Video Transcript - Mineral Dependence – Gemstones to Cellphones

Announcer: Some of our most valuable gems and rare minerals are found concealed in bands of pegmatite rock. How do these rocks produce the minerals we use for everything from jewelry to the batteries for our cell phones? Scientists are studying pegmatites and their incredible crystals to unlock [00:00:30] their mysteries. Join us now for a conversation with geologist Mike Wise to dig deeper into the science of nature's crystal factories. Now, here's your host, Maggy Benson.

Maggy Benson: Hi. Welcome, everyone. Thanks for joining us for another episode for another episode of Live from Q?rius, Smithsonian Science How? We're so happy to have you here with us today. We're also really excited to welcome our special guest, geologist from the Smithsonian's National Museum of Natural History, [00:01:00] Dr. Mike Wise. Hi, Mike. Thanks for joining us today.

Mike Wise: Hi, Maggy. Thanks for having me here.

Maggy Benson: Mike, you're a geologist here at the Smithsonian.

Mike Wise: Yup.

Maggy Benson: Can you tell us what you do?

Mike Wise: A lot of different things. I study rocks and minerals primarily, in the lab and in the field. When I'm not doing that, I also have duties helping to build our collection on rocks of rocks, minerals, and gems. I also do some educational outreach here at the museum and also out visiting schools.

Maggy Benson: Very cool. What made you get interested [00:01:30] in geology as a field to make it your career?

Mike Wise: I got into geology by accident. As a young boy, I was always interested in science, whether it be astronomy or biology or chemistry. But where I grew up, there were no rocks. So, I didn't really have a rock and mineral collection like a lot of geologists may have had when they were younger. I really didn't get into geology until I went to college at University of Virginia as an undergraduate and a took a couple of courses and got exposed to geology, and I found out I really enjoyed [00:02:00] it.

Maggy Benson: Mike, here at the Smithsonian as a geologist, you study one very special kind of rock.

Mike Wise: Um hmm (affirmative).

Maggy Benson: What is that?

Mike Wise: I study a rock called pegmatite. It's a type of igneous rock that's pretty unique, I think.

Maggy Benson: What is igneous rock?

Mike Wise: Igneous rocks are rocks that from the crystallization or solidification of molten magma, or melted rock, whether it be below the surface or erupted at the top like volcanoes.

Maggy Benson: Is that similar to something like granite that I'm familiar with as [00:02:30] an igneous rock?

Mike Wise: Yeah. Actually, in fact, pegmatites have mineralogy very similar to granite. Typically, a granite is made up of feldspar and quartz and maybe some micas, and pegmatites as well. I have some examples here. This is a mineral, feldspar. We have an example of quartz and a big sheet of mica. It's basically the same mineral as most granites.

Maggy Benson: What's different?

Mike Wise: What's different is the grain size, the crystal [00:03:00] sizes. If you look at a typical granite, most of the crystals are really small, about a millimeter or so, but pegmatites can grow these giant crystals, and I mean giant! Bigger than you, bigger than me, and I'm six-foot-three. Some of the largest crystals ever reported came from pegmatites, and they're about 50 feet long. So, think about the size of a telephone pole, to give you an example.

Maggy Benson: That's huge. What we're looking at here, I mean, this mica that you just showed us is gigantic.

Mike Wise: Gigantic for most igneous rocks. If you look at volcanic rocks or any other type of igneous rocks, [00:03:30] they don't form crystals that are very large. Only pegmatites do.

Maggy Benson: What makes pegmatites unique in their formation?

Mike Wise: Well, they're unique in their formation in that they are able to concentrate a lot of rare elements. A lot of elements that don't occur in large quantities in most igneous rocks. For example, we have elements like tantalum, beryllium, and lithium that may occur in those pegmatites, but in the [00:04:00] formation of a granite body, the style salt is a granite melt below the surface.

Maggy Benson: So that's volcanic material.

Mike Wise: Well, it's not really volcanic material. It's molten rock. We only consider it volcanic material when it erupts at the surface. But as the granite is crystallizing, the elements like tantalum and lithium don't go into the mineral structure of the

feldspars and micas. They remain behind, and they end up in this water-rich solution that eventually squirts [00:04:30] out into the country rock, and those eventually crystallize to form pegmatites.

Maggy Benson: Wow. Very cool. I see a huge diversity of shapes and colors in the huge crystals that are here on the table. What causes this diversity?

