Video Transcript – Fossil Forensics – Plant and Insect Relationships

Maggy Benson: Hey, welcome everyone. Thank you so much for joining us for this special edition of Smithsonian Science How. We are behind the scenes here at the Smithsonian's National Museum of Natural History. Today we're going to be exploring the associations between plants and insects. These associations happen today just as you see here, bee on a flower. Perhaps you've even seen some leafcutter ants in the woods. Plants and insects are everywhere, and they've been associating with each other for millions of years. Both associations are found in the fossil record, and today we're going to be talking to Dr. Conrad Labandeira, a paleobiologist here at the Smithsonian, to understand how he finds the evidence of these interactions in the fossil record and what they all mean. Conrad, thank you so much for having us here in your lab.

Conrad L.: Thank you, Maggy. This is the Labandeira Lab at the National Museum of Natural History. I'm in the department of paleobiology and what I do is study the history of life. That's what paleobiologists do. In particular, I study the history of plants and insects and their relationships through time.

Maggy Benson: Now, what made you get interested in studying plants and insects in fossils?

Conrad L.: Well, I grew up on a farm in central California and there were a few years we had cotton. It was a major crop at that time.

Maggy Benson: Is this you as a child?

Conrad L.: Yes, that's me.

Maggy Benson: Very cute.

Conrad L.: That's my dad in the background. We had to pick cotton. This is before they had the regular pickers on John Deere tractors. I was more interested in the insects on the cotton than actually picking the stuff. The aphids were amazing. What they would do is that they would pierce and suck the stems and draw sap from the stems. You can actually see them, if you have very good eyes, imbibe the sap. Then there were the predators that were around them, and these were the ladybird beetles, the larvae, and also sometimes the adults that would feed on the aphids. It was an amazing relationship between the plant, the herbivore, which is the insect that feeds on the live foliage or the live leaves, and then the predator of that insect.

Maggy Benson: That's what spurred your curiosity, observing that at an early age. Now you study it in the fossil record.

Conrad L.: Absolutely. What we do in terms of plant/insect interactions, or associations through the fossil record, is to actually look at these snippets of time in time and space. We're trying to put together these ancient ecosystems. We need to put together the plants, the insects, and the damage. It's like a jigsaw puzzle and we're trying to recreate this lost world of relationships in far distant time.

Maggy Benson: Wonderful. Well, we have a lot of students here watching today. We see them from Illinois, from Iowa, from South Carolina, Texas, but they're all interested in learning about this lost world. Is that what we're looking at right now?

Conrad L.: Yeah. This is a scene from the Yorkshire flora of middle Jurassic age in the United Kingdom. We're looking at some plants and insects that no longer exist. The damage still exists, though.

Maggy Benson: To help you understand a little bit of the damage that you see in the fossil record, you actually start with modern stuff, stuff that's living today. Is that right?

Conrad L.: Yes. We need to understand the fossil record of what we do, the plant/insect interactions. We have to kind of look at what they do today.

Maggy Benson: Let's take a look at what we have.

Conrad L.: We have a really beautiful lubber grasshopper and he's trying to escape.

Maggy Benson: No, no, no!

Conrad L.: But as you can see, he has some really amazing mouth parts. I don't think he's going to escape. Well, maybe he will. But you can see the head and you can also see the mandibles. He's moving his palps back and forth. He's moving his antennae and this is all part of a system in which he's feeding on this lettuce, which is really great food. This is our buddy.

Maggy Benson: You can see this lettuce here. Are those-

Conrad L.: This is a type of damage. It's actually probably DT12 or margin feeding. I think he's getting a little anxious.

Maggy Benson: Alright, let's put him back in.

Conrad L.: Okay.

Maggy Benson: What else do we have here? Let's see.

Conrad L.: Okay.

Maggy Benson: Alright, let me get the lubber hopper back in there. Now we have another one.

Conrad L.: We have here a beautiful example of a stick insect. This entire body is the stick insect. You can see his head right here. I don't think he's all that comfortable, but these we can see that he clings onto this leaf. There's the head and the mouth parts.

Maggy Benson: What's important, though, are all of these leaves around here which are clearly chewed.

Conrad L.: These are chewed. We have given them numbers. This is a damage type 13, this is a damage type 12, and a 14 over there.

Maggy Benson: The marks that this insect leaves on the leaf might be a little bit different from the marks that the lubber grasshopper leaves.

Conrad L.: That's right. That's right, although there could be some similarities, as well.

Maggy Benson: Alright. We have another.

