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[00:00:00] **Peter Brannen:** The biggest mass extinction of all time is this thing called the End Permian mass extinction, and it's caused by this mind-bending series of volcanic eruptions over tens of thousands of years in Siberia that are injecting tens of thousands of gigatons of CO2 under the air jackknifing temperature by something like 10 degrees C.

[00:00:16] So all the stuff we're worried about today, but the less you learn from those is here's the absolute worst case scenario. While we aren't emitting as much CO2 as the end Permian mass extinction, we're doing it probably like 10 times faster. The path we're on leads to some pretty gnarly outcomes.

[00:00:35] **Nate Hagens:** Today I am rejoined by journalist and author Peter Brannen to discuss the central role of Carbon in earth and human's history. Peter Brannen is an award-winning science journalist and contributing writer at The Atlantic. He has published two books, including the Ends of the World, volcanic Apocalypses, lethal Oceans, and our Quest to understand Earth's past mass extinctions.

[00:01:01] And we did a podcast on that a couple years ago. And most recently, the story of CO2 is the story of everything. Additionally, Peter is an affiliate at the Institute of Arctic and Alpine Research at the University of Colorado Boulder, and was previously a visiting scholar at the Klug Center at the Library of Congress.

[00:01:23] In this episode, Peter and I take a deep dive into how carbon, especially carbon dioxide, has shaped the history of our planet from the beginning of life to the dawn of agriculture all the way through to today. Peter also shares some common misconceptions about carbon and how understanding our deep time

history can help us better prepare for the coming decades living in a world that's heating up.

[00:01:48] Before we begin, if you are enjoying this podcast, I invite you to subscribe to our substack newsletter where you can read more of the system science underpinning the human predicament, where my team and I share written content related to The Great Simplification themes. You can find the link to subscribe in the show description.

[00:02:06] With that, please welcome back Peter Brannen. Peter Brannen. Great to see you.

[00:02:12] **Peter Brannen:** Great to see you again as well, Nate.

[00:02:13] **Nate Hagens:** It's been, almost two years, since our, first podcast, where we discussed your book, the Ends of the World, which was about, earth's previous mass extinctions. You have a new book that was just out in August, 2025 called The Story of CO2 is the Story of Everything, A 4 billion year Chronicle of Planet Earth and.

[00:02:38] Hour. It's a dramatic relationship with carbon dioxide. What possessed you to write such a book?

[00:02:45] **Peter Brannen:** It actually sort of naturally came out of the first book process where, I thought there was sort of this newsworthy thing when I wrote the first book that, keeping my finger on the pulse of the geology community.

[00:02:56] It turned out that most of the mass extinctions, unlike most people had heard, where I think there's this general understanding that they're, what happens when space rocks fall outta the sky and, kill everything on the planet? Turns out most of them. this is sort of a recent ish discovery from the geology community

that most of them are associated with sometimes huge injections of CO2 in the air and runaway warming.

[00:03:17] Sort of like the experiment we're running on the planet today. Sometimes CO2 declines and you pass these thresholds and you go into ice ages. and that can be similarly devastating. So that book was really about what happens when. Sort of CO2 goes wrong. And in the process of writing that book, I had to spend a lot of time hanging out with the geoscience community and auditing classes on geochemistry and the history of life on earth.

[00:03:40] And I realized that there's just a much bigger story to tell that, this thing isn't just something that when it gets outta control, it kills everything. But it is actually fundamental to why planet Earth is planet earth. Its behavior on this place is what makes this place special. So I feel like that story hadn't really.

[00:03:57] You know, penetrated the, you know, public imagination because CO2 is mostly talked about as this industrial byproduct that just happens to come outta smokestacks. And I kind of wanna reintroduce the reader to, it as this thing that is fundamental to our existence on this planet.

[00:04:11] **Nate Hagens:** So we're two minutes into this conversation and already there are some listeners saying, oh, another CO2 climate, podcast, or, I'm not, I know everything I need to know.

[00:04:22] it's too late. And we've become such a polarized, tribal society. Where's the nuance between the viewpoints? Why should people listen to the rest of what I expect to be a long conversation?

[00:04:34] **Peter Brannen:** Yeah. I mean, so sometimes you'll see this thing where it'll be, you know, some, a climate denni online will say, CO2 is just plant food.

[00:04:43] Why are we worried about it? It's great for life Loves CO2. And I read those statements and I think absolutely you're a hundred percent right.

[00:04:49] **Nate Hagens:** Yeah.

[00:04:50] **Peter Brannen:** but. Because it's good in certain respects, then they discount the, possibility that it could have negative effects. And what my book argues is that because this stuff is so important to the maintenance on operation planet Earth, that's why you don't wanna mess with that with it that much.

[00:05:06] 'cause yes, plants love CO2, life on Earth is carbon based and the ultimate source of that carbon is CO2. it also happens to provide this control knob of the planet's temperature and the ocean's chemistry. So it is kind of this miraculous substance, the way that it behaves on planet earth through these processes that are completely mind blowing and make you grateful to even be alive, once you learn about them.

[00:05:30] So I kind of wanted to. Inspire a little cosmic wonder as well, not just like the, death and destruction of the mass extinctions and when CO2 gets outta control, but, in happier times. it is, it's kind of miraculous that it does the things it does here.

[00:05:44] **Nate Hagens:** So is that the carbon cycle?

[00:05:46] **Peter Brannen:** It the carbon cycle is so much more than just that.

[00:05:48] **Nate Hagens:** We haven't had anyone really explain it. Maybe you could spend a few minutes explaining the carbon cycle.

[00:05:53] **Peter Brannen:** I mean, I just as easily could have called the book. The carbon cycle is the okay is, everything because it happens both at these

microscopic nano machinery of the cell level where photosynthesis is doing this on a molecular scale.

[00:06:08] It's, there's this huge exchange between the biosphere where CO twos in the ocean's an atmosphere life transforms it through these tiny little processes into things like shells, like calcium carbonate or into plants and things like that. And that happens on a nanosecond timescale. And then you have. If you also have these, timescales and scales physically of the carbon cycle that take place over entire mountain ranges in continents and that are on a hundred thousand year timescales.

[00:06:35] And so all these different things are acting together to keep this place habitable and inhabited in the good times. And when you throw off this finely balanced sort of, cycle is almost the wrong word, but. This finally imbalance, just flux of carbon and CO2 in the atmosphere. Then you get nasty things like mass extinctions.

[00:06:57] **Nate Hagens:** You just implied that these things are happening in order to have life thrive. Is there a, volition and a purpose there and a, homeostasis like, Gaia theory or what are your thoughts there?

[00:07:09] **Peter Brannen:** I dunno if it's a happy accident, but there are things that make you wonder. Like this planetary thermostat, animals can only list live within a very narrow temperature range and for the entire age of animal life.

[00:07:21] for the most part, we've stayed within that range. And the primary knob governing earth temperature as a classic paper, puts it. is CO2, but CO2 has to navigate this incredibly narrow window where, so for instance, 50 million years ago, CO2 was 0.1% of the atmosphere and there were crocodiles and palm trees in the Arctic.

[00:07:40] And then 20,000 years ago, it was 0.01% of the atmosphere and there were, a third of North America was covered in ice. And there the sea level is 400 feet lower. So that's a tiny little narrow window and it manages to stay mostly within these bounds through this thing called the rock weathering cycle.

[00:07:58] So this is sort of what I was talking about, this thing that happens over hundreds of thousands of years that maintains a. A habitable temperature. So I'm already getting too wonky. I can tell, but we can, delve into that. This

[00:08:08] **Nate Hagens:** is a wonky podcast. Yeah. And I'm curious about this because I don't fully understand it.

[00:08:12] **Peter Brannen:** Yeah.

[00:08:13] **Nate Hagens:** So if we did nothing and humans, disappeared tomorrow, explain the process of how CO2 from planetary forces would decline from its 430 parts per million, now from rock weathering and these long term things.

[00:08:31] **Peter Brannen:** Yeah, a lot of it would be absorbed by, The biosphere. But on the long term, sort of the long term temperature regulation mechanism is this thing called rock weathering where CO2, if we weren't here, comes out of volcanoes at a, rate about one 100th that we're putting it out.

[00:08:47] And that's a rate that the earth can kind of accommodate it. And in fact, it's a good thing that CO2 comes out of volcanoes because, if it didn't, there would be no feedstock for all of life. There would be no, we photosynthesis would stop. but also the planet would not be habitable. the temperature would not be habitable.

