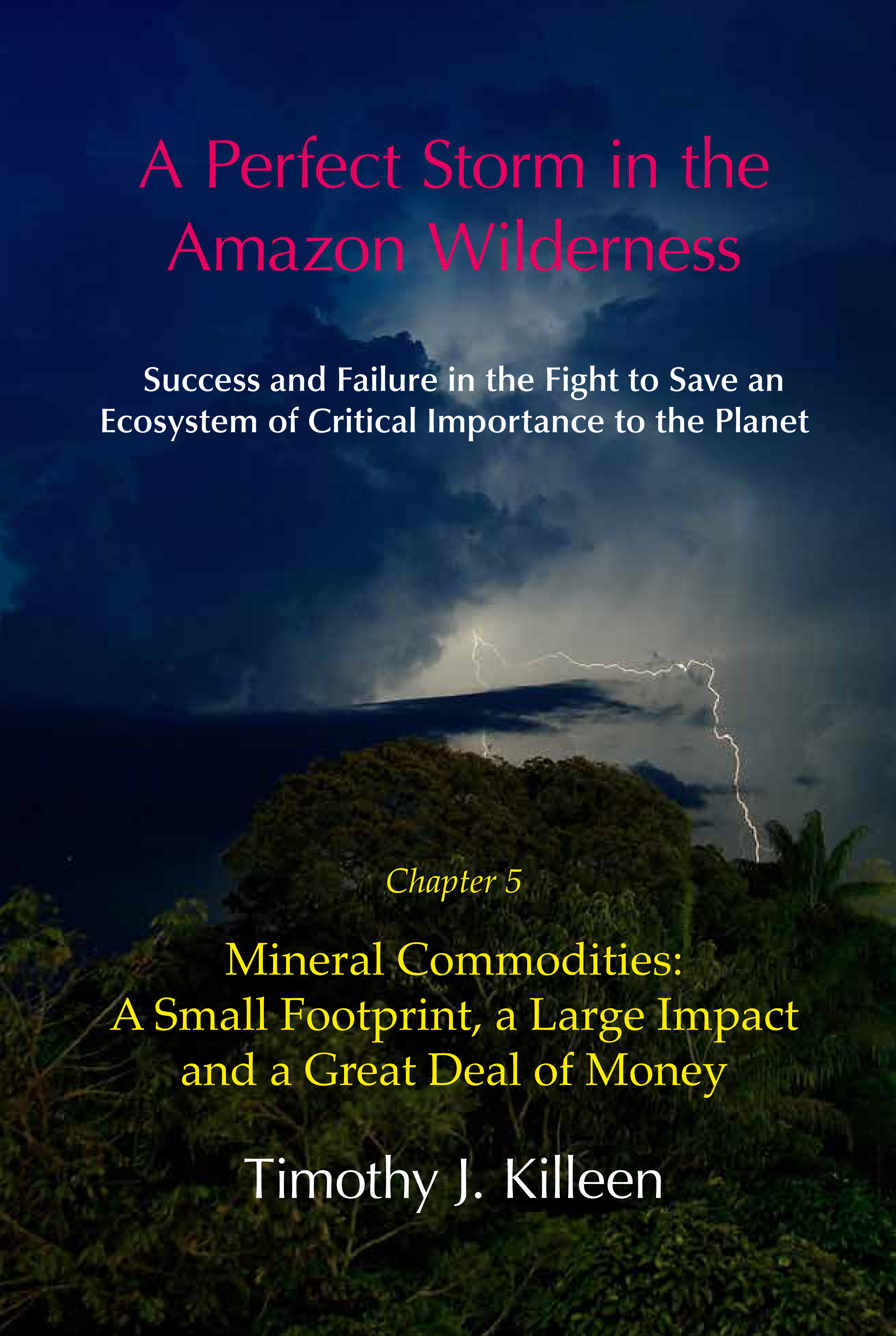

A Perfect Storm in the Amazon Wilderness

Success and Failure in the Fight to Save an Ecosystem of Critical Importance to the Planet

Chapter 5

Mineral Commodities: A Small Footprint, a Large Impact and a Great Deal of Money

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Chapter 5: Mineral Commodities: A Small Footprint, a Large Impact and a Great Deal of Money

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Chapter 5

Mineral Commodities

A Small Footprint, a Large Impact and a Great Deal of Money

Mineral extraction is a major cause of contention among the inhabitants of the Pan Amazon. Thousands of families depend on economic activity that originates, directly or indirectly, from the mining and hydrocarbon industries. Simultaneously, thousands of families suffer, directly or indirectly, from the impacts caused by the exploitation of non-renewable natural resources.

The mineral sector can be organised into three areas based on the type of commodity being extracted: (1) Industrial minerals, such as iron ore, bauxite, copper, zinc, magnesium, nickel, lead, molybdenum and tin, which are key to essential supply chains in the global economy; (2) Gold, which has only limited industrial use, but which occupies a strategic position in financial markets due to the value assigned by human society; (3) Hydrocarbons, specifically natural gas and petroleum, which power electricity and transportation systems that are still much in demand by the global economy and are integral to the macroeconomic health of domestic economies, although their future utility is limited by the reality of climate change and the accelerating transition to renewable energy.

The extractive industries rely on the approval (legal) or acquiescence (illegal gold mining) of national governments, who are motivated by short-term economic benefits that are quasi-addictive in their macroeconomic impact. The hard reality of an unfavourable balance of payment situation forces governments to promote mineral development, even when the overall cost–benefit equation might call for a different development strategy. This predisposition is replicated by regional and local governments, particularly those controlled by local elites that benefit from secondary business opportunities. Local populations are commonly conflicted by mineral development projects and some welcome employment opportunities, even when transitory, while others fear the well-documented social and environmental impacts that can persist long after the productive life cycle of the so-called extractive asset.

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The petroleum sector's business model is contingent upon exploration and discovery. Since oil and gas are nonrenewable natural resources, they must be replaced at the same rate they are consumed. The Bolivian oil company (YPFB) has invested in numerous exploratory wells in the Bolivian Yungas, including within protected areas and indigenous lands.

The operators of a mine or an oil field are morally, legally and financially liable for the environmental and social impacts caused by their business ventures. They share that liability with the state, however, because governments are the recipients of taxes and royalties, as well as the administrators of the agencies charged with regulatory oversight. Because minerals are export commodities, the cost of avoiding, mitigating or remediating impacts are (theoretically) shared by consumers and downstream industries as well as financial institutions that vet and approve all legally constituted projects. Outside of these easily identifiable and coercible stakeholders are the wildcat miners who benefit from the acquiescence (malfeasance) of elected officials, while being rewarded by an international financial system that buys their gold. Nobody has assumed the moral, legal or financial responsibility for remediating the massive impacts caused by wildcat miners. That cost is borne by the inhabitants of the Amazon.

The Environmental and Social Liabilities of the Extractive Sector

Environmental advocates routinely oppose mining and hydrocarbon development projects because they believe that remote areas of the Amazon should remain pristine. Typically, they organise their opposition during the environmental review process with campaigns that focus on issues that are local (water quality), regional (biodiversity) and global (climate change). Occasionally, they succeed in stopping a project, but more often they must settle for environmental and social action plans that ameliorate only the worst aspects of what are, essentially, irreversible changes to habitats and ecosystems.

Indigenous peoples are outspoken in their opposition to mineral development because their communities can be transformed by immigrants or disrupted by catastrophic events that threaten their livelihoods. They have been particularly successful in resisting projects that impinge upon their territories due to a legal principle incorporated into international law, which obligates governments and developers to obtain their 'free prior and informed consent' (FPIC). Not surprisingly, their successes in halting or delaying several highly lucrative development projects have led to a political backlash.

Industrial Mines

A modern industrial mine is a highly engineered hole in the ground. Depending upon the target minerals and the geological setting, the mine can be a complex underground structure or a surface excavation covering thousands of hectares. All mines are accompanied by infrastructure to transport massive amounts of rock and ore and a mill to grind the ore into fine particles that are (usually) mixed with water to create a slurry that is processed to concentrate the target mineral into an industrial commodity.

An industrial mine is physically unsafe due to the heavy machinery designed to excavate, transport and crush millions of tonnes of rock; consequently, mining companies spend significant financial resources to make them less hazardous. They also present a long-term health threat to employees and the surrounding communities, particularly if the milling technology generates large volumes of tailings. Tailings are dangerous because they tend to be toxic, especially if they have been treated with chemical reagents to free and concentrate the target minerals. They are extraordinarily hazardous if they are stored in poorly engineered ponds that can leak – or fail – and release their toxic contents into the environment.

Accidents have provoked mistrust among inhabitants living on mining landscapes, and environmental advocates question the integrity of the waste-management strategies in an inadequately regulated mining industry. Mining companies are aware of the environmental risks associated with their industry; this does not mean, however, that they take the necessary measures to ensure they are fail-safe.

Mine Types and Their Impacts

Underground mines were the predominant mining technology for centuries because they are efficient at extracting valuable minerals from high-grade veins and lodes. They are used in the modern mining industry only when the ore body is both deep and rich. Underground mining is a mature technology and miners have access to a variety of technological options that reduce risk and maximise productivity. In modern mines, waste rock from the construction of shafts and logistical areas is used to backfill previously mined areas, a practice that provides structural support against cave-ins, while minimising the need to manage waste rock on the surface.*

An open-pit mine is a large-scale, hard-rock operation that exploits a mineral resource close to the earth's surface. The use of open-pit mines is the consequence of a decrease in the availability of high-grade mineral resources that can be profitably exploited by an underground mine. A moderate- or low-grade ore body demands an operation that is based on the economies of scale, which is why open-pit mines tend to be extraordinarily large. Individual pits are abandoned after about ten years, and mines that operate over longer periods do so by opening additional pits above adjacent ore bodies. The most obvious impact, a giant hole in the ground, is accompanied by two others: a massive amount of waste rock and waste tailings, both of which must be accommodated in areas adjacent to the mining pits.

'Overburden', is the term used to describe the waste rock removed from the surface to expose the ore body; unlike an underground mine, it cannot be used to backfill the pit, which becomes wider and deeper as the mine matures.† Fortunately, waste rock is usually chemically inert and is simply consigned to a nearby area and planted with grass or trees to control erosion. Managing the risk associated with tailings is more challenging because chemical processing renders them toxic, while their physical state (pulverised rock sludge) makes them difficult to store.

A strip mine is similar to an open-pit mine but is associated with a mineral resource that occurs as a subsurface layer extending over a relatively

* 'Room and pillar' techniques, the most common technology, maintain structural integrity via pillars and accommodate waste rock in previously mined chambers. 'Cut and fill methods,' which are common in the Andes, hollow out the entire ore body and use the waste rock as floor to support mining activities and, eventually, to fill the chamber to the ceiling and provide structural support. Source: https://www.britannica.com/technology/underground-mining.

† Occasionally, and only then in very large mines with multiple pits, an operator will place waste rock in an abandoned pit; for example, at the Serra Norte do Carajás, which has a total of twelve separate pits, only two have been used as recipients for overburden removed from younger pits.

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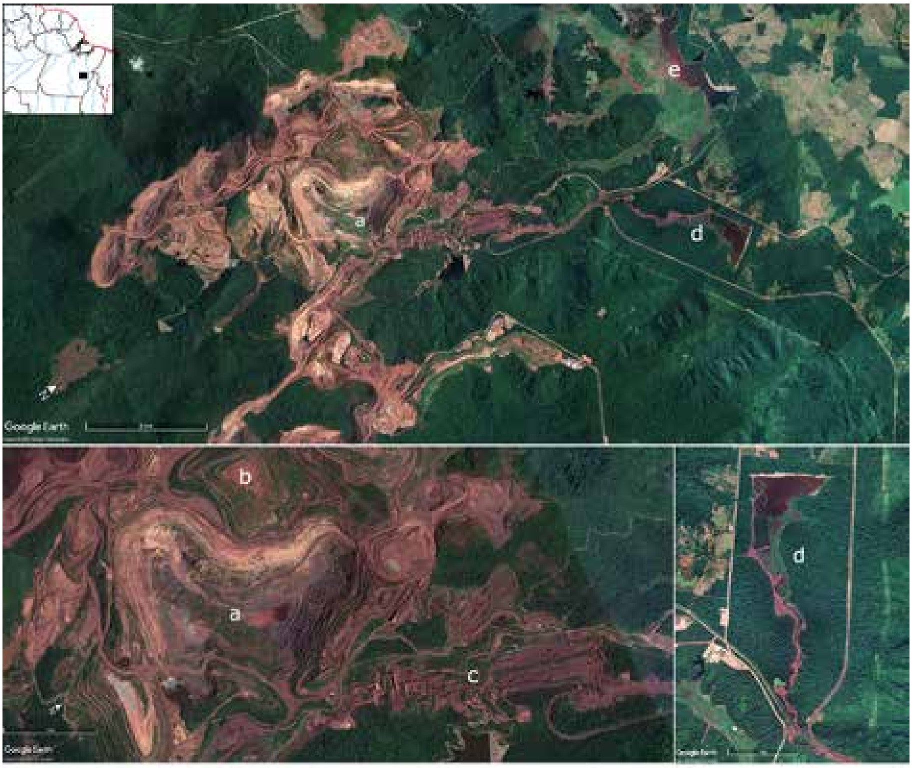
The scale of the Carajás Serra Norte open-pit iron mine in Parauapebas, Pará (top) is exemplified by the dimensions of the trucks used to haul ore from the open pit to the processing mill (bottom). The mine exploits a massive ore body considered to have the richest concentration of iron on the planet. The mine was opened in 1984 by the state-owned Companhia Vale do Rio Doce (CVRD); the company was privatised in 1997 and is now a multinational corporation with operations on five continents.

Data source: Vale.



Google Earth

The Carajás Serra Norte complex (top) includes eight open-pit iron ore mines, numerous overburden dumps, one tailings ponds and several reservoirs. The largest and oldest pit (bottom left) was opened in 1984 and decommissioned in 2017; it is 250 metres deep and 2.5 kilometres wide. The tailings pond (bottom right) has a dam with a downstream design; in 2022 it held ~150 million cubic metres of tailings and was ~80% full. Details (a) pit, (b) overburden dumps, (c) concentration mill, (d) tailings pond and (e) large reservoir to catch runoff from mining landscape.

Data source: Vale (2020).

large and homogeneous landscape (bauxite, phosphate or cassiterite). Strip mines are more amenable to reclamation because the overburden is used to backfill previously mined areas. Before the development and implementation of environmental laws, operators made no serious effort to reclaim strip mines (see Guyana and Suriname below). Currently, multinational mining companies are spending significant financial resources to restore a semblance of natural vegetation.

The Chemistry of Mineral Concentration

Tailing storage facilities are the most pernicious of the environmental liabilities that confound the mining sector. Not all tailings are equally bad or equally voluminous. The amount depends upon the mineral concentration of the ore body, while the degree of toxicity depends on the chemistry used to extract the target mineral from the pulverised ore.

Base metals, such as copper, zinc and nickel, are characterised by ores with extremely low grades of mineralisation, typically between 0.5 per cent and 2.5 per cent; consequently, these mines produce vast amounts of rock that must be pulverised and processed using acidic solutions and flotation ponds that demand large volumes of water and milling technology known as 'flotation', where chemical reagents are added to an aerated slurry permeated with bubbles.* Mineral particles liberated by the reagents adhere to the bubbles and float to the surface; the residue sinks to the bottom and is removed as a thick slurry that is dumped into a pond or impoundment referred to as a 'tailings storage facility'. The tailings are noxious because the reagent (sulphuric acid) is toxic, but also because the process liberates other heavy metals, such as arsenic, cadmium, lead and antimony.† The volume of tailings produced by an open-pit exploiting a low-grade (< 2%) copper deposit is massive, because ~95 per cent of the original ore is converted to tailings.‡ The technology is widely used in Peru and Brazil.

A less detrimental technology is the 'heap-leaching' process where crushed ore is placed in a 'heap' on a pad that is irrigated with reagents leaching the minerals from the pulverised rock. The target mineral is chemically extracted from the solvent, which is recycled and stored in small pools, while residues are immobilised in the heap. Superficially, a tailings heap may resemble waste rock from the overburden; but tailing heaps are toxic and must be isolated indefinitely by a geomembrane. Mines must build and maintain a containment pond below a tailings heap to collect and recycle the reagent (over the short term) and guard against the release of toxic residues

* Similar technologies include 'agitation' and 'tank leaching' where the target mineral is extracted by a solvent rather than by adhesion to bubbles; all three produce large quantities of tailing sludge that is stored in tailing ponds.

† Arsenic acts by causing severe vomiting and damaging the nervous system; sub-lethal dosages may reduce blood-cell production, enlarge the liver and cause brain damage; long-term exposure to low-level concentrations in drinking water can cause cancer of the skin, lungs, bladder and kidney. Cadmium damages both the liver and kidneys, while trace quantities are carcinogenic. Lead poisoning can damage almost every organ in the human body and in children it can permanently impact growth and development; in adults, lead can damage the brain and nervous system, the stomach and the kidneys, as well as cause high blood pressure and other health problems.

‡ Mills at copper and zinc mines produce a concentrate (~25% metal) that is shipped to a refinery for purification.

Google Earth

The tailings storage facility of the El Porvenir underground polymetallic mine in Pasco, Peru has expanded over time to accommodate an ever expanding volume of waste. The tailings pond has two containment dams, both with a centre-line design. The mine was opened in the 1970s and is currently operated by Nexa Resources, a subsidiary of the Votorantim Group of Brazil; it is scheduled to be decommissioned in 2028.

into regional watersheds (over the long term). This technology is used by many of the large-scale gold mines in Peru and will be used increasingly as the formal gold sector expands activities in Brazil, Guyana and Suriname.[*]

The degree of toxicity is a function of the chemical procedures used to free the target metals from the mineral ore. Iron ore and bauxite have mineral grades that range from forty to 65 per cent, which significantly decreases the relative volume of tailings when compared to the original volume of the mined ore. Nonetheless, the gigantic size of these mines, which are among the largest on the planet, generates massive volumes of tailings. Because of its high grade, the concentration process is largely mechanical, and, with

[*] Alternative technologies (flotation, agitation and tank leaching) can recover up to 97% per cent of the mineral in the ore, compared to about 60–70% for heap leach technology.

Google Earth

The Corporación Minera Centauro started mining operations at Quicay in Pasco, Peru in 2000. The gold deposit was exhausted by 2011 and the mine was decommissioned in 2017. Features include: (a) the flooded open-pit mine; (b) overburden dumps planted to grass; (c) heap leach tailings; (d) cyanide catchment ponds; (e) a natural lake that predates the mine. The mine produced 600,000 ounces of gold worth approximately $US 500 million.

Data source: https://www.cmcentauro.com/mina-quicay

very few exceptions, tailings are less toxic than at mines that use chemical processes to free the target metals from the mineral ore.

The Legacy of Tailing Storage Facilities

On 19 August 1995, a tailings containment dam at the Omai gold mine in Guyana collapsed and spilled three million cubic metres of cyanide-laced effluent and heavy metals into the Essequibo River.[12] The cause of the disaster was the object of considerable speculation, but eventually independent engineers attributed the failure to a combination of poor design, substandard maintenance and extreme rainfall, which overwhelmed the mine's tailings storage facility. The containment dam was rebuilt, and the mine continued to operate until 2007 when it was closed due to the low price of gold and declining productivity. Legal action filed on the behalf of Guyanese citizens was disallowed in Canada based on jurisdictional grounds, while the Supreme Court of Guyana dismissed the case for lack of evidence.[3] The operating company, Cambior Inc,[*] was never held responsible for the incident.

