RUTGERS GEOLOGY MUSEUM

47th Open House

January 31, 2015

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LAURA ADAMO: Good morning, everyone. I am Laura Adamo. Welcome to the 2015 Rutgers Geology Museum's 47th Open House. I see familiar faces from the past, thanks for joining us again. A couple of announcements. You guys know the drill but we will have four speakers today.

If any of you are educators looking for educational credit, Missy and John up here will be handing out the certificates. So, at the end of the talks, find one of them and get your certificate for the teacher's credit. Also, please check out the Rutgers Geology Museum at some point. We have a bunch of activities going on over there. The field station dinosaurs have a table over there. Someone is painting over there. We have some students that are going to be doing micropaleontology. Plus, check out our mineral sale.

The coffee and donut proceeds go to the Geological Club. The club wants to let you know they will order pizza for lunch so you can buy pizza for lunch. That will be good news for some of you. After the second talk they will have pizza delivered which will be for sale. I would like to introduce Bill Selden, our host for the day, who will be introducing the speakers .Bill is not a stranger to you, as he was the Museum director for 30 years. We are pleased to have him back to do the intros. I will turn it over to Bill. Welcome, Bill.

(Applause)

BILL SELDEN: It is great to be back and see familiar faces. One of the things I face is speaker ideas. Looking around Rutgers University, it is exciting to see all of the projects going on. One of my favorite departments is the Coastal Studies Department. They always have something nice. This year is no exception. But, the -- today we have a speaker, Janice McDonald and her colleague, Sage Lichtenwalner to talk about the work they are doing with realtime education. Janice is something of an adventurer. She has been all around many places in the world. She was on the Johnson Sea Link where she dove two and a half miles down. She has a story to tell. She works for the National Science Foundation's Centers for Ocean Science Education Excellence Networked Ocean World (COSEE-NOW).

This is so important. This is one of the same ideas that we are doing here at the Geological Museum and everyone in coastal studies. Let's welcome Janice and Sage to our program today and they will tell us all about it.

(Applause)

JANICE McDONNELL: Good morning, everybody. Thank you for coming this cold January today, pre-big game. We appreciate your coming to chat with us about the ocean today. I am Janice McDonald and like Bill, I have been working at the department more than 25 years. I have been fortunate. I think it is the best department. No offense to Lauren and Patty. I think it is the best department in the university. We work with a lot of scientists, help them translate their language to ordinary people.

I am a trained marine scientist as is Sage. But we really work on the interface of trying to help scientists trying to translate their research so everybody can benefit from their emerging knowledge. So, that is what we are going to try to do today. Everybody should have a little clicker, a cream-colored clicker that will help you interact with us. It will be like a Jeopardy game. We will have fun talking about the ocean. Those clickers are commonly used in undergraduate teaching especially lecture hall classes to help professors who are obviously outnumbered by students, help them interact and understand how they are comprehending knowledge. So, we are going to use them for fun. It is not a test.

(Laughter)

JANICE McDONNELL: We will have fun. Before we get started I want to thank Lauren and Patty for inviting us. We look forward to chatting with you. Feel free to interact with us at any time. We are not going to hold questions until the end.

So, here's a picture of our building.

VOICE: Can you get the lights or partial lights?

JANICE McDONNELL: Sure. How do we do that. How's that? Better.

>> Marginal. That is better.

Audience: Better.

JANICE McDONNELL: You are interacting already. This is great.

VOICE: More.

VOICE: No.

JANICE McDONNELL: This is a quick screen shot our building. We are on the Cook College campus on the other side of the river. We just have been there since the early 1990s. 40 research faculty work within this department. We have chemical physical, biological, oceanographers. We will talk about the disciplineses and how they interact with each other. We also have field stations.

We have our marine field station in Tuckerton New Jersey, just north of Atlantic City. Old Coast Guard facility converted into a marine science laboratory. It is an interesting place if you get the chance to go to their Open House in October. I encourage you to do that. It sits on the marsh here. It is run by Dr. Ken Able who studies the early life of fish. He has amazing data records looking at the 30, 40 years. He has been a long time working on this. Fascinating place to visit. We have two research vessels at this facility and lots of coastal work is done there.

There is the Jack Cousteau Educational Center. Do a lot of education. Kids, interested in more public program on the ocean, that is a great place to go. This is the part where we test the clickers you have to see if they are working properly and have fun wit. We would like to know where you are from: North, central, South, Shore or elsewhere. Press the button that.

Number that responsible and responds to where you are.

Last call? Anybody who hasn't pushed a button yet, go ahead and do so. Sage is going to push -- there we go. Looks like 52% of us are from central New Jersey which makes sense, close here to the University. 21% -- yes, from the Shore. 6% from the south. Somebody took time to drive here. That's great.

One more question for you to kind of get warmed up about the ocean: How often do you get to visit the ocean? This is probably a geological-interested crowd. How many of you get to visit the ocean and how often daily, weekly, monthly, once a year, all the time, in the summer. Once a a week in the summer or never. Not a place that you go.

Go ahead and put your response in.

(Pause)

>> Last call.

>> Does it count driving over the Tappan Zee.

(Laughter)

JANICE McDONNELL: No, no, it doesn't count.

(Laughter)

JANICE McDONNELL: So unfortunately, many of us don't get there daily. I wish I did. I used to. But it looks like what do we say -- once a year. Oh, my goodness. Once a year or once a week in the summer. I like that answer better. Once a week in the summer. It looks like some of us get to go there. New Jersey is a coastal state so it is not a ridiculous drive for us to get there. we are fortunate we have access to thing ocean. But, it is a great place to visit, honestly. Let's talk about that. Here's what we are going to do today: Take you on a little journey to talk about: What is the social; it's impact on you; our impact on the social and why should should we care about it. We will have a reflective discussion on that and finally: What is Rutgers doing to study the ocean. We are blessed to work with a variety of scientists to highlight some of their work. They have some idea of how -- the research that is going on, how it all fits together.

That is our journey today.

So: How do we use the ocean? Some of us come once a week in the summer. More than likely come for this.

[See Screen]

To go, sit on the beach and relax with that wonderful ocean sound and smell and use it as a place of solace and relaxation and recreation. Some of us are doing that.

We also use the ocean to ship our goods all over the world. There are some amazing figures that say something like 90 plus percent of the things you own or wear come from some container ship that has used the ocean to get the material to you. All of the clothes we wear, materials we buy all come from different places. The ocean is a transport system that helps us get things from point A to point B.

JANICE McDONNELL: We obviously use it as a source of protein. So, large fisheries appear in New Jersey. Very important part of the coastal ecosystem is the fisheries. We will talk about that more later. Finally, getting back to recreation. Also, many people find the ocean an incredible place for reflection and peace for just meditation and relaxation.

And that's -- I find the social to be that for me.

And very, very important.

So, everybody has a a personal connection in some way to the social. And my person connections started with this guy on the far left, Jack Cousteau. Sometimes when I work with small children which I do a lot, they don't remember who he is because the show has been off the air so many years. But I used to watch his show every Sunday and it was -- I was fascinated with all of the adventures that he went on. I continue that interest and love until I met the guy in the middle, Dr. Lagara [phonetic] who was my biology teacher in high school, he sent me me to the University of Connecticut, his alma mater. That is where I dove in the submersibles. This is the delta submersible that can send you about 3,000 feet down. You stick your head -- you lie you down flat and your head ends up in this portal here. You can literally get your face on the ocean floor. It is pretty amazing. I also dove as a Bill said, in the Johnson Sea Link a much larger submersible, kind of shaped like a fish bowl. Except the fish are on the outside and you are in the fish bowl. That is fun too. I got to go two and a half miles down in that. Did a lot of work with the under sea center early on coordinating research for that. I thank these two guys mostlily for that love and passion for the ocean. I will introduce you to Sage, who has a similar job to mine on the research side. He is a physicist and he will talk to you.

(Applause).

SAGE LICHTENWALNER: Thank you, guys. So, I am a Rutgers alum, I came here, like all freshman did not know what to study. I did what most people did, exactly what my dad did: Study physics. I figured I would do that four years then figure out what I want to do when I grow up. Luckily I came to great place like Rutgers who which has a wonderful Marine Science Department. I did an internship with the physical oceanography group was on the RC Caleta. I drove this little guy right here, a mini Bat which has wings, instruments and he basically -- we throw him off, the ship goes up and down.

This was 15 years ago. We did not have a lot of systems so I had to stand 12 hours on the ship pushing an up button and down button. The coastal shore off New Jersey is shallow. If you are not careful, you ram this into the ground, have to stop the boat, pull the thing up. We had to do that twice a day, replaced the barge. Like most people in New Jersey, I grew up going to the Shore once a week as my family did. I did research when I came here to Rutgers University and fell in love with the science and the people I work with. Oceanography and Rutgers University. You find something you like and people you like to do with, then, you are doing well. That is why I stayed where I am.

So, that brings us to basically the title of our talk of who we are. Today we are going to talk about a dip in the social, an interactive exploration of how the ocean impacts us and how we impact the ocean as Jan said. We are going to test you about the ocean. First real quiz question.

(Giggles)

JANICE McDONNELL: Real one! You ready for this: Here's what we want to know.

[See Screen]

>> Click your guess

>> 100 responses!

JANICE McDONNELL: Anybody else in everybody have their votes in? Fabulous. Looks like everyone's on the right track there. About 70% of our planet is covered by the ocean. If we look at it from this point of view -- Sage has a slide there that will help you see it better. It is about 71%. When you turn the Earth you can really see the differences based on point of view, right. If you look at it from a US-centered point of view -- it is different. It is not as impressive as the ocean. But looking from the Antarctica perspective, from the poles, you can really see how that kind of covers, the massive coverage of the planet is the ocean.

We have about 97% of the Earth's water. Average depth of 12,000 feet. And makes up

99% of the living space on the planet. So, it is a dominant feature. Many of us the ocean sciences say it should have been called Planet Ocean instead of Planet Earth. Only a small percent is explored by humans. We are going to talk about submersibles. So much is unexplored. It kind of taps into the National Geographic explorer for us to want to know more about the ocean world. Next question: How many oceans are there? What do you think about that? Get your votes in.

SAGE LICHTENWALNER: Okay. So, we have basically a quarter of the people say five. About the same number say seven. A couple say six. A couple say way more than ten. And we have maybe about ten people in the room saying one.

(Laughter)

SAGE LICHTENWALNER: So obviously we have a lot of agreement.

(Laughter)

SAGE LICHTENWALNER: This is of course very interesting. Some of you were thinking -- looking at the oceans, trying top count, there is the Atlantic, the Pacifice the north and south Atlantic, is that two? Indian Ocean. Oh, wait, I heard of the Seven Seas. Somebody sailed the seven seas at some point. And I tell you: Go home, look up the seven seas on Wikipedia and there are three, four different counts of the seven seas. Depending on whether it is ancient or modern history.

What we like to say is: Imagine you were a whale, dolphin or fish: Are there any tollbooths between any of the oceans? Does anybody top stop you, check your visa, passport? Any major barriers? We have drawn the barriers geographically saying if you are on this side you are on the Pacific, this side, Atlantic. But, where is the southern ocean versus the south Atlantic? Where is that line?

These lines are very hard to see. I think what you maybe have started to realize now:

When we talk about the ocean, Earth and geological we tack about a it as one interconnected system.

(Applause)

SAGE LICHTENWALNER: We like to think of it as one ocean. This shows general simulated currents. Sailing over the Atlantic. Showing the circulation, proposed by Wally Bowder at a conservatory 30 years ago. The waters of the north Atlantic. Go around with a big gyro. Some waters get cold in the poles, sink. Get dense. The deep water circulation pulls down to the south Atlantic. Down to the southern ocean of the southern ocean is where the currents around the whole world are connected.

The only place the waters can circulate the whole world without being blocked. Basically there is still a lot of research in this area. That water comes back up and enters in the surface ocean and starts the cycle all over again. The estimates are basically, on average, a par sell of water would take a thousand years to go around the whole Earth. Whatever we do here -- we throw something into the river here in the Raritan, it will go out into the Atlantic and basically, touch the entire world.

This is basically the view we are told in school.

[See Screen]

We have major currents, major gyres and this is not what is happening in the deep ocean. The reality is much more complex.

This is and animation of NASA showing -- if anybody wants to know -- talk now.

(Laughter)

SAGE LICHTENWALNER: This is an animation of NASA, a high resolution ocean model. This monitor is not great but the colors show temperature and the squiggles are basically the currents moving in the ocean. You can see the eddies off South African. This is a current here. You can see eddies off Florida. Gulf stream which goes into the Atlantic. Eddies form there. The loop current in the gulf of Mexico.

There is a loop coming off here which is about to break off and form its own eddie. The ocean is complex but it is connected. It is connected to the at atmosphere. What happens in the ocean eventually becomes geological which is what we are all here today. Another quick question [See screen] If you cut off Mt. Everrest put it in the deepest part of the ocean would there still be water covering the top of the mountain? Yes or no.

(Pause)

Is Mount Everest taller than the ocean is deep. Or is the deepest part of the ocean bigger than Mount Everrest? Yes. The Mariana Temple, the deepest part -- remember: James Cameron was there a year ago -- is 7 miles deep. So, there would be a mile of water on top of Mt. Everest.

>> How do you measure that depth, how deep that is?

SAGE LICHTENWALNER: You make a noise, wait to see how long it takes for it to reverberate off the ocean floor. Now we have things in space that look at subtle shifts in gravity. But that is the traditional way.

JANICE McDONNELL: We will do a demonstration to think about the key factors that influence our ocean, how it moves. That animation and graphic shows it is a dynamic place which has a lot to do with the physics of the ocean. Physical oceanographers are focussed on this aspect. It drives biology that can exist in that environment based on the physics.

There are three things to think about: The density, how denies is the water. The salinity which is obviously related and the temperature. So, what Sage is doing here now, we have a little tank on the other side of this pod um yum. We will talk a little about a dense city. He is going to set this up. We are going to look at one side of the tank being salty water and the other side freshwater.

We think about in the ocean, places where that happens, freshwater mixes with saltwater. That typically happens along estuaries where the rivers meet the sea freshwater rivers come in, meet the bays or the ocean. This is the kind of interaction between the fresh and saltwater that is so important. Sage is mixing it up right now. Here's what we are going to do. We are going to take a little predict shun. We will add salt in a minute. On the blue side will represent freshwater? Okay and the red side will represent salty water. There is a little divider in between, right here (indicating) and what do you think is going to happen when we pull up that divider? He is adding the salt on this side, what will happen with those colors: Options it will turn purple. What will you see. Is there a young person in the audience? I like little people. A little person want to come up here, answer that a? Come on up.

Come on up you. Help us out here. We need some help. What is your name. Renee.

>> What do you think will happen when he pulls you that up.

>> Renee: The water will mix but not completely?

JANICE McDONNELL: Okay.

>> Renee: It will kind of mix but some of it will still stay.

JANICE McDONNELL: Some stay red, some blue. You want to go ahead.

SAGE LICHTENWALNER: Real quick to make sure you know what we do as oceanographers I have here (indicating) I have here a sensor basically that measures the temperature and salinity. If I put it in the freshwater see it is about 15°C and zero parts per thousand salinity. I added geology to the water. I have added: 18 parts per thousand salt are in the water.

So, that is the science there.

JANICE McDONNELL: We are going to put it back on, so you can see. Renee is going to pull the divider and we will see what really happens. There you why. Can you you see that.

[See Screen]

Voice: Wow.

SAGE LICHTENWALNER: You saw right there: What was on the bottom? Audience: Salt.