[00:09:03] So if all CO2 went outta the atmosphere all at once, temperature dropped something like 60 degrees Fahrenheit in the next 50 years. so it's a good

thing that there's some see it two in the air, it. Provides the biosphere basis, and it keeps the temperature habitable, but the planet has ways of sequestering it at the, basically the same rate that it comes out of volcanoes.

[00:09:23] And the main one is this thing I keep talking about rock weathering, which is that CO2 reacts with rainwater and it makes it slightly more acidic that rainwater washes over rocks. It's just what it sounds like. it chemically and, physically weathers them. And eventually through a series of, sort of chemical transformations that CO2 in the air, which, slightly acidifies rainwater delivers, by carbonate to the oceans.

[00:09:53] And that can partition into carbonate, which then sea creatures can use to build their shells. And eventually they've snowed down into the bottom of the ocean and become this calcar ooze that on the long term can become things like limestone, which then that sea floor can abuc. The crust and come out of volcanoes of CO2 again.

[00:10:13] And that's the long cycle of this stuff. where volcanic gas becomes air becomes, Chemicals in the ocean that become creatures that become rock, that then become CO2 out volcanoes again. So that's the really long term carbon cycle.

[00:10:29] **Nate Hagens:** Now I have a ton of questions. So setting humans aside for the moment, I have read that over time, over long time, like 500 million years into the future, this rock weathering cycle will

[00:10:42] **Peter Brannen:** Yeah.

[00:10:42] **Nate Hagens:** Combined with the sun expanding

[00:10:45] **Peter Brannen:** Yeah.

[00:10:45] **Nate Hagens:** Will be such that we won't have enough CO2 for photosynthesis and complex life at all. Life will die on earth. Something like that. Is that, the scientific consensus now or what do you have to say about that?

[00:10:58] **Peter Brannen:** I mean, there aren't that many people plotting out the really long term trajectory of life on earth, but I literally just had a conversation a week or two ago with this guy, Benjamin Mills at the University of Leeds in the uk who's working on that exact problem.

[00:11:10] And yeah, his models do sort of pump out this world where as the sun gets brighter, it is a. Speeding up the water cycle. It's evaporating more water, which is ramping up this weather cycle. It's wearing rocks down faster chemically, it's sequestering more CO2, that he does think you're gonna have this secular decline of CO2 over hundreds of millions of years.

[00:11:29] Where eventually he says the last stage of sort of complex life is you get into this grass world phase. 'cause grasses are evolved in this relatively low CO2 world of our recent history. And then after that, it gets too low even for grasses and then sort of photosynthesis stops.

[00:11:45] **Nate Hagens:** I would argue that complex life would've stopped long before just grasses.

[00:11:49] Grasses aren't complex in, in my

[00:11:51] **Peter Brannen:** Oh no, but you'd have like a grazer based or like Oh, I see, Or like ecosystem. You'd have like a planetary Savannah basically. And then it would get too, it would get too low for, even for grasses. But this is all very speculative. I think he has papers coming out on this, so I don't mean to, to

[00:12:04] **Nate Hagens:** yeah,

[00:12:04] **Peter Brannen:** to

[00:12:05] **Nate Hagens:** no.

[00:12:05] **Peter Brannen:** Spoiler

[00:12:05] **Nate Hagens:** alert that I, I think that's, super interesting what happened at, from the beginning of life. All the way to when humans, evolved. There were a lot of events involving CO2, we talked about it in our first conversation. Yeah. Maybe you could just give a brief overview of some of the things like snowball earth and Siberian traps, et cetera.

[00:12:25] **Peter Brannen:** Yeah. It's sort of this mystery that the greatest climate catastrophe in earth history happens in the lead up to animal life where there hadn't been animals for 4 billion years. roughly you have this crazy climate catastrophe, and then sort of the champagne cork of animal life explodes in its aftermath, and that's a mystery.

[00:12:43] so I should explain. Snowball earth is this period where, ice sheets that begin nucleate at the poles eventually race all the way across the entire planet and lock even the tropics and ice, for tens of millions of years.

[00:12:57] **Nate Hagens:** And it, becomes kind of meta stable at that point.

[00:12:59] **Peter Brannen:** Yeah. And in fact, when this first popped out of, climate models and the climate scientists thought.

[00:13:07] Well, this is just an artifact of the models. 'cause clearly this has never happened in earth history 'cause it's so extreme that we wouldn't be here to talk about it, and there's no way out of this, death sentence for a planet. But then geologists actually kept finding evidence for ice sheets at the tropics at sea level, 700 million years ago, which just shouldn't happen.

[00:13:28] and this is a story, so today we're worried about CO2 going up too fast and it getting really warm. But, it's thought that this was caused, or at least a, an explanation that I feel like there's some sort of consensus triangulating towards is that CO2 is declining in the lead up to this, Climate catastrophe.

[00:13:47] because of this, what I was talking about earlier, rock weathering sort of accelerated. So today geo engineers are exploring things like basalts to just inject CO2 straight into, and you basically accelerate these processes that take hundreds of thousands of years by just turning it into limestone right there, essentially.

[00:14:03] So there was, an accelerate period of accelerated rock weathering because you had this ancient supercontinent that was covered in basalts, like the ones that we look at bearing CO2 in today. And as it broke apart, it exposed. The interior of the supercontinent covered in basalts to these trade winds and hurricanes that were just like a, you're revving the engine of this rock weathering process and eventually you pass a th a threshold and the ice sheets progress far enough, which isn't, it's like 30 degrees on either side of the equator.

[00:14:30] And after that, you hit these ice albido feedbacks where you're just reflecting more and more sunlight off. And then they raced all the way to the tropics in a matter of centuries.

[00:14:38] **Nate Hagens:** So when the, in the second snowball earth, around 700 million years ago, yeah. Was there, like, what kind of life was on the planet?

[00:14:44] **Peter Brannen:** Arguably, there was only microbial life. Except for some very interesting, but pretty or very, simple, but not very interesting. experiments in multicellularity. So sort of like seaweedy stuff, but mostly microbial. there are some disputed fossils that some people have pointed to a sponges slightly before snowball earth.

[00:15:08] they're the simplest kinds of animals.

[00:15:09] **Nate Hagens:** So the Cambrian explosion happened after that.

[00:15:12] **Peter Brannen:** After that, yeah. You have this insane thaw where you go into this super greenhouse immediately after snowball earth, which is from high CO2. because while you're covering the planet in ice, that CO2 is not getting sequestered by photosynthesis.

[00:15:26] and there's no rock weathering. But meanwhile it's just coming out of volcano slowly so it builds to an insane level, and then all of a sudden the thing melts overnight.

[00:15:34] **Nate Hagens:** So there's, even at the planetary scale, there's a lot of positive and negative feedbacks.

[00:15:40] **Peter Brannen:** Yeah.

[00:15:40] **Nate Hagens:** But also those feedbacks are at different scales.

[00:15:43] There might be a huge small, negative feedback, but it runs into a. Even bigger positive feedback.

[00:15:49] **Peter Brannen:** Yeah. Yeah.

[00:15:50] **Nate Hagens:** So is it common that when there was a big swing in either hot house earth or, a snowball earth that we air, largely in, in the opposite direction soon after?

[00:16:01] **Peter Brannen:** Yeah. I mean, and I think you see that in the mass extinctions too, and it gets super hot.

[00:16:05] Then you accelerate all these CO2 sequestering, processes, and so you do see these crazy swings and, temperatures and things. But this is over thousands and hundreds of thousands of years.

[00:16:16] **Nate Hagens:** I don't know that everyone would agree with this, but, I think you have a cool job because you're paid to just be a nerd for two years and learn about this.

[00:16:27] **Peter Brannen:** Yeah.

[00:16:27] **Nate Hagens:** From an ecologist's perspective, what you're describing kind of is akin to the Bible. I mean, it's, an ecological, not an ent anthropological story. Yeah. and this is our origin story, all of us. So why does life exist at all? What is your take on that? I know you wrote about that in your new book.

[00:16:48] **Peter Brannen:** So I have this account of the origin of life where I sort of felt the energy in that community heading towards a particular explanation where it's sort of the received wisdom, sort of starting with Darwin's warm little pond, that, you know, you just had a warm little pond on ransomware and it seems like there's a different sort of, locus of study these days that is attracting a lot more energy, which is that there might not have been any.

[00:17:14] Land in the hadan when life evolved. so you might not have had any anywhere to put warm little ponds. The surface would've been bombarded with UV radiation and, asteroid impacts, and it just would've been a horrible place. But you have these very gentle, hydrothermal vents called alkaline hydrothermal vents at the bottom of the ocean that were in, you had the interior of the earth, which was exposed, that the sea floor was sort of out of equilibrium.

