Rare Earth Elements Podcast - Nolan Theaker

[00:00:00] **Bridget Scanlon:** I'm pleased to welcome **Nolan Theaker** to the podcast. Nolan is a senior **research manager at the College of Engineering and Mines Research Institute at the University of North Dakota**. So Nolan has been working on quantifying the potential to develop critical minerals and rare earth elements from coal in North Dakota since about 2016.

Thank you so much, Nolan for joining me today.

[00:00:26] **Nolan Theaker:** Oh, glad to be a part of it and talk about **critical minerals and lignite**.

[00:00:30] **Bridget Scanlon:** So Nolan we first started collaborating a few years ago when we were both writing proposals for the Department of Energy C**ORE-CM Program**, Carbon Ore Rare Earth, and critical minerals. And I greatly appreciated your support because you had done a lot more work in this area than that we had done in the Gulf Coast, so that was huge. Thanks for sharing, also, the recent report by **Levi Moxness** and his colleagues at the **North Dakota Geological Survey,** which shows some very promising, rare earth element results from **coal** in North Dakota. So I guess these results came from additional sampling of about 50 different sites recently.

Maybe you can describe those results, Nolan and why it is so exciting.

[00:01:14] **Nolan Theaker:** Yeah, so then to kinda set the stage on the results, the past few years the North Dakota geologic survey is finally kind of narrowed down a possible **enrichment model** for rare earths in the coal. And so that's enabled them to kind of focus more on the expected high zones. And so what they found in the most, most recent board, I mean, they found some incredible enrichment in coal. On a **coal basis** as much as almost **6,000 parts per million**. On an **ash basis in certain samples, up to weight percent** in certain cases. Over one weight percent.

And what the exciting part for us here is they're finding thick, **thicker coal seams now**. Not just three six inch margins, but **multiple feet seams** that have this enrichment which is a lot more amenable to development, and finally, mining and extraction. A three to six inch seam isn't impossible to mine, but it's very unlikely to be economic.

But if we're talking about a multiple foot thick seam, that's certainly plausible for mining moving forward.

[00:02:17] **Bridget Scanlon:** Right. And the North Dakota Geological Survey has done a lot of sampling over the years, mostly in **outcrops** and more recently, these **boreholes**. So I think you have analysis for at least about a 2000, **2,500 samples,** which gives you some idea and that has allowed you then I guess, to define where you might find the highest zones.

And so the recent report mentions **two different members**, the **Bear Den member and the Rhame member** as being very promising. So maybe you can describe a little bit that conceptual model, Nolan, and what they have discovered.

[00:02:54] **Nolan Theaker:** So the operating model they're working under right now, which isn't necessarily the only enrichment model that can be true for coal. But what they found in North Dakota is the enrichment model honestly follows a very similar enrichment model to the **Chinese clays** in the southeastern part of China, where there was a **high temperature hot, humid weathering** period. Where essentially very **acidic rainwater** was **leaching** out rare earths from one strata, and moving it down to another strata where it could be captured. In this case, the strata, where it was being captured was **coal**, some carbonaceous clays and a few clay materials. Where it'd be, where likely the pH would change or you'd have the organic pickup. Essentially, that model means anywhere that they found really **heavy weathering of clays,** they start, they can analyze those clays, see if they're **depleted** in rare earths. And if they are, then you can start tracking below those clays in the subsurface to find where would be the first logical point. The rare earths would fall out, and they tend to show up there. And so it's not so much blind sampling anymore as much as if we detect a zone of **weathering**. Let's look below it at the kind of nearest possible zones where those rare earths could land, and we're typically finding them there.

[00:04:15] **Bridget Scanlon:** Right, and so then, the coal could capture the rare earths then, that were leached out from above. And I guess a lot of people have **carbon filters or GAC filters,** granulated activated carbon in their homes. Then that coal traps these rare earths just similar to what they use filters in your home for.

[00:04:35] **Nolan Theaker:** It's actually really similar because those filters are designed to try and get the heavy metals more than anything else. And the rare earths essentially being pretty high on the periodic table and atomic number, will functionally act as those. And so the coal will be more selective to grab those than things like sodium or calcium in their organic matrix. And so that's how it ultimately lands in the coal in that way.

[00:04:57] **Bridget Scanlon:** Right, so, so you mentioned a couple of things Nolan. So one is how you represented the concentrations and then how we evaluated the concentrations. So you mentioned **concentrations on a dry, coal basis.** And then you also mentioned on **an ash basis** and then how we evaluate to whether it's enriched or not relative to average values in the **continental crust.**

So maybe just backing up a little bit rare earths are not truly rare. They're found everywhere. You find them in your backyard. But the concentrations are generally low. And we don't find ore grade deposits, very much of rare earths. So maybe describe to the listeners a little bit about that background.

