Introduction

> No hay otro tranque de relave en Chile con las características de Carén, que, por lo demás, es de CODELCO. (There is no other tailings dam in Chile with the characteristics of Carén, which, besides, belongs to CODELCO.)
>
> ANA LYA URIARTE, *CONAMA director, July 7, 2006*

GRAY WORLDS

It took us awhile to reach the top of the wall. The dirt road leading us there started at ground level, climbing for a dozen meters until reaching a flat stretch that marked the maximum height of an earlier stage in its construction process. It then climbed another dozen meters to a new flat stretch. It continued thus until reaching its current summit, from where we could see a panoramic view of the entire basin. Although only half its projected final size, the wall is already massive. Made of rocks and dirt, it is more than 90 meters high and a kilometer wide. We drove along it for a few minutes, finally stopping at its middle section, with the front of our truck facing east toward the millions of tons of tailings already accumulated there. It was January 2014, and we were visiting for the first time Embalse Carén, the current tailings dam of Mina El Teniente.[1]

Property of the public company Corporación Nacional del Cobre (CODELCO), Teniente is located 100 kilometers south of Santiago, Chile's capital city, in the Andes Mountains. Sitting on "the world's largest known porphyry Cu deposit," the mine has been in industrial operation since the beginning of the twentieth century and currently comprises more than 3,000 kilometers of tunnels; it is usually considered the largest subterranean mine in the world.[2] The mine produces mostly copper (470,000 metric tons in 2018), among other refined minerals. As usual in contemporary mining, each copper ton involves the parallel production of around 99 tons of tailings, residues that need to be removed rapidly from the processing plant in order to avoid clogging the system. Immediately after being produced in

FIGURE 1. Eastward view from the Carén Dam wall

massive decantation ponds, Teniente tailings are put into a concrete canal, through which they flow for 85 kilometers across Chile's central valley until they reach Carén Dam, located in a valley in a mountain range known as Altos de Cantillana.

The view was truly impressive. In the area near the wall (see figure 1), tailings were covered by a large body of bright green water, stretching for several kilometers into the distance to what looked like a white sandy beach, with only the surrounding mountains breaking the impression that we were seeing something like an artificial tropical sea. This impression was misleading. Water only covered a tiny fraction of the dam (see figure 2). Similar to other tailings dams that we had visited, most of the surface was a monotonous light gray emptiness, totally flat and seemingly borderless, where nothing grew or lived. Kilometer after kilometer of lifeless gray.

Emptiness was accompanied by stillness. From our vantage point that day the dam looked like the epitome of tranquility. Nothing seemed to be moving in the gigantic infrastructure and its environs, especially the millions tons of tailings right in front of us. We experienced a sort of glacial time, tailings as a mass that was not only immobile but seemingly immovable, its

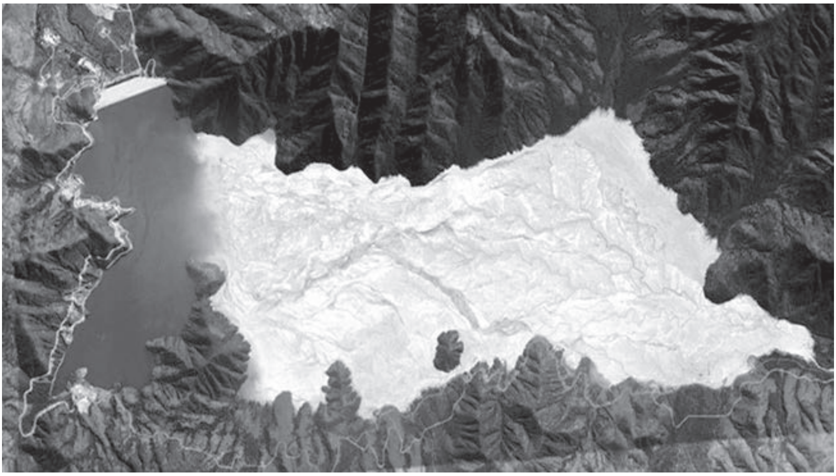

FIGURE 2. Satellite view of the Carén Dam

stillness difficult to imagine changing substantially in the short term, even in the decades to come. It was a gray world, seemingly firmly located in the deep time of geological processes.

