Video Transcript - Volcano Geochemistry - Windows to Earth's Interior

Maggy Benson: When you [00:00:30] think of volcanoes you might imagine mountains towering over the landscape, lava flowing towards villages, and geologists on mountainsides measuring seismic activity. But, most volcanoes are hidden thousands of feet under the sea. These volcanoes erupt and eject magma, just like the volcanoes on land. So how do scientists study them? Geologists must gather evidence from underwater. Today, we'll see how Smithsonian geologist, Dr. [00:01:00] Elizabeth Cottrell, uses volcanic rocks from the sea floor to learn more about these submarine volcanoes and to better understand Earth's interior.

Maggy Benson: Hi, thanks for joining us I'm Maggy Benson, host of Live from Q?rius, Smithsonian Science How? We have a really great show for you today but before we get started I want to ask you a question. You can respond using the poll that appears to the right of your video screen. Which of these does not erupt out of volcanoes? [00:01:30] Is it smoke, rocks, glass, mist, lava, or magma? Take a moment to think about it and put your answer in the window to the right.

Maggy Benson: While the results are coming in let's go to our special guest. Today we have with us Dr. Elizabeth Cottrell, geologist here at the Smithsonian's National Museum of Natural History. Thanks for joining us Liz.

Liz Cottrell: [00:02:00] It's great to be here.

Maggy Benson: So as a geologist here, you're actually more specifically an igneous petrologist, that's a mouthful. Can you tell us what an igneous petrologist does?

Liz Cottrell: Sure can. As a petrologist I study rocks. Petrology the study of rocks. An igneous petrologist studies rocks that cool from liquid hot magma. So you've a lot of familiarity with these things, volcanic rocks are igneous rocks, if you've ever have used a pumice in the shower [00:02:30] to scrape off calluses or if you've been to graveyard and seen the tombstones, they're usually made of granite, which is an igneous rock.

Maggy Benson: Yeah, is that the same thing that you'd put on your countertops?

Liz Cottrell: Yeah. Lots of our viewers may have granite countertops right in your kitchen.

Maggy Benson: Great. So let's go to our results. They're kinda split but 50 percent of our viewers that glass does not erupt out of volcanoes. What do you say?

Liz Cottrell: Glass does erupt from volcanoes, in fact, the thing that does not erupt from [00:03:00] a volcano is smoke. Smoke does not erupt from volcanoes, though you can be forgiven for thinking that it does, because of the images we see of volcanoes do look like big eruptions with smoke plumes. What I have right here in this can is the material that came out of Mount St. Helens when it erupted here in the United States in 1980. Now I'm gonna dump this out on the table.

Maggy Benson: Huh, there's ...

Liz Cottrell: This-

Maggy Benson: That looks like smoke.

Liz Cottrell: It looks like smoke doesn't it? That's very fine pulverized rock, what we call [00:03:30] volcanic ash. Smoke in a volcano ... Smoke in fireplace is the product of burning wood. The product of burning organic material, it feels soft, it feels smooth. Unlike this stuff here which is pulverized rock. And you can stand in the smoke that's generated by fire but if this were to hit you in the face it would really hurt.

Maggy Benson: Yeah, that would not feel very good.

Liz Cottrell: No, and it's full of glass. Glass that comes out that's really rapidly quenched magma.

Maggy Benson: Interesting. So [00:04:00] I know that lava definitely does come out of volcanoes, is that right? And I see a piece that looks familiar here.

Liz Cottrell: Yeah. You might be familiar with this if you've ever been to Hawaii, for example, this is pahoehoe lava from Kilauea and what we have here is this glassy surface, the magma comes out of the volcano and then once it does it's lava and can flow gently down the hill. You can actually get quite close to this, while it's erupting.

Maggy Benson: Oh, wow. So [00:04:30] does this lava, does it come from deep within the Earth?

Liz Cottrell: That's a great question, it depends on your definition of deep. In the center of our planet, towards the center, we do have a liquid core. And that liquid core is liquid iron metal. It generates our magnetic field, incredibly important for life on this planet, but the majority of the planet is solid rock. This solid mantle, that's the biggest volume of our planet. Now it's solid not because it's cool, [00:05:00] because it's actually extremely hot. The reason it's solid is that it's under incredible pressure. So if we're some atoms down in the Deep Earth and we're pushed together-

Maggy Benson: You go together.

