SPEAKERS
Brendan Meade, Jennifer Berglund

Jennifer Berglund 00:04
Welcome to HMSC Connects! where we go behind the scenes of for Harvard museums to explore the connections between us, our big, beautiful world, and even what lies beyond. My name is Jennifer Berglund, part of the exhibits team here at the Harvard Museums of Science and Culture, and I'll be your host. Today I'm speaking with Brendan Meade, a Professor of Earth and Planetary Sciences at Harvard. Brendan's studies earthquakes—why they happen and where they happen. And he uses that data to predict how they might occur in the future. I wanted to ask him about how he answers big questions about Earth's movements, and how he gleans inspiration from what happens deep below our feet in Earth's crust. Brendan Meade, welcome to the show.

Brendan Meade 01:14
Thanks so much for having me. It's a pleasure to be here.

Jennifer Berglund 01:23
What is it that you do as a scientist?

Brendan Meade 01:27
When most people think about studying earthquakes, the focus is, of course, on what happens after the earthquake has occurred. It's how much shaking occurred? How did that knock buildings down? Did that earthquake create a tsunami, or did it not? And those are great questions, and they're studied extensively. But they represent only a small fraction of what happens during the earthquake cycle. That is the process of the buildup of energy and the release of energy during a earthquake or series of earthquakes. And so, I always like to say a lot of earthquake science is really about pathology. It's about what happens after the catastrophic event has already occurred, and when we talk about forecasting earthquakes and earthquake prediction, what we better want to focus on is something more akin to epidemiology. We want to understand the causes of earthquakes. We want us to understand how earthquakes spread along a given fault or move from one fault to the next. And it's not a hard distinction, it's a soft distinction. But it's a shift in mindset from responding to events, to planning for events.

Jennifer Berglund 02:35
Can you talk a little bit about how this data is collected? And how you process it to paint a picture of what's happening underground?

Brendan Meade 02:46
I mostly looking at the type of data that we're all very familiar with, and that's position data. And what I mean by that is, how do we figure out where we are on the Earth's surface? And a lot of people have a lot of experience with this because if we ask our phones to give us guidance from one place to the next, they do so, and they do that using GPS. However, the GPS we use for science is very high precision. It takes something that's bigger than a phone to measure it. It takes something that's about a foot and a half across. But with that we can measure to sub-millimeter precision.

Jennifer Berglund 03:20
Brendan Meade 03:21
And that's awesome for us, because it's actually precise enough that we can measure how the Earth moves in between earthquakes. And one of the things we can see happening in between earthquakes is we can actually directly detect how much the Earth's crust--that is the cold rocky upper layer of the earth that we live on--how much the Earth's crust is being squeezed and deformed, and actually storing up energy that's going to be released in the next earthquake. And so what I do is I study large amounts of GPS data to try and estimate how much strain energy is being built up in the Earth's crust, and then take that information and use it to figure out what Where and how big future earthquakes might be.

Jennifer Berglund 04:03
What does that actually look like? I mean, what happens in between earthquakes?

Brendan Meade 04:09
One of the ways I like to think about earthquakes is not as these primary agents, which magically shake the earth on occasion, but rather as byproducts, almost accidents. And so what are the accidents of? And the answer to that is one of the greatest theories that we have in all of science, and that's the theory of plate tectonics. Plate tectonics provides us with an explanation for why there are mountains where they are, why the continents have the shapes they have. And the core idea is that our major continents have slid around on the surface of the earth and separated and collided with each other, and as they do that, it takes no imagination at all to understand that that is not a gentle process. When two large pieces of rock are being pushed into each other, they do not want to move past each other. So when they don't want to move past each other, what happens? They get stuck together for a little while. And so, after they've been stuck for a little while, well, eventually the strain energy kind of builds up in the crust, and that energy exerts a greater and greater force, and then finally, there's a break, there's a snap. And that's what generates the earthquakes in the first place. So what I try to do is in between earthquakes, plate tectonics keeps going, the plates are still moving. And that's something we can measure. And that provides us with a great sense of how frequently we might expect certain earthquakes in certain regions, and it provides us with a great sense of the type of earthquake that's going to happen in certain regions, and a long list of other things that we can deduce by measuring what happens in between earthquakes.