[00:17:41] And I write about in the book that when systems are pushed really far from equilibrium, you get these complex dissipate of structures that are weirdly

low entropy, but they are in service of dissipating energy and creating higher entropy.

[00:17:55] **Nate Hagens:** But is that what life is?

[00:17:56] **Peter Brannen:** Yeah. I mean that's, that is the explanation I kind of go with in that.

[00:18:01] So if you have a boiling pot of water. Even though it is a lower entropy locally to have these convecting cells, it's a quicker way of dissipating heat. And hurricanes are quite complex self-organizing structures, but are actually better at dissipating energy and relieving de sequi libria And life kind of might have served a similar role at the beginning of time,

[00:18:21] **Nate Hagens:** but you know, that I, likened the global 21st century economic Superorganism as a dissipate of structure.

[00:18:30] I mean, are humans different in aggregate from other aspects of nature that do what you just described, a hurricane and, convecting.

[00:18:40] **Peter Brannen:** Yeah,

[00:18:40] **Nate Hagens:** currents.

[00:18:41] **Peter Brannen:** Well, I poses that question to, I thought, to this origin of life researcher Mike Russell, thinking he was gonna just tell me I was insane. where the things that he was describing.

[00:18:51] Up to and including the, you know, these nano turbines that we have in our cells that are powered by electricity and send energy across the cell.

[00:18:59] **Nate Hagens:** Nano turbines.

[00:19:00] **Peter Brannen:** Yeah. So in your, mitochondria, you burn. You burn plant matter with oxygen and release CO2. But you do that rather than just burning it like a fire does, where you just release energy and heat all at once.

[00:19:14] You actually send an electric current down an electron transport chain that powers protons to one side of a membrane that then when they come back down, power this turbine that makes a TP that sends it all over the sh all over the body.

[00:19:25] **Nate Hagens:** I didn't know that.

[00:19:26] **Peter Brannen:** It is basically the same thing as pumped hydropower storage.

[00:19:28] We've just reinvented it 4 billion years.

[00:19:31] **Nate Hagens:** isn't it fascinating how stuff just rhymes and matches at Yeah. At the micro and the macro scale?

[00:19:37] **Peter Brannen:** Yeah.

[00:19:38] **Nate Hagens:** It's like a Russian doll all the way to the planetary level.

[00:19:41] **Peter Brannen:** Yeah. And so to him I was like, well, the original life, just like life today feeds off these.

[00:19:46] Energy gradients and, does work on the environment and has these complex little machines at the, at the boundary between these out of equilibrium reservoirs. And I was like, that sounds a lot like what's going on today, doesn't it? He is like, no, it's exactly, that's exactly what's going on today.

[00:20:02] **Nate Hagens:** So here's a thought.

[00:20:03] this is probably for, later in the conversation, but I've, thought about. Describing a potential fifth law of thermodynamics in the fourth law of thermodynamics. A lot of people, compete for credit for that, but Howard Odom thought that the maximum power principle where organisms and ecosystems, behave in such a way to maximize the access to, useful energy.

[00:20:32] And the fifth law would be that conscious life, us a species learns everything you just described, learns what we're doing to the world, learns about the fourth law and, maximum power principle and actively changes their behavior to throttle down the metabolism of an otherwise law of thermodynamics.

[00:20:56] What are your thoughts on that?

[00:20:58] **Peter Brannen:** Yeah, I mean, I spoke to people for the book who thought we were just like a hurricane and we're just gonna dissipate all this energy Yeah. Until we run outta steam. And

[00:21:04] **Nate Hagens:** that's the default path.

[00:21:06] **Peter Brannen:** Yeah, But I think humans are. Maybe I give us too much credit, or maybe I'm just not willing to throw in the towel yet.

[00:21:12] That, I think there are things that are quite novel about us, like, cul the culture and the transmission of culture through generations and our ability to organize societies and customs and, adaptively. so I write in the book that it wasn't, you know, fangs or thick hides that kept us alive through the ice ages, which were really volatile swings between temperatures, but it was adaptively, you know, coming up with technologies and transmitting cultures and things like that.

[00:21:41] So given that we have this superpower that we can actually regulate ourselves in theory, that is, I think where the hope is for ourselves, not just being a hurricane that dissipates all the heat until we disband and numb,

[00:21:52] **Nate Hagens:** except realizing that we're functioning like a hurricane is a necessary first step.

[00:21:56] **Peter Brannen:** Yes, I agree.

[00:21:58] **Nate Hagens:** So let's, go back to, the carbon cycle. I have in recent years in my presentations. Kind of cheekily, in a funny sort of way, but also real say that all the talk is about humans are talking climate change. But climate change actually caused humans in some regard because for the longest time it was super volatile extremes.

[00:22:23] Yeah. And there were hominids, and pre homosapiens hominids. Mm-hmm. And we never, I mean, lemme tell you, a hundred thousand years ago, humans were smart. They knew how to plant seeds. They knew how things grew. Right. But they just didn't have the capacity because of the change. Yeah. And temperatures and, volatility.

[00:22:41] And then all of a sudden poof. Just stabilized.

[00:22:43] **Peter Brannen:** Yeah.

[00:22:44] **Nate Hagens:** In the Holocene, what are your thoughts on that?

[00:22:46] **Peter Brannen:** Well, I think it's both. I think it's reciprocal. So there's an explanation that. you know, our genus shows up right when we go decline into the ice ages around two and a half million years ago.

[00:22:57] Is

[00:22:58] **Nate Hagens:** that right?

[00:22:59] **Peter Brannen:** Yeah, So you suddenly enter this really volatile period. So I, chart out this longer story of the Age of Mammals, where basically we inherited ma we the we mammals did the greenhouse. Sauna, climate of dinosaurs, and over 50 million years, you have this long slow decline in CO2, and it gets cooler and cooler until finally around, two and a half million years ago.

[00:23:22] You suddenly, well, around 34 million years ago, Antarctica, gets an ice cap for the first time, and then you keep declining. There's a little hiccup along the way, but you keep declining. And then around two and a half million years ago, you CO2 has suddenly passed this threshold.

[00:23:36] **Nate Hagens:** Where was CO2 then?

[00:23:37] Two and a half million years ago, roughly.

[00:23:38] **Peter Brannen:** I mean, it's where you start getting into this 2 80, 180 world that we've been seesawing in and out of, around then around 300 parts per million is, I think where people put the threshold. But then finally. Your blanket that you're wearing as a planet is thin enough that, these very regular changes to the orbit and the tilt of the planet that haven't really mattered, in the same way in earth history suddenly become hugely relevant.

[00:24:04] 'cause, they CO two's low enough that you can have ice forming if you have. Lower sunlight in the northern latitudes during summer, then you can build up ice sheets over year and suddenly you can go in and outta these crazy ice ages and that incredibly volatile, environment, which has switched between 40,000 year, then a hundred thousand year ice ages.

[00:24:27] and brief sort of spring times like the one we're in today. This is like an interglacial that if we weren't here, we'd have another ice age. Probably coming at some point in the next few tens of thousands of years is thought to have shaped humanity because it was an incredibly difficult and volatile world.

[00:24:42] it might have selected for things like the use of fire, which then totally transformed our anatomy and a lot of to have these energy hogging brains and have things like culture and language and technology, but. Things like agriculture in this volatile world were very difficult, both because you're having these rapid climate swings where if you are, if you wanna have some generational homestead, it's a bad idea if next year like a sandstorm can come and sweep it away.

[00:25:07] So it might've just been difficult to stay sedentary in one place long enough. But another interesting idea is that at least for the evolution of homo sapiens, which is only in the last, couple hundred thousand years, that during the last ice age CO2 might have been too low, because a lot of the founder crops are this older pathway of photosynthesis that's actually better at higher CO2.

[00:25:28] So they would've had a really difficult time, when CO2 is around 180 parts million. And you maybe you couldn't have even, had agriculture just 'cause there's not enough CO2 until around, you know, what, 11,000 years or so when, the Holocene starts.

[00:25:41] **Nate Hagens:** So, In all of your study of prior mass extinctions and the carbon, cycles, historically, what, are some of the main takeaways, the main lessons that you learned?

[00:25:54] **Peter Brannen:** I mean, the biggest mass extinction of all time we talked about it on the last podcast, is this thing called the End Permian Mass Extinction, where this is 252 million year million years ago. It's before dinosaurs evolve, but there still is a land ecosystem of predators and things like that. And

there's sponge reefs and trilobytes and sea scorpions and some stuff that people might have seen in a natural history museum.