The gray worlds of tailings are not so still, however. Tailings are described in the technical literature as "mixtures of crushed rock and processing fluids from mills, washeries or concentrators that remain after the extraction of economic metals, minerals, mineral fuels or coal from the mine resource."[3] Besides an indication that the term's first known usage was in 1764, little is known about the origin and early meanings of *tailings*.[4] This lack of clarity also results from the fact that historically several terms were used interchangeably to describe the same substance: in English *sludge*, *slag*, *slime*, and *slum*; in Spanish *relaves*, *colas*, *jales*, *barros*, and *lamas*.[5]

These shadowy origins also apply to the substance itself. Tailings can contain a wide array of components, starting from the highly variable composition of the geological strata from which the crushed rocks have been extracted. In addition, a wide array of reagents could be added to them in order to enhance the recovery of valued minerals, including "organic chemicals, cyanide, sulfuric acid, and other[s]."[6] Some of these components, such as cyanide, are well-known toxicants, whose negative effects on human and environmental well-being have been known for a long time. However, many kinds of tailings do not include these potentially toxic elements in high concentrations, making them far less potentially damaging. Tailings are quite variable entities, hence their exact chemical composition varies from one mine to the next, even in the same mine at different points in time. As the ores, reagents, and processing technologies change, so do tailings.

Current Teniente tailings are composed of around 45 percent water; the rest is a solid fraction formed of clay (21%), silt (68%), and sand (11%).[7] Regarding their chemical composition, these tailings are mostly a mixture of sulfide minerals such as pyrite, covellite, and bornite. Although not very toxic in themselves, their small particle size and their rapid dry-out in the semiarid conditions of the basin mean that these sulfide minerals could easily oxidize, generating acid mine drainage, one of the most common forms of pollution associated with large-scale mining.[8] Other minerals found in these tailings are copper, zinc, and molybdenum. Although their relatively low concentrations diminish their potential toxic effects, at least molybdenum has been of concern for both mining operatives and authorities in recent years (as we will see in chapter 2).

Besides their potential toxicity, what makes the issue of tailings' environmental impact pressing is that even midsize mines produce thousands tons of tailings *per day*, in all reaching a "global quantity of approximately 18 billion m^3 per year . . . [which could be on] the same order of magnitude as the actual sediment discharge to the oceans."[9] Traditionally, this enormous amount of waste was simply washed out to the nearest body of water, taking advantage of tailings' semiliquid condition. This practice caused massive damage, completely obliterating ecologies downstream. As a way to deal with this situation, since the beginning of the twentieth century most mines (although not all) have opted to build massive dams to store tailings.

The dams where tailings are accumulated usually become enormous, extending for hundreds of square kilometers and reaching depths of several hundred meters. Thus, it is not surprising that a survey on the topic called them "probably the largest man-made structures on Earth."[10] Given this scale, the whole process of producing and accumulating tailings (along with other mining waste products) not only "comprise[s] the world's largest industrial waste stream" but also is seen as on "the same order of magnitude as that of fundamental Earth-shaping geological processes."[11] For example, already by 2007, Embalse Carén "occupied an 8.5 km-long and up to 2.5 km-wide area of the valley. . . . With an average deposition of ca. 200,000 t/d tailings . . . , the total volume of the Carén dam was estimated at 7.6Mm^3 with a total surface of 22 km^2."[12] What we were seeing that day at the dam wall, putting it brutally, were the very bowels of the Andes.

