

Kailey Gilbert: I'm Kailey Gilbert, and this is Hot Shit, where you get the scoop on animal poop. Today Marti Sorensen takes the hot seat to talk fossilized packrat poop, pollen, and climate change.

Before I talked with Marti, I had heard whisperings of Professor Larry Coats's work in the RED lab at the University of Utah. The Red lab stands for the Records of Environmental Disturbance, and Professor Coats specifically has been working on packrat middens for a while. In his bio on the University of Utah page, featuring a photo with a pursed smile and caving headlamp and helmet, he is described as a paleoecologist specializing in the Quaternary — a geologic age, that has been divided into the Pleistocene, often referred to as the ice age, was from 2.5 may to 11,700 years ago, and the Holocene, the period we're in now... although there is some debate about the start of a new geologic age dominated by human influence, but that's a whole different conversation. When I reached out to Professor Coats, he told me poop and poop adjacent topics (my pitch of the podcast) sounded right up their alley! He put me in contact with Marti. Marti just finished her Master's degree with her thesis on packrat middens from the Range Creek site in the Book Cliffs of Utah. It's where the Red lab does a lot of their field research, including archeology and paleoecology. She's been going out there since partway through her undergraduate degree, and the project she's been working on started way back in 2005. Let's get into it.

The RED lab uses data from sediment cores — a method of revealing climate history and, apparently, botanical communities from thousands of years ago. Basically, there's this big tube that they drill into the bottom of a lake bed, and when they pull it out you can see the layers of sediments that have established over thousands of years. But this method has its limits. Marti says that to take a sediment core, there needs to be an established wetland. And in Utah's arid deserts, that makes a lot of the plant data inaccessible. That's where middens come in. A midden is poop? Pee? Other?

Marti Sorensen: Yeah so it's really interesting so packrats never pee and they don't drink water. They get all their water from the plants they're collecting, and from that they secrete a viscus substance called amberrat and that's what makes it so sticky and such an amazing preserver because its truly just the stickiest, weirdest coolest excretion. And then they do have like poop pellets in there, and they reuse the same like bathroom area over multiple generations, so multiple packrats will find an area that they've deemed the midden poop nest itself, and they'll choose to use that over and over again. That's how you get so much information in one spot and the thing I think is so cool about this is that in order to get pollen to preserve, and the reason its important to reuse packrat middens in arid regions is because sediment cores, in order to preserve the macrofossils and the pollen, you need continuously anoxic conditions that wet bog areas provide you -- there's not a lot of oxygen in that, its continuously wet. But what the packrat midden does is the amberrat is so sticky and covers so much of the surface area that once something lands in it it creates those anoxic conditions where it forms around it so tightly that no oxygen can get in. That's how it can be preserved for thousands and thousands of years and provides really the only archives of that much detail in arid regions because there's not a whole lot of continuously wet areas.

Kailey Gilbert: Do they stink?

Marti Sorensen: They do! Yeah I personally think they smell not that bad, I wouldn't say good, but its like an old bale of hay

Kailey Gilbert: That's so specific!

Marti Sorensen: It is, it's a very specific earthy scent. This will give you an idea of what they smell like. Yeah. Yep.

Kailey Gilbert: Oh yeah. They are stinky! Oh god! It's like sour?

Marti Sorensen: Yeah! Yeah, like a weird earthy sour. And there are some people who say you can tell how old a midden is by how sweet it smells. There are some people that think that the older ones have a sweeter smell. I personally can't really tell like there are differences in the smells for sure, some are definitely a little bit more forgiving than others, but it's not like a poop scent that you would think of. Think of really really earthy because there's just a lot of plant vegetation in there.

Kailey Gilbert: Now I think it's worth noting that Marti grew up on a cattle ranch, so perhaps she's a bit more desensitized to the pungency than the rest of us. Middens are an adventure to get to! Marti describes people having to climb up rock faces with chisels, chipping away and poop that may or may not be thousands of years old, putting it in a bag, and shuffling back down to safety.