Jennifer Berglund 05:47
In my mind, I'm kind of trying to picture what this data would look like, sort of mapped out on a picture. Right? So do you do anything like that? I'm just imagining if you're sort of charting the movements of something that's happening underground, using all the numbers that are kind of flying in like sort of the matrix, right? That's how I'm picturing your world.

Brendan Meade 06:08
Right? I don't have the skill to read the matrix stuff. I just

Jennifer Berglund 06:13
You don't?

Brendan Meade 06:14
No. I mean, it's cool. But the green text falling down my screen is something I haven't deciphered yet. So one of the first things we do when we download new data, or when new data comes in, is we plot it on a map. And for us, one of the primary ways we do that is by taking a map of the globe, and then for every place, we have a station that's measuring GPS, and there are approximately 20,000 of these globally. One of the things that we do there is we will plot something like how much has the station
moved over the past year, or over the past two years? And we represent that with an arrow and so we end up making maps of the Earth that have arrows all over them, and those arrows show us how this data is telling us how the Earth actually moves. So these arrows are the key to us diving in there and starting to get a visual sense of what's going on. Almost all of our analysis actually starts with looking at the data. We end up analyzing it deep in these computational models that link what happens at the surface to what happens at depth, but we spend so much time just looking at these maps that we generate and saying, what is that over there? That is strange! And I, I can point you to things that we have plotted and other people have more than 10 years ago now, and we still don't know what it is. It seems like a behavior we just don't understand yet.

Jennifer Berglund 07:43
Like what? What's an example of that?

Brendan Meade 07:46
We're all familiar with earthquakes. Earthquakes are these sudden movements in the Earth's crust that cause shaking and a lot of damage. But what if earthquakes weren't so sudden? What if earthquakes were slow so they didn't cause any damage? So, what if an earthquake that normally takes a minute instead took a week. If that happened, you wouldn't even notice it. In fact, this type of earthquake was discovered in the late 1990s. They're now called slow or silent earthquakes. And I like to say they're the only good news that's ever happened in earthquake science. There's a type of earthquake that doesn't cause a lot of damage. So they're just, they're fantastic. And they release strain energy just like regular earthquakes. Now, one of the things we don't know about them is how long all of them last. And so, in certain places, say in the pacific northwest of the United States, we have lots of observations of these. They happen fairly regularly once every 13 or 14 months. But there are other places where there are hints that these sorts of slow earthquakes or slow slip events may last for months, years and possibly decades. And these are very hard things to explain because we don't have great theory for how these ought to work. And we certainly don't have a lot of observation because we've only been making these GPS observations for a short period of time, maybe 25 years now. And so, there are these classes of things that we can observe, where we look at it and say, I don't know, maybe it's an earthquake that's been going on for 30 years? And we just don't know at this point, how to think about those things. So that's one of the canonical examples of when we make these maps, we see things and we look at them, and even a bunch of professional scientists look at the data and are like, good question. Yeah, we've got to keep working on that one.

Jennifer Berglund 09:49
How and when did you become interested in the field?

Brendan Meade 09:54
For me, it was definitely not a case of I knew I wanted to study earthquakes from day one. When I was a kid, I was definitely really interested in the outdoors. My parents made it very easy for me to be outdoors a lot. In fact, they insisted upon it with great frequency. And I think from that I developed kind of a love of nature. There was something so palpable about being able to be outdoors and think about nature. Now, I say that because I liked it, but at that time, I had no idea I wanted to do science in any way. That was not a thing that was really on my radar. And so at the same time that I was getting interested in nature, I was going to school like everyone else, and I started getting really interested reading, and turned out that there were these things called video games that were incredibly cool, and they were all on computers. And so my interest kind of eventually grew as kind of an amalgamation of these things. I didn't realize this really until sometime in college. I realized you can start to put these things together. Once I started to understand that you could do really cool computational things to start to understand our world in a better way, that seems like a fantastic way to help the world and a fun thing to do with my life.
Jennifer Berglund 11:14
When was it that you got your first computer and what did you do with it?