SAGE LICHTENWALNER: Salty water. What was cool, when Renee pulled up the barrier, the red went over to the blue, then came back here and now we have a red-blue layer. I will show you what's going on.

JANICE McDONNELL: This is another quick satellite image, NASA Aquarius. We are able to sense the salinity of water. Measures the top millimeter of ocean water, gives us a reading. You can see, on the scale here, with the red being saltiest water and the blue and Violet being less. It varies across the planet but not dramatically.

The range is such that salinity is not too variable over time.

So, let's move on to some biology which is my personal favorite since I am a biologist. Most sea life: Does it live in the top 500 feet the ocean, on the sea floor, in the great ocean basins or is evenly dispersed throughout the ocean depths? What do you think? Put in your votes.

It looks like most everyone thought: Blue --

SAGE LICHTENWALNER: Surface.

JANICE McDONNELL: That would be correct. Most living things are in that top sunlit layer. That is where all of the action is. That is where we have the primary production happening with phyto plankton, the tiny one-cell plants. They drive the rest of the food bed. We see things like the large schools of fish, the phytoplankton plumes, the sunlit, top 200 errs. Then still see life, bizarre life if you have ever seen it on Nova or one of the Discovery channels, the crazy deep sea or tube worms that life there. We are fortunate we have a number of scientists who work from the geological and buy logical perspective studying these.

There is an IMAX movie that focuses on Rutgers focussed on hydro therm am vents. Check that out if you have the chance. We are going to switch gears and talk a little about the ocean's impact on you.

Scary picture that was, right? Let's talk about where most of the Earth's oxygen comes from. If we think -- maybe the rainforests for the young people here in the room, know that there are lots and lots of curriculum material around rainforests. Or it could be the ocean or land plants or you just don't know. Where do you think most of the oxygen comes from? Get your votes in oh! Lots of you think the ocean. If everybody takes a deep breath right now. Take a deep breath in. That one: You can thank the land for. About 50% of the oxygen we breathe is from the land. Another deep breath. You can thank the phyto plankton for that are one. 50-50, the oxygen produced in the planet. 50% of the oxygen breathed is produced from the tiny microscopic plants that dominate the 200-meter zone that I was talking about. This is a graphic. I think you are up, Sage.

SAGE LICHTENWALNER: This he shows the seasonal cycle. The first stim of 50-50 was made in 1998 when it was looked at how much vegetation is on land and cycles of the land and ocean, basically how much plant is in each place. We can see on land in the spring we get nice, big, the Appalachian ridge up to Canada. In the spring we see lots of snow, runoff and activities in the coastal regions. There is a seasonal cycle which is revisioned in the southern hemisphere.

As Janice said: Half of the oxygen, primary production that is occurring is actually occurring from microscopic organisms in the ocean. There are so many on their life span is so short that is what dash they are able to count for some of the primary production. If we looked at the whole world we can see an image like this showing where is all of this activity occurring. Just like on land it is not the same. We have deserts in the Southwest, the Sahara, the plateau.

The rainforests, we have, the east coast of the United States, same patterns in the ocean: Lots of productivity, lots of phytoplankton growing, mostly in the polar regions, somewhere in the mid latitudes around the equator and mostly the coastal regions, the nutrients are washing off from land and into the ocean. We have this one global biosphere of land and ocean. But the patterns are not the same.

JANICE McDONNELL: Another question.

[See Screen]

What percentage of the world gets their primary source of protein from fish? What do you think about that?

(Pause)

JANICE McDONNELL: I don't know how often you all eat fish. Put your responses in.

Looks like more than half of us think 25%. That would be right. It varies from country to country a the world. Asians eat a lot more than we do in the US. It is a developing resource for many third-world developing countries as a major source of protein. So it is very, very important to our world population to manage this resource. Emerging resource for many.

I want to mention here: This is Daphne Munroe. I mentioned we were going to vignette some of the scientists we were happy to work with. Daphne works at another of Rutgers' labs in Shellpile New Jersey. They study shellfish. Daphne is a relatively new faculty member. She is focussed on working in that ecosystem level it face of understanding the ecosystem to help fishery managers better manage the stock.

She is very, very engaged in that, particularly around shellfish. You can see from this: New Jersey I think.

[See Screen]

I checked with her she said it is true: It is the third largest producer of clams for soups and whatnot Progresso soups in the world. Over 85% commercial fishery landing are in the invert range. All of the blue crabs and shellfish we talked about are all part of the fishery.

She is really working on the early life stage of shellfish, trying to understand how they get from microscopic to dinner plate size. Especially with changing pHs and changing temperatures and water quality here in New Jersey as a result of climate change. A lot of her work is focussed on that, particularly mollusks, clams, oysters, and scallops. She is doing some amazing things. Very interested in research.

Another thing we wanted to touch on is a source of interest here at Rutgers, sea level rise. There are many people working on that point. But, really the three I want to point out today Ben Horton, Bob Kopp and Rick Lathrop are working on sea level rise. We all saw this iconic image after Sandy. There is no doubt we can experience sea level rise here along the New Jersey coast.

This graphic is from Ben Horton. It really shows that from 1992 until 2012 we have seen a steady increase in a trend of 2.6 millimeters a year in see level rise. You can see the projections are for it to get much worse in terms of rising see levels. Why does that happen? Well it's really all about as sea water warms its volume increases. This thermal expansion accounts for about 50% of the past century's sea-level rise. Part is natural in thermal expansion. Some is not. Some is a result of what we are seeing in terms of a changing climate. We can see from these pictures clearly, melting of mountain glaciers. They contribute about a third of what we account for in sea-level rise. They predict, by 2100 they will probably add a few inches to sea level. But not feet. You can see the different. Top is from 1934 and the bottom is 2011, same mountain. You can see the difference in the decline. Bus these mountains do not con thin that much ice. These do, these are green land ice sheets which could account for much more sea level rise. I am sure you see on the news the melting of these ice sheets as a result of climate change is a cause for concern. This can raise sea level 25 feet due to warming climates. This is impressive. You see the person standing at the top of the glacier there on the right side to give you perspective.

Here we have kind of a breakdown of what's going on here.

From 1972 until 2008 Ben's work is saying it is about 1.8-millimeters a year, most of it from thermal expansion, glaciers, ice caps then the ice sheets melting. Then the change here is definitely rising from 2003 to 2008, 2.5-millimeter increase, thermal expansion accounting for less and the melting and ice caps taking on more of the role of what's going on.

So it is definitely cause for concern. On top of that, we have changes in land level. US Atlantic coast is kinking as the result of geological forces. Related to an extinct ice show. The land is sinking the sea level is rising. You get this combination effect that any of thely causes more concern. I see a better expert than me in the audience, Dr. Kenneth Miller up here who could tell you a lot more about this can than I can. But it is a very interesting topic and one with policy implications.

Bob Kopp and Rick Latrhrop are experts in geographic information systems. They are helping map what sea levels will do in communities so people can make plans for changes.

VOICE: the previous slide said 3.6. Then you had two slides with overlapping dates which didn't match. One said 2003 and the other said 2008. Is there a reason the numbers do not match?

JANICE McDONNELL: I think there are averages for the decades. He averaged them. The difference in the thermal expansion accounting for less of the sea level rise than in the previously decade. I think he was averaging it.

>> Was 3.6 -- including land subsidance in . . .

JANICE McDONNELL: Yes, absolutely.

>> The last slide, how would the ice sheets make the land surface go down. Wouldn't there be rebound after the sheets melt?

Don't we find that the land raises up?

SAGE LICHTENWALNER: You do but Atlantic City is south of where the ice sheet was. Basically think of a seesaw. If the ice sheet was here, if it goes away --

>> I see.

SAGE LICHTENWALNER: Yes. Underneath the ice sheet, yes, you do get the rebound.

JANICE McDONNELL: Let's shift gears the last couple of minutes and talk about how we impact our ocean. Here's another question for you.

[See Screen]

There are as many fish in the ocean today as there were before World War II. True or false. What do you think about that one?

>> You are talking about numbers, right?

JANICE McDONNELL: Yeah.

JANICE McDONNELL: It looks like most of us agree that that's false. Really, it's very disturbing when we think about the loss of big predators: Tuna, large-scale predatory fish. They estimate something like 90% of their population has declined since World War II. We are definitely overfishing them. This graphic here is to show.

[See Screen]

-- it is all about perspective. When we talk about people who are younger, born when they are used to looking at a particular perspective or point of view. It looks normal to see an ocean that looked like this. But in the 1960s if you were an oceanographer, it may have been looked more like this.

[See Screen]

The baseline of what looks normal. We have been taking fishery stocks for years. It is really about perspective and looking at shift over time. We have several scientist, most notably Dr. Pinsky and Ken Able, the director of the marine field station, getting to understand the changes over time.

Another question for you: Where does the majority of plastic garbage that pollutes our oceans come from. Boats, land-based sources, airplane waste, illegal dumping. Where does most of it come from? Looks like most of us think it comes from land-based sources. That would be true.

When we work with little kids they think it would be from illegal dumping, all about ocean dumping. It is not true. It is people pollution. We are the source of many, many problems with plastics in the ocean.

This is a picture of the North Pacific. There are lots of groups looking at a trying to see what they call garbage patches in the gyres you get a circulating collection of garbage that is pretty impressive when you look at it.

Some say that the garbage patch in the North Pacific is the size of Texas. And it's really not floatable, big bottles like you are thinking in your marine isotope. It is really little broken down bits of plastic, like that create this queer colloid of material that fish eat and it gets into the food chain that way. It looks like food to them. They are ingesting the plastic and it is making its way into our food supply from the fishery we talked about before. There are folks at the institute in California, SCRPPS -- looking at garbage patch, would the concentration be that high?

JANICE McDONNELL: This is from a mission and this was 100 consecutive samples taken at various depths, net size over a 17-mile path through the patch. That is what it looked like. Thank you for pointing that out. Tiny concentrations, bits like that.

>> Wow.

JANICE McDONNELL: They skim the surface.

>> Is there any effort to clean it up?

JANICE McDONNELL: It is difficult. Whose financial problem is that? Who pays for it is what it comes down to. It is really a challenge politically -- from a political point of view is how it gets looked at.

>> How wide is that? That round picture.

JANICE McDONNELL: That is just a container that dumped out -- yeah, like that. Not a huge one. It comes off the plankton net. I wish I had one to show you. The plankton net runs through the surface of the water. It has a wide mouth then narrows to a triangle, to a container at the end. That is the picture of the container at the end that siphoned off --

>> You look other side of the ship looks not like much?

JANICE McDONNELL: No. But you can see it. A fisherman first discovered the garbage patch. His name doesn't come to me at moment. This is definitely concentrated.

We have five minutes left.

JANICE McDONNELL:

SAGE: So there are a number of impacts on the ocean. We read about them everyday in the news. The question is you know what should we do about it. In particular, what are we doing here at Rutgers. Janice mentioned a number of experiments going on. Right now we have a whole bunch of people in Antarctica, under Guatemala, graduate students and faculty on three different -- four, five different scientific projects going on last year, three going on this year basically looking at what is happening in Antarctica.

This is Oscar Schofield, the chair Department of Marine Sciences. He is one of the principal investigators part of the long-term research. He has been going down there since he was a graduate students in the 7s or '80s. Basically he has been observing the changes going on firsthand. He studies in the Antarctic peninsula spits up towards South America. Basically, the National Science Foundation has a research station, Palmer station in the middle of Antarctica. Here is a nice arrow.

What is interesting is that the West Antarctic Peninsula is the fastest winter warming place in the world. Parts of Antarctica are getting colder. But the west peninsula, we think deep warmer ocean water coming up the coast are drastically change the environment on the peninsula. The food web is actually not very complex relatively.

It is basically we have lots of phyto plankton growing because there are lots of nutrients, sunlight this time of year which is the summer in Antarctica, these declining populations of krill and salps feed on phytoplankton. They are studying that. They think the types of phyto-planktons are changing which changes the populations of krill and salps and they feed the penguins on up the food chain, the whales. That has drastic impacts on what is going on to the rest of the food web. And in particular the story of the Adelie penguins which used to be numerous at Palmer station just 30 years ago; are really beginning to shift and change as their diet has to change. Basically as I said the krills are increasing in the area. This is basically the conclusion.

What we have here is the red line showing the Adelie population which requires a colder temperature. They hatch eggs earlier in the season so they need colder temperatures but as the temperatures are changing, as their diets are changing they are decreasing in levels so now -- this is a graph that is ten years old. Even ten years ago, they were at 30% of what they were -- their populations in 1975. Meanwhile they are replaced by Jentu and Jinstrap penguins who can handle that situation more.

In five, ten years there won't be Adelie penguins there. There are some populations growing in the south. But there are drastic changes. As I said, there are a number of researchers down there now. We have four of these guys (pointing to the glider in front of him on the stage).

A final question. I have this robot standing in front of me. My question for you is: In what year did the first underwater robot cross an ocean all by itself:

A: 1927.

B: 1960.

C: 1999.

D: 2005.

E: 2009. or:

F: It hasn't happened yet?

>> Whoa!

(Laughter)

>> 1927 is a red herring. That is the year Charles Lindberg crossed the ocean above the ocean.

(Laughter)

1960 is an interesting year, the year that Jacques Picard and what's his name? 1960 was the first year that two humans made it to the bottom of the Chillier Deep, Jacques and Picard and a pilot -- no, a sailor. James Cameron is the third person to make it to the deepest part of the ocean. 1999 is the first year that one of these guys went into the ocean off the coast of New Jersey. Just off that picture that Janice showed earlier on.

They had a rope tied to it, wanted to make sure they got it back up. That happened in 1999. 2009, congratulations as for those of you who read Rutgers Magazine, we actually crossed the Atlantic Ocean with a glider. It took 221 days for the glider to make this very circuitous route. It left from Tuckerton, New Jersey and ended up in Baiona, Spain, that year.

We had students in charge of flying this glider across the ocean. Figuring out the way -- it was not a straight path, you see. They had to come in everyday and figure out the best past. 221 days, 7,409 kilometers, 11,000 dives and one thousand climbs. That is the ship in Baiona. That is a Spanish ship that picked it up. Here's a picture of everybody on the ship when they picked up the glider, included the chef, very important.

(Giggles).

>> December 9, 2009. Had a hero's welcome. Several hundred school kids came to town. The town went all-out. Baiona, Spain is the town where the Pinta arrived to northern Spain a month before Columbus did. He got to southern Spain a month later. Technically, Baoina has news of the New World before Columbus arrived to Spain. There is a plaque on the sea wall, it has all of the names of all of the sailors. The town was so excited we chose there to land our glider they created this plaque and hung it up right next to the Pinta to say here's the Pinta and here's a the RU 27 Scarlet Knight.

(Applause)

>> If you are there, take a picture and send it to us, please! So we can check it out.

>> How do these work. Glider. People say -- you mean in the water, right? People hair airplane gliders. We call them gliders because they are like airplane glider. It has an at I am ter in the front that tells how deep the water is underneath. It has a bionic pump, a piston that moves -- basically a cup of water in and out of the glider. That cup of water moving in and out changes the volume of the glider which changes the density which allowses to rise and sink.

The middle part is the science part. The scientist has an instrument, can cram it in there, they can monitor it. This is the modular part. You had to take it apart in the earlier versions. They said this is silly, let's swap these out. The back bay is electronics. There is an air bladder -- you get Boop an to boost the antenna out of the surface every couple of hours. In the antenna is a GPS. There is a satellite. No matter where it is in the world it can call home, let us know where it is what is missing.

>> Batteries.