[00:05:40] **Nolan Theaker:** Yep. As you mentioned that the rare earths aren't particularly rare. They're kind of dispersed everywhere. And so in trying to find **economic deposits** of rare earths, you either have to look for very, highly **enriched deposits**, such as kind of traditional ores where you're talking about the **percentage range**, or you find deposits that have a very high percentage of valuable rare earths particularly the **magnets** and some of the heavy rare earths.

The **third option**, typically want at least two of these, is you want a deposit that's very easy to recover and it's very **easy to extract** from. And so it may be less grade, but if it's significantly cheaper to extract from, it's much better. And that kinda leads me into the ash basis, coal basis material. So on a **dry coal basis**, kinda what that means is that's how much rare earths are physically in the coal while it's still coal.

We're discounting any moisture attached to the coal. And why that's important is essentially you're not digging up ash, you're digging up coal. So this tells you how many tons of rare earths you physically dig up in the ground when you're mining this coal. That's actually more important for Univ. of N Dakotas process because we are a **pre combustion extraction**. We do extract from the coal itself.

So on an **ash basis**, you have a really high ash basis being essentially after you burned the coal, whatever's left, that's how much rare earths are there. You may have a really high ash basis number, but if you have an extremely low ash fuel, like let's say you have a thousand parts per million on ash basis, but you only have a half a percent ash, that means on the coal basis you're only talking about 50 parts per million.

So you'll have to mine tremendous amounts of coal to be able to get that. Whereas for us, us essentially being a pre combustion process, we care about how much is in the **coal itself.** So that dry coal basis number is much more important to us. And I also find it easier to compare ore resources because like if we're looking at like the traditional **rare earth mines,** they're talking about their grade as it sits in the **ground**, an ash basis number isn't as it sits in the ground, it's after you've processed it some.

[00:07:51] **Bridget Scanlon:** Right, right, so that can get confusing. So for example, if you had a thousand parts per million total rare earths on a dry cold basis. And if that sample had 10% ash then you would multiply that thousand by 10 on an ash basis. So I think sometimes people like to represent the data on an ash basis because it can really increase the numbers and make it look.. But I mean, it also depends how you are processing.

So you mentioned that **University of North Dakota**. You are working on the **raw coal,** you are going to extract the rare earths from the coal itself, not the ash after the coal has been burned at a power plant. And so then it's the concentration in the coal that's most important for you.

[00:08:36] **Nolan Theaker:** Yeah, that's correct. And the reason why we looked at the coal basis really for our extraction process is we found, once again the **ash basis number is going to be five, 10 times higher concentration than the coal basis**. So that's that higher grade that I talked about. What we found is that the process of extracting from ash, particularly fly ash, after a kind of a hot combustion in a power plant, makes it far more difficult to extract than what it was in the coal.

And so while you may be able to **enrich your overall material by burning it,** if you make it considerably **more difficult to extract**, it becomes kind of a challenge. Have you while you're processing less material, if you've added so much cost per material that you process, it may not be **economic**. Ultimately for **lignite** we have found, and I'm not saying this is true of all grades and may not even be true of all lignite, but for lignite generally what we've found is in the coal, similar to your discussion on that GAC filter the rare earths are attached to kind of in an **organic form.** They're not rocks, they're not minerals in the coal. And so it much makes it much, much easier to extract from that material, much more selective and easier in terms of cost than trying to get it in the fly ash. And so even though burning it gets you the higher initial number, it can be a lot more costly to to handle after that point.

[00:10:03] **Bridget Scanlon:** So there are a lot of **tradeoffs** to consider. So there's the **concentration** of the rare earths And then there's the **ease of extraction**. And that will affect what chemicals you can use if it's going to be **environmentally benign**, if you can use weak acids or things like that.

and then the **cost of those chemicals**, and so it all feeds into **economic analysis**. But, so the coal that you have in North Dakota is an **immature coal, a brown coal,** I think **lignite**. Similar to what we have in the Gulf in much of the **Gulf Coast.** It's a lignite And so those immature coals then the rare earths are still, you have found that they're associated with the **organic phase** and so can be much more readily **extracted**.

[00:10:46] **Nolan Theaker:** Yep, that's correct. So the oxygen in the coal that's still remaining before it **coalifies** to something like bituminous and anthracite coal. That oxygen gives it **organic functional groups** that can bind certain metallic ions. Rare earths have found to be one of the strongest bound materials that it likes to bind to.

And so, any kind of rare earths moving in a liquid phase that pass over this coal, similar to a GAC filter will get caught up in the coal. And so the coal is able to hold those in that organic phase, and then we extract them functionally in the same way. You would remove something off a GAC filter of essentially just a quick pass with a solution that elutes those ions, a **weak, dilute acid** as you mentioned, and then your material is back to unloaded of your rare earths, and you have your rare earths now in a liquid solution.