Mike Wise: The diversity is due, in large part, to the chemistry. It's a very unique chemistry as far as most igneous rocks go. Pegmatites, whatever that process is that makes pegmatites, allows it concentrate a lot of unique elements. Almost half the periodic table, in [00:05:00] fact.

Maggy Benson: Wow.

Mike Wise: Yeah. Most igneous rocks don't do that. These concentrations can be very, very high.

Maggy Benson: You said that these minerals are made up of elements and sometimes rare elements. Do you have an example of a rare element here from a pegmatite?

Mike Wise: Yeah. We have this mineral called tantalite. It's extremely rare, and it's only found in pegmatites. One of the major elements in this mineral is called [00:05:30] tantalum. Now, tantalum is important because it is useful in the making of electronics. If you look at the abundances of tantalum in the earth's crust, you'll see that it's about one part per million. If you look at the tantalum concentration of typical granite, it's about two. That's still pretty low, but typical for most igneous rocks. The pegmatites and tantalites can have up to 300 to over 750,000 [00:06:00] parts per million tantalum. That's a lot of tantalum.

Maggy Benson: Basically, you're being able to get a crystal large enough with enough tantalum in it to actually use that tantalum.

Mike Wise: Right. For most rocks where tantalum would be considered rare, pegmatites, not so rare.

Maggy Benson: You said that pegmatites are able to concentrate many different elements.

Mike Wise: Um hmm. Yep.

Maggy Benson: Is this rare for other rock? Is this unique to pegmatites, or does this happen in [00:06:30] other rocks too?

Mike Wise: Well, other rocks may have those same elements, but only in very small quantities. And there are some pegmatites that also have these rare elements, but in small quantities. But In special pegmatites, like some of the examples I have here, yeah, you can get large quantities of tantalum, beryllium, lithium, and other rare metals.

Maggy Benson: Very cool. Mike, just in this brief amount of time, you've taught us that pegmatites have this ability to concentrate lots of different types of elements into very large crystals that can then [00:07:00] be used for other things. I wonder what the most important property is, though, about pegmatites. Should we ask our viewers?

Mike Wise: Yeah, let's find out what they think.

Maggy Benson: All right, viewers. Here's your opportunity to participate in a live poll with us. You can respond using the window that appears to the right of your video screen. Tell us what you think. What is the most important property of pegmatites: Lots of types of minerals? Large crystals of minerals? Minerals valuable for human uses? [00:07:30] or Minerals rarely concentrated elsewhere? Take a moment to think about it and put your answer in the window to the right.

Maggy Benson: [00:08:00] Mike, the results are coming in, and we really have a pretty even distribution between large crystals of minerals and minerals valuable for human uses. [00:08:30] The poll is still changing, but what do you think?

Mike Wise: Well, all of those are pretty good answers, but I think the most important feature is the large crystals because, frankly, that's what defines a pegmatite, is by their large crystals. For me, that's the most important feature.

Maggy Benson: What makes large crystals so special?

Mike Wise: Well, large crystals enable you to make very large gemstones, really super nice mineral specimens, and it just makes some pegmatites fun [00:09:00] to study.

Maggy Benson: And really beautiful.

Mike Wise: Yeah, really beautiful.

Maggy Benson: All right. Mike, we have a student question. Are you ready to take it?

Mike Wise: Okay. Fire away.

Maggy Benson: All right. Let's see.

Ella: Hi, I'm Ella, and I'm a fifth grade at Flores Elementary School. My question is what do pegmatites tell scientists about the region's history?

Mike Wise: Wow. That's a really good question. Sometimes, pegmatites can tell you a little bit about the geology, the local [00:09:30] geology that's present, but sometimes they don't. Sometimes, pegmatites occur in rocks that have nothing to do with the geology around you. And in other cases, they're related to the granite bodies that probably formed them.

Maggy Benson: Great question, Ella.

Mike Wise: Yeah, that was a good one.

Maggy Benson: We have another question here, and this one comes from the MSNV school. How many pegmatites have you found?

Mike Wise: How many have I found? Wow, that's a hard one. [00:10:00] Ummm. I can't say that I have found some new ones myself. I visit a lot of places around the country, but there are some pegmatites that I have looked at that have never been studied before or have been studied in detail. I don't think I can really answer that, how many new ones I found.

