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LITHIUM, COPPER, AND THE GLOBAL BATTLE TO POWER OUR LIVES

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This is for Sharon, Maryanne, and Thérèse.

"It takes as much energy to wish as it does to plan."

—Eleanor Roosevelt

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THE GLOBAL BATTLE FOR GREEN ENERGY MINERALS

PROLOGUE

A Discovery

A GLINT OF LIGHT CAUGHT JERRY TIEHM'S EYE LATE ONE AFTERNOON as he drove through the cragged Nevada landscape and into the encroaching dark.

The New York Botanical Garden had sent the thirty-one-year-old botanist to collect samples of Nevada flowers and other vegetation for its library of plant samples known as a herbarium, the largest of its kind in the Western Hemisphere. Tiehm's assignment was simple: Find odd, unique, colorful, and hopefully undiscovered plants. He was then to flatten them using a press he kept in the back of his truck, store them between sheets of newspaper, and send them to New York, where they would be glued to large sheets of white paper, studied, catalogued, and preserved for future generations. If any plants were found to be interesting, more scientists would be sent out for further research. Then as now, Nevada's flora has long been the least explored in the United States; more is known about plants and flowers in remote Alaska than the jagged, desert corners of the Sagebrush State.[1]

"To me, it was a dream job," recalled Tiehm, who studied botany at the University of Nevada, Reno, partly to avoid being drafted for the Vietnam War.[2] "Nevada has always been the last frontier for plant collection."

It was May 18, 1983. Ronald Reagan lived in the White House. The space shuttle *Challenger* had its maiden launch the month prior and telecom provider Ameritech was preparing to make the world's first commercial cell phone call.[3] Six years prior, a scientist at Exxon (yes, *that*

Exxon) had invented the lithium-ion battery, a feat that would eventually revolutionize the world's economy and its fight against climate change. It was also an invention that would link directly with Tiehm's Nevada work that day, work that would attract one of the world's largest automakers, stoke the ire of one of America's most preeminent conservation groups, and spread worry through the corridors of power in Washington and Wall Street.

Tiehm was very much unaware of that future as he guided his burnt-orange-colored Chevrolet Blazer down a steep embankment of gravel barely recognizable as a road. All the botanist could think about was finding a safe place to camp. Those barren hills of Nevada known as the Silver Peak Range were not forgiving for those without a plan, especially in the stygian dark. But that hint of light, flickering ahead of the dusk, beckoned Tiehm.

Amid what looked to be unusual, light patches of ground surrounded by a sea of darker rock, the botanist noticed a wildflower that hugged the earth, almost like an herb.[4] Stems of about six or so inches protruded from the soil with leaves of a bluish gray hue and flowers of pale yellow.[5] Hundreds of the plants seemed grouped together densely at the site, known as Rhyolite Ridge, but Tiehm was unsure why. He had stumbled upon the plant at the peak of its blooming season, from May to June, when the golden flowers emerge resplendent for nature and dazzle the bees, spiders, and other creatures that pollinate it in the seemingly barren desert. By July, the flowers turn red with age and begin to cast off ripened seeds, propagating their next generation. Late summer brings a hibernation that lasts through the next year.[6]

Tiehm followed procedure. He collected fifteen samples of the flowers, pressed them, labeled them, and catalogued them for New York out of the bed of his truck. He pulled out his tent and camped for the night under the wide expanse of the Milky Way.[7] Back east, months later, Tiehm was reviewing his field notes and still couldn't identify the plant. James Reveal, a University of Maryland professor, who had also studied his notes, wrote to say why: Tiehm had likely discovered a species of plant previously unknown to science. Reveal, Tiehm, and a group of other botanists visited the site the following summer and collected even more samples. In 1985, Reveal announced the findings to the world in an academic journal. And in honor of its discoverer, the plant was given the moniker *Eriogonum tiehmii*, or Tiehm's buckwheat.

A small plant, Tiehm's buckwheat looms large in the green energy transition. Beneath the roots of the plant that Tiehm first discovered that warm spring day sits a massive deposit of lithium, which is used to make lithium-ion batteries that power millions of consumer electronic devices and electric vehicles. While Tiehm would eventually have seven plants named after him, it is Tiehm's buckwheat that grows only in the lithium-rich soils of those Nevada hills and nowhere else on Earth for reasons that rank among the many mysteries of the plant kingdom.[8]

When I visited Tiehm in Reno in the summer of 2022, he wore white New Balance sneakers and was dressed in a white *Hawaii Five-O* T-shirt tucked into navy-blue shorts. A pair of reading glasses rested on top of his balding head. Fit and trim, Tiehm's youthful physique and sharp mind belied his seven decades. He had no plans to retire and cede his unofficial title of "Nevada's premier modern botanist and plant explorer."[9]

Tiehm had been teaching at the University of Nevada, Reno, since 2014 and before that worked as a bellman and limousine driver for three of Reno's casinos, mostly the Peppermill.[10] He would often take long weekends away from the slot machines and poker tables to explore the state's remote landscape. "My experience in looking at plants out at the desert for fifty years is that the plants grow where they want to grow. And nowhere else," he said.

In 2016, an Australia-based company was hunting for gold in Nevada and realized that Rhyolite Ridge contained lithium. If it could be mined, it would be wildly profitable just as global demand for the white metal was set to spike. Electric vehicles from Tesla and others were increasingly seen as key tools to fight climate change. To get at that lithium, though, would require the company to dig an open-pit mine right where Tiehm found the flowers.

