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The Rare Metal Age

David Abraham and Eli Kintisch

AT a recent American Association for the Advancement of Science (AAAS) Center for Science Diplomacy (publisher of Science & Diplomacy*) event, Eli Kintisch discussed the role of rare metals in international relations with David Abraham, the author of the new book* The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age.

Partial Transcript

Eli Kintisch: So we live in an increasingly complex world. Today we’re going to talk about the material aspect of that complexity. A person today consumes ten times…the amount of minerals that they did at the beginning of the twentieth century. And the aspects of that—the facets of that changing dynamic between people and the earth—are the subject of David Abraham’s new book, *The Elements of Power*. I’ve known David for probably twelve years as a friend here in Washington. He worked, before, at the White House Office of Management and Budget [OMB] overseeing natural resources. He worked as an analyst on risk at Lehman Brothers

David S. Abraham is the director of the Technology, Rare and Electronic Materials Center and author of The Elements of Power.

Eli Kintisch is a contributing correspondent for Science. *His work has also appeared in* The Washington Post, Slate, Discover, MIT Technology Review, *and* The Daily Beast.

and then at Barclays. And he's run an NGO called Clearwater, which focuses on water issues in Africa.

Now David is mostly based in Bali. And his book, I think, is going to be a very important part of the discussion on sustainability, materials, our lifestyles, as well as some of the new geopolitical and scientific challenges that face us as we get into a world where our relationship with minerals is much more complex than before. So I'd like to thank you all for being here, and ask us to welcome David Abraham.

David Abraham: Thank you very much, Eli, for the generous introduction. I want to thank AAAS, as well as Tom [Wang] and Caitlin [Jennings] in particular, for hosting me here. …Rare metals came to my attention when I was in Japan in 2010. I had the good fortune of working in Japan's Ministry of Economy, Trade and Industry in late 2010 when China restricted exports of rare earths. And I—as one of…two foreigners working in the ministry—I thought I had a great ringside seat to what was going to be one of the great geopolitical battles over resources; one that we hadn't expected in many circles. And what amazed me was, after China had restricted what seemed to be these obscure materials, Japan capitulated on a lot of China's demand regarding this territorial dispute, which brought up the original export ceasing to Japan.

And, so I wanted to understand: what are these rare earth materials? Why are they important? So I did some digging and found out that China exports and produces roughly 95 percent or 98 [percent] depending what you read, and that Japan is wholly dependent on China. I did some more digging and found out that they fill very critical roles in magnets that are in phones that help with the vibration or the sounds. They're in wind turbines. They help make energy air conditioners that much more energy-efficient. There are a number of roles that they fill, so I started to do more digging and tried to learn about other materials that may fill similar roles. And I looked into indium and antimony and tungsten, and I found out that Japan and the world is really dependent on a whole set of specialty metals that we really though not much about. And rare earths—this set of seventeen metals—came to the fore that were really dependent on a whole bunch of resources for very specific functions that we never thought much about.

Now, when I look around, I look at the products that we have every day, and I look at the smart phone, and what amazes me most about the smart phone is it takes roughly half the elements known to man to make this thing. There's indium in the phone, which allows your finger to interact with the applications. It serves as this transparent conductor. There's dysprosium, which helps with the vibration. [There are] even metals that help make the iPhone. There's cerium, which buffs the glass super smooth. So each one fills a very specific role, and without one of them, there's a problem to produce at all. …The fact that we can produce these things at all is as impressive as the functions that it can do.

So, I spent a lot of time trying to look at the future resources that we're going to need, and I look around at the growing technologies that we're seeing, and it is in the high tech area; it's in the green tech area. And as we start to push further into green technologies, as we start to need batteries in larger quantities to fill various green technology goals, we really need to start to understand what it takes to make these things. So my book, at its very highest level, is [trying to] give some insight into what it takes to make the materials that we need now and that we're increasingly going to need, because there is no ingredient list on the iPhone package. And I think we increasingly need to understand what the ingredients are.

Eli Kintisch: …In your book you write about a coming resource crunch. What do you mean by that, and what do you think's going to happen?

David Abraham: So I talk at the beginning about demand, that we see this demand coming. And these materials are wonderful things, because they allow us to do so much. Scientists are just starting to play with these materials, because, unlike copper—[which has] been around for millennia—we're just learning what these materials can do. So [there are] a lot of great opportunities that could come about. It's just like a chef who recently got a whole bunch of new ingredients.

The demand is there; the question is the supply. And when I looked at the supply lines for rare earths, you saw that they were mostly in China. And that was because of a number of reasons, because of geological good fortune, but also some government policy. And what you see is that throughout the whole rare metal industry—indium, niobium, tungsten, metals that are usually produced in smaller amounts, in the hundreds or thousands of tons rather than the millions of tons for base metals—…they're really limited to a certain mine or a certain country. So there are sovereign risks that loom quite large in the industry.