Mining engineers have long been aware of the need to improve the design and management of tailings storage facilities (TSF)[4] and investment in new technologies reflects the increasing demands by regulatory agencies and investors for improved environmental risk management. Despite numerous initiatives and significant investment, the number of incidents classified as 'serious' or 'very serious' has increased over the last thirty years.[†] Ironically, the incidence of containment structure failures has decreased; however, the severity of impacts has increased because: (1) the expansion in the scale of mining operations driven by the reduction in ore grades is generating ever larger quantities of mine tailings; and (2) the financial pressure to control costs motivates operators to stretch the capacity of waste-management facilities.[5]

The key infrastructure asset of a conventional tailings storage facility is a dam. Dams are seldom built to their final dimensions, but are raised incrementally as the mine matures. Engineers use one of three major approaches (Figure 5.1).[6] Historically, upstream designs were most prevalent because they are the most economical to build; they are unstable, however, because the dam foundation is built on top of the tailings. Downstream designs are considered to be best, but many modern facilities, and all TSFs that have been retrofitted, use the centre-line design because it minimises the amount of rock required to reinforce the containment dam and avoids rebuilding the entire structure.

Regardless of the design, any engineering solution can fail when conditions cause the dam to breach or slide downhill due to a liquefaction event.[‡] There are three, overlapping and synergistic, causes of failure: (1) structural, which occurs when there is a physical rupture of the embankment material; (2) hydraulic, which describes the erosive impact of surface water and rain; and (3) infiltration, which is the consequence of the internal erosion of fine particles via a process referred to as 'piping'. The collapse of a dam can occur suddenly if monitoring has been inadequate or mainte-

[*] Cambior Inc was acquired by Iamgold in 2006, both corporations were (are) domiciled in Canada and are listed in the Toronto Stock Exchange.

[†] Serious: Loss of life and/or release of ≥ 100,000 cubic metres of 'semi-solids discharge' (sludge); Very Serious: Multiple loss of life (~20 individuals) and/or release of > 1,000,000 cubic metres of sludge, and/or a downstream impact in greater than 20 kilometres. See Bowker and Chambers (2015).

[‡] A phenomenon where water-saturated, unconsolidated sediments are transformed into a semi-solid colloidal substance that acts like a liquid; they frequently occur during earthquakes and dam failures. Source: https://www.merriam-webster.com/dictionary/liquefaction

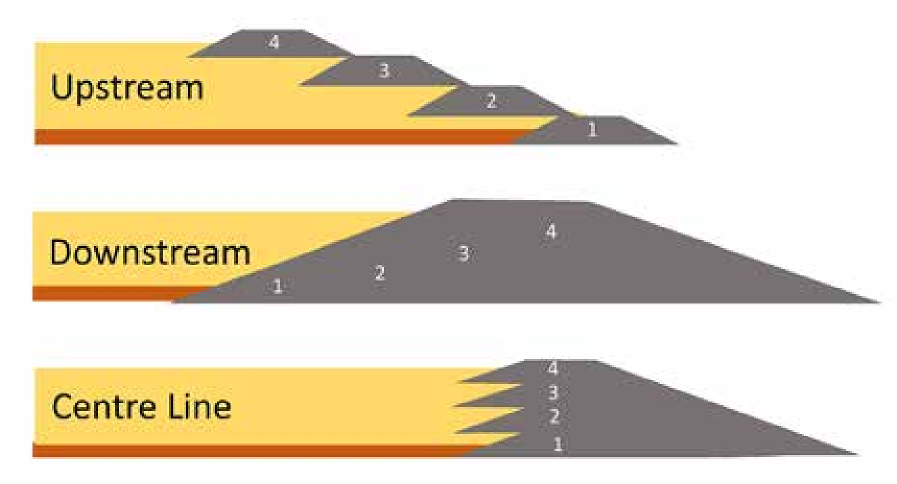


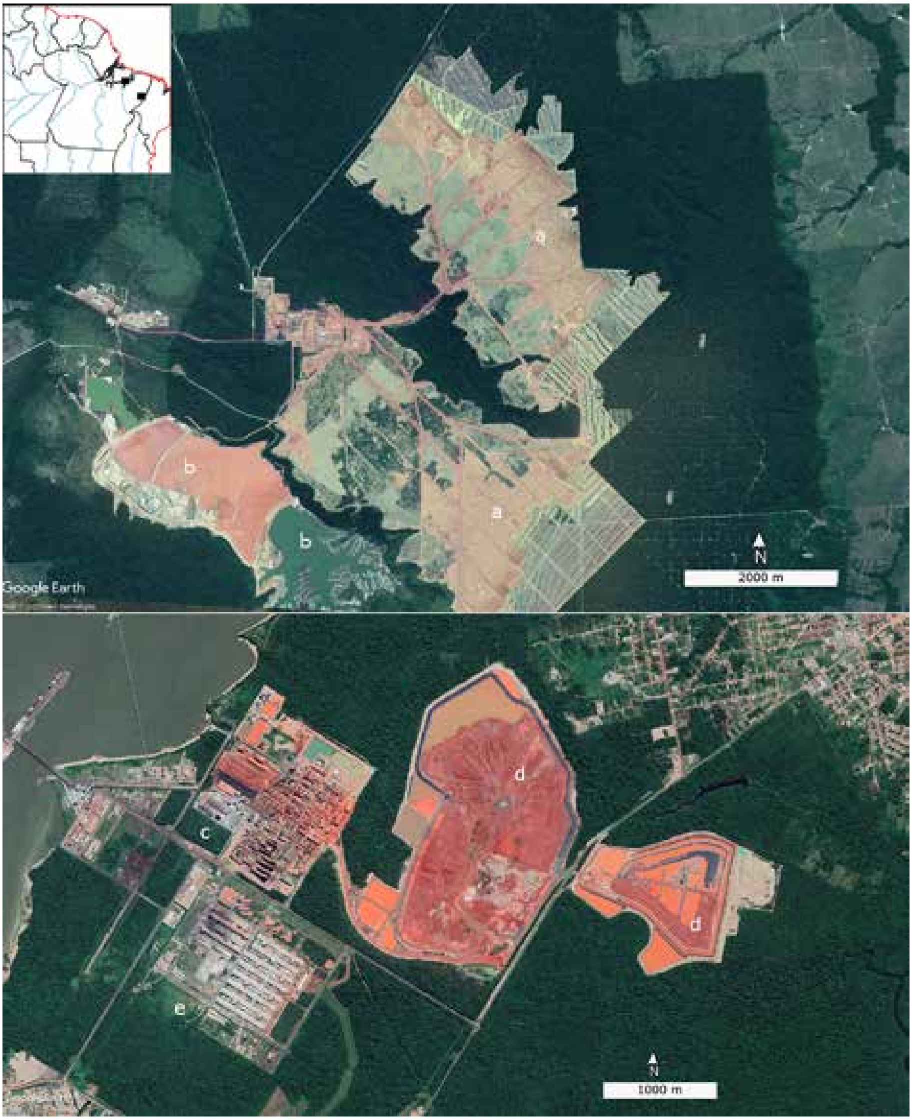
Figure 5.1: Three methods for the sequential construction of a dam for a tailing storage facility or pond. The dam is raised as the tailings accumulate. Upstream designs, which were widely used in the twentieth century, are unsafe. Downstream structures are most reliable but are more costly than centre-line systems. Modelled on Kossoff et al. (2014).

nance delayed; typically, it occurs during a decadal-scale rainfall event or earthquake, which will quickly reveal the weaknesses of a TSF.[7]

The financial shock caused by recent dam failures in Minas Gerais has finally forced mining companies to proactively review and reinforce all the containment dams in their active and inactive portfolio.[*] It also motivated governments to conduct inventories of the tailing dumps at closed, abandoned and derelict mines. In Amazonian Brazil this encompasses more than one hundred tailings storage facilities in Amazonian jurisdictions with a clearly identified corporate owner.[8] These include the ever expanding tailing ponds at the bauxite mines and refineries in Pará and the Pitinga mine in Amazonas, as well as the copper mines in the Carajás mining district. This inventory does not, however, take in the thousands of unorganised ponds on the tributaries to the Tapajós River, nor the decades-old legacies of cassiterite mining in Rondônia.

The situation is more complicated in Peru, where a recent nation-wide inventory identified more than 8,500 sites with some form of environmental liability; about 75 per cent of those are located on an Amazonian tributary.[9] More than 800 are derelict mines lacking a legal entity that can be held responsible for management and remediation.[10] The most prominent (and

* There have been 247 failures of containment dams since 1918, with 13 failures in Brazil between 1984 and 2018 and 17 in Peru since 1952. Source: Rana et al. 2021.



Google Earth

Norsk Hydro operates an integrated aluminium supply chain in Pará, Brazil. Top: The strip mines (a) in Paragominas are refilled and reforested, while tailings are stored in adjacent ponds (b) that are dewatered sequentially as the mine expands. Concentrated bauxite is transported via a slurry pipeline to an industrial complex in Barcarena. Bottom: The Alunorte alumina refinery (c) generates massive volumes of 'red muds' that are dewatered and stored in long-term tailings storage facilities (d); a leak in 2018 released toxic waste into a backwater river occupied by traditional communities. The Albras foundry (e) transforms the alumina into aluminium using electricity generated at the nearby Tucuruí hydrodam.

Data source: Norsk Hydro.

largest) are associated with the polymetallic mines that use sulphuric acid as the reagent for extracting the target minerals from pulverised ore. Perhaps the most salient risk, and one that is seldom discussed, is catastrophic failure due to periodic weather events linked to the El Niño and climate change. Earthquakes occur with decadal-scale regularity and represent a long-term liability for all containment structures.

Across the entire Pan Amazon, there has been no serious effort to mitigate the environmental impacts, nor to restore the riparian landscapes that have been transformed by wildcat placer mines.[11] No attempt has been made to remediate their impacts by investments in reforestation, soil reclamation or wetland restoration. Regulation of informal mining is ineffective because governmental agencies do not have the resources to impose effective control. Elected officials do not have the political will to confront large populations who have grown accustomed to operating outside the confines of the law.

Remediation and Restoration Ecology

The mining industry manages the environmental risk inherent in its operations by implementing the so-called 'mitigation hierarchy': avoid, minimise, remediate and offset. Mainstreaming these concepts onto their business operations has allowed companies to improve their profitability, while limiting their exposure to long-term liabilities, particularly those linked to derelict mines and tailing storage facilities. Not all impacts can be avoided or completely mitigated, however. Consequently, long-term liabilities must be remediated or offset. For example, habitat loss caused by a massive open-pit could be offset by creating a protected area with similar biodiversity. In contrast, tailing storage facilities cannot (and should not) be offset; the risk from catastrophic failure must be eliminated by effective remediation.

The simple and least expensive option is to 'decommission' a tailings pond by reinforcing the dam, while removing excess water to ensure it is secure. Nonetheless, even a decommissioned TSF will require routine maintenance. A definitive solution, known as 'de-characterisation', requires the detoxification of the tailings, the removal of the dam and the transformation of the site so that it merges into the surrounding landscape. De-characterisation seems absurd when the TSF is adjacent to a massive abandoned open-pit mine but might be a logical solution for smaller tailings storage facilities associated with underground mines, or the floodplains impacted by cassiterite mines in Rondônia and Amazonas.

Restoring a landscape to its original state is, perhaps, an idealistic and unattainable goal in most instances. But there are exceptions. Brazil's largest bauxite miner (*Mineração Rio Norte*)[*] has spent decades, and tens

[*] Mineração Rio Norte is a joint venture owned by Vale (Brazil), Norsk Hydro (Norway), Companhia Brasileira de Alumínio (Brazil), Rio Tinto (UK) and South32 (Australia).

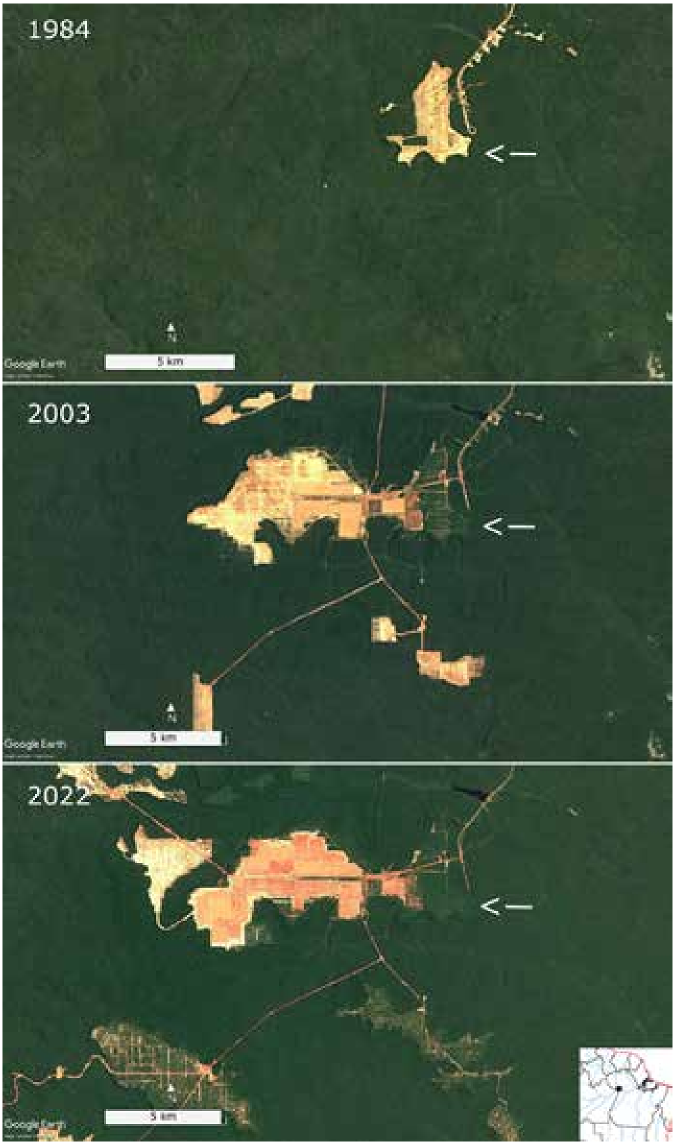
Google Earth

Vale's Igarapé Bahia gold mine operated between 1990 and 2002. The pits have filled with water (a), the tailings pond has been dewatered and decommissioned (b) and the overburden mound has been revegetated with grass (c). The site also has a catchment reservoir that isolates the mine site from surrounding watersheds in the FLONA Carajás. The mine site is known to sit on top of large copper deposit and will, eventually, be reactivated.

Data source: Vale SA.

of millions of dollars, working to restore the ecological functionality and some of the biodiversity that characterised pre-mining landscapes at the Trombetas mine in Oriximiná.* Measures include saving and reusing topsoil and spreading woody debris and detritus on the soil surface in order to reintroduce soil fungi. Native tree communities are reassembled using

* Ecologists that led the restoration work are largely from the *Instituto Nacional de Pesquisas da Amazônia* (INPA) and *Instituto Brasileiro do Meio Ambiente* (IBAMA).



Google Earth

A time series of the Trombetas bauxite mine in Oriximiná, Pará, Brazil. The mining complex is operated by Mineração del Rio Norte (MRN), a consortium of domestic and multinational mining companies. MRN has restored ~10,000 hectares of remediated strip mine into a quasi-natural forest habitat (see arrows for oldest patch of restored forest). It is unclear whether the consortium will implement a similar strategy for the tailing storage facility, although it has committed to dewatering and decommissioning the 1,000-hectare structure when the mine is closed in approximately thirty years.
Data source: MRN (2022).

seedlings germinated in nurseries from seed collected locally; epiphytes and lianas are salvaged when the mine is opened and maintained in living collections for reintroduction.[12]

According to the MRN website, more than 5,750 hectares have been incorporated into the restoration process out of a total of 8,600 hectares that have been mined since initiating operations in 1979. Similar efforts are underway at the Alcoa mine, which initiated mining activities in 2010 on the opposite side of the Amazon River in Juruti municipality. Presumably, the mine in Paragominas in Eastern Pará operated by Norsk Hydro also has a forest restoration program. In contrast, the (currently inactive) bauxite mine at Los Pijigüaos mine in Venezuela is being remediated with cultivated grasses and commercial tree species.

Gold: The Icon of Capitalism

Gold is universally recognised as a form of money that has retained value over decades, centuries and millennia. Since it is non-corrosive and precious, approximately 95 per cent of the gold mined since the dawn of civilisation remains in circulation (~205 million tonnes). The largest share (~47 per cent) is held as jewellery, which in addition to its sentimental value is an important store of family wealth. Governments hold ~17 per cent, which was used historically to back the value of national currencies and, although this is no longer the case, these reserves are often used in times of political crisis to stabilise a national economy.[*] As an elemental metal, gold has numerous uses: about ~10 per cent has been incorporated into electronics, computer and aerospace components, as well as in dental applications and medical devices. The rest (~23 per cent) is held by private investors as a financial asset to hedge against inflation and geopolitical instability. Often referred to as 'goldbugs', these individuals are ardent believers that the long-term trend in the price of gold is upward.

Only a small fraction of financial transactions is conducted using physical bullion. The overwhelming majority of trades are executed via derivative securities that track (and drive) the price of gold. Until recently, this mainly consisted of futures and option contracts, but increasingly traders speculate in exchange-traded funds (ETFs) that are essentially 'derivatives of derivatives'. Buyers are wagering the price will rise, while sellers are betting the opposite, at least over the short term. Gold markets are an example of pure financial speculation. (Figure 5.2)

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[*] The value of currencies has nothing to do with the size of a nation's gold reserves, which, instead, reflects macroeconomic factors such as gross domestic product and balance of payments.

Figure 5.2: The price of gold has nothing to do with supply and demand for jewelry or industrial uses; rather, it is driven by macro-economic phenomena linked to major economies. Prices above $US 750 per ounce are sufficient for mining companies to pursue billion dollar investments and inspire tens of thousands of men and women to strike out for the gold fields.

Data sources: Indexmundi (2022) and Corporate Finance Institute / Inflation calculator (2022).

Corporate Gold Mines are Money Machines

The price of gold is (and always has been) greater than the cost of extracting it from the bowels of the earth and all the major mining companies have subsidiaries that specialise in gold. Large companies seldom spend money to look for gold, however, and instead rely on 'junior' companies that exist solely to discover and develop mining projects.* Exploration and early development typically cost between tens and a hundred million dollars, while developing an industrial scale mine requires several hundred million to a couple of billion dollars. When a Junior verifies an exploitable resource, they sell themselves to a larger company with the financial capacity to mobilise the necessary capital resources.

The environmental and social impacts of corporate gold mines are similar to polymetallic industrial mines. Like those operations, the degree and type of impact depends on whether the mine is an underground or surface mine as well as on the chemical process used to concentrate the gold. Corporate mines use cyanide compounds to release mineralised gold

* Most juniors are domiciled in Canada, but domestic companies in Peru and Brazil have almost identical business models and investment strategies.

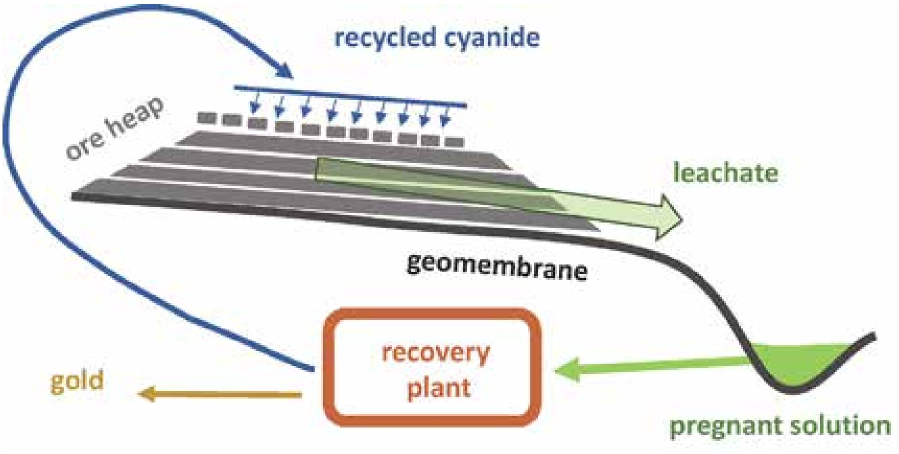

Figure 5.3: Heap leach technologies are used by corporate miners to extract minerals from pulverised ore using cyanide (gold) or sulphuric acid (copper, nickel, zinc). Although these solvents have their own environmental challenges, they dramatically reduce the demand for water and avoid the long-term liabilities associated with tailing ponds.
Data source: 911metalurgist (2023): https://www.911metallurgist.com/blog/heap-leaching.

from the ore body; this makes their operations even more toxic than their polymetallic cousins that rely on sulphuric acid. Cyanide poisoning can occur through inhalation, ingestion and skin or eye contact. Aquatic wildlife dies when cyanide concentrations exceed a few micrograms per litre, whereas bird and mammal deaths occur when concentrations reach over a few milligrams per litre. There are two types of cyanide concentration: (1) tank-leach, which demands large quantities of water and (2) heap-leach, which uses less water but is less efficient in recovering gold. The tank-leaching technology creates a tailings pond that is isolated by a dike or dam, while the heap-leach technology creates an artificial hill permeated that is isolated from the environment by a membrane and internal drainage system that collects the runoff in a pool where it is recycled (Figure 5.3).