Liz Cottrell: And we're pushed together under great pressure, we're pushed together to make a solid. Now what's really challenging to understand is that this solid, over long time scales, flows. But it's incredibly viscous. You can imagine taking a jar of honey, for example, and opening it and putting it [00:05:30] upside-down in your freezer. Now definitely, you might get in trouble with your mom if you do this at home, but if you do try this experiment you'll see that the honey does flow over time, even though you could still bang it and crack it with a hammer. It's flowing on long time scales. Now that solid rock is flowing and then as the pressure releases we're able to move apart and get-

Maggy Benson: And actually move.

Liz Cottrell: ... a little squiggly. Yes. And we become a liquid magma, that then rises up through the volcano [00:06:00] and ultimately erupts.

Maggy Benson: So that liquid magma, what happens when it actually comes up and actually reaches the surface?

Liz Cottrell: Again, it all has to do with pressure. The pressure continues to become less and less, as you move up. If you've ever been swimming in the bottom of a pool and you feel that pressure on your ears, you know that when you have the weight of something above you it puts you under pressure. As this magma comes towards the surface the pressure is released. So what I have here is a perfect supermarket [00:06:30] metaphor for a volcano. A great experiment that you can do at home. We have here seltzer water, and we all know that from having drunk soda at any time, that the contents are under pressure. It always says, "Warning, contents under pressure." And the gas, carbon dioxide, is dissolved in this water. Even though we can't see it.

Maggy Benson: Can't see it.

Liz Cottrell: You can't see it, it looks just like water. So in this analogy, the water is our magma and volcanic gases [00:07:00] from deep in the Earth are dissolved inside. Now, just like a volcano, when the pressures released ... Sorry, Maggy! I guess I should've given you some warning, I'm sorry about that.

Maggy Benson: It's all right.

Liz Cottrell: But this is exactly how a volcano works, and exactly why you don't want to be near one. Now, let's take a look inside our bottle here. You can see all these bubbles desperately trying to get out towards the surface. This, these, carbon dioxide, in this case, is buoyant, it [00:07:30] nucleates into these bubbles, they are wanting to escape so quickly that they take the magma, the water, with them and erupt it out the top. So in a volcano the magma is brought rapidly to the surface by these bubbles expanding, is ejected from the volcano and the magma cools very quickly, to a glass. And that's what we have right here, we have a great example of one here, this is a pumice from a volcano called Vulcano, actually.

Maggy Benson: Very creative name.

Liz Cottrell: Yep. And what [00:08:00] you can see here, are these big vesicles, these giant bubbles. These bubbles are trapped gases from in the Earth that have rapidly expanded and thrown this magma out into the air and it cooled so quickly that it made a glass. This is volcanic glass, it's called pumice. And so these, these vesicles are direct evidence of the gases coming out of volcanoes that cause them to erupt.

Maggy Benson: Now that one looks very different from say, this rock, right here.

Liz Cottrell: Yes.

Maggy Benson: What's the difference?

Liz Cottrell: But they're actually [00:08:30] incredibly similar, what's happened here is that you can see that glassy crust, you can see that rapidly, what we call, quenched, rapidly cooled exterior that gives it this appearance, and then what happened is it cooled quickly and then those gases inside continued to expand. Pushing and breaking the crust and this is actually called a bread crust bomb. We call it a bomb because, "kaboom," it's a bomb, but the bread crust is due to that texture.

Maggy Benson: And it looks like bread crust.

Liz Cottrell: It does look like bread crust. It's one [00:09:00] of those great names that really looks the part.

Maggy Benson: So these pieces of volcanic glass, can I call them that?

Liz Cottrell: Mm-hmm (affirmative).

Maggy Benson: Look very different than this material that you have here. It's much shinier.

Liz Cottrell: Yes. And this is different. This is really my favorite kind of volcanic rock. This is from an underwater volcano and turns out that most volcanoes on Earth are on the ocean floor, under the water where we don't see them erupting, even though they're erupting all the time. So this erupted on the ocean floor [00:09:30] and it's got this shiny look to it because it cooled so rapidly. Essentially the water on the ocean floor is extremely cold, about 4 degrees centigrade. This has erupted under pressure, so if we go back to our soda bottle and we see those bubbles coming out essentially what's happened here is that we've kept the pressure on a little bit by being on the ocean floor, and a lot of these gases are still trapped in here cooled really rapidly to make this shiny glass. It's not so different than window glass actually.