But beyond sovereign risks, what you're seeing is [that] the challenge to set up new mines or metal processing is tremendous. And research, whether it's from the U.S. government or from the EU or industry, will show that it takes ten to fifteen years or even longer to set up supply lines. So if we're looking to the future and trying to predict the resources we're going to need in 2030, that's going to be a little bit challenging. And what we're seeing right now is there's not a lot of investment going into commodities. Commodity prices are low, and there is a cyclical nature to all of this. But what concerns me most is that these materials are so challenging to produce that just because you have it in the ground doesn't mean you can produce it economically.

So, when I'm talking about the crunch, it's not "can the market produce it?" or "are we running out of these materials?" it's "can we produce them [in a] timely [way]?" Because my biggest fear is we're going to realize that there's a great potential to some of these resources, and we can't deliver them at the right price, or the right quantity at the right grade, or at the right time, so a lot of these resources of the future will remain resources of the future. And…we won't be employing them in a lot of green technologies where otherwise they could be used.

And one other point that concerns me is that here we are with a whole bunch of new ingredients to use in our products, and some of our best scientists in the world—especially in 2011, 2012, 2013—were trying to find ways not to use these materials. They're the best materials for certain applications, but our best scientists are finding alternative ways. And I think that's useful if the material is in very limited quantities, but when it's a geopolitical concern, we're ceding a lot of the periodic table to elsewhere.

Eli Kintisch: You say in your book that there is a kind of mismatch in supply and demand. Why won't the market ensure the right amount of materials reach the market—reach the people who need them?

David Abraham: I think, when you look at the market, it's always a specific point in time, and I think what I'm trying to highlight is the timeliness issue. Producing certain rare metals is akin to producing fifteen-year-old scotch: it takes fifteen years to produce it. So if you need them tomorrow, unless the supply chain is already there, you're not going to produce more to meet the demand, so price will increase. There are a number of ways that capacity can increase, but my fear is that the market doesn't work timely enough to produce the materials when we need them. And because of the critical nature of these materials, I think there should be more thinking about how we can develop the supply chains. The challenge that comes about is who invests in these and how do they do it, and we can talk about that at a later time.

But it's more of the mismatch that I see between how supply lines can produce, and do they meet demand, because we're now getting to a point where products go around the world far faster than they ever have before.…Within four years, six percent of the planet had [a smartphone] in their hand. The refrigerator, the radio, they never spread around the world that quickly. And now we're having two billion people enter the middle class, and we're setting up these wonderful manufacturing facilities so that products can really help lift people out of poverty, but, on the same end, I would just worry about the ingredients that go in them.

Eli Kintisch: Why don't you give an example of a case in which one of these materials led to conflict between countries...

David Abraham: …If we go throughout history, you see certain points where materials have been a part of conflict. And there's not just one instance where the materials caused the conflict. In terms of 2010, when China restricted rare earth access to Japan, they used it as [a] tool in conflict. In the 1970s, when there was fighting in Zaire, there was cobalt being mined there, and the price of cobalt shot up because there [were] fears that the Soviet Union was coming in and getting involved in the supply lines. And there was a fear that [the] U.S. wouldn't have [a] supply, and the combination of the war and the fear, and the price of cobalt jumped.

If we look back to World War II, you see that the U.S. was heavily involved in trying to restrict tungsten, which is a steel strengthener, to the Germans, who were very metallurgically savvy.

So throughout history you see it, not necessarily as the initial cause of conflict, but heavily involved in it. And I think what we forget is, if we look back to the 1950s and 1960s at how heavily involved the U.S. government was in resource policy, there was [a] State Department non-ferrous metals office. To think that we'd even have a metal office, let alone non-ferrous metal office; and we had money… to develop titanium—[there was] more money going into titanium back then than goes to all critical materials now. So there was a heavy focus on how do we use materials for defense, but there was also that economic concern as well.

Eli Kintisch: I want to understand a little more for this audience that focuses on science policy, what's the role of innovation? Can you give an example of a particular innovation that has helped create new supply lines, make materials available, help process or mine the materials better?

David Abraham: You can go back to the Hittites. …Their scientific breakthroughs… allowed for the dispersion of materials…that wasn't happening before. And I don't know if [there] were necessary policy developments [so much as] scientific developments that unlocked new metallurgical secrets. And I think where science policy now lines up with that is how do we invest in the types of research that allows the breakthroughs that we need? And when I talk to people in mineralogy and material science and metallurgy right now and ask them what they're focusing their research on, [they say] it's increasingly driven by [the] specific demands of the day rather than this broad research that may help forward new ideas. So if I speak to the people at the Colorado School of Mines, they don't have access to funds that allow them to do the big thinking and make the big breakthroughs. And when you travel around to a lot of these processing facilities in China or Brazil or elsewhere, you're struck by how old the technology is. And in some cases it's very appropriate. As one person said, we're just heating things up and breaking them.