Each mine is unique and the environmental and social liabilities are dependent on the idiosyncrasies of each mine site, including the biodiversity and ecosystems that will be lost or compromised, as well as the willingness of the surrounding communities to accommodate an industrial enterprise in their neighbourhood.

Corporations share gold production with small- and medium-scale gold miners, who cover approximately twenty per cent of global annual production. Not infrequently, they are wildcat miners responding to a gold rush triggered by a new discovery that can motivate thousands of individuals to seek their fortunes in the wilderness. When war comes or inflation threatens, a spike in the price of gold can motivate individuals to strike out for the gold fields. Domestic politics also play a role: Governments recognise that the opportunity to strike it rich provides the illusion of economic opportunity for marginalised populations.

Unfortunately, most wildcat miners make no effort to conform to the social and environmental standards required by law. Very few pay either royalties or income taxes. Critics often refer to them as illegal miners or, if they seek to engage them in a constructive dialogue, use the less pejorative term informal miner.[13] Since there is a massive international market for gold, they can launder their proceeds via multiple legitimate and illegitimate supply chains.[14] All the governments in the Pan Amazon are complicit in the trade of so-called illegal gold – in part due to social pressure, but also because they need (or appreciate) the contribution of gold exports to the balance of payments.[*]

In Brazil, wildcat miners are known as *garimpeiros,* a term derived from the word garimpo, which is a landscape where people mine alluvial gold using rudimentary mining technology. The term *garimpeiro* conjures an image of a solitary individual searching for gold using a pick, a shovel and a gold pan, but modern *garimpeiros* include small or medium-sized enterprises with access to a range of technologies. They are relatively numerous and form associations, cooperatives and syndicates,[†] which allow them to exert political influence with state and municipal governments.[15] Their special status is recognised in the Brazilian constitution of 1988 and subsequent laws established a special regulatory system to facilitate their activities. The Temer administration decentralised this system in 2018, and now mining permits are approved by state or local authorities.[‡]

Garimpeiros have enjoyed the unbridled support of Jair Bolsonaro, whose father worked as one in the 1980s and who himself participated in gold-mining ventures in the 1990s.[16] One of the most controversial policies of the Bolsonaro government was a proposal to open Indigenous territories to both industrial and artisanal mining. Although legislative changes to

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* In 2020, Bolivia had a net foreign reserve of only US$4.5 billion. That same year gold exports contributed about US$2 billion to the balance of payments. Source of data: Instituto Nacional de Estadística (INE).

† *Cooperativa dos Garimpeiros da Amazônia* (RO, AM, PA), *Associação dos Garimpeiros Independentes de Roraima* (AGIRR), *Cooperativas dos Extrativistas Minerais Familiares de Manicoré* (AM), *Cooperativa dos Extrativistas Minerais Familiares de Humaitá* (AM) and *Sindicato dos Garimpeiros do Estado de Mato Grosso* (MT).

‡ *Agência Nacional de Mineração* (ANM) a semi-autonomous regulatory agency linked to the Ministério de Minas e Energia (MNE) issues *Permissão de Lavra Garimpeira* via a decentralised system that coordinates closely with state governments with subsidiary regulatory regimes.

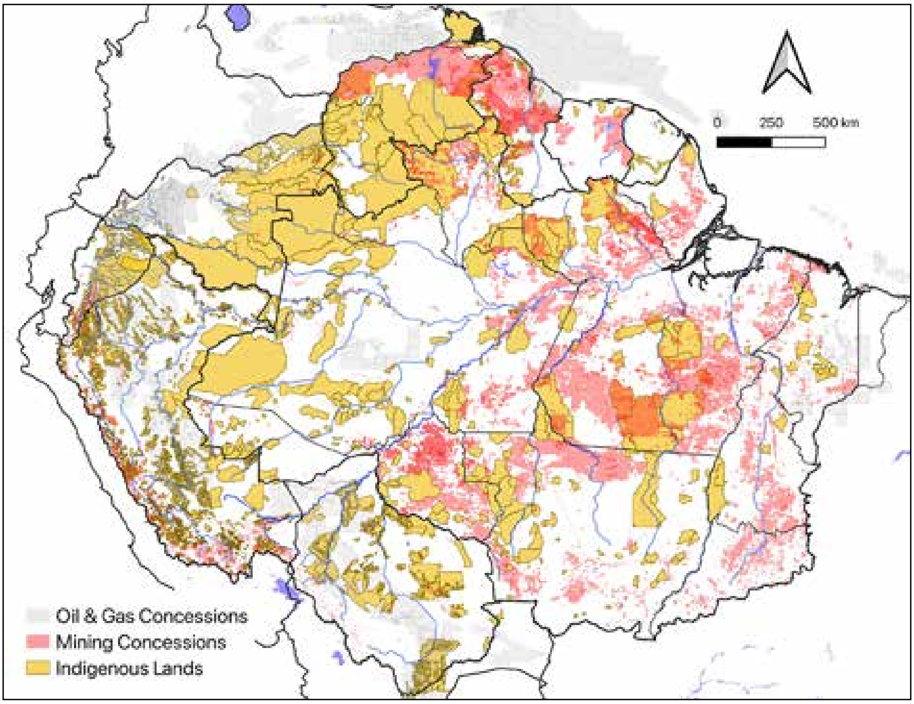

Figure 5.4: One of the most controversial policies of the Bolsonaro government was a proposal to open indigenous lands to both corporate and wildcat mining. In the Andean Amazon, a similar conflict revolves around the production of oil and gas. In all Amazonian countries, the state retains ownership of all below-ground mineral resources, including under indigenous territories and landholdings. Exploitation is theoretically dependent upon the developer and the state obtaining the 'free prior and informed consent' of indigenous communities, but governments have been reluctant to surrender control of what they view as strategic national resources.

Data source: RAISG (2022).

the regulatory regime were not successful, the administration defunded actions to combat illegal mining within Indigenous territories.[17] (Figure 5.4)

Placer Gold and the Legacy of the Garimpo

Wildcat miners are the source of the two most insidious environmental and social impacts associated with the extractive industries in the Pan Amazon: floodplain destruction and mercury pollution. Both are associated with a centuries-old technique that collects and concentrates gold deposit, which mining engineers refer to as a 'placer', a sub-surface alluvial strata composed of silt, sand and gravel accumulating heavy gold particles (nuggets and dust).* A placer is a source of 'free gold' that has accumulated over thousands of years by erosion from the veins and lodes associated with mineralised ore bodies, which are the target of industrial mines. Placer technology is used on some upland landscapes where free gold is located within the soil profile (e.g., colluvium and saprolite),† which include some of the richest gold strikes in the Amazon, including Serra Pelada (Pará, Brazil) and Claritas (Bolivar, Venezuela).

In its simplest manifestation, a placer mine is nothing more than a pick, shovel and gold-pan, but more often includes specialised equipment to collect, shake and separate gold from the sand and gravel. Water is central to the entire process. Typically, the first miners at a site use rudimentary technology, but these are followed by an increasingly sophisticated cohort that excavate placers at greater depth, while processing larger volumes of sediment (Table 5.1). A placer mining landscape will contain a mixture of mining types with the least sophisticated miners operating around the margins, or at the leading edge of an expanding mining frontier.

Floodplain Destruction

Floodplains are extraordinarily productive because they are the interface between aquatic and terrestrial ecosystems. They are remarkably diverse because they integrate a mosaic of lakes, marshes, palm swamps and inundated forests, which create the complex food webs that support fish populations. Floodplain habitats are socially and economically vital because tens of thousands of families depend upon their natural resources for their livelihoods (see Chapter 9).

The impacts from placer mining are catastrophic to floodplains because miners overturn the top layer of soils to expose the gold-bearing placer sediments, leaving behind a desolate moonscape. A placer mine typically occupies a floodplain in its entirety, extending from terrace to terrace and expanding upstream and downstream over dozens of kilometres. A common variant consists of a dredge mounted on a barge that exploits the channel bed of larger rivers that drain wildcat mining landscapes. The combination of placer mines in the headwaters and dredge-barges working downstream can convert a clear-water riparian ecosystem into a silt-laden and polluted river (e.g., the Tapajós).[18]

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* The English word 'placer' was originally used to refer to a sand bank or gravel bed located adjacent to a river or stream and was taken from Spanish placea, which is derived from the word plaza. Source: Encyclopaedia Britannica, https://www.britannica.com/technology/placer-mining

† Colluvium describes unconsolidated sediments that have accumulated at the base of hill slopes due to creep caused by gravity. Saprolite refers to soil formed in situ by weathering of the underlying bedrock. Source: USGS.

Table 5.1: Typology of placer miners in the Pan Amazon

Type	**Volume of Sediments per day (m³)**		**Technology**	**Landscape**
	Min.	Max.		
Pick and shovel with wheel barrel and gravity pan	2	15	Manual labour, using gravimetric concentration with natural water flow sluice, normally one mercury amalgamation event per day	Riverbanks and abandoned rivers within walking distance of water; prefer beaches where high water levels have deposited gold near surface
Pick and shovel with rocker and sluice box	3	30	Manual labour, using gravimetric concentration with pump-assisted sluice, normally one mercury amalgamation event per day	Riverbanks and abandoned river channels, constrained by length of hose (~100 m) from water
Hydraulic mining	80	200	High pressure water used to dislodge sediments (ore) and channel them to a pump-assisted sluice, normally one mercury amalgamation event per day	Flood plain, abandoned river channels and adjacent upland benches; constrained by distance to water
Dredges	50	150	Sediments vacuumed into a barge-like vessel and delivered to a pump-assisted sluice, one to two mercury amalgamation events per day	River channels, abandoned river channels
Heavy machinery	300	500	Earth moving by front end loader and trucks to deliver sediments to pump-assisted sluice, normally 2 mercury amalgamation events per day	Flood plain, abandoned river channels and adjacent upland benches, where other methods have identified extensive deposits; not constrained by distance to water

Sources: Mosquera et al. 2009; Heck et al. 2014; *Sociedad Peruana de Derecho Ambiental, Lima.* https://repositorio.spda.org.pe/handle/20.500.12823/274

The floodplains of the Andean piedmont and certain geologically defined landscapes on the Brazilian and Guiana Shield attract tens of thousands of wildcat miners, who employ placer mining technology that is particularly destructive and extraordinarily toxic. They include small-scale artisanal miners, as well as businesses that masquerade as mining cooperatives in order to avoid taxes and environmental regulation.

Google Earth

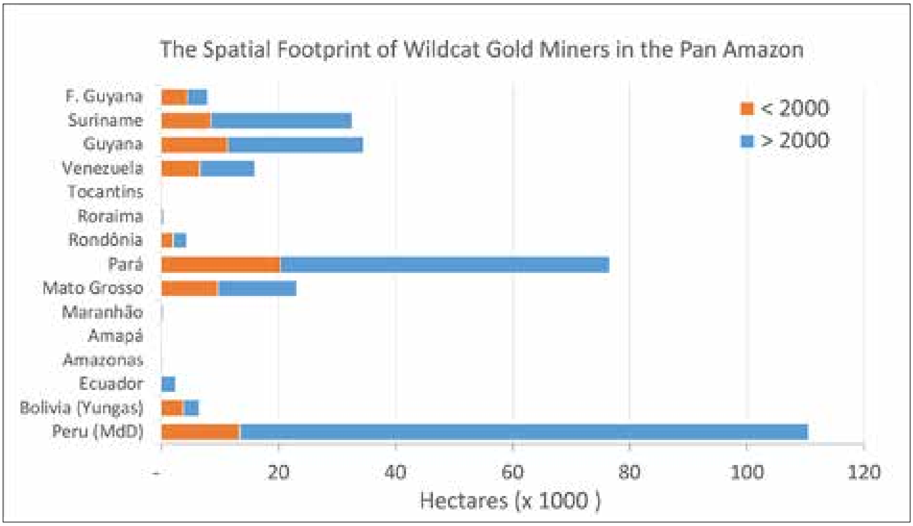
Wildcat placer miners (garimpeiros) have selectively targeted the alluvial floodplains of secondary and tertiary rivers across the forest landscapes of the Área de Proteção Ambiental (APA) Crepori. Garimpeiros discovered gold in the 1950s and a full-fledged gold rush swamped the region in the 1970s and 1980s. Referred to as the Tapajós, it remains the most active of Brazil's garimpos and experienced a renewed surge of wildcat mining starting about 2018.

At least 350,000 hectares of forest and wetland habitat have been lost in the Pan Amazon due to placer mining activities (Figure 5.5).[19] This value, which is derived from satellite images, underestimates the true area, however, because the historical archive does not have images of sufficient spatial resolution to capture very small-scale mining camps (e.g., Roraima), nor monitor the impact from the hundreds of barges that ply the region's rivers. Remote sensing technology does, however, capture the trend in the level of disturbance, which has increased in recent years due to market demand for gold and the relaxation of environmental enforcement in Brazil.[20] The historical archive also exposes the permanence of placer mining impacts: Floodplains destroyed in the mid-1980s remain devoid of vegetation in 2020.

Mercury: Slow Motion Suicide

The impact from wildcat mining on floodplain habitats is visually obvious. In contrast, the effects of mercury poisoning are silent and, for a time, invisible. Eventually, however, the toxicity will manifest in the health of the miners, their families and nearby communities.[21]

Artisanal miners use mercury at the final stage of their processing system when they see bits of gold in sediment. Mercury is added to the earthen mixture because it absorbs gold to form a physical amalgam; gold is recovered by vaporising the mercury, usually over an open flame. Mercury can be inhaled, ingested or absorbed through the skin, but there are technologies that do not depend upon mercury and others to keep it from escaping into the environment. Unfortunately, artisanal miners do not have access to these technologies and large amounts of mercury pollute Amazonian rivers each year.[22]



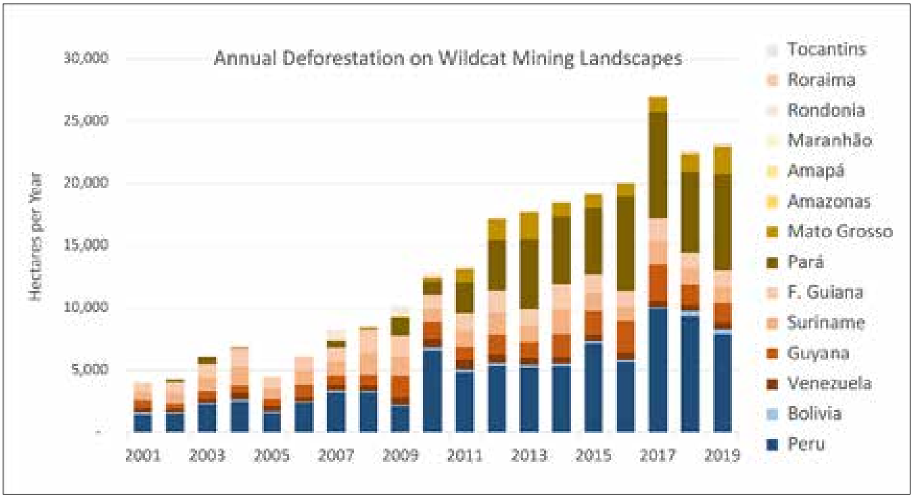


Figure 5.5: Wildcat gold miners, sometimes referred to as 'artisanal small-scale gold miners' (ASGM), have been active for decades across the region. Top: The scars left by placer mines are long lasting and have more than quadrupled since 2000. Bottom: The rate of change has been increasing linearly since about 2005, particularly in the gold fields of Madre de Dios (Peru), the Tapajós (Pará) and the Guiana Coast (Guyana, Suriname and French Guiana).

Data sources: Mapbiomas (2020) and RAISG (2022).

Elemental mercury is noxious, but under anaerobic conditions microbes transform mercury into an organic compound, methylmercury, that is far more dangerous to humans. Methylmercury is a stable molecule that is a hundred times more likely to be absorbed by an organism; once ingested, it is incorporated into living tissues rather than eliminated as waste. This leads to the phenomenon known as 'biomagnification', an eco-physiological process that causes mercury to accumulate in organisms over time and become concentrated in long-lived carnivores situated near the top of food webs.[23] In humans, mercury is transported freely throughout the body and can cross the placenta where it will impact the development of a foetus. In adults, it causes neurological disorders, including clumsiness, difficulties in speaking, hearing impairment, blindness and death.[24]

Mercury poisoning is endemic to communities on the rivers located within or downstream from placer mining landscapes. In a review of 33 studies conducted in the Tapajós watershed, the elevated presence of mercury was ubiquitous. The highest levels were documented in individuals directly involved in gold mining, but it also impacted non-miners who rely on fish as a food source. In the preferred fish-food species, methylmercury was consistently above the maximum level recommended by the World Health Organization (WHO).[25] Elevated levels of mercury have been documented in migratory fish populations far removed from mining areas and even in urban populations.[26] One recent study revealed that 75 per cent of the population of Santarem had elevated levels of mercury with some residents having four times the limit established by the WHO.[27]

Mercury contamination is a long-term threat, which has actually increased over the last decade due to the increase in gold prices and the subsequent boom in wildcat mining. One study estimated that ~200 tonnes of mineral mercury are released each year,[28] but, as more data becomes available and the activity increases, that figure may surpass 500 tonnes (Table 5.2). If true, the amount released into the environment over four decades would sum to approximately 8,000 tonnes. Of this total, about forty per cent has been dumped into the Amazon River Basin, while another forty per cent has been expelled into rivers of Coastal Guianas, with the remainder into the Caroni River in Venezuela.

Social Impacts of Wildcat Mining

Efforts to improve environmental compliance would almost immediately improve the health and social welfare of wildcat miners and their families. This includes children who work as employees or as participating members of a family enterprise. The list of activities pursued by children is long and depressing; it includes working as peons in underground mines, as underwater divers operating suction hoses on river dredges and as operators of the processing equipment used to separate the mineral gold from

Table 5.2: An estimate of the demographic and spatial footprint and potential annual input of mercury into the watersheds of the Pan Amazon; land-use change (LUC) and gold (Au) volume are 5-year averages, while the amounts of mercury (Hg) are based on a model based on the amount of gold produced per square metre of LUC and the reported volume of gold commercialised by wildcat miners.