[00:11:36] **Bridget Scanlon:** Right, and the coal in North Dakota is different from the coal in, say, for example Wyoming, Western US and also the Appalachian basin. So those are higher grade coals, so bituminous coals and the rare earths in those coals are generally associated with the **mineral phase**. And, oftentimes more difficult to extract then they're associated with the **silicates** and others, and so requires a much stronger acid and more difficult to extract.

[00:12:03] **Nolan Theaker:** Yeah, or at least a different process. So I've seen some processes that don't necessarily need much stronger acids, but they require **roasting** and they require **fine grinding**, and that there's definitely some different processes needed. While it's still in that organic phase, which in sub-bituminous coals, there's evidence to suggest that some of it is still, those organic phases aren't completely broken down.

But as you get into those **bituminous** and particularly **anthracite** those organic phases are largely gone, and so the rare earths, if they stay in the coal, they have to form essentially a **secondary mineral** dispersed in the coal.

[00:12:38] Bridget Scanlon: Right, and so the Department of Energy **CORE CM program** then was designed to look at the potential for developing critical minerals and rare earths from **unconventional sources.** And so maybe you can describe a little bit the **conventional sources** like **Mountain Pass** Nolan, and how it compares then with the coals.

[00:13:00] Nolan Theaker: Yeah. So conventional sources, they're going to be essentially **discrete, rare earth minerals** found in kind of a seam that, like **Mountain Pass** that you mentioned there, there're kind of three main types of conventional rare earth minerals: **Monazite, Bastnaesite, Xenotime**. There are a bunch of other smaller ones, but those are the three major ones that seem to accumulate in certain zones.

And so things like, particularly in rich seams like at Mountain Pass, the rare earth is much, much, much higher than you would see in an inground zone. In coal, we're talking about **tens of thousands of parts per million** rather than few hundreds to potentially a couple thousands. But the form of the mineral kind of dictates what rare earths are going to be present in what amounts.

For instance **monazite** is a primarily a **cerium** based mineral. And so the light rare earths, Lanthanum, Cerium, Praseodymium, Neodymium, sometimes Samarium, pretty much form the vast majority of all the rare earths that will actually bind in that zone. Everything to the right of **Neodymium** as well as Samarium. Those generally are difficult to bind into that mineral and may go elsewhere.

You have different distributions depending on what mineral is present specifically and how that works. What we've seen, at least in **coal** is the distribution is a lot more similar to the **Upper Continental Crust**. It's able to capture roughly everything. Typically, it can actually capture heavies more than lights, which is relatively unique, but there are minerals like **Xenotime** that are more heavy, rare earth and rich. But the point of those kind of second, those traditional ores is much **higher in grade**, but the distribution may have a slightly less valuable distribution and they can also be a lot harder to process. We're talking about **hard rock minerals**. So you have to **roast** those, fully dissolve those in **acids**, and then work those up, rather than essentially an ionic substitution in the organic phase.

[00:15:03] Bridget Scanlon: Right, and so, considering the recent report then by Moxness and others. You have, high concentrations of many of the **permanent magnets** and the **heavy rare earths**. So, you mentioned praesodymium, neodymium being light, and then Terbium and Dysprosium being heavy. And so you have high concentrations of those.

And the overall concentrations, I mean, I recall on a dry cold basis you have, **1000 to two**, I guess the maximum was about almost **6,000 parts per million** total rare earths, which is all the lanthanides, the 15 lanthanides, and then yttrium and scandium.

[00:15:44] Nolan Theaker: Yep, that's correct. Yeah, that it found some pretty enriched. I mean, for coals in parts per million and the thousands of parts per million, is extremely rare. We haven't found that. With all the sampling everyone's done around the country, there's only a few zones where you find that regularly. And so now that they've kind of developed a model where they can regularly find zones in that concentration level is really exciting for essentially being able to develop this further.

[00:16:08] Bridget Scanlon: Right. Right. And when we were chatting recently, you mentioned in particular one of the **cores**, the core two, which is maybe I'm not sure. Is it like up to **five feet thick**? Possibly, with elevated high, fairly enriched rare earth elements. And I mean, if I just take one of the samples from there, the **two B two sample**, that's a thousand parts per million rare earth elements.

And then the **magnets**, the permanent magnets they're about 67 times the concentration in the crust. And they're the valuable rare earths.

[00:16:39] Nolan Theaker: Yeah, no. So it, it looks, really promising for what rare earths are present, how much there are, and then also the enrichment in **scandium, germanium, gallium** that we're seeing in these coals. All of those are also very highly valuable. And what we found is our processes at varying degrees of effectiveness, also able to capture those elements, concentrate them up, and produce those into a final product.