Maggy Benson: [00:10:00] Interesting. So as an igneous petrologist you're really studying these rocks that come out of volcanoes but by doing that you're also understanding the inside of the Earth as well.

Liz Cottrell: That's correct. Volcanoes are really our windows into the Earth's interior. We, as people, can't get down deep into the Earth to sample. So we are really like detectives. We're using the clues brought to the surface by volcanoes to try to understand what was underneath the volcanoes, how our inner Earth is working, [00:10:30] and so there's this incredible communication between the surface of the Earth and the interior and volcanoes are really the conduit of that information.

Maggy Benson: Great. So we have a student question for you, are you ready to take it?

Liz Cottrell: Sure.

Maggy Benson: Okay, this one comes from Lions Creek Middle School, they want to know, "Can you jump into a volcano that has no magma and end up in the center of the Earth?"

Liz Cottrell: You cannot end up in the center of the Earth. The deepest hole that humans have ever drilled or dug is only about fifteen kilometers depth, that's [00:11:00] on the order of several miles, maybe 5 ... 5 miles. That's because of the incredible crushing pressure, so when we go down into these really deep mines it's really hot, and if you go down in the Earth there's no open caverns, it's all very high pressure. If you were to jump into a volcano you would end up in what we call the plumbing system. Just like you have under your sink, you have the volcano and down into these long plumbing system that variably fill with magma, or not. You [00:11:30] might end up in a magma chamber, that would not be good for you. Or you would just hit the solid interior of the planet.

Maggy Benson: Interesting. Great question Lions Creek.

Liz Cottrell: Yes, fantastic.

Maggy Benson: So where do you get these rocks. I know you said they're your favorite, how do you get them?

Liz Cottrell: You have to get to the middle of the ocean. And so that's really difficult. The volcanoes are several kilometers depth in the ocean and so I've had the opportunity to go to see, on a research ship, and go to these long chains of volcanoes that are all [00:12:00] along the ocean floor, like big mountain ranges. We know where the volcanoes are and it's pretty low tech, we take a big bucket you just saw a picture of this kind of big steel bucket we throw it over the back, we pay out thousands of feet of crane cable, and if you can imagine it's about 10 thousand feet. So imagine a mountain, if you've ever climbed a mountain 10,000 feet high, and many of our viewers at home probably have not climbed a mountain that high, we drag a bucket along the ocean floor and then we reel it in like fishermen. And see what we catch.

Maggy Benson: Interesting. With this methodology [00:12:30] you must be out at sea all the time collecting these rocks.

Liz Cottrell: Luckily, I work here at the Smithsonian. At the National Museum of Natural History were we have this incredible collection of volcanic rocks. We have the world's largest collection of sea floor rocks, about thirteen thousand sea floor volcanoes sampled in this collection, and the great thing about it is I can go in, check out a glass, kind of like borrowing a book from the library, perform analyses on it. And it's not just me, [00:13:00] anyone in the world, internationally, researchers come and borrow from our collections all the time. It's an incredible resource, because when we go to sea it costs many millions of dollars for one of these expeditions, and so we want to be really ... treat these rocks with care and keep them for all time.

Maggy Benson: So thank goodness for that huge collection.

Liz Cottrell: Yeah.

Maggy Benson: So how do you do the analysis on this glass?

Liz Cottrell: Well, we start low tech, with a chisel. And we just chip off some of this glass. Then we have to make it really thin, about [00:13:30] the width of a human hair, so if you can just grab a piece of your hair here and look at it. A human hair is about thirty microns thick and that's how thin we need to make these volcanic glasses. Now even though it's a rock, when it's that thin it's transparent to light. We can look right through it-

Maggy Benson: You can actually see right through.

Liz Cottrell: These are some beautiful images you're looking at now of chips of volcanic glass that are transparent to light. Then we can go and throw an entire analytical arsenal at these glasses. We'll look with something called an electron microprobe, which shoots a beam of electrons [00:14:00] down at the sample. And then x-rays are readmitted, that gives us the chemical composition of our glasses. We can look at them with infrared spectroscopy to see the dissolved volatile contents that we were talking about before. The carbon dioxide, the water. And then we can look with x-rays and even see the speciation of elements, the valence state of elements in the glass. So we can really hit them with whatever we've got, once we've got them back on land.