Conrad L.: This is a different kind of insect. These are the larva. These are adults, but this is the larva of what we call a holometabolous insect. These are the ones that transform themselves from an egg to a larva to a pupa to an adult.

Maggy Benson: We're looking at the caterpillar here.

Conrad L.: We're looking at the caterpillar, which is the larva. We notice that there's not only damage on the leaves, but there's also fecal pellets, or poop. That poop contains very good information that's also preserved in the fossil record because from the proof, we can actually determine the plant host, because sometimes the preservation is perfect.

Maggy Benson: Sometimes you get poop in the fossils.

Conrad L.: Yes, as well as the leaf damage.

Maggy Benson: Alright. Right here, these are not alive.

Conrad L.: These are pinned cicadas.

Maggy Benson: Let me help you out here.

Conrad L.: If you look carefully, this structure right here, this long behind the needle, is the beak. That's a piercing and sucking structure for imbibing sap that goes into the esophagus, but it's pumped by this structure, this food pump, on the head. You can see those faint lines. Those are actually muscles that compress the pump to basically force fluid food into the esophagus.

Maggy Benson: Now, I don't know if all of our students can see that at home, but that is a huge pump relative to the size of this body.

Conrad L.: Yes.

Maggy Benson: Next time there's a cicada emergence, everyone should find some of these and take a look at it themselves.

Conrad L.: The reason why it's so large is because it feeds on a fluid that is not that nutritious. It's called xylem, which is mostly watery sap.

Maggy Benson: Now, Conrad, you look at these insects and their mouth parts and the damage that they're leaving on the leaves to basically understand the different kinds of feeding modes that can happen, but are these the same kind of feeding modes and the same kinds of insects that were around in millions of years ago in the fossils that you have?

Conrad L.: Well, in the case of the Jurassic, for example, which is a time period in the Mesozoic, the damage types are very similar and we have some examples here. But the insects themselves are very different. We have a situation when we go deep into time. We have different plants, we have different insects, but we have the same kinds of damage, which is kind of interesting because I think, we'll develop this later, I think the best analogy for that is like a baseball team.

Maggy Benson: Conrad, we have a video question from a student.

Conrad L.: Sure.

Maggy Benson: Let's take a look.

Speaker 3: Where do you get the fossils from?

Conrad L.: Well, the fossils come from all over the world. It depends on the question that we're asking. For example, if I'm asking about what happened to insects and their associations, the dinosaurs became extinct at about 66 million years ago. I go to western North America, especially Wyoming, or southern Argentina. If I'm interested in the earliest period of pollination in the mid-Mesozoic during the Jurassic, for example, I go to northeastern China, which we have right here.

Maggy Benson: Which is what we're looking at here.

Conrad L.: At a place, Daohugou, which is the Jurassic and the other places which represent the middle Cretaceous.

Maggy Benson: What are these illustrations that we're looking at?

Conrad L.: In this particular case, we're looking at some angiosperms. This is a period of time-

Maggy Benson: Angiosperm is a flowering plant.

Conrad L.: It's a flowering plant that came after these deposits. It's probably from North America. We also have some other kind of deposits that are much earlier and we'll be looking at some of those, as well.

Maggy Benson: Can you give us a reference for what time period we're looking at? This is a geologic time chart. Where are we exploring today?

Conrad L.: We'll be looking at two major times periods, the Jurassic, which is in the green, and the Cretaceous, which is in the tan, which is the upper and middle parts of the Mesozoic Era.

Maggy Benson: How many millions of years ago was that?

Conrad L.: In this particular Jurassic department, the age of this is 165 million years. That's a radioisotopic age date. For the Cretaceous, the middle part of the early Cretaceous is 125 million years. They're separated by about, you know, a few tens of millions of years.

Maggy Benson: Conrad, thanks for giving us an introduction for how you use modern examples to begin to understand the interactions between plants and insects, and then you apply that to fossils. We're going to get to the fossils in a moment, but we're going to give our students a chance to have some of their questions answered, so let's get to some of those now.

Conrad L.: Sure.

Maggy Benson: This question comes from a student in Tampa. "What do you use to dig fossils? How deep do you have to go to find them?"

Conrad L.: It depends. Some deposits are on the surface and we use a combination of picks and shovels, and actually brooms. Other deposits tend to be much deeper and we have to use things like jackhammers and, frequently, backhoes in order to get to them. It depends upon the way that the deposits are preserved. What we have is a combination of tools. We often use a geology hammer with a broad end to actually collect the fossils, as well.