Given their potential toxicity and enormous volume, tailings have become the most important source of mining-related pollution and destruction. A cadastre on the issue carried out by the official industry organization, concluded that worldwide since the 1970s there has been at least one major failure of a dam each year.[13] The identified causes of these faults are multiple, including, among others, liquefaction under seismic activity, extreme pressure at the dam wall, ground faults, excessive water levels, and leaks. Such failures have caused massive ecological and social damage, becoming in some cases the worst environmental disasters experienced in the affected countries, as happened in the Bento Rodrigues (2015) and Brumadinho (2019) disasters in Brazil. Worryingly, such failures have increased substantially during the ongoing mining supercycle, especially due to the growing exploitation of complex ore bodies with lower concentrations of valued minerals, which involve the production of more tailings.[14] In addition to the risk of utter collapse, tailings ponds are associated with forms of regular pollution, as variable amounts of tailings regularly spill out of the dams, polluting local streams and being carried away by the wind as dust. Dams constantly break and leak, especially older ones.[15] Given their huge volumes and geomorphological properties, their multifarious risks and toxic potentialities, and their "deep time" implications, we could easily see tailings dams as a key materialization of the Anthropocene.

Like all things related to the Anthropocene, tailings and their destructive capacities are also crisscrossed by deep patterns of inequality and violence. Although tailings ponds are among the largest structures ever made, most people—especially in the affluent West—have never seen one, much less been affected by its contents. This is not accidental. The largest and most risky tailings dams worldwide are located in medium- to low-income countries, places already marked by high levels of social inequality, weak governance, and systemic corruption.[16] Inside such countries, the dams also tend to be located in areas of little value, usually far away from the centers of local power, places where other discards of global capitalism already reside: among the urban poor, neglected ecologies, indigenous communities, invasive species, and the like. Obviously, no member of these groups is ever consulted about the arrival of such a massive (and troublesome) neighbor. The locations of these dams therefore are not only a practical or economical matter, but reflect (and amplify) deep patterns of social and environmental inequality.

This forced cohabitation usually goes hand in hand with multiple forms of violence. Tailings transport, disposition, and (mis)management are usually accompanied by a series of malpractices typical of mining corporations.[17] Practices such as land grabbing, violence against communal leaders (especially indigenous populations), damage to farmlands and cultural heritage, and a long list of others continue to characterize an industry that historically "has taken a 'devil may care' attitude to the impacts of its operations."[18] It is not surprising that mining is usually seen as one of the most socially and environmentally destructive industries, especially when it is set in the colonial mode of transnational corporations operating in remote locations, where they encounter little regulation and accountability, as usually happens in Latin America. The few valuables that corporations actually extract from such locations—the high-grade minerals—rest on the creation of vast tailings flatlands, always prone to collapse and pollute, whose management usually involves adopting violent means to address any kind of local opposition.

Reacting to this violence, since the 2000s massive social movements emerged against mining throughout Latin America, some of them directly focused on the nefarious environmental effects of tailings and tailings dams. Under the concept of *extractivismo*, mining in Latin America is conceived of as an enterprise whose sole focus is the export of raw materials. As declared by Gudynas, "in extractivismos nothing is produced, there is only an extraction."[19] Extractivismo "refers to a 'mode of appropriation,' rather than a mode of production," appropriation that in most cases only benefits a small local capitalist elite and, increasingly, transnational corporations.[20] For most of the affected others, extractivismo is only a source of dispossession and poverty, as well as "serious and irreversible damage to the natural environment."[21] Derived from this conception, these movements are commonly focused not only on rebalancing the distribution of wealth and well-being, but on the utter elimination of mining projects. Increasingly organized as transnational networks, movements against extractivismo have rapidly become one of the most prominent forms of environmental activism in countries such as Chile.

Mineral extraction is damage and pollution, it seems, especially when seen from the optics of tailings, the monstrous "tails" of capitalist extractive efforts. These tails are so massive that not only damage local people and ecologies on a daily basis but are even reconfiguring the planet's geomorphology. In multiple locations throughout the world, tailings dams actualize colonial regimes of power and violence, cementing over all kinds of local life projects, especially the ones already affected by multiple other forms of precariousness.