Maggy Benson: So interesting. So I wanna go back to the location of where you find these. [00:14:30] Why are volcanoes are all over the ocean bottom?

Liz Cottrell: They are not all over the ocean bottom, they're in long linear mountain belts. So we can look here, we have a globe. If you were able to strip all the water off of the surface of the planet and just look at the crust of the Earth we would have these large low areas that are the ocean floor and we have down the middle here-

Maggy Benson: Down here.

Liz Cottrell: You see this ridge, yes right there, you're running your finger along it right now. See this long chain of volcanoes down the middle of the Atlantic ocean, there's also in the Pacific ocean, these are the system of mid-ocean [00:15:00] ridges and at these locations new crust is being generated all the time. So I think we'll see a graphic here in just a second of new crust being generated, the age of the ocean floor getting older as you move away from these ridges.

Maggy Benson: So here we see, too, an underwater volcano, is this typical of what they might look like?

Liz Cottrell: Yes, this is really rare footage actually, of a volcano erupting under [00:15:30] water. Again, you can see what I was talking about before, you can see that that magma coming out, cooling very quickly on the ocean floor. Here's a map, where again, you can see kind of what we saw on the globe. These long chains of volcanoes running down the center, these long ridges and when that magma erupts it's generating new ocean crusts and the ocean floor is being resurfaced all the time. Here in red, that's where the ocean floor is youngest, it gets progressively older, yellow to green to blue, and older as you move away. And that's how our ocean floors [00:16:00] are resurfaced. The continents are old but the ocean floors are young. And as you noted, or as you asked about, how are the volcanoes distributed, they're in long linear belts. Here you can see all these white flashes are earthquakes and where we have earthquakes on the ocean floor we have volcanoes. So you can kind of see those chains here, and also along the continents we can see these chains of volcanoes.

Maggy Benson: So I'm really curious about this idea that they happen along these long lines around the globe. I think that [00:16:30] might be a good question for our viewers, what do you think?

Liz Cottrell: Sure.

Maggy Benson: All right. So, what causes lines of volcanoes? Is it horizontal lava flows, plate boundaries, sideways budding of new volcanoes, or volcano cloning? (Music plays.) [00:17:00] So the results are coming in and the biggest response has been plate boundaries. What do you think?

Liz Cottrell: Great answer. Plate boundaries is exactly correct. The plate boundaries are where tectonic plates on the Earth's surface come together and so ... the mid-ocean ridge system is an example of a divergent plate margin where, as I said it's an expression of the interior of the Earth, the heat trying to escape, creating new crust. Africa and North America are moving apart from each other [00:17:30] all the time, we're getting further and further away from Europe, for example. But as you might have guessed the Earth is not getting bigger and bigger.

Maggy Benson: No.

Liz Cottrell: So, how do we account for all this additional crust that's being created? It's a process called subduction. What happens is the sea floor is generated at the mid-ocean ridge and it transits the ocean floor and then it gets cooler, and denser, and it eventually runs into a continent and starts to subduct.

Maggy Benson: Underneath it.

Liz Cottrell: Underneath the continent it subducts, it recycles [00:18:00] back into the Deep Earth. Our ocean basins are very young for this reason. New lava, new crust generated here, transits the sea floor and generates back down underneath. And what you can see here on your screen is the ring of fire, these classic subduction zone locations where ocean floor is subducting beneath the continents. And similar to what I just showed you with my hands here's a graphic that shows you ocean crust moving along and subducting down beneath the continents [00:18:30] and generating volcanoes in that location and so that's why we get those long subduction zone volcanoes where the crust is being recycled.

Maggy Benson: So, what's the importance of these subduction zones? And these volcanoes? I mean the recycling the Earth's crusts so that our Earth is staying the same size but ...

Liz Cottrell: That's a good thing.

Maggy Benson: I know you're also looking at the chemistry of what is happening inside our Earth, how does that all connect?

Liz Cottrell: Well volcanoes are incredibly important to life on Earth. They re-fertilize [00:19:00] our soils, they create land that we live on, but also they are creating the atmosphere that we breathe. They've created the oceans that make our planet habitable. So really we owe our lives here to the presence of volcanoes. That's what makes ... one of the very many things that makes Earth a unique and habitable planet.