But there are a lot of opportunities for advancements in material science throughout the supply chain, because there are a lot of minerals where a lot of these elements are found that we don't know how to get them out of. So they may be in the ground, but we don't have the ability to get them out.

Eli Kintisch: For example?

David Abraham: Rare earths—they're in a number of minerals, but we can only extract them from just a handful. Or we're close to being able to extract them, but we can't extract them profitably, which is the only way for them to get to the market. So I think there's a lot of opportunity for more of the big thinking, but, as someone who did work in the budget office in the government, I do understand the competing concerns just to even stay open, unfortunately, in these days. So to get the money to allow us to think a little bit more broadly is sadly more of a challenge. But that means the arguments that we have to make have to be that much stronger.

Eli Kintisch: I was struck reading your book, David, at how complex it can be to obtain a single rare metal. Could you choose one metal and walk us through how you identify its mineral, how you mine it, prepare it, the long chain that's required and how that might require several countries for it to work?

David Abraham: I think the one thing that was most striking to me, maybe it's my American education, was that when I traveled to some of these places and they would…show me the ore, it looked like a bunch of rocks, sand, and dirt. And then I'd go to another place, and it was the same rocks and sand and dirt, but just a different color. And I always thought, just like the people who'd go out west, [that] you would dig up the rocks, and there would be the metal, there would be the gold. And it just surprised me…that there's a whole supply chain that's necessary just to get the metal. And sometimes we don't even need the metal.

So…the general process is you're finding a rich ore body—you're finding the minerals in the ground in a high enough concentration that you think you can dig it out.

Eli Kintisch: Where did you go? You could give an example of where you went.

David Abraham: So in China, I went to Baotou, which [is]…where most of the one set of rare earths [that I spend most of my time on] comes to us. And really what they're doing there is they're digging iron ore out of the ground. And it's a small iron ore mine, but it's a large rare earth mine, because usually minor metal mines are quite small. And as an aside, what's most interesting about that particular place is that they don't produce rare earths for themselves. Rare earths are a nice byproduct, meaning their costs of production are really tailored to the iron ore, and it's really tough for a lot [of] other places to compete, because they're mining this as a side business. So, in some cases, it's free or close to it to produce the minerals to make the rare earths.

But I jump back, so you've got a rich ore body in Baotou. The materials come out, then they're ground up and brought to a processing facility which tries to concentrate the minerals into more…

Eli Kintisch: Also in Baotou?

David Abraham: Yes, an element-rich heavier concentration. Then the next step is to build that into an oxide, and then sometimes the material can be sold at that level to someone who may need the elemental powder, because an oxide is not something that's hard, it's more of a powder. And then it can be made into a metal, either in Baotou—

I believe, but I'm not a hundred percent—either in Baotou or in Southern China, where there's another processing step. But some rare earth facilities, like the one we know in California, can only make the oxide, they can't make the metal. [This] highlights another concern—that you could produce the certain material, but not have the one that you need to make X-product or Y-product.

So it's a long chain. Sometimes it'll start in Russia and then go up to Estonia and then back down to Russia. Sometimes it'll start in Brazil and go. So mining is…just the beginning. It's a question: can you make the material that you need?

Eli Kintisch: We've been talking about the problem. I want to turn, for a couple of minutes, and talk about some potential solutions as you view them. But before we do that, can you talk about…China, Japan, and the United States, [and] how their policies on this issue might differ?

David Abraham: China's policy for rare materials goes back to the late 1970s, 1980s, when they were trying to develop a hard currency. And they looked around the world and saw what metals or materials were being used and realized they didn't have a lot of them, but they had a whole bunch of other materials that they would look at. And that was when Deng Xiaoping said that Saudi Arabia has oil, we have rare earths. And really what he meant by that was we have something we can sell, too.

And so in the early 1990s there was a big push to sell the materials and develop the industries for hard currency. Over time it switched up to developing processing lines, so it wasn't just producing the material....And, basically, what they're trying to do is use these materials at the heart of an economic and manufacturing strategy to produce not just the materials, but the components that go in our smart phones and then eventually, the end product themselves—the trains, planes, smart phones—because they don't want to rely on internal components. Right now they roughly rely on 75, 80 percent of components to be imported.

Eli Kintisch: For the things they build.

David Abraham: For the things they build. They want to change that, which has a lot of repercussions in the future. So they're heavily invested in…ensuring that they have secure supply lines, domestically. And [they are invested in] using access to resources to help companies invest in the country. So, if you're a component manufacturer, they want you there, and they'll give you a lot of discounts, and ensure you have the resources.

