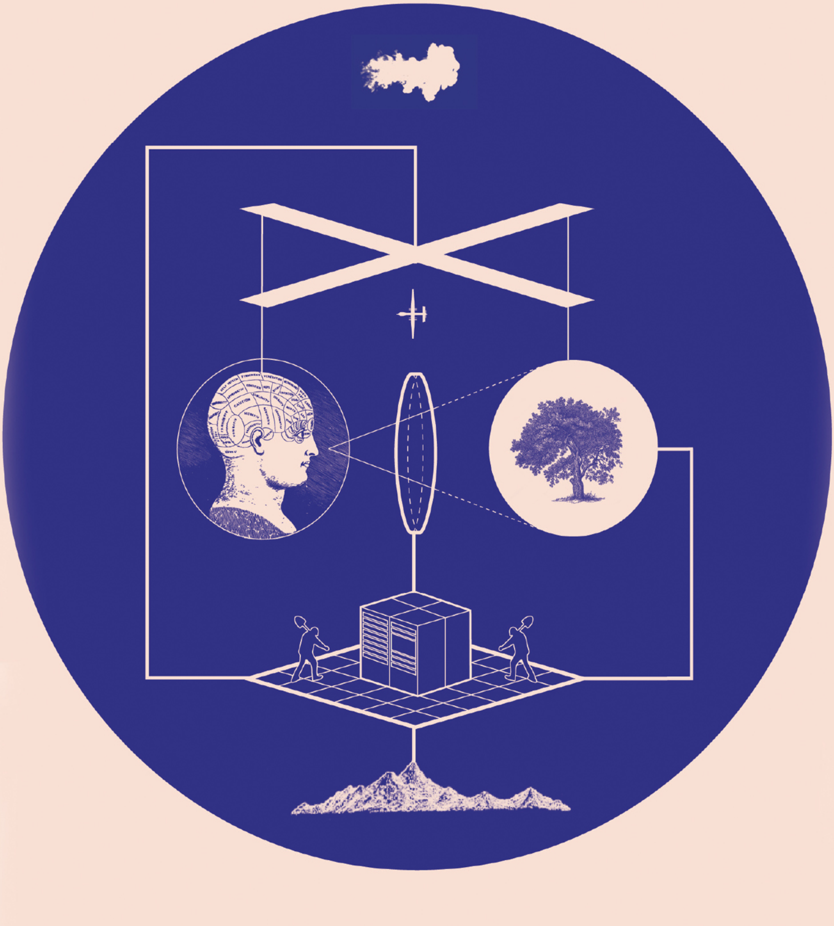
KATE CRAWFORD



ATLAS OF AI

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Power, Politics, and the Planetary Costs of Artificial Intelligence

KATE CRAWFORD

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For Elliott and Margaret

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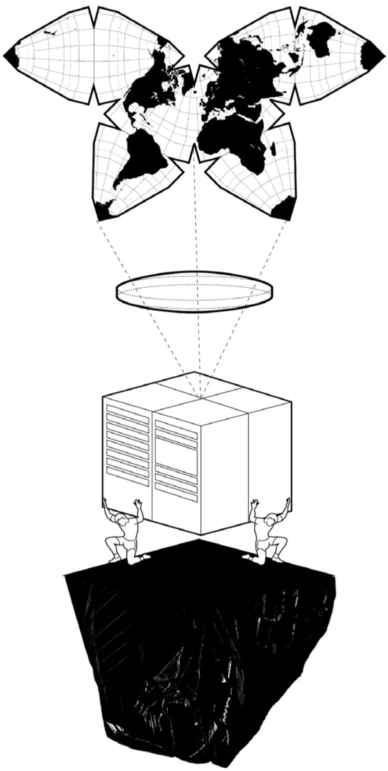

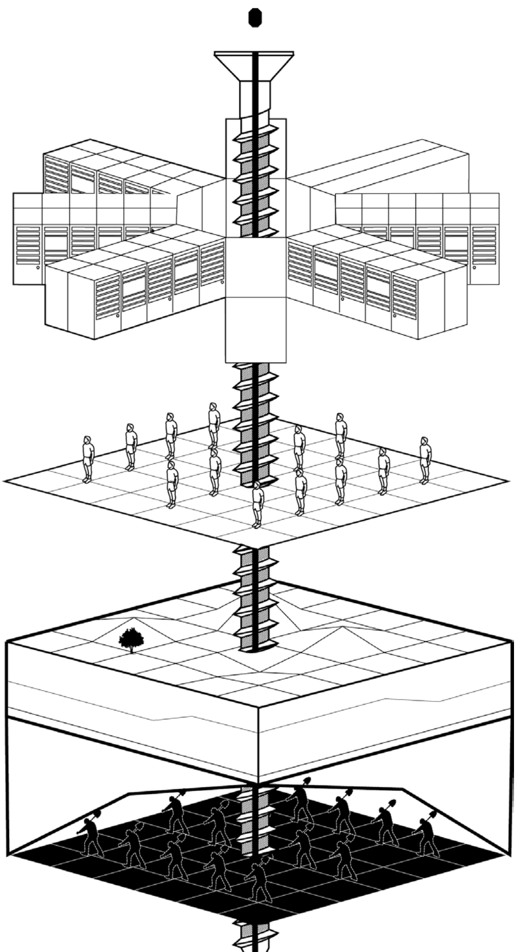

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Earth

The Boeing 757 banks right over San Jose on its final approach to San Francisco International Airport. The left wing drops as the plane lines up with the runway, revealing an aerial view of the tech sector's most iconic location. Below are the great empires of Silicon Valley. The gigantic black circle of Apple's headquarters is laid out like an uncapped camera lens, glistening in the sun. Then there's Google's head office, nestled close to NASA's Moffett Federal Airfield. This was once a key site for the U.S. Navy during World War II and the Korean War, but now Google has a sixty-year lease on it, and senior executives park their private planes here. Arrayed near Google are the large manufacturing sheds of Lockheed Martin, where the aerospace and weapons manufacturing company builds hundreds of orbital satellites destined to look down on the activities of Earth. Next, by the Dumbarton Bridge, appears a collection of squat buildings that are home to Facebook, ringed with massive parking lots close to the sulfuric salt ponds of the Ravenswood Slough. From this vantage point, the nondescript suburban cul-de-sacs and industrial midrise skyline of Palo Alto betray little of its true wealth, power, and influence. There are only a few hints of its centrality in the global economy and in the computational infrastructure of the planet.