			Estimated production Au tonnes/year		**Estimated Use of Mercury Hg tonnes/year**	
Wildcat Mining Jurisdiction	Approximate number of Livelihoods	Recent land use change ha/ year	Spatial Model	News Reports	Spatial model @2 Hg : 1 Au	Market model @5 Hg : 1 Au
Madre de Dios, Peru	100,000	4,432	22.2	23.4	44	117
La Paz Yungas, Bolivia	150,000	309	1.5	33.3	6	167
Guyana	15,000	2,026	10.1	20.0	41	100
Suriname	20,000	1,397	7.0	14.8	28	74
French Guiana	12,000	2,000	10.0	1.5	40	8
Venezuela	100,000	555	2.8	7.8	11	125
Roraima	20,000	42	0.2	4.0	1	20
Rio Madeira	5,000	-	-	6.4	-	32
Pará	50,000	6,198	31.0	9.0	124	45
Mato Grosso	5,000	1,266	6.3	6.5	25	33
Total	478,000	16,974	84.9	119	320	779

Sources: Bolivia http://www.mineria.gob.bo/revista/pdf/20220418-13-45-40.pdf, Brazil http://www.lagesa.org/wp-content/uploads/documents/Manzolli_Rajao_21_Ilegalidade%20cadeia%20do%20Ouro.pdf,Fr. Guiana https://blogs.lse.ac.uk/latamcaribbean/2022/01/06/understanding-garimpeiros-in-french-guiana, Guyana https://www.planetgold.org/guyana, Misc. https://www.gold.org/goldhub/data/gold-production-by-country,Peru https://www.oas.org/en/sms/dtoc/docs/On-the-trail-of-illicit-gold-proceeds-Peru-case.pdf,Suriname https://www.trade.gov/country-commercial-guides/suriname-mining-and-minerals,Venezuela https://oroinformacion.com/las-autoridades-venezolanas-anuncian-que-la-republica-bolivariana-ocupara-el-primer-puesto-de-produccion-mundial-de-oro/.

Spatial data: MapBiomas 2020 and RAISG 2022.

the crushed rock, as well as manipulating the mercury that threatens their development.[29] The exact number of under-age children working in illegal mines is not known with any kind of precision, but estimates run as high as twenty per cent of the workforce in Peru and Brazil.

Because they are often organised as family enterprises, women participate in mining ventures and, not infrequently, assume managerial responsibilities. Their participation provides a pathway for introducing better practices, particularly if they are made aware of the risk to their family's health.[30] Other, well-known, social impacts include forced labour and sexual trafficking, crimes that often assume a high-profile aspect of the law-and-order initiatives that are periodically organised in Brazil and Peru (see Chapter 7).

The most salient impact, at least in international forums, is the encroachment of wildcat miners on the Indigenous and traditional communities that occupied these landscapes prior to the discovery of gold. In the 1980s, most Indigenous communities were overwhelmed, and some leaders negotiated access agreements to their traditional lands and, in the process, captured a portion of the revenues (see Chapter 11). These arrangements were routinely ignored, however, and Indigenous groups quickly soured on them. Native communities are now the most vocal opponents of mining, although they continue to be overwhelmed by miners willing to resort to violence.

Mitigation and Remediation

Placer mining was widely practised during the gold rushes of the nineteenth and early twentieth century in North America, and created a massive environmental liability similar to now that being generated across the Pan Amazon. In North America, the cost of remediation was assumed by the federal and state governments, estimated at hundreds of billions of dollars.[31] Placer mining is still used by small-scale miners in Alaska and the Yukon, who are obligated to restore a functional wetland after they have exploited the resource. Remediation is planned before operations so that landscape can be reconfigured at a reasonable cost; compliance is guaranteed with a bond held by the state.[32] In some jurisdictions, placer miners go beyond remediation and seek to restore quasi-natural habitats by accessing incentives from civil society that typically also open high-value markets.[33] The social and economic differences between Alaska and the Amazon are obvious, but solutions will be based on broadly similar strategies.

Confronting the illegality that pervades wildcat-mining landscapes is daunting. The state is either partially or totally absent. Imposing an unpopular policy is complicated by the number of individuals that directly or indirectly depend on the wildcat-mining economy.* In jurisdictions heavily dependent on wildcat gold mining, residents don't view it as illegal, but as one of many informal activities. Initiatives that target specific communities or subsectors, such as women or Indigenous miners, have generated positive results but have not changed the structural elements that define the sector.[34] Law-and-order campaigns organised in Brazil and Peru have made headlines – and have decreased illegal activity for a period of time – but they have not changed the economic and cultural dynamic that motivates individuals to defy the law.

Governments have been more successful in registering individual miners, or their associations, in national mining databases. Miners participate because they desire a legal document validating their claim and, presumably, are aware that it provides authorities with information that will facilitate the collection of royalty taxes.[35] Royalty receipts have increased across the region, although it is widely assumed miners are underreporting their production. Registration and tax collection are the first steps in reforming mining practices. Guyana has succeeded in registering most of its small-scale miners and is using that information to engage them in educational and technical programmes to improve their productivity and, in the process, eliminate the use of mercury.[36]

There have been several research projects that seek to identify practices for remediating the environmental impacts of placer mining. Although they have demonstrated it to be technically feasible, they have also shown that it is socially and technically challenging.[37] A study in Madre de Dios, Peru, found that a barren floodplain, nineteen years after the cessation of mining operations, required investments in soil reclamation and tree planting of between US$ 2,000–3,500 per hectare.[38] Other studies that track reforestation efforts over multiple years report costs twice that amount.[39] Considering there are more than 75,000 hectares of abandoned placer mines in the Madre de Dios (see Figure 5.5), it would require at least US$250 to US$500 million to restore them to a semblance of a functioning natural ecosystem.[40] A large sum, perhaps, but less than two per cent of the value of the gold extracted from the Madre de Dios over the last thirty years.

Environmental (Mis-)Management of the Oil and Gas Industry

The petroleum industry has a long history of operational calamities, large and small, that has created an equally long history of efforts to manage the

* Madre de Dios: an estimated 30,000 miners out of a population of 175,000 (USAID 2021); however, an estimated 70% of the regional economy depends on mining (Instituto de Ingenieros Mineros del Perú). Itaituba, Pará is home to about 10,000 garimpeiros out of a population of 100,000 (Prefeitura de Itaituba 2019).

environmental and social liabilities that are an inherent outcome of their business model. This includes both corporate and governmental actions that seek to mitigate the impact of their day-to-day operations as well as to remediate damage caused by negligence, ageing infrastructure or acts of God. The environmental policies of oil companies were grossly inadequate until about fifty years ago, when the nascent environmental movement demanded action following several high-profile disasters that wrought havoc on natural ecosystems and human communities.[*] Both the scale of these environmental disasters and the inherent toxicity of crude oil forced a fundamental reform on the industry. Reform was first imposed upon the oil giants,[†] and soon extended down through their supply chains to change the practices of their international service providers and state-owned partners in developing countries.

In 1990, the petroleum industry in the Pan Amazon was dominated by state-owned companies which had inherited the oil fields and pipeline systems from multinational companies that had pioneered the industry in the 1960s and 1970s. Unfortunately, most had maintained the pre-reform practices of their private sector progenitors. Change came in the unlikely form of the Washington Consensus, a controversial suite of policies imposed by multilateral agencies to foster economic growth via the private sector, which included the promotion of direct foreign investment in the hydrocarbon sector. The return of foreign (Western) oil companies in the 1990s changed how oil fields and pipelines were managed, because they also introduced the emerging concepts of sustainability into the hydrocarbon sector.

The criteria of sustainability concepts have evolved over time and now span six major themes that reflect the current emphasis on ESG investment.[‡] In the late 1990s and early 2000s, when the oil and gas boom

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* Among the most consequential in the public debate were Torrey Canyon, United Kingdom (1967); Texaco-Denmark, Belgium (1969); Santa Barbara, California (1969); Amoco Cadiz, France (1978); Ixtoc-1, Mexico (1979); Castillo de Bellver, South Africa (1982); Odyssey, Nova Scotia (1988) and Exxon-Valdez, Alaska (1989). Source: https://geology.com/articles/largest-oil-spills-map/.

† Referred to as 'super majors,' these US and European corporations undergo periodic changes in their corporate identity due to mergers and acquisitions; in 2022, six companies had revenues greater than $US 100 billion: ExxonMobil (Standard Oil), Chevron (Texaco/Gulf), BP (British Petroleum/Amoco), Shell (British Gas), Eni and TotalEnergies (Elf -Aquitaine/Petrofina). Source: https://seekingalpha.com/article/4160397-oil-supermajors-seven-sisters-battling-for-top-oil-honors.

‡ (1) Reporting and Monitoring, (2) Governance and Transparency, (3) Climate Change & Energy, (4) Environment, (5) Safety, Health and Security, (6) Social Engagement. Source: International Association of Oil and Gas Producers (2020) Sustainability reporting guidance for the oil and gas industry, 4th edition, 2020: https://www.iogp.org/bookstore/product/iogp-437-sustainability-reporting-guidance-for-the-oil-and-gas-industry/.

was underway in the Pan Amazon, companies emphasised mitigating the impacts of operations on biodiversity and aquatic systems via avoidance and remediation (cleanup). Social programmes focused on engagement with local communities with the objective of avoiding opposition to their activities. To this end, these programmes sought to generate 'goodwill' by building schools, clinics and basic infrastructure. Companies were motivated by the imperatives of risk management. Projects in the Amazon always incorporate a relatively high element of risk because of the region's notoriety and importance as a biodiversity and cultural hotspot. Social conflict, particularly involving an Indigenous group, can paralyse a project and render a multi-decade investment inviable.

Western oil companies obligated local service providers to embrace the sustainability philosophies as a prerequisite for winning a contract. Second-tier oil companies demanded the same level of compliance with environmental and social protocols, as, theoretically, did the state-owned companies from Russia and China.[*] Petrobras anticipated these reforms because its executives have long aspired to build a global company able to compete with the super-majors.[†] By 2000, the state-owned companies in the Andean republics had likewise implemented environmental and social criteria into their business practices; nonetheless, they are frequently involved in controversies because their executives are obligated to execute policies dictated by elected officials that run counter to the principles of sustainability.

In addition to state-owned corporations that operate oil fields and pipelines, governments also have ministries that promote the development of the extractive sector, as well as regulatory entities that impose rules reflecting the principles of sustainability and good governance. Most of these agencies were established (or reformed) in the late 1990s by the same multilateral agencies charged with implementing and financing the Washington Consensus.[‡] The objective was to separate the policy-making

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[*] Prominent second-tier companies (revenues > $US 25 billion) that have operated in the Pan Amazon include Hunt Oil, Occidental, Repsol, Marathon Oil, Conoco-Phillips, PlusPetrol, Sonatrach, SK Group, Suncor, Galp. Companies from China include China National Petroleum Corporation (CNPC) and China Petrochemical (SINOPEC); the only Russian company operating in the Pan Amazon is Rosneft.

[†] Petrobras qualifies as a second-tier company with annual revenues of $US 84 billion in 2021.

[‡] The Washington Consensus refers to a suite of policies advanced by the World Bank, The International Monetary Fund (IMF) and the development agencies of the advanced economies, which were intended to create a market economy based on private sector investment; among its components were initiatives to create environmental ministries and regulatory agencies to supervise the development of natural resources (see Ch. 7).

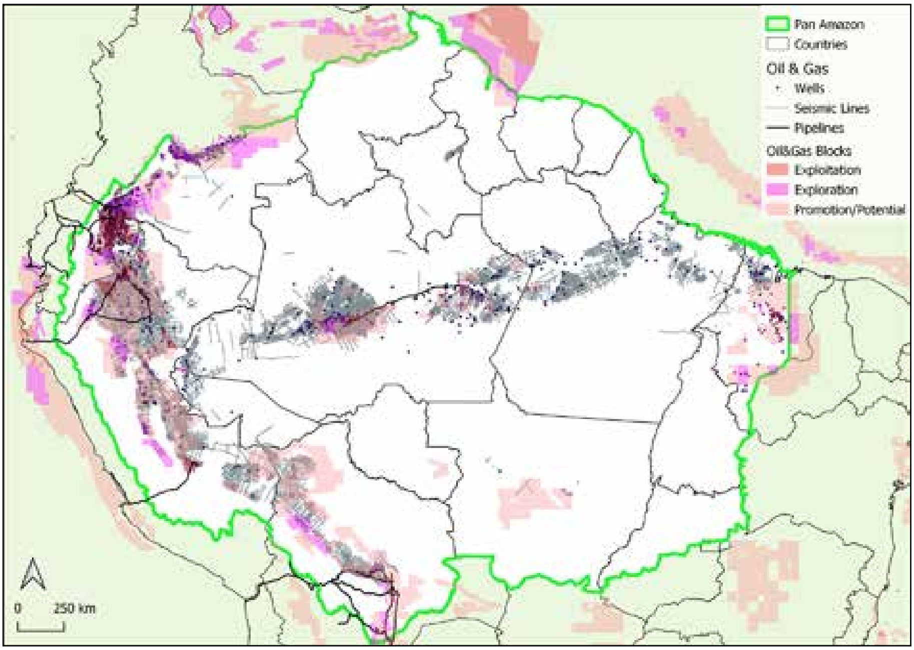

Figure 5.6: The spatial footprint of the oil and gas industry in the Pan Amazon includes low-impact seismic surveys and moderate-impact exploratory wells. Serious long-term impacts are caused by leaks from production wells and pipelines.

Data source: Codato et al. (2019).

ministries that implement initiatives sponsored by elected governments from the regulatory process that should, theoretically, protect society from malfeasance and negligence, while providing legal security for investors (see Chapter 7).

Drill Baby Drill – Exploration and Production

The hydrocarbon industry is based on the permanent need to discover and develop new sources of oil and gas. Exploration begins with a seismic survey, which in the Amazon will employ hundreds of unskilled workers who cut thousands of kilometres of transects and clear hundreds of hectares of forest to create campsites and helipads across tens of thousands of square kilometres of wilderness (Figure 5.6). Fortunately, the impacts are short-lived because the natural forest ecosystem remains intact and, within a couple of years, little evidence remains of the seismic crew's presence. The risk is greater for Indigenous communities, particularly those living in voluntary isolation. In most cases, they will avoid contact, but even a brief encounter would be catastrophic for individuals that lack immunity to many common diseases (see Chapter 11). More ominously, the potential discovery of oil or gas is a powerful disincentive for establishing an indigenous reserve, which is essential for providing these groups with long-term security.*

The number and extent of seismic surveys reached its peak between 1990 and 2010 and has decreased over the past decade.† Nonetheless, geophysical studies continue to be programmed by the governments of Ecuador and Brazil, a clear signal that they intend to expand operations over the medium term, because seismic data is used to locate exploration wells. Typically, this involves drilling between five and ten wells within a concession that spans between 100,000 and 300,000 hectares. Unless they are located very close to an existing road system, river transport is used for heavy machinery, and helicopters and mid-sized aircraft for personnel. Roads may be built to connect drilling pads, but these are rarely connected to regional transportation systems, at least not until there is a discovery.

Each drilling pad requires a forest clearing of between two to ten hectares. Most are surrounded by a berm, which is constructed to contain crude oil that might be released accidentally during drilling operations. Each well must have a pond to contain 'drilling muds', highly toxic industrial chemicals, which are recycled during the operations but which must be disposed of when the well is decommissioned.‡ Inadequate storage or disposal can contaminate both superficial and groundwater.

Unsuccessful wells (dry holes) are decommissioned and abandoned. If properly remediated, the drilling pad and mud pond will be reclaimed by the forest, but only if the compacted soil is scarified to promote natural regeneration.§ A successful exploration well will be converted into a production well, but will probably be capped until the development of a transportation system. In remote landscapes, this usually consists of some combination of road, barge or pipeline. Producers prefer pipelines because they are less expensive to operate and cause fewer oil spills. Gas wells can only become operational when they are connected to a pipeline.

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* Since people living in voluntary isolation cannot participate in a dialogue, they are represented by umbrella Indigenous organisations whose members have historical memories of their own first contact with western agents. Recent examples include Indigenous groups in Ecuador and northeast Peru (see Ch. 11).

† In Peru, the total length of seismic surveys totalled 40,000 kilometres (1990–2000), 50,000 kilometres (2000–2010) and 22,000 kilometres (2010–2015), but there has been no new seismic data reported since 2015. Source: PeruPetro, https://www.perupetro.com.pe/wps/portal/corporativo/PerupetroSite/.

‡ There are four methods for disposing of these toxic chemicals: (1) bioremediation (decomposition using bacteria in 'land farms'), (2) injection into the abandoned well, (3) incineration or (4) solidification and burial. Source: Ahmad et al. 2020: p. 8.

§ Mobil Oil drilled five exploratory wells in the late 1990s in the Manuripi-Heath Reserve in Pando Bolivia. In 2022 only one of those sites was discernible with high-resolution satellite imagery. Source: Google Earth.

A single production platform in Amazonian Ecuador now supports up to 35 wells using horizontal drilling technology that lowers the cost of development and operations, while minimising the spatial impact of oil production. The technology has allowed the government and its private sector partners to exploit the oil underneath Yasuni National Park, including in Bloque 16 which has been producing oil since 2000 following a controversial consent agreement with an organisation that represents the Huarani indigenous people. In 2022, the field was operated by New Strata (Canada) in a joint venture with Sinochem and Sinopec (China). The concession was originally held by Conoco (1985–1991) who sold it to Maxus (USA), which was acquired by YPF (Argentina) and later Repsol (Spain).

Data source: Acción Ecologica (2006).

Operators will drill multiple production wells once the presence of commercial volumes of oil or gas has been verified. Prior to the 1990s, this consisted of multiple individual platforms with one or two wells established in close juxtaposition. After 2000, however, the adoption of directional drilling has allowed companies to place dozens of wells on a single platform. The ability to concentrate dozens of wells on a limited number of platforms is key to the Ecuadorian government's strategy to exploit the reserves underneath Yasuní National Park where more than 300 wells are distributed across about twenty platforms.*

* The government highlights the fact that the area covered by oil infrastructure within Yasuní National Park is a small fraction of its total area. Source: https://ecuadorchequea.com/guillermo-lasso-dijo-que-no-se-puede-dejar-de-explotar-petroleo-ni-minerales/.

Google Earth

The Urucú gas field in Amazonas state was developed in the 1980s and 1990s when drilling platforms typically supported a single oil or gas well (top and a). Petrobras adopted the enclave model where oil and gas are transported via a pipeline but avoided creating a road connection to nearby population centres, relying instead on fluvial transport for equipment and air services to support personnel.

Data source: Petrobras

Modern drilling platforms are a vast improvement over the wells established prior to the introduction of modern drilling technology and the adoption of comprehensive environmental and social criteria. The original companies (Texaco in Colombia and Ecuador and Occidental Petroleum in Peru) only made limited efforts to contain or remediate their operations. Drilling muds were dumped into unlined ponds and crude oil was used in inappropriate ways,* practices that contaminated waterways and seriously impacted the health and wellbeing of Indigenous communities. These environmental liabilities have yet to be fully remediated, and Indigenous communities have been denied compensation due to the legal manoeuvres of operating companies and the failure of state-owned oil companies to assume their share of the legal responsibility (Text Box 5.1).

Natural gas wells are similar to, and different from, oil wells. The drilling technology is essentially the same, but oil must be pumped out of the ground while gas is simply harvested under pressure. This is particularly true in the Andean foothills where gas is trapped within super-pressurised formations. In Camisea, for example, only five platforms with 32 wells exploit the highly productive 'megacampo'. More wells are needed to generate commercial flows from a conventional gas field, such as Urucú, which has a typical constellation of more than eighty platforms with 130 wells.[41]

Most oil wells also produce gas, which is burnt (flared) if there are insufficient volumes to justify a gas pipeline. In Ecuador, there are reports of at least 447 separate flares and, presumably, smaller numbers in Colombia and Peru.[42] This waste of energy is a major source of the industry's internal greenhouse-gas emissions. Flaring is better than releasing methane into the atmosphere, but the gas can also be reinjected into wells or used locally to produce electricity. Most gas wells also produce gas-liquids, which share many of the toxic attributes of heavier forms of petroleum. At Urucú and Camisea, the separation plant that removes the gas-liquids is located in the field with parallel gas and liquid pipelines.

The average lifetime of an oil or gas well is approximately thirty years. Since the oldest fields in Colombia, Ecuador and Peru have been operating for more than fifty years, there are dozens of non-productive wells. Most are simply turned off without being fully retired, which creates a different type of environmental liability since many will leak small amounts of oil over years, if not decades, unless they are properly capped and decommissioned.