Thus, the paradox: What matters more, the plant or the lithium beneath it? This is a story about that choice, and the choices facing other regions across the United States and the world replete with lithium or copper, nickel, rare earths, or cobalt—metals critical to the construction of solar panels, electric vehicles, batteries, wind turbines, and an array of other products heralded as key to electrifying the world's economy and easing carbon emissions. Tiehm would later call it "blind luck" that such a rare plant sat atop this giant reserve of a key battery metal, but if that is the case, an industry hungry for lithium would surely call it misfortune. Throughout the world, supplies of metal sit atop land considered sacred, or too special, or too ecologically sensitive to disturb. Whether these lands should be dug up in an attempt to defuse climate change is one of the defining questions of our time. For the United States, which has less than 5 percent of the world's population but consumes almost 17 percent of its energy, this new green energy economy requires a collective reflection to which many are not accustomed. Other governments, too, are grappling with this transition, including China, which has 18 percent of the world's population and consumes 25 percent of its energy.[11]

Jerry Tiehm's discovery on that quiet Nevada hill in 1983 is emblematic of the stark choices at hand and a harbinger of the fight to stem climate change. "I'm now botanically immortal," Tiehm told me. "Years after I'm dead, people will still be talking about my discovery and its implications."

Tiehm had no clue just how right he was.

INTRODUCTION

A Turning Point

On Earth Day 2016, the United Nations held a signing ceremony in New York for member states to begin ratification of the Paris Climate Accords, the culmination of years of negotiations that had begun with the Framework Convention on Climate Change in 1992. Secretary-General Ban Ki-moon, U.S. Secretary of State John Kerry, and President François Hollande of France were among the scores of dignitaries that descended on the Big Apple, a collective show of unity designed to underscore the seriousness of the topic.[1] Kerry brought his granddaughter to indicate his belief that the agreement would benefit generations to come.[2]

Nearly two hundred nations had gathered in a suburb of the French capital months earlier to hash out ways the globe could speak and act with one voice on a strategy to mitigate climate change. The resulting agreement set a long-term goal of limiting the rise in average global temperatures this century to 2 degrees Celsius (3.6 Fahrenheit) and to reach net-zero global emissions by 2050. For that goal to be reached, it would mean ending the era of fossil fuels and converting the global economy to run entirely on batteries powered by wind turbines, solar panels, and other devices that churned out renewable energy. President Barack Obama called the Paris Accords one of his proudest accomplishments. "If we follow through on the commitments this agreement embodies, history will judge it as a turning point for our planet," Obama said when the accords went into effect after fifty-five countries representing 55 percent of global emissions had signed.[3]

Beyond the goals for member governments, the Paris Accords asked consumers across the globe to consider how their daily habits contributed to climate change. And that was a very good thing for the electric vehicle industry. Transportation accounts for almost a quarter of global carbon dioxide (CO_2) emissions, according to the International Energy Agency, boosting the greenhouse gas effect and warming the Earth.[4] In 2020, greenhouse gas emissions from the transportation sector accounted for roughly 27 percent of total U.S. emissions, or 1.6 billion metric tons (tonnes) of CO_2. That makes it the largest contributor to the country's emissions. The rate of the transportation sector's emissions jumped in absolute terms more than any other sector from 1990 to 2019, largely due to an increase in travel, according to U.S. Environmental Protection Agency data.[5] And distances traveled have only grown; in the United States, the number of vehicle miles traveled jumped 108 percent from 1980 to 2010.[6] These and other human-wrought changes to the Earth's environment have likely sparked a new age in the planet's history known as the Anthropocene, the age in which humans put their collective stamp on the planet and its climate.[7]

Put simply, personal automobiles that burn gasoline or diesel fuel are making the planet warmer, a fact the nearly two hundred nations that signed the Paris Accords seemed to acknowledge publicly. Lithium demand was projected to boom, with the International Energy Agency forecasting a 40 percent jump by 2040 in global demand for the white metal used to make EV batteries if the world is going to meet the goals set by the accords.[8] Other metals would be needed in far greater quantities as well. The IEA found that between 2022 and 2030 the world needed to build fifty new lithium mines, sixty new nickel mines, and at least seventeen cobalt mines.[9] The moment was ripe for EVs and other green energy devices to go mainstream; the technology was already in place, fueling global interest in the building blocks needed to go green.

As this transition began to unfold, I was reporting for Reuters about another energy transition—the U.S. shale revolution. For more than six years I had tracked the technology, the money, and the people reviving the American oil and natural gas industry. It was an in-depth

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assignment that took me from the news organization's offices in New York's Times Square, to a nearly two-year stretch living in North Dakota's Bakken oilfields, and then down to Texas to cover ExxonMobil and Chevron, with several Vienna secondments in between to cover the Organization of the Petroleum Exporting Countries. (The cartel's ministers at the time were curiously afraid of America's fracking renaissance.) In mid-2018, I was ready for a change and jumped at the chance to write about the metals that were set to undergird the green energy revolution. I had already reported on one major energy transition; here was a chance to cover a second one, and one that held the potential of making more of the world not only energy independent, but healthier as well.

LITHIUM-ION BATTERIES WERE first invented in 1977 by the U.S. scientist Stanley Whittingham, who was working for the oil giant Exxon in its New Jersey laboratories.[10] While Whittingham and two peers eventually were awarded the Nobel Prize in Chemistry for the invention—the Nobel Committee in 2019 lauded it for "making possible a fossil-fuel-free society"—Exxon passed on the technology in part due to concern that early versions of the battery would spontaneously combust, a problem known as "thermal runaway," one caused by lithium's reactive properties.[11] Falling oil prices also revived gasoline's appeal after the end of the Arab Oil Embargo, lessening the crunch to find an oil replacement.[12] The addition of cobalt to the battery's composition was later found to be a way to mitigate those explosions. Japan's Sony eventually ended up with the patents and in 1990 debuted a line of handheld camcorders powered by rechargeable lithium-ion batteries. These batteries were just as powerful as traditional lead-acid batteries. Thanks to lithium's electrochemical properties, they could be engineered to be lighter and smaller.