FIGURE 3. Downstream view from the Carén Dam wall

A GREEN PLACE

Upon reaching the other side of the wall that day, our initial assessment of Carén Dam was rapidly challenged. Besides the wall itself, the view downstream clearly departed from the image of damage and pollution we associated with tailings ponds. A narrow creek emerged at the bottom of the wall and then ran down towards the valley. Although crossing through bare lands at first, a bit farther down it was surrounded by a fair amount of greenery, both agricultural fields and forests. The view downstream (see figure 3), appeared to be an open negation of what we had seen on the other side of the wall.

This impression only confirmed what we had seen upon approaching the Carén complex after a two-hour drive southwest from Santiago. From the road, we didn't see any signs of the million tons of potentially toxic tailings accumulating just a few kilometers away. There was no gray wasteland, no massive pieces of mining-related infrastructure or the dark-orange-colored water associated with acid mine drainage, as we had observed in the vicinity of other tailings dams in Chile. To our eyes, the basin appeared as fairly typical of Chile's central valley, relatively arid but with plenty of agricultural fields, with crops such as corn and potatoes, plus livestock, interspersed with some houses and a couple of small businesses. After crossing the gates of the Carén complex, we saw not only a highly productive experimental farm but even a beautiful lagoon surrounded by grown trees, home of several wild bird species.

Such a view was even more surprising considering the so-called megadrought affecting central Chile.[22] Lasting more than ten years, this event shattered all the recorded minimum levels of water precipitation, being widely seen as the foremost manifestation of climate change in the country. The extreme lack of water has progressively turned areas in the direct vicinity of the Carén basin into drylands. If agriculture is still possible there, it is only because massive infrastructure has been erected to extract groundwater, usually involving wells hundreds of meters deep. As most small landowners cannot afford the investment needed to drill such wells, they have been forced to sell their lands to large agro-industrial corporations, Chile's other main extractive industry.

The name Carén comes from a combination of the Mapudungun words *karv* (green) and *we* (place). And this was largely what we had found there since first arriving to do fieldwork: a relatively green place in the midst of the anthropogenic devastation caused by the megadrought. This greenery was a product not only of the presence of deep wells and large corporations, but of dozens of low-income landowners cultivating relatively small plots of land, usually in a highly artisanal fashion. In a way, to the visitor the basin appeared as a relic from the past, one in which surface water was still regularly available, so with little investment one could run a productive farm. And this was *because of*, not *despite*, the tailings dam.

Carén, we rapidly realized, was a paradox.

This paradoxical character started from the very top. CODELCO was created in 1976 as a publicly owned company in charge of the management of the recently nationalized copper mining industry (further explored in chapter 1), becoming as a result the biggest copper mining corporation in the world. In achieving this status, its operation has been repeatedly associated with most of the conventional negative effects of large-scale industrial mining in the global south: environmental degradation; violence against local communities, especially indigenous people; destruction of cultural heritage; and so on.

At the same time, CODELCO does several things that are much less common for large mining corporations. First, and foremost, being a publicly owned company, its revenues do not go to some group of wealthy individuals located in a faraway country. On the contrary, they go directly to the Chilean state and are in fact its primary source of revenue. Second, CODELCO is expected to act in a state-like manner, considering the public well-being along with the search for profits. Even before the current hype about corporate social responsibility (CSR) in the mining sector, CODELCO was for years aiming at achieving higher standards in social and environmental issues than other, privately owned, mining corporations operating in Chile. Although these initiatives do not usually go beyond establishing clientelistic relationships with communities surrounding the mines, they raise not inconsiderable points of friction with the mine's daily operations.