Marti Sorensen: Packrat midden is solid. Like, completely solid. It's like a concrete block, essentially.

Kailey Gilbert: So this sticky, stinky sweet poop filled secretion creates the perfect environment for pollen and plant matter to be stored for thousands of years. Middens can be as old as 40-50,000 years, all the way to the limit of radiocarbon dating. But the fossils we're talking about here don't look like fossils you would see at the Natural History Museum. It's not organic matter that's been replaced by rock. No, this is the real deal. These are plant parts that have been so well preserved, they look like something you could pick up outside. The plants have lost their green color, sure, but if you gave me a dried-up juniper twig and put it up next to what we're calling fossils, I probably wouldn't be able to tell the difference. But how do they get to all this plant matter?

Marti Sorensen: So once you find one that's pretty well sheltered, they're either in a little cave thing or an alcove or sheltered by the cliff face, you would get that with a crowbar and all of your equipment and supplies and chisels and what not and then you would put it in your bag, take it back here to the RED Lab, and then we would soak it for about a week. You need it to be at least a week in order to get everything in that matrix to break up. Then you'd pour off a top layer with pollen and set that aside for future chemical processing, and then sieve through a mesh sieve screen and then we dry that out on trays until it's dry to the touch, then we hand sort through it with a hand lens. You can do it with the naked eye, but sometimes I feel like you miss the small details on seeds and stuff like that. You can find different things in the packrat middens you can find bones, you can find insect bits, but here we're focused specifically on the micro and macro botanicals. So with that you would hand sort through for diagnostic characteristics in plant bits.

Kailey Gilbert: Even though they're focused on plants, they keep everything. And I mean everything. Marti showed me the cupboard where they keep the 45 samples from her Master's project — each midden is sorted into categories of plants, bones, insect bodies, poop, etc. and stored in the lab in case some super smart scientist comes along and finds something interesting to do with them. But the plant material they're sorting through is... unassuming to say the least. Marti showed me a midden that had been soaked and sieved and dried, but not sorted. It looks like a mess of sticks to me. But to Marti's master eye, it's a lot more

Marti Sorensen: So you're looking for patterns on seed, dried fruits, diagnostic twigs, things like that. It's really just anything that a plant puts off that you could use as a key identifying feature. And that's one of the main advantages of packrat middens being used for macro botanicals as well because you can get down to species level because you can look at so much detail where as reconstructing with traditional pollenology most of the time you can only get to family. Sometimes you can get to genus, if you're really lucky you can get to species, so it's a really robust analysis when paired with pollen because you can get a very large overview of the taxonomic breakdown of that area.

Kailey Gilbert: But she isn't just looking at plant parts. Marti's research also looks at pollen samples

Marti Sorensen: With the pollen, I love pollen I think it's so fun I love processing, it makes me feel like such an official scientist.

Kailey Gilbert: When Marti says she loves pollen, she really does. Through all my conversations with her, she was absolutely stoked to talk about her research. But when we started to look at pollen? This girl lit up brighter than the sun.

Marti Sorensen: We're not interested in anything inside the pollen itself we just need the outside structure to be able to tell what species or family it's in and that outside of the pollen grain is made out of sporopollenin which is an incredibly durable protein that it makes, so with that it can withstand all this chemical processing.

Kailey Gilbert: Basically, they process the sediments in the packrat midden to get out as much gunk as possible, then use a series of chemicals to strip out a bunch of the insides to reveal the pollen structure. It's a massive oversimplification of the process, but what you need to know is that the structure of the pollen is retained, then dyed and plated on a microscope slide. There is still some gunk, but it makes it way easier to see

Marti Sorensen: I think it's so cool how pollen can be so strong and how each species has its own diagnostic features. It's kind of similar to the macrofossils where you have to know what you're looking for.

Kailey Gilbert: Pollen grains are usually only able to be identified to family, sometimes genus, and even more rarely, species. But that's the cool thing about the middens. Because you have macro fossils (plant bits) you can identify a lot of material all the way to species.