And so, it's not so much go after kind of the traditional, we go after the **magnet rare earths,** that once again, we're, 10 to a hundred to 500 times less concentrated than something like at Mountain Pass. So going after the magnets alone likely isn't going to be even in spectacularly enriched zones, it's going to be difficult to make that economic.

But if you go after these other elements, the g**ermanian, gallium semiconductor elements**, **scandium for alloying**, few other critical minerals. That can essentially help the overall economic picture of these extraction processes.

[00:17:40] **Bridget Scanlon:** So, we are talking about total rare earth, a thousand to 5,000 or 6,000 almost for the very enriched ones. And then, if you're trying to estimate the value, then you convert those to **rare earth oxides**. And then you estimate the price or the value of the samples, just as a back of the envelope, to get an idea.

And so maybe for listeners, maybe give them an idea of what the value would be. I mean, I was just doing some analysis for that **two B two sample.** $30 a ton for rare earth elements plus yttrium. And then if you add scandium that brings it up to $70 per ton. And then the primary magnets, then we're about $27 a ton just for that sample.

[00:18:25] **Nolan Theaker:** Yeah, and so that. What we try and do is at least for kind of a back of the envelope and it, this simplifies a lot of stuff. But yeah, try doing what you're saying. Essentially trying to convert it into what a **separated saleable value** would be.

So like the **magnets**, **scandium, germanium, and gallium.** Sometimes if **cobalt's** really enriched, we toss that in there as well. And essentially trying to figure out what's the **total contained metal value** in these. For certain samples of which I, I haven't done specifically the **two B two** specifically, but certain samples we've seen over a **hundred dollars, over $150** in separated metal value, particularly with those **germanium, gallium,** if they're enriched and tossed in what those show. In extraction process, at least ours isn't going to get all of that.

But we try and get at least a majority of what we can and the majority of the value. And in that then that kind of gives us an idea of how valuable this or resource might be. Now that doesn't account for the costs to actually reach those separated rare earths in those separated materials, which can be substantial, particularly in very dilute ores such as coal.

But what it does give you is essentially some idea of **comparing**. And if at least ores on the same type, so **lignites to lignites,** this has a total separated value of $200 and another one has 40. The 200 is very likely going to be the preferable one to pursue. And so it, it just essentially allows you to give a quick comparison tool.

Now, it's not going to be comparable to other seams. I personally wouldn't compare a separated value of lignite to a separated value bituminous because you're going to need a different process between the two. So I can't tell you if the lignite one's going to be better, if the bituminous one's going to be better based on just money alone, but at least lignites it gives within a single rank, you can figure out what the ores of greatest interests are.

[00:20:22] **Bridget Scanlon:** Right, and when I was just quoting those values for that one sample as an example, I was assuming, the **extractability** would be like **50%**. And you mentioned in the past, Nolan that sometimes you might restrict the extractability because of **uranium and thorium,** and you don't want to generate a **radioactive waste** in the process.

[00:20:44] **Nolan Theaker:** Yep. So in the process, I mean. Typically we find in lignites up to about 80 to 90% of the rare earths are organically associated. But unlike your GAC filter in your house or your water softener at home, it's not one seamless organic, it's a multitude of whatever nature threw at you in that organic stream.

So some bonds are going to hold the rare earth stronger than others. And what we found in our extractive process, once again, trying to extract from the organics. We can leave elements we don't want to extract behind by essentially just **tuning the extraction process** to only get what we do want. And **uranium and thorium** is an endemic problem in rare earth mining industries.

Like the lanthanides on the periodic table, that long list to the bottom right below them is the **actinides**, and they're very chemically similar. But what we found is at least while they're in their organic phase, uranium and thorium can be much stronger bound than the rare earths. And so if we only leach some of the organics, the uranium and thorium are still kept in a very dilute form in the coal.

Essentially what would be background normal, what you'd find in your dirt outside. Probably a radiation level lower than what you find in average bananas, as a note. But if you extract that in a rare earth process, they're going to follow the rare earths all the way to the end. And then, let's say the rare earths, let's take a **thousand ppm for sample. That's 0.1%**. If you concentrate that up to a hundred percent, that's a 1000 times increase. And if you have five parts per million uranium and concentrate that up a thousand times as well, you're now talking about a **half percent uranium**. That starts to be a problem in radioactivity levels.

So trying to keep them in that original dilute form can really mitigate the possible concerns downstream that processing would entail.