SAGE LICHTENWALNER: Yes, good old D cell batteries. These glide errs are really cool, easy to deploy. Just dump it off the side of the ship and you are doing done. Changing oceanography. Don't need a big ship. The gliders are sinking here. The buoyancy pump is pushing the water out. That makes the glider whiter. The glider comes up to the surface, basically goes up and down. If it did not have wings, the glider would just go up and down. There is a device a drifter. There are things going up and down in the ocean, telling us what is happening in the top 3,000 feet in the ocean like weather balloons. Come, send data to the satellites, drift at the mercy of the ocean currents. The glider has wings so like an airplane glider we can turn that up and down motion to a forward motion. That is all it takes: Little wings -- how an airplane works -- glider need another plane to bring it up. If it didn't have wings, two come down fast. The wings allow it to come down slowly and move it forward. This is a quick example, showing the glider coming up and down in the water.

Then basically it come tots surface as I said. No matter where in the world it is there are four in Antarctica now, coming back, beaming data to the surface. We get slices of what's going on in the water. This device on the side is a conductivity temperature depth sensor. It is a identical to the thing we used before to tell us how salty and warm the water was before. Satellites tell us what is going on on the surface. Gliders tell us what is going on underneath.

There is a lot going on underneath. As I said before, there are a lot of scientists -- scientists are taking this new technology, going to town with it, coming up with sensors that listen for fish, for whales. There are a lot of fish and flounder that have transponder on them, like EZ Pass sailing around the coast of New Jersey with them, finding out where the wish are.

The sensor, second graph is developed by scientists in Florida that look for red tide, toxic algae. They are interested if that red tides discovered in the 1500s by Francis Desoto they are a public problem as well. Really changing the face of oceanography. People ask us what does the ocean think of the gliders.

(Laughter).

SAGE LICHTENWALNER: This pattern right here, you can see -- guess what that might be? That is a shark we are pretty sure. A a shark bite. We get likes of bio -- the gliders can't go forward if there is too much, too much drag. The Gulf of Mexico. These Ramoras suction to the glider and pull it down.

(Laughter)

>> They think the glider's going to give them good food I guess.

>> Hitching a ride.

SAGE LICHTENWALNER: That is what Janice and I do. Work with great scientists here at Rutgers. Great technology. Bring students from all around the world to basically see what is going only the ocean is changing, the climate is changing and we need to understand better what is going on.

We have basically used these technologies to bring the ocean to our students right here on campus. This is our cool room over on Cook Campus. We have video walls that show what is happening all around the world as we collect the data.

Students are learning about the oceans, are being the pilots flying the gliders and helping us solve the challenges that are going to be the challenges they face in their generation. So, with that, thank you.

(Applause)

>> A question: What's the present idea about where all this water came from to form the

oceans? I know Comets have been ruled out recently? Say saw there is an article. I am not up on that research so I don't know.

SAGE LICHTENWALNER: Don't forget to give your clickers to the students at the doors. We have bookmarks up here. If you want to know more about the ocean.

And ocean technology we have a video ocean gazing. We have middle school programs: Science Saturdays.

JANICE McDONNELL: Bring your young people to campus for more things like this.

SAGE LICHTENWALNER: If you have questions feel free to come up and ask. Thank you.

LECTURE #2:

11:30-12:30 p.m.

Dr. Ramaydalis Keddis

Extremophilic Environments and Microbial Diversity Within

BILL SELDEN: Welcome to our second presentation this morning.

We are very pleased to have Dr. Keddis talking about her work in microbiology, especially all the way down to the bottom of the ocean where the physical temperatures, pressures are very strange compared to what we are used to. Dr. Keddis is a lecturer in general studies at Kean University, teaching students how to do research which is important. The difference between simply counsel loading information. Also the what you do with the informing as you get it. Please welcome Dr. Keddis. We will find out about strange places and conditions.

(Applause)

RAMAYDALIS KEDDIS: If the microphone does not work, I will raise my volume. I am Dr. Ramaydalis Keddis, as Bill graciously said.

I did my doctorate at Rutgers in the Deep Sea Microbiology Lab. I have always been fascinated with places that shouldn't have living things but they do and actually quite a lot and very interestingly.

I am originally from Puerto Rico. When I was an undergrad, what turned me to love for microbes was looking at marine salterns a little and Archaea and deep sea events. I know it's the weird time right at lunch. So I will try to be as entertaining as I can be.

(Laughter)

RAMAYDALIS KEDDIS: And not bore you. If we get out early, that is great. What do you guys think an extreme environment is? Why do they call them extreme environments? That is because of our nature. They are extreme to us, humans.

>> Can you do the lights again. The slides are too faint to see.

RAMAYDALIS KEDDIS: They are called extreme environments because they are extreme to us.

We are in a very little, small tip over here (indicating) in this whole tree of life. All of these two domains Archaea and bacteria, live very happily there. Some Eukarya live happily there. And can only live in these environments. One thing I want you to realize that we all come from one common ancestor. The interesting thing about the organisms that live in these environments is that they are meant or thought to be one of the early branching organisms that appear in this Earth.

So, why are these important? Well, right now there has been a whole branch of biology called -- a biology that is coming forth. It is what is happening or going on in planets that are not our own believe it or not, our Earth has environments similar to environments on other planets. I will point them out as I am talking to you guys today. Some that come from these organisms have been and might be used for biotechnological processes.

We are going through a lot of environments. I went arbitrarily with the order. I am going to start with the acidity. Anyone know what the acidity of our stomach is.

>> Three.

RAMAYDALIS KEDDIS: Yes. Lemon juice is around three, four. Our stomach is two, three. That is really, really acid.

Acidic environments occur on Earth both naturally by geological processes or artificially. Most of the time what happens is there is an exposure of metallic ores or metals, mostly iron. You will see the beautiful color iron makes when it oxidizes in a little bit. When it is exposed to air and moisture. I have two examples here. One is natural environment. So it's naturally processed like that. And the other one is the consequence of mining.

Some of you might know of these examples. One of them is the Rio Tinto in Spain. This is how this river looks all the time. It is called Tinted River. This is the consequence of mining. The first mining in this river was 3000 BC. Then it was shut down. Then the mining activity resumed about the 1500s. Still to this day it is being mined constantly because of the iron-rich metals that occur there.

Because if you don't know, every time something gets rusty, it gets red, right? That means that the iron is being oxidized. That's why this has this color.

Can anybody guess the pH of this water?

>> Two.

>> One.

>> At most it's a three. When it doesn't rain it can reach one.

So, what lives here? That is the most weird thing. If you literally go -- your skin disintegrates at this temperature, more or less or gets really, really badly burned. Nobody wants to get burned with acid. So, who lives there? Actually it has been found that -- I mentioned the normal pH of the river is two. Why this is important is because they think this might be a good analog to Mars.

Again, I go back to astrobiology. They say if we study what's here maybe at some point in time we might be able to discover if life would be possible on Mars.

I will talk about the organisms in a little bit. The second environment is an environment right here in the United States. It is all over the world, Italy, Europe, Asia. But some of you might know this. This is in Yellowstone Park. These are called calderas. Why are they called that? It means that there was a volcanic eruption and there was a collapse in the fault and it makes a little caldron.

What is interesting about Yellowstone Calderas is they are not stagnant. They are consistently provided with heat and magma, by a hot plume. That does not look inviting: Ferrous iron materials and other metals being crusted there. these are not only acidic, they are extremely hot. In some extreme conditions -- and it was very difficult to separate these different types of environments. Most of them go hand in hand together.

So, acidic environments sometimes are regular temperature. But sometimes, as in this condition, high in acidity and high in temperature. So, the organisms here not only have to with stand and deal with pH one or two but also have to deal with sometimes temperatures of 100° Celsius.

If you see here there is a cyanobacterial mat. Algae growing as a community on top of the water or next to the geysers. Next time you visit Yellowstone Park look out for these.

So, acidophiles.

We are part of Eukarotes. But these have been found in all domains of life. In Eukarya there is algae called Dunaliella acidophila. Anything that ends with "phile," it mean that is it loves that environment. In this case it loves acid for bacteria there is

Acidithio bacillus ferroxidans

Acidithio bacillus

Thioxidaseare and Archaea -- it is

Ferroplasma.

I showed you 60% of the biomass in this environment consists of this algae.

As you may assume, because these environments are so constrictive, sometimes, their ecosystem is not very diverse.

So, sometimes -- it is good for microbiologists then that they don't have to worry about getting . . . you know, we don't have to deal with a large number of microbes per millimeter when you are looking at environments but they are all unique and extremely interesting.

So, how do these algae deal with all that acid? The main mechanism of defense is by producing something that releases osmotic pressure. And also something that deals with all of the cations, protons, everything going in and out.

One of the main products this algae makes is glycerol which is a type of lipid, it is used as oil.

What they do is all of this inside the cytoplasm is comprised of glycerol. Sometimes this is for industrial applications. They say instead of using a chemical procedure, why don't we use organism the like this harvest glycerol instead of spending all that money.

And these Acidithiobacillus ferroxidans and Ferrooxidans -- biomining -- mining is: Extract ores, refine them, make metal. But if you didn't know, these processes contaminate a lot. They create byproducts that are extremely dangerous and extremely polluting. These are used now because they dissolved metal ores then you can harvest the metal. This is used a lot in Europe.

These bacteria, the optimum pH, which means the ones they are din happiest in, is 1.5 to 2.5. After, the cMax pH they grow on, is 4. That is lemon juice for you. Up to, after that, it does not grow. It dies very easily.

So -- I am going through the tree. This is da a Eukaryote. These in this slide are bacteria. This is an Archae. They are interesting because they are similar to Eukaryotes more similar to us than bacteria.

This is said to be the domain that is the most patient. Weird figures, metabolisms. This was extracted from a caldera in Yellowstone also. They don't all look alike so they might be contaminated. This bacteria are called pliomorphic: In different conditions they grow differently. If they are really happy they look round and fat and happy.

(Giggles)

>> If they are stressing out a little bit, they start changing at once.

So, moving from acid to salt -- this is one of my favorite environments. They are characterized by having salt concentration up to 40%. The saturation of water is 35. But sometimes when temperature is a role or when pH is a a role, saturation of water can get higher.

There are natural salterns and you might be familiar with the Great Salt Lake in Utah. But there are also man-made salterns, usually marine salterns. I did my first undergraduate research in this this is the Great Salt Lake in Utah. This was a satellite picture from 2003. You see a difference between the top of the lake and the bottom of the lake, right?

This is because in this part, probably the salt concentration was higher and Arcaae bacteria that grow here tend to have a natural sun block called bacteria Dawson [phonetic] that is red. They use that as protection from UV light. They are pounded all the time. They have no brain. They have to find a way to not get the DNA destroyed. This was in a drought. That explains --

>> Why is the boundary there so shallow?

RAMAYDALIS KEDDIS: I don't know. Sometimes these lakes don't have a lot of movement and they don't have a lot of flow.

>> Is there a bridge there?

>> There is a raised road across there.

RAMAYDALIS KEDDIS: There might be a raised road, yes. The actual salinity is 20% by some volume. Anyone know the salinity of the ocean?

>> 35 parts per thousand.

RAMAYDALIS KEDDIS: 3.5 perspective. This is 20%. Naturally.

Marine salterns -- this is from my hometown in Puerto Rico. This was man-made. They don't even know when they first were constructed. Every time you buy sea salt, this is where you get it from. This is how they do it. They build these ponds close to the ocean and sometimes they are gradual. I didn't bring more pictures because I didn't want to bombard you guys.

If you see here, this is close to the estuary, the ocean. That white patch there are actually the salt mounds. I have been there. They look like mountains. They harvest it, then they sell it. The part of the island where this happens has very little precipitation. Maybe a couple of inches in the summer. This is good for salt harvesting because temperature in Puerto Rico in the summer is 95° to 100°. There is no rain.

So, you keep getting mounds and mounds of salt. And sometimes the one that's closer to the ocean tends to be lighter pink than a the ones at back. The ones at the back tend to be darker. The interesting thing is that -- I have been there when it starts raining, in August, when the really active hurricane season starts. They lose all their color.

>> They let water from the ocean flow into those?

RAMAYDALIS KEDDIS: Yes. Then they close them. The water keeps moving inward and inward. At the last pond they start collecting the salt and start making mounds and sell it to distributors.

>> I meant to ask a question earlier.

RAMAYDALIS KEDDIS: It's fine.

>> This is really fascinating. So when you were talking earlier about the extreme basic acid conditions, what keeps the -- is it the glycerol that keeps the outer protein coat from being denatured?

RAMAYDALIS KEDDIS: These proteins -- there is a lot of protomotor force going on. They spit out -- have a lot of motion. Their metabolism is little faster. Their DNA is twisted. Thermophiles have a modification. Instead of moving the way our DNA moves to cluster itself it moves the opposite way. Also, their membrane layers tend to have a lot of transpostasis that moves stuff in and out of the cell.

>> I was trying to imagine a protein existing like that.

>> What are the organisms eating?

RAMAYDALIS KEDDIS: Most of them use inorganic carbon, some sulphur. We are heterotrophs or organotroph; eating organic carbon. These eat inorganic elements: Sulphur, iron. Acidophiles can breathe hydrogen, hydrogen sulfite. Other things than oxygen. There is a theme in micro- biology. They say everything is everywhere but the environment selects.

Some people do not agree with that and some people do.

But it is interesting to see that sometimes some organisms you just find in that area and nowhere else.

Some of them you might find in Puerto Rico. Then you go to China and find it in a similar condition, right? It just baffles my mind how does that happen? How do they move or how do they transport themselves to those environments. So, that is an argument for everything is everywhere but the environment selects.

Those are all allophiles. What are the difference between these and soda lakes which I am going to talk about now. So, soda lakes are alkaline. So, these are mostly comprised of sodium chloride, normal salt. All chlorides: Magnesium chloride, sodium chloride. There are some sulfates. Soda lakes are mostly comprised of carbonates, things that are CO, carbon dioxide and stuff like that. Carbon dioxide from the environment they fix it into organic carbon for somebody else to eat.

So, soda lakes have now -- again as I said, some of these environments are interconnected.

And have more than one extreme condition. This is Mono Lake in California. This is all calcium carbonate if you have seen any reefs and the structure you see in corals. That exoskeleton is made of calcium carbon. The pH there is pH 10.

That is why they called it a soda lake.

This, again -- this lake was once thought to be completely dead.

Also, that happens with the Dead Sea. The Dead Sea has a high saline concentration. Actually it is one of the most productive areas in California. They have shrimp that evolved to live here very happily. Flies that only live here. They go to reproduce they are alkali. In the middle it is interesting to see the islands pop up. It has to do with precipitation: The drier it is, the more these structures happen because of evaporation of water.

>> The salt lake, the flies that you see at night are feeding off the algae? What are they feeding off?

RAMAYDALIS KEDDIS: Algae. Cyanobacteria and algae.

>> That is how they reproduce and everything else?

RAMAYDALIS KEDDIS: Yes. I will talk later about a lake in Kenya where flamingos, a specific type, go there and eat. The reason they are pink is because of what they eat in the lake.

And they only go to breed there and they go seasonally like any bird. They go there. That is their area.

>> The ones in salt lake are tremendous.

RAMAYDALIS KEDDIS: I wish -- I mean, I haven't been there. I find it extremely fascinating. You know, it's one of the things that is on everybody's bucket list: Go to Yellowstone. Go to Great Salt Lake.

This is what I was talking about. This is in Kenya. It is called the Kenyan Valley Rift. There are many, many lakes that go around that rift, right? As you see here again, the pink color and salt crusts on top of the water.

This is actually fed underground by marine springs, thermal springs.

As I said -- I forget the name now, a specific type of flamingo goes in seasons and feeds off there. Hence, their pink color comes from the organisms they eat there.