Maggy Benson: All right. We have another student question. This one comes from Sahaj. Do you only study gemstones?

Mike Wise: No, I don't [00:10:30] only study gemstones. In fact, I also study minerals from pegmatites that are pretty black and ugly. Most people probably wouldn't even pick them up in the first place. Even those minerals can give us some information about how pegmatites form.

Maggy Benson: Wonderful. Great questions, keep them coming.

Mike Wise: Yeah, that was a good one. That was a real good one.

Maggy Benson: Mike, I want to learn more about the human uses of pegmatites? What kind of economic value does this type of rock have?

Mike Wise: Well, unlike a lot of other igneous rocks [00:11:00] or other rocks in general, pegmatites have basically four different types of material that they can produce. There are things we call strategic metals, industrial minerals, gemstones, and collectibles.

Maggy Benson: Let's explore each one of those now.

Mike Wise: Okay.

Maggy Benson: Let's start with strategic metals. What does that mean?

Mike Wise: Well, these are metals that are required and used in industry, in technology, and in the military field.

Maggy Benson: What kind of pegmatites are used?

Mike Wise: Well, [00:11:30] it's not so much the pegmatites themselves. It's the minerals that are present. For example, tantalum, tantalite. Tantalum is really important in the use of electronics and today's technology. Without tantalum, a lot of the

things that we use or take for granted, don't work properly. For example, your cell phone and smartphones have this little device called a capacitor. In this particular one which we ripped the back off, there's this little tiny little square thing here called a [00:12:00] capacitor which stores electrical energy that the cell phone can then use. Pretty much every electronic device like cell phones, computers, and video game consoles can have capacitors in them.

Maggy Benson: What happens if there wasn't tantalum?

Mike Wise: They might not work. In fact, there were several years ago when the PlayStation 2 came out, video game came out, there was a shortage because of the shortage of tantalum. There was not enough tantalum to make all the capacitors needed to [00:12:30] fill their orders for these PlayStation 2s.

Maggy Benson: Wow. Interesting. So, tantalum and pegmatites are incredibly important for our gadgets to work.

Mike Wise: Yep. Also, an element called lithium, and lithium is used in making lithium batteries, which we all know are in the cell phones as well.

Maggy Benson: What kind of pegmatite does that come from?

Mike Wise: It can actually be in a same pegmatite that has tantalite. It comes from the mineral spodumene, which is the primary ore for lithium.

Maggy Benson: Very cool. Let's explore [00:13:00] another one of those human uses. You said that they're used in industry.

Mike Wise: Yeah.

Maggy Benson: What kind of industry?

Mike Wise: Well, the industrial minerals are basically nonmetals. Things like quartz, and feldspar, and micas, which are not really metallic minerals. They are used or mined from pegmatites for use in the glass-making industry, in making cookware like Corning Ware, things like that. The micas are used in paints and in cosmetics like makeup, eyeshadow.

Maggy Benson: [00:13:30] Oh.

Mike Wise: Yeah.

Maggy Benson: I have to thank pegmatite mineral for makeup today.

Mike Wise: Yeah, it's what makes it glitter. All that glitter is due to little tiny pieces of mica that's ground up and incorporate it into the cosmetics.

Maggy Benson: Wow, Mike. Who knew that everything from makeup to cell phones to gaming consoles depend on the minerals that are produced by pegmatites?

Mike Wise: That's right.

Maggy Benson: There's another one that, another use that you mentioned, gemstones. I see some beautiful stones here.

Mike Wise: Yes. We have a few gemstones here. This is what most [00:14:00] people may be familiar with things like aquamarine and topaz and tourmaline and garnet. They're found as gemstones that are cut from minerals from pegmatites.

Maggy Benson: Now, some of them, I would hate to actually cut up. Is there a use for some of these minerals in this raw form?

Mike Wise: Well, I hate cutting them up too, but before I get onto that, I have something I want to share with our viewers.

Maggy Benson: All right. What could it be?

Mike Wise: [00:14:30] In order to cut gemstones, this is a cut stone of quartz. You're speechless.

Maggy Benson: I'm totally speechless.

Mike Wise: This is-

Maggy Benson: I could never wear that in a necklace.

Mike Wise: No, I couldn't either, and you wouldn't try. But think about this. In order to cut a gemstone this big, you got to have a big crystal. This is just a simple quartz. This particular specimen from Brazil is almost 20,000 carats.