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* Apparently, crude oil was sprayed on roads to fight dust and mud, practices that were, allegedly, approved by the state-owned oil company Corporación Estatal Petrolera Ecuatoriana (CEPE). Source: personal communication to the author by J. Quevedo, the General Manager of Texaco-Ecuador in the 1980s.

Text Box 5.1: Texaco and Ecuador

Texaco was a pioneer in the exploration and production of oil in the Amazon with operations in Ecuador from 1964 to 1992. During that time, Texaco pursued practices that are now deemed grossly inadequate, including dumping crude petroleum into pits that were not isolated from aquifers or dumping contaminated water into the region's rivers.

Multiple legal actions have been filed on behalf of affected communities to hold Texaco, which was acquired by Chevron in 2000, responsible for the full cost of remediation and to compensate communities that suffered the impact from their negligence. Chevron has avoided legal responsibility by maintaining it complied with its legal obligations based on a 1998 termination agreement. In this agreement Texaco assumed responsibility for cleaning up specific localities at an estimated cost of US$40 million, while Petroecuador, the majority partner in the joint venture, assumed responsibility for broader remediation.[296]

The plaintiffs maintain that this agreement is invalid and does not preclude class-action suits against Texaco/Chevron. They prevailed in Ecuadorian courts and were awarded US$9.5 billion in compensation in 2012. Chevron refused to pay and a US court found that the Ecuadorian decision was vitiated by unethical actions on the part of the plaintiffs and judicial authorities in Ecuador. The case was submitted to the International Criminal Court, which declined to consider the matter.

In 2014, Petroecuador, assumed responsibility for the remediation of all of the sites previously operated by Texaco. Since then, it has cleaned up approximately 750,000 cubic metres of soil and eliminated 520 sources of pollution at the cost of approximately US$100 million.

Sources:
Juicio Crudo. 13 Oct. 2016. 'Historia de Texaco en Ecuador': https://www.juiciocrudo.com/articulo/historia-de-texaco-en-ecuador/6452.
The Amazon Post. 8 Aug. 2016. 'U.S. Appeals Court Affirms RICO Judgment Against Lawyer Behind Fraudulent Ecuador Lawsuit': https://theamazonpost.com/u-s-appeals-court-affirms-rico-judgment-against-lawyer-behind-fraudulent-ecuador-lawsuit/.
Petroecuador. 12 July 2016. 'Proyecto Amazonía Viva remediará 350.000 metros cúbicos de suelo en 12 meses': https://www.eppetroecuador.ec/?p=12699.

Pipelines and Oil Spills

All three legacy-oil pipelines in the Andean Amazon system are old. The *Oleoducto Transandino Colombiano* (OTC) has been operating for 53 years, followed by the *Sistema de Oleoducto Transecuatoriano* (SOTE) at 50 years and the *Oleoducto Norperuano* (ONP) at 45 years. Pipeline technology has changed dramatically since their construction, with improvements in steel alloys, welding technology and surface coverings. These systems' greatest flaw, however, was the decision to build them above ground, a practice that had been abandoned by the industry in its US-based systems long

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Three major oil pipelines in the Andean Amazon (OTC, SOTE, ONP) are more than 40 years old and in need of investment to lessen the risk of catastrophic failure. Most sections are located above ground, which increases the risk of failure from corrosion, accidents and sabotage.

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Top: Oil spills are particularly pernicious to riparian habitats because their toxic components will quickly be transported hundreds of kilometres downstream. Inadequate remediation compounds the damage by disrupting the ecosystem function of natural fisheries, on which many communities depend as a source of protein. Bottom: The risk of oil spills is particularly acute in Ecuador where the feeder pipelines run parallel to the regional road network.

before these pipelines were constructed.* Superficial systems are prone to failure because they either lie directly on the soil surface, which increases the rate of oxidation, or are supported by struts and beams, which make them susceptible to mechanical failure. Most importantly, above-ground systems are more likely to be physically compromised by human actions, either accidental or deliberate.

The exposure of these key infrastructure assets to sabotage is most evident in Colombia. Between 1986 and 2015, petroleum infrastructure was attacked more than 1,000 times in Putumayo, triggering at least 160 oil spills.[43] Marxist militias justified their action by claiming they were resisting exploitation by foreign oil companies. However, Indigenous communities suffered most of the impacts of their actions (see Chapter 6). Attacks decreased after the initiation of the peace process (2016–2018) but returned to the *status quo ante* as armed militias once again asserted their power. Apparently, attacks are a ploy to sow chaos and disrupt the formal economy but, since the pollution of aquatic habitats disrupts traditional livelihoods, they also increase the militia's ability to recruit young people from Indigenous communities.[44]

Ecuador has suffered an even larger number of pipeline failures, with more than 1,000 incidents between 2000 and 2021.[45] The majority were caused by vehicles crashing into feeder pipelines that parallel the region's secondary road network. The environmental impact of these small-scale leaks has not attracted the same media attention as the large-scale failures of the two trunk pipelines, but their cumulative damage is significant and long-lasting. An estimated 130,000 barrels of crude oil have been released onto landscapes inhabited by tens of thousands of rural families.[46] More serious are the ruptures to the SOTE trunk pipeline, with 65 incidents between 1972 and 2019 spilling ~730,000 barrels. Most incidents are caused by a landslide or riverbank erosion, but it has twice been severed by an earthquake.[47] The most problematic sector is a stretch in the foothills of the Andes where high rainfall and flash floods have caused several large-scale accidents.† Nonetheless, the company has improved its performance, and the volume of oil released into the environment is considerably lower than in the early years of its operations (Figure 5.7)

* Presumably the decision to build above-ground systems was based on a cost–benefit analysis and the assumption they would be located in sparsely populated areas. Building above-ground systems in the United States was discontinued in the 1920s and is only allowed when soil conditions are not appropriate for below-ground systems, as is the case with the Alaska pipeline. See https://www.ferc.gov/oil.

† Incidents include floods (1974: 65,000; 1978: 48,000 barrels), landslides (1974: 28,000: 1998: 44,000), earthquake (1987: 70,000 barrels), an accident in 2009 (11,070 barrels). Source: https://www.primicias.ec/noticias/economia/sote-petroecuador-impactos-riesgo-ecuador/.

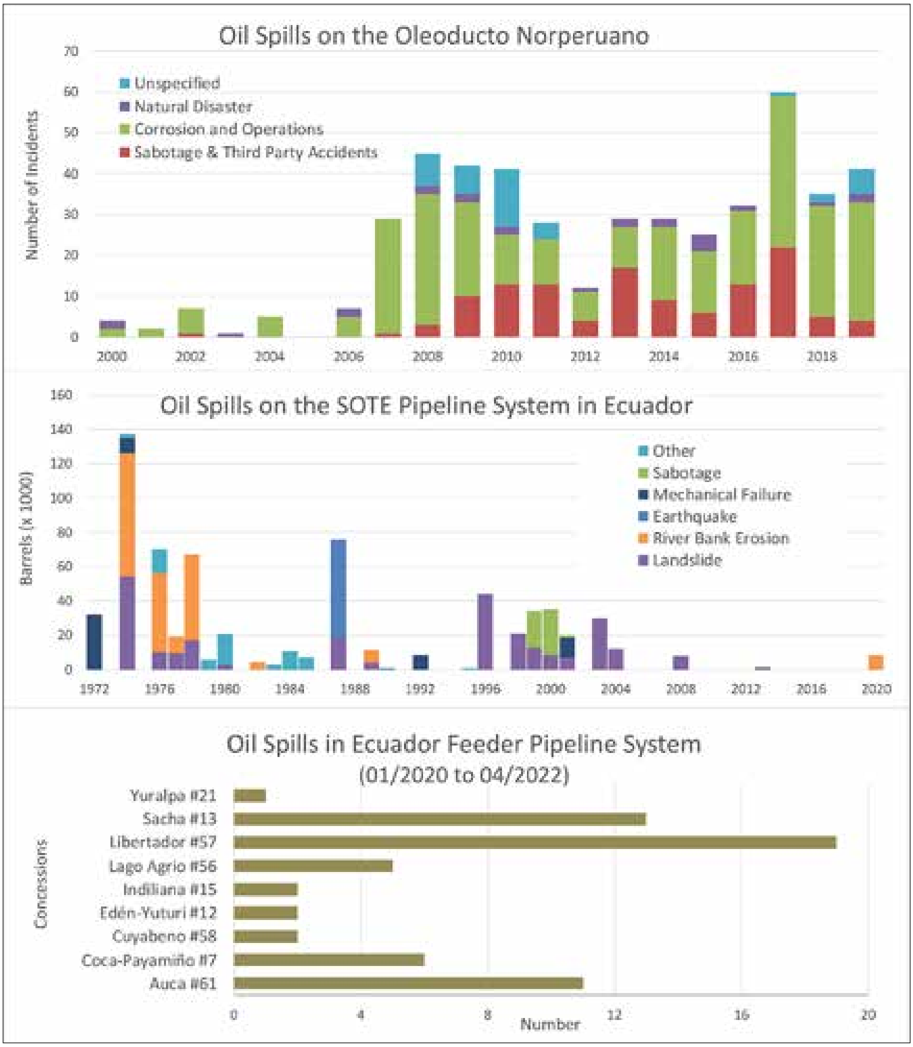


Figure 5.7: The 50-year-old oil pipelines in Peru and Ecuador have suffered leaks due to natural disasters, mechanical failure and sabotage. Top: Incidents on the Oleoducto Nor Peruano have increased over the last fifteen years due to inadequate maintenance and sabotage by third parties seeking to extort money from Petroperú. Middle: Petroecuador improved its record but in 2020 an unusual erosional event at the San Rafael waterfall led to breaches in both the SOTE and OCP pipelines. Bottom: Success in the SOTE belies a serious maintenance issue besetting the feeder pipelines that service production blocks in the most densely populated regions of Amazonian Ecuador.

Data sources: Primacia (2021), León and Zuniga (2020) and Ruiz Aguila (2022).

Petroecuador began a programme to bury the lowland components of the SOTE system in 2013, an investment that dramatically reduced incidents until 2020 when an 'act of God' severed not only the SOTE but also the OTC and a third pipeline (*Poliducto Quito Sushufundi)*, causing a massive oil slick on the Río Coca that impacted downstream habitats and communities all the way to Peru.* As of 2022, Petroecuador and the OCP consortium redesigned their pipeline systems to avoid this type of failure at an estimated cost of ~US$200 million. [48] Meanwhile, they will spend an undisclosed amount of money on remediating the impacts of approximately ~15,800 barrels of leaked oil.

The Peruvian pipeline system suffers from a combination of accidents and sabotage. Information on early operations in Peru is not publicly available, but there were 497 oil spills between 2000 and 2019 (Figure 5.7).[49] Numerically, most of the leaks have occurred in the feeder pipelines servicing the two major production fields (Lotes 8 and 192), but three sections of the ONP have suffered from 27 incidents and are the source of the most oil released into the environment. Effective management has deteriorated significantly since 2016, when thirteen events released ~6,000 barrels of oil into forest and aquatic habitats. The environmental agency (*Organismo de Evaluación y Fiscalización Ambiental* – OEFA) conducted an inspection of the accident sites and concluded that most of the failures had been caused by a combination of internal and external corrosion. The agency cited and fined a state-owned company for inadequate maintenance and ordered a halt to pipeline operations until the company developed a plausible strategy for repairing and operating the pipeline.[50] A subsequent review by the *Organismo Supervisor de la Inversión en Energía y Minería* (OSINERGMIN), a semi-autonomous agency affiliated with the energy ministry, challenged those conclusions and determined that ten of these incidents were the result of deliberate attempts at sabotage by third parties.[51]

Indigenous communities are now cognisant of the damages they have suffered after five decades of neglect and lax operational controls, as well as the repeated failure of the government to attend to their demands. Civil disobedience, a time-honoured ploy in Andean communities, is now a routine tactic in the oil fields of the Peruvian Amazon. The most famous incident was the *Baguazo,* a deadly showdown in 2009 between President

* Erosion underneath a volcanic lava flow diverted water from the San Rafael waterfall, creating a deep gully that progressed upstream; the erosional gully eventually exposed the three pipelines and destroyed a major highway. It also threatens the intake structure of the Coda-Coca Sinclair hydropower facility located an additional 15 km upstream from the site of the incident. Source: Primicias. Apr. 2020.'Ecuador declara la fuerza mayor en el sector petrolero por erosión en río Coca': https://www.primicias.ec/noticias/economia/ecuador-declara-fuerza-mayor-sector-petrolero/.

Alain Garcia and Indigenous groups opposed to policies that would have expanded oil production in the Maranõn sub-basin (see Chapter 11). The Indigenous communities have since used sit-ins and ritualised hostage-taking to protest the ongoing failure of the government to attend to their demands, many of which have little or nothing to do with the actual operations of the pipeline. Protests increased in frequency in 2018 when villagers on the Río Morona impeded clean-up operations and occupied a pumping station.[52] This was followed in 2019 by a sit-in at Pump Station #5, a key logistical centre near Saramiriza, which was occupied again for several weeks in 2021.[53]

Throughout this period, deliberate acts of sabotage have released thousands of barrels of oil into the rivers and streams.[54] Social unrest has caused the ONP to cease operations for weeks, sometimes even months at a time, exacerbating the already challenging operational environment in the *Selva Norte* production area. Plans to extend the northern spur to transport oil from the region's most promising oil field (Lote 67) are, apparently, in question: two companies, Frontera Energy (Lote 192) and GeoPark (Lote 64), have left the country. PetroTal, the operator of the only field producing oil (Lote 95), has started exporting crude oil via barge and the Amazon Waterway (see Chapter 2).[55]

The pipelines that service both Camisea and the Urucú are underground systems that have enjoyed, more or less, problem-free operations. There are no reports of any incidents on the Urucú–Manaus pipeline since its completion in 2009, nor of the associated gas-liquids pipeline between Urucú and Coari that initiated operations in 2000.[56] The gas-liquids pipeline between Camisea and the Pacific coast system experienced five ruptures in its first three years of operations (2004–2007), which motivated the operator to modify the design of the system. The gas pipeline has yet to experience a failure.[57]

Mitigation and Remediation of Oil Spills

Environmental management protocols by oil companies focus on the avoidance and mitigation of oil spills. If a spill occurs, the first priority is to recover as much oil as possible. After that, the impacts must be remediated.

Spills on land are easily contained, thus facilitating recovery. Polluted soil can be scooped up and taken to treatment facilities, known as 'land farms', where specially selected bacteria break down the long-chain organic molecules and aromatic compounds that constitute crude oil. If left untreated, natural processes will eventually degrade and decompose the oil, although it will take many decades and, in the interim, poison the local environment.[58]

Spills into water are even more problematic. Oil slicks rapidly expand across the entire surface area of the water body while streams and rivers will amplify its impact by transporting it downstream. Oil slicks from spills on the Coca River in Ecuador in 2013 and 2020 reached Peru more than 250 kilometres downstream.[59] Backwater habitats, such as seasonal marshes and palm swamps, are particularly vulnerable because they are characterised by standing water where oil is trapped. As water levels fall during the dry season, the oil slick will permeate soil surfaces and poison the benthic habitats that are the foundation of aquatic food webs. Microbial degradation occurs more slowly in these oxygen-starved environments because oil-eating bacteria largely work via aerobic metabolic processes.[60] Oil is especially toxic to frogs because of their fragile and highly permeable skin; fish and waterfowl will also die when exposed to oil.[61]

The impact from oil spills in the Amazon is immediately felt by the human communities. Indigenous and ribereña/ribeirinha communities are clustered along rivers and highly dependent on fishing for their livelihoods. Not surprisingly, they are the most vocal critics of the oil industry in Colombia, Peru and Ecuador (see Chapter 11). They protest about the increasing occurrence of oil spills, as well as the failure of institutions to remediate past spills and fairly compensate them for damages they suffer over the short and long term.[62]

In Colombia, the struggle is led by representatives of the Siona, an Indigenous group settled along the banks of the Río Putumayo whose militancy has been assisted by members of their ethnic group in Ecuador. Ecuador's indigenous groups, particularly Waorani, Cofan, Siona and Kichwa, have succeeded in articulating their demands through civil protest. However, they have elevated their grievances into the judicial sphere, winning important decisions in both domestic and international courts. The situation is more chaotic in Peru due to a national proclivity for civil disobedience, where protestors associated with the Achuar, Awajún and Huambisa have essentially shut down the ONP (see Chapter 11).

Governments are highly dependent on oil revenues and are not eager to forgo revenues in favour of remediating environmental problems which impact a very small fraction of the national population.[63] It is difficult to hold state-owned companies responsible due to the political protection inherent in their corporate governance systems. Attempts to hold multinationals accountable have likewise not prospered, in part, because legal systems have been compromised by corrupt acts that provide companies with an opportunity to prolong and deflect legal actions (see Text Box 5.1).[64]

Secondary Impacts

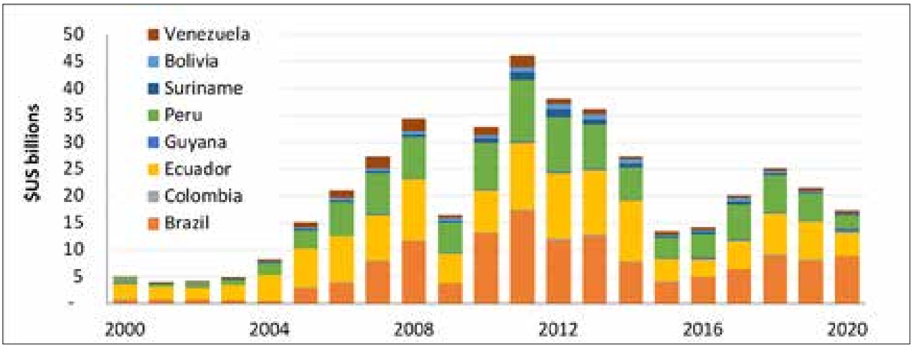
The secondary and indirect impacts caused by the development and exploitation of hydrocarbons has provoked even more concern. The experience of Ecuador in the 1970s and 80s, where large-scale deforestation accompanied the development of the oil fields in Sucumbíos province, is an example of the power of synergies from multiple policies. In this case, the government decided to link the development of the oil fields with investments in roads, agricultural development, poverty reduction, land reform and national security. More than forty per cent of Ecuador's total Amazonian deforestation has occurred as a consequence of that decision (see Chapter 2). A similar process happened in Colombia with the development of oil fields just across the border in the Department of Putumayo.

These policies were not repeated, however, in Northern Peru where oil fields were developed using techniques not unlike an offshore oil platform.[65] Equipment was moved via rivers while the pipeline was built, without creating a permanent trunk highway. Local roads were built to link oil-well platforms, and a temporary access road was established to service the construction of the pipeline, but it was not improved with embankments or bridges. Consequently, it did not create an immigration corridor between the populated areas of the Peruvian coast and the remote landscapes of the oil fields. The offshore (or enclave) approach was also used in the development of the Camisea gas field in the lowland provinces of Cusco Department when it was connected to overseas and domestic markets by a gas pipeline in 2004. Similarly, the Brazilians chose to develop the Urucú gas field between 2006 and 2009 with a minimum of road building and adopted a policy to discourage settlements. There is no evidence or reports of settlement or unauthorised forest clearing linked to either of those projects.

The Economic and Regulatory Framework

The extractive industries are strategic components of the economy of all Amazonian countries, but the degree of their importance varies greatly (Figure 5.8). Mineral extraction creates tangible economic benefits for a sovereign state. Converting a non-renewable natural resource into money can provide an emerging economy or middle-income country* with much-needed financial capital for infrastructure development and poverty reduction. The resource exploitation generates foreign earnings essential for providing citizens with the goods and services that are not produced by the domestic economy. Unfortunately, many, or perhaps, even most, resource-rich countries of the Global South suffer from corruption, poor governance and adverse social conditions that impede sustainable investment of extractive wealth.

* Brazil, Peru and Colombia are considered emerging economies; Brazil, Colombia, Ecuador, Guyana, Suriname and Peru are considered upper-middle income; Bolivia is classified as lower-middle income; and Venezuela is not classified currently but was once considered to be an upper-income country. Source: The World Bank.