The invention helped personal electronics go mainstream. Soon, laptops, cell phones, and a range of other consumer electronics were everywhere, powered by the rechargeable batteries built with metals that can be reused thousands of times.[13] Even still, most of the world's consumers paid little attention to how much the Periodic Table of Elements affected their daily lives and, increasingly, their futures. While the United Nations declared 2019 the International Year of the Periodic Table of Chemical Elements to honor the 150th anniversary of Dmitri Mendeleev's creation of the iconic chart, the average shopper in a department store would struggle to identify which of its constituent members go into a computer battery, or an automobile, or a solar panel. Just over a quarter of Americans told a 2019 survey they had never heard of rare earths elements, the crucial materials used to build magnets that power electric vehicles.[14]

When Martin Eberhard founded Tesla Motors in 2003, the lithium-ion battery was very much fringe in the automobile sector, treated as a kind of science experiment by Ford, Chrysler, and other auto giants. Elon Musk joined Tesla the following year and started the company on a path to launching its first vehicle—the Roadster—in 2008. It was a journey that involved battery partnerships with Germany's Daimler, Japan's Toyota, and even the U.S. government, a tortuous path chronicled in *Car Wars*, John Fialka's definitive account of the early years of the EV industry.

With electric cars making oil changes, miles per gallon estimates, radiators, and other staples of the internal combustion engine a thing of the past, consumers increasingly are being forced to master a new set of terminologies, starting with the structure of the lithium-ion battery. It has four main parts: an anode, cathode, electrolyte, and separator. An anode is typically made with graphite. A cathode is made with lithium and, depending on design, a mix of nickel, manganese, cobalt, or aluminum. Between the two is an electrolyte solution often made of lithium, with a separator composed of plastic in between. Inside an EV's motor sits more than a mile of copper wiring that is used to help turn power from the battery into motion. When the battery is powering a car or other device, lithium ions flow from the anode through the separator to the cathode. The process is reversed during charging.[15]

A lithium-ion battery's power is directly related to its metal content, but unpacking the difference between kilowatts and kilowatt hours, when many have grown accustomed to thinking of a vehicle's power in "horsepower" for the past hundred years, can seem daunting. Solar panels and wind turbines also generate electricity in kilowatt hours.

To get answers, I asked the Argonne National Laboratory chemical engineer Shabbir Ahmed to help me understand not only how much lithium, copper, cobalt, nickel, and other metals goes into the average electric car but also to better understand the language of electricity.[16] Ahmed, who studied at the Bangladesh University of Engineering and Technology before earning his Ph.D. from the University of Nebraska, runs Argonne's BatPaC tool, which helps calculate the materials needed for a battery's energy storage capacity.[17]

A kilowatt is the rate of energy flow and a kilowatt-hour is a quantity of energy.[18] (In a gasoline-powered engine, the fuel injection rate can be expressed in kilowatts, while the gasoline in the fuel tank can be expressed in kilowatt-hours.) The larger the battery, the greater its electricity storage capacity. The standard Tesla Model 3—the most popular EV in the world in 2021—has a 55.4 kWh battery, meaning it can deliver 55.4 kilowatts of power for one hour.[19] How fast that battery charges depends on the charger itself; a typical household plug charges at about 1 kW, meaning it would take about fifty-five hours to charge the Model 3 in this analogy. But most commercial or public chargers operate far faster, typically 50 kW, meaning it would take slightly more than an hour to recharge that car. Some superchargers operate at 250 kW or more.[20]

"If you have more energy to store, then you need a bigger battery. And the bigger the battery, the longer the driving range you have," Ahmed explained over Zoom, his long white hair evoking Doc Brown from the 1985 film *Back to the Future*. Not surprisingly, the bigger the battery, the more metals you need. That Model 3, Ahmed explained, uses 0.11 kilograms of lithium for every kWh. (One kilogram is about 2.2 pounds.) That means that Tesla's 55.4 kWh battery was built using roughly 6 kilograms of lithium.[21] Using Ahmed's estimates, that same battery's cells also held about 42 kilograms of nickel, nearly 8 kilograms of cobalt, 8 kilograms of aluminum, nearly 55 kilograms of graphite, and about 17 kilograms of copper, with even more aluminum and copper elsewhere in the battery.

The problem for the U.S. automakers, though, was that the United

States was producing very few of these metals just as EVs and other green energy devices began to go mainstream, a concern of industry executives that has only grown since Tesla introduced the Roadster.[22] Coronavirus put these fears into overdrive, reinforcing to consumers how much their everyday lives depended on products such as pharmaceuticals, clothing, and energy, which were linked to far-flung manufacturing plants, a point driven home in *Pandemic, Inc.: Chasing the Capitalists and Thieves Who Got Rich While We Got Sick*, J. David McSwane's deep dive into the shady financial underbelly of the governmental response to COVID-19. Russia's invasion of Ukraine further focused these fears.

Energy security *used* to be about crude oil and natural gas. Now it's also about lithium, copper, and other EV metals.