>> Organisms found here are in all domains of the tree of life. If you see a familiar genus, Dunaliella. These are the most diverse metabolic organisms in algae. It is no mistake. If they are this diverse they live in acid environments and also in high-salt environments. Bacteria, there are many, many, many, many bacteria. I just will talk about one and the Archae They complies one branch. They are salt loving. Dunaliella, you get from carrots and toe mates, it produces beta carotene, the Dunaliella. They harvest this for use in cosmetics and dietary supplements, in A capsules. They take out the carotene.

>> It is green because it has chlorophyll and does photosynthesis?

RAMAYDALIS KEDDIS: It does photosynthesis. It has chlorophyll.

>> So, it neat needs the light for that.

RAMAYDALIS KEDDIS: It does need the light. It is algae so, a photosynthetic organism, produces photosynthesis and is the basis for the food chain in the environment.

Not all environments have that. Most environments that are exposed to air. The pigmentations are not because of this.

[See Screen]

Bacteria, Salinibacter. This is ruber. Isolated from a saltern pond, man-made pond in Spain.

Saltern pond, The minimum of 15% salt concentration for growth and optimal is 20-30%. This is a long, complicated name.

[See Screen]

Natronobacterium Nitratireducens. When oxygen is finished they start using nitrate to breathe. This was discovered in a soda lake in China their pH range goes from neutral, 7.5 to 10.5. It is happiest at 8.5. Yes.

>> Are any of these bacteria as detrimental to humans?

RAMAYDALIS KEDDIS: No. I will tell you a little anecdote. When I was an undergrad I worked with Allophilic Arcahea. He said we are going to extract DNA. I learned to do that in microbiology lab by dividing fragments, adding ethanol -- he said no, we don't do that here. Put a little distilled water and they burst. Okay?

What I did for two months probably -- these bacteria take a really, really long time to grow, Archaea. They can grow one, two weeks to a colony. All I had to do was put a little distilled water and that is it.

Archaea are in our soil. They are very important. They produce methane. They use methane. Instead of breathing oxygen, they breathe methane. They are thought to be a key component in how our environment works. Most of them have not been discovered. Most have not been characterized. If you see the diversity of Archaea, most have numbers not names. Why? Because they cannot grow them. It is very difficult to find where they are happy enough to grow. It takes a very, very long time.

Now I want to talk about what I did a long time: Deep sea hydrothermal vents. They occur at the bottom of the ocean where plate tectonics meet. What happens is you have a rift and then, because of those cracks, ocean water goes down to the chamber. When the water gets in touch with the magma it undergoes a transformation. Then this becomes a hydrothermal vent. Not water anymore.

The characteristics of this fluid is: One, it is very hot. By the time it reaches here it is around 300°. It is -- has no oxygen. It is very, very anaerobic. It has metals, gasses, everything mixed together.

I will show you a picture of what it looks like. Really looks like a cartoon. Then the buoyancy of that changes and it shoots up through what we call a black smoker chimney. Sometimes there is a little more mixes in the -- next to the axis. That liquid then gets spewed out through the sides.

That liquid is still hard to move but dash usually 60° Celsius and contains a little oxygen. This is where most maritime animals, clams, shrimp are. This is around 3,000 meters, the bottom of the ocean. No sunlight trickles down to it.

This environment completely lives on chemosynthesis. Everyone knows what photosynthesis is: Production of organic carbon and oxygen, utilizing sunlight. Chemosynthesis is then obtaining organic carbon from inorganic elements: Hydrogen nitrogen and sulfide. We also see zinc, methane, lead, mercury.

So, in these outside ridges, we sometimes see these organisms.

[See Screen]

These are called tube worms. they are red because they have a type of hemoglobin inside them that carries oxygen and hydrogen you will fight to the bacteria that live there in them. They say okay we have a partnership. You live inside me so you are not floating around and have somewhere to live. I will give you hydrogen sulphur and oxygen and you give me -- make the hydro carbon. It is found that when this stops it mean that is when one dies the others die. That is why they call them a black smoker. Because, when this very hot liquid comes up with -- seawater temperature is 2° Celsius (please check #). It is a tiny bit colder than if you put your hand in the refrigerator. Something hot coming in contact with something cold, everything precipitates. These are the minerals, metals and anionic species vastly precipitating out.

This chimney is really hot.

What happens is chimneys are -- sometimes they are small but sometimes they are very, very wide. Between the inside of the chimney and the outside, the temperature grade went very, very sharp.

So you might have 350 in the middle, the mouth. By the time a you reach the wall it is around maybe 50, 60°. From 300 to 360 in centimeters. .

I am going to talk about Yellowstone Park. This bacteria changed molecular biology forever. Isolated in 1969 I think from Yellowstone. Thermus aquaticus. They found an enzyme. Hopefully everybody here or not is familiar with polymer chain reaction. Basically you do a chain reaction, what we all do to replicate our DNA. A long, long time ago in the '70's and '80s when this process was being designed it was actually done with E. coli. Everybody knows what that is. Our worst friends sometimes.

They are polymerase their enzymes help the DNA replicate. It is used from that. They have to be refreshed. Every 30 minutes add more polymerase. Around that time they said the enzymes -- it is a thermophile. Let's check the enzyme that does the DNA replication with stands the PCR cycle. It did which is now called Taq polymerase. Everybody in a lab used this for PCR reactions. Use very little, one shot, it's done. So you get really cool things from this.

This is why these organisms are so interesting and it is so interesting. Biotech companies are interested in them. Because if I can find a process that is quicker, less invasive. It might take a little time developing but at the time I get more than what I paid for.

Then, that is perfect.

This is was themovibrio ammonificans. There are multiple hydrothermal vents. One right off the coast -- from California all the way to Mexico, all the way to South America. That is the closest to us.

The other that is famous is at the Midland Ridge in the middle of the Atlantic.

This was isolated by Vetriani. It uses ammonia to breathe.

This gross in a range from 60 to 80°. The optimal temperature, happiest, is 75.

I will uses hydrogen sulfide but prefers ammonia. That was interesting because at that point in time everybody thought hydrogen sulfide is so much everybody must be using it. No quite a few organisms do not only use that. They have a plethora of tools in their tool box, just in case something happens.

This is the organism that defied conditions that organisms could live in. This is Pyrolobus fumarii isolated from a black smoker in the mid Atlantic ridge. You saw a black smoker. This is Archae. Grows between 90-113° Celsius. They did an experiment.

Microbiologists sterilize things, putting them in a big oven, autoclave, 115° Celsius, 15 pounds of pressure. This little one, survived. It can grow at 121° Celsius. Before the threshold for surviving temperatures was # 113. This little guy now taught us that it's not. Optimum, temperature it is happy at is 106. I don't even want to convert it to Fahrenheit.

>> In the previous slide there are large occlusion bodies of vesicles?

RAMAYDALIS KEDDIS: They sometimes produce sulphur granules.

>> Those are sulphur granules?

RAMAYDALIS KEDDIS: Yes, they keep it in storage.

>> Thank you.

RAMAYDALIS KEDDIS: Now we go from really hot to really cold, the opposite of the speakers before us was talking about this. Since 2012, they have been trying to drill the lake, it is contaminated coming up. Tried again in 2014. Let's see what comes out of that. They found in Lake Vostoq in Antarctica. Researchers are are interested if this because they think it is and a log for the Jupiter moon Europa. Going back to what we have here we can work with that is similar to something happening another place.

This paper was published in Nature. They found microbes, this is a glacier that sits on top of the lake and the glacier moves. They took two ice sheets from the top of the lake when the glacier moved. They took a piece. They said we think that is from the lake. They analyzed it found a bunch of bacteria. This was once thought to be completely sterile.

And the reason for that is when they went to look in microscope, the biomass, there were 6 per milliliter. Normal diversity is one to the ten to the sixth.

By milliliter.

So it is very, very scarce. Why? Temperatures run from negative 40. On a good day.

(Laughter).

RAMAYDALIS KEDDIS: The other thing is they can't reach -- researchers can't reach -- can't go to Antarctica until summer because it is very, very dangerous. They can only drill when the permafrost starts to melt a little. They found a lot. That was good. They want to actually drill to get to the water in the lake.

The first time they tried was in 2013 by a Russian group. When they did, they actually -- went through a lot of drill bits to get down there. This is 4- , 4,000-meters. When they did and they reached it, the liquid that came out of there was contaminated -- contaminated by the oil and wall Rutgers um all the other things they have to put in the drill to lubricate to get it down. Now they are trying to find another way to get pristine samples.

>> How did they know initially there was a lake there?

RAMAYDALIS KEDDIS: I do not know. That is very interesting. I don't know.

Usually they use satellite imaging. They have heat machinery. I mean if I was a geo chemist or a geographer, geologist, I would be very interested to know that.

So, psychrophiles grow between negative ten and 42°. But seldomly grow in 42. They are psychrotolerant not psychrophiles. Tolerate but don't like. Most grow at the temperature of your fridge. They like freezer and below. Again, just as some Archaea, they take a really long time to grow. Nobody wants to be in a fridge looking at stuff because once you put it at room temperature, they mostly die.

This is psychrobacter species.

Again, this is -- the reason I don't have a lot of information on this is this is one of the newly discovered areas.

As I said, they are very difficult to culture, very difficult to keep alive long enough. So, I characterized an organism, I went to publication all that, events. The bacteria I discovered . . . it usually takes a year and a half to two years to characterize for publication. That is with the bacteria behaving itself. So, with these organisms, what I want you guys to keep in mind is that: They are very -- it takes a special kind of person to work with them.

(Laughter)

RAMAYDALIS KEDDIS: You have to be extremely patient and extremely tolerant to failure and very, very cavitiy with your troubleshooting. This area is actually the new area they are trying to look at diversity. Again, just as some of the Arahaea most of these don't have names yet, numbers as detected in microscopes. Thank you. Hopefully you learned a little about extreme environments. Do you have any questions?

(Applause)

>> Considering diversity of life forms you described today what is the evidence they derived from a common ancestor?

DR. RAMAYDALIS KEDDIS: Taxonomy is based on the discoverny of the 16 SRR name, a portion of our ribosome is the one good enough to determine diversity in taxonomy. There is a little bit of controversy on that, but as of now that is how it's mapped. They use a lot of algorithms notations to calculate evolutionary distance in the tree I showed you at the beginning.

[See Screen]

This is looking at 16 SRR sequences. Basically come from mutations. Then they calculate the distance between them .this is what comes up.

I know it is not the perfect way but it is the way that has been done awhile. I know they are trying to find other ways to see more conserved or diverse areas. Some people use ATPase, that gets a whole look. That is just the technical background. Yes.

>> Given everything you know up to this point if they announce next week that they have discovered existing or fossil evidence of life on Mars or some other solar system body are you going to be surprised?

RAMAYDALIS KEDDIS: No.

(Laughter)

RAMAYDALIS KEDDIS: I am not. There used to be water on Mars. There is still ice on Mars. So, where there is water, there is probably a bacteria somewhere.

>> I wags amazed years ago to find meteorites actually come from Mars to the Earth. Then especially in the early days when there was a tremendous amount of bombardments. There is probably a great deal of mixing of materials from Mars to Earth and Earth to Mars. And all sorts of -- Venus. Is it possible that maybe all a of these billions of years ago there were these

lives.

RAMAYDALIS KEDDIS: We don't know. That is the interesting part of it. That is why there is so much effort going into -- studying these are types of environments that are analog to other planets. If we find this is what they like, this is the environment they live in. This is how we detect them. When you go over there, get samples, you might -- might have an idea how to work with them.

>> Did you say you found one and it's being used -- where did you find it?

RAMAYDALIS KEDDIS: Okay. So I -- I was like the odd person out in my lab of everybody worked with anaerobic bacteria, that does not use oxygen to live, to breathe. I wanted to go a little sideways, so I focussed on the parts that were oxygenated. So, the side axis. I was working at bacteria to see if there were bacteria that lived there that ate petroleum naturally. Those environments because they have hot rock and cold water exposed to it by some abiotic process called the Fisher Trope reaction, they produce small size hydrocarbons. So, carbon and hydrogen.

Also because of the high temperature and pressure -- I didn't talk about a aspects of this today that is another pressure. All things that die there get disintegrated quickly. Those are all alcane. Petroleums are alcanes. Simple chain hydrocarbons. The concentration of petroleum there is 30, 40 times as much as in the whole ocean. Pristine ocean, let me say da. I know, not Gulf of Mexico.

Then I wanted to -- if it's there: Is somebody eating it, right? Is somebody living off it. We found that yes and quite a lot. They are not primary producers like some of these but do help, we found, detoxify the environment. Take the mercury and change it to something that is not toxic. So, that the worms, clams, shrimp can live there. I found one with one of my colleagues. Carbovaculum hydro themalus and eats 16 chain hydrocarbon. Carcinogenic. I forget the name. They are toxic to us. Also we found this bacteria produces soap, bio surfactants. Why bacteria use this: Oil and water do not like each other. These bacteria need to harvest the oil for themselves. They produce soap, bio surfactant to get it closer to them, so they have more to eat. Again I was the one looking at aerobic bacteria, then petroleum. We found these environments have them. In the situation, I was mid-Ph.D. when the whole Gulf of Mexico BP oil spill happened. I remember going to a conference and talking about it. And one of the people -- I said well this could be useful for open ocean oil spills.

One of my professors said well, that is not even going to happen so why are you even looking at it. Six months later, April 2010 comes around. And BP oil spill happens. So now, everybody's looking at it. So, it's very interesting to see that something at 3,000-meters -- some of these environments are used to this. Not used to that volume. It gets very overwhelmed and you get into an issue where there is no oxygen what happens, other bacteria goes there, who can use it. Also these hydrocarbons are very toxic to some bacteria, not to others. So, basically --

>> Thank you.

>> How long do these organisms live and in colonies?

RAMAYDALIS KEDDIS: Usually in symbiosis. Some live in soda lakes, the fungi live with the bacteria to help each other. Hydrothermal events are not free living. It is a very dynamic environment. They live in biofarms encrusted within the rock with salt. A little community. Think of it as a little skyscrapers. Primary producers in the bottom, organic carbon is produced by them. That goes up and up. The worms and the plants and crabs then position themselves on top of that. Also there is an idea that some of these bacteria might live, incross Tate under the Earth's crust. Sometimes they can be seen that instead of the black smoke that comes out of the chimney there is what is called snow blowers, specs of microbial Biofilms popping out of there. We don't know where those come from. It is said that under the Earth's crust there might be a circulatory system. Marine isotope you, think about it that way, that transports these bacteria different places.

>> Repeat the question, please.

RAMAYDALIS KEDDIS: They were asking if they are free living or living in communities.

>> I read a couple of years ago that some people estimated that the biomass living under the crust could be equal to the biomass above. Do you believe that? I mean, how much could there be down there?

RAMAYDALIS KEDDIS: Again -- there is legal action -- with drilling, right. Drilling in this area is very controversial.

And very, very difficult. The way we get down there is with a -- with DS Alvin, a deep submersible vehicle that fits three people. It takes four, five hours to get down there and four to five hours to get up. There is very little vessels to get down there for drilling. There is a lot of research to be done. Everything is possible.

>> Under the crust, there could be a biomass equal or greater than that above. Wow, that is a lot.

RAMAYDALIS KEDDIS: I don't know.

>> You may have said this earlier. But in general terms, what's the difference between bacteria and Archaea?

RAMAYDALIS KEDDIS: Genetically they are completely different. If you go by taxonomy, they look more and are more similar to Eukaryotes than bacteria. Metabolism is similar but cellular membranes are different, the way they do DNA. We have entrons as humans, Archaea do too. Bacteria do not.