I spent a good two hours looking at different macro fossils and pollen grains with Marti. Under a dissecting scope, we looked at *Juniperus osteosperma* (the Utah Juniper) and *Juniperus scopulorum* (the Rocky Mountain juniper). The Rocky Mountain Juniper has longer, more slender and smooth scales, where the Utah Juniper scales are more stout and, under the dissecting scope, have teeny tiny little teeth lining the sides.
Wait this is crazy you can see like scales within scales

Marti Sorensen: Yes!

Kailey Gilbert: Another plant, Coyote Tobacco (*Nicotiana attenuata*) has seeds with these really intricate squiggly structures.

Marti Sorensen: There we go. That's like the most...

Kailey Gilbert: Oh my god wait! That's crazy! They're like little amebas that have just been drawn on these.

I compared them to little amebas, but they also look a little bit like those flowers from sponge bob? There were leaves and seeds, all perfectly preserved in time with veins and little hairs and tiny details — it's hard to believe these specimens are thousands of years old! Now, I'm a big plant girl. I can appreciate the intricate details of a juniper scale, how cool teeny tiny seeds are, teeny tiny hairs on plants that take us back in time... but seeing pollen was mind-blowing. I'm not sure if it's Marti's passion or how beautiful the pollen is, or perhaps a little bit of both? But we spent an hour and a half looking at these samples alone. I was blown away by the detail.
This is super layery

Marti Sorensen: Yeah and you can see in all that debris that texture, that game, isn't it so cute?

Kailey Gilbert: This is crazy Marti. There's a whole world I can't even see!

Some pollen, like the pinyon Pine, have these big sacks (well, big for a microscopic sample) that are called bladders. Basically, it's like two textured bubbles on the side of a tube. Most of the time, these kinds of samples are air-pollinated, so scientists think it helps the pollen float freely through the air. Other pollen, like from Junipers, almost look like the animations of bacteria — little globes with dimples or spikes or layers. I got to look at a couple species of *Ephedra*, which has this tube-like pollen with folds all throughout.

Marti Sorensen: This is another one of my favorites! I'm so excited. This one is so fascinating and truly just one of the coolest grains and nothing else looks like it.

Kailey Gilbert: Well I'm surprised at how distinct all of them are. Like I thought it would be way harder to tell them apart. What is this! Wow its like spirally.

When Marti would get really excited about a sample she would do this silly little laugh

Marti Sorensen:

Oh yeah, (laughs)

Kailey Gilbert: The evil laugh? That's crazy! Muahaha come see my pollen.

Now, remember the inside of the pollen has been chemically obliterated, so what we were looking at is the casing around the outside. Because of that, Marti recommends moving the focus in and out to get an idea of the overall structure. It lights the pollen in these beautiful, almost kaleidoscope patterns. I got to see maize pollen samples, which are huge and indicate human presence, some sage species, dandelion, and other sunflower family pollen, and, I may be biased because it's my favorite family of flowers, I got to look at pollen from a flower in the Malvaceae family — the Indian Mallow or *Abutilon incanum*.

Kailey Gilbert: Wow! What? This is crazy!

Marti Sorensen: Isn't he beautiful? This is one of my favorites!

Kailey Gilbert: This is insane. Also the red makes it look like it's on fire.

Marti Sorensen: Yeah! And I'm sure you've noticed, some of them take the dye better than others.

Kailey Gilbert: It was by far my favorite pollen, with all these twisting spikes coming off the sides. If you ever have the chance to look at pollen samples, I would highly recommend it. I could, and did, spend hours looking at them with Marti.

Marti's master's project asks how the pollen in the middens compares to the macro fossils, how the midden samples compare to the sediment cores in the area, and attempts to understand how to interpret and utilize the results of packrat middens.

Marti Sorensen: In my Master's research I found that packrat middens do a fantastic job at identifying pollen rain, but they have a huge advantage in identifying insect pollinated taxa that aren't necessarily going to fall into a continuously wet area, whereas the sediment cores' main advantage is that they're getting an incredibly regional pollen sample from all that pollen rain as well as capturing aquatic species.