Brendan Meade 11:18
Oh, I still remember it. I remember my parents, they were able to save up and buy my sister and I a computer. It was a radio shack TRS Color Computer 2, and it had cartridges that went in the side had a cassette tape player to actually load programs. When you booted it, it actually booted into a programming language. So the first thing you could do with it was program it. That was literally the first thing you could do with it. And so what did I do? I tried to program it. And I didn't know anything, but I really grew a lot and learned a lot from the ability to try things rapidly on the computer. I could try something out and the computer would say, that didn't work. But the computer never got mad at me or upset at me because I had the wrong answer. It just said, hey, you can try it again. And again and again and again. So as a kid, it really enabled me to kind of grow and learn at my own pace, which I think was just incredibly encouraging.

Jennifer Berglund 12:21
So this is what you do for a living now, but when you were a kid, what kinds of things would you have your computer program for you? Or what would you do?

Brendan Meade 12:30
I mean, the only thing I wanted to do was make a video game. And so back then, graphics weren't that great, so there was an old video game called Zork--Z O R K--which was text-based, and I remember me and a friend of mine, we tried to make our own kind of text-based video game in the computer. And it was, I'm sure a horrible product, but a great, great fun. Absolutely. And I have to say I think I learned something there about the notion of having the chance to do work not just to accomplish it, but also to do work for the sense of kind of trying to create something that's worthwhile. It grew from just accomplishing the task to actually trying to create something beautiful or worthwhile. I try to carry that over to today to what I do.

Jennifer Berglund 13:16
You know, you mentioned before that one of the reasons you like computing is that if you get an answer wrong, the computer isn't going to get out of you. In a way it sounds like it's kind of an awful lot like research, right? Where research is kind of about asking questions, whether they're right or wrong.

Brendan Meade 13:34
You know, I had never, I had never thought about it that way, but that makes so much sense to me. You know, one of the great disciplines that that I've learned is that, you know, you got to be okay with being wrong a lot. Scientists work so hard, and at the end of the day, most of what we think about is incorrect. But if you keep, kind of, not just grinding through it, but, like, welcoming each roadblock, you get to, say, all right, that's one more way I learned that this thing doesn't work. You know, I've accumulated a great list of ways that don't work. Eventually, you start seeing paths forward. And so, that discipline of being able to kind of continue to go on, despite the fact that things aren't making sense to you, like it's the thrill of that journey. It's the ability to persist through that journey that I think defines the path forward in science. I remember a time when I was an undergraduate, I was taking the exam. I always kind of liked exams, like, they were. I don't know. I guess that's just strange.

Jennifer Berglund 14:38
You are very unique in that way. I'll tell you that.

Brendan Meade 14:41
So, I remember taking this exam, and there was this question, we were asked to estimate two quantities. And I did the calculation, I followed the math exactly, and I got an answer that made no sense to me, because one of the quantities was positive and the other one was a negative number. And I looked at this and I said, this makes no sense to me. The quantities we were being asked to estimate can only be positive. And so, on the exam, I wrote down the wrong answer. I ignored the math, and I wrote down the positive version of both those numbers. And of course, I was incorrect. I was deeply wrong. I got, I got the question wrong on the exam. And it was only after that, that I learned this very important lesson. What was wrong there was not the calculation that I had done. What was wrong, was how I was thinking about the problem. What was wrong was my preconceptions that I had brought to this problem. And I can tell you, I think about this. There's, there's not a week that goes by that I don't think about that problem on that exam. And I learned a very valuable lesson then, that while we continue to try to inform our intuition by learning more and more bits of science, and we try to calibrate our intuition, it's not always enough. And the process of discovery in science is often about, in fact, the exact opposite of that. It's about breaking our intuition. And that exam problem that I faced as an undergraduate sums all of that up in kind of one neat little place for me, and that's why I circle back to it.