The environment they live in is very, very wide.

>> Do they have a cell wall?

RAMAYDALIS KEDDIS: They do. Depends on how it is structured. We have lipid, bilayer, phospholipids. Archaea have a mono layer, only one.

>> Do they have a rigid cell wall?

RAMAYDALIS KEDDIS: Very rigid cell walls.

>> Going back to Mars, there have been confirmations now about methane releases on Mars. If you had to guess there was an extreme environment, what might be living there, and it is similar to what is on Earth, from what you have there?

>> Methanostrobes produce methane and methano --

>> In the Archaea.

RAMAYDALIS KEDDIS: Yes. Methanobacterium, methano coccus, and pyrus, which means warm.

>> Do other people think that?

RAMAYDALIS KEDDIS: I mean --

>> You are guessing?

RAMAYDALIS KEDDIS: Yes, we are guessing. If we don't have any hard evidence, we can't say anything. It does have a lot of -- a lot of different requirements. Like in Lake Vostok, they thought it was sterile. I guess in 20, 30 years, hopefully sooner, before we all pass away, we will find out, right?

>> What was around three and a half billion years ago: Which came first, bacteria or Archaea?

RAMAYDALIS KEDDIS: Archaea. You see the common ancestor -- well, it says that Aquifex, hypothermic bacteria, was one of the oldest. Then the ones that come there from Archaea. The closer it is to the bottom, common ancestor, the older it is.

>> Wouldn't there be a lot of these guys down in water tables transposed from one part of the continent to another?

RAMAYDALIS KEDDIS: They do move sometimes. Again, some of these, hydrothermophiles cannot live in temperatures under 65°. So -- that is a mystery. Even with the worms. These worms find the same type from the east Pacific rise and the Mid-Atlantic Ridge. How does it happen? Nobody knows. The ocean is the most mysterious part of our Earth. It is the most interesting part because it is the part least explored. This was discovered in 1975. Everybody thought the bottom of the ocean was just dirt. Then we found this organism that has a lot of biomass, a lot and is not dependent on sunlight. So, there is so much more we don't know.

>> What would you say would be the likelihood given the two worms can pop up on the Atlantic, Pacific, everything is everywhere, environment selects that we accidently colonized Mars with some extremophilic?

RAMAYDALIS KEDDIS: That is another thing. Biocolonizing is a real question questions all the time. You go down there in a submarine, pick up a column of water. How do you know what is down there is not from going up in up in the water column. We as scientists and marine microbiologists and every type of microbiology do follow guidelines to ensure that does not happen. But, how do you not know -- the rockets we are sending, Mars recover, were not contaminated with something, right?

>> I was going to make a comment and maybe a question. So, you were talking -- two things. You were talking about mostly exploring existing bacteria, not genetically modifying them and about industrial process.

I assume that is one of the great advantages of this work: That you don't have the resistance that you would have if you genetically modified an organism --

RAMAYDALIS KEDDIS: It does it anyway.

>> When you talked about that very, very hot bacteria, does that give any key because I know we have a friend that is a vet and she is working with mad cow. The Preons -- you can't autoclave they don't go away.

RAMAYDALIS KEDDIS: Preons are not even -- there is a question -- they are not living things same as viruses -- well: Virus. Virus, if we follow the guidelines: What is a living thing, it shouldn't be. Preons are proteins that come together, do this thing. Apples and oranges. It is difficult to do and log.

LAUREN ADAMO: You can take one more question.

(No further questions)

RAMAYDALIS KEDDIS: Thank you, guys, so much for coming.

(Applause)

** Luncheon recess **

LECTURE #3:

1:30 - 2:30 p.m.

Dr. Jean-Paul Ampuero --

Earth's Cocktail Party: Deciphering the Physics of Earthquakes with Networks of Seismic Arrays.

>>BILL WELDEN: Welcome back, everyone. Our next speaker is Dr. Jean-Paul Ampuero, who is and Assistant Professor at the California Institute of technology Seismological Laboratory. He completed his Master's and Ph.D. in Geophysics from Institut de Physique du Globe de Paris or IPGP. In 2014 Jean-Paul was named the IRIS/SSA Distinguished Lecturer at the Incorporated research institutions of Seismology and Seismological Society of America.

[Applause]

(Brief technical difficulty)

JEAN-PAUL AMPUERO: The earthquakes in the past century are shown here. So each red or blue belt here is where an earthquake happened in the last hundred or years or so. In comparing these two, earthquakes do not happen everywhere. They cluster in places where there is a cor responsible tens of boundaries of tectonic plates. Earthquakes are very important to understand because they have a huge impact on society huges waves in the ocean can affect this very much. This is a picture of Japan. On the right side of my slide are the effects of a tsunami. They can also cause secondary damage, for example lighting fires.

Other effects we call liquefaction. Soil Liquefaction. They shake, come almost water. Not all earthquakes happen at plate boundaries. You may have felt one not long ago an earthquake a few years ago in Virginia. This map here, the star is where the earthquake happened. The colors here indicate how intense was the shaking felt by people on the East Coast of the US this also generated some damage to monuments. Like damage to the Aquarium.

(Laughter)

>> I remember that.

[See Screen]

>> We can crack a joke about an earthquake. Unfortunately some earthquakes have more more impact than what we felt a few years ago. But 2011 was a useful earthquake to raise awareness here on the East Coast.

This is the original position of the crust. There is a road crossing -- a fault. You don't see a signature fault yet. There are two plates here in contact. The plates are moving slowly and storing elastic energy. This happens through many, many years. Energy builds up until suddenly, it slides. And that is the earthquake: Sudden release of the elastic energy stored at the contact between two plates.

So, that boundary is slippery but it sticks most of the time and slips only for a few seconds. Then the cycle starts again.

The plates keep moving and pushing each other. The time scales are very diverse.

The time scales of slow energy buildup are so as to thousands to hundreds of years, are very short.

We are interested in this very short time span. We want to know what happens during this time. Here we are looking at a cross-section of the crust. There is a fault here. An earthquake just started at that point (indicating). As the earthquake shakes the ground, that shaking starts to propagate everywhere.

That movie that we are seeing on the right --

[See Screen]

-- shows how the motion inside the Earth is propelling out of the focus point. Those waves will go all around the world. They are comparing damage especially to those nearby, close to the Earth. They also carry information because they go deep into the Earth then come back to the surface. As they come back. They bring the information. About what happened. In the fault.

Also, about how -- what is the structure of the deep Earth? While earthquakes are damaging they are also very useful to advance our science and understanding about Earthly processes and the dynamics of the very deep Earth.

Let's get into the details of what an earthquake is.

Let me use some analogies here. So, we can break a pencil. The rupture of the pencil generates a sound wave. That sound wave is our analog for seismic waves. It is vibrations of the Earth propagating away from the rupture of the pencil.

Just as seismic waves propel away from the earthquake hypocenter. In this representation the source of that sound is the very localized spot, the point. But actually an earthquake happens on a fault. These faults are large; could be tens, hundreds, sometimes thousands of kilometers long. An earthquake is not at a point, it is and a extended source and it is a moving source. A better analogy would be this: You have a piece of paper that you begin to tear. As the tip of the tear moves, that tip radiates constantly, sound waves around it. This would be the tip, the rupture propagating along the fault during the earthquake.

Here is another analogy. Drop a rock in a pond. That is a point source, small. But, a ship moving along the sea, generating these water waves and, that is a moving source. Has a large size.

So, what we would like to learn is what happens inside the fault plain during an earthquake. Earthquakes occur weekly beneath our feet. Depth of 10 kilometers. It is not easy to drill, open the Earth, see exactly what happened. That is one of the biggest challenges for us seismologists. We hope we can learn as much as possible about the earthquake process from the recordings of round motion at the surface of the Earth, more than 10-kilometers away from where in the Earth it is happening.

Here's what we usually can do. This comes from the computer simulation.

So, we open the Earth to look at what's happening on the fault plane during the earthquake. This plane here is the surface that is sliding, the fault. And this upper surface here is just the ground above.

And we have seen two things in this movie.

We have seen the Earth rupture itself, propagate along the force. These colors indicate the speed at which the two sides of the fault are even offset by the Earth. As this happens, we are seeing also above the surface of the Earth the ground motion, seismic waves being radiate bid the earthquake source.

Here's another computer simulation. This is the one actually used to evaluate the impact, what we are expecting. So this is southern California. And this scenario, San Andreas fault, part of that fault is this dashed line here. The earthquake will start here and will unflip this San Andreas fault toward the north.

This upper figure, we will visualize the velocity at which the ground moves. This lower figure will visualize the fall plane inside the velocity of the two side of the fault are sliding.

Are this is a shakeout scenario which we use for our yearly drill in California. This looks plate. It is not a single process. That makes it very challenging for us as a I said before, this is not reality, this is our view of how reality may look. This is a a computer simulation where we put as much physics as we know but it is a big challenge because we don't know so much about what is really controlling Earth rupture.

So we record this ground motion at the surface using Sissmometers. There is a network of them around the Earth. They record round motions. Seismograms. Our job is to satisfy the seismograms and take the information to confirm what happened along the fault. We want to know how much slip, offset you have accumulated during this earthquake. Also how did the earthquake progressed and propagated from the fault. How did we manage to run and break this whole segment of the San Andreas.

Was it fast? Was it slow, smooth? Complicated, loud, silent.

Some of the deep questions that we are pursuing is why do earthquakes and how do they start and grow and finally stop.

These processes are controlled by physics that happen -- very small scales inside the Earth.

So if you want to learn something about this process, we need to get very sharp images of what's happening on the fault.

That's a big challenge. Today, this is a type of image that we would love to have and this comes from computer simulation.

This is what we actually have as an image that we can retrieve from our seismic recordings on the surface. It is a very blurred image of the earthquake process.

So, our goal has been to push the level of resolution of earthquake source imaging. Similar to the transition we saw some years ago between the standard TV sets to high definition TV. Here, we really want to do very dramatic steps in clearer images for earthquake sources.

Why is there such a challenge? There is a concept in seismic wave that is the frequency of the wave. If you take the analogy of sound, the frequency of sound -- high frequency means the high pitch sound. Low frequency is the low sound.

So, an orchestra, you have instruments that are lib a tuba very low. The violin, very high. There are differences between high and low frequencies.

This is my look-alike. Conductor of the Philharmonic.

(Giggles)

>> We have something in common beyond the curly hair. We are both from South America, a very earthquake-prone place. Growing up and feeling so many earthquakes was one of my motivations to something to become a seismologist.

So what's up with the high frequencies? We would like to extract information from high frequencies but that is very difficult. Why? Because of scattering. What is a scattering? We take an example from ocean waves. You can see the wave field at the surface of the sea.

And you can see from these patterns that the waves have interacting with these small islands and have generated this very complicated patterns. The same, we expect, in the Earth.

Here's another seismic wave simulation where the waves are interacting with disorder in the Earth. They are generating a lot of scattering, generating a very complicated wave. The high frequency, high pitch seismic waves are very sensitive to small islands inside and the low frequencies are not. So, we would like to extract information from the high frequencies but they are also more scattered, complicated. Extremely challenging to extract information.

The goal of the developments has been to push virtually the higher frequencies. I will show you some of the processes behind some of the techniques to achieve that. This technique is called back-projection sourcing.

Let me say that there is another complication in this program. As we saw before, the earthquake sources very complicated. And it is not made of a single source propagating along the fault. But, there are movable sources. Not even this their is a good analog for when the Earth is moving.

Maybe this or multiply this by ten. So, there are several tears and ticks radiating waves at the same time.

This brings us to analogy to the cocktail party problem. This is actually a very serious problem in signal processing. It is the problem of figuring out in a crowd, when everyone is talking, who is saying what. If someone is moving in the room, you want to be able to track his movements.

Where is that voice coming from. There is a movie -- moving and voices are going on at the same time. We do manage to do that.

We manage to focus our attention into one particular voice and to track it despite the movement of other voices. Although sometimes it is challenging. How do our brain and ear manage to process the information and locate a speaker? So, let's make an experiment. Let me ask you to close your eyes and don't move your head. I will keep talking. I turned off the microphone.

And I am still talking and your eyes are closed and your head is still facing the screen.

And you will notice that I am moving around the room. So, your perception of sound, your ears and your brain are acting together to process this acoustic waves, sound waves and locate my position.

You can open your eyes now.

(Laughter)

How do we do that? Well, we have two ears. That is a hint.

If you are talking, on my left sound, the sound will reach first my left ear then keep propagating, then reach my right ear.

Tiny, tiny, tiny waves. We are able to detect those slight differences in the timing arrival of sound waves through our ears.

And if you were to my right, the opposite would have happened and my brain can process that information and knows which ear that hears the sound first. From that information, we can locate where the speaker is.

If the speaker is in front of me, the information will reach both ears at the same time.

So, I have some clues about the angular position of the source.

Our situation is more complicated thank the cocktail party. Many sources are acting at the same time. How are we going to distinguish among them; how are we going to accurately locate them, track them as they move? A big ear's one solution. Not quite. The solution is to use more than two ears. Multiple ears. This is what is done in acoustic. Resolves the type of problems, instead of one microphone. We can set an array of microphones. There are four by four. 16 microphones acting together. 16 ears, measuring the slight delays of arrival time of sound waves. From that information, figuring out where the speaker, how did he moving. This has many applications.

Military applications. Civil safety applications.

You know, the army may use this in battle situations to relocate. Or you can use systems of several arrays. Gunshots. Actuallyly, these techniques are applied widespread. They are used in telecommunications. They are used in medicine. Radars.

So, when we started making use of this in seismology, there was already quite a good amount of research and techniques.

However, the challenges we had in earthquake seismology were different than the challenges that are faced in all of these other applications.

Why? Because earthquakes move very fast.

There is really a lot of disorder in the fault and there is a lot of scattering in the Earth.

So, this makes it a very grows environment.

But it makes it also very interesting. We like challenges.

A hundred seismologists as a community went into improving the state of affairs. Seismologists starting developing and deploying large and dense arrays of Seismographs. Every point in the map of the US is a point of a seismograph station. Not all of these stations were deployed at the same time. Each color band was deployed for one or two years at a time. This was moving across the continent.

So, this is how an installation looks like as a whole. As shielded from the especially environment. Inside, we place a very sensitive ground motion detector.

Then we close it and hide it.

Let me show you a movie here of how these instruments recorded the ground motions. First look on the left at a movie of how the US array, which is this big seismic network recorded the earthquake in Honshu Japan. You will see the colors changing. Red colors mean motion up and blue colors mean motion down.

Times evolving. Look carefully. It is moving.

[See Screen]

What do you see in you see some stripes that are moving across the US seem to be coming from the northwest. Interesting. Look at the other movie. This is another earthquake. This was not in Japan. It is somewhere in the south of the Pacific Ocean. Again we see a pattern of waves passing by.

But there are different, right? From the pattern and how it's moving you can tell that the earthquake on the right, she is waves were coming from the south and the other was coming from the north. This is our hundreds of years of working together to figure out where the Earth is.

the earthquake is originating. Another important point of the movies is you can see there are places in the US very densely instrumented but others coarsely instrumented. If you try to find the pattern in the coarsely instrumented regions it is really hard. You need high density in the seismic network to extract this information.

To highlight some of the challenges, the two examples I showed you were from two earthquakes that were very far apart from each other. You can tell by eye the difference of wave patterns across the US. During a single earthquake, the sources moving along the fault.

And you cannot really see it by eye, but the direction of arrival of the waves is changing with time. But, very slightly. It is not something you can tell by eye. You need sophisticated signal processing techniques to extract that information.