Maggy Benson: So thank you volcanoes for life on Earth.

Liz Cottrell: Yes. Thank you volcanoes.

Maggy Benson: So it's been so fascinating learning a little bit about your work as a geologist here at the Smithsonian. We have a lot of really great student questions, are you ready to take them?

Liz Cottrell: [00:19:30] Sure.

Maggy Benson: All right. This one comes from Mrs. Bradford's class, "What is the closest you've gone to an active volcano?"

Liz Cottrell: Right there on crater summit. We, at the Global Volcanism Program, here at the Smithsonian consider a volcano active if it's erupted, or is believed to have been erupted in the last ten thousand years. Now ten thousand years may seem like a long time to our viewers but it's actually geologically yesterday. So I've been to Vesuvius, which is an active volcano that [00:20:00] is very hazardous for Naples, in Italy, which is right beneath it. Mount Rainier in the Seattle Tacoma area is an active volcano that I've walked right up to, so as close as you can get.

Maggy Benson: Cool. All right, so we have another one and this one comes from Dawson. How do you know what's in the center of the Earth if you can't go there?

Liz Cottrell: What a fantastic question. That's a great question. We have so many ways of understanding what's inside the Earth. So the first thing we've got a magnetic field, [00:20:30] okay? The magnetic field is generated by liquid iron flowing around in the outer core, the flow of that liquid iron generates our magnetic field protects us from cosmic rays thank goodness for volcanoes? Well thank goodness for for the magnetic field. That's evidence of the liquid core.

Liz Cottrell: Seismic energy because we have a solid, because it's a solid rock that energy passes through, and we can listen to that energy on the other side and map the interior of our planet using seismic energy. [00:21:00] For example seismic waves, certain kind of seismic waves, don't pass through liquids, that's another reason we know we have a liquid core.

Liz Cottrell: We also have the Earth's moment of inertia. If you're an ice skater and you're spinning and you pull your arms in, you'll spin much faster. So the rate at which the Earth is spinning tells us about the distribution of mass. And finally, and most importantly, we've meteorites and we can date the meteorites and look at their composition and it turns out that a class of meteorites has the same composition as the sun, and so we [00:21:30] believe all the inner planets formed from the same meteorite material so we know the bulk composition.

Maggy Benson: Wonderful. So I have a question, I know that you're also a mother here and a scientist at the Smithsonian. How does that work-life balance work?

Liz Cottrell: I would strongly encourage our viewers to have work-life balance, but also to say that you can be a scientist and a parent. You can be a mom, a dad, and a scientist and find a way to make that work. I have two kids, [00:22:00] a five-year-old and two-year-old, bring them to school, bring them home. I think my kids are proud of me and proud of what I do. And I would say that I would encourage anybody to pursue science as a career. It's fascinating job.

Maggy Benson: Wonderful. All right. What do volcanoes reveal about the Earth?

Liz Cottrell: Well volcanoes are really our windows into the planet. I have a great example here I'm going to pull off the table, okay. We talked in the webcast about the gases coming out of volcanoes. [00:22:30] So, volcanoes reveal the gases inside our planet, you want to understand something like the carbon cycle. We're made of carbon, I'm made of carbon, you're made of carbon. Carbon not only is on the surface; most of the carbon on our planet is located deep in the Earth. So if we want to understand the carbon cycle, we need to understand the whole Earth cycle of those plates recycling, and the gases coming out of volcanoes. Volcanoes also bring to the surface actual pieces of the Earth's interior. We've got here pieces of that solid Earth mantle, this beautiful green material that's been brought to [00:23:00] the surface, you can kind of see this-

Maggy Benson: This is part of the mantle.

Liz Cottrell: This is part of the interior of the Earth, that solid part. When you melt the solid Earth you get the basalts, you know this basalt that we saw earlier. So we can see this volcanic rock with these holes in it that it has erupted so violently and so quickly, it's actually ripped parts of the interior of our planet up here on the surface so that we can study them. So that's a very direct way that volcanoes allow us to learn about the inside of our planet.

Maggy Benson: Great question. This one comes from Damako: Are there any dormant volcanoes in [00:23:30] Eastern United States?