[00:26:15] But, it's the biggest mass extinction of all, By far of all time, and it's caused by this, mind bending series of volcanic eruptions over tens of thousands of years in Siberia that are injecting tens of thousands of gigatons in the, of CO2 under the air, jackknifing temperature by something like 10 degrees sea and acidifying the oceans 10

[00:26:35] **Nate Hagens:** degrees c over what timeframe?

[00:26:37] Roughly?

[00:26:38] **Peter Brannen:** We haven't narrowed down to like 30,000 years or something. The ocean acidification, which is what happens when CO2 too much CO2 reacts to seawater. So all the stuff we're worried about today, but the less you learn from those is here's, if we just kept going as far as we could, it's like, here's the absolute worst case scenario, We're probably not gonna reproduce the Permian. but it shows you. The path we're on leads to some pretty gnarly, outcomes.

[00:27:05] **Nate Hagens:** So let me, double click on that. my colleague, DJ White, has been on the show, before, and, he's floating this idea of the HATM, the Holocene and Anthropocene Thermal Maximum as, a corollary to the paleocene, eocene thermo maximum.

[00:27:24] meaning that the things that we're triggering and the dissipative structure that is, mining and releasing this ancient carbon. Thousands of times faster than these volcanoes of past will lock in certain things. James Hansen has talked about some long-term potential eight to 10 degrees Celsius, which rhymes with

[00:27:48] **Peter Brannen:** Yeah.

[00:27:48] **Nate Hagens:** the PETM. Can you give any thoughts on that?

[00:27:52] **Peter Brannen:** So the PTM is this weird thing in the early age of mammals when it was already quite hot and over something like 20,000 years, the temperature goes up a further five to eight degrees Celsius, from a similar volcanic, event that was happening in the North Atlantic that then triggered, might have triggered some feedbacks where more carbon was released from, the environment.

[00:28:12] But there's something of a puzzle why that wasn't a mass extinction. 'cause it's, not too far off the map from some of the earlier mass extinctions. it could be that the earth system got more resilient in the meantime, the carbon cycle became more resilient for, strange reasons that we could get into.

[00:28:26] But that event leaves a very, visible legacy in the rocks that I think. Undoubtedly will, ours will resemble in certain ways. So I've seen oceanographers will show you these sediment cores that they pull up from the North Atlantic Ocean. which you have this calcar, kind of ooze this white stuff, for meters and meters, and then suddenly it goes red and becomes clay like, for hundreds of thousands of years.

[00:28:54] And then it goes back to. White chalky stuff again. And that's because it's an ocean acidification event. It causes a, coral reef collapse, which we're worried about today. you do see some extinctions, so we will leave a similar geological legacy in the rock. You see similar stuff in the mass extinctions.

[00:29:13] They're just more extreme. But I, there, I do often put myself in the mindset of like, if you're a geologist a hundred million years from now, what will our legacy look like in the rocks? And the pessimistic case is that it's something

like one of these mass extinctions where you might get, you know, just a couple funky layers of like black shale or something in the middle of limestone and a lot of crazy swings and isotopes that show you the earth system's going crazy in a lot of different ways.

[00:29:40] And then we're not there in the, layers above. The optimistic case is a few meters above. We're still there, in which case it meant that we figured out a way to live, into the future geologically. And we aren't just this carbon pulse as you describe it,

[00:29:52] **Nate Hagens:** but is it crazy to make a comparison, of the Holocene Anthropocene thermal maximum to prior, extinction events?

[00:30:03] **Peter Brannen:** No. No, not at all. it's gonna take hundreds of thousands of years for all the carbon docks that'd be put in the, into the system to get washed out and scrubbed and, turned into limestone.

[00:30:14] **Nate Hagens:** So right now, what we're doing, if humans went away tomorrow, it would take hundreds of thousands of years for Earth's processes to equate

[00:30:23] **Peter Brannen:** to get the last residual sort of bits out there.

[00:30:25] There's a lot is taken up. IM immediately after, I think this is somewhat new research in the last year or two. I think it used to be thought that if we stopped all emissions tomorrow, then it would keep getting warmer and warmer and warmer indefinitely into the future. I think the thinking now is that if we really do stop tomorrow, which we're not going to, then a lot of the carbon will be sequestered.

[00:30:49] You will have cooling off a little bit. the problem is the further we push on the system, we're really pushing into the unknown, because. Well, we aren't emitting CO we haven't admitted as much CO2 as the end Permian, mass Extinction or the PETM. We're doing it much faster. It's much more intense,

[00:31:08] **Nate Hagens:** like a hundred times faster or something like that.

[00:31:10] **Peter Brannen:** For the Permian, it's probably like 10 times faster than those volcanoes. 'cause they're over tens of thousands of years.

[00:31:15] **Nate Hagens:** Right.

[00:31:15] **Peter Brannen:** So, well, it's, the thing is the carbon cycle's incredibly complex and, we, don't perfectly understand it and we're really pushing on well forces that we don't really understand.

[00:31:28] **Nate Hagens:** Okay. So, Setting humans aside for the moment, explain what happens in the carbon cycle. The sunlight comes in, what percent like gets absorbed by the oceans and the forest, and then, contrast that to what's happening now with human economy.

[00:31:44] **Peter Brannen:** Well, we're just introducing this geological store that normally is not in communication with the surface.

[00:31:51] so the normal carbon cycle as it normally operates is you have this very thin trickle from volcanoes that is very, there's this very thin trickle out of the system as well. But in the meantime, it's being exchanged between the oceans and atmosphere and biosphere where, plant life is taking it in, turning it into organic carbon.

[00:32:11] The rest of life on earth is eating it and turning it back into CO2. which is a good thing because if photosynthesis, if unchecked could drain the skies of

CO2 in something like seven years, and that would be the end of life on earth. 'cause you don't wanna get rid of CO2. So there's this fast, crazy, jostle of it on the surface.

[00:32:29] And we are just retrieving all the old plant life from all of earth history. From

[00:32:34] **Nate Hagens:** millions and millions of years in a century or two.

[00:32:37] **Peter Brannen:** Yes. So this took up, this took 500 million years to build up this battery of fossil fuels in the crust and. Releasing it in a matter of centuries on the surface of the planet, and expecting that not to be chaotic and, disruptive, is just not realistic.

[00:32:53] **Nate Hagens:** So I'm gonna ask you a question that I've asked several guests and I've never gotten a satisfactory answer. So, pressure's on, often I hear that, well, no temperature leads CO2, not the other way around. Can you gimme the best scientific, explanation of what's happened in the past? if you look at a chart of CO2 in temperature, they're highly correlated.

[00:33:15] Yeah. But I understand there's quite a bit of nuance there, but what, why do we know that CO2 is the control knob as you write in your new book?

[00:33:25] **Peter Brannen:** Well, from just basic physical principles for one, so we understand like spectroscopy and what parts of the, electromagnetic spectrum, CO2, absorbs and reradiate heat, and it is a part of the.

[00:33:41] It's a part of the spectrum that is not really covered, very well by other gases. So, water vapor is a more powerful greenhouse gas, which another thing that, you know, climate deniers will point to, which is totally true, but water vapor, unlike CO2, it condenses and rains out on a matter of something like nine days on

average or something like that, where any additional amount of CO2 you put into the air, can stay up there essentially indefinitely.

[00:34:04] And so the water vapor is actually a feedback is a positive feedback. You, put this more permanent gas in the air and you'll evaporate more water into the air, which moves a lot faster, which will then keep the temperature a lot, warmer than it would otherwise be. So since we, since the industrial revolution, the water cycles increased by something like a quarter.

[00:34:23] **Nate Hagens:** what does that mean? The water cycles increased by a quarter,

[00:34:25] **Peter Brannen:** like evaporation and precipitation rates have ramp up. So there's more rain. Yeah, there's more rain, but there's also more drying, there's more droughts. But there's more water vapor in the air, which is a powerful greenhouse gas.

[00:34:36] it's just not the reason why they call it the control knob is 'cause it's kind, it, the other ones sort of are feedbacks to it and it does block out this very important, part of the spectrum. But you can explain the depths of the last ice age or the, the escape from them without CO2. And we wouldn't be in an ice age in the first place if CO2 wasn't in this sort of weird low state that it's been in the last couple, million years.