[00:22:35] **Bridget Scanlon:** Right, right. And so another aspect is, you have a lot of coal in North Dakota. I think I was reading someplace at **1.3. trillion tons of coal.** And in another report they were mentioning maybe **25 billion tons economically recoverable.** I'm not sure to what depth that would be. And these are young coals, **paleocene, eocene.**

And when you mentioned the conceptual model for the rare earth. The concentration was a **thermal maximum, I guess, in paleocene, eocene times,** and then the leaching of the rare earth into the underlying coals. So, when they say 25 billion tons of economically recoverable coal, what does that refer to?

Is it in the top hundred feet or 200 feet?

[00:23:21] **Nolan Theaker:** So that specific number to my knowledge was determined by, within the coals, within the **top 200 feet,** with the similar or lower current **strip ratio** as to the current mining strip ratios. Strip ratio being how many feet of overburden of clay and rock do you have to remove before you get to the coal, versus how many feet of coal are you going to be mining once you're in there?

And so that essentially allows you to say, okay. And so what that number does is it discounts things like a what **foot seam**, 50 feet away from everything else, because that wouldn't be economically recoverable. But if you have a **10 foot seam**, that's 50 feet away from everything else and strip ratio of then five to one, that would be considered economically recoverable.

But yeah, it's to a certain **depth and a certain strip ratio** to essentially make it so that, barring increases in essentially labor costs or fuel costs, general inflation, the cost to mine that, at least the physical amount of work needed to mine that, is still the same.

[00:24:25] **Bridget Scanlon:** Right, right. And some of the recent results are, the high levels are found near some **existing coal mines**. And so then they would benefit from all of the infrastructure and everything that's being used currently to mine those coals. And so without too much additional capital costs, then you could likely extract the rare earths.

[00:24:48] **Nolan Theaker:** Yeah, that, that's one really key aspect we're looking at least, right now for the short term, is what's nearest or in the coal mines that we could potentially use those resources with essentially just a slight expansion or change to the existing mine. Rather than trying to go after new resources, you'll have to **permit** a new mine for that being said, if there are truly spectacular resources, I mean, if we found a five foot thick, 5,000 part per million coal somewhere else, you would eventually try and mine that. It might take quite a bit of time because you'd be designing about that, you'd have to build a new mine for that, but that would be a goal.

And kind of adding onto that mining concept, one thing our technology focused on, since it's **pre combustion,** we extract the rare earth, but we don't damage the coal. We actually **improve the coal** as a result. And one thing we've looked at is with that really improved coal, there's really **ultra clean organics** in there.

What kind of **side products** can we make? We've looked at **fertilizers**, we've looked at **graphite**, **building materials**, a whole variety of things. But in this new mine scenario where we're talking about opening a new coal mine to get these rare earths, the envisioned goal I see is there'd be **no CO2 generated**.

You wouldn't burn any of it. It would go all into **products**, and there's actually a potential pathway where you could actually mine a hundred percent of your coal, have **no coal waste** of any kind and **no combustion,** and you have various carbon products and your rare earths and critical minerals extracted, essentially with a no combustion, no ash pits, no waste kind of mine, which is really exciting for us. Mind you, that's still many years away because that's permitting a new mine. But the idea of essentially a mine that produces no CO2, and produces no ash pits, and there's no horrible wastewater impoundments or tailings impoundments you have to worry about, I think is very promising for the future of mining and the focus on new sustainability.

[00:26:45] **Bridget Scanlon:** That's amazing.

So, I was looking up, it seemed like you've got **four big active mines** and **two smaller mines** operating in North Dakota at the moment. **Center, Falkirk, Freedom, and Coyote.** All of those have a **mine mouth power plant** also, so they have a power plant at the mine.

If you could find resources near some of those active mines that would be interesting, would really alleviate much of the cost.

[00:27:13] **Nolan Theaker:** Yeah. And that's kind of also how we're viewing our kind of process. I mean, lignite is only extremely rarely in the world shipped anywhere. It's a lower grade thermal coal, so it doesn't have the same **BT units per pound**. It also typically has a tremendous amount of water, **30 to 40% to 50% water** in some cases around the world. And so, I mean, you don't want to ship water around on rail that, that ends up wasting a lot of money. So typically all lignite, you process it right wherever you mine it. And that's kind of what we would envision for our processing technology too, is we want to locate **right beside a mine**.

And what we're trying to identify is, what we think we understand from the economics and kind of, technical basis of our technology to date, is it actually makes more sense to have **multiple plants at multiple mines** rather than have one huge plant that mines then ship material into. Because that shipping cost is going to grow very rapidly, because of how much weight of material we're shipping that doesn't have rare earths, or isn't even coal, and it's just water.

[00:28:17] **Bridget Scanlon:** Right, and I was looking up at the **electricity generation in North Dakota** and noticed that, in **2023**, about 20, **22**% was from coal of your electricity, 15% from hydro. You have the second largest **reservoir** in the US, Sakakawea. And then 20% from natural gas 22% from natural gas, 26% from oil. That surprised me.