I'm here to learn about artificial intelligence and what it is made from. To see that, I will need to leave Silicon Valley altogether.

From the airport, I jump into a van and drive east. I cross the San Mateo–Hayward Bridge and pass by the Lawrence Livermore National Laboratory, where Edward Teller directed his research into thermonuclear weapons in the years after World War II. Soon the Sierra Nevada foothills rise beyond the Central Valley towns of Stockton and Manteca. Here the roads start winding up through the tall granite cliffs of the Sonora Pass and down the eastern side of the mountains toward grassy valleys dotted with golden poppies. Pine forests give way to the alkaline waters of Mono Lake and the parched desert landforms of the Basin and Range. To refuel, I pull into Hawthorne, Nevada, site of the world's biggest ammunition depot, where the U.S. Army stores armaments in dozens of dirt-covered ziggurats that populate the valley in neat rows. Driving along Nevada State Route 265 I see a lone VORTAC in the distance, a large bowling pin–shaped radio tower that was designed for the era before GPS. It has a single function: it broadcasts "I am here" to all passing aircraft, a fixed point of reference in a lonely terrain.

My destination is the unincorporated community of Silver Peak in Nevada's Clayton Valley, where about 125 people live, depending on how you count. The mining town, one of the oldest in Nevada, was almost abandoned in 1917 after the ground was stripped bare of silver and gold. A few gold rush buildings still stand, eroding under the desert sun. The town may be small, with more junked cars than people, but it harbors something exceedingly rare. Silver Peak is perched on the edge of a massive underground lake of lithium. The valuable

Silver Peak Lithium Mine. Photograph by Kate Crawford

lithium brine under the surface is pumped out of the ground and left in open, iridescent green ponds to evaporate. From miles away, the ponds can be seen when they catch the light and shimmer. Up close, it's a different view. Alien-looking black pipes erupt from the ground and snake along the salt-encrusted earth, moving in and out of shallow trenches, ferrying the salty cocktail to its drying pans.

Here, in a remote pocket of Nevada, is a place where the stuff of AI is made.

Mining for AI

Clayton Valley is connected to Silicon Valley in much the way that the nineteenth-century goldfields were to early San Francisco. The history of mining, like the devastation it leaves in its wake, is commonly overlooked in the strategic amnesia that accompanies stories of technological progress. As historical geographer Gray Brechin points out, San Francisco was built from the gains of pulling gold and silver out of the lands of California and Nevada in the 1800s.[1] The city is made from mining. Those same lands had been taken from Mexico under the Treaty of Guadalupe Hidalgo in 1848 at the end of the Mexican-American War, when it was already clear to the settlers that these would be highly valuable goldfields. It was a textbook example, Brechin observes, of the old adage that "commerce follows the flag, but the flag follows the pick."[2] Thousands of people were forced from their homes during this substantial territorial expansion of the United States. After America's imperial invasion, the miners moved in. The land was stripped until the waterways were contaminated and the surrounding forests destroyed.

Since antiquity, the business of mining has only been profitable because it does not have to account for its true costs: including environmental damage, the illness and death of miners, and the loss to the communities it displaces. In 1555, Georgius Agricola, known as the father of mineralogy, observed that "it is clear to all that there is greater detriment from mining than the value of the metals which the mining produces."[3] In other words, those who profit from mining do so only because the costs must be sustained by others, those living and those not yet born. It is easy to put a price on precious metals, but what is the exact value of a wilderness, a clean stream, breathable air, the health of local communities? It was never estimated, and thus an easy calculus emerged: extract everything as rapidly as possible. It was the "move fast and break things" of a different time. The result was that the Central Valley was decimated, and as one tourist observed in 1869, "Tornado, flood, earthquake and volcano combined could hardly make greater havoc, spread wider ruin and wreck than [the] gold-washing operations. . . . There are no rights which mining respects in California. It is the one supreme interest."[4]

As San Francisco drew enormous wealth from the mines, it was easy for its populace to forget where it all came from. The mines were located far from the city they enriched, and this remoteness allowed city dwellers to remain ignorant of what was happening to the mountains, rivers, and laborers that fed their fortunes. But small reminders of the mines are all around. The city's new buildings used the same technology that came from deep within the Central Valley for transport and life support. The pulley systems that carried miners down into the mine shafts were adapted and turned upside down to transport people in elevators to the top of the city's high-rises.[5] Brechin suggests that we should think of the skyscrapers of San Francisco as inverted minescapes. The ores extracted from holes in the ground were sold to create the stories in the air; the deeper the extractions went, the higher the great towers of office work stretched into the sky.

