let the police know what had happened, but the police were a very long way away. And he sat down apparently and said [in Australian accent] "Well, you know, I'm going to have to go down and I'm probably going to have to go to jail, but it's a pity to waste all this beer." So they sat down and drank the stock before the police arrived, and when we arrived, the pub was closed but all of these cans were full of empties.

[30:51] Australia is famous in paleontological circles for this wonderful late-Cambrian soft-bodied fauna, the so-called ediacaran fauna, and that's one from the Flinders ranges, which I've also visited. This is the sort of dawn of life, and it's important in revolutionizing the way life diversified before the Cambrian. It can't be overestimated. But I was struck when I was there, nearby there were some of these Aboriginal drawings on the rock, or petroglyphs, I suppose you should call them. I couldn't help wondering whether some of the Aboriginals themselves hadn't been inspired by the fossils in the rock. You can find things that look not-so-different.

[31:32] I also encountered in Australia the world's nastiest bush, which is called spinifex. Now, if you're out collecting in Australia and brush past one of these, it has silica-tipped spines that break off and work themselves slowly into your legs. And it's a bit of a hazard if you go out in the night to perform natural bodily functions, as you can imagine. It also has the propensity to burst into flames. [laughter]

[32:07] Well, those of us who have been watching the news recently know what this results in, and my nine lives three and four both relate in a way to this. Because I was out there with a bushman, and inadvertently he set a spinifex bush on fire and within about twenty-five seconds there was a raging bush-fire. That is an extremely terrifying experience. Bush rules tell you you mustn't run away from a bush fire, so we had to kind of hang around there trying rather ineffectually to put it out. And it didn't go out until the nearest ranch people brought in a grader to build a fire-break in front of it.

[32:44] And then I went back to the farm in the evening, which was very brilliantly lit, and walked (having had a few beers, as they say in Australia) walked from the brightly-lit interior out into the dark and tripped and landed on a fencing spike, which punctured my femoral vein, but fortunately inside the skin. So my leg turned blue. So there I was, in the middle of the middle of nowhere. But the Australians are extremely tough, so they looked at my blue leg, and said, [in Australian accent] "I don't think it's worth calling out for doc." [laughter] "You better lie down and have a few beers." [laughter]

[33:26] So over the next week, I saw my bruise gradually turn from blue to yellow and then fade away. I survived, but when i got back to civilization, I did go see a doctor. His words are with my still. He said, "Christ, mate, If you punched your skin, you'd have gone out like a geezer." [laughs] So i was lucky to survive that one.

[33:49] And I also wanted to just point out a geological phenomenon, which I'm still not sure about the reality of it. This was limestone country, of course, where the best trilobites are found.
On the mounds, on the top of little limestone mounds, there were these rather curious depressions, usually with a little runnel coming out of it. I found this extremely puzzling.

[34:11] My Australian companion said, "Oh yes, round here we call it KP withering." I said, "What on earth does that stand for?" “Well, you see these kangaroos come along, and they sit on top of the mounds, and they relieve themselves, and then it sort of dribbles over the edge. That produces these shallow depressions." I still haven't worked out whether KP withering was winding me up or whether it was a real geological phenomenon. [laughs].

[34:35] Well, from hot and dry to hot and wet, and this is the only time that I think I have collected from some of the comparable habitats to the ones you have described. Still in pursuit of the Ordovician. This time in Thailand. Now, the wonderful things about trilobites is that they date rocks very accurately. So if people get puzzled doing geological maps and want to know the age of strata, they can call you in to solve a geological problem.

[35:00] And this is an area that was hardly studied. It was not just Devonian. That's what it's like, so it's beginning to look a little like some of the other slides we've seen today before. Extremely unpleasant collecting. Far worse than a dry desert or even the high arctic because it was so damn hot and humid. I had somebody standing over me with a sunbrella, feeding me continuous iced coca cola, which used to come out of the forehead as fast as it went into the mouth, and breaking limestones is usual.