Consider the following:

- Chile and Australia by 2023 were the world's largest lithium producers but relied on China to process much of that metal into a form usable for EV batteries. Two of the world's largest lithium companies are Chinese, one of which also controls a quarter of its Chilean rival SQM, which produces much of the world's lithium in the Atacama salt flats. The United States produces only small amounts of lithium at a facility first built in the 1960s and has no large-scale facilities to process it, even though it has enough untapped supply to build millions of EVs.[23] China has some lithium reserves locked in hard-to-extract deposits.[24]

- China is the world's largest copper consumer and aggressively buys the red metal, a major conductor of electricity, from Chile, Peru, and other nations. U.S. copper production dropped nearly 5 percent from 2017 through 2021 despite the country having twice as much supply as China.[25]

- Indonesia holds the world's largest supplies of nickel and has moved to block exports of the key metal to build its own EV industry.[26] The only U.S. nickel mine will be depleted by 2025 and the United States does not have a nickel refinery. The metal is key to boosting an EV battery's energy density, and thus allowing an EV to drive farther on a single charge. An EV battery made with nickel uses 40 to 60 kilograms of the metal, whereas an internal combustion engine only uses 1 to 2 kilograms.[27]

- The Democratic Republic of the Congo holds the world's largest supplies of cobalt, which is used to prevent EV battery erosion, but child labor often is used there to extract the mineral, a source of large concern for automakers, regulators, and policymakers.[28] Elon Musk vowed in 2018 that future versions of Teslas will use no cobalt as a result, though as of this writing he had not achieved that goal.[29] The United States in 2021 imported fourteen times more cobalt than it mined.[30]

- The United States started the modern rare earths industry in the years after the Second World War, but slowly let the entire industry move to China, which now controls the mining and processing of the critical elements used to make magnets that translate power into motion.[31] Without rare earths, there would be no wind turbines, no Teslas, and no F-35 fighter jets, among myriad other high-tech devices built using specialized magnets made from rare earths. China threatened in 2019 to block its export to the United States, which has one rare earths mine but no processing facilities.[32]

- No new mines for any of these metals have opened in the United States for decades, with the exception of a small Nevada copper facility in 2019.[33] Yet multiple projects have been proposed that could produce enough copper to build more than 6 million EVs, enough lithium to build more than 2 million EVs, and enough nickel to build more than 60,000 EVs.[34]

- In 2019—the last full year not affected by the coronavirus pandemic—nearly 250,000 EVs were sold in the United States.[35]

EV sales in the country were slightly above 400,000 in 2021[36] and 807,000 in 2022. That same year, total U.S. auto sales fell by 8 percent, hinting at Americans' disillusionment with internal combustion engines.[37]

- That rising EV demand will need to be met by a fresh supply of lithium and other metals. "We want to figure out what are limiting factors for accelerating the advent of a sustainable energy future and whatever those limiting factors are, Tesla will take action on those limiting factors," Musk said in April 2022. "So right now, we think mining and refining lithium appears to be a limiting factor, and it certainly is responsible for quite a bit of cost growth in the sales. It's, I think, the single biggest cost growth item right now, percentage basis, although just for those who don't totally know this, the actual content of lithium in a lithium-ion cell is maybe around 2 or 3 percent of the [battery] cell."[38] The average U.S. price for an EV jumped to $66,000 that summer, up 30 percent from the prior year, as lithium prices spiked amid rising demand and little supply.[39] Tesla imposed one of the biggest price jumps.[40]

- Despite the role such proposed U.S. projects would play in abrogating climate change and even lessening the cost of green energy products, each one faces strong, legitimate opposition from environmentalists, neighbors, Indigenous groups, or others, underscoring the dilemma facing the country as it tries to go green.[41]

- In 2021, China had either built or was building 148 of the world's 200 lithium-ion battery gigafactories. Europe had 21. North America had 11.[42] By 2029, 101 of the additional 136 lithium-ion battery plants planned for development will be in China.[43] Despite that, auto industry executives had grown increasingly concerned that at least 90 percent of the battery supply chain—including mines—needed to meet aggressive EV transformation targets for the global transportation sector didn't exist yet.[44] By 2023, China had cemented its EV supply chain prowess and it cost about 10,000 euros less to build an EV in China than in Europe.[45]

- U.S. environmental regulators have put multiple proposed domestic mines under regulatory scrutiny, even as other parts of the government consider loans for new projects, a disconnect in strategy that frustrates miners and conservationists alike. Presidents Obama and Trump blocked mining projects for environmental or cultural reasons. (Yes, even Trump.) Biden blocked some mines, yet ordered government attorneys to defend others, often without any clear indication as to what prompted the differentiation.

- The net result has been a chilling effect on U.S. mine development, even after 2022's Inflation Reduction Act linked EV tax credits to domestic production of EV minerals. (If mines can't get built, how can consumers get the EV tax credit?[46]) Automakers protested almost as soon as the measure was passed that it could take years to find adequate metals supply in the United States.[47] Opposition to mines has long forced the country to rely on metals imports, a step that ironically has boosted global greenhouse gas emissions by increasing shipping from overseas mines to processing facilities, most of which are in Asia.

"The United States must secure reliable and sustainable supplies of critical minerals and metals to ensure resilience across U.S. manufacturing and defense needs, and do so in a manner consistent with America's labor, environmental, equity and other values," Biden's White House explained in a 2021 report on gaps in the EV supply chain.[48] To achieve the climate goals set out by the Paris Accords, global demand for lithium and graphite for EV batteries will need to increase more than 4,000 percent by 2040. President Joe Biden has promised to convert the entire U.S. government fleet—about 640,000 vehicles—to EVs.