San Francisco is enriched once more. Once it was gold ore that underwrote fortunes; now it is the extraction of substances like white lithium crystal. It's known in mineral markets as "gray gold."[6] The technology industry has become a new supreme interest, and the five biggest companies in the world by market capitalization have offices in this city: Apple, Microsoft, Amazon, Facebook, and Google. Walking past the start-up warehouses in the SoMa district where miners in tents once lived, you can see luxury cars, venture capital–backed coffee chains, and sumptuous buses with tinted windows running along private routes, carrying workers to their offices in Mountain View or Menlo Park.[7] But only a short walk away is Division Street, a multilane thoroughfare between SoMa and the Mission district, where rows of tents have returned to shelter people who have nowhere to go. In the wake of the tech boom, San Francisco now has one of the highest rates of street homelessness in the United States.[8] The United Nations special rapporteur on adequate housing called it an "unacceptable" human rights violation, due to the thousands of homeless residents denied basic necessities of water, sanitation, and health services in contrast to the record number of billionaires who live nearby.[9] The greatest benefits of extraction have been captured by the few.

In this chapter we'll traverse across Nevada, San Jose, and San Francisco, as well as Indonesia, Malaysia, China, and Mongolia: from deserts to oceans. We'll also walk the spans of historical time, from conflict in the Congo and artificial black lakes in the present day to the Victorian passion for white latex. The scale will shift, telescoping from rocks to cities, trees to megacorporations, transoceanic shipping lanes to the atomic bomb. But across this planetary supersystem we will see the logics of extraction, a constant drawdown of minerals, water, and fossil fuels, undergirded by the violence of wars, pollution, extinction, and depletion. The effects of large-scale computation can be found in the atmosphere, the oceans, the earth's crust, the deep time of the planet, and the brutal impacts on disadvantaged populations around the world. To understand it all, we need a panoramic view of the planetary scale of computational extraction.

Landscapes of Computation

I'm driving through the desert valley on a summer afternoon to see the workings of this latest mining boom. I ask my phone to direct me to the perimeter of the lithium ponds, and it replies from its awkward perch on the dashboard, tethered by a white USB cable. Silver Peak's large, dry lake bed was formed millions of years ago during the late Tertiary Period. It's surrounded by crusted stratifications pushing up into ridgelines containing dark limestones, green quartzites, and gray and red slate.[10] Lithium was discovered here after the area was scoped for strategic minerals like potash during World War II. This soft, silvery metal was mined in only modest quantities for the next fifty years, until it became highly valuable material for the technology sector.

In 2014, Rockwood Holdings, Inc., a lithium mining operation, was acquired by the chemical manufacturing company Albemarle Corporation for $6.2 billion. It is the only operating lithium mine in the United States. This makes Silver Peak a site of intense interest to Elon Musk and the many other tech tycoons for one reason: rechargeable batteries. Lithium is a crucial element for their production. Smartphone batteries, for example, usually contain about three-tenths of an ounce of it. Each Tesla Model S electric car needs about one hundred thirty-eight pounds of lithium for its battery pack.[11] These kinds of batteries were never intended to supply a machine as power hungry as a car, but lithium batteries are currently the only mass-market option available.[12] All of these batteries have a limited lifespan; once degraded, they are discarded as waste.

About two hundred miles north of Silver Peak is the Tesla Gigafactory. This is the world's largest lithium battery plant. Tesla is the number-one lithium-ion battery consumer in the world, purchasing them in high volumes from Panasonic and Samsung and repackaging them in its cars and home chargers. Tesla is estimated to use more than twenty-eight thousand tons of lithium hydroxide annually—half of the planet's total consumption.[13] In fact, Tesla could more accurately be described as a battery business than a car company.[14] The imminent shortage of such critical minerals as nickel, copper, and lithium poses a risk for the company, making the lithium lake at Silver Peak highly desirable.[15] Securing control of the mine would mean controlling the U.S. domestic supply.

As many have shown, the electric car is far from a perfect solution to carbon dioxide emissions.[16] The mining, smelting, export, assemblage, and transport of the battery supply chain has a significant negative impact on the environment and, in turn, on the communities affected by its degradation. A small number of home solar systems produce their own energy. But for the majority of cases, charging an electric car necessitates taking power from the grid, where currently less than a fifth of all electricity in the United States comes from renewable energy sources.[17] So far none of this has dampened the determination of auto manufacturers to compete with Tesla, putting increasing pressure on the battery market and accelerating the removal of diminishing stores of the necessary minerals.

Global computation and commerce rely on batteries. The term "artificial intelligence" may invoke ideas of algorithms, data, and cloud architectures, but none of that can function without the minerals and resources that build computing's core components. Rechargeable lithium-ion batteries are essential for mobile devices and laptops, in-home digital assistants, and data center backup power. They undergird the internet and every commerce platform that runs on it, from banking to retail to stock market trades. Many aspects of modern life have been moved to "the cloud" with little consideration of these material costs. Our work and personal lives, our medical histories, our leisure time, our entertainment, our political interests—all of this takes place in the world of networked computing architectures that we tap into from devices we hold in one hand, with lithium at their core.

The mining that makes AI is both literal and metaphorical. The new extractivism of data mining also encompasses and propels the old extractivism of traditional mining. The stack required to power artificial intelligence systems goes well beyond the multilayered technical stack of data modeling, hardware, servers, and networks. The full-stack supply chain of AI reaches into capital, labor, and Earth's resources—and from each, it demands an enormous amount.[18] The cloud is the backbone of the artificial intelligence industry, and it's made of rocks and lithium brine and crude oil.

In his book *A Geology of Media,* theorist Jussi Parikka suggests we think of media not from Marshall McLuhan's point of view—in which media are extensions of the human senses—but rather as extensions of Earth.[19] Computational media now participate in geological (and climatological) processes, from the transformation of the earth's materials into infrastructures and devices to the powering of these new systems with oil and gas reserves. Reflecting on media and technology as geological processes enables us to consider the radical depletion of nonrenewable resources required to drive the technologies of the present moment. Each object in the extended network of an AI system, from network routers to batteries to data centers, is built using elements that required billions of years to form inside the earth.