[00:35:00] Because we know when 50 million years ago, when it was a thousand parts million, it was a incredibly warm world that we would not be, we would, we're not evolved for. It's just way too hot for, mammals like us. So, yeah, I mean a lot of this stuff is pretty, was worked out in the 19th century. Just the sort of the role of CO2 as a, greenhouse gas.

[00:35:22] **Nate Hagens:** How frustrated do you get. Just talking to people that don't, haven't looked at it as deeply as you have because it's, I understand this pretty well, but I couldn't have explained what you just did. I mean, it's incredibly complex.

[00:35:36] **Peter Brannen:** Yeah. I mean, it's frustrating. I wish people understood how advanced this, the science was, because I'll go to these geoscience conferences and they're not litigating stuff that we figured out decades ago.

[00:35:49] 'cause that's a waste of time. And instead we're making these incredible advances and understanding earth's past and the way the climate has, looked and why, you know, how the earth maintains a habitable temperature and what happens when it gets outta control. And this is really exciting stuff and I love it.

[00:36:04] Which is why I got into it and I didn't get into it. 'cause I, you know, wanna argue about, the, basic sort of chemical and, Yeah, physical properties of this gas. I don't think that's very interesting. Like we understand that stuff. It's time to build on that, knowledge.

[00:36:20] **Nate Hagens:** These conferences that you go to, are they mostly in the United States or all around the world?

[00:36:25] And, my, I the reason I ask is, The pushback, and not agreeing and misinformation and such. Is that a global issue or do you find that concentrated in our country? primarily.

[00:36:41] **Peter Brannen:** I think it's certainly, pretty, I mean, it's. Very focused in the United States compared to like Europe. But my favorite conference I go to is the Geological Society of America annual meeting, which kind of moves around to different cities.

[00:36:54] But it's, also fascinating because in one wing you'll just have paleoclimatologists talking about things like the Permian or the PETM, and then you'll also have the exploration petroleum geologist in another wing talking about oil plays. And, you'll, go to these talks where people find some amazing dinosaur bone and they'll thank their sponsors and it'll be Exxon and, Chevron and things like that.

[00:37:15] And so it's this really weird melange of these, different communities that I feel like are in more conversation with each other than the public, presentation of it. You might think.

[00:37:25] **Nate Hagens:** So, if this is, on the top of your head, can you update us on, the emissions per year from global human impact?

[00:37:37] How much of that is getting absorbed by the oceans and the forest and adding to the increased CO2?

[00:37:45] **Peter Brannen:** in the atmosphere. Well, I know that to date the oceans have absorbed something like 30% of our emissions. I mean, that's why the oceans have conversely gotten 30% more acidic, since the industrial revolution.

[00:37:55] That's the flip side of them absorbing. CO2 is CO2 reacts with water to make carbon acid. So, and then forests, I know recently there's been this fear that they're basically not a sink anymore, that in certain parts of the world they're, I think in 2023 they,

[00:38:12] **Nate Hagens:** because of fires and such, because

[00:38:13] **Peter Brannen:** of fires and things

[00:38:14] **Nate Hagens:** like that, becoming a source of carbon.

[00:38:15] **Peter Brannen:** Yeah. But I also think there's this misimpression that forest are just, if we weren't here, forest would just be like sucking down CO2, which obviously isn't true. 'cause then CO2 would go to nothing and there wouldn't be life on earth. So it's really this interplay between, CO2 being drawn down by life, but then also being released by life.

[00:38:33] normally that's a good thing and it's imbalance. It's just that we are essentially metabolizing not life on earth. But we're calling up all these reserves of old life and fossil fuel. We're calling up

[00:38:44] **Nate Hagens:** our, ancestors.

[00:38:44] **Peter Brannen:** Yeah. And

[00:38:45] **Nate Hagens:** we're, and throwing a party with them.

[00:38:46] **Peter Brannen:** Yeah. And so we're throwing that balance wildly off by emitting like 40 gigatons of CO2 into the air on top of what life does it.

[00:38:54] **Nate Hagens:** So we are doing what nature would do. We're just doing it at, 8 billion hominid strong with airplanes and jets and factory farms and, skyscrapers and all the things. Yeah. So it's the scale of what we're doing that we're functioning like volcanoes of old.

[00:39:11] **Peter Brannen:** Yeah. and I, I. At the beginning of the book, I highlight this experiment from this French natural philosopher, Antoine Le Wasier, who in the 18th century discovered that if you put a gerbil in like a thing of ice, and you measure the gases going in and out, oxygen goes in.

[00:39:32] CO2 comes out and it melts some of the ice. And he did the same thing with a chunk of charcoal, and he realized combustion and aerobic respiration are just the exact same thing. So what we're doing is we're basically

aerobic respiring all, we're the most powerful organism in earth history. We're just eating all the life from 500 billion years and respiring it all at once.

[00:39:51] **Nate Hagens:** But in order to eat it, there needs to be an oxygen commons, which isn't talked about that often.

[00:39:57] **Peter Brannen:** Mm-hmm.

[00:39:59] **Nate Hagens:** There are fossil fuels on some of the moons of, Saturn and such. Oh yeah. But they're inert because there's no oxygen there. They couldn't burn.

[00:40:07] **Peter Brannen:** Yeah.

[00:40:07] **Nate Hagens:** There's no gradient. So, so we take the oxygen for granted and the oxygen is actually declining slightly in the atmosphere, but quite a bit in the oceans.

[00:40:14] Like over 2%.

[00:40:15] **Peter Brannen:** Yeah.

[00:40:16] **Nate Hagens:** What part of our, endowment of life is the oxygen commons that are part of this planet.

[00:40:24] **Peter Brannen:** Yeah. So a really wild thing I talk about in the book is this, why the planet is oxygenated in the first place, I think is not well understood by anyone other than from

[00:40:33] **Nate Hagens:** Strites.

[00:40:34] **Peter Brannen:** Well, yes. So photosynthesis is a necessary condition for oxygenating the planet, but it is not sufficient and weirdly.

[00:40:44] the charging up of the earth's trust with fossil fuels is the reason why there's a lot of oxygen in the air today. this is a very strange idea that is, seems like geologists are keeping it secret.

[00:40:54] **Nate Hagens:** The sequestering of all this ancient carbon is why we have oxygen. Please explain that.

[00:40:58] **Peter Brannen:** Yes. So if you, I mean, there's this, also, there's this mystery of the earth history that photosynthesis might have evolved something like three and a half billion years ago.

[00:41:08] And it doesn't rise to levels that we would find at all breathable until only the last few hundred million years, which sounds like a lot, but that's like a very short period of earth history. So there's this mystery, what explains this, gigantic gap. and the book I, talk about what actually oxygenates the planet is.

[00:41:25] If you imagine you have a tree somewhere and, it creates oxygen in life by making tree stuff. When it dies and decomposes or is eaten by beetles or fungi, they use the auction in the air to break down that organic matter and turn it back to CO2 and essentially use up the entire surplus of auction that tree would've made it in life.

[00:41:45] That leaves a surplus of basically zero oxygen. and there's about 800 times more oxygen in the air than, the pie of fear could make in the first place. So where does all that oxygen come from? If you imagine that same tree when it dies quickly, gets covered in sediment and is shielded from the oxygen made in life and is just preserved as a tree forever, then that surplus of auction, it made stays in the air.

[00:42:07] And this infinitesimal leak of carbon into the crust in plant matter, where they're economically exploitable, we call them fossil fuels, but there's a lot of, or organic carbon in the crust. That is what charged up the, atmosphere with auction. So the industrial revolution also couldn't have happened.

[00:42:25] It could only happen now hundreds of millions years later where you.

[00:42:32] Splitting these two reservoirs of highly reactive stuff until finally you can reunite them and then release all that energy all at once and then reach equilibrium. But like I said, with the origin of life, you have these two things that are way out of equilibrium and bringing them back to equilibrium releases a lot of energy, and that's what we're doing.

[00:42:48] **Nate Hagens:** So what do you think the future of Earth likely looks like? You could paint a distribution and tell me the midpoint of the distribution based on current warming projections, and CO2, from the best science that you're aware of. And before you gimme your opinion, how uniform is the distribution of the people that, that you know in, in the space?

[00:43:11] is there a lot of disagreement or are they converging on kind of a this is if we do nothing, this is where we're headed, sort of thing and then gimme your opinion.

[00:43:20] **Peter Brannen:** Well, I think a, it's pretty, it's a lot of scientists. Making conjectures about what human society's gonna do in the next few decades.