That plan alone could require a twelvefold increase in U.S. lithium production by 2030.[49]

"You can't have green energy without mining," said Mark Senti, chief executive of the Florida-based rare earths magnet company Advanced Magnet Lab Inc. "That's just the reality."[50] The United States wants to go green, but to do that, it will need to produce more metals, especially lithium, rare earths, and copper. That means more mines. And mines are very controversial in the United States. Who wants to live next to a giant hole in the ground? Mines are dusty, increase truck traffic, and use dynamite for blasting that can rattle windows and crack foundations. Many mines throughout history have polluted waterways and produced toxic waste that scarred landscapes for generations. They also require astronomical amounts of water to operate. Stewart Udall, who ran the U.S. Interior Department under Presidents John. F. Kennedy and Lyndon B. Johnson, described mining as a "search-and-destroy mission."[51]

And yet more than 90 percent of U.S. households that own a vehicle would spend less on energy and reduce their greenhouse gas emissions if that vehicle were electric-powered, a startling finding from University of Michigan scientists that laid bare the need for more metals.[52] Wall Street expects lithium demand to surge by 2030 but is skeptical that mining companies will be able to match that demand with supply, especially for lithium.[53] And the process to produce these metals can vary widely by type and is vastly different than oil and natural gas production. Given all this history, it's perhaps understandable that U.S. government officials in Washington have not spoken with one voice on the issue. While the Pentagon grew increasingly concerned at the dawn of the twenty-first century about China's control of the industry that makes rare earths and other weapons-grade minerals, one of its divisions for years, under Democratic and Republican presidencies alike, sold domestic stockpiles of minerals considered strategic.[54] Trump used the coronavirus pandemic to fast-track development of the Thacker Pass lithium project in Nevada, even while he killed the proposed Pebble Mine in Alaska, which would have been a large source of domestic copper.[55, 56] Biden froze development of the controversial

Resolution Copper mine in Arizona, even while his administration's lawyers defended it in court.

"This country has to make a decision," Senator Joe Manchin, a West Virginia Democrat, told me. "We're so pristine in America, we think someone else will do the dirty work of mining for us. But we're just in a very, very vulnerable position."[57]

China has been scouring the world the past twenty years for cobalt, lithium, copper, and other metals. After the United States pulled out of Afghanistan in 2021, Chinese mining companies began negotiating with the Taliban to develop the Mes Aynak copper deposit, about two hours outside of Kabul.[58] China's mining companies spent billions of dollars buying cobalt mines in the Congo.[59] In Argentina, China has invested in six major lithium projects.[60] As 2023 dawned, India began scouring Argentina's reserves of copper and lithium to sate its burgeoning EV industry.[61] The European Union aims to be carbon neutral by 2050, a plan relying on increased metals supply.[62] Each of these moves reflects just the latest iteration of the global hunt for metals, a hunt that has been going on for thousands of years. Paul Julius Reuter, the man who founded the news organization for which I work, signed a contract with the Shah of Persia in 1872 that gave him complete control over the mining of iron ore, copper, and other metals across the country now known as Iran. (The contract collapsed a year later under intense local opposition to a foreigner digging up the countryside.[63])

The mines opposed by the environmental lobby in the near term are, paradoxically, necessary to battle climate change in the long term. Recycling alone cannot provide the materials needed to fuel the global green energy transition.[64] Before its very eyes, the United States is watching its petroleum dependence on the Organization of the Petroleum Exporting Countries transition into a dependence on China, Congo, and others for the building blocks of green energy devices. China has threatened to block exports to the United States of rare earths, used to make the magnets that help turn power from an EV battery into motion.

The oil and natural gas revolution that swept the global economy in the late nineteenth century and early twentieth century involved little to no collective weighing of the environmental, social, and economic costs and benefits of burning fossil fuels. Indeed, while the muckraking journalist Ida Tarbell became famous for exposing the malfeasance of John D. Rockefeller Sr.'s Standard Oil, she did so primarily to point out his greed and monopolistic business practices, not the environmental harm that can be caused by oil extraction and refining. The electrification transformation now taking place does and must involve a dialogue about what society is willing to accept and what it is expecting.

And in some sense, to rely on other nations for the building blocks of green energy is to perpetuate the very kind of economic colonialism that has pervaded Western culture for centuries. In *The Nutmeg's Curse*, a seismic tome on climate change and human exploitation, Amitav Ghosh explores how what we think of as the root causes of the climate crisis (coal, crude oil, and natural gas production) extend further back to the fifteenth century and the enslavement of Banda Island residents by Dutch invaders to produce nutmeg via forced plantation farming. By imposing such a rigorous and destructive style of cultivation that eschewed traditional farming techniques and disrespected natural processes, Ghosh argues, the seeds of the climate crisis were planted.[65] Extrapolating Ghosh's core argument for the green energy transition requires grappling with where, how, and why each nation procures its own green energy building blocks, and that there likely will not be an equitable green energy transition unless the globe reckons with how the climate crisis began.

"We throw around these words 'energy transition' and 'the future of energy' and 'climate action,' but basically what we're doing right now—this generation—is having a massive overhaul of the entire global energy system while at the same time we are electrifying everything," said Amos Hochstein, an energy advisor to Obama and Biden. "The geopolitics of energy of the 20th century that centered around producing countries of oil, gas and coal is now changing . . . to the producing countries of all the inputs for solar and electric vehicles and batteries. And that is things that we haven't talked about in the 20th century. That's the nickel and magnesium and graphite and cobalt and lithium and rare earths and other critical minerals."[66]

The United States is expected to produce just 3 percent of the world's annual lithium needs by 2030, even though it holds about 24 percent of the world's lithium reserves.[67] The country should want to produce more of these metals and support a diversified, global network for production to prevent geopolitical rivals from cornering the supply of these strategic materials as the world goes green, Hochstein added. That logic, though, has been cold comfort to the many who oppose new mines, whether for religious, cultural, or environmental reasons, and who have spent decades sounding the alarm about humanity's deleterious impact on the planet's environment.