Once you have figured out from which direction the waves are coming, we can use our accumulated knowledge of wave propagation in the Earth to back-propagate this towards the earthquake source region and figure out how the rupture was moving in Japan.

And elsewhere. That is the basic idea of projection of source. This would be the product of that. The white lines here are the coast lines of Japan.

And the color image here shows how intense was the radiation coming from the fault.

So, the warm regions, close to red are those regions of the default. We are exciting very strong high frequency waves. You can see that that blob is moving along the fault. So, we have achieved what we wanted to track the source of the earthquake as it moves along the fault in Japan. Using recordings of ground motion thousands of kilometers away crossing the Earth. Question there is a question.

>> The waves we saw are those low or high frequency waves?

JEAN-PAUL AMPUERO: Low frequency waves. To make it visible I am showing you what we call the surface waves. But we are actually using tiny waves that arrive earlier than this and are higher frequency. You can barely see them.

So -- yes.

>> How high is high?

JEAN-PAUL AMPUERO: Around one hertz. So, vibration ups of one second.

>> What is low?

JEAN-PAUL AMPUERO: Ten seconds and longer. I am not sure I will have time to go into a lot of detail about the motion -- let me just give you a strong message about what we learned from the Japanese earthquake which was the example we have been looking at so far.

So what is on this map is that area of the fault that radiated its high frequency waves. What is in yellow is the area that radiated low-frequency.

So we now have an arc stray analogy. The light blue area is the violins and the tuba is here. The two regions do not overlap much. The high frequencies are much closer to the coast than the low frequencies.

This has important implications for the type of damage that it can cause. High frequency shaking is very damaging for low-story buildings and low-story houses. Long periods, low frequency shaking will affect very tall buildings.

This is giving you some information about that. If your tall building is somewhere here, it is good to know the low frequencies are not coming from near the coast but further away. The shaking will be a little lower than we would expect with the other.

Low frequencies also have another big effect which is the cause of tsunamis. They lift up the sea floor and that will generate the big wave that is the tsunami.

Before we had this image of how the high frequencies were moving around the fault we thought that these two parts of the spectrum of the earthquake were actually happening in the same areas of the fault. Those were the models we were using to predict the ground motion for the future. So, these observations changed enormously our understanding of how earthquakes happen, potential damage.

We have been working also in trying to put this into renewed picture of the structure of subduction fault.

Here's a sketch of a subduction region, a region for the plates are sinking below the Continental plate. I flipped my Japanese image to correspond to the sketches. Japan, the ocean plate is subducting with Japan.

If we were able to open the Earth and look at the surface of the fault something that we have never been able to do and probably never would have been able to, this is what we think we might see. This picture is coming from this type of observations.

So we think that there are the surface of faults are very he heterogeneous and diverse. The mechanical behavior of this fault is changing system at a include with depth. As you go deeper there is more and more confinement, stresses, higher and higher temperatures.

And a very intense topic of research is how those changing conditions affect the heterogeneity and mechanical behavior of faults to create this distribution of the faults forecasting.

So, thanks to this new techniques, we have been able to look at many, many earthquakes in the past few years. These have been very busy times for seismologists. For those of you who have lived longer, earthquakes were in the news more often in the last ten years than before then.

Those are you who have lived even longer remember that I think in the '60s there was a period like that. Maybe things was not nine same was news was not as widespread as it is today with the Internet.

We can learn about this.

So, those earthquakes have brought a lot of damage and awareness about earthquake hazards. Also they have brought an opportunity for seismologists to gather information about earthquake processes; learn more about earthquake processes. The Earth, fortunately, moves slowly, so huge earthquakes happen only rarely.

But it also mean that is we don't have very often the opportunity to observe very carefully an earthquake.

So, this has been a very unique decade for the young seismologists, like me. Despite suffering from the impact that the earthquakes are having on societies, we are are taking advantage of this opportunity to try to make progress towards a safer future.

We have applied it to many, many earthquakes and this is something that happens very often in science. Develop a new technique, new wave looking at an object, at something. Inevitably discoveries come out of this. For each of the earthquakes, finding unexpected behavior. Things that have been shaping our understanding of how earthquakes work.

We like the unexpected. We like when something doesn't happen as we thought it would. Because that is where our theories get tested. That is the way we can evaluate hypotheses.

So, the earthquake I was going to show you in detail -- I will show you very briefly now, is an earthquake that happened very far and so offshore that there was no other way of figuring out what happened. When an earthquake happens, this is the continent we have, seismic stations nnearby and GPS stations nearby and satellites that can record the information on the ground that was not the case for this offshore earthquake.

It is the kind of earthquake that happens on the San Andreas fault. It was different from the suppression earthquake this was the biggest of its kind. You may not have heard about it. It was so remote it does not cause any damage. It gave us an opportunity to study the monster earthquake. And one of the only ways to study this earthquake was using this techniques that I presented here.

These two movies show you two images of how the high frequencies are moving along the fault as seen from two different places: From the US -- no. From Japan and from Europe.

If you want to learn about an object, the move view angles you have on it, the more information you will be able to extract. That is why we explore as many areas as possible.

Let's focus on the figure in the upper right corner. From each frame of the movie, I will extract the position of the highest and strongest point. I will plug them together in this picture here. And I will use colors to indicate time.

So time goes from blue to red. The earthquake started here in light blue, moved into the yellow then into the red.

In the sketch at the bottom, it summarizes the rupture pattern. It does move extremely complicated at first. It did not involve a single fault but several faults were crisscrossing the oceanic crust.

So, this is a very good example of patterns that emerge from new kinds of observations.

>> That many observations have changed enormously. There are some theories explaining earthquakes that we had to reconsider.

Anyway, let me close with just a summary. Of this. The first point is that to be able to address those open questions on earthquakes we really need to go into the finer details of what happened on the fault during the earthquakes. To do that we need to get information from the high-frequency, high-pitch seismic waves. That comes with a lot of time. That kept us busy for five -- the past a five, ten years.

We now have the tools and are moving forward with that. We are looking at the earthquake with unprecedented detail. From these observations we are seeing unexpected behaviors that are modifying our understanding of earthquake activity.

Thank you very much.

(Applause)

>> The Indian Ocean seismic activity, when you put those two together, the Japan and US view and look at that, how did that look?

JEAN-PAUL AMPUERO: Overall there are similarities. When you look in detail there are differences. Some of the differences are new due to well the uncertainties in our measurements. But also part of those differences are expected.

You are looking at one object, two different sides. So you are seeing two different aspects of the Earth.

>> The graphs are showing the scale and degrees that first was shown the fault is slipping along maybe 600 kilometers; is that correct?

JEAN-PAUL AMPUERO: Yes.

>> The San Andreas fault that you had previously, that is slipping over a lot more, a thousand or 2,000. Did it slip as much?

JEAN-PAUL AMPUERO: The simulation I showed before had a rupture of about 200 or 300. San Andreas fault is very long, like a thousand kilometers long. Not all of the San Andreas fault has -- at least in the historical earthquake break. That we know of. This particular earthquake on the slide her, if I add up all of the separate lengths it makes up 500 kilometers.

This is long.

>> Besides the Richter scale, what other scales are there and on what are they based?

JEAN-PAUL AMPUERO: This is a a source of confusion for me and everyone. There is the density scale and there is the magnitude scale. The intensity scale measures the level of damage caused by the earthquake or the potential damage. Whereas the magnitude measures the size of the earthquake itself.

Now if there is a magnitude six earthquake, that is magnitude scale. I am 10 kilometers from that, I am going to feel intensity 7. But at 100 kilometers away, I would feel intensity of 3. Intensity is a measure of your feeling of the shaking, of the damage it causes. It depends also on the distance to the Earth. So, those are different.

>> Question on an earlier slide, the project that was moving did that define information locally as it moved or was it to look across the world -- in other words what they saw from the global sense a benefit that was not intended.

JEAN-PAUL AMPUERO: There are seismologists interested in the Earth, structure and the crust. Another part of the community are interested in how earthquakes happen. This type of experiment actually serves both sides of the community. I am exaggerating because there is a lot of overlap and people from both schools and interested in each others' work. This as it was moving was measuring the crust. At the same time it was recording -- both purposes.

>> Seems like you want to look at the Earth as a whole as opposed to local form this array gets. Someone in Eastern Canada there is some really stable rock so you would have less local variation. Wouldn't that be the ultimate destination -- the most recent ultimate destination for the array?

JEAN-PAUL AMPUERO: That depends on the purpose of the array. Obviously, if you are in a more simple part of the continent you would have less scattering, it would be easier to image aspects of the deeper -- that would be a good strategy to do this but here they were also trying to learn about a shallow -- the first say 100 kilometers of the Earth.

In the back?

>> Are there any thoughts about and effect on the frequency and duration of earthquakes? Ice caps warm the water. Correlation?

JEAN-PAUL AMPUERO: There is no correlation between the ice processes and the potential for large earthquakes.

The interaction that psychologists are having with climate change problem is that as ice caps melt they generate also their own quakes. The ice will fracture. That is also ice quakes that we can record; and we have seen more ice quakes than in the past decade. Seismology is also a way to add more evidence to the point of global warming.

>> Is the spectrum of waves from earthquakes a continuous or discontinuous spectrum between high and low frequency.

JEAN-PAUL AMPUERO: It is a continuum of frequencies. We see more from a single period of earthquakes. Those are not the same as this, the ones I was talking about here. Those do not necessarily occur around faults. Those are programs vibrations, resonance of laugh a formations, for example. Those would take place in very particular places.

>> A follow-up: Does this possibly have to do with the physical properties of rock? Phase transitions for different depths; fracture, generate the use of different frequencies?

JEAN-PAUL AMPUERO: Okay. The phase transitions as a mechanism to generate an earthquake will start to be effective at very -- very deep in the Earth. That is a very good explanation for earthquakes that happen at 300, 600 kilometers deep. We have been also very interested in those.

>> What does fracking have to do with --

JEAN-PAUL AMPUERO: Fracking is the process of putting water in small cracks to let oil and gas through, is generating fractures by definition. That is what they want to do. Each fracture is a tiny quake. Fracking rarely causes earthquakes that are damaging. I emphasize rarely. It could happen. We don't know yet.

Now, there is another process that is related to fracking but it is not fracking itself. All of that water that you are being driven in the frack is dirty water. You have to do something to it. It comes back to the surface, you need to store that dirty water somewhere. Where? Well, inject it back to the Earth, somewhere else.

The injection of wastewater involves huge quantities of water; and that can trigger earthquakes that can be damaging.

So, in the big picture, fracking is one of the culprits because indirectly it is feeding wastewater that has to go somewhere. That causes earthquakes.

>> What causes earthquakes that are not close to plate boundaries?

JEAN-PAUL AMPUERO: different things. Could mean for example a mantle plume that is raising and changing the conditions of that continent interior and generating additional stresses. The Virginia earthquake, for example, which is not a particularly active plate, it was -- a led to the buildup of the Appalachians. You had the different subcontinents that then created the big continent.

There are developments of this extremely old process. Remnants of faults out there that are still accumulating very slightly, very, very slow slowly. They will even slowly. They are moving very slowly.

>> Missouri had a tremendous one.

JEAN-PAUL AMPUERO: I am not familiar with the particulars there. Yes.

>> Is there any reason why California has these earthquakes every hundred years and other

places that have that kind of predictability of whether there would be an earthquake?

JEAN-PAUL AMPUERO: Well they are not as predictable as you may think. This hundred-years ballpark is really a guess.

And we haven't had an earthquake in southern California in more than 170 years.

Earthquakes because this energy keeps -- the plates keep pushing. If they are pushing at the same rate, the process will repeat an average amount. But that will depend on the fault and other properties. It is rare to see an earthquake that repeats perfectly. But, that happens for some very small earthquakes in California.

These very small earthquakes are, for example, sticky spots of the fault. Imagine you have a fault that is full of honey, sliding slowly. You have a sticky spot which will break. We have seen stuff like that. But more large earthquakes are not predictable.

>> The slide after this where you show the animation of the -- yeah. Where you are showing the wave from the Japanese quake and the Samoan Islands earthquake you see the Japanese one coming from the upper left. Then towards end it Peters out, when you get to the opposite end you can see from the graph at the bottom, the waves seem to be reversing?

JEAN-PAUL AMPUERO: Yes.

>> What would account for that?

JEAN-PAUL AMPUERO: These are R1 and R2 waves, surface waves. The one you see first -- this is the Earth, Japan is here, US is here, a wave that travels along the surface of the Earth. The one that you see later is a wave that traveled the other way around.

AUDIENCE: Ahhh.

JEAN-PAUL AMPUERO: If I let this go longer, you will see R3, R4, R5; then you cannot see it.

>> The slide you showed off the coast of Japan with the high and low frequency does that

mean that in those particular areas you only have high frequency and low frequency or is it a majority of low frequency in one place and high frequency in the other?

JEAN-PAUL AMPUERO: Well, this is a sketch. So, there is a progression and proportion of high to low frequency. What this means is that here high frequencies are dominant and here low frequencies are dominant.

>> Combination the two.

JEAN-PAUL AMPUERO: Combination. But the ratio --

>> If you extend that out in three nexts would it show the same thing or differ because of different consistency of rock.

JEAN-PAUL AMPUERO: In different dimensions the fault is localized. It is a surface, not a volume.

As you can see here on the top. This is a cross-section. This was the interface between the Oceanic crust and the Continental crust. The earthquake happens only here (indicating). If I open the Continental crust I will get the view on the bottom right. It is only that surface. It is not a full process.

LAUREN ADAMO: One more question.

>> Have there ever been incidents of earthquake moves under going linear position?

JEAN-PAUL AMPUERO: There are linear waves. If two waves reach the same point at the same time the amplitude will add up. If you come back to the example of the surface waves going around the Earth. As they propagate they become weaker but as they merge, there is an amplification.

>> Has that caused damage that was unexpected?

JEAN-PAUL AMPUERO: When those waves submerge, generates earthquakes on the other side of the Earth, my colleague did not find evidence for that.

LAUREN ADAMO: Well, thank you so much.

(Applause)

LECTURE #4:

3:00 - 4:00 p.m.

Dr. Don Monteverde

The Art of the Geological Map.

BILL SELDEN: Good afternoon again and welcome to our fourth presentation today. I am pleased to welcome Dr. Don Monteverde to talk about the art of geologic mapping. He is a Research Scientist at New Jersey Geological and Water Survey and Adjunct Professor, Departent of Earth and Planetary Sciences at Rutgers.

One of the things you look at a map say it is a map, use it, take it for granted. But there is a huge detective story that I goes into the making of these things. I am pleased that Dr. Monteverde is here this afternoon to take us through the process of discovery.

(Applause)

DON MONTEVERDE: Hopefully when I am done I will receive the same amount of applause whether for a good speech or "finally, he shut up."

(Laughter)

DON MONTEVERDE: When Lauren asked me to give the talk I said sure, fine. A week later I am like why did I do that? She asked me for a topic. I said what do I do? One of the main things I do is make geological maps for the State. I work for the State 29, 30 years, done many maps for different scales and sizes.

I came up with this topic that I truly think in constructing a geological map it is not only scientific but also takes you to the background images of maps I have been involved with, co-authored with people I worked with, some I have been in charge of. So as far as the geological map, it is pretty basic. It is telling you what the person who created the map found.

And different maps have different meanings. I have done geochemical maps, dots where you have taken soil samples measured for base metals. We looked for prospects for maps in West Africa. There are different types of maps. It depends on what you want. You can show everything. You can show the rocks or the surficial material.

If you run into geologists there is all always this battle back and forth about hard and soft rocks. I am a hard rocker, something you can hit with a hammer. My friends are what we call superficial geologists.