Japan is a little bit in flux at the moment. They do look at rare metals as the lifeblood of their economy and their manufacturing economy, and they're right, because they make a lot of these components and heavy industrial products like turbines. So they really need these supplies, and they're less afraid to put money to ensure supply lines are strong, although that's faded a little bit. But they also invest a lot more in education and giving money to universities to focus on a lot of these materials.

And then there's the U.S., where there's a focus strictly on do we have enough beryllium [and] titanium for our tanks and weapons systems? And if you want to get an ear to the government, you need to talk about…how China is monopolizing these resources (so we're not going to be able to fight the next war) or…about…how we need domestic supply lines to ensure our tanks can roll. And so it's a very different view, where China and Japan look at the economics, the U.S. really looks at the defense policy.

Eli Kintisch: I was surprised reading your book, when you mentioned that there were 25,000 rare earth experts in the United States…thirty, forty years ago. You said there's now 1,500. Why such a big change, and what do you think could turn the tide and develop more experts in this important area?

David Abraham: There's been some scientific studies that show the fact that we're not producing a certain material, [and, therefore] the downstream industries have left and the researchers are not here. So when I go to China, and I go to a rare earth conference, there are 500 people there all talking about how we can use rare earths for a number of applications; how we can replace rubber with rare earths. And then I go to a conference here on critical materials, and there's maybe a hundred people all talking about how do we not use these things…. As I mentioned before, [it] is a great challenge.

Eli Kintisch: You mean find alternatives.

David Abraham: Find alternatives, and not use certain materials, because we might not have access to them.…

[At] the conferences I go to the people are older than [at] the conferences I go to when I used [to] focus on oil and gas. The expertise is waning. A material scientist would rather work [for] Facebook, because it's a lot more exciting. And we have to find ways to make material science, the whole supply chain, that much more interesting. All those words are a mouthful when you put them all together. But we have to focus on the science, whether that's creating stronger universities or funding them at a higher level, there are a number of things that we can talk about.

Eli Kintisch: Please, what would you do if you were in charge of improving this policy in the U.S. government?

David Abraham: One of the things that I look at [is] Shark Tank [the television show]. Basically, people come up with their new idea and then they sell it. … The heroes of the show are the investors, the people with the money….It's not the ideas, but it's the people who are investing. And we have to find ways to ask the questions that get investors interested in these materials and in the properties. And I look at Elon Musk, and he's setting up questions that are pushing the material science along. What he could help do to batteries could be tremendously helpful to the whole world, the whole green economy and start spurring people's interest in batteries.

Since I've started doing this research in 2010, there [has been] a little bit more buzz about batteries. It's really hard to sell, because the advancement is hard to see. It's not like going into Shark Tank. But we have to develop that same enthusiasm for those incremental steps. So on the outside…the investors [are] asking the big questions. But I think, as people in policy and in government, sadly, [it often comes down to money] and people talking about these issues about the importance of material science and the powers that these materials provide. And I hope that, in some sense, the book [helps people] understand what it takes to make these things.

And I think that first, if we can start to understand what it takes to make these things, then there can be a greater case to be made for [why] we should really be funding these things. And if I want to take the geopolitical argument, then it would be, if we're not going to make them here, China's going to make them there, and they're going to do a heck of a lot better…. They're already dominating the production of materials. If we don't watch out, pretty soon they're going to [do] it with the planes. I think that's a little bit more alarmist, but it rings a lot more clearly to policy makers.

Eli Kintisch: So just to push you a little more, when you were at OMB, you looked over a particular area. If this was your area of the federal government, what sort of changes would you like policy makers to make specifically?

David Abraham: So I think in the critical material space…we're starting to set up the structures to allow investment into critical materials. We have a critical materials hub. So what that has done is brought together a number of different institutes to come together to share information.

Eli Kintisch: It's a part of the federal government?

David Abraham: It's [funded] by the federal government; Ames Laboratory in Iowa is the lead. There are researchers at MIT, at Yale, at Colorado School of Mines that come together. So that setting [up] of the infrastructure so [that] people talk to each other takes some time. So it's nice to see that that is there. The question is, can we start funding them to a level where we can start making some real scientific gains, because we're spending twenty-five million for all the critical materials, when I think we spend thirty million for algae research. And algae research is great, and I'm not knocking algae research. I just think that these things are so important there's more that could be done here.

So there is the tradeoff between do we give money to research, or do we give money for operations? In my experience at OMB, do we set up a new program, or do we give some funding out in chunks? And I would like to see us start to give some more money in chunks to researchers so that they can think what are the big things that we need to think about? …Giving them the access to a little bit more funding…would be a good initial start.

…In summary, set up the structures so that scientists can communicate and understand what's going on, and then give them the funding to think of broader research. SD