Mining does not have the best reputation. There's no way around the fact that mines are gargantuan creations that maim the Earth's surface. They are loud and they are intrusive. Going back to the dawn of time, mines have displaced thousands—perhaps millions—of people, polluted waterways, and produced trillions of tonnes of waste, some of it radioactive. In Chile, the world's largest copper producer and second-largest lithium producer, 65 percent of the country's water is used by its mining sector alone.[68] Mining is also in a perpetual state of decline, forcing its practitioners to always be searching for the next deposit of metal to dig up, process, and sell. Mining practices have improved since the turn of the twenty-first century, with many companies envisioning a day when fully electric fleets of bulldozers and dump trucks won't spew diesel exhaust into the air.

Some miners try to use their place in the burgeoning EV industry to shield their industry from any criticism. In May 2020, the mining giant Rio Tinto blew up Aboriginal rock shelters in Western Australia that had stood for more than 46,000 years. The move was entirely legal—Rio had followed the permitting process—but drew immediate outcry because the company had destroyed a site considered sacred to the traditional owners, known as the Puutu Kunti Kurrama and Pinikura peoples (PKKP).[69]

As boneheaded and disrespectful as Rio's mistake was, it paled in comparison to what had happened in Brazil the year prior at a mining complex owned by Vale, another mining giant. In January 2019, as hundreds of employees were in a Brumadinho mess hall eating lunch, the nearby B1 tailings dam collapsed and released a torrent of toxic sludge that quickly subsumed the dining hall, its inhabitants, and much of the nearby countryside. Nearly three hundred people died.[70] (Tailings dams store the detritus of the mining process. If every hundred pounds of dirt removed from the earth contain only one pound of copper, for example, that means there's generally ninety-nine pounds of waste in liquid or solid form that must be stored in perpetuity, usually in such tailings dam facilities.)

Security camera footage shows the moment the lip of the 86-meter-tall dam collapsed, followed by the base and then the entire structure. Played out in slow motion, the collapse looks like something from a children's TV show, while angles from the footage show trucks furiously straining to escape the river of deadly mud.[71] It didn't have to happen, especially because that tailings dam had been known to have structural issues since 2003. The accident reinforced the broader public's mistrust of the mining industry, especially claims that modern mining eschews the practices of the past and "is not your father's mining," a popular talking point from industry executives.

"Automakers are realizing their future is in EVs, but that the supply chain for those EVs cannot be tainted by human rights abuses and toxic pollution," said Payal Sampat of Earthworks, an environmental advocacy organization that closely tracks the global mining industry. Another organization that monitors mining is the Church of England, which uses the clout of its pension fund, worth more than £3 billion by 2024, to sway corporations to boost safety practices. The church's pension fund found late in 2019 that more than a third of the world's tailings dams were at high risk of causing catastrophic damage to their neighboring communities if they collapsed. They also found that more tailings dams had been built in the past decade than during any previous decade. (Chinese and Indian miners did not participate in the Church's study, which prompted more questions about mining safety practices in those two countries.) The mining industry, it was clear, had work to do.[72]

In the aftermath of the disaster Brazil's government outlawed the type of tailings dam design that had collapsed, but the United States did not follow suit, fueling concern in Minnesota, Arizona, and other states that similar collapses could happen there if new mines were built. “We’ll be looking up at a 500-foot dam containing 1.6 billion tonnes of toxic waste and wondering when it is going to collapse and bury the community,” an Arizonan said of Rio Tinto’s plans to build a large copper mine and tailings waste storage site.[73] It was a fear that had petrified residents near a diamond mine’s tailings dam in Jagersfontein, South Africa, for years before it actually happened one summer day in 2022 when the dam collapsed, sending a wall of muddy sludge into a nearby residential community. Rio-Rita Breytenbach, a local resident, was swept up by the muck and dragged for six miles.[74]

Are risks—even tragedies—such as these to be tolerated on the road to a green energy future? Conversely, if the United States halts mining projects, does that hasten the onslaught of climate change while also giving China and others an economic weapon? Even Hollywood is thinking about the topic, albeit in its own zany way. The 2021 satirical film *Don’t Look Up* depicts the global response to the Earth’s pending destruction from an inbound comet and the decision by U.S. policymakers not to blow it up because it contains highly valuable concentrations of rare earths to aid the climate fight. When a plan to harvest those minerals fails, the planet is destroyed.

Mine supporters frequently say the United States already has some of the strictest environmental standards for mining in the world. It takes as much as a decade (or longer) to obtain a federal mining permit, but in Canada the process routinely takes only a few years.[75] Mine opponents ask about the cost. *Is this mine worth it? Does this piece of land need to be dug into? Why here? Why now?* When asked at each successive mine site, the opposition adds up, essentially blocking new projects and ultimately America’s efforts to honor the spirit of the Paris Accords. Yet while it can be cumbersome to obtain a U.S. federal mining permit—and there have been legislative attempts to shorten the process[76]—the benefits can be immense: Companies do not have to pay royalties on minerals they extract from most federal lands, a quirk of the law that has governed mining in the western United States since 1872.