(Laughter).

DON MONTEVERDE: This tells you what we know about it. The first geological maps were economic maps. Mining. Where was the gold, silver. They tried to figure out where it was, was traced. I found a lot of quarries in the northwestern part of the state where Native Americans early inhabitants of this part of the world would quarry chirp to make points. They always seemed to find the chirp base seemed to foe which layers had the chirp.

I like to think of them as the first geologists in the region. It was an economic process. We also do sinkholes. I get lots of calls "My land is sinking." I look at the geological rocks I say, you don't have the right kind of rocks; that is not natural. Somebody did something. We can do this lots of ways. Landslide potential, everything.

When I look at a geological map because I am associated with the academics here I kind of like to look more academically. As was described to me it is a crime scene. Somebody beat these rocks up or some thing. How did they start from nice tranquil ocean deposits to be something that is solid, folded, faulted, everything on top of it, baked. I like to try to understand that kind of stuff. There are all types of geological maps. The first were resource maps. There are a lot of mineral ages maps. I will show the map that changed the world of the UK. The oldest map is Egyptian. You can see the age right here. It was found in the 1840s in a tomb and there have been several pieces put -- this is the whole thing put together. This shows half of it. I show the same half twice. Okay. Minus ten points. This is the source, the two men who worked this were able to figure out they had a sign here that said gold mountain, another over here gold mountain and two up here, gold mountain. Able to figure out where it was in Egypt.

The colors actually represent when you you stand someplace, the colors of the rock. They didn't say this is granite this is serpentine. This is pink, this is green. That rock has gold in it. I blew it up. Right here was gold, over here was gold then there was gold here and over here this is an alluvial deposits, river deposit, lots of possiblies.

This is the first geological map on papyrus. Here is the other half. I think these are two slides versus one. You can see the other half. A lot is missing. This was the first geological map. If we go to now -- we have so much knowledge we don't even have to be places. We can do geological maps remotely. So, this is a USGS product, 2014. This is the geological of Mars. Just by looking at land forms from satellite images and how they look there are some obviously impact craters some look volcanic. Some look like flowing water deposited it.

The good thing about these: There is nothing green, no foliage so everything's exposed. If we go back to our part before the map that changed the world, I was looking, we actually have older maps than England did. 1806 he was a Scottish geologist. These are mountains.

If you want to think of primitive think of Protozoic rocks as red.

Yellow is much more recent. Think of this as sediment.

Blue is middle Paleozoic and older.

Red is generally early Paleozoic.

If you look, there is early New Jersey right there. Then he redid the map the same author. He was the president of the Academy of Natural Science in Philadelphia. He reprinted it again.

The cartography is better. This is the time we just purchased the Louisiana Purchase. So this is not a country map. It is a regional map. But once again if you look, there is New Jersey this is a physiographic province map, elevations, but elevations are controlled by the types of rocks. A very simple geological map. I tried to color it the same as a New Jersey. They did a good job, combined some units. The angles I think they gave too much pink.

1815. I am impressed with how they were done.

This was the map that changed the world. William "Strata" Smith they called him.

He wasn't a big geologist I think he was the local pastor. This was done for economic reasons. He was digging canals in England. When you dig any hole, rock is exposed. So he was beginning to look at the rocks. He was seeing certain fossils were always in the same order in the same layers. So he was using those fossils to see where was the coal. It was in a certain interval bracketed by types of fossils.

Lots of people came to him saying I have this land do I have any coal on the land. He started biostratification using these fossils. It was productive. Somebody took this section of the map. What they did was updated it, put it on a three dimensional. Previously it was all flat. They tried to map mountains. Here you can see elevations. That is the book. If you enjoy this type of stuff -- I tend not to read geological maps for pleasure. But I did enjoy it. I like to separate pleasure from work even though whenever I go anyplace out with my wife, I am always looking at the rocks.

(Laughter)

DON MONTEVERDE: This really started everything.

The first map not only of all of England. I think the was mostly Scotland a and Wales. Covered a large area. He used fossils to create his map. Of course like so many other things he was not recognized at first. It was only later that people can to realize how important he was.

Now, the British Geological Survey has an award that goes out in his name. So there is a lot to what he has done. I think this was beautiful I think of it as art. This was done by Charles Darwin when he was on the Beagle, the boat he took when he landed on the UK and wrote "The Origin of the Species." Somewhere went across the Andes. This is the beach this links up with that are part this links with this. He has everything color-code, how the beds were dipping. Just the fact of going through the Andes at the time I think would have been difficult. The fact that he was able to construct the different units.

These were dipping south and over here you have vertical units and then things beginning to dip north, stuff like that. He actually put out a geological map of the southern tip of South America. In my mind not only does it display the science of the time period but I would have no problems hanging it in the house. My wife probably would make me put it in the bathroom but I still would hang it in the house.

(Laughter)

DON MONTEVERDE: If we go to just our state. Yes, it is very small but we have a lot of evidence of different major time events from all over the East Coast. We seem to have a piece of almost everything. This is 1835, one of the first maps. I should note one of the maps is going to show the Rutgers -- if you are looking for old historical maps Rutgers has a fantastic library you can download -- I downloaded this as an image. So, some of these are from Rutgers, the historical maps. You can see we are -- these are the Watchung Mountains. I am going to bring it up close again.

If you think about the Highlands they are whatever color you want to call this (indicating). These are the carbonate valleys, the slates, that is Kitatinny Mountain and this what we are standing on is Mesozoic Basin. Red rocks, you find. If you are thinking Sourland Mountains, the Palisades so you can get your bearings. I want to go through ages of map, you can see how things changed with knowledge.

This was 1868 done by the geological survey. George Cook was one of our first state geologists. Cook College is named after him. He was pretty big on the Rutgers campus also. The colors are getting a little better, they are starting for connect thing. Then we move up to the 1880s. Somebody was colorblind when they put these things together. But you can begin to see the Watchung Mountains are well placed ow. This is Sourland Mountains. These are the Highlands. Hard to pick. The carbonates are in blue. The slates up here, there is Kitatinny mountain. This is a small-scale map so it is not showing everything. The features are pretty much established. Then we have the new state map. This is a one to 250 map. It says 2011. Somebody was giving a talk and showed it. This came out actually this week. It is a big-scale map on really good paper. This looks like somebody spilled a bowl of chili.

We have terms lumpers and splitters. This is a splitter's map. I was involved with this and this. Splitters go out, see a little difference and say I am going to call it a different rock. I am going to separate this one. They have a lot of thin sections with smaller rocks versus people who says who care if it's green it is still a slate. They will lump things together. A lot of the previous maps those were lumpers. If you look here, these are the carbonates. It is all one color.

If you look here, the same carbonates are about five, six different colors. So we are starting to define a lot more of the intimate changes of these rocks. We are identifying once you realize that this is not just one continuous unit it is actually a unit that has been broken and repeated so you put a fault in between we are starting to understand how these things became in their present position.

All of these backgrounds as I said, multi geological map. What is in a geological map? It is a freebie from njgeological.org. This is what we call an information circ, what Scott Stanford put together an geological mapping. Geological maps if you are in the rocks you are dealing with this surficial sediments river and glacial deposits which you can map as that then the rock underneath which might have a fault, might be folded. So you want to show that on the same map.

So you run around in the field, collecting this data and put these two things together.

If you are in the southern part of the state, the coastal plains, south of the fall line. The fall line is a point where north of it there is waterfall. Maybe small things, little recommendings not 20 feet tall. Small ones the rock is lithified, it is a rock. South of it is all sand and gravel. It shows the cycles of sea levels coming in and out. It was never lithified into ledges. There the rocks are gentle, dip towards the coast basically.

Then you have the same river deposits then you can put these back geological maps should show the stacking event of different time periods of rocks, different events. So this is a typical what I would consider a typical geological map. Now, if you look, I am the first author, therefore it is 100% correct.

(Laughter)

DON MONTEVERDE: I am glad you guys understand sarcasm. When I think about a geological map these are the parts of the map. Of course this is the map itself. You are not supposed to be able to right. I will be pulling pieces up towards you to see this. One of the first things we do is describe what are these colored rocks. What are they. You can see silt to clayey silt. We are described it in infinite amount. If you ever can't sleep: Read one of these.

(Laughter)

DON MONTEVERDE: These are some I have written myself. Unless you are really, you know, involved in the study of this and there are slight variations that answer questions that you are trying to answer . . . but wife to do this to let you know what you are looking at. So, that is the description of units showing you the colors that appear on the map.

The next part is this thing taking those same little squares, colors which you hopefully are still awake after having ride and it is giving you the age of the different units how they react. These are right on top of each other. They you have an igneous body that sticks its way into it. This is a dye base, intrusive igneous rock that forced its way between the different layers. So it is actually younger than all these but older than all those. It is giving you the idea of the ages, what happened during different times.

If you look at these different types of maps you will actually see that we are missing more time than we show. We don't have everything. It's kind of like buying a book within chapters 14 through 17 are missing and you are still enjoying it. That is basically what a geological map is. That is the nature of the beast: We don't have those chapters but we have to make the map.

Then we have -- this is going to the map itself, these are the symbologies on the map. We have stuff like this. There is an old copper mine. Usually if it is abandoned it has a line through it.

These are the bedding symbols. It tells the layers which started out horizontal now are inclined and the tick mark points to the direction they are inclined. It tells how the beds are laying. Is there a fold in there. We can use that to define it. If we have folds we can outline them versus what is an anticline versus a Syncline showing how it was compressed. This tells a lot about the symbology on the map.

Then we have a cross-section. This is pretty simple. Most of it is based on we have geological at the surface and because of other people during work a lot of academics these fossils have actually been intensely studied at Rutgers. How thick the layers are. If we have data here, we can kind of project it south. The map is icing on the cake. You want to know is it yellow or brown cake and does it have that gooey lemon stuff. Every birthday I went to as a kid had that stuff. I hate it.

(Laughter)

DON MONTEVERDE: This is like we are going to slice the cake as best we can and this is what we think it is. Then we also have this kind of stuff. This is a hill-shaped map. Planes fly all over the place sometimes the elevation is only 1 foot. You can put this into a hill shaped map and this is vertically exaggerated.

In order to see the hills better instead of making the exaggeration 100%, make it 300%. Things stand out more. You see later that some of the ridges, layers that you barely see come out as graphic features so you know I can trace these pretty well even though they are not exposed. I will see that in a stream cut. But there are topographic features telling me they are there.

I don't know why I show this one. This is basically a a compass reading. These are orientations. We take compass readings on everything. We take it how the bed's laying. This is northeast but dipping to the northwest. All the others are fracture trends. Fractures are important because that is where the water is. Doing this, being able to understand how the rock was compressed, what were the forces I am also collecting data that ground Staudt Is do to figure out where the water is going.

Yeah, I am kind of old. This is showing you -- I am trying to show you the equipment that I grew up with using in the field of course you have to bring your map. I do a lot of work in carbonate. I bring an acid eye dropper bottle, dilute acid in it, you can get it on your hands, it does not do anything. I burned holes in my vest pockets.

If you put it on carbon dolomite it fizzes. The fizz tells me what rock I see in the field. Of course field book, clipboard, write everything down. This is a standard geologic compass. I used a French compass. I worked in French West Africa; their compass is different. Every one of mine have the mirrors broken. I don't understand.

(Laughter)

>> Consider this a hand lens. Some people call it a loop. I call it a hand lens. Some of the grains are so small you have to get in particular igneous, metamorphic rocks you have to identify the minerals, have to give it a name. This is my favorite tool the hammer. This other stuff. You are going to see that as time is advancing they are starting to basically you know -- Smartphones and tablets you don't need this other stuff. Even pencils.

I am waiting for a Smartphone that has a hammer app. I tried to get a picture of it but all I got was people hitting their phones with a hammer. If you can get a hammer app with your smart phone or tablet, I am changing.

Today's kids in a few words are mostly going to electronics which is good because most of the work in creating the maps is digital now. It is no longer in pens. It is all on the computers. The main thing when you go to a site you want to describe everything.

Because, one, you don't know if what you are describing -- it may not do anything for your map but may answer a a question somebody else has. Maybe I haveveins as fractured, colored wrong, colored differently, shows water is going through there. I have a buddy in my office doing a a groundwater study he needs that data. You want to collect everything and you want to do that because you may never get there again. Working for the State 30 years, I always can get back to one of my spots. My Master's was up in Alaska, helicopter-supported. No way I was ever going back there.

You have to write down everything. Don't just write down the data. Your description for the rocks is A/A which is basically saying As Above, I don't feel like writing it the 14th time. You really should write down everything you can. Everything. Pictures are really important too. Either in the field notes drawing them or cameras but there are also things you don't want to see. These are the ones I have encountered.

(Laughter)

I was in Africa run off a field site by a troop of baboons. I ran into a spitting cobra. This one you are wondering what is a fighter plane doing -- I was mapping on the border of Wyoming and Colorado and we are coming up -- there is a ridge crest with a valley. I peaked it. I do this plane. I didn't know the valley was being used by a fighter pilot division for training. This plane just went right through and it was below me. You are on a hill and you see this fighter plane shoot through there. Don't chase a ground hog until it is cornered. I was chasing it. Don't ask me why.

(Laughter)

DON MONTEVERDE: You are out in the woods, bored, hey, there is a ground hog. It runs aorund the barn, I am running, didn't know there is a fence. All a sudden he is coming at me. I did the Looney Tunes speed up in the air, trying to back out. The turkey was the same thing. I didn't chase it. I had done my traverse, had all of the data, walking back to my car. It's springtime so the foliage a half up.

I am thinking geological, I got this one. I step over a branch and this big black thing goes up over me flailing. Backwards about ten feet. I didn't have to change my shorts though. I have run into bears different places. So far I didn't have any problems. I see them, can't avoid them. That hasn't been a problem.

But this is where we started to get to the artwork. Max Needle, I asked for his, he is more artistic than I am. You can begin to see how people can draw pictures to depicket. He is looking at igneous rocks. There are a few dikes in here. I forgot to bring a camera.

Now I have a Smartphone so I do have a camera. I have been to so many places I have no pictures. I don't have the artwork. It was a trail I was on. I was looking at different sedimentary rocks with channels. It allows you to understand -- a picture's worth a thousand words.

So, by showing this I can show you there is a channel here that a seems to repeat down here. Kind of giving me an idea of what I am looking at. Then we have this. This is the computer part of it. One of the guys I work with. This is a digital -- a colored hill-shaped map. He took the libor data then created his color scale because he wants to see his own things.

This is the Delaware River. I live here. This is Mesozoic and this is much older. He is a surficial geologist. He is looking at the terraces in the Delaware River to try to understand how that evolved from glacial time. Each time it does something, it cuts down, creates a new terrace. So he did a blow-up of this area, goes down. You can make out all of the terraces' elevations which are different time are periods. By this methodology you can do a lot of great science.

And you don't have to leave the office.

(Laughter)

DON MONTEVERDE: But after you collect all of the data you have to make a geological map. You have data here, data there. You spent this. I have my data in one spot. I ask my friends who went with me what do you have. In the field we share data. Whatever compass reading I read it to my buddy, he reads me his. It is kind of like a puzzle. I always loved puzzles as a kid. You are basically taking all of your data, bringing it to one spot. Can't put anybody in there have them take data.

You have to understand what's going on in this area. What's the general idea. If you saw, we have old maps. They know where things are but we are trying to break things down. You have to fill in the holes. By holes I mean somebody was selling this beautiful map as a puzzle.

So, when you are making a geological map this is what you have. I I like to think about it as a 500-piece puzzle where they only give you 350-piece puzzles. We know if we had one like that no one would keep it we would throw it out. This is what geology is. You have to fill in the holes and make an educated guess as to what is going on.