I don't, I'm not familiar with many oil power plants. But that's what I saw from the EIA data. And then 15% from wind.

[00:28:53] **Nolan Theaker:** So kind of clarifying at least that those, somewhat numbers, that's kind of a, yeah. That, that's essentially what's consumed in North Dakota. That's not necessarily what's produced. Vast majority of **coal, electricity goes elsewhere on major power lines**, so that oil consumption for kind of what that looks like is in the territory of like **generators** in the **oil fields**.

So that's essentially small scale. Those aren't power plants, but those are essentially. A lot of everything you want to use to power these different facilities. I just saw that for all of North Dakota's generation capacity and not just consumption, **coal's about 55%** wind is actually still pretty high up there. **Wind's 36%** actually. So it's one of the highest renewable states that exist actually, apparently.

But the vast majority of the electricity is sent out of the state, so that's why 36% wind generation, but consumption's only 15. The vast majority leaves to things like **Minnesota and Minneapolis** to the Iron Range up north in Minnesota, into Montana, and a few other zones.

So North Dakota's a very heavy electricity exporting state, and so that's why the consumption numbers are radically different than the use numbers, in terms of what what's there.

[00:30:10] **Bridget Scanlon:** Well, thanks for clarifying that because, I was just trying to understand what was going on. And of course all that oil, you say small generators and stuff like that. And you have the **Bakken oil field**, so you are producing a lot of oil from the Bakken, and so they need a lot of generators and stuff to, to keep that stuff going.

So that's interesting. Yeah, I was a bit perplexed.

[00:30:31] **Nolan Theaker:** And at least historically the **Bakken** was very remote. There, there wasn't water capacity, there wasn't electricity capacity in a lot of those wells. And so they essentially needed a local generation on the well site and not just hooking up to power utility lines. They're now expanding **transmission** up there so that essentially, hopefully we, we burn less oil and burn less gas for electricity.

We can use the cheaper **coal**, more **renewable wind** or cheaper wind essentially in that, and sell more gas and oil. But that's the sudden demand that the Bakkens had, I mean, only in the last like 16 to 20 years has it been really heavily active. And the gigantic energy consumption that it is, it, there's a lot of transmission lines going there, but **transmission lines** are very slow to build, very slow to permit, and so they take some time to materialize.

[00:31:27] **Bridget Scanlon:** Right, I can understand. And I know in Texas, you mentioned North Dakota, you have a lot of wind. And we do in Texas also. And I think many years ago they spent $7 billion on expanding the **transmission** from West Texas to the population centers in Central Texas. So the **Crez Line**.

So, Nolan, a lot of your work then has been looking at **extraction** of the rare earths. And you mentioned that they're associated with the organic phase and so they're readily extractable. And so typical percentages that you can get at the lab scale, at the bench scale. And then you also have been working a lot on scaling up the process to pilots scales. Maybe you can describe that a little bit.

[00:32:08] **Nolan Theaker:** Yeah, so on. Can I answer in the first part first of like, what can you really realistically **extract**?

Once again, I mentioned about **80 to 90% of the rare earths** can be organically extractable. It doesn't mean that 80 to 90% should be extracted for kind of the **uranium and thorium** reasons. Typically, what we find economically best and most sustainable is somewhere in the territory of that **50, 60 ish percent.** Just so that uranium and thorium don't come out and become problems. And that's what we kind of find throughout the various scales. But on the scaling up the facility, once again, we started testing in 2016 on how were the rare earths associated and what can we do? In a lab scale, worked that up to a bench scale where we're then processing in essentially 55 gallon tanks, or that scale was about 10 to 20 kilograms per hour of throughput.

And now at our pilot scale, we scaled that up to about **500 kilograms per hour** of throughput, about half a ton, and that we're processing essentially tons of material. For instance, like the most amount of material our bench scale ever processed was, I think in total is probably about four tons of coal.

And that's what we do within a day at the **pilot facility.** And the pilot facility is now processed over **140 tons to date.** So this has given us kind of more confidence that this technology does work as we scale it up. The efficiencies aren't just a lab, lab phenomenon, they only work in the lab. And as you go to more industrial equipment and potentially dirtier environments, it becomes more challenging.

We do still get similar efficiencies similar chemical usages. All of those things are roughly the same. We've actually found we can potentially reduce those through some variety of things that are much easier to test on a pilot system than in a lab, just from kind of process control and developments in that way. But, from a technology readiness standpoint with this pilot data, we feel comfortable that essentially if we had an ore that looks really promising to move to a commercial scale, we could pilot that, get all the data that we could use for an engineering of that plant and then build that plant. I'm, we're not certain we need really another scale up.