Maggy Benson: [00:15:00] 20,000 carats!

Mike Wise: Yeah. Yup, and it's from a pegmatite, or the crystal is from a pegmatite.

Maggy Benson: That is so incredible.

Mike Wise: Yeah.

Maggy Benson: This huge gemstone, I mean, the actual crystal that it came from must've been-

Mike Wise: It had to be big. It had to be at least twice that size, at least.

Maggy Benson: Wow. That's amazing.

Mike Wise: Yup.

Maggy Benson: Let's talk about the actual crystal that it came from.

Mike Wise: Yeah.

Maggy Benson: Is there a value for those?

Mike Wise: Well, actually, there are. I mean, just like [00:15:30] people collect stamps and collect coins, model cars, whatever the case may be, there are people who collect minerals as a hobby. This has been going on for many, many decades. Even today, they still collect pegmatite minerals because they're beautiful.

Maggy Benson: They really are. I'm truly speechless. These are just ... It's just an amazing array of materials. Are these actually in the museum's collection?

Mike Wise: Actually, [00:16:00] pretty much all of these are. There are a few things that I collected during my research, but hopefully, they'll get into the museum collection when I'm done with them. You can see, people, visitors can come to the museum and they can see things like this in our Geology, Gems, and Minerals gallery which has a whole section that's devoted to pegmatites.

Maggy Benson: Very cool. Mike, I'm ready to go out and start mining these myself.

Mike Wise: Mining. Yes. Sure.

Maggy Benson: Digging, looking for pegmatites [00:16:30] myself. We have a student video question though, so let's view that.

Mike Wise: Okay. All right.

James: My name is James.

Collin: And my name is Collin. We are fifth graders at Flores Elementary school.

James: Our question is where do you find most of your pegmatites?

Mike Wise: Great question, guys.

Maggy Benson: Mike, I think that's a question that we should actually ask our viewers.

Mike Wise: Yeah, let's do that.

Maggy Benson: We're all ready to search for pegmatites. Here's another opportunity for you to answer a live poll with us. Tell us, where do you find pegmatites: Deserts? Mountains? [00:17:00] Ocean floor? or Marshland? Take a moment to think about it and put your answer in the window to the right of your window screen.

Maggy Benson: [00:17:30] Mike, the results are still coming in, but 85 percent of the viewers think that the answer is B, mountains. How did they do?

Mike Wise: All right. That's good because most granites ... What most of the pegmatites are associated with or occur in mountain ranges.

Maggy Benson: Can you give us an example of some pegmatites that you've actually found in your career here?

Mike Wise: Yeah. When I first started here, I [00:18:00] actually was spending most of my time in Maine, looking at pegmatites there. Then I started working in Rhode Island, and then Virginia, North Carolina, and then as far west as California and Colorado and Nevada.

James: My name is James.

Collin: My name is Collin. We are fifth-

Maggy Benson: I know that you found an amazing specimen in Colorado. Can you tell us about that?

Mike Wise: Yeah. During one of my trips out there, one of the miners had found some pegmatites, and he found these pockets, which are essentially holes in the pegmatites where crystals can grow into. [00:18:30] He invited me to stick my hand in and see if I could pull something out and I did. I reached in, felt something that felt like quartz crystals, wiggled it out, pulled it out, and pulled out a very nice amazonite specimen, which is this green feldspar with black smoky quartz.

Maggy Benson: This is what we're seeing here.

Mike Wise: Yeah. That's the piece. And they nicknamed it the Smithsonian Pocket because I was a Smithsonian employee at the time, but the sad thing is we didn't get [00:19:00] to keep this for the museum.

Maggy Benson: It's really a spectacular sample.

Mike Wise: Yeah, it was fun. I mean, being the first to pull something out of the ground for the first time.

Maggy Benson: Mike, are pegmatites located all over the world?

Mike Wise: Yep. They're located on every continent, even Antarctica. With all that ice, you never would expect that there are rocks there, but there are rocks exposed. And there are pegmatites in some of the mountain ranges in Antarctica.

Maggy Benson: If I wanted to go search for pegmatites, like the minerals that this [00:19:30] one produced, would I know where to look? Do scientists know where certain pegmatite minerals are found?