[35:26] But there were nice trilobites there. Now, I've been saying a lot about new ones. Sometimes it's important to find ones that have been described before. That was the case with these nice ones from Thailand. These are all the same species as you found in a particular part of China. Now when you go back to the Ordovician, you're talking about a world that doesn't resemble ours at all. Continents have been drifting and reassembling, and one of the things, the end points of all this work, is to try and use the trilobites to reconstruct the map of the ancient world.

[35:57] So all of this information is being added up to a world picture to actually map out the continents that used to exist. So this Thai fauna was extremely important from the point of view of telling us that this part of Thailand was adjacent to what is now rather a distant part of China. A fact that wasn't known before.

[36:18] And this slightly scruffy trilobite was also important because at the end of the Ordovician there was a major glaciation. Another big defining extinction event in the history of life. When that glaciation occurred, the trilobites dropped enormously in diversity, and one particular rather dull trilobite spread around the world. And this is it. Hitherto, we had no idea that this glaciation event had been found in this part of the world whatsoever. So sometimes, an old friend is a good friend.

[36:47] I've collected the same thing from the tip of South Africa, for example. So it's all part of creating the narrative of geological time, which is the end point of the science part of this exercise.

[36:59] So back to a desert. even dryer than central Australia if possible of course is Oman and Saudi. This was I confess a slightly posed shot of 40 of Arabia [laughs]. A very nice Berber did the headdress for me. Here, well you can see it's not very verdant, these rocks again had hardly been visited before.
And this is the only time I've been useful because I was actually paid by the Petroleum Development of Oman to go out and sample these rocks because they wanted to know what age they were. And this strata when it gets under the ground, is the principle oil bearer for the sultan of Oman, so it's important to know what age the oil is or form what rocks it occurs. Rather hard work actually.

These are not good rocks to find fossils. The redder the rock, the harder it is to find fossils is a good rule. But some of it isn't red. I hadn't been banging around for long when I recognized not trilobite body fossils but trilobite tracks.

There are some mollusks here too for other phylum lovers.

These are the plowing marks left by trilobites where they've plowed through the sediment in order to extract edible particles. Whole groups of trilobites, and I haven't got the time to talk about this today, about different life habits, specialized in this mode of life, and they left trails behind. But rather like criminals and crimes, actually finding a trilobite associated with this trails is extremely rare. The conditions right for preserving trails are the wrong ones for preserving trilobites themselves.

Trilobites are made of calcium carbonate, which is highly soluble. Sandstones are highly porous, so you tend not to find the two together. But here we did. As you can see, they're all kind of speckly, sandy looking, that's because they're cast in sand.

By carefully measuring the tracks and measuring the size of the trilobites, we were actually able to point the smoking gun for once at the particular trilobite that made this particular trail. This was entirely an offshoot of being asked out by petroleum development of Oman to dig their rocks. The dating took ten minutes, and the field work was there for another four.

In the same rocks, in the parts of these rocks, we found- this is actually the same species as I showed you earlier- merchants collected from Wales back in 1832. It's a fairly distinctive animal. Again, this is telling us something about the way the Ordovician world was.

I'll come back to that right at the end. I'm now going to show you when I leave the Ordovician, I now trace the Ordovician. This particular layer in the Ordovician more or less around the world. I'm not going to take a leap up the geological column and change countries to Morocco.

And that from the top, is a nice but slightly unremarkable looking trilobite perhaps. From the side, it's spectacular. This is the trilobite with the ultimate eyes. It's been a rule of mine to only work on animals that I collected. But this is where I broke the rule because I saw this for sale in the Cambridge Dealers. It was such a fantastical animal that I managed persuade the Natural History Museum to buy it. Which you will acknowledge is a considerable achievement. [laughs]

This is a perfect demonstration of how sophisticated the trilobite eye became. This is a Devonian animal, so it's more than a hundred million years younger than other things I've been talking about. Perfectly vertical sided things, and look at the size of those lenses. In trilobite eye, the lenses are actually made of calcium carbonate, so it's a unique experiment in the history of how to do an eye. The crystal of calcium carbonate is organized calcite in such a way that light
passes through the surface of the lens normal to the surface of each individual lens. So you can work out the field of view of the trilobite by taking the pole of all those lenses.