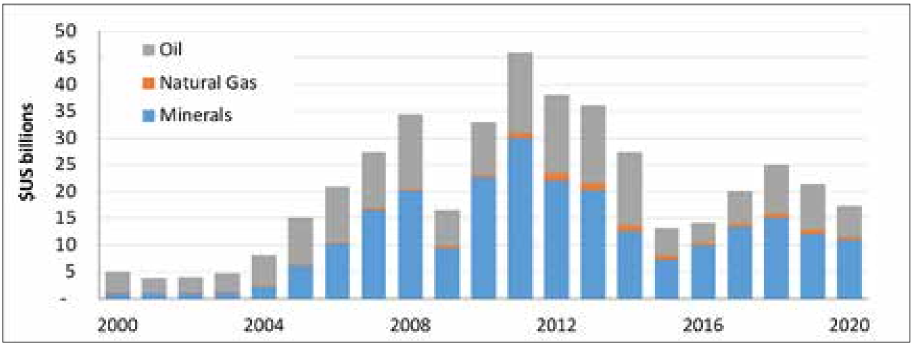


Figure 5.8: Mineral and hydrocarbon rents originating in the Pan Amazon, stratified by country (top) and commodity type (bottom). Values underestimate the economic impact of the mineral sector, because 'rents' are net revenues after the cost of production, which can vary between 30% to 70% of gross revenues. The cost of production is spent domestically, while rents are shared by the state (taxes) and producers (profits).
Data source: World Development Indicators (The World Bank), modified by data from national ministries.

Macroeconomic Realities

The Pan Amazon is a massive reservoir of mineral resources, and the extractive industries represent a large component of the regional GDP (see Chapter 1). The combined importance of the mineral sector varies among countries, ranging from a high of almost 25 per cent in Venezuela, to just a bit more than two per cent for Brazil.[66]

Mining has long dominated the natural resource sector in Peru, Guyana and Suriname, while hydrocarbon extraction predominates in Venezuela, Ecuador and Colombia. Only a fraction of Colombia's oil and gas fields are located within the Amazon, which like those of Venezuela are located in the Orinoco basin just north of the Amazon Ecoregion.[67] The Bolivian

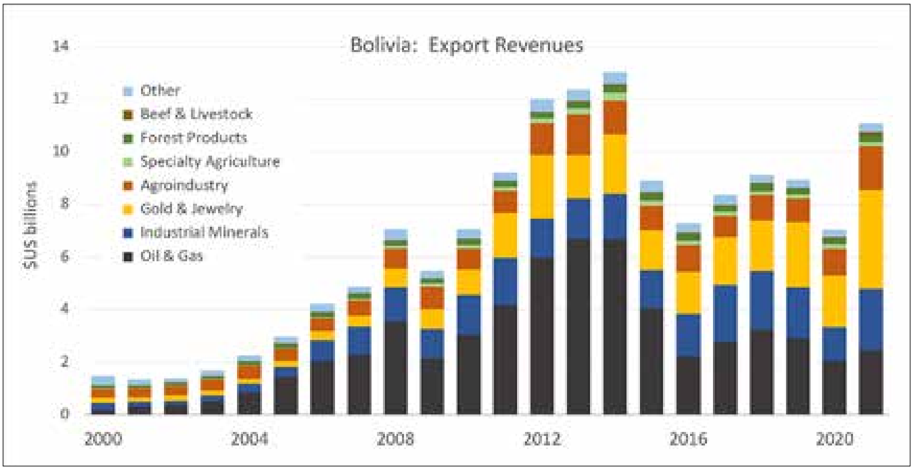


Figure 5.9: Bolivia relies on its extractive sector to generate foreign reserves that are essential for financing imports. Hydrocarbons were predominant between 2005 and 2015; gold was the largest source of foreign currency in 2021. The minuscule contribution of specialty agriculture and the forest sector highlights the challenge of converting the Bolivian economy to one based on biocommerce and sustainable agriculture.

Data Source: INE (2022).

economy is highly dependent upon natural resources (Figure 5.9), although most of its mineral wealth has been exploited on landscapes outside the Amazon Basin. All the countries have gold-bearing rocks located within their Amazonian jurisdictions and all have vibrant, if problematic, wildcat gold-mining communities.

Of all the Amazonian countries, Brazil has the most diversified economy and is the least reliant on mineral exploitation; nonetheless, it has the largest mining sector and slightly more than 27 per cent of its total national production of industrial minerals originates in the seven states of the Legal Amazon.[68] Wildcat goldminers, known as *garimpeiros*, constitute an important economic constituency with significant influence on local and regional political systems. Brazil is also one of the world's largest producers of oil and gas, but only one per cent of its oil production and about fourteen per cent of its natural gas production comes from fields located within the Legal Amazon.[*]

[*] Agência Nacional Petróleo. 2017: https://www.gov.br/anp/pt-br/assuntos/exploracao-e-producao-de-oleo-e-gas/dados-tecnicos

Statistics that estimate 'mineral rents' actually underreport the economic impact of the extractive sector,[*] because exploration and operations represent a significant part of the total cash flow, which varies with the commodity cycle. When prices are high, the cost of production might be as low as five per cent, but when prices crash, companies can lose money and go bankrupt.[†] Similarly, mineral revenues are not an accurate measure of the impact of the extractive sector on national and regional economies. The expenditures related to exploration and operations are more likely to be spent in the region and benefit local communities via job creation and the consumption of goods and services. In contrast, the so-called 'rents', which are net revenues, benefit national economies via taxes and foreign exchange earnings, but the primary beneficiaries are the multinational corporations that export their earnings to the nations where they are distributed to the investors that provided the capital for project development.

The total revenues generated by the extractive industries is highly cyclical. In 2019, total revenues were estimated at ~US$29 billion (Table 5.3), considerably less than the US$100 billion worth of minerals exploited in 2014 but still double what they were prior to 2007.[‡]

Legal Frameworks and Tax Regimes

Essentially, there are three approaches for managing the relationship between companies and sovereign states:

Concessions provide companies with the exclusive rights to explore and exploit the minerals of a specific geographic area. This is the predom-

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[*] The income generated by the mineral extraction industry is referred by economists as a 'rent', a form of property income consisting of payments to landowners by a tenant for the use of the land (forest rents), or payments to the owners of subsoil assets for the exploitation of mineral deposits (mineral rents). The World Bank reports annual income from rents as one measure of the economic output of national economies; this metric excludes the cost of production, so it essentially documents the net economic benefit derived from the conversion of a natural resource into money.

[†] The cost of production of the Carajás iron ore mine is reported as $10 per ton; prices have fluctuated between $US 175 (5% cost) and $US 28 (20% cost) over the last two decades. Source: https://www.statista.com/statistics/282830/iron-ore-prices-since-2003/. A competitor, MMX Mineração, had costs of production near $US 50 per ton and declared bankruptcy in 2016: https://www.reuters.com/article/mmx-mineracao-bankruptcy-idUSL1N1DR0L9

[‡] The estimate of the value of mineral rents is based on statistics published by The World Bank, using GDP reported in current US dollars and the 'percent rents of GDP' for each mineral commodity group as reported in the World Development Indicators database. See http://data.worldbank.org/data-catalog/world-development-indicators. Allocation inside or outside of the Legal Amazon is based on information reported by the Instituto Brasilero de Mineracão – IBRAM and Agencia Nacional Petroleo – ANP via Koenma.com.

Table 5.3: The contribution of the mineral sector to the national and regional economies in 2019.

	GDP $US millions	Amazonian GDP $US millions	Amazonian mineral revenues $US millions[3]	Amazonian mineral revenues % national GDP	Amazonian mineral revenues % Amazonian GDP
Bolivia	40,408	21,635	1,050	3%	5%
Brazil	1,608,981	118,537	10,353	1%	9%
Colombia	314,322	11,109	1,226	0%	11%
Ecuador	93,177	8,273	5,327	6%	64%
Guyana	7,409	7,409	1,627	22%	22%
Peru	223,249	36,754	7,300	3%	20%
Suriname	5,370	6,307	1,304	24%	21%
Venezuela	47,255		1,735	4%	> 50%
Total	**2,340,173**	**211,759**	**29,922**	**1%**	**14%**

Sources of data: Bolivia https://siip.produccion.gob.bo/repSIIP2/formPib.php#, Brazil https://www.ibge.gov.br/estatisticas/economicas/contas-nacionais/2021-np-contas-regionais-do-brasil/9054-contas-regionais-do-brasil.html?=&t=resultados, Colombia https://www.dane.gov.co/index.php/estadisticas-por-tema/cuentas-nacionales/cuentas-nacionales-departamentales, Ecuador https://www.bce.fin.ec/index.php/component/k2/item/293-cuentas-provinciales, Guyana https://repositorio.cepal.org/bitstream/handle/11362/42002/12/EEI2017_Guyana_en.pdf, Peru https://www.inei.gob.pe/estadisticas/indice-tematico/producto-bruto-interno-por-departamentos-9089/, Suriname https://www.statistics-suriname.org/wp-content/uploads/2019/02/suriname-natrek_natacc-estimates-2013-2017.pdf, Venezuela https://www.epdata.es/evolucion-pib-venezuela-fmi/f73e4fdb-2a08-4bf1-b657-a9a87c23f803

inant model for mining ventures (except in Venezuela) and is the system used in Brazil,* Peru and Colombia for oil and gas contracts.

Production sharing agreements are joint ventures between a national oil company and corporations that agree to finance and manage operations in exchange for a proportional share of production within a concession. This model predominates in Bolivia, Ecuador, Venezuela, Suriname and Guyana; it is also the model used to manage two of

* The standard model is used for most high-risk concessions, including all those in the Legal Amazon, but production sharing agreements are used for selected Pre-Salt concessions where the risk of discovery is deemed to be limited. Source: https://petrobras.com.br/en/our-activities/performance-areas/oil-and-gas-exploration-and-production/regulatory-framework/

Suriname's corporate gold mines.*

Service contracts are arrangements between national oil companies and a contracting company that is paid a fee to manage oil and gas assets; Ecuador uses this model for operations on older fields controlled by the state-owned oil company.

There are three principal mechanisms that states use to capture revenues: royalties, corporate income taxes and profits from state-owned companies. These are complimented by licensing fees, property taxes and signing bonuses as well as windfall-profit taxes created to claw back revenues when commodity prices spike and corporate revenues increase far beyond the cost of production (Table 5.4).

Royalties are calculated on the gross value of the raw commodity regardless of the cost of extraction. This is a straightforward calculation based on the market price and the unit of the mineral commodity: barrels of oil, cubic metres of gas or tonnes of mineral ore [concentrate]. Several states have a stratified regime that lowers levies on smaller mines and oil fields, which rise as the scale of operations and production increases. Mining royalties tend to be smaller than for hydrocarbons. Presumably, this reflects the greater cost of mining operations compared to drilling for oil and gas, but the disparity also reflects the history of the industry and a legacy of exploitation commonly attributed to – largely foreign – oil companies.[69]

Corporate income taxes are calculated on the profits of the operating business unit after subtracting the full cost of exploration, production and processing as well as payments for royalties and taxes. This approach allows companies to manage the price risk of commodity markets while motivating them to invest in future production capacity. It is less transparent, however, and susceptible to corporate malfeasance.

State-owned oil companies and joint ventures are an important source of revenue for the national government. Investment decisions are subject to political considerations, however, and operations are not usually as operationally efficient as a private company. They may or may not pay corporate income tax depending upon the state† – but all pay royalties.

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* The Sarramaca mine (a subunit of the Gros Rosebel mine) is a joint venture between Zijin Mining Group (70%), while the Merian Gold Mine is a limited partnership with Newmont Mining (75%); the Republic of Suriname holds the remaining equity shares in both cases. Sources: https://www.mining-technology.com/news/iamgold-deal-rosebel-gold-suriname/, https://www.newmont.com/operations-and-projects/global-presence/south-america/merian-suriname/default.aspx

† Petrobras is a public company listed on stock exchanges; however, the Brazilian state owns 36% of outstanding shares and is effectively controlled by the government. Source: https://www.investidorpetrobras.com.br/en/overview/shareholding-structure/.

Table 5.4: Royalty and tax regimes for the eight Amazonian nations; all values are percentages.

	Bolivia	Brazil	Colombia	Ecuador	Guyana	Peru[v]	Suriname	Venezuela
Corporate income tax (CIT)[i]	25	34	33	25	35	28	36	50
Mining royalties[ii]	5–7	1–3.5	4–5	5–8	2–5	1–13	1–6.5	33
Hydrocarbon royalties[ii]	18	5–15	8–25		2	5–35	6.25	33
Hydrocar-bon taxes / surtax[iii]	32	10–40[4]		25				80–95[4]
Hydrocar-bon profit joint venture[iv]	50	30		25	50		15	> 50
Mining profit joint ventures							5–30	55

i. Based on net revenues or profits
ii. Based on gross revenues or the value of the minerals prior to costs or depreciation; actual rates vary depending on the mineral and the volume of the commodity being commercialised.
iii. Applied on windfall profits when price rises above a designated benchmark
iv. Profit sharing after taxes and royalty payments.
v. See https://www.mef.gob.pe/es/?option=com_content&language=es-ES&Item-id=100960&lang=es-ES&view=article&id=453.

Table 5.5: Revenue sharing dispositions to local and regional governments for the eight Amazonian nations; all values are percentages.

	Bolivia	Brazil	Colombia	Ecuador	Guyana	Peru	Suriname	Venezuela
Mining royalties								
Local		60	35–45	60	na	80	na	1
Regional	100	20	42–45		na	20	na	5
Oil and gas royalties								
Local		20	32–12	1[i]	na	80	na	1
Regional	11	70	52–48		na	20	na	5

i. The value of one dollar per barrel of oil is paid into a fund dedicated to the development of Amazonian Ecuador.

The lion's share of revenues captured by income taxes is retained by central governments, but a significant portion is returned to the regional and local government via revenue sharing policies unique to each country. In general, payments to subnational jurisdictions are managed via the royalty regime, which might explain why rates tend to be low (Table 5.4) while the proportion returned is relatively high (Table 5.5).

Some royalty regimes contemplate a solidarity provision that allocates resources to regions and communities that lack revenue-generating mineral resources.* Moreover, all governments also transfer funds from the general treasury to subnational jurisdictions via the regular budgetary process.

Ecuador has adopted a system based on the volume of oil extracted from the Amazon. The value of one dollar per barrel of oil is deposited in a fund that invests in the economic and social development of communities in the region. In 2019, that amounted to about five per cent per year of the rents derived from production, which would be the lowest level of revenue sharing in the Amazonian region. Peru has the most generous system and includes not only 100 per cent of the revenues generated by the royalty system, but also fifty per cent of the revenues captured via the corporate income tax.[70] The Peruvian system, known as the *canon*, also specifies the proportional share allocated to the regional government and the local communities that host to, or are impacted by, the extractive activities.

The Extractive Sector in the Regional Economy

The Pan Amazon is a significant source of several key industrial commodities. Global markets are not overly dependent on the region; nonetheless, production from Amazonian mines is not insignificant.† Development of mineral resources is a decades-long process and, if the extractive sector were to abandon the region, as proposed by some environmental advocates, the global economy would find other geographies to supply these essential minerals. Oil and gas production is insignificant at the global scale (< 0.1%) and production could be wound down without difficulty. In purely financial terms, the Amazonian minerals sector is minuscule, with a total GDP of ~US$20 billion in a global economy estimated at US$85 trillion in 2020, of which about three per cent was attributed to oil and gas (US$2.1 trillion)[71] and one per cent to industrial minerals (US$850 billion).[72] The global economy could easily adapt to an Amazon that did not include an extractive sector. The same cannot be said for the Amazonian countries.

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* Peru's Canon system transfers royalty and tax revenue to adjacent municipalities and provinces within the beneficiary department, while Bolivia's IDH allocates revenues to non-producing departments (see below).

† Iron ore (~10%); bauxite (~10%); copper (~9%). Source: http://minerals.usgs.gov/minerals/pubs/mcs/

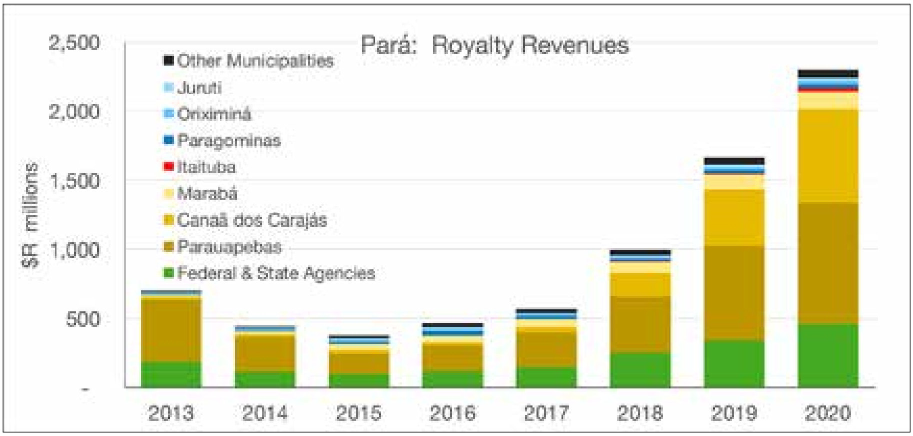

Figure 5.10: Royalty income from the mineral sector in Pará, Brazil. The municipality of Parauapebas received the lion's share of royalties due to the mines at Carajás Serra Norte (iron ore) and Salobo (copper). After 2018, operations at the S11D (iron ore) and Sossego (copper) mines started generating revenues for the municipality of Canaã do Carajás.

Data source: CGA (2022).

The net revenues from minerals extracted from the Pan Amazon in 2017 were equivalent to about eight per cent of regional GDP (see Chapter 1). If all extraction were to stop, the impact would be even greater, however, due to the heavy reliance of the finance and service sectors upon economic activity linked to the extractive sector. Brazil would suffer significant economic dislocation of mineral revenues, but the impact would be catastrophic for Peru, Ecuador and Bolivia. The strategic importance of the mineral sector is evidenced by the current state of the Venezuelan economy that has destroyed its oil sector and a once thriving mining industry based on iron ore and bauxite.

The mineral sector is of less importance to the actual residents of the Amazon, in part because the lion's share of that revenue is exported from the region. The per capita GDP for all minerals in 2019 was about US$800 per Amazonian inhabitant, but only about six per cent of this amount is returned to local and regional governments. Even this number is deceptive, however, because of the uneven distribution of revenues among jurisdictions.

For example, the state of Pará received a total of ~R$2.3 billion (~US$480 million) in royalties in 2020 (Figure 5.10); however, only three municipalities (Parauapebas, Marabá and Canaã dos Carajás), home to nine massive open-pit mines, captured more than half of that amount (R$1.7 billion).*

* In 2022, 11 open-pit mines were operating in the Carajás mineral district, including three iron ore complexes (Serra Norte, Serra Leste, Serra Sur), two manga-

They were followed by five municipalities (Paragominas, Oriximiná, Terra Santa, Juruti and Barcarena) that received R$81 million in royalties from the bauxite industry and another fifteen municipalities that host legal (and quasi-legal) gold mines, which paid another R$81 million. Fifty-three local governments split about R$1.3 million linked to construction materials or in compensation for indirect impacts generated by logistical infrastructure. Seventy-three municipalities received no royalty income of any kind, presumably because they are not home to any type of extractive industry.[73]

The state government of Pará receives fifteen per cent (R$345 million in 2020) plus another R$230 million from a tax rebate linked to export income, which sum to about three per cent of the total state budget.[74] The mining industry enjoys the fulsome support of the state government and its regulatory agencies that oversee the industry. The state of Pará is responsible for about ninety per cent of the mining activity in the Legal Amazon, so the royalty revenues from mining provide few benefits to the inhabitants of the other five Amazonian states. Similarly, the distribution of royalties from the exploitation of oil and gas production is concentrated in only a few municipalities; however, the distribution of oil and gas royalties favours state governments. In 2020, Amazonas state received R$224 million in royalty revenues with R$67 million allocated to the sparsely populated municipality of Coari in Amazonas state, home to the largest natural gas field in the Brazilian Amazon (Figure 5.11).