That is one of the reasons mining is the most lucrative part of the EV supply chain, with returns in recent years above 10 percent, according to a study by the banking giant Citi. Automakers, that same study showed, make returns of less than 2 percent when building an EV.[77]

"One of the ways we address climate change is to produce more EVs, and that needs more copper. That copper mine has to be somewhere, and some will support that mine, others will oppose it," said Scot Anderson, an attorney who helps mining companies navigate the U.S. permitting process.[78]

Relying on imports—jockeying for supply on the global market—also would delay efforts to electrify the nation's automobiles and could boost greenhouse gas emissions by increasing shipping from overseas mines to processing facilities, most of which are in Asia, partially undermining the rationale behind building more EVs. In an attempt to contend with that supply chain and spur U.S. production, the Inflation Reduction Act, approved by Congress and Biden in 2022, links the country's EV tax credit to production from either the country itself or twenty free trade partners, only one of which is on the African continent.[79]

"The (EV) supply chain has to go all the way to the mines. That's where the real cost is, and people in the U.S. don't want mining in their neighborhoods," Jim Farley, the head of Ford Motor Company, told a gathering of Detroit business leaders in 2021.[80] At the time, Farley and Ford had begun to consider where exactly they would procure lithium for their ambitious electrification goals.

They started to look at Rhyolite Ridge.

CHAPTER ONE

A Choice

“You should meet James Calaway.” So advised a banking contact of mine in the fall of 2018. “He knows everything there is to know about lithium and starting a lithium company.”

I was transitioning from my coverage of the U.S. oil industry’s fracking revolution to coverage of the miners jockeying to supply lithium and other metals for the green energy transition. It was an opportunity I looked forward to, even if it was daunting. I had already reported on one major energy transition; here was a chance to cover a second one. Opportunities like that don’t come along too often. But while the politics and production of fossil fuels are well understood and similar, making a battery would require multiple metals, some made and sourced in wildly different manners. Rather than report on just oil and natural gas, I would now find myself digging into lithium, copper, nickel, cobalt, and a strange classification of seventeen minor metals known as rare earths. (Not to mention gold and silver, which had been the mining industry’s mainstays for thousands of years.)

I dove into the challenge of meeting new experts, especially those like Calaway with money on the line and skin in the game. So, on my banking contact’s advice, I emailed Calaway one morning in December 2018 asking if he would be open to meet over a casual coffee. Within ninety minutes, my cell phone buzzed.

“Hello, is this Ernest? This is James Calaway. I got your email.”

Now, *here* was someone eager to talk about lithium.

Not only was Calaway eager to talk, he was also based in Houston, where I had decided to remain after I switched beats. Calaway and I agreed to grab lunch later that week. The first thing I noticed about Calaway were his eyeglasses, broad, rimmed glass circles evoking the style of J. K. Rowling's Harry Potter. He dressed casually, with his shirt untucked in the style of an executive who didn't care to put his brainpower into how he looked or what he wore, but into other things. (It was not at all what I was used to; ExxonMobil, for instance, has a conservative dress code.)

Calaway had spent the bulk of his career on a string of seemingly whimsical yet extraordinarily complex ideas, each helping form what he had grown to consider his life's mission: saving the planet from the ravages of extreme temperatures and climate change. It was a mission fueled in part by his family's background. A sixth-generation Texan, Calaway grew up watching his father single-mindedly build a successful oil and natural gas company in the world's energy capital. His father even gave him the middle name Derrick to evoke the towers commonly seen atop oilfield wells.

Given that lineage, the idea that Calaway would one day run not one but two companies underpinning the renewable energy revolution was remarkable. Fossil fuels, certainly not lithium or other electric vehicle building blocks, flowed through his veins. "When people think of Texas, they think of oil," Calaway told me. "But the roots of my interest in energy were in just the opposite area."[1]

An enticing offer came to Calaway in early 2016 to help build a mine in a remote Nevada desert. While the entrepreneur relished a challenge, he wasn't sure the United States had the willingness to stomach a new mine. The country had last opened a hard-rock mine in the 1970s. (Hard-rock mines are for gold, iron ore, silver, and other metals generally considered "tough," whereas soft-rock mines tend to be for coal and other fossil fuels, as well as chalk, like the famous white cliffs in Dover, England.[2]) This was not a stereotypical mining project to produce gold or iron ore, but rather lithium, a key ingredient for lithium-ion batteries. The project's significance began to crystallize. Calaway was intrigued.

FEW WERE TALKING about climate change when Calaway came of age in the 1970s. That was because nuclear weapons were widely seen as the most likely way a mass-extinction event would take place. It would be more than thirty years before Al Gore's film *An Inconvenient Truth* made the greenhouse effect a common talking point in American households.

At the University of Texas at Austin, Calaway studied economics under Walt Rostow, who had been U.S. National Security Advisor to President Lyndon B. Johnson. Inspired in part by Rostow's anti-Communist stance, Calaway found the first way he could try to save the planet: nuclear arms control. "I perceived great risk at the time between nation-states. It was just madness that we had this globe and we run the risk of nuclear attack destroying everything," he said. Rostow pushed Calaway to pursue a graduate degree at Oxford University, and for two years on the banks of the River Cherwell, Calaway immersed himself in the politics and policy of halting nuclear arms proliferation.

Ronald Reagan's 1980 presidential election changed Calaway's plans; the new president from California signaled a willingness to boost the nation's arsenal of nuclear weapons, and he did. If the world wasn't going to stop making bombs, Calaway thought the best place for humans to go was up, as in outer space. He and some retired NASA engineers formed Space Industries Inc., a private company with the goal of commercializing space travel and space living.