[40:43] Now this trilobite was actually looking, well looking towards you as it is from the side. Looking sideways over the sediment surface. It had a big 180 degree sweep over the sediment surface, but it didn't look upward at all. In fact, it was prevented from so doing by having an eye shade on top, which actually projects out over the visual surface of the eye. It was a unique animal.

[41:07] Unlike most trilobite eyes too, it was more or less vertical. It wasn't curved, bulging outwards like most trilobite eyes. And I worked out the optics of this. What this animal was adapted to was for seeing well at distance.

[41:21] If you are into this particular game, one of the things that can happen -- well you think of yourself when you're looking over the Serengeti Plains or something -- is you need to shade your eyes to keep out distracting light that is coming from above. This trilobite was no different. This was a kind of visor, and you could demonstrate it quite easily by just shining a light from above, in which case at one point all the instant light was cut out over the visual surface of the eye, so it was a unique optical experiment, the trilobite with an eye shade. This again is something that might nudge its way into the more amusing part of the weekly publications. So it made its way into the brevier[?] of science. But a wonderful animal to find.

[42:03] And that led me to work a little more on these Moroccan trilobites and I just thought I'd finish with some pictures that are just about as they good as it get, trilobites, since you've had to put up with all of those fragments of the [inaudible]. This is about as good as they get.

[42:18] These are whole ones from Morocco. Now if you go the big show at Houston[?] you can buy one of these. I don't know what the going rate is for it now, but it would be $1000 possibly. When I first saw one of these it was brought into as an inquiry in the Natural History Museum. I'd never ever seen a trilobite remotely like it with this trident on front. And I thought, "This is a fake."

[42:45] It has to be said, fakes are well known from Morocco. The trilobites are there genuinely, but the Moroccans have discovered that it's rather a good way of earning a few extra bucks. So they have trilobites factories, I've been to them. Where they start off with one genuine one and produce some quite convincing replicas, even down to the point of staining the rock the right color and so on and so forth. It's easy to know once to know you've got a fake but some of them are rather subtly done.

[43:14] So when I first saw this I thought it was a fake. By the time I'd seen three of them I realized it wasn't. By then, slightly to my annoyance, a Frenchman had given it a generic name, before me. That's the competitive aspect. I would have liked to name this animal because it's so remarkable. And I would have given it an interesting name. Robert, the Frenchman, called it Walliserops. And he was doing this in order to creep up to Herr Professor Walisse, a German professor. I think a much more interesting name would have involved something to do with a Triton bearer, something like that. Which would much better describe the animal. I did feel cheated, genuinely.

[43:54] But not too bad, because having seen this trident bearer, I joined my friend Brian Chatterton and we went off to Morocco to try and work out the field occurrence of these things.
We eventually ran it to earth\[?\], that one was known, but we found two very good different species of Walliserops. So you know, it's a jolly good clade.

[44:16] I'm still terribly puzzled by the trident. Now you should remember that trilobites have a rigid exoskeleton. You can't bend this trident, it's a fixed object. So it's no use saying, this is actually some sort of sphere, like the ones people actually used for that purpose. Because the food would remaining forever rightly, like the carrots at the end of the stick, the food would remain forever out of reach.

[44:44] There's some other puzzles about it. For example, if you look at them sideways, that's the long [inaudible] trident form. You'll see the trident actually curves upwards before flattening out distally. So when that trilobite was walking along the trident is held above the sediment surface.

