FEATURE

WHAT LIES BENEATH

Josh Goldman (2002) knows our clean energy future means electrifying transportation, so he created a company to get us there more quickly.

BY ALEXANDER GELFAND

Josh Goldman, cofounder and president of KoBold Metals, is not a typical mining executive. But KoBold is not a typical mining company.

Goldman earned dual master degrees—one at Cambridge in applied mathematics and theoretical physics, and another at Imperial College London in the history of science—before acquiring a PhD in physics at Harvard, where he adapted methods of measuring the properties of individual electrons to the realm of quantum computing.

KoBold, meanwhile, uses data science and artificial intelligence to identify deposits of the metals that are used to manufacture rechargeable batteries and other components for electric vehicles. The name KoBold is an historical play on words: The German miners who discovered cobalt in the late Middle Ages named the metal after the kobold, a mischievous spirit from Teutonic folklore, because it looked like silver but released toxic fumes when smelted.

Replacing the more than 1 billion cars and trucks that run on fossil fuels with ones that run on electricity generated from renewable sources like wind and solar represents a necessary step towards establishing a low-carbon economy and averting catastrophic climate change. But discovering large deposits of the metals needed to power EVs over long distances is becoming more difficult; the ones that are closest to the surface have already been discovered, and the rest will require increasingly sophisticated techniques to locate. KoBold, which has raised more than $400 million since it launched in 2018, is trying to solve that problem by using new scientifically sound methods to predict the location of ore deposits that lie hidden deep within the Earth's crust. As such, it is as much a scientific R&D operation as it is a mining concern.

"We're trying to make inferences about things we can't see, which is what scientists do all the time," Goldman says. Towards that end, he and his colleagues—the company employs more than 100 technical personnel, ranging from geologists to data scientists and software engineers—put as much effort into pondering the nature and limits of their geological knowledge as they do into boring exploratory drill holes. They have even written a formal statement on principles and practices, "KoBold's Epistemology of Exploration," on how to hunt for metals in a scientifically rigorous manner.

It is a task to which Goldman, with his firm grounding in both the practice and the history of science, is uniquely well-suited.

"KoBold is something of a philosophical project," he says. "We're trying to reason about how we know what we know about what's under the surface of the Earth. And having read the greatest hits in the philosophy of science, and having had plenty of opportunities to talk about those things over pints at the pub, turns out to have been incredibly useful."

Growing up in South Lake Tahoe, California, Goldman did not dream of becoming an entrepreneur. Rather, his earliest aspiration was to become a professional blackjack dealer (he has always loved games); but his interests soon turned to science and mathematics. He was especially drawn to physics, which satisfied his taste for quantitative problem-solving and mind-bending concepts. "I chose physics in high school because I liked having to learn about special relativity and electromagnetism and all the things that you have to work really hard to get your head around," he says.

Yet by the time he found himself working on experimental quantum computing, Goldman had come to suspect that he might be happier putting his scientific skills to work on something that had more immediate social and economic relevance.

"I wanted to be making decisions about technology development and decisions about investment that relied upon having a deep technical understanding," he says.

Goldman had already joined a clean-energy reading group led by his future KoBold cofounder, Kurt House; and given the growing urgency surrounding climate change, he decided to throw himself into enabling the transition to renewable energy.

Doing that, however, required some retraining. Goldman figured that if he wanted to work on disruptive technologies that could help wean the global economy off fossil fuels, he would first need to learn how the incumbent energy industry worked. But he didn't want to go to business school to do it. So in 2011, he took a job with the consulting firm McKinsey & Company, where he spent several years advising clients in the conventional energy industry such as oil and gas companies and electric power producers. The job also allowed him to work out of Houston, not far from his wife and fellow Marshall Scholar Courtney Peterson (2002), who had a postdoctoral position in Louisiana at the time. Then, in 2015, Goldman joined a company Kurt House started that used data science to guide investments in oil and gas projects—work that foreshadowed what the two would later seek to accomplish in the realm of battery metals. "That was a really useful experience, but not what we wanted to spend our time doing," Goldman says. "We wanted to work on the natural resources that we're going to need for a low-carbon economy. So after a year and a half, we were both like, 'Okay, enough. It's time.'"