From the perspective of deep time, we are extracting Earth's geological history to serve a split second of contemporary technological time, building devices like the Amazon Echo and the iPhone that are often designed to last for only a few years. The Consumer Technology Association notes that the average smartphone life span is a mere 4.7 years.[20] This obsolescence cycle fuels the purchase of more devices, drives up profits, and increases incentives for the use of unsustainable extraction practices. After a slow process of development, these minerals, elements, and materials then go through an extraordinarily rapid period of excavation, processing, mixing, smelting, and logistical transport—crossing thousands of miles in their transformation. What begins as ore removed from the ground, after the spoil and the tailings are discarded, is then made into devices that are used and discarded. They ultimately end up buried in e-waste dumping grounds in places like Ghana and Pakistan. The lifecycle of an AI system from birth to death has many fractal supply chains: forms of exploitation of human labor and natural resources and massive concentrations of corporate and geopolitical power. And all along the chain, a continual, large-scale consumption of energy keeps the cycle going.

The extractivism on which San Francisco was built is echoed in the practices of the tech sector based there today.[21] The massive ecosystem of AI relies on many kinds of extraction: from harvesting the data made from our daily activities and expressions, to depleting natural resources, and to exploiting labor around the globe so that this vast planetary network can be built and maintained. And AI extracts far more from us and the planet than is widely known. The Bay Area is a central node in the mythos of AI, but we'll need to traverse far beyond the United States to see the many-layered legacies of human and environmental damage that have powered the tech industry.

The Mineralogical Layer

The lithium mines in Nevada are just one of the places where the materials are extracted from the earth's crust to make AI. There are many such sites, including the Salar in southwest Bolivia—the richest site of lithium in the world and thus a site of ongoing political tension—as well as places in central Congo, Mongolia, Indonesia, and the Western Australia deserts. These are the other birthplaces of AI in the greater geography of industrial extraction. Without the minerals from these locations, contemporary computation simply does not work. But these materials are in increasingly short supply.

In 2020, scientists at the U.S. Geological Survey published a short list of twenty-three minerals that are a high "supply risk" to manufacturers, meaning that if they became unavailable, entire industries—including the tech sector—would grind to a halt.[22] The critical minerals include the rare earth elements dysprosium and neodymium, which are used inside iPhone speakers and electric vehicle motors; germanium, which is used in infrared military devices for soldiers and in drones; and cobalt, which improves performance for lithium-ion batteries.

There are seventeen rare earth elements: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, and yttrium. They are processed and embedded in laptops and smartphones, making those devices smaller and lighter. The elements can be found in color displays, speakers, camera lenses, rechargeable batteries, hard drives, and many other components. They are key elements in communication systems, from fiber-optic cables and signal amplification in mobile communication towers to satellites and GPS technology. But extracting these minerals from the ground often comes with local and geopolitical violence. Mining is and always has been a brutal undertaking. As Lewis Mumford writes, "Mining was the key industry that furnished the sinews of war and increased the metallic contents of the original capital hoard, the war chest: on the other hand, it furthered the industrialization of arms, and enriched the financier by both processes."[23] To understand the business of AI, we must reckon with the war, famine, and death that mining brings with it.

Recent U.S. legislation that regulates some of those seventeen rare earth elements only hints at the devastation associated with their extraction. The 2010 Dodd-Frank Act focused on reforming the financial sector in the wake of the 2008 financial crisis. It included a specific provision about so-called *conflict minerals,* or natural resources extracted in a conflict zone and then sold to fund the conflict. Companies using gold, tin, tungsten, and tantalum from the region around the Democratic Republic of the Congo now had a reporting requirement to track where those minerals came from and whether the sale was funding armed militia in the region.[24] Like "conflict diamonds," the term "conflict minerals" masks the profound suffering and prolific killing in the mining sector. Mining profits have financed military operations in the decades-long Congo-area conflict, fueling the deaths of thousands and the displacement of millions.[25] Furthermore, working conditions inside the mines have often amounted to modern slavery.[26]

It took Intel more than four years of sustained effort to develop basic insight into its own supply chain.[27] Intel's supply chain is complex, with more than sixteen thousand suppliers in over a hundred countries providing direct materials for the company's production processes, tools, and machines for their factories, as well as their logistics and packaging services.[28] In addition, Intel and Apple have been criticized for auditing only smelters—not the actual mines—to determine the conflict-free status of minerals. The tech giants were assessing smelting plants outside of Congo, and the audits were often performed by locals. So even the conflict-free certifications of the tech industry are now under question.[29]

Dutch-based technology company Philips has also claimed that it was working to make its supply chain "conflict-free." Like Intel, Philips has tens of thousands of suppliers, each of which provides component parts for the company's manufacturing processes.[30] Those suppliers are themselves linked downstream to thousands of component manufacturers acquiring treated materials from dozens of smelters. The smelters in turn buy their materials from an unknown number of traders who deal directly with both legal and illegal mining operations to source the various minerals that end up in computer components.[31]

According to the computer manufacturer Dell, the complexities of the metals and mineral supply chains pose almost insurmountable challenges to the production of conflict-free electronics components. The elements are laundered through such a vast number of entities along the chain that sourcing their provenance proves impossible—or so the end-product manufacturers claim, allowing them a measure of plausible deniability for any exploitative practices that drive their profits.[32]

Just like the mines that served San Francisco in the nineteenth century, extraction for the technology sector is done by keeping the real costs out of sight. Ignorance of the supply chain is baked into capitalism, from the way businesses protect themselves through third-party contractors and suppliers to the way goods are marketed and advertised to consumers. More than plausible deniability, it has become a well-practiced form of bad faith: the left hand cannot know what the right hand is doing, which requires increasingly lavish, baroque, and complex forms of distancing.