[00:43:29] **Nate Hagens:** Right. we, it's so difficult to Yeah. Because I've had a lot of like, unbelievable climate ocean biogeochemical experts on the planet, but then they get into talking about renewable energy and governance.

[00:43:43] **Peter Brannen:** Yeah.

[00:43:43] **Nate Hagens:** And Marxism or an, you know, neuroscience or whatever, just stick to the stuff that you know the best.

[00:43:49] And you just wrote a book on this.

[00:43:51] **Peter Brannen:** Yeah.

[00:43:51] **Nate Hagens:** So let's, keep the, human element out of it for now. Like the default if we don't do anything significant, what does the future look like 50, a hundred years from now? And, how sure are just the scientists about that without any interventions?

[00:44:11] **Peter Brannen:** Well, the most common numbers I see are like a little over three with these huge error bars, depending on whether the carbon cycle agree.

[00:44:19] Like is complies with our

[00:44:21] **Nate Hagens:** And what does that mean?

[00:44:22] **Peter Brannen:** So it could be, I mean, we don't understand the carbon cycle, perfectly, and you could have it reacts much more so like, things like permafrost, stores could be right, could release. I mean, there's a lot of

[00:44:34] **Nate Hagens:** unknowns.

[00:44:34] **Peter Brannen:** There's a, yeah. there's a lot of unknowns.

[00:44:39] things like forest dieback releasing a lot of carbon, changes in ocean biogeochemistry. The just, we don't really, as I said before, and the harder we push on the system, the. Less we understand what we're doing. So once you start

to look at that, like three plus range in warming the error bars, can, you can shoot for three degrees of warming and easily end up at four.

[00:45:03] And I don't know if that's a level of warming that human society, the way it's currently, organized. Can,

[00:45:09] **Nate Hagens:** well, since you brought that up, I'm gonna read you a quote from your book, which means that you wrote this, anyone who tells you they know what even four degrees of warming or more in a century will actually mean, or what that will look like on a planet gripped by ice ages for the past 3 million years is full of shit, especially if they are an economist.

[00:45:29] you wanna unpack that a little or. Is it pretty self-explanatory?

[00:45:33] **Peter Brannen:** Yeah, I mean, well, there's a lot of, you know, there's the standard beating up on Nord house saying that three degrees is actually the ideal, temperature, for, future human societies. But both the carbon cycle and human societies as currently constituted, I would argue, are complex, dynamic far from equilibrium systems that are completely unpredictable, or not completely unpredictable, but relatively unpredictable and layering that complexity on top of complexity and then asking the question, you know, will human, will humanity thrive in cer under a certain temperature regime?

[00:46:10] **Nate Hagens:** We're not thriving. Now at, one and a half. There's events. I mean, it's 80 degrees today. It's almost October.

[00:46:16] **Peter Brannen:** Yeah. So I would just caution or just counsel, Caution and humility as we're, pushing on these systems that we don't really understand.

[00:46:25] **Nate Hagens:** We're not good at either of those things.

[00:46:26] **Peter Brannen:** Yeah. So, but that would advise for like a precautionary principle that we shouldn't just sort of be complacent with oh two and a half.

[00:46:32] Maybe we can deal with that. Like, who

[00:46:33] **Nate Hagens:** knows. Well, this gets into another question is, if everyone in the world understood the 4 billion year CO2 history of Earth and US and how we got here, w would that matter, would that change the dissipative structure? I would like to think it would, which is why I have this platform.

[00:46:53] but it, seems like swimming upstream a bit

[00:46:58] **Peter Brannen:** for me, taking this deep time perspective has. It both provides sort of these grim lessons from the past, but it also inspires like a deep sense of gratitude and cosmic wonder that we're even here having this conversation both

[00:47:14] **Nate Hagens:** agreed

[00:47:15] **Peter Brannen:** because there are these earth systems that somehow made this place perfect for us.

[00:47:18] And then when you get into the nano machinery, the cell stuff that I talk about in the book as well, that's equally miraculous. The fact that we're having this conversation and we don't just fall apart after a few seconds is kind of incredible when you look at what's actually happening at the smallest levels.

[00:47:31] So there's, I think that has motivates me. You know, you might hear about climate change is, well there was the little ice age a couple hundred years ago, and this is just like, acid rain or some other pollutant, and it's all, you know, it's, there's precedence in human history. But when you realize that what we're doing is almost unprecedented in a lot of geological history and that we're

messing sort of with these, The things that make Earth, earth, that sense of wonder and gratitude to be here makes sort of red redoubles my, my, inspiration to care about this stuff. And so I'm hoping that telling that story inspires a similar level of, wonder based action, I guess.

[00:48:17] **Nate Hagens:** Well, I think wonder and Action are two different things.

[00:48:19] Mm-hmm. And I think the wonder is what we need more of.

[00:48:22] **Peter Brannen:** Mm-hmm.

[00:48:22] **Nate Hagens:** Because I think so many people argue about. Whether it's true or not, but in that argument, they immediately go to some solutions that aren't systemic and are not likely to work, and therefore the person they're arguing with will critique the solutions instead of just understanding the story of humans earth, CO2, and how we got here.

[00:48:45] We have to nail that first and understand it in a transpartisan way, in a science tethered way, so we understand the deep time story that brought us here. Full stop. Mm-hmm. Okay. Now let's have a conversation, right? What to do, if anything, what this means, who it affects?

[00:49:00] **Peter Brannen:** Yeah.

[00:49:01] **Nate Hagens:** What's at stake? that's how I see it.

[00:49:04] **Peter Brannen:** Yeah. and you can't really understand how radical the experiment running on the planet is now without that deep time perspective. So you hear people just say, oh, we're CO two's. As high as it wasn't the ply aine. It's like, what the hell's the ply? Aine, right. It is. 3 million years ago, the Panama Canal hadn't finished closing.

[00:49:20] There were camels in the Arctic with evergreen forest in the Arctic, and sea level was 70 feet higher, and it was before homo sapiens evolved by three, almost over 3 million years. Like this is a totally different planet and you can't really appreciate what we're do, how crazy it is to reproduce that climate in a matter of centuries.

[00:49:37] Unless you understand

[00:49:38] **Nate Hagens:** that, you said was three degrees Celsius higher than

[00:49:40] **Peter Brannen:** today. Yeah, three to four, something like that.

[00:49:42] **Nate Hagens:** Yeah. Yeah. So getting back to a question that I asked you before, how uniform are, are, people have a larger distribution of opinions in the climate science geoscience community than a decade ago?

[00:49:56] Or are they converging on this is what we face?

[00:49:59] **Peter Brannen:** I think they're realizing that sort of the hand waving, well, we'll just build solar panels and wind turbines and

[00:50:05] **Nate Hagens:** that door number one doesn't work. So now we're at door number two and three.

[00:50:09] **Peter Brannen:** Well, yeah. Or just that it's a couple bad actors and we could have done this easily if we had, if only there wasn't some villain somewhere stopping us from it.

[00:50:15] Yeah. Turns out it's a very hard, problem and I think people are realizing that this is, you know, a story for political economists and sociologists and, we know this, you know, it's not really a science question anymore. we're trying to

understand the sensitivity of the climate to different levels of CO2, but, the trajectory, you're asking me what is sort of leaving humans out?

[00:50:37] You can't really do that. We've become the most important part of the carbon cycle. So the response of the permafrost or the sensitivity of clouds. Just as important is in the next few decades, is how do these weird human institutions evolve and, modulate the carbon cycle? So it's un, I tried not to write about humans for a long time because it's so messy, but increasingly I'm realizing we just can't leave us out of the story.

[00:51:02] And that we're really the main, we're the main knob on this main knob on the planet. Now.

[00:51:07] **Nate Hagens:** The knob is moving. Whether we're controlling that or not is another, is a separate question.

[00:51:13] **Peter Brannen:** Yep.

[00:51:13] **Nate Hagens:** We're it's like the fourth law of thermodynamics sort of thing.

[00:51:16] **Peter Brannen:** Mm-hmm.

[00:51:16] **Nate Hagens:** But, you know, what are the biggest risks and what are the biggest opportunities, in coming decades?

[00:51:23] do you see from, this lens?

[00:51:25] **Peter Brannen:** I mean, I've always viewed my job as descriptive, and I'm very bad at the per prescriptive stuff. And I even say at the end of the book, well, here's, you know, what I've read might help, but who knows if they'll, this all adds up. Like China right now is trying to experiment where, going all in on.