If we were going to a massive scale, millions of tons per year, yeah, we'd probably want at least one more intermediate scale up. But the next scale that we're looking at, which can be commercial plants that live on their own and produce a profit and pay for themselves, those are in the hundred thousand per year ton per year kind of range.

Few hundreds of thousands.

[00:34:44] **Bridget Scanlon:** Well that's fantastic and, I hope that in the Gulf Coast, because we have similar lignites. And you've done some preliminary analysis indicating that the rare earths of the **Gulf Coast** are also associated with the **organics** and maybe you could use the same extraction procedures with those that you could parlay all the knowledge that you have developed in North Dakota to the Gulf Coast.

[00:35:06] **Nolan Theaker:** That's certainly the hope. And yeah, as you mentioned, the tests we've done it, it's sometimes not quite all the way to 90%. Maybe it's only in the **75 to 85%** organically extractable. But in essentially our process where we're only aiming at that 50 to 60 range is a good chance we might still be able to get almost very similar performance to the Gulf Coast lignites as to North Dakota.

And if there happens to be less uranium and thorium or actinides in the Gulf Coast, we might even be able to get more.

[00:35:36] **Bridget Scanlon:** Right, right. And so, when you process this pilot scheme, then you are creating a mixed, rare carbonate. Is that correct? With a certain purity, and then you would send that to another place like Rare Earth Salts in Nebraska to purify it further.

[00:35:54] **Nolan Theaker:** Yeah, so the process is making a mixed rare earth concentrate. There's kind of **three forms** available to us right now. One is an oxalate, which is exactly how we precipitate it, but nobody likes processing that, so we typically try to convert that, either into a carbonate or just a direct oxide for processing.

But those, all th**e rare earth**s are together. They're in a **purified form 75**. We've hit as much as **93%** pure rare earths. But then you don't use **mixed rare earths** in anything. Typically, you only want neodymium or your lanthanum, or you want terbium. And so you have to **separate** those. And so we've worked with a refiner **Rare Earth Salts** to essentially qualify our material.

They are able to separate it. We have produced **concentrates of purities** that they say would be saleable in that kind of **70 plus, 75 plus percent range**. So there, there's essentially hope there. And also the process, the g**ermanium and gallium**, we end up, kind of putting into those final concentrates as well.

One technology we're looking at with **Micro Beam**, which is another company we work with, is actually in our **roast**, and some of our roasting steps where we convert it into a **carbonator** and **oxide**, can we capture the **germanium or gallium** in those roasting steps to essentially get that separation for free, functionally, because the process needs to roast those anyway. And get those materials in a much purer form.

And so we're looking at exactly what we're going to include, but in a **commercial facility,** we don't envision this plant having its own refinery, unless a refinery kind of commingles with us. These plants, at least from coal that we're talking about, I mean, **Mountain Pass** is what, **30,000, 40,000 tons per year of rare earths** we're talking about a **couple hundred tons of rare earths per year** that it doesn't make sense to build out a huge refinery for that plant alone. But it can sell to other refiners. One being **MP Materials** themself in their refinery because they're looking for heavy rare earth concentrates of which lignite forms are this. And also **Rare Earth Salts** that we've already worked with in the past, and that have already looked at our material and seen what essentially they can do with it, so that.

[00:38:04] **Bridget Scanlon:** It's very exciting. And **MP materials**, I think maybe they're in Dallas Fort Worth area, that's Mountain Pass materials that I guess is linked to Mountain Pass some indirectly, or something. And **Rare Earth Salts is in Nebraska**, so. It's great to link up with them.

The price of Rare Earth is sort of **volatile**. But you have a lot of **co-products** that would help to stabilize the economics of the operations. And you described those briefly earlier on, **humic acid** for soil amendments. That's really **ultrapure activated carbon**. And then **Americarbon liquifaction** for eco pitch, for **coal tar,** and then **synthetic graphite and graphene.**

So lots of different things. And you mentioned **Micro Beam** and also **Semplastics**. So a lot of options there.

[00:38:53] **Nolan Theaker:** So the idea behind kind of these co-products that, on the one hand, most people don't want to make a **commercial** plant even more complicated than it needs to be, but. For these rare earth prices, without a guaranteed price floor for the rare earths from the federal government or something like that, there's concerns that, the rare earth price is too volatile, or China or other actors can move the rare earth price with dumping or restricting access.

And so, these plants for **long-term industry viability** need something to help **stabilize revenue**. And the way we've kind of envisioned that are these various products. So **germanium and gallium,** they're not rare earths, and they have volatile markets, but they're not paired with the rare earths. So their volatility is different than the rare Earths.