While mining to finance war is one of the most extreme cases of harmful extraction, most minerals are not sourced from direct war zones. This doesn't mean, however, that they are free from human suffering and environmental destruction. The focus on conflict minerals, though important, has also been used to avert focus from the harms of mining writ large.

If we visit the primary sites of mineral extraction for computational systems, we find the repressed stories of acid-bleached rivers and deracinated landscapes and the extinction of plant and animal species that were once vital to the local ecology.

Black Lakes and White Latex

In Baotou, the largest city in Inner Mongolia, there is an artificial lake filled with toxic black mud. It reeks of sulfur and stretches as far as the eye can see, covering more than five and a half miles in diameter. The black lake contains more than 180 million tons of waste powder from ore processing.[33] It was created by the waste runoff from the nearby Bayan Obo mines, which is estimated to contain almost 70 percent of the world's reserves of rare earth minerals. It is the largest deposit of rare earth elements on the planet.[34]

China supplies 95 percent of the world's rare earth minerals. China's market domination, as the writer Tim Maughan observes, owes far less to geology than to the country's willingness to take on the environmental damage of extraction.[35] Although rare earth minerals like neodymium and cerium are relatively common, making them usable requires the hazardous process of dissolving them in large volumes of sulfuric and nitric acid. These acid baths yield reservoirs of poisonous waste that fill the dead lake in Baotou. This is just one of the places that are brimming with what environmental studies scholar Myra Hird calls "the waste we want to forget."[36]

To date, the unique electronic, optical, and magnetic uses of rare earth elements cannot be matched by any other metals, but the ratio of usable minerals to waste toxins is extreme. Natural resource strategist David Abraham describes the mining in Jiangxi, China, of dysprosium and terbium, which are used in a variety of high-tech devices. He writes, "Only 0.2

percent of the mined clay contains the valuable rare earth elements. This means that 99.8 percent of earth removed in rare earth mining is discarded as waste, called 'tailings,' that are dumped back into the hills and streams," creating new pollutants like ammonium.[37] In order to refine one ton of these rare earth elements, "the Chinese Society of Rare Earths estimates that the process produces 75,000 liters of acidic water and one ton of radioactive residue."[38]

About three thousand miles south of Baotou are the small Indonesian islands of Bangka and Belitung, off the coast of Sumatra. Bangka and Belitung produce 90 percent of Indonesia's tin, used in semiconductors. Indonesia is the world's second-largest producer of the metal, behind China. Indonesia's national tin corporation, PT Timah, supplies companies such as Samsung directly, as well as solder makers Chernan and Shenmao, which in turn supply Sony, LG, and Foxconn—all suppliers for Apple, Tesla, and Amazon.[39]

On these small islands, gray-market miners who are not officially employed sit on makeshift pontoons, using bamboo poles to scrape the seabed before diving underwater to suck tin from the surface by drawing their breath through giant, vacuumlike tubes. The miners sell the tin they find to middlemen, who also collect ore from miners working in authorized mines, and they mix it together to sell to companies like Timah.[40] Completely unregulated, the process unfolds beyond any formal worker or environmental protections. As investigative journalist Kate Hodal reports, "Tin mining is a lucrative but destructive trade that has scarred the island's landscape, bulldozed its farms and forests, killed off its fish stocks and coral reefs, and dented tourism to its pretty palm-lined beaches. The damage is best seen from the air, as pockets of lush forest huddle amid huge swaths of barren orange earth. Where not dominated by mines, this is pockmarked with graves, many holding the bodies of miners who have died over the centuries digging for tin."[41] The mines are everywhere: in backyards, in the forest, by the side of the road, on the beaches. It is a landscape of ruin.

It is a common practice of life to focus on the world immediately before us, the one we see and smell and touch every day. It grounds us where we are, with our communities and our known corners and concerns. But to see the full supply chains of AI requires looking for patterns in a global sweep, a sensitivity to the ways in which the histories and specific harms are different from place to place and yet are deeply interconnected by the multiple forces of extraction.

We can see these patterns across space, but we can also find them across time. Transatlantic telegraph cables are the essential infrastructure that ferries data between the continents, an emblem of global communication and capital. They are also a material product of colonialism, with its patterns of extraction, conflict, and environmental destruction. At the end of the nineteenth century, a particular Southeast Asian tree called *Palaquium gutta* became the center of a cable boom. These trees, found mainly in Malaysia, produce a milky white natural latex called gutta-percha. After English scientist Michael Faraday published a study in the *Philosophical Magazine* in 1848 about the use of this material as an electrical insulator, gutta-percha rapidly became the darling of the engineering world. Engineers saw gutta-percha as the solution to the problem of insulating telegraphic cables to withstand harsh and varying conditions on the ocean floor. The twisted strands of copper wire needed four layers of the soft, organic tree sap to protect them from water incursion and carry their electrical currents.