Maggy Benson: This question comes from Cyber Kid. "What is the biggest insect fossil you have found?"

Conrad L.: Well, one of the largest I have found is actually this lacewing from the middle Jurassic of China. These things had wing lengths, or wingspans, up to 16 centimeters, which is several inches long. From wingtip to wingtip, it's that distance.

Maggy Benson: Wow, that is a huge fossil. Does this have any modern analogs?

Conrad L.: No. This is an extinct family. The closest modern analog would be related families, such as lacewings, or maybe even antlions.

Maggy Benson: Alright. We have another question. This one comes from Grassroots. "How do you get the fossils?"

Conrad L.: Well, it's kind of a complicated process by the time we obtain the fossils in the field to where they're access here in the museum. We have to dig for them, we have to wrap them up usually in toilet paper, which is one of the most important items that we have in the field, is to wrap them up in toilet paper so that they're soft and they don't get damaged. Another thing that we have to do is we sometimes have to send them in crates and send them to this museum or some other museum. Then students or volunteers uncrate them and then we give them numbers. We have to prepare them, sometimes with dental picks, sometimes with other kinds of implements, including a rotary drill. Then eventually, they're here in the lab for us to study.

Maggy Benson: Let's get to them now. Let's learn about some of the fossils that you've actually pulled out of the drawers in the collection to show us today. Let's start by exploring this fossil. This fossil doesn't look like the rest. What is this one?

Conrad L.: Fossils are preserved in two fundamentally different ways. They're preserved through permineralization, which is a three-dimensional type of preservation such as this coal ball from the Illinois Basin of Illinois, and then we also can make peels of these things such as this. There's a process where we just actually peel it off.

Maggy Benson: This is actually fossil material, but it's paper thin.

Conrad L.: Yes. It's cellulose acetate. Then in some cases, we can actually cut the peel off and we can mount it on a slide like that.

Maggy Benson: We have a cut piece here and we see the slide here. What kind of information is contained in that coal ball which you eventually put on a microscope slide?

Conrad L.: In this particular coal ball, we have this huge fecal pellet, or coprolite, or poop. This poop came not from an insect, but from a related group of arthropods called millipedes or arthropleuras. An arthropleura is a millipede-like arthropod that is now extinct. You can tell what it fed on from the coprolite because it fed on detritus. It's not feeding on live tissue. They also have other coprolites that have galls, such as these two structures, from the rachises of this tree fern.

These galls represent this kind of structure that is found in the rachis of these large fronds that are part of this tree fern.

Maggy Benson: Now, why are there so many more of these flat fossils? Some of our students are asking, "What are the most common types of fossils you find?" I'm wondering, are these fossils, these are compression fossils, is that correct?

Conrad L.: Correct.

Maggy Benson: Are there more compression fossils available that have the information you need than there are-

Conrad L.: Absolutely.

Maggy Benson: -coal balls?

Conrad L.: Because it's really difficult to get information out of a three-dimensional structure. You have to actually saw it. You have to take peel after peel after peel. This could take, you know, several thousand peels to go through the entire structure and you have to make slides, whereas with compression fossils, which are actually preserved two-dimensionally, you have surfaces such as these surfaces that contain all the information that you need. We can actually count the numbers of damage types. We can actually count the diversity of damage types. We can actually digitize the surface area of these things.

Maggy Benson: We're looking at the screen now. Is this a type of damage that you're actually seeing on the fossil, just like we saw on the modern leaf?

Conrad L.: The damage that you see that says 80, actually that refers to another kind of damage. But it is this damage, which is damage type 12.

Maggy Benson: You're showing us here the guide that you have that outlines all these different types of damage types that you have in the fossil record. We're going to actually give our students another opportunity to participate in a live poll in a moment, but first we're going to walk through some of these different damage types. Can you explain what we're looking at here?

Conrad L.: This is surface feeding. This is a fossil ginger found in the late Cretaceous. This is margin feeding.

Maggy Benson: This is when an insect eats around the edges like a caterpillar.

Conrad L.: Like a caterpillar or maybe a grasshopper-like insect. This is skeletonization where an insect actually feeds through the blade but leaves behind the small delicate veins. This is whole feeding, where an insect feeds through the leaf blade but leaves nothing behind.

Maggy Benson: Alright, thanks for giving us that overview. Those are just some of the more common types of feeding that you find in the fossil record. We've looked at the fossil leaves, but what about the insects that are leaving the damage? How often do you find those? Can we take a look? I see some of them right next door.