[00:51:43] Solar panels and EVs and selling 'em to the rest of the world, which. Could work out, but right now they're burning four times more coal than the US ever did. Its peak. And they're saying it's gonna, it's gonna go down next year. But they've been saying that for a while. So we're, it's a big bet that this is,

[00:51:58] **Nate Hagens:** we,

[00:51:58] need fossil fuels to make solar and wind and batteries and the whole economic system.

[00:52:03] I, let me backtrack, because I've critiqued some of my own guests in the past where they step outside their wheelhouse. Mm-hmm. And I don't want you to offer prescriptions. I want you to tell us the science that you've learned. Yeah. Doing the deepest dive possible. And the reason I love interviewing people like you is if there was a climate scientist was a specialist on the Arctic or some microbes and that was their thing

[00:52:27] **Peter Brannen:** mm-hmm.

[00:52:27] **Nate Hagens:** You've had to integrate a lot of different disciplines to write your book. So you kind of have an aerial view on the aerial view. Yeah. so keep going on, on like what is the default? Like what are people not aware of the average person, what does a three C world potentially look like, and how likely is it unless we manage to find some, interventions or we run out of the stuff at the scale that we have today, and then that's a different challenge we face then,

[00:52:58] **Peter Brannen:** I mean, I think it's very likely that we end up in a three C plus world again, what that would mean for human societies where we have bread baskets in certain countries where crops would be completely jumbled up by where, you know, future changes to where droughts are and where.

[00:53:13] Reliable precipitation is, the average person on earth today relies on a supply chain for food of, an average of 1300 miles. So we have this and that food is shipped in bunker in commercial ships with powered by bunker fuel. and those, crow crops are irrigated with, fossil fuel powered pivot irrigators and fertilized with phosphate mined in Morocco, which is shipped across the world and spread on the middle of the, Midwest.

[00:53:47] And so we've built up this incredibly complex, networked, unbelievably energetic, global industrial civilization, you know, is really struggling to accommodate a degree. Plus C.

[00:54:03] **Nate Hagens:** Yeah.

[00:54:04] **Peter Brannen:** and all of human civilization, all of recorded history has happened, in a bizarrely stable window in this interglacial, which is kind of, we could talk about why that was.

[00:54:16] so we have this institutional memory of what the climate should be like, and we're just leaping into the unknown, having built this unbelievable, unbelievably complicated energetic Superorganism. And I don't know where the, stress points are or whether that could, you know, collapse like a network.

[00:54:34] You know, house cards in the mass extinction is actually one of the ideas is that the biosphere kind of collapse is not because, the stress gets so bad, but because you knock out enough nodes in the ecosystem that suddenly the whole thing.

[00:54:45] **Nate Hagens:** That's exactly how I see it. Yeah.

[00:54:47] **Peter Brannen:** So maybe, industrial societies like that too.

[00:54:50] We, don't know. And the harder we push on the system, the more we, you're,

[00:54:52] **Nate Hagens:** so you just mentioned something that I would like to know the answer to because if you look at historical temperatures. They're fluctuating all over the place. And then 10,000 years ago, it's like an EKG meter just stopped. Yeah.

[00:55:05] Why? I mean, I've never seen that in the grass before. Yeah. Do you, can you explain what happened to stabilize it for the, that and during the Holocene?

[00:55:14] **Peter Brannen:** So I explore a very intriguing idea that is still debated, but it was put forward by, you know, a very well-respected paleo climate guy, William Ruddiman at University of Virginia.

[00:55:26] And his idea is actually that in previous interglacials where you, so you're, you rock it out of an ice age and then, because of. The Earth's tilt in its orbit where sunlight is, hidden in different parts of the planet. You then slowly decline back into ice age, and then you pass these thresholds and you go back into a deep ice age again.

[00:55:45] And he has these graphs where similarly, at the beginning of the Hal scene, you, rock it outta ice age. And then when CO2 and, methane start declining in previous interglacials. We started declining and then we went up a little bit and then flatlined for a long time around 7,000 years ago. And he thinks that's because of land clearance for agriculture.

[00:56:05] Long before the industrial Revolution, emitted giga hundreds of gigatons of CO2 into the air and actually kept CO2 artificially high for thousands of years.

[00:56:16] **Nate Hagens:** So would've the default if that had not happened is CO2 would've continued down lower?

[00:56:21] **Peter Brannen:** Potentially, if he's right, then we would've started going back in on ice h thousands of years ago, which would've been a bad thing.

[00:56:26] so it's a good thing that CO2 remained artificially high. Yeah. But the alternative we've now done, which is launching us into this alien planet Yeah, from millions of years ago, millions is just as dangerous, I would argue as, that alternative trajectory.

[00:56:38] **Nate Hagens:** Sometimes I get frustrated that we're still talking about this and we're learning new things for sure, but we knew this.

[00:56:45] 30, 40 years ago.

[00:56:47] not as much as we know today. Mm-hmm. And now here, 2025, where you're explaining the carbon cycle to me, for our listeners, and it's our cognitive neocortex that's processing this, not our emotional thing, because deep time doesn't hit our emotions, which is why I used to give away lytes and, little insects trapped in amber to my students as prizes.

[00:57:11] Mm-hmm. Because they could look at something that was alive 80 million years ago trapped in amber. Mm-hmm. And it's like that affects your emotions a little bit.

[00:57:18] **Peter Brannen:** Yeah.

[00:57:19] **Nate Hagens:** But it's. I do get frustrated that we continually, even, I'm guilty of this, we have this naive assumption that there is an information, gap in the world.

[00:57:33] And if there was just more information that we would respond,

[00:57:36] **Peter Brannen:** we have this neocortex, but we're also an emotional animal and people have vested interest and people have jobs, then they have local industries. And, we can also be powerfully motivated to believe things that serve our self-interest.

[00:57:48] So, you can point show all the graphs you want to someone if they're not, If they're motivated not to learn it, then, they won't, I guess. and there's also powerful actors that work actively seeding the, public sphere with, misinformation. So

[00:58:06] **Nate Hagens:** from your perspective, of all the things you learned, what research still needs to happen, what things are you curious about or the community, the broader climate geoscience community, what are they really curious about and would like to understand?

[00:58:21] What's important to know?

[00:58:22] **Peter Brannen:** So I think on the, in the scary realm, it's what actually does go wrong in the mass extinctions because you'll have these few layers of rock and you'll get some wacky isotopic signals and you'll know a lot of CO2 came into the air and you'll know it got really warm over tens of thousands of years.

[00:58:38] But how that actually plays out and conver and is converted into the mast die off of most life on earth is still kind of a open question. I would say in a more inspiring geoscience question is, we really don't understand how. Animal life started, or, why auction started to rise latent earth's life and how this place became habitable in the first place.

[00:59:01] And given that it's the only inhabited, inhabitable place we know of in the entire universe, I think there's a lot of emphasis on going out and studying exoplanets and stuff like that. And I support that research. But, I think most people would be shocked how little we understand about how this place, how earth became.

[00:59:18] Came to be Earth in the first place. And so if people are fired by that question, I would tell 'em to get into geoscience. 'cause it's still a very active area of research.

[00:59:26] **Nate Hagens:** So a lot of the feedbacks that we can anticipate, like permafrost and, methane and things like that, are positive feedbacks in a negative sort of way.

[00:59:36] Mm-hmm.

[00:59:36] **Peter Brannen:** Like,

[00:59:36] **Nate Hagens:** they're gonna take us in the direction of Ven Venus ification.

[00:59:41] **Peter Brannen:** Yeah.

[00:59:41] **Nate Hagens:** Can you speculate, is there any wild card that Mother Nature might help us, even if humans don't choose the control knob? Is there anything on the horizon that might make the environmental circumstances, a little bit better than we would expect?

[00:59:58] Or is it just a unknown and you can't,

[01:00:02] **Peter Brannen:** I think it's mostly unknown. Unknown. I think so there's things like coral reefs, which most forecasts are just

[01:00:08] **Nate Hagens:** Yeah. I just

[01:00:09] **Peter Brannen:** un I just

[01:00:10] **Nate Hagens:** had grim a, guy on that said they're gonna be gone by 2050.

[01:00:13] **Peter Brannen:** Yeah. Which could be the case. Maybe evolution will surprise us.

[01:00:19] They might be more mobile than we thought. The coral reefs do migrate faster than I think people realized, not too long ago. So evolution could surprise us. Life might be more adaptable than, we give it credit for. It's been through a lot before. it's survived all the mass extinctions and then all the ice ages and things.

[01:00:35] So we just don't know. I think that's the thing is that we're just, you know, as we, as I said, sort of meddling with forces we don't really understand,

[01:00:42] **Nate Hagens:** but are there any negative feedbacks, that from your research? Yeah. you talked about rock weathering, but that's a hundred thousand years sort of thing.