Jennifer Berglund  16:21
Can you talk a little bit about the importance of creativity and imagination in what you do and how you use it?

Brendan Meade  16:29
I love what you just brought up. I think it's fantastic because there's this caricature of what science is and what scientists do. I do this professionally, and I know no one like that. I know no one who does science like that. I know a lot of people who work really hard on problems and struggle to make smallest bit of progress. It's a hard and difficult thing. When I think about creativity in science, I think it's very real. And in fact, I think the history of science tells us that it's one of the ways that breakthroughs are made. People are able to look at something and, eventually, there is sometimes a flash. There is this thing where they say, you know what might work? And it's not a case where they've deductively reasoned through one step to step two to step three to step 70, but sometimes people are able to have these insights. For me personally, I like to hope there's some creativity, but I think sometimes what we call creativity is really just a lot of persistence and stubbornness. It's the discipline to keep trying new things, new ideas, even if they don't make sense to you. Even if you don't believe that it's the right path. It's the ability to just keep trying new things, and eliminating the ones that don't work. And hopefully finding some that do. Some of the best days in science, I always say, these are the days when you're wrong. It's the days when you figure out that you're wrong, that it's such a relief. It's this wall breaking down that was a preconception you had and when that wall falls, you may not know what the answer is, but at least you're not running into that wall anymore. And that's a great day because suddenly this wall is gone, and there's a field of things you can try out there in front of you. And so, it's kind of strange. For me, it's honestly the days when I figure out what I'm wrong about that are my happiest days in science.

Jennifer Berglund  18:23
What's the most interesting thing about your work? Why do you love it?

Brendan Meade  18:30
I'm going to say something that sounds a little strange. I feel it's a great honor and a great privilege to study the Earth. It's an incredible, incredible physics laboratory. But also because I'm studying earthquakes, I kind of hate it a little bit. So, I mean that in a positive way, though. I don't know that there are many doctors out there who say they love studying cancer. And I kind of feel the same way about studying earthquakes. If I had it my way, I wouldn't spend the rest of my life doing this. I would solve the problem. I'm not good enough to do that, but that's one of the things that's deeply interesting
about Earth science, whether it's climate science, whether it's hydrology, whether it's earthquakes, whether it's volcanoes. There's this juxtaposition between studying something that's very beautiful and very visceral and palpable, that we can see, and something where we study it to try and better humankind, and we want to be able to complete the part that betters humankind, but we still want to be inspired by the romance and the beauty of the things we see in nature. And so, studying earth sciences complicated it in that sense. It's slightly negligent to simply love it for the sake of loving it, but at the same time, if you focus strictly on the hazards posed by the planet we live on, that's not a super fun or inspiring way to go about things. And so, earth science presents this real tension between these being inspired by nature, and also loathing all the things that nature does to hurt humanity. And it's an interesting discussion that I don't think is had enough about how we how we navigate those things. But I will say, I am compelled by both of them. I'm compelled by the mysteries that the world presents to us, and by the opportunity to make the world a better place.

**Jennifer Berglund  20:22**
Brendon Meade, thank you so much for being here today.

20:25
It's been an honor to be here today. It's great to chat. And, you know, this is the type of thing that we love about the Harvard Museums. They allow us to get involved in many ways, and we'll get back there with my kids and family soon enough.

**Jennifer Berglund  20:35**
Can't wait to see you! Today's HMSC Connects! podcast was produced by me, Jennifer Berglund and the Harvard Museums of Science and Culture. Special thanks to Brendon Meade for his wisdom and expertise. And thank you so much for listening. If you like today's podcast, please subscribe on Apple Podcasts, Spotify, Podbean or wherever you get your podcasts. See you next week!