While Reagan's plans killed Calaway's arms control aspirations, the president made amends in 1988 by proposing to Congress the new startup company be given a $700 million contract to build and operate a private space station where NASA could run experiments on microgravity, material science, and other areas focused on how humans could eventually live full-time outside the Earth's atmosphere. It was a bold plan, years ahead of its time, that in many ways evokes the current arrangement the space agency has with SpaceX, the rocket company controlled by billionaire Elon Musk, who also controls EV giant Tesla, which overtook Toyota to become the world's most valuable carmaker in 2020.[3]

Like most things ahead of its time, Space Industries failed. The NASA bureaucracy feared it would sap funding for its own space station plans and lobbied heavily against it behind closed doors. Congress was anxious about spending too much money on a private venture literally out of this world. The final blow came in 1989 when the National Research Council—a collection of scientists that advises the U.S. president and Congress—urged that the program be scrapped. Calaway himself is quoted in press coverage from the time urging NASA not to be shortsighted and to realize a small, private space station could be the bridge to a large, public-run station, which would take years to build. (The International Space Station would not debut for another decade.)

Beyond the failure, it was Washington's inability to create a cogent, unified plan for furthering an essential area of study—in this case, space exploration—that irked Calaway the most. How could Washington's policymakers be so shortsighted? Didn't they realize this private space station would help the United States immensely in the areas of science, exploration, and automation? Did they even care beyond the next election cycle? Were different parts of the government talking to one another? (Years later, Calaway's company would be named a finalist for U.S. Department of Energy funding, even as the U.S. Fish and Wildlife Service threatened to take an action that could effectively kill the company.) Space Industries was sold off to a company that used its technology to make research equipment. A private station was never built. "That was my first experience in business recognizing that what politicians say they want and what they actually propose as law and policy are not the same thing," Calaway told me.

Years went by and Calaway focused on a string of seemingly unrelated businesses. He built, ran, and sold a software company just as the Internet was ascendant. He opened a dessert bar. He joined the board of a Houston charter school. Still, the Texan's legacy in energy and its money kept calling. With his identical twin brother, John—they each call themselves "Brother"—he started a business focused on 3D seismic technology for the oil and gas industry, a mistake, he now admits, given what he had grown to consider his raison d'être. After a few years, he quit.

"It was not morally okay for me to continue to be devoting my life to producing oil and gas that was going to harm the planet for my children and grandchildren. I just couldn't get myself to continue to do that." The entrepreneur warned his home state to diversify its economy: "The promise for young people is not in oil." But where to go next? What to do? Calaway embarked on a metaphorical wandering in the corporate wilderness, searching for where he could put his entrepreneurial skills to work.

In 2007, Calaway did what a lot of America's corporate dreamers do when they're hungry for inspiration: He went to Aspen. The Aspen Ideas Festival, founded by the historian Walter Isaacson, was focused intently that year on the ongoing wars in Iraq and Afghanistan. The region also contains a lot of oil, which held little interest to Calaway. "All the discussions were invariably about the Middle East, the Middle East, the Middle East," he recalled. "I just couldn't take it." Tucked in a corner of the agenda, Calaway found a breakout session billed to discuss electric vehicles, a topic he knew little about. General Motors had launched the all-electric EV1 in 1996, and Toyota launched the hybrid Prius model globally the following year. Both were niche products that gained instant cult status.

GM gained notoriety by deciding after only three years that the EV1 was unprofitable to produce, in part because it couldn't find enough replacement parts to repair the vehicles when they broke down, a problem that presaged the battle to create a U.S. electric vehicle supply chain. GM had all the EV1 models destroyed, fueling conspiracy theories that it was in bed with the oil industry and providing ample fodder for the 2006 documentary *Who Killed the Electric Car?*

In the television drama *Brothers & Sisters*, Sally Field's matriarchal character Nora Walker drives a Prius and frequently waxes poetic about the dangers of climate change. Field's Walker likely had little clue the lithium used to make her Prius came from South America and was processed in China before being turned into a battery cathode in Japan, a meandering supply chain little changed in the ensuing years.[4] Few knew this, including Calaway, until he went to Aspen and got hooked on the potential of electric cars to help save the planet.

"I was reading everything I could about electric cars, but there was not that much out there to read about them. I found myself going to battery conferences, and that was one of the worst things you could ever do with your life because it's all just a bunch of chemical engineers."

I won't disagree with Calaway. My first time at a battery conference—in 2018 for Reuters—was overwhelming, dizzying, and confusing. Acronyms like NCA, LCE, NCM, and BEV were bandied about like a secret language known only to the initiated. I grew to dread going to the conference happy hours, fearing that as a journalist covering the industry, I would be expected to go toe-to-toe with Ph.D. scientists on the most esoteric of EV topics. Calaway felt the same. So he started reading academic papers. He subscribed to journals. He brushed up on his chemistry. Increasingly, he started noticing a pattern. Sprinkled throughout all the papers he was reading, like pepper in a salad, was a two-letter chemical symbol: Li.

Li stands for lithium. The lightest metal, it's found near the top of the Periodic Table of Elements and is enormously good at retaining an electric charge, making it the perfect anchor for the lithium-ion battery. Calaway realized that all the chemical equations used to build those batteries contained that symbol: Li. "And I said to myself, 'Well, heck, if there's going to be an electric vehicle revolution, we're going to need a whole lot of lithium.'" In that moment, Calaway knew he had to find lithium somewhere in the world.

⚡

LITHIUM CAN BE found in several types of rock that tend to have some connection to ancient volcanoes, hinting perhaps at the primordial origins of a metal that is now seen as key to saving our planet. The Swedish chemist Johan August Arfwedson is credited with being the first to identify lithium when, in 1817, working in the laboratory of one of the founders of modern chemistry, his fellow Swede Jöns Jacob Berzelius, he successfully separated it as a salt from the mineral petalite. (Lithium is also found in spodumene, a mineral common across Australia; lepidolite, which is found in parts of China; and deposits of salty water known as brine.) A Brazilian scientist, José Bonifácio de Andrada e Silva, had previously discovered petalite on a Swedish island but had not been able to tease out the metal inside. Production of lithium grad-