Peru is the most generous of the Amazonian countries in returning mineral taxes back to the producing region (Table 5.3). The centrepiece of this policy is the *Canon*, which allocates fifty per cent of the corporate income tax to local and regional governments, as well as the traditional royalty tax.[*] Of the total amount returned, ten per cent is allocated to the district that hosts the mine, 25 per cent goes to the corresponding province, while forty per cent is distributed to all of the district-level governments within the region (department); 25 per cent is allocated to the regional government and its associated public university. A slightly different regime is used for hydrocarbons, which reflects the geographic idiosyncrasies of the Peruvian Amazon.[†]

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nese mines (Buritirama, Azul) and three copper mines (Salobo, Sossego Antas, Maravaia); a fifth copper mine (Cristalino) and a nickel mine (Vermelho) were under development. Source: SIGMINE, https://geo.anm.gov.br/portal/apps/webappviewer/index.html

* There are five distinct regimes (Canon Minero, Canon Hidroenergético, El Canon Petróleo, El Canon Pesquero and Canon Forestal) that reflect the idiosyncrasies of each industry.

† The Canon y Sobrecanon Petrolero allocates 52% of tax revenues to the regional government of Loreto versus 20% for Ucayali; there is also a special tax regime for natural gas (Canon Gasifero), similar to the Canon Minero. Source: Ministerio de Economia y Finances de Perú, https://www.gob.pe/mef.

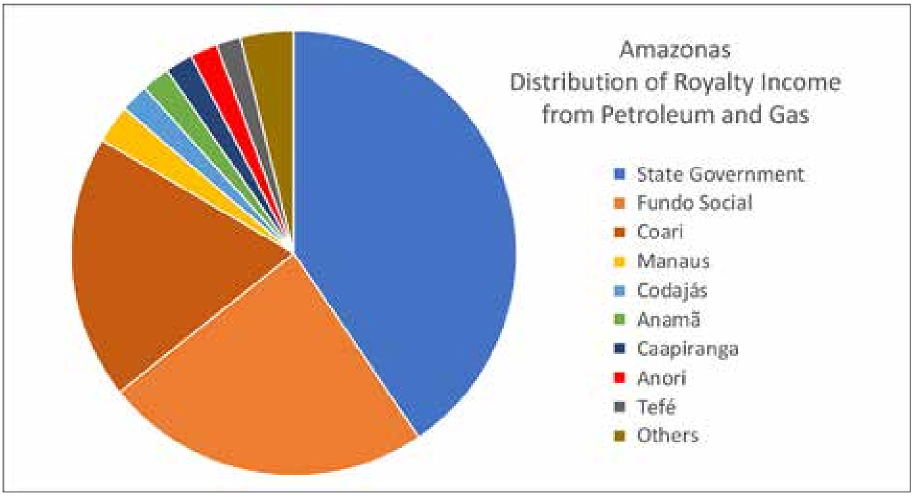

Figure 5.11: The distribution of royalty revenues from the oil and gas sector favours the state over municipalities. The Fundo Social, an autonomous federal entity, invests in education and health infrastructure.

Data source: ANM (2022).

Most other states in the Pan Amazon return only the royalty portion of the revenues to local jurisdictions and corporate income taxes are appropriated by the central government. This generates a level of dissatisfaction based on the perception that the central state does not invest enough resources in the development of their Amazonian hinterlands.[75] Nonetheless, the extractive industries are strongly supported by local governments. Although the majority of revenues are exported from the region, those allocated to capital expenditures and operations support thousands of direct jobs, while the service sector and commerce generate tens of thousands of indirect jobs that enormously amplify the impact of the mineral sector. Importantly, the development of a mine or oil field ensures that improvements are made to health and educational systems, as well as significant improvements to transportation infrastructure.

Most of the residents of the Amazon, particularly the economic elites, hold conventional views about development and the importance of infrastructure is paramount in their list of priorities. The current legal framework for spending royalty revenues reinforces this bias. For example, the *Impuesto Directo a los Hidrocarburos*[*] in Bolivia and the *Canon Minera* in

[*] IDH – *Impuesto Directo a los Hidrocarburos* is a 35% surtax applied to the gross revenues of oil and gas wells; 12.5% is distributed to the producing department, 31.25% to non-producing departments and 56% is captured by the central government. Source: Impuestos Bolivia, https://impuestos.com.bo/ley-3058-idh/

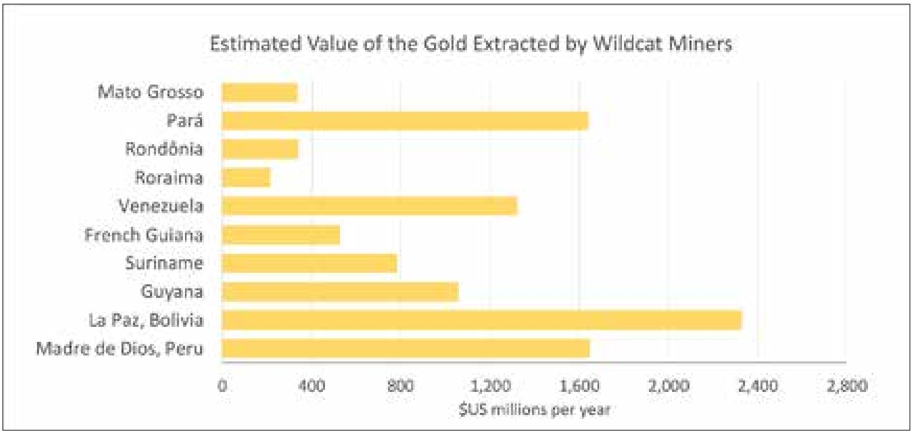

Figure 5.12: Wildcat gold miners, sometimes referred to as 'artisanal small-scale gold miners' (ASGM), mostly operate in violation of tax, labour and environmental laws, while a large subset infringe upon indigenous lands and protected areas. In 2021, they exported gold worth an estimated $US 8.5 billion.

Data sources: WGC (2002) modified by the subtraction of legal gold production reported by government ministries and other independent sources, being OAS-DTOC (2021), planetGOLD (2022) and Reuters (2022).

Peru obligate the local governments to 'invest' this money, rather than to pay salaries or other forms of fixed operating costs. Conspicuously absent from any of the regulations concerning the disposition of the royalty or tax revenues from mineral extraction is the environment. None of this money is allocated to conservation, nor is any allocated to the remediation of the environmental impacts linked to its exploitation.

Presumably, the lack of funding for conservation initiatives is compensated by the environmental action plans that accompany all large-scale initiatives within the mineral sector. Essentially, all mitigation and remediation are considered to be the responsibility of the enterprise that is organising the investment. This is appropriate, but it also tends to focus these actions locally, to the landscapes in the immediate vicinity of the mine or oil field; in that sense, private actions are similar to the distribution of royalty income.

The social and economic impact of the informal gold mining sector (wildcat gold miners) is deeply embedded in the Amazonian economy, in part because the distribution of its economic benefits is extraordinarily democratic (Figure 5.12). By almost any standard, even the largest so-called 'artisanal' miner is a small businessman and it is common for them to organise as cooperatives. Many adopt a business model where the net revenues (and risks) are shared among participants. For many, it is a rare opportunity to escape from poverty.

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The cooperative miners of Bolivia completely dominate that nation's gold mining sector. They have supported the socialist governments of Evo Morales and Luis Arce, who have formalised mining claims and collected a significant share of royalty taxes since about 2015. In November 2022, miners organised street protests until the government agreed to exempt the sector from income and value added taxes.

Wherever gold is discovered, it creates an influential constituency that tends to dominate local political institutions. Wildcat miners are influential, because their activities are economically significant. For example, the public prosecutor's office in Brazil (*Ministerio Público Federal* - MPF) estimated that 58 per cent of the gold in Pará reported to the government between 2019 and 2020 (30.5 tonnes) was mined by artisanal miners.* Bolivia and Peru likewise tolerate a large cohort of small to medium-scale miners who ignore environmental regulations and evade taxes, but who avoid oversight due to their raw political power.

* According to the MFP, legal miners purchase the illegal gold from garimpeiros at a discount and then report it as their own production. Source: MPF – Ministerio Publico Federal. 30 Aug. 2021. MPF pede suspensão de instituições financeiras que compraram ouro ilegal no Pará: http://www.mpf.mp.br/pa/sala-de-imprensa/noticias-pa/mpf-pede-suspensao-de-instituicoes-financeiras-que-compraram-ouro-ilegal-no-parar

The Natural Resource Curse

A popular refrain used to disparage the extractive industries is the argument that export revenues distort the economies of countries that rely on them as a major source of GDP. This critique stems from the observation that certain resource-poor countries have enjoyed sustained levels of economic growth, while many resource-rich countries suffer from boom-and-bust commodity cycles that impede their long-term development.[76] This hypothesis triggered a policy debate in the late 1990s as the concepts of sustainable development were being incorporated into strategic frameworks in both the public and private sector.[77] The critique was controversial, in part, because it questioned the lending practices of multilateral development agencies, such as The World Bank, but it was overly reliant on statistical correlations that included numerous obvious exceptions.[78] Like all correlation-based suppositions, the relationship between resource dependence and economic stagnation could be a 'cause and effect' type of phenomenon – or a manifestation of other factors that impede or foster sustainable growth across the entire economy (Table 5.6). Regardless, developing countries in the twentieth century had few options, because they needed financial resources to grow their economies and fight poverty. Those that were successful used their 'natural resource endowment' to diversify their economies and improve the wellbeing of their citizens.[79]

Most economists tested the natural resource curse/endowment hypothesis using their favourite metric, gross domestic production (GDP); however, an alternative approach relies on the human development index (HDI), a metric that combines data on income, health and education.[*] At the global scale, those analyses show that the monetisation of mineral wealth is positively correlated with human development. In Latin America, however, that benefit is neither strong nor uniform.[80] The inability of the region's nations to 'graduate' from developing or emerging economies into advanced economies is perplexing, but there is no overriding evidence that it is caused by an over-dependence on mineral-based production systems.[81]

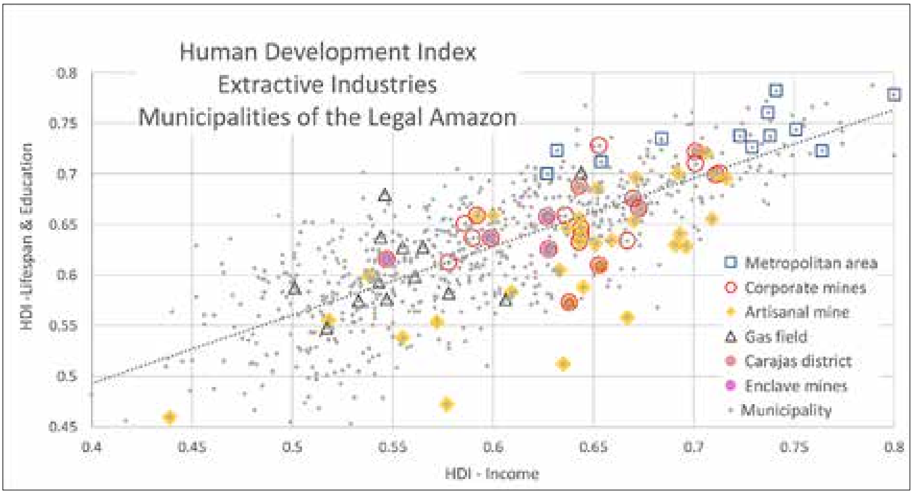
In the context of the Pan Amazon, where the cost and benefits of the extractive industries is even more germane, the results are similarly ambiguous (Figure 5.13). When the HDI is used as a measurement of progress within subnational jurisdictions, there is an obvious correlation between per-capita income and human wellbeing, but the presence of an extractive

* The health dimension of the HDI is assessed by life expectancy at birth. The education dimension is measured by means of years of schooling for adults (>5 years) and expected years of schooling for children. The standard of living dimension is measured by gross national income per capita. The scores for the three HDI sub-indices are aggregated into a composite index using geometric mean. See https://hdr.undp.org/data-center/human-development-index#/indicies/HDI.

Table 5.6: The issues related to the so-called natural resource curse.

Factor	Cause / Effect	Manifestations	Policy Solutions
Inadequate monetary and fiscal policies	Resource revenues suffer from commodity price volatility. Governments and private sector suffer from boom-bust cycles.	Governments overspend on salaries, fuel subsidies and (unnecessary) mega-projects. Government and private sector over-borrow when cyclical high revenues improve creditworthiness.	Practise fiscal discipline. Invest in health and educational systems. Invest in infrastructure and industries that generate employment and tax revenues.
Dutch disease	Resource revenues distort the economy due to capital allocation and exchange-rate appreciation.	Domestic manufacturing and service sectors cannot compete with imports.	
Limited government capture of benefits	Governments provide too-generous fiscal terms to attract investment in extractive industries.	Capital-intensive extractive industries provide few non-tax benefits (jobs, local services). Stingy royalty regimes.	Increase effective tax rate. Promote domestic services Spend more on remediation and compensation.
Weak institutional development	Elites use influence to capture revenues (rent seeking).	Nepotism and corruption impede competency. State-owned companies dominate sector.	Improve governance transparency. Empower regulatory and oversight agencies.
Gender and racial discrimination	Women and minorities receive less benefits and larger share of impacts.	Patriarchal governance. Violence against women. Marginalised ethnic groups.	Gender-based reforms. Direct payments to citizens.
Social and environmental problems	Poorly designed investment creates impacts. Inadequate consultation magnifies impacts.	Environmental degradation impacts health and livelihoods. In-migration displaces indigenous communities.	Improve local consultation. Compensate communities. Remediate impacts.
Conflict	Unequal distribution of wealth and impacts provokes unrest and violence.	Civil war: Colombia. Civil disobedience: Ecuador, Peru, Bolivia. Human rights violations.	Decentralisation of the administrative functions of the state. Judicial reform (land reform).
Weak democracy	Revenues from extractive industries empower populists	Natural resource wealth fosters authoritarian governments.	Strengthen civil society. Bolster democratic systems. Promote decentralisation.

Modified from NRGI 2015.



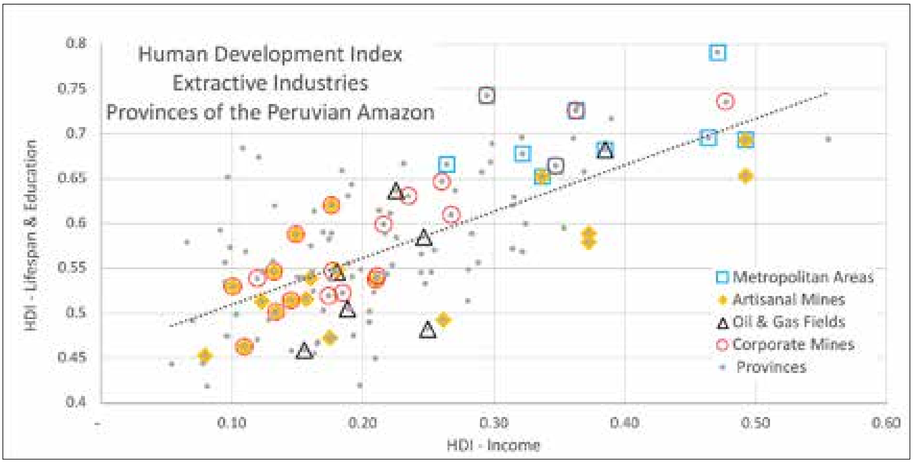


Figure 5.13: The presence of a corporate mine, wildcat mining activity or the production of hydrocarbons confers no systemic cost or benefit to human wellbeing as measured by the components of the human development index (HDI). Index components are positively correlated across all jurisdictions, but those with extractive enterprises are distributed across both gradients, as well as above and below the trend line.

Data sources: Atlas do Desenvolvimento Humano no Brasil (2020) and Instituto Peruano de Economía (IPER) (2020).

enterprise has no recognisable impact – either positive nor negative – on the development status of the region's inhabitants. A closer look at individual jurisdictions illuminates why the benefits are illusory and the costs difficult to alleviate.

The most conspicuous example of a 'successful' development outcome is the Carajás mining district in Pará, where vast mineral wealth is still driving expansion fifty years after the first mine was opened in the 1980s. Investment and royalty revenues have been concentrated in three municipalities (Parauapebas, Canaã dos Carajás and Marabá), with lesser but still significant levels of mineral development in two adjacent municipalities (Ourilândia do Norte do Norte and São Felix do Xingu) and a metallurgical manufacturing complex in Açailândia (Maranhão).[82] All six jurisdictions score well according to the HDI, but three are above and three below the trend line; only one (Parauapebas) has values that approach those of the region's metropolitan centres.

It is difficult to attribute Parauapebas's relative prosperity to the mining industry, however, because its development was preceded by investments in transportation infrastructure (see Chapter 2) and a land-distribution programme (Chapter 4), both of which triggered a migratory wave that cleared the forest and created an agrarian economy (see Chapter 3). The combination of policies, which were synergistic by design, caused environmental and social impacts far beyond what might be attributable solely to the mining venture.[83]

Indigenous natives in the Carajás mining district retreated into newly created reserves, which, although large, are a fraction of the size of ancestral lands (see Chapter 11). The new inhabitants are culturally committed to the conventional economy and have elected representatives that support the expansion of the mining industry. Nonetheless, as the frontier society matured, officials have begun to question the new *status quo* with demands for greater levels of royalty-based compensation and development initiatives that 'add value' to raw mineral commodities.[84] Although citizens accept the role of the mineral sector in their communities, they also voice concern about environmental degradation and petition authorities for more sustainable options.[85]

Similar intensive mining districts include the Pasco, Yauli, Cajamarca and Pataz provinces in Peru and the coastal plain of the Guyana and Suriname, all which have been mining centres for more than a century. None of these landscapes could be described as 'prosperous' by any objective observer, and all have only middling HDI values despite decades of investment, economic activity and royalty revenues.[*] Their mining legacy includes significant environmental liabilities in the form of abandoned tailing ponds and denuded landscapes destroyed by strip mines. In Ecuador, the nascent development of the copper and gold mines in the Cordillera del Condor

* Suriname: Marowijne (0.721) and Para (0.746); Guyana: Upper Demerara-Berbice (0.704); Peru: Pasco (0.546), Yauli (0.637), Cajamarca (0.535). Pataz (0.393). Source: https://globaldatalab.org/register/ and https://www.ipe.org.pe/portal/indice-de-desarrollo-humano-idh/

would appear to be following a similar development paradigm, with one industrial-scale mine operating, one under construction and seven in various stages of planning.

Other mining ventures have demanded a different approach, either because they were too remote or were not (yet) incorporated into an infrastructure initiative that might have subsidised their development. Referred to as 'enclave mines', these rely on waterways (*hidrovias)* as a cost-effective commodity-transport system; they include investments in roads and railways, but only to connect the mine site to the river port. Migration is not expressly prohibited, but private investors have little incentive to open adjacent landscapes to settlement that might expose their operations to social conflict. Not infrequently, existing (non-indigenous) communities are amenable to the project, particularly if it includes a compensation package that precedes potential revenues from a royalty tax.

The enclave model was pioneered in the 1950s with the magnesium mine at Serra de Navio (Amapá) and the iron ore mines at El Pao (Bolivar, Venezuela). Subsequently, the model was deployed for additional iron ore and bauxite mines in Bolivar in the late 1970s, the Trombetas bauxite mine in Oriximiná (Pará) in 1979 and the Pitinga cassiterite mines (Amazonas) and, most recently, the bauxite mine near Juruti (Pará) in 2010. None of those mines have noticeably improved human wellbeing as exemplified by their HDI values, which are located near the trend line that tracks the correlation between family income versus health and education (Figure 5.13a). In the near future, this type of development model may prevail in the potash mine being planned for the Autazes municipality at the mouth of the Rio Madeira (Amazonas).