As the global submarine telegraphy business grew, so did demand for *Palaquium gutta* tree trunks. The historian John Tully describes how local Malay, Chinese, and Dayak workers were paid little for the dangerous work of felling the trees and slowly collecting the latex.[42] The latex was processed and then sold through Singapore's trade markets into the British market, where it was transformed into, among other things, lengths upon lengths of submarine cable sheaths that wrapped around the globe. As media scholar Nicole Starosielski writes, "Military strategists saw cables as the most efficient and secure mode of communication with the colonies—and, by implication, of control over them."[43] The routes of submarine cables today still mark out the early colonial networks between the centers and the peripheries of empire.[44]

A mature *Palaquium gutta* could yield around eleven ounces of latex. But in 1857, the first transatlantic cable was around eighteen hundred miles long and weighed two thousand tons—requiring about 250 tons of gutta-percha. To produce just one ton of this material required around nine hundred thousand tree trunks. The jungles of Malaysia and Singapore were stripped; by the early 1880s, the *Palaquium gutta* had vanished. In a last-ditch effort to save their supply chain, the British passed a ban in 1883 to halt harvesting the latex, but the tree was all but extinct.[45]

The Victorian environmental disaster of gutta-percha, at the dawn of the global information society, shows how the relations between technology and its materials, environments, and labor practices are interwoven.[46] Just as Victorians precipitated ecological disaster for their early cables, so do contemporary mining and global supply chains further imperil the delicate ecological balance of our era.

There are dark ironies in the prehistories of planetary computation. Currently large-scale AI systems are driving forms of environmental, data, and human extraction, but from the Victorian era onward, algorithmic computation emerged out of desires to manage and control war, population, and cli-

Palaquium gutta

mate change. The historian Theodora Dryer describes how the founding figure of mathematical statistics, English scientist Karl Pearson, sought to resolve uncertainties of planning and management by developing new data architectures including standard deviations and techniques of correlation and regression. His methods were, in turn, deeply imbricated with race science, as Pearson—along with his mentor, the statistician and founder of eugenics Sir Francis Galton—believed that statistics could be "the first step in an enquiry into the possible effect of a selective process upon any character of a race."[47]

As Dryer writes, "By the end of the 1930s, these data architectures—regression techniques, standard deviation, and correlations—would become dominant tools used in interpreting social and state information on the world stage. Tracking the nodes and routes of global trade, the interwar 'mathematical-statistics movement' became a vast enterprise."[48] This enterprise kept expanding after World War II, as new computational systems were used in domains such as weather forecasting during periods of drought to eke out more productivity from large-scale industrial farming.[49] From this perspective, algorithmic computing, computational statistics, and artificial intelligence were developed in the twentieth century to address social and environmental challenges but would later be used to intensify industrial extraction and exploitation and further deplete environmental resources.

The Myth of Clean Tech

Minerals are the backbone of AI, but its lifeblood is still electrical energy. Advanced computation is rarely considered in terms of carbon footprints, fossil fuels, and pollution; metaphors like "the cloud" imply something floating and delicate within a natural, green industry.[50] Servers are hidden in nondescript data centers, and their polluting qualities are far less visible than the billowing smokestacks of coal-fired power stations. The tech sector heavily publicizes its environmental policies, sustainability initiatives, and plans to address climate-related problems using AI as a problem-solving tool. It is all part of a highly produced public image of a sustainable tech industry with no carbon emissions. In reality, it takes a gargantuan amount of energy to run the computational infrastructures of Amazon Web Services or Microsoft's Azure, and the carbon footprint of the AI systems that run on those platforms is growing.[51]

As Tung-Hui Hu writes in *A Prehistory of the Cloud*, "The cloud is a resource-intensive, extractive technology that converts water and electricity into computational power, leaving a sizable amount of environmental damage that it then displaces from sight."[52] Addressing this energy-intensive infrastructure has become a major concern. Certainly, the industry has made significant efforts to make data centers more energy efficient and to increase their use of renewable energy. But already, the carbon footprint of the world's computational infrastructure has matched that of the aviation industry at its height, and it is increasing at a faster rate.[53] Estimates vary, with researchers like Lotfi Belkhir and Ahmed Elmeligi estimating that the tech sector will contribute 14 percent of global greenhouse emissions by 2040, while a team in Sweden predicts that the electricity demands of data centers alone will increase about fifteenfold by 2030.[54]

By looking closely at the computational capacity needed to build AI models, we can see how the desire for exponential increases in speed and accuracy is coming at a high cost to the planet. The processing demands of training AI models, and thus their energy consumption, is still an emerging area of investigation. One of the early papers in this field came from AI researcher Emma Strubell and her team at the University of Massachusetts Amherst in 2019. With a focus on trying to understand the carbon footprint of natural language processing (NLP) models, they began to sketch out potential estimates by running AI models over hundreds of thousands of computational hours.[55] The initial numbers were striking. Strubell's team found that running only a single NLP model produced more than 660,000 pounds of carbon dioxide emissions, the equivalent of five gas-powered cars over their total lifetime (including their manufacturing) or 125 round-trip flights from New York to Beijing.[56]

Worse, the researchers noted that this modeling is, at minimum, a baseline optimistic estimate. It does not reflect the true commercial scale at which companies like Apple and Amazon operate, scraping internet-wide datasets and feeding their own NLP models to make AI systems like Siri and Alexa sound more human. But the exact amount of energy consumption produced by the tech sector's AI models is unknown; that information is kept as highly guarded corporate secrets. Here, too, the data economy is premised on maintaining environmental ignorance.

In the AI field, it is standard practice to maximize computational cycles to improve performance, in accordance with a belief that bigger is better. As Rich Sutton of DeepMind describes it: "Methods that leverage computation are ultimately the most effective, and by a large margin."[57] The computational technique of brute-force testing in AI training runs, or systematically gathering more data and using more computational cycles until a better result is achieved, has driven a steep increase in energy consumption. OpenAI estimated that since 2012, the amount of compute used to train a single AI model has increased by a factor of ten every year. That's due to developers "repeatedly finding ways to use more chips in parallel, and being willing to pay the economic cost of doing so."[58] Thinking only in terms of economic cost narrows the view on the wider local and environmental price of burning computation cycles as a way to create incremental efficiencies. The tendency toward "compute maximalism" has profound ecological impacts.