Their timing was in fact ideal. In 2018, the move to electric vehicles was finally gaining momentum: Governments around the world were pumping money into EVs in an effort to reduce greenhouse gas emissions, and virtually every major automaker had a global electrification agenda. The chemistry of long-range rechargeable batteries, meanwhile, was well-established; and it was clear that large quantities of lithium, cobalt, copper, and nickel would be required to meet anticipated demand. The IMF, for instance, estimates that achieving global net-zero emissions by 2050 will require a sixfold jump in lithium and cobalt consumption. Or as Goldman likes to put it, human beings will have to pull an additional $10 trillion-plus in battery metals out of the ground over the next several decades to build a fully electrified light vehicle fleet.

Unearthing those metals, however, won't be easy. The success rate of conventional mineral exploration has steadily declined over the past century as mining companies have exhausted the supply of easy-to-find deposits that lie close to the surface. Only the deeper ones remain, and while there are undoubtedly plenty of them (only a small fraction are exposed at the surface thanks to geological processes), they are much harder to locate: At this point, fewer than one percent of exploration projects turn up deposits that are worth building a mine around.

KoBold is trying to improve those odds with scientific rigor and cutting-edge technology.

The company has developed a data system called TerraShed to house every scrap of information that could potentially be of use to an exploration program. Hand-painted geological maps, chemical analyses of old borehole samples, high-resolution satellite imagery: Goldman and his team want it all, since every piece of data they acquire helps them build stronger hypotheses about where the metals they seek might be located and gives their models greater predictive power.

They also want to gather as much existing information as possible because acquiring new data is so expensive: As Goldman points out, sending a team of geologists to a remote location to gather rocks or chartering a plane to do an aerial magnetic survey to identify conductive materials buried underground—both of which KoBold does on a regular basis—costs a great deal of money.

Integrating all that data is no small task. Even in a single jurisdiction like northern Quebec, where KoBold has an active exploration program, there may be thousands of different geophysical and geochemical surveys that were conducted at different times using different equipment by different geologists, all recorded in different formats. "The data is a mess," Goldman says.

Nonetheless, once it has been organized, digitized, and massaged into a form that can be interpreted by humans and algorithms alike, that data is used to train hundreds of machine learning models. Known collectively as Machine Prospector, those models generate predictions that guide every decision KoBold makes, from which provinces the company should explore to where it should drill its next hole.

While it might seem counterintuitive, Goldman and his team concentrate their efforts on exploring those areas where the models are most confused. That is because their ultimate goal is to reduce the uncertainty in our understanding of the subsurface; and the most efficient way to do that is to gather fresh data that will improve the strength and certainty of their predictive models

So far, the approach appears to be working. In a recent foray into northern Quebec, 8 out of 10 exploratory drill holes yielded positive results—a rate that Goldman says is easily 10 times better than what one would expect using conventional methods. And the company expects to see a commercially viable deposit emerge from its drilling program in Zambia within the next few quarters.

Not every exploration program will succeed. Indeed, says Goldman, "most projects are still going to fail." But even those failures can offer lessons about where—and where not—to look for the metals that will be needed to prevent the worst effects of climate change.

"And the more we learn," Goldman says, "the smarter we get."

Josh Goldman earned his PhD. in physics from Harvard University for experiments in atomic physics that demonstrated how trapped electrons could be used to make quantum computers. He also holds master's degrees in history of science from Imperial College London and applied mathematics from Cambridge University, where he was a Marshall Scholar, and a B.A. in physics from Cornell. Josh was an advisor to top executives at oil & gas, electric power, and energy equipment and services firms with the Houston office of McKinsey & Company, and later worked as principal of Phase Change Resources (PCR), where he led business development, sourcing investment opportunities, and leading commercial underwriting and valuation of all PCR transactions.