[01:00:50] Yeah. are there any negative feedbacks that could kick in? Or are they all in the opposite direction?

[01:00:56] **Peter Brannen:** I guess it's like if ecosystems are more resilient than we give 'em credit for.

[01:01:00] **Nate Hagens:** Yeah.

[01:01:01] **Peter Brannen:** and I do, because I hang out with geologists, I do think on longer term timescales, and there are all these, if it really is kind of inspiring the way Earth brings its itself back from the brink.

[01:01:11] They're just on millennia, multi millennia, tens of millennia timescales.

[01:01:15] **Nate Hagens:** I've had many guests that use, different words to describe this. Tom Chi, who's a, innovator, says net positive for the planet. What if humans on mass widened our, boundaries of analysis are our values, our boundaries of care, where, what got us status and, public acceptance and approval.

[01:01:41] Were doing things that. Sequestered carbon or we're regenerative agriculture or things that, that actually did minimize the, trajectory that is the default that we're headed towards. So that is we are nature. Mm-hmm. And that would be doing things, combining technology with how nature works. Mm-hmm.

[01:02:03] **Peter Brannen:** Do

[01:02:03] **Nate Hagens:** you have any hope in that, direction?

[01:02:06] or insight?

[01:02:07] **Peter Brannen:** I don't know. all I point to in the book is that human societies have been organized around lots of different value systems. And if you look at sort of where the most expensive neighborhoods are today, or, you know, Ferrari dealerships and in, the, you know, sand flats and the Persian Gulf, and you see how energy is directed in society today, it doesn't seem like it's the most adaptive way possible.

[01:02:30] **Nate Hagens:** Turning billions of barrels of ancient sunlight into microliters of dopamine wherever you look.

[01:02:35] **Peter Brannen:** Yeah. but I pointed out that, you know, you. You find artifacts from human cultures, like sort of the communal, more communal way of organizing society of the longhouse, but you also have this spectacle of the coliseum.

[01:02:49] And so we've, been lots of different kinds of humans before. And whatever kind of human you find, hundreds of thousands of years from now, if we're still here, they will not be evaluating the same things we value today. They won't be, look, they won't look the way they do today. We will have found a way to, you know, streamline our values, how we organize society.

[01:03:08] We have these long term, Earth systems and cycles,

[01:03:12] **Nate Hagens:** they're gonna be hella surprise when they dig up all those, sex toys made out of plastic that last forever.

[01:03:18] **Peter Brannen:** Yeah. Right.

[01:03:20] **Nate Hagens:** I mean, I do wonder, the guy that made that movie Idiocracy, often says it was meant as a comedy, but I didn't know it would turn into a documentary.

[01:03:28] Right. So soon.

[01:03:29] **Peter Brannen:** Yep.

[01:03:29] **Nate Hagens:** So has your worldview changed since you read your, wrote your first book and now this book, you were on the show almost two years ago and we discussed some closing questions. ha Have you shifted in your, worldview.

[01:03:43] **Peter Brannen:** I think I'm just as agnostic about what the next few decades hold.

[01:03:50] but if anything, coming back to this sense of gratitude, I'm, if anything more grateful to be alive in the first place. Just 'cause I've done this deeper dive in geoscience and realized that, yeah, there's the scary moments in art history, but it's a miracle that we're here in the first place. So that's what I've come away with.

[01:04:04] **Nate Hagens:** I increasingly feel that myself. what's next for you, are you gonna write another book?

[01:04:10] **Peter Brannen:** This one was very difficult to write. It took me twice as long as I thought, and it ended up being twice as long physically as I thought it would be.

[01:04:18] **Nate Hagens:** How many hours does it take you a week to do this? And is it like studying for a final exam, but you don't have a professor?

[01:04:24] You have to be your own master?

[01:04:26] **Peter Brannen:** I, it kind of consumed my life for the last, like there was no concept of a weekend or anything like that really. If I, did have fun on a weekend, in the back of my mind there'd be this program running my brain.

[01:04:34] **Nate Hagens:** And, what percentage of that work was, oh, I have to write this book and I have a publisher and what percent was Peter Brennan's individual curiosity, I want to understand and learn this.

[01:04:43] **Peter Brannen:** It was a, wrestling match between those two things. Okay. Where if the publisher didn't finally put the foot down and say, you have to

give us something, then I would've just done it forever. but yeah, I mean it's a, kind of peril of this line of work is that, you know, I'm obsessed with it, which.

[01:05:00] so I, in theory, I wanna do it all the time. So

[01:05:03] **Nate Hagens:** what next question could you ask after writing this book, which is kind of the epic story of humanity in our planet?

[01:05:09] **Peter Brannen:** I think I'm kind of, I'm going to set aside things that happened an extremely long time ago for a little bit. and coming from this last book process, I find that in the same way that this book came outta the first book process, I find my attention now being drawn to this human component of the carbon cycle and understanding just where the rubber meets the road and where the lovers are in this thing.

[01:05:33] Because I think sometimes people talk like you can just wave this magic wand, but it, the human institutions that are actually, you know, pulling the levers here are things like sovereign wealth funds and private equity and, commodity trading companies. And so I've been doing this deep dive into, political economy and finance and things like that.

[01:05:55] I can just tell that I am reading things that are pretty deadly and boring in theory, that I'm actually very interested in. So maybe I should follow that line of thinking even more.

[01:06:05] **Nate Hagens:** You should follow my podcast.

[01:06:06] **Peter Brannen:** I do. Follow your podcast.

[01:06:07] **Nate Hagens:** Yeah. So this morning, what is today? September 22nd?

[01:06:13] **Peter Brannen:** Third.

[01:06:14] **Nate Hagens:** 23rd?

[01:06:14] Yeah. I recorded a frankly, uniting the last two weeks podcast, Luke Kemps and, Reed Malloy and Nancy McWilliams on psychopathy. And I came up with my own speculative theory that, the median human is different than the mean human. Mm-hmm. Because the tales pull us, A metabolic Superorganism.

[01:06:39] And so the formula is you combine large numbers of humans with vast energy surplus, with 1% adult males, clinical psychopaths, and you end up getting iterations of power control hierarchy and you end up where we are today. Not eminently provable, but it actually is really hopeful for me. To view it that way because this isn't who we are.

[01:07:10] We being 8 billion of us.

[01:07:12] **Peter Brannen:** Mm-hmm.

[01:07:13] **Nate Hagens:** there were many m much more sustainable cultures in the past that just got steamrolled with this conquest hierarchy, growth dynamic. Not all of us are that way, and there may be ways to bind this phenomenon in the future that I don't know and can only speculate. Do, you have any thoughts on that at all?

[01:07:34] **Peter Brannen:** Well, I would imagine other cultures previously had ways of channeling things like psychopathy and aggression. Well,

[01:07:38] **Nate Hagens:** yeah. They put people out on ice flows or they sent them into the monastery. but that was, its small numbers of people. Yeah. With a hundred people or 200 people, everyone knows each other and there's reciprocity and there's gossip and there's ceilings to what people can get away with.

[01:07:52] But now we have porous borders and you can move money and reputation, you know, with algorithms and everything immediately.

[01:08:00] **Peter Brannen:** I'm gonna listen to that podcast.

[01:08:02] **Nate Hagens:** Okay. Peter, Brandon, thank you so much for your Thank you scholarship your time. Do you have any closing words for our viewers?

[01:08:09] **Peter Brannen:** I don't think so.

[01:08:09] Other than just learn more about the carbon cycle. 'cause it is, it sounds boring, but it is, it's the whole story as I try to, claim in my book.

[01:08:17] **Nate Hagens:** The carbon cycle is also the story of us.

[01:08:19] **Peter Brannen:** Yes, we're an expression of the carbon cycle.

[01:08:21] **Nate Hagens:** Yeah. Thanks so much.

[01:08:23] **Peter Brannen:** Thank you, Nate.

[01:08:24] **Nate Hagens:** If you'd like to learn more about this episode, please visit The Great Simplification dot com for references and show notes.

[01:08:31] From there, you can also join our high low community and subscribe to our Substack newsletter. This show is hosted by me, Nate Hagens, edited by No Troublemakers Media and produced by Misty Stint. And Lizzie Ani. Our production team also includes Leslie Balut, Brady Hyen, Julia Maxwell, Gabriela Slayman, and Grace Brumfield.

[01:08:55] Thank you for listening and we'll see you on the next episode.