Liz Cottrell: Are there any dormant volcanoes in the Eastern United States? Well the Eastern United States right now is a passive margin. What we call a passive margin. So while we have a lot of volcanoes off the coast the mid-Atlantic ridge in the middle of the ocean, the margin that we're at now, on the east coast doesn't have volcanoes. We have essentially North America moving away from Africa eventually it should become a subduction zone and we should have lots of volcanoes on [00:24:00] the east coast, but none of us will be around to see it.

Maggy Benson: This one comes from West Side School 8th grade class. I want to know what led you to start studying volcanoes?

Liz Cottrell: Well, as a child I was always interested in science and then in high school I became most interested in the topic of chemistry, and then when I went to college I took a class about volcanoes on other planets. Which was an amazing class I learned about volcanoes on Mars and volcanoes on the [00:24:30] moons of Jupiter and I just thought it was really fascinating to apply chemistry to understanding the huge landscapes and understanding volcanic eruptions and the landscape around us. And you get to go outside more often.

Maggy Benson: This one actually comes from Mrs. Crockenberg's class. Why are there different kinds of lava?

Liz Cottrell: There are different kinds of lava because volcanoes form in different tectonic settings. So when we melt the solid Earth we generate basalt and that's [00:25:00] what we have right here, right we have basalt that was generated on one of those mid-ocean ridges, a divergent margin on the sea floor. It's a direct melting of the Earth's interior. When we go to a subduction zone setting, the reason we have those subduction zone volcanoes, we've talked about the process of subduction it's the release of water into the Earth's mantle that allows those volcanoes to form. We've added water, we're erupting through continental crust. That's getting all mixed in and changing the chemistry by [00:25:30] mixing in other ingredients and so that not only gives our volcanoes in different settings different chemistries it gives them different looks, different what we call morphologies.

Maggy Benson: Interesting. So this one comes from Lillian. Lillian wants to know is basalt like obsidian?

Liz Cottrell: No. It's not. They're both black and that's true. It does look like obsidian but obsidian actually has much higher content of silica, [00:26:00] the element silicon, than basalt does. And they form in very different environments. Obsidians form on land, for example, Yellowstone is a big volcano we have here in the United States where you have a lot of obsidian. Whereas, these basalts are more common in subduction zone settings but mostly on this mid-ocean ridges, underwater volcanoes.

Maggy Benson: This one comes from Nick. When does the mist come out of a volcano?

Liz Cottrell: The mist [00:26:30] is the gas. So again we have to back to our soda bottle which is a really great example of how a volcano works. Just like we have carbon dioxide dissolved in this water, which comes out, in the Earth we also have carbon dioxide dissolved in our magmas and it creates a mist but what you're really seeing, when you see steam coming out of a volcano that is water. So the most common gas coming out of volcanoes is actually water vapor.

Maggy Benson: So [00:27:00] this one comes Lake Lure and they want to know what is the newest technology you use to study volcanoes? We only have a short time left.

Liz Cottrell: Okay, I'm gonna talk quickly. Two new technologies, one is I take my chips of volcanic glass and I go to something called synchrotron radiation facilities, which I do a technique called X-ray absorption near edge structure spectroscopy which allows us to-

Maggy Benson: Sounds very high tech.

Liz Cottrell: Yes. To know the valence state of atoms in those glasses and another great new technology that we're using in [00:27:30] my group is satellite remote sensing where we're actually looking at the volcanoes from satellites in space and looking to see if we can detect carbon dioxide coming out of volcanoes from space. And that's a new technology.

Maggy Benson: Wow. I'd love to be a volcanologist. So interesting. So Liz, can you tell our viewers about what you're going to be working on and where they can learn more about your work?

Liz Cottrell: Absolutely, research-wise for myself I'm really excited to have a new project starting up in the Aleutians. The Aleutians are a chain [00:28:00] of volcanoes off the coast of Alaska. You might not know but the United States has the most volcanoes of any country in the world, they're just most of them are fortunately located way off the coast, they ... I'm looking forward to doing some work there. But for volcano information generally I think there's no better site than volcano.si.edu. That's the website of the Global Volcanism Program and you can find everything volcano there. You can find videos, you can find demonstrations, and you can find great data [00:28:30] that you can work with yourself about volcanoes. Any volcano in the world.

Maggy Benson: Wonderful. Well thank you so much Liz.

Liz Cottrell: Well thank you.

Maggy Benson: And thanks again for tuning in today. If you miss some of this show, or want to see it again it'll be archived later today on qrius.si.edu.