Conrad L.: Fortunately, in the [inaudible] formation, which is the middle Jurassic unit that we're looking at, we'd also have insects preserved in the same deposits. It's interesting that we have the damage and the plants, I mean, they are on top of one another, here, but the challenge is to associate the insects with the damage. There are various ways that we can do this. We can look at modern analogs and maybe figure out what was around-

Maggy Benson: Like what we were doing earlier.

Conrad L.: -but here we actually have the insects. Here is a grasshopper-like insect. You can see the color banding on the wings. There's the head and there are the mouth parts. Those are the chewing mouth parts.

Maggy Benson: Would that be like anything we're used to seeing today?

Conrad L.: It's just like the grasshopper that we saw earlier. These are the mandibles. If you looked at this under the microscope, you could probably see some palps, as well. That's one insect. We also have a stick insect, a very distant ancestor of what we saw in the beginning. This is the stick insect. We can see its hind legs, mid-legs, and forelegs.

Maggy Benson: Let's point it right here so our students can take a look at it.

Conrad L.: There's the head, there are the antennae.

Maggy Benson: There we go.

Conrad L.: Unfortunately, these types of insects had their mouth parts underneath the head. We can't see the mount parts from the dorsal view, but if you were to flip this, imagine this insect on its ventral side, you would be able to see the mandibles, the palps, and some other features.

Maggy Benson: Now, our students from Tampa are asking how old these fossils are.

Conrad L.: These are all the same age as the foliage. This is 165 million years old. We also have cicada-like insects. We saw some cicada-like insects. The wings are better preserved than the head, but here you can actually see a slight thickening and the beak is about maybe a half a centimeter long. Here you can see the head pump, the food pump, and the medial styloid. But much better is looking at it through the side. This is another example. Here you can see the food pump, which is right here, and this structure extending to the right in that position is the beak. That is the organ that actually takes up the food.

Maggy Benson: These fossils actually have their mouth parts preserved well enough so that you're able to understand their biology. A lot of that is because you understand modern insect biology.

Conrad L.: Correct.

Maggy Benson: A lot of our students are asking where these fossils come from. They're here at the Smithsonian at the National Museum of Natural History.

Conrad L.: Yes. Now, some of them are on loan from other institutions, such as Capital Normal University in China.

Maggy Benson: We're going to get to one final section in a moment, but let's get to just a couple student questions before we move on.

Conrad L.: Uh-huh (affirmative).

Maggy Benson: This question comes from Garrett, and he wants to know, "What are the holes in the fossils?"

Conrad L.: Oh, these structures. This is the bane of a paleontological existence. These things are called conchostracans, and conchostracans are bivalved arthropods that occur in lake deposits. The problem is that they get in the way of people like me. Frequently I've had a fantastically preserved insect, and then right in the area where their mouth parts are, we can see the most detail, there's a big conchostracan covering it.

Maggy Benson: Bad luck.

Conrad L.: Yeah. Even though I'm offending a lot of people that study conchostracans, I wish they weren't in this deposit at all.

Maggy Benson: This one comes from St. Anthony's School, who is actually here watching and Curious at the Smithsonian. They want to know, "How long does it take to find a fossil?"

Conrad L.: It takes quite some times. In order to find these fossils, you have to know where to look and you need a geologic map. You also gotta know what the favorable environment of deposition was of the particular deposit. There are certain kinds of deposits that contain better fossils than others, and more fossils, such as lake deposits. These fossils comes from large lake deposits in northeastern China. That's why we find these idiotic conchostracans. That's one place. Another place to look at in the case of the three-dimensionally preserved coal balls are coal swamp deposits, such as this from Illinois.

Maggy Benson: Now, Conrad, we are pretty deep into our show, but we want to talk very briefly about pollination. It's a major plant/insect interaction now and you're actually looking at it in the fossil record, as well. Can you show us some evidence of insects and plants that we have here before we get to some more student questions?

Conrad L.: Yeah, let's start with the insects first. This is a lacewing. We've seen this before. There's the head there are the mouth parts. This is one group of insects and they're in the order Neuroptera. Another group of insects in the order Mecoptera, or scorpion flies, are these things. This is one family. You see this little mosquito-sized scorpion fly? It has a proboscis of about a millimeter long.

Maggy Benson: Yeah, I can see.

Conrad L.: There's this one, and then there's this much larger one. These belong to two different families. A third family, or lineage, are these things. This has a proboscis that you can see up here.

Maggy Benson: Oh, I don't think our students can see. Let's put it down right here.

Conrad L.: Okay. It's this. This is part and counterpart. It's this one.