These contradictions have been very much present in the case of Teniente. Since its very beginning, the mine has focused not only on the production of copper, but also on the management of local populations. This aim was first directed toward turning them into trustable and loyal workers.[23] As critical voices were raised against the mine's environmental impact beginning in the 1990s, the program was progressively enlarged to include the population living in the mine's vicinity, establishing clientelistic patterns of relations with them (usually based on the provision of various goods and services). As we experienced frequently during fieldwork, CODELCO's behavior and image among locals were clearly different not only from the image of mining corporations elsewhere in Latin America, but even from analyses of the operation of CODELCO at other locations in Chile.[24] In line with recent ethnographic explorations of mining corporations, the version of CODELCO emerging from our fieldwork at Teniente was many things at once.[25] Certainly it was capable of embodying the monstrous corporation of extractivismo narratives, but it also was able to become a force locally recognized as having a positive impact, even a source of pride, the "orgullo de todos" (pride of everyone), as its slogan declares.

Finally, there was the issue of water. As mentioned, the Carén complex is located 85 kilometers east of Teniente, across Chile's central valley. To bring tailings there, it was necessary to build a massive canal, which includes several large bridges and tunnels and passes through areas of intensive agricultural activity and urban centers. Tailings move solely by the force of gravity through this canal, so it is necessary to add a significant amount of water to help them drain. In most mines in Chile this water is afterward returned to the processing plant. In the case of Teniente, however, the distance and geographical obstacles make this return impractical, so the water that comes with tailings is released in Carén Creek after being treated. At Teniente extraction involves mobilizing not only ores and tailings, but also water, turning the dam into a lifeline for the whole basin, a paradoxical antidote against the megadrought.

We had arrived at Carén expecting to find extensive pollution and obliterated ecologies. We certainly found them, as the chapters of this book testify. But we also found many other things, several of them openly contradicting the destruction usually associated with mining environments. There were productive agricultural fields. There were strange wildlife entanglements. There were people who saw this as a "natural" spot. There was damage, for sure. But also, there was life. *Life within extraction*.

When trying to decide how we should read the material collected there, these multiple encounters between tailings and life, we found ourselves increasingly at odds with most social science literature on the extractive industries, especially in Latin America. Against critical notions on the extractivismo literature of mining as the "*singular point of origin* of a range of social, economic, and environmental pathologies," in Carén we found tailings causing both disruption *and* emergence of life, usually in the same movements.[26] The pathologies were there, but usually accompanied by several unexpected vital developments, some of them even pointing toward tentatively hopeful futures, to less-damaging, (even) fulfilling ways to live with tailings and other residues of industrial processes.

In this book we aim to delve into Carén's contradictions to explore the possibility of thinking (and doing) extraction differently. Following Donna Haraway and many others in the environmental humanities and science and technology studies (STS), we aim at "staying with the trouble" of tailings.[27] Staying with the trouble of tailings necessarily implies properly *seeing* them, assigning them analytical and ethnopolitical space, and recognizing in them a certain dignity, even a right to existence.

GEOSYMBIOSIS

A first hint of a more generative approach to Carén was suggested when we read a geochemical description of the tailings produced by Teniente:

> Mill tailings, derived from mining sulfide-bearing ore deposits, are essentially composed of crushed rock. These systems are typically devoid of organic carbon, which limits biological cycling of sulfur, iron, and other metals in these environments. Sulfide-oxidizing bacteria, such as Acidithiobacillus

> ferrooxidans, are autotrophic and can assimilate organic carbon from CO^2. These bacteria derive energy through the catalysis of inorganic reactions. Microorganisms can act directly in the oxidation of metal sulfides . . . as a catalyst for ferrous to ferric iron oxidation . . . , in element liberation, as well as in retention and neutralization processes in mine-waste environments. . . . The interactions between the mineralogy, microorganisms, and organic metabolites are some of the key parameters to understand the formation of contaminated mine waters.[28]