Mike Wise: We have a pretty good understanding of where the major pegmatite deposits are, the major pegmatite areas, there are so many. Brazil is one of them, in fact. But one of the things I'm trying to understand is, is there a connection between the type pegmatite and broad geologic processes? For example. We know there are places [00:20:00] where the Earth's crust comes together to form mountain chains, like Himalayan Mountains or the Appalachian Mountains. There are large amounts of granites were they develop and there are pegmatites strewn all along those mountain chains. Whether we can determine if there's a specific type of pegmatite in those mountain chains, that's one of the things that we're trying to understand a little bit better.

Maggy Benson: As a scientist here at the Smithsonian, you're actually looking at the internal structures of these crystals and trying to better understand their chemistry. What kind of techniques do you use to do that?

Mike Wise: [00:20:30] A lot of different techniques. If I find a mineral that I don't know what it is, the first thing I will do is use our x-ray diffraction machine, which actually gives us an idea of the atomic arrangement of that particular mineral. It's essentially a fingerprint. Every mineral will give off a specific x-ray pattern. From there, I'll move on to the electron microprobe, which gives us chemical information. So, it allows me to determine which elements make up that particular mineral.

Mike Wise: Then we have a scanning electron [00:21:00] microscope which is basically used for imaging, although we can get some chemical information. It allows us to see surface features or if we have a polysection, we can see things like zoning or if there's replacement going on. A whole bunch of really neat things you couldn't see with the naked eye.

Maggy Benson: But you said earlier that you can see some things with the naked eye, such as color indicates chemistry.

Mike Wise: Yeah.

Maggy Benson: Do you have an example to show us here?

Mike Wise: Yes, I brought with me a specimen. It's a slice of a mineral liddicoatite. [00:21:30] It is a type of tourmaline. One of the neat things about this particular sample is that you can see various colors.

Maggy Benson: It's beautiful. I see a pink triangle right in the middle.

Mike Wise: Yeah. There's a pink triangle there, and then there's green bands. And we know from studying tourmalines that the green color is due to the presence of iron, and the pink color is due to the presence of the element manganese. Just by looking at this, we can, much like the rings of a tree, we're looking at the growth history of this particular tourmaline.

Maggy Benson: [00:22:00] Wow, that's fabulous.

Mike Wise: Yeah, pretty cool.

Maggy Benson: Do you have any other examples of how you can sometimes use techniques such as light to better understand?

Mike Wise: Yeah, I have an example of what's called opal. It's not like the opals that most people see in jewelry, okay? It's still opal nonetheless because it has the chemical composition of opal, which is silicon, oxygen, and a little water. But one of the neat things that happen when you subject this to ultraviolet light is [00:22:30] that it changes color. So, you can dim the lights [crosstalk 00:22:34]-

Maggy Benson: Can I see it?

Mike Wise: Sure.

Maggy Benson: Yeah, let's dim the lights. Oh, how cool? It's actually glowing.

Mike Wise: It's actually glowing. So, we don't really know what causes this. Not all opals do this, but this particular type of opal may have little bits of uranium. I mean, really, really tiny amounts, that cause it to react with the energy from the ultraviolet light [00:23:00] and cause it to glow.

Maggy Benson: Do all opals glow like that?

Mike Wise: No, they all don't. Most opals, again, that you use in jewelry will not do this. This is not a property of those types, but I've looked at a few opals from pegmatites, and almost all of them do.

Maggy Benson: Wow. That's really fascinating. Mike, you've taught us a lot about pegmatites, their amazing diversity, and how you're studying them, so thank you for that. I think we should go to some student questions. What do you say?

Mike Wise: Okay. Let's go.

Maggy Benson: All right. This question [00:23:30] comes from The Auburn School. What temperature and depth do emeralds form?

Mike Wise: Wow, emeralds.

Maggy Benson: Are emeralds part of the pegmatite family?

Mike Wise: Well, sometimes it can be. They don't always grow right in the pegmatites, but to form emerald, you need two things to happen. You need a source of chromium, that's what gives it the green color, and you need a source of-

Maggy Benson: An element.

Mike Wise: An element, you need the element beryllium, which, in most cases, come from pegmatites. [00:24:00] You typically find them on the edges of pegmatites if that pegmatite intrudes the right type of rock. The temperate of the formation could be 500, 400 degrees Celsius, and we may talk about five, six kilobars of pressure, something in that range.

Maggy Benson: A lot of pressure.