Hydrocarbons are commonly used as an example of the natural resource curse and the pejorative is frequently used to describe the history of the oil and gas industry in Bolivia, Colombia, Ecuador and Venezuela. Within the Amazon, these countries have pursued a range of investment strategies that are not unlike the intensive and enclave models used to describe industrial mines.

Ecuador pursued an intensive approach when it developed the oil fields of Succumbios and Orellana in the 1960s, which was accompanied by parallel investments in a regional road network, a land distribution programme and extension programmes promoting agroforestry. Despite the vast wealth extracted from its petroleum reserves, the Ecuadorian Amazon remains the poorest region in the country.

In contrast, Peru developed its reserves of oil (Marañón) and gas (Camisea) using an enclave-like model where production fields are compared to an offshore oil platform. Equipment is transported by waterways, while personnel and supplies are ferried to and from the platform by light aircraft and helicopter. This system has ensured that secondary impacts, such as the road building, migration and deforestation, were largely avoided. Peru has the most generous royalty and tax regime in the Pan Amazon, but there is no evidence the local populations, which are for the most part Indigenous, have experienced any measurable enhancement of their well-being, at least when compared to the rest of the provinces in the Peruvian Amazon (Figure 5.13b).

Both the Ecuadorian and Peruvian systems have been plagued with oil spills that have polluted the soils and waterways surrounding the oil fields. For more than two decades, indigenous organisations have campaigned to drive the hydrocarbon industry out of their territories. Support for the industry is still strong in urban centres, such as Iquitos and Lago Agrio, where administrative and logistical facilities are economically important, but urban inhabitants have started to question the cost–benefit calculation in the light of serious environmental liabilities.[86] In contrast, the Camisea gas field and associated facilities have been relatively conflict free. This may reflect the benefits of a revenue-sharing scheme that favours local over regional governments but, more likely, it is a pipeline system that has avoided large-scale spills.[*]

Brazil used the offshore development model to develop the Urucú gas fields in Coari (Amazonas), a municipality in the geographic centre of the Amazon that is uncharacteristically devoid of Indigenous populations.[†] Most inhabitants live in the urban centre (~75%), a river port and logistical centre for the liquids terminal and gas pipeline; the rest are largely *ribeirinho* communities living on the banks of the Rio Solimões. The municipality has the third highest GDP per capita in Amazonas state but scores poorly for the HDI metric, ranking well below Tefé, a neighbouring municipality that is similar in most respects but which does not receive gas royalties.[‡] A high-profile corruption scandal in 2008 (*Operação Votrax*) led to the prosecution of twenty municipal functionaries for defrauding the state of ~$R40 million.[87] Corruption is a recurring problem and an investigation in 2019 led to similar charges that implicated the son of the previous ringleader, the former mayor of Coari.[88]

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* There were four pipeline incidents in the first year of operations (2006) due to landslides in the high-rainfall section of the Andean foothills, which led to changes in the route and improvements in the engineering design; since then, there have been no reports of major incidents in either the gas or liquids pipelines (see below).

† There is only one formalised Indigenous territory in Coari municipality: TI Cajuhi Atravessado is located on the Rio Solimões ~500 kilometres from the gas field; the Urucú–Coari pipeline transects the territory, but it was built (1996) prior to the creation of the territory (2015).

‡ Coari: HDI: 0.603 (income: 0.606; health: 0.780; education: 0.045). Tefé: HDI 0656 (income: 0.637; health: 0.640; education: 0.511) Source: IBGE 2022.

Investment Criteria and Risk Management

Mining and energy companies invest in the Amazon because it is profitable. Opportunities are large because of geology, but development is costly due to the region's isolation and lack of infrastructure. The decision to pursue a mineral exploitation project depends on several factors, but there are two primary technical criteria: (a) the richness of the mineral deposit, which determines the cost of extraction; and (b) the volume of the geological formation, which determines the productive lifetime of a mine or oil and gas field. Taken together, these two factors allow investors to estimate the return on investment and decide whether or not to deploy financial capital. Scale is essential to ensure that the cost of production is lower than revenues; consequently, only the richest and largest deposits are developed.

Any investment opportunity is balanced by risk, which includes market risk driven by macroeconomics and geopolitics, as well as social and environmental risk unique to each project and nation. Corporations tend to be skilled at managing the former, but they often mismanage the later. Social conflict can delay a project and wreak havoc on the financial models used to guide investments, while a botched environmental review can lead to its rejection by a regulatory agency.

Greenfield versus Brownfield Investments

An investment that occurs in a geological formation that has not been previously exploited is known as a 'greenfield' investment. The term 'green' has nothing to do with ESG* investing principles, however, and is used to describe a new project where the developer will have to plough up or alter a virgin (green) landscape. In contrast, a 'brownfield' investment describes new projects on landscapes with a prior mining or oil field production history; they are referenced as brown because they have been impacted previously by industrial development.

Greenfield investments are inherently risky, even when the ore-bearing formation or the oil field is accurately mapped to generate estimates of reserves.† They tend to be more expensive, because developers must build a processing mill and develop a rail or pipeline infrastructure to move the mineral commodity to the nearest export terminal. Many things can go wrong, and numerous projects have been delayed or cancelled by unforeseen complications linked to the remoteness of the construction site or inadequate management of environmental and social liabilities (See Text Box 5.2).

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* ESG investments (allegedly) benefit society because they comply with environmental, social and governance criteria believed to be essential for sustainable development (see below).

† These are usually reported as proven, probable and possible.

Text Box 5.2: Investment Risk in the Mining Industry

In spite of the very large sums of capital required to install a mine, the risk associated with that investment is moderated by the discovery process and the technology of industrial mines. Geological risk is virtually non-existent because a mine is opened only after years (decades) of exploratory drilling, which ensures the mineral content and volume of the ore body are fully documented. Operational risk is eliminated by business models that incorporate precise estimates of milling and transportation costs and revenue streams based on conservative estimates of future commodity prices. Market risk is more difficult to estimate, even with complex models that project global trends in economic growth and commodity demand; large companies rely on their ability to access capital markets, which allows them to tolerate market cycles. In reality, an industrial mine is guaranteed to make money – unless there is an environmental or social incident that paralyses activities, creates a legal quagmire or explodes into a political scandal. The management of waste rock is particularly problematic because deficiencies in tailing storage facilities will persist for decades and, potentially, become worse over time. Consequently, investments in environmental and social review are not 'window dressing' but are essential tools to mitigate the largest source of risk to the extractive industries. Companies that underestimate the risk of social and environmental liabilities are typically poor investments.

Large expanses of the Amazon are still considered wilderness and any sort of development will trigger robust opposition from local, national and international organisations, particularly if the mineral deposit is located within or adjacent to a protected area. When this is the case for an Indigenous reserve, the potential for delay is compounded by the obligation to consult with Indigenous communities, many of whom are vehemently opposed to the extractive sector.

Opposition tends to be much less intense for brownfield initiatives. Previous development will have degraded natural ecosystems or altered the social landscape, which tends to lessen the degree of opposition from environmental and social advocates. Cattle pastures do not provoke the same reaction from environmental and social activists when compared to pristine forest, while private landholders are much more amenable, if not eager, to sell or grant access to their land holdings. There are exceptions, particularly when catastrophic events, such as oil pipeline failures, have led to severe impacts that have alienated the local population.[*]

Economic factors also favour brownfield developments. Royalty payments for local governments create a dependence on mineral rents for maintaining essential social services.[89] Local and regional politicians are eager to keep the income stream flowing well into the future and, since

[*] Examples include numerous pipeline failures in Peru and Ecuador that have caused Indigenous groups to fiercely oppose any type of oil field investment.

mineral deposits are finite, the lifetime of facilities can only be extended by the discovery and development of new mineral deposits. Mine owners and oil field operators seek to extract more value from infrastructure assets created with the initial greenfield investment. All these factors are obvious to banks and investment funds that seek to minimise risk and maximise profits by expanding their investment portfolios. Brownfield investments meet all these criteria.

There are numerous examples of the evolution from greenfield development to brownfield investment. The original Carajás iron ore mine in Pará was a classic greenfield investment. It took more than twenty years to develop after the discovery of the mineral deposit in 1962 and the initiation of mining activities, which occurred only after the Carajás railway was completed in 1985. The subsequent expansions from one to eight open-pit mines were all brownfield investments that were accomplished with a minimum of environmental review. More extensive evaluations were carried out for the development of nearby mines at Salobo, Onça Puma, Sossego and S11D; in each case, they were approved despite opposition from environmental and social advocates. Investment risk was diminished because of previous investments in geological surveys and exploration, while profitability was enhanced by the expansions of the Carajás railroad, associated port facilities and the administrative capacity at regional corporate offices.

Investments in the oil production in Amazonian Ecuador in the 1970s was also a greenfield investment, and have led to more than fifty years of additional exploration in adjacent blocks to ensure that production and revenues remain high. A key brownfield investment was the construction of a specialised pipeline in the early 2000s, which was needed to transport heavy crude oil discovered in the 1990s. Ironically, the ongoing expansion of exploratory and production drilling in Yasuní National Park can be considered a brownfield investment designed to prolong the life of and extract more value from the existing infrastructure of the Ecuadorian hydrocarbon industry.

The original investments in the first three Camisea gas pipelines (TCP-Gas, TGP-Liquids and Peru-LNG) were part of a suite of early phase investments that carried significant political risk during a time when populist governments across the region were questioning the benefits of direct foreign investment. Royal Dutch Shell initiated the project in 1981 when it started exploration activities but it walked away from the project in 1998 due to contract disagreements with the Peruvian government.[90] Other companies completed the project according to the terms dictated by the

Peruvian government,* which now had less production risk because the reserves were already well documented.[91]

The Impacts of Global Markets

Investment capital flows when prices are high, but companies scale back investments when they fall. Nonetheless, companies do not often abandon projects once underway; in part, this is a natural resistance to writing-off an existing investment, but experienced businessmen also know that markets are cyclical. If companies wish to 'cash in' when prices are high, they must have installed capacity in order to ramp up production when the price is right.

The prices of industrial minerals were at historical lows prior to 2000 but increased dramatically through the next two decades as China began its unprecedented build-out of infrastructure as it transitioned from an emerging economy into a global superpower. The demand for industrial minerals was mirrored by increased demand for oil and gas at a time when supplies were constrained by war and geopolitics. Coincidentally, the price of gold quadrupled due to fiscal and monetary policies in the United States partially resulting from the credit crisis of 2008.† This trifecta of market conditions favoured expansion of the mineral sector across the Pan Amazon, which saw revenues increase by 500 per cent between 2000 and 2013 (see Figure 5.8).[92] Following the fall of commodity prices in 2014, most companies scaled back their investment strategies. Chinese companies were the exception; they were flush with cash and responded to a management philosophy that considers the strategic interest of the state.[93] They have since scaled-back investments, presumably due to reduced demand in China linked to policies to slow infrastructure development.

Because mineral commodity markets are volatile, companies will model the viability of a project based on a price that is below the mean market value calculated over at least a decade. For example, gold projects are modelled on an international price of about US$1,200 per troy ounce, which is only seventy per cent of its price in January of 2023.[94] Oil companies once assumed that the long-term price of oil was about US$100 per barrel but, following the collapse of oil prices in 2015 they lowered that benchmark to US$50, which is about fifty per cent of the cost-of-production for an existing oil field in Ecuador.[95] Between 2020 and 2022, the price of oil fell to a

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* Pluspetrol (27.2%), Hunt Oil Company (25.2%), SK Corporation (17.6%), Repsol YPF (10%), Tecpetrol (10%), and Sonatrach (10%). Source: Hydrocarbons (2010) Camisea Gas Project and Gas Processing Plant, Peru. Source: https://www.hydrocarbons-technology.com/projects/camisea/

† In 2000 gold was valued at US$270 per troy ounce and increased to US$513 in 2005 and US$1,500 by 2010; it has traded in a range between US$1,000 and US$1,200 between 2014 and 2018 but rose to US$1,900 in March 2022. Index-Mundi (2022). Source: https://www.indexmundi.com/commodities/?commodity=gold&months=300

remarkable low of US$30 due to the global recession caused by COVID-19, but rebounded to US$130 following the Russian invasion of Ukraine.

As of January 2023, another commodity boom would appear to be underway. In part, this is due to the war in Ukraine and the (still unknown) dimensions and duration of the sanction regime imposed on Russia by the United States, the European Union and their allies in the Asian Pacific. This commodity boom will be different, however, due to the growing demand for certain strategic minerals needed to manufacture the components and infrastructure required by the energy transition from fossil fuels to renewable energy. These minerals exist in the Pan Amazon in globally significant quantities and there will be significant economic pressure to develop those resources.*

The Reality of Political Risk

Unlike mineral rights in advanced economies, the below-ground resources in all Latin American countries belong to the state, irrespective of the owner of the land. This includes private properties but also communal landholdings and territories that have been ceded by the state to Indigenous groups and traditional communities. Consequently, the relationship between the state and the private company defines the legal liability that is partitioned between the state and the operator, as well as the distribution of the costs and benefits that accompany mining and oil field development. Landholders may not have legal rights to the economic benefits, but they do have the power to disrupt a development by civil protest, which explains the design of royalty schemes to favour local communities.

The extractive industries are 'capital intensive', a term use to describe enterprises that require a large, typically upfront, deployment of financial capital prior to the generation of cash income. Industrial mines can require more than a billion dollars to develop; more than a decade, sometimes two, will separate the discovery of a mineral deposit and its eventual exploitation. Oil and gas development is even more expensive, due to the cost of seismic surveys and exploratory wells – many of which fail - that precede the decision to develop a field. Time itself is a risk factor because time is money; it is a cliché because it is true. A delay can turn a promising investment into a mediocre venture, while an environmental calamity or political revolution can turn into a financial disaster. Successful ventures succeed because their proponents effectively identify and manage the various forms of risk that might imperil their investments.

The surge in revenues from the extractive industry in the 2000s heightened the political risk that reflects Latin America's history of political

* Copper, nickel, niobium and tantalum; rare earth elements are known to occur in a variety of locations, including legacy cassiterite mines in Rondônia and Amazonas state (see below).

turmoil.[96] The region had experienced a boom of investment following the privatisation of state-owned companies in the 1990s, which catalysed the surge of new projects that matured in the 2000s and enabled the phenomenal growth in government revenues during the commodity boom. The high-tide of neoliberal policies led to a backlash in Bolivia and Ecuador but, despite the rhetoric by left-leaning governments, mineral development and exploration largely remained the domain of the private sector. Only Venezuela excluded investment from the private sector, and its natural resource economy, including both hydrocarbons and industrial minerals, is currently only a fraction of the size it was in the 1990s. The Peruvian election of 2021 highlighted the potential of political risk with the election of a socialist candidate who (briefly) voiced a desire to nationalise strategic industries.[97] His removal from office in December 2022 has led to widespread protest that threaten to further destabilise the country.

Stakeholders and Vested Interests

The revenues generated by the exploitation of industrial minerals and hydrocarbons flow into the balance sheets of corporations with shareholders on six continents, including several that are among the largest corporate entities on the planet.* Their operations are supported by a multitude of local and national enterprises, either as contractors or as purveyors of essential inputs and services. Together, these multinational corporations and their domestic partners create tens of thousands of jobs that span the social spectrum from common labourer to skilled engineer. Corporate offices in regional and national capital cities usually employ members of social and political elites. Like businesses everywhere, they exert influence by purchasing publicity in major media outlets, by participating in chambers of commerce and by lobbying lawmakers to formulate policies that benefit their industry.

Governments are predisposed to support the mining and hydrocarbon industries because they are export-oriented and generate revenues for the state. With very few exceptions, mining companies can count on the backing of finance ministries that are attuned to (obsessed with) the need to maintain a positive balance of payments.[98] The same logic holds for the production of oil and gas, but is reinforced by domestic production that alleviates the need for energy imports. Finance ministries are among the most influential government ministries, in part because of their technical expertise, but also because of their close relationships with multilateral

* From the Fortune Global 500, in order of estimated market capitalisation (rnk): CNPC – Chinese National Petroleum Company (3), Sinopec – China Petroleum & Chemical Corporation (4), Glencore (14), Petrobras (148), CITIC – China International Trust Investment Corporation (151), BHP – Billiton (168), Chinalco – Chinese Aluminum Company (262), Rio Tinto Group (296), Jiangxi Metals (328), China Minmetals (323) and Vale (417).

development banks that view the extractive sector as an essential component of the global economy. Moreover, loans based on the extractive sector appeal to officials at development banks who are evaluated on their ability to close deals and generate interest income for the institution.

One of the more important tasks of multilateral development agencies is to organise and finance national development strategies; these guide loan portfolios and reflect the long-term development priorities of governments. Over the last two decades, the philosophical orientation of these documents has gradually evolved to incorporate the concepts of sustainability; nonetheless, they retain the core components of conventional economic models. National strategic plans often seek to add value to natural resource commodities and are accompanied with initiatives to transform commodities into industrial goods. This requires energy, sometimes a lot of energy, which has fostered the expansion of hydropower and bioenergy.*

In the twentieth century, development strategies largely emanated from national agencies, but now they are also being generated by regional governments where elected officials are less committed to sustainable development and remain a powerful force for promoting the expansion of the extractive sector (see Chapter 7). Local elites tend to have a philosophical orientation grounded in conventional business models and, although many pay lip service to sustainability and conservation, they simultaneously support the extractive sector.

The extractive industries also benefit from a revolving door of technical expertise between the private companies and government ministries. Although they may be bound by professional ethics, government functionaries often share a vision with their corporate colleagues that reflects their own personal ambitions. They believe a robust and profitable mineral sector is in the national interest. Many are committed to the concepts of sustainability and are convinced their actions to promote best practices are beneficial to the sector and the nation.

The stakeholders of the conventional economy are powerful and well-connected, but they must contend with a countervailing movement that opposes the ongoing development of the extractive sector. Organised as non-governmental organisations (NGOs), environmental advocates operate at the global, national and local level. Some are adept at waging public relations wars and routinely oppose all types of mineral development, while others seek to reform the industry by promoting best practices in both the environmental and social sector (see below). Both groups rely on information provided by academics skilled at identifying and quantifying

* There are two steel mills near Açailandia (TO) that use vegetable charcoal as an energy source and to reduce iron ore into pig iron; Alcoa and Vale participate in a consortium that built and operates the Estreito hydropower facility on the Tocantins River (see Ch. 2).

the environmental and social impacts that influence a regulatory process known as an environmental impact analysis (EIA). Critics contend this process is biased in favour of companies and governmental stakeholders; a view shared by local communities who are understandably reticent about welcoming a massive alteration to their local landscape. The most recalcitrant stakeholders are Indigenous communities who have inhabited the project landscape for decades, centuries or longer.

Indigenous groups know from first-hand experience that benefits from mineral extraction are short-term and that damage will be permanent. They also know that most of the economic resources, including the royalty and tax income, will flow to local and regional governments that are seldom controlled by their community. In the recent past, they have been entirely dispossessed of their lands, either by being displaced from the mineral concession itself or by a flood of immigrants who have been enticed by government programmes to settle the lands adjacent to the mine (e.g., in Parauapebas, Pará, Brazil) or along the access roads built to service the oil fields (e.g., in Succumbios, Ecuador).

Indigenous groups have become adept at defending their rights. Fortuitously, they possess an enormously powerful legal weapon referred to as 'Free, Prior and Informed Consent'. Known by its English acronym FPIC, this principle is enshrined in an international treaty that obligates governments and corporations to sit down with the affected communities and explain, in accessible language, the dimensions of the proposed development. The project can only proceed if they consent to its execution. Because the treaty has been ratified by national legislatures, its elements are enforceable under the civil, administrative and penal codes of the signatory nation. Essentially, Indigenous communities have obtained *de facto* veto power over the development of any mineral resource located beneath or adjacent to their territorial lands. (see Text