Kailey Gilbert: She says that sediment cores paired with packrat middens is probably the way to get the most robust reconstruction, but if there were no sediment archives, packrat middens could be another option.

The RED Lab isn't the only people using packrat middens this way. While she says it is a bit of a niche interest, middens are used in lots of places throughout the West, particularly in arid regions similar to the ones we see in the Book Cliffs. While I'm sure their research and field sites are captivating and amazing and wonderful, it's hard to not feel pulled to the places Marti speaks of.

Marti Sorensen: When I go into the canyon it's kind of a feeling of being -- this is not on a scientific level at all but more on the same lines of my personal life, like it feels more like a spiritual experience like you're entering into a sacred space because it's been the home of people for so many thousands of years. It's seen so much good times like good corn yields but it's also seen so much devastation with the disappearance of the Fremont people and homesteading. It was used as a site for homesteading for a really long time. There's just a lot of rich history to the land itself.

Kailey Gilbert: When she describes the first time she visited the Range Creek Field site, she says in some ways it felt like a homecoming. She was raised in the desert of Utah, with a family who had jobs in cattle ranching and oil mining. While she recognizes the value those jobs had to her family and their livelihood, looking at the landscape as a whole lot of nothing doesn't do it justice. Seeing the land as something more than a resource changed something for her.

Marti Sorensen: I think that it being "nothing" is truly what makes it so special though because there's so much going on there and being able to be there with people like Larry and Andrea and Mitch who all have these like really intense deep knowledge of the setting, how it got there, and the plants that have been able to endure in that space, I guess the feeling I would describe is like a reverence to be there because you're taking in just how much everything flows together and how resilient that space has been to survive and still be here.

Kailey Gilbert: She describes a stand out moment from her first visits to Range Creek.

Marti Sorensen: Something I think about a lot is when Larry took us to one of the granary sites, they're everywhere, but one in particular you could see the thumb print from the people who made it. It was just the most surreal experience to think that I'm here in this space where they were at building these and living in this canyon, and like oh my god! They were living in this canyon! Like they were so smart and had so many tools and a well structured society within this area and I think that was kind of lost on me before I went down, just how special and the environment and the study of paleoecology ties into disciplines like anthropology.

Kailey Gilbert: Now when she went to the field station the first time, they were busy. She says they got to help with a maize growth experiment (maize is the science term for corn), they got to witness an archeology dig site, and while they did collect a packrat midden, the more stand out moment for her was when she got back to the lab.

Marti Sorensen: The more stand out moment to me was when we had the middens back in the lab and we were learning how to process them. He's so funny. He's so nonchalant about things. He was showing us how to soak them and put them into bins and it was literally just taking a mound of poop and putting it into a blue bucket and being like alright we check back in a week and he was kind of like alright now we move onto the next thing and I was like "This is the coolest thing I've ever done in my entire life!" You're telling me that a tiny little rodent went out and collected things 8,000 years ago and we now get to hold these things in our hand and like look through them and see their tiny little teeth marks on each tiny little twig and things like that and I remember him laughing at me and being like "You're going to love the next step when we actually get to look through them and not just soaking them in buckets.

I think it's important for multiple different reasons. I think it depends on who you are and what your interests are in. I think that's the really cool thing about paleo work is that I feel like everyone can benefit from it but the thing that means the most to specific people depends on what you're specific interest is in. When we're working with archeologists it's important to them because they're looking at the climate in which they're studying human behavior. Why are people doing the things they're doing? Why are they farming in this area? Why are they storing their grains in these particular areas and that is really shaped by what the climate is like and that in turn also shows you what vegetation would have been there and what they would have been

eating, if they would have relied entirely on scavenging or foraging or more reliant on agriculture stuff.

Kailey Gilbert: Marti says that this research can also be used to understand what climate may have looked like and how it's changed in recent millennia. By looking at the plants in the area, we can reconstruct a basic understanding of ecosystem function and how it's changed over time. We can understand how ecosystems respond to climate change, and we can anticipate how ecosystems may change moving forward.