Tailings are not dead. From their very first moments, as they travel the canal toward Carén, tailings become home to multiple kinds of microorganisms, especially bacteria such as *Acidithiobacillus ferrooxidans*, the main agent in their oxidizing. Although the existence and capacities of such bacteria have been known by the industry for awhile, generating a whole set of technical processes to use them to speed up the extraction process, it is also clear that "the metabolic capacities of microbes have their own rhythms . . . [and] transcend spatiotemporal limits associated with extraction of metals from low-grade and complex sulfidic ore, they produce new ones."[29] Bacteria produce new orderings in the dam, as they become entangled with a plethora of organic and inorganic entities. In doing so, bacteria—along with many other organic entities, as we will see—utterly transform the dam from a place of gray death, the "ultimate sink" for the industry's residues, into a place teeming with life.[30]

The presence of bacteria in tailings directed us to the work on symbiosis carried out by multiple evolutionary biologists since the end of the nineteenth century, most notably Lynn Margulis, and their forays into the environmental humanities and STS.[31] Breaking with conventional readings of Charles Darwin's evolutionary theory as pure competition, these researchers posited the need to understand the evolution of life on Earth also as a matter of symbiotic entanglement, especially at the bacterial level. By symbiosis Margulis simply meant "the physical connection between organisms of different species."[32] The evolutionary relevance of this process is that long-term contact could produce *symbiogenesis*, or "the appearance of new bodies, new organs, new species," resulting in more complex life forms.[33]

Given the prominence of such symbiotic entanglements in most ecologies, the very concept of individuality loses meaning. Any organism, especially complex ones such as human beings, should be seen instead as *holobiomes* or as "a collection of interpenetrating ecosystems," formed by a vast array of smaller organisms entangled in symbiotic relationships.[34] Any kind of development—human or otherwise—implies "becom[ing] with others" in multispecies entanglements; "symbionts and hosts do not lead independent existences.[35] Rather, they are the mutual cause of the other's development."[36] Instead of being merely the background for a well-defined set of individual species, an ecology is growingly seen as an ever-changing arrangement that "organisms actively modify to suit their responses" but that modifies them in response.[37]

In this process of continual symbiotic emergence, conventional nonliving entities such as minerals occupy a central place. Not only do minerals affect biological entities, forming a major part of their structure, but biological entities "are intimately associated with the biogeochemical cycling of metals."[38] For Caldwell and Caldwell, this process leads to the emergence of what they have called *geosymbiosis* or "a reciprocal relationship in which the restructuring and proliferation of a mineral affects the proliferation rate of an organism, and the restructuring and proliferation of the organism affects the proliferation rate of the mineral."[39] In a similar way to purely biological symbioses, "both geosymbiotic partners affect and are affected in return," representing "cross-linkages between the pipelines of biological and geological innovation" and even leading to the formation of whole new holo(geo) biomes.[40] Some of these geosymbioses can lead to a flourishing of biological life in places with intensive concentrations of heavy metals, such as in phytoremediation. In other cases, such as acid mine drainage, geosymbioses can negatively affect several biological entities. What is undeniable is that minerals are not passive recipients of symbioses but very much participants in them, being importantly changed as a result. Even conventionally "toxic" chemical compounds could be seen as "[geo]symbiotic partners of coevolution," not necessarily attacking biological entities but taking them somewhere else.[41]

To recognize that a certain degree of entanglement is at least as important as competition for the emergence and maintenance of life does not mean that symbioses are necessarily an improvement for all the entities involved, as is usually assumed. As stated by Sapp, one of the more complex issues regarding the historical development of symbiosis theory has been the tendency among many of its practitioners to equate symbiotic entanglements with social and/or moral orderings.[42] Against the rampant spread of global capitalism and its unabashed support of individual competition, symbiosis appeared to "naturalize" an alternative social ordering in which cooperation and mutual care was the rule, not an exception. Such a tendency to moralize symbiosis has been strengthened through its uptake in the environmental humanities.[43]