And so they kind of allow you to have multiple revenue sources that aren't essentially associated with the same basis. And also what we've found, **carbon products.** I mean, if we're talking about extracting **0.1% of material**, you want to do something with the 99.9%, what's remaining? And that's going to be the carbon products.

And why we're looking heavily at that. We purify the **coal** a lot or the organics and the coal a lot. And so there's a lot of advantage to using that for **non combustion uses**. It still is good as a blend fuel, but we have interest in non combustion uses. But those carbon products then, like if we're talking about, old tar pitch, like the **Americarbon process,** it has a wildly different market than the rare earths and germanium and gallium. And so that pairing means that a plant can depend on the carbon product revenue potentially to help stay afloat. While the rare earth price plummets due to foreign manipulation or like in graphite or graphene, those can help stabilize the price while other prices are moving to fluctuating too much. And so it gives a variety of kind of, revenue sources to help make sure you're not reliant on only one source.

[00:40:57] **Bridget Scanlon:** Right, and the quality of the products, like you mentioned earlier, **humic acid, that would have less than 0.25% ash.** So that would be ultrapure so that could get a higher value. And then maybe there may be some value making sure that you have **zero**, reduce any **waste** that you might create in the process.

So that would also give you positive points.

[00:41:20] **Nolan Theaker:** Yeah. And to be clear, I mean, we haven't figured out what the best **carbon product** to use for this is. We're still essentially trying to figure it out. I mean. We've only been producing **tonnages** of this stuff very recently, and so somebody who wants to test, "Ooh, will this work in making **bricks**?" Getting 20 grams of material isn't going to help them to determine whether bricks can be made from this.

They're going to need much larger quantities. And so now that we are at the **scale** of making larger quantities, we're starting to essentially figure out what are the best uses? Where does this treated material have the biggest value add in other processing technologies where essentially they can take advantage of what we've done and not essentially just use the coal separately for a completely different reason.

And so we're still trying to figure that out, but we do think there are some very promising opportunities that take advantage of those clean organics.

[00:42:15] Bridget Scanlon: And the product that you generate, then, maybe like the bricks could be **stronger**. I mean, some of your preliminary analysis suggest that after processing it for the rare earth, then that you create a stronger product.

[00:42:27] Nolan Theaker: Yeah, so **Micro Beam'**s testing found that any coal that we, our process treated, and it was any coal, it doesn't necessarily have to be the rare earth enriched, although that's what our process would focus on was about **20 to 40% higher strength** with their binder than without our processing method. And the reason essentially, we suspect it wasn't fully confirmed in those projects was that those **clean organic bonds** that are much that, that are now essentially purely **organic carbon, oxygen, hydrogen** rather than mixed with these inorganics, can form better bonds to their **organic binder.** And essentially those better bonds create a stronger product, that is less brittle, less prone to cracking, and also has strength in the **concrete levels** of territory. Which was really exciting for us to see that, yes, there are value additions here.

Also, the mentioning that the **humic acid**, that, essentially the humic acids produced from coal that's been treated this way can have as little as a quarter of a percent ash, whereas kind of if you extracted those from lignite directly, they're in the 4 to 5% range. That's a significant purification that essentially is done through this extraction process, and we would hope that we could get some value add in those propositions as well.

[00:43:48] Bridget Scanlon: So, last couple of questions is, so the **Williston Basin** is a large basin. I've never talked to you before, but I mean, it extends into **Canada**, right? Or are the Canadians looking at any of this or they've got other more promising rare earths?

[00:44:01] Nolan Theaker: So we've actually talked with the **Saskatchewan Research Council** before, right? North Dakota. Williston Basin extends into them. They happen to be blessed with more conventional, rare earth mineral resources that they're looking at developing now. And so they haven't had a extreme focus on their searching for their lignites, but I don't, it stands to reason that if there are enriched rare earths and lignite in the same geologic strata in North Dakota, there, there's no arbitrary line on the map. Our arbitrary line on the map called a border isn't going to make geology change north of that border as well.

So it stand to reason, they probably do have some pretty enriched stuff. **Montana** has a bit of the Williston Basin too, so does South Dakota. But, and essentially some exploration around those is now beginning and IT, and focusing particularly on the US side with the CORE-CM program you mentioned.

But those were just very early stage rather than the **North Dakota Geologic Survey**, working for the past 11 years and spending millions of dollars at the state, funding them with millions of dollars to really explore this and really develop the mechanism they have.

[00:45:07] Bridget Scanlon: Right. Well, thank you so much. Nolan. Our guest today was Nolan Theaker, and he was talking about rare earth elements and critical minerals from lignite in North Dakota. And we both collaborate in the Department of Energy CORE-CM program. And hopefully we'll have the next phase of that to collaborate further.

Thank you so much, Nolan.

[00:45:28] Nolan Theaker: Thanks very much for hosting me.