Data centers are among the world's largest consumers of electricity.[59] Powering this multilevel machine requires grid electricity in the form of coal, gas, nuclear, or renewable energy. Some corporations are responding to growing alarm about the energy consumption of large-scale computation, with Apple and Google claiming to be carbon neutral (which means they offset their carbon emissions by purchasing credits) and Microsoft promising to become carbon negative by 2030. But workers within the companies have pushed for reductions in emissions across the board, rather than what they see as buying indulgences out of environmental guilt.[60] Moreover, Microsoft, Google, and Amazon all license their AI platforms, engineering workforces, and infrastructures to fossil fuel companies to help them locate and extract fuel from the ground, which further drives the industry most responsible for anthropogenic climate change.

Beyond the United States, more clouds of carbon dioxide are rising. China's data center industry draws 73 percent of its power from coal, emitting about 99 million tons of CO_2 in 2018.[61] And electricity consumption from China's data center infrastructure is expected to increase by two-thirds by 2023.[62] Greenpeace has raised the alarm about the colossal energy demands of China's biggest technology companies, arguing that "China's leading tech companies, including Alibaba, Tencent, and GDS, must dramatically scale up clean energy procurement and disclose energy use data."[63] But the lasting impacts of coal-fired power are everywhere, exceeding any national boundaries. The planetary nature of resource extraction and its consequences goes well beyond what the nation-state was designed to address.

Water tells another story of computation's true cost. The history of water use in the United States is full of battles and secret deals, and as with computation, the deals made over water are kept close. One of the biggest U.S. data centers belongs to the National Security Agency (NSA) in Bluffdale, Utah. Open since late 2013, the Intelligence Community Comprehensive National Cybersecurity Initiative Data Center is impossible to visit directly. But by driving up through the adjacent suburbs, I found a cul-de-sac on a hill thick with sagebrush, and from there I was afforded a closer view of the sprawling 1.2-million-square-foot facility. The site has a kind of symbolic power of the next era of government data capture, having been featured in films like *Citizenfour* and pictured in thousands of news stories about the NSA. In person, though, it looks nondescript and prosaic, a giant storage container combined with a government office block.

The struggle over water began even before the data center was officially open, given its location in drought-parched Utah.[64] Local journalists wanted to confirm whether the estimated consumption of 1.7 million gallons of water per day was accurate, but the NSA initially refused to share usage data, redacted all details from public records, and claimed that its water use was a matter of national security. Antisurveillance activists created handbooks encouraging the end of material support of water and energy to surveillance, and they strategized that legal controls over water usage could help shut down the facility.[65] But the city of Bluffdale had already made a multiyear deal with the NSA, in which the city would sell water at rates well below the average in return for the promise of economic growth the facility might bring to the region.[66] The geopolitics of water are now deeply combined with the mechanisms and politics of data centers, computation, and power—in every sense. From the dry hillside that overlooks the NSA's data repository, all the contestation and obfuscation about water makes sense: this is a landscape with a limit, and water that is used to cool servers is being taken away from communities and habitats that rely on it to live.

Just as the dirty work of the mining sector was far removed from the companies and city dwellers who profited most, so the majority of data centers are far removed from major population hubs, whether in the desert or in semi-industrial exurbs. This contributes to our sense of the cloud being out of sight and abstracted away, when in fact it is material, affecting the environment and climate in ways that are far from being fully recognized and accounted for. The cloud is of the earth, and to keep it growing requires expanding resources and layers of logistics and transport that are in constant motion.

The Logistical Layer

So far, we have considered the material stuff of AI, from rare earth elements to energy. By grounding our analysis in the specific materialities of AI—the things, places, and people—we can better see how the parts are operating within broader systems of power. Take, for example, the global logistical machines that move minerals, fuel, hardware, workers, and consumer AI devices around the planet.[67] The dizzying spectacle of logistics and production displayed by companies like Amazon would not be possible without the development and widespread acceptance of a standardized metal object: the cargo container. Like submarine cables, cargo containers bind the industries of global communication, transport, and capital, a material exercise of what mathematicians call "optimal transport"—in this case, as an optimization of space and resources across the trade routes of the world.

Standardized cargo containers (themselves built from the basic earth elements of carbon and iron forged as steel) enabled the explosion of the modern shipping industry, which in turn made it possible to envision and model the planet as a single massive factory. The cargo container is the single unit of value—like a piece of Lego—that can travel thousands of miles before meeting its final destination as a modular part of a greater system of delivery. In 2017, the capacity of container ships in seaborne trade reached nearly 250 million deadweight tons of cargo, dominated by giant shipping companies including Maersk of Denmark, the Mediterranean Shipping Company of Switzerland, and France's CMA CGM Group, each owning hundreds of container vessels.[68] For these commercial ventures, cargo shipping is a relatively cheap way to navigate the vascular system of the global factory, yet it disguises far larger external costs. Just as they tend to neglect the physical realities and costs of AI infrastructure, popular culture and media rarely cover the shipping industry. The author Rose George calls this condition "sea blindness."[69]

In recent years, shipping vessels produced 3.1 percent of yearly global carbon dioxide emissions, more than the total produced by Germany.[70] In order to minimize their internal costs, most container shipping companies use low-grade fuel in enormous quantities, which leads to increased amounts of airborne sulfur and other toxic substances. One container ship is estimated to emit as much pollution as fifty million cars, and sixty thousand deaths every year are attributed indirectly to cargo-ship-industry pollution.[71]

Even industry-friendly sources like the World Shipping Council admit that thousands of containers are lost each year, sinking to the ocean floor or drifting loose.[72] Some carry toxic substances that leak into the oceans; others release thousands of yellow rubber ducks that wash ashore around the world over decades.[73] Typically, workers spend almost six months at sea, often with long working shifts and without access to external communications.