We are filling in and making a guess. I did this without looking underneath. All of these lines are good. I blew this one because it goes way over here. Because we don't have all of the pieces now we know certain units or thicknesses. We can guesstimate. We have an idea because the areas were not previously mapped it is kind of like you have a general picture on the front of the puzzle but you don't have the exact everything so you have to create it yourself.

So, when you look at this -- this is the northern part of the state, Newfoundland Quad. Everyone of these dots is where we have data. Somebody -- Rich -- all of these are Highlands rocks, 1.2 billion years old, have been met amorphosed. I put a circle a each of these. 500-foot radius. Probably will continue 500 feet. So, there is our puzzle. You can see how much we don't know.

These things we kind of know how thick they are. These we don't. This is where the missing pieces come in where we have to try to figure out if I have a whole bunch of these, going across it is probably the same unit going across. This is one the geological knowledge end but also the artistic end. If you go back and forth a few times you can see how we have been able to do this. This is what all geological maps are. Mars you have a picture of everything. When they train us for geological mapping they usually take you out West someplace where rocks are exposed you you can see them. Then you come back to New Jersey.

When you guys drive home, think about how many exposures of rocks you see. It is not that many. So in an area like this, where it is highly, densely populated we have a lot of foliage it is much, much harder. But these rocks stick out a lot better.

This is another map of mine. This is Sourland Mountains. Princeton. Hopewell. Route 31, going up to Flemington. I have a lot less dots. Mesozoic Basin. The rocks we are sitting on now. They weather quickly, so they don't stay. If you look you can picture okay wherever you see data like that -- I was walking a a stream. A stream has a lot of data in it. I know because of the bedding that these things are all aligned like that. I can turn them to understand and stretch them a bit. But once again I have to use my geological knowledge of what could be here.

Then I can use this too, that I showed you before. I am looking at these gray beds. Most of this is the red shells and silt stones. Shallow lakes. Green lines are gray beds, deep lakes, marker beds. But if you have a core you can look at them for a long time. They are great. When you walk in the woods I can't tell this one's gray so is that one, that one, that one. Try to go to other people to figure out -- this is the purple . . . these are just a few quotes.

(Laughter)

[See Screen]

>> DON MONTEVERDE: If I gave this identical data to myself and four buddies guaranteed we would not have the same maps. There are too many openings. The fifth may we map we would get together and say yeah, I agree with that. I work with Avery Drake. The day your map is published it is out of date. I agree. All you have is one guy putting in a pool of the data. You go there, he has a fault you don't know anything about it. Your map's out of date.

What is the caveat? Well, I did it with the best available data. Meaning you only have so much data. So, you have to make a map. You use it. Can't wait. Well there will be a pipeline coming through in three years. I am not going to put it out for three years. This data needs to come out.

Here, we are starting -- I skipped a slide. Here we get into the artwork of the geological map. I will show you pictures of people who used geological for purely artistic methods. This woman Esty did every state as a silver -- medallion. I have no idea how she did it. You can see the Highlands, Newark Basin. Geological map of Colorado. Mickey Moused up. Actually it is a beautiful map.

(Laughter)

DON MONTEVERDE: People think the maps are beautiful enough to turn into something that they will wear. This is a tattoo. It actually goes along the front too. This is a local graduate. Doctoral graduate student. You know how the youngsters are really into tattoos. She did this for a mapping project. To me that is a beautiful cross- section from her mapping. She decided it was so beautiful she had to get it tattooed. A new geophysicist working in my office, I showed her the slide. As soon as I showed her this she said that is Helen; I went to school with her. That is how I found out she was a local Ph.D. student.

Carl Zimmer who was a famous science writer, had a site where people showed you their science tattoos. This one really hit me. This was some guy who had a blog for geology. This is his groomsmen wedding cake.

(Laughter)

DON MONTEVERDE: He even threw a fault in there. Pretty good. This is cake. This brought me to something else -- I love these things. Structural Neopolitans -- won't believe me. What are these? Clay models of faults.

So Martha and Roy are structural geologists who do clay models where the material they are using is a different scale but correlates to the model Earth layers so they can do different things with this clay, pulling them apart, creating faults, squishing things together to give us an idea of what could happen in nature.

I love going to see where they are making these things. I looked at the surface on some of these and they actually helped me understand how I should be mapping my rocks. These are actually -- these are clay, have to lay each layer individually, these if they want to make them -- these are hard now. Takes three months for them to be dry enough to cut them but you see how the little faults occur as you pull these two things apart.

Just to let you know -- and I knew I was doing this talk two months ago. I don't procrastinate. I took these pictures 1:00 this afternoon. I still had a good hour. I don't waste time.

(Laughter)

DON MONTEVERDE: Once again, these layers are all cut. Then you have this basin -- the structural basin is completely filled with material really thick that you barely have up here. It is really telling us a lot of what could be going on there. These are types of ideas we should think about when making these geological maps. I pulled three out quickly because I had to get done by 1:00.

(Laughter)

DON MONTEVERDE: You can see these types of things. This is another one. I saw this as a greeting card. This is done by Harold Fisk 1944 for the Department of Army. Army Corps of Engineers. These are meanders in the Mississippi River.

AUDIENCE: Wow.

DON MONTEVERDE: The colors are for every time period. You can download this it is a free PDF. He is going far they are and far they are down river mapping, about 20 of these. The science is phenomenal but it is also a beautiful work of art. Truly is. It also tells you anybody who picks a river as a state boundary needs to think again.

(Laughter)

DON MONTEVERDE: In some places there are parts of Mississippi that are on this side and parts of Louisiana. All of these meander. You keep cutting off, it meanders, a lake that sediments up.

I found this one. I loved it. This is artwork called Scarp. It is no longer there. You can see the cross- sections. This is the website. The guy is talking about clothing. He went to Goodwill where they gave him the clothes. He makes this beautiful color cross-section. I said whoa when I saw this picture. I wish I had seen it when it was still present.

The dimensions of this, it doesn't make sense the way it is. You can see things are knitted in. If you look at the map of Wyoming, the artist took strips of the map and wove them in. If you go back and forth you can see the map in his design.

I love these two. The person who did this realizes what beauty there is in geological maps.

But just think yeah these are really nice Oars there is science there if you figure out original base map there is really neat science there.

This guy is an Emeritus professor. He is an artist too. He is taking the knowledge of all of these maps of different types of rocks, different times. Do they form in rivers. What do they form in.

And he created this image. As you are going to see -- you can just see the United States image right there. Canada, US. This picture, we are in a mountain range. If you know your geological this is a subduction phone.

This is a plate boundary, this is island arcs. This is millions of years. I think it starts at 550. You can see how the Continental crust plate tectonics how these things have moved. It is going to run itself. There is 550 million years old. Here is an island arc coming towards -- we are right there, shallow would you right now. You can see, through time, how this is evolving.

This is wonderful. This is the first time or the second time the Appalachian Mountains rose. This is the Taconic Orogeny. Although and behold we have another island arc system coming. Drawing these pictures it gives everybody -- you are in the way-back machine now. We are playing God, looking down, can see things happening.

So, there is probably the Arcadian. There is Africa coming in. African. Now Pangea. Here are the huge Appalachians. I would argue a little on his years but it is just too good to argue.

So you can see the Appalachians. Now we are starting to get some tension, stuff like that.

That is the Equator. Starting to get the East African rip lakes. The sediments that you are standing on formed in these lakes.

So, we are starting to pull them apart, we are stretching them. This will have a bunch of folds like the faults, Neopolitans we are trying to do. The North Atlantic. The South Atlantic takes longer. It gives you a good idea of howeverrer everything evolved. Remember geological is deep time. I studied 20 million year old rocks. Those are young.

Okay?

So there is the Crutaceous interseaway. This.

The boulder that hit, best estimate, what killed the dinosaurs. Not much happening, at a passive margin.

It keeps -- right now the New Jersey coast line is just the seas go in, the seas go out and so on.

I think the next one -- next one after this is the glacial period. The latest Wisconsin glaciated. That is how they think man came across North America. I love these things. I decided okay, if geology is art, well, how can I really show that? So I took this and decided I am going to make a geological map of this and decided I am going to make the colors and the ages. I first had the faults going the wrong way ;it didn't make sense. Once again I didn't wait until the last minute, did this 1:00 at night. I did this cross-section. I forgot to flip the teeth. Well ,so what ,you screw up. I started looking at it, turned and I was ready to scream what the hell's going on. They I realized oh, yeah, it's The Scream.

(Laughter)

DON MONTEVERDE: I was making a geological map out of that. To show yeah, art can be geological when we do it these are the things we need: To be able to bring the knowledge. We don't have all of the pieces. It is both artistic and scientific. When you go to the art museum be see something like that, maybe we should see something like this, okay.

(Laughter)

DON MONTEVERDE: Then I would be there signing pictures. Thank you. Or something like this. When you think about a geological map it is a huge amount of scientific knowledge it is also an artistic event.

Oh, yeah, any geological map, look for the mistakes, they are always there. Because is it this interpretation or that interpretation? Oh, look, there is a new hole there saying it is a third interpretation. I have a map, I cut the wrong data, Jesus, I blew it. I am wrong. Thank you and good night.

(Applause)

Any questions?

>> Actually I have two questions. One: In your talk you were showing the red dots where you --

DON MONTEVERDE: -- had data.

>> Looked like no dots were on Sourland Mountain. Why is that?

DON MONTEVERDE: Because you don't care about Sourland Mountain.

(Laughter)

DON MONTEVERDE: I was doing the sedimentary rocks. There are a lot of boulders there. I need connected stuff. We didn't show what we call float deposits. Sour land the loose rocks are the same are material, dye material. Same as the Palisades. That is how I mapped that contact, sedimentary, metamorphic rocks, boulders. All of the boulders were the same.

>> The other question I had is what about the strength of acceleration due to gravity? Isn't that useful data?

DON MONTEVERDE: You mean how much will I get hurt if I fall asleep in the field standing up?

(Laughter)

DON MONTEVERDE: I am sorry. The strength of --

>> Of gravity. Doesn't that vary from point to point, depending on what is underneath?

DON MONTEVERDE: Yeah. That is looking more at deep stuff and big, wide things. I can walk a stream here, find seven different layers. I don't think you would be able to pull that apart with gravity. Gravity's good to tell we have dense bodies below and a dense body would have to be a type of rock. Sedimentary rocks won't be that dense. It has to be dye based.

>> I thought you were you interested in what's underneath, slicing the cake.

DON MONTEVERDE: True. But, when I was doing it -- with the best available data!

(Laughter)

DON MONTEVERDE: I don't think we had really good gravity maps of that. We have a statewide gravity thing. So, anyone of these -- most of my maps were seven and a half topographic standard base maps. A lot of times gravity unless you do a detailed gravity study when you go out with a gravimeter everything's so widely spaced it doesn't really help you.

Another thing, real quick I want to mention when you get digital maps, there was digital data put in which was scaled at 1 to 100,000. If you bring it down to your driveway, the error bar is so huge it is not any good. You have to watch out how good is the data that you are using. The 1 to 100,000 is that scale. When you bring it down to 1 to 24,000 instead of the lines staying the same thickness it should be much thicker to let you know there is error there. Any other questions?

>> Will your next project be the map of Mars?

(Laughter)

DON MONTEVERDE: Ralph Cramden sent Alice to the moon. Men are -- wait, who is from Venus and who is from Mars?

>> Women are from Venus, men from Mars.

>> Is the new map of New Jersey available to the general public?

DON MONTEVERDE: Can you give me your credit card and special number right now?

(Laughter)

DON MONTEVERDE: We have a bunch of them, yes, they are on sale. Almost all of the maps I showed, you can download free from our website. That one because it has thick, high quality paper --

>> Which is, the website?

DON MONTEVERDE: Njgeology.org.

>> Are you able to utilize data from there?

DON MONTEVERDE: They have fantastic tools that you can put down a home. It is basically geographically referencing, taking pictures of the side of the hole which you can pull up, geographically reference, get data from it. That is fantastic. One of my maps we have that data where we collected the data in the hole projected up to the surface so you can make lines. I did that.

There are some drillers who are fantastic; some guys are not that good. When you talk about somebody drilling a hole, lots of people cannot tell the difference between Highlands rocks and carbonates. Tough call. You can make it out. A lot of times I used drillers. I like to use them if something is red and the connection is green. That is great. In the wells there are so many -- down south in the coastal plain we can run gammalogs. If it is sand, goes to the right, clay to the left or the opposite if I have screwed up. It is fantastic for mapping the sand beds. For aquifers as well. I am doing that also.

We also have seismic where we have a frequency wave. I am involved -- anybody lose any sand during the Hurricane Sandy? Beach got wiped out, stuff like that? One of my jobs is to go out off Shofar and find ridges of good, thick sand the Army Corps of Engineers can blow back on the beach so the next storm can take it back.

(Laughter)

>> More job security.

(Laughter)

DON MONTEVERDE: We can do these tools that can -- actually can send -- like the gentleman before me was a really good speaker. I really enjoyed his talk. We are making our own seismic source, earthquake in the water which is sending a pulse through the water, penetrating down into the sediments below. Remember he said high and low frequency if you have a low frequency pulse you can't penetrate very far. We might see 50 feet down. They have stuff with a lower frequency that you can see a second down which is like 800 meters, 900-meters you can see inside. Whatever toys we can use if we can have them, yeah, we would use them.

If we had fine detailed gravity, yaws, (?) there is no reason not to use it. Anybody else? Thank you. Yes.

(Laughter)

>> How do you decide which color to use for any given rock unit?

DON MONTEVERDE: There are USGS, United States Geological Survey standards. Unfortunately our photography people -- I might be working with this map dealing with cartographer, my buddy working with this map. His colors might be wrong, mine are right; he didn't pay attention -- no.

(Laughter)

DON MONTEVERDE: I was talking to our photographer. I said we have to standardize colors so no matter the map the unit will always be this color. With the USGS, certain colors are for certain time periods. If you have a bunch of units, you run out of greens fast. I try to stick with the national standards. If I see a contact between a carbonate and another thing, the line is solid. If I see a carbonate and a metamorphic rock there I will put a dot line. It might be there or over there.

The type of lines lets you know how sure I felt about where that line is.

>> Last year I tried to go to Big Brook Park. Are there any maps that show the geology? When I started looking at the hillsides, you see the exposed rock it is very difficult for me to . . .

DON MONTEVERDE: That is in the south, the coastal plain. I only work in subsurface; I only work in quads. I am not sure what that quads -- we are mapping every quad in the state, federally funded. Trenton, Princeton and north are almost completely done.

We are almost done with the maps, sending them out for review, making sure people say we make sense. In the southern part, close to the fall line, southern plane we don't have a lot done yet. Big Brook, famous fossil collecting site, I am sure there are maps about that. Everybody knows about that and the fossils would tell us so much about the different units. That is like a golden spike for the regional geology in that area. I unfortunately can't tell you yes, go here, go there.

Anybody else?

>> If you go to Geoweb, you can do a geologic map.

DON MONTEVERDE: Everybody hear that?

DON MONTEVERDE: Thank you for reminding me. Is that the DEP site?

>> Yeah. Geoweb. It has all of this data on it. It is one to 100,000. You can do a search, pull up geology, photos, detection sites. All of this data. To answer your question about Big Brook ,we have not 1-100,000 but 1-24,000? I don't know.

DON MONTEVERDE: Geoweb, go to different places there. Click on it and different layers appear. Thank you.

(Applause)

LAUREN ADAMO: Thanks, everyone. See you again next year.

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