Maggy Benson: Oh, beautiful.

Conrad L.: Right there. Yep.

Maggy Benson: Then what's this final family up here?

Conrad L.: These are true flies. This proboscis is here. It's relatively short, but it's stout. This is a family that still occurs today. They're called tangle-vein flies. Here's another example of the same species preserved in a slightly different way, again with the same sort of proboscis.

Maggy Benson: The preservation on these are truly incredible.

Conrad L.: Yes.

Maggy Benson: Now, what were they pollinating? Do you have any plant evidence?

Conrad L.: Well, we have in the same deposit, not excluding these from the middle early Cretaceous, we have these bennetitalian organs. They're the fructifications or the reproductive organs of these bennetitalians.

Maggy Benson: They're pre-flowers.

Conrad L.: Yes, and they may look like flowers, but they have no relationship to angiosperms or flowering plants. We have the male organ here. This is an example with-

Maggy Benson: It's beautiful.

Conrad L.: It's opened up, probably after the organ was spent and no longer valuable for pollination, and this is the center part. These are bracts. They kind of look like petals, but they are not equivalent to petals. Then this is another example of another male organ and it's a tubular- Here's the base and it's a large tubular structure. The female organ are these structures here. This is the central receptacle, which is a dome, and it contain all the small ovule. Each ovule secretes a little pollen drop. Then this distance is kind of like the conical part of the female organ, and it is the part that had been penetrated by a long proboscis pollinator.

Maggy Benson: To help some of our younger viewers understand this, those pollen drops are incentives for insects and they actually eat those pollen drops with their mouth parts.

Conrad L.: They're the reward. Another potential reward could be the pollen in the male organ, too. There are some insects that actually consume some of the pollen, and of course, other parts of the pollen, or other pollen grains, go to pollinate the female organ. Here's an example of another female organ. This is a bit different species than this one and then we have all of the different separate elements that become separated once the structure falls apart after it's deposited in some sediment.

Maggy Benson: Now, what's the significance of finding the insects that have these mouth parts that indicate that they might be pollinating, and finding the plant material that has evidence of pollination?

Conrad L.: The keys to putting these two together, and this is a very- There's several students in my lab that are working on this. We need to look at the presence of pollen on these insects that trace it back to the plants that they pollinated. That's one type of indirect evidence. Actually, that's pretty direct evidence. A more indirect evidence is the nature of the mouth parts and the nature of the female structures that are being pollinated and the male structures that are being pollinated. Do they have certain structures? For example, like nectaries or other kinds of glands that would be rewards for insects.

Maggy Benson: Alright, we have just two more questions. I'm going to wrap them into one.

Conrad L.: Okay.

Maggy Benson: This one is from Winter Code School and the other one is from Aiden. "Have you ever visited the Devonian Fossil Gorge in Iowa City?" And another general collecting, "How many fossil do you think you've found?"

Conrad L.: No, I've never been to the Devonian Fossil Gorge in Iowa City. I know about it. It's a very famous deposit. In terms of fossils that I've collected, probably tens of thousands, and almost all of them are either fossil leaves or fossil insects.

Maggy Benson: Is that exciting? Every time you find them it has to be.

Conrad L.: Yeah, it's extremely exciting and the most exciting part is working up the data and then publishing our results.

Maggy Benson: Conrad, thank you so much for helping us understand a little bit more about your work and inviting us behind the scenes here at the Natural History Museum. Can you tell our viewers where they can explore this idea if they're interested in looking for the damage themselves or even interested in fossils?

Conrad L.: Actually, if you're looking for damage, you can go to any forest and find all kinds of damage. The most common biological item on land is probably a leaf. Next to that would be insects. Those are the two most diverse, seed plants and insects are the most diverse groups of organisms around today. There's no absence of leaf damage, of leaves, and insects that you can find today. In terms of the fossil record, then you probably would go to your local museum or university and maybe ask somebody who knows about fossil deposits on land. Then of course our museum, we have Curious, which is an amazing resource for students that are very interested in this type of topic.

Maggy Benson: Conrad, thank you again so much for introducing us to your work and inviting us here.

Conrad L.: Okay.

Maggy Benson: Students, thank you all for your questions. It's been wonderful getting a chance to ask them and have Conrad answer them. If you want to join our next program, we'll be live on March 22nd and if you want to view this archive again, it will be available on Q?rius later this evening. You can visit Q?rius To see resources about Conrad's work, as well. Thank you so much for joining us here on Smithsonian Science How. We hope to see you next time.