[45:02] On the other hand, one of the new species, and here it is, has the trident coming off right from the front of the head, flat on the ground as it were. Now, I don't see how that animal could have progressed very satisfactorily like that. Or at least when it moved along, it would need to lift the trident up. And now if we go back to the other one, you'll notice a funny effect. That's the adnate trident bearer, the one with it lying directly on the ground. And can you notice how the next spine here is twisted to one side. And these spines are twisted the other way.

[45:35] Now most trilobites are rigidly bilaterally symmetric. And this is the only departure I know from that. And I'd be interested to know from you beetle people how many departures from bilateral symmetry you get. The point is that this trilobite, when it walked along, could tilt its head backwards to lift the trident up from the sediment surface as it moved along. Then presumably it lowered it down to do whatever it did with the trident, when it got to where it wanted to get. But you couldn't do that without producing a certain amount of asymmetry to these spines.

[46:05] When I found the first one, I thought, well this could just be a pathology. Eventually we got to seven, I know that's not a great number, but it's an awful job to prepare these things out of the rock. If you've got seven, and they always bend the same way, I think that is a feature of the biology of the animal.

[46:22] It still doesn't solve what the hell the animal was doing with the trident! And I received all kinds of suggestions -- I always show this, because maybe somebody is going to have the right answer. I've received semi-jocular explanations, jousting is one I quite like. But it could be a secondary sexual feature. Generation of electrical fields. I should point out that these are probably solid. There may just be a thin little tubular hole up the middle through which the nerve could travel.

[46:50] And then how do you explain the different shapes? This one's got flat paddle-like ones, these have spikes, and that's got the long [inaudible] on the trident. Here I'm just reinforcing what everybody else has been saying today. The great thing about doing systematics and exploration is, as Mr. McCrory used to say, something always seems to turn up. You can't simply say, "Well we know what we need to know now, and we'll just get on to do communities or whatever else you can do with animals."

[47:22] One of them most interesting things is to go out there and find out what there is. Now we don't have the wonderful colors, and I wish we did, of living organisms, but you can do that with fossils just the same as with living organisms. And these things have a lot of details on spikes.
and tubicles and knobs and so on, which are not so different from the kind of features we've been seeing: colored stripes, pimples, and all the others things that you have on living taxon. So I feel lucky to work on something like trilobites. You can probably get somewhere near real zoological species as well.

[47:55] So just to finish, as I remarked, the end point of this is putting together the world. And this is a map of just this time period, this time slice, that I worked on in Spitsbergen when I was still very young. At which time nothing of this was known.

[48:13] That's a map of the world as the trilobites tells us it looked about 478 million years ago, to be precise. That's North America there lying on the Equator, and actually Spitsbergen lies at the edge of that area right up there. At the edge, because we know there are these deep water things there. The big continent of Gondwana was assembled then. And those rather curious trilobites in Oman are found again in South America, and in fact around a rather large part of this Gondwana continent.

[48:43] So we used the trilobites to map out Gondwana. There's the Baltic, I haven't talked about Baltic, although I have worked there too. That has a completely different assemblage of trilobites all over again, except for the deep water which is widespread. And that probably occupied intermediate latitudes.

[48:58] As for the British Isles, well rather interestingly, they probably formed a microcontinent. And we were hearing with New Caledonia an example of that earlier today. It starts off sharing a lot of things with Gondwana, then it goes into a phase where its got a lot of endemics, which may even be New Caledonia. And then at some point it moved over the other side and docked with North America, and everything else that we find later on in the Silurian for example, is like North America. So it had an independent history starting here and moving there.

[49:32] There's a lot of geological evidence that I haven't got time to go into for that kind of thing. So you see you start with systematics, and field collection, and new discoveries, and that's tremendous fun. And then eventually you finish up rebuilding the world. And I suppose that's quite a good definition of what being a scientist is.

Thank you very much.

[applause]

Announcer: [49:59] This lecture is part of the Arizona State University Darwin Fest. And is sponsored by the Institute for species Exploration, the College of Liberal Arts and Sciences, the School of Life Sciences, and is a production of Grass Roots Studio.