Mike Wise: A lot of pressure and not very high temperature.

Maggy Benson: Very cool.

Mike Wise: Great question.

Maggy Benson: We have another question, and this question comes from Mr. Holmes' class. They want to know, are certain [00:24:30] type of pegmatites more common than others?

Mike Wise: Good question. And the answer is definitely yes. In fact, if you took a survey of all the pegmatites in the world, if we could, and we would come up with such a large number, well over 100,000 pegmatites, probably 99 percent of those are very simple mineralogy, just quartz, feldspar, and mica.

Maggy Benson: Just like granite.

Mike Wise: Just like granite. Less than 1 percent of them have all these really cool minerals that we've shown here.

Maggy Benson: [00:25:00] We have another question. This one comes from Meg in Charlotte. What is your favorite pegmatite specimen at the Smithsonian and why?

Mike Wise: Meg, everybody asks me that question. I have a hard time picking a favorite because I like them all, whether they're really gem quality ones or just this cruddy black little skim on the surface. I do have a favorite pegmatite gem though, and that's called a tourmaline. [00:25:30] It's a Paraiba tourmaline, which has a very unique color. It's the color of Windex. It's this Windex blue color. It gets its color from the presence of copper in the tourmaline, which is quite uncommon for tourmaline, in general, to have copper in it.

Maggy Benson: Very cool.

Mike Wise: Yeah.

Maggy Benson: We'll have to find some Paraiba tourmaline.

Mike Wise: Paraiba tourmaline, yeah, if you want to find Paraiba tourmaline, you got to go to Brazil or Nigeria or Mozambique.

Maggy Benson: I have to add it to my list.

Mike Wise: Well, I'm ready. [00:26:00] Let's go.

Maggy Benson: Okay. This one comes from Julia. Have you ever discovered a new mineral?

Mike Wise: Funny you should ask, Julia. I haven't discovered one yet, but I'm working on a couple. One of them is from the pegmatite down in Virginia, the Morefield pegmatite. A few years ago, a collector sent me some material to look at, and it turns out that it's not like any mineral that we know of at this point. I'm actually still doing some of [00:26:30] the chemical work, some of the x-ray work, and hopefully, it will become a new mineral species.

Maggy Benson: We have one last question, and this one comes from MSNV school. Have you ever looked for pegmatite in Maine? If so, what have you found?

Mike Wise: Probably the best question of the day, only because that's where I started my research here when I started working for the Smithsonian. I spent a lot of time, a lot of years looking at the pegmatites in Maine, primarily the pegmatites in the western part of the state [00:27:00] close to the New Hampshire border. And I found all kinds of minerals. In fact, this tantalite specimen that I brought with me, it's from Maine.

Maggy Benson: Wow.

Mike Wise: It's from what's called the Hayes Quarry. I had to fight off one of my colleagues to bring it back because he wanted to take it, but I found tantalite. We found beryl and spodumene.

Maggy Benson: Oh, I know I'm very interested in looking for pegmatites and maybe some of our viewers are too in Maine and in Virginia. How can students get involved if they're interested to learn more?

Mike Wise: Well, if you want to learn more about geology, [00:27:30] I would suggest you go outside. Go look at a rock. Pick it up. Study it. Break it open, see what's in it because, frankly, rocks give us a clue to understanding how the earth works. This is what geologists do. We look at rocks. If you don't have rocks in your area like I didn't have any when I was growing up, go visit your local museum. Look at

the geology collection that are displayed. If you're in DC, visit the Smithsonian here. Visit the Natural History Museum and stop by the Geology, Gems, [00:28:00] and Mineral gallery. If you have time after all that, you can stop by Q?rius and you could actually pick up specimens, look at them under a microscope, handle them, much like a-

Maggy Benson: Like this.

Mike Wise: Yeah, much like a geologist would do.

Maggy Benson: Thank you so much, Mike, for helping us better understand what pegmatites are and how cool they really can be.

Mike Wise: Thanks for having me. Thanks for all the great questions. I hope you guys have some young pegmatologists out there in the future.

Maggy Benson: Me too. Thank you so much for joining us for this episode of Smithsonian Science How? If you want to see [00:28:30] the program again, it'll be archived later this evening on qrius.si.edu.

Announcer: Thanks for watching. You can explore more Smithsonian Science How? shows and teaching resources on our website, qrius.si.edu.