Here, too, the most severe costs of global logistics are borne by the Earth's atmosphere, the oceanic ecosystem and low-paid workers. The corporate imaginaries of AI fail to depict the lasting costs and long histories of the materials needed to build computational infrastructures or the energy required to power them. The rapid growth of cloud-based computation, portrayed as environmentally friendly, has paradoxically driven an expansion of the frontiers of resource extraction. It is only by factoring in these hidden costs, these wider collections of actors and systems, that we can understand what the shift toward increasing automation will mean. This requires working against the grain of how the technological imaginary usually works, which is completely untethered from earthly matters. Like running an image search of "AI," which returns dozens of pictures of glowing brains and blue-tinted binary code floating in space, there is a powerful resistance to engaging with the materialities of these technologies. Instead, we begin with the earth, with extraction, and with the histories of industrial power and then consider how these patterns are repeated in systems of labor and data.

AI as Megamachine

In the late 1960s, the historian and philosopher of technology Lewis Mumford developed the concept of the *megamachine* to illustrate how all systems, no matter how immense, consist of the work of many individual human actors.[74] For Mumford, the Manhattan Project was the defining modern megamachine whose intricacies were kept not only from the public but even from the thousands of people who worked on it at discrete, secured sites across the United States. A total of 130,000 workers operated in complete secrecy under the direction of the military, developing a weapon that would kill (by conservative estimates) 237,000 people when it hit Hiroshima and Nagasaki in 1945. The atomic bomb depended on a complex, secret chain of supply, logistics, and human labor.

Artificial intelligence is another kind of megamachine, a set of technological approaches that depend on industrial infrastructures, supply chains, and human labor that stretch around the globe but are kept opaque. We have seen how AI is much more than databases and algorithms, machine learning models and linear algebra. It is metamorphic: relying on manufacturing, transportation, and physical work; data centers and the undersea cables that trace lines between the continents; personal devices and their raw components; transmission signals passing through the air; datasets produced by scraping the internet; and continual computational cycles. These all come at a cost.

We have looked at the relations between cities and mines, companies and supply chains, and the topographies of extraction that connect them. The fundamentally intertwined nature of production, manufacturing, and logistics reminds us that the mines that drive AI are everywhere: not only sited in discrete locations but diffuse and scattered across the geography of the earth, in what Mazen Labban has called the "planetary mine."[75] This is not to deny the many specific locations where technologically driven mining is taking place. Rather, Labban observes that the planetary mine expands and reconstitutes extraction into novel arrangements, extending the practices of mines into new spaces and interactions around the world.

Finding fresh methods for understanding the deep material and human roots of AI systems is vital at this moment in history, when the impacts of anthropogenic climate change are already well under way. But that's easier said than done. In part, that's because many industries that make up the AI system chain conceal the ongoing costs of what they do. Furthermore, the scale required to build artificial intelligence systems is too complex, too obscured by intellectual property law, and too mired in logistical and technical complexity for us to see into it all. But the aim here is not to try and make these complex assemblages transparent: rather than trying to see *inside* them, we will be connecting *across* multiple systems to understand how they work in relation to each other.[76] Thus, our path

The ruins at Blair. Photograph by Kate Crawford

will follow the stories about the environmental and labor costs of AI and place them in context with the practices of extraction and classification braided throughout everyday life. It is by thinking about these issues together that we can work toward greater justice.

I make one more trip to Silver Peak. Before I reach the town, I pull the van over to the side of the road to read a weather-beaten sign. It's Nevada Historical Marker 174, dedicated to the creation and destruction of a small town called Blair. In 1906, the Pittsburgh Silver Peak Gold Mining Company bought up the mines in the area. Anticipating a boom, land speculators purchased all of the available plots near Silver Peak along with its water rights, driving prices to record artificial highs. So the mining company surveyed a couple of miles north and declared it the site for a new town: Blair. They built a hundred-stamp cyanide mill for leach mining, the biggest in the state, and laid the Silver Peak railroad that ran from Blair

Junction to the Tonopah and Goldfield main line. Briefly, the town thrived. Many hundreds of people came from all over for the jobs, despite the harsh working conditions. But with so much mining activity, the cyanide began to poison the ground, and the gold and silver seams began to falter and dry up. By 1918, Blair was all but deserted. It was all over within twelve years. The ruins are marked on a local map—just a forty-five-minute walk away.

It's a blazing hot day in the desert. The only sounds are the metallic reverberations of cicadas and the rumble of an occasional passenger jet. I decide to start up the hill. By the time I reach the collection of stone buildings at the top of the long dirt road, I'm exhausted from the heat. I take shelter inside the collapsed remains of what was once a gold miner's house. Not much is left: some broken crockery, shards of glass bottles, a few rusted tins. Back in Blair's lively years, multiple saloons thrived nearby and a two-story hotel welcomed visitors. Now it's a cluster of broken foundations.

Through the space where a window used to be, the view stretches all the way down the valley. I'm struck by the realization that Silver Peak will also be a ghost town soon. The current draw on the lithium mine is aggressive in response to the high demand, and no one knows how long it will last. The most optimistic estimate is forty years, but the end may come much sooner. Then the lithium pools under the Clayton Valley will be exsanguinated—extracted for batteries that are destined for landfill. And Silver Peak will return to its previous life as an empty and quiet place, on the edge of an ancient salt lake, now drained.