Marti Sorensen: I also just think it's important for everyone in general to know the history of where they're at. I think it makes you more in tune with where you're living and it makes you see everything as like more of an opportunity. I think a lot of people look at rodents and packrats like nuisances which I totally get like if you have a house or something and they're burrowing into your chimney and grabbing your reading glasses or something I can get that it's annoying but I think it shifts your perspective on things. In the immediate that's true but like long term these are little scavengers for environmental archives. It just makes you see nature and the time scale that we're here in a completely different light. It makes you appreciate everyone's role in the community. All the animals, all the plants, they all serve a purpose and we're all part of that ecosystem. I think it just makes you appreciate the spaces you're in and the long history.

Kailey Gilbert: But this research and experience means a little more to Marti. In her thesis right before the table of contents, there's a dedication page. "To my grandma, Verrena 'Sweet Pea' Simmons Prescott." She passed away when Marti was 16. In some ways, Marti feels like this project embodies her.

Marti Sorensen: My grandma was an amazing person. She just really loved the outdoors. When I was younger my dad got sent to the hospital for about three months and we were homeschooled, my brother and I together, so my grandma took over that position and was teaching us her lessons. She would downplay a lot of her knowledge like oh I can't really teach you all the things when it comes to math or science or all those things but she really connected us with plants and her garden. I know she wasn't doing it at the time to be environmentally conscious but when I think of what it means to live with the land and appreciate the plants that are around and to live with intention and to be resourceful and aware of how much you're consuming I think of her because she saved everything, every scrap of fabric, every button. It just reminds me of her and how to find home and meaning in things and how to connect that to plants and how that leads back to community.

I think the overarching theme that this has taught me is that science itself is successful in communities. I know we like to be subjective in science and have this observer mindset, but to me it's been more about connecting and community. The community of researchers there are down in Range Creek, the community of passions and how we all get into projects and get to help with the excavation and things like that, it's really just about supporting each other. It's the same thing here at the RED lab. I've met so many great friends and the people who have trained me, and not even just the people I've worked with but like looking back to the people who founded this department that I've been looking up to meet. We wouldn't have the knowledge we have now if it weren't for the people before us who put in so much time and effort. Sorry I didn't

realize I would be emotional about this too. But like putting in the effort to keep our field alive and truly doing it all for a sense of passion because...

Kailey Gilbert: There is no money in science

Marti Sorensen: That's what I'm saying like not to be pessimistic or anything but there's not a lot of money coming in for paleo ecology, so everyone who's here is doing it because they love it and because they care about it and know how much value it has. It's not just about recreating plants, its about sharing the love of community and connecting eith your environmental surroundings and realizing part of your community is not just each other but also the plant communities the animal communities like they're all part of the overall picture and we're all working together to educate each other and keep our communities going.

Kailey Gilbert: Marti hopes to continue to foster community within her lab, but also in her home town.

Marti Sorensen: I come from a family that did a lot of oil field work so I feel like I have an understanding of both sides. I see the human side of it and I definitely see that my hometown economy is entirely based on oil field stuff you know there are people out there doing really hard work. And honestly like grueling work. Like hard, physical labor that are just coming home to feed their families at the end of the day. I think I came into it for more of a perspective of no matter how we all feel about this subject, the main thing at the end of the day is that we deserve to be in loving communities where our families are happy and healthy.

Kailey Gilbert: As Marti continues her research, pursuing a PhD she's working to foster more of that community.

When we talk about science, about climate change, about human history, I think it's important to recognize the human aspects of our differences. It's easy to get caught up in the whole us vs them rhetoric. It's easy to antagonize people. I hope that moving forward, I can learn a thing or two from Marti by building community around me, both within research and academia and outside it. Because climate issues impact everyone, and the only way out is together.

Music featuring Flirty by JMHBM from Free Music Archive. Huge thanks to my professor, Maria Shilaos for teaching me the foundations of podcasting, and to my family and friends who have listened to my indecent ramblings about this project for the last two years, and to you, a listener, for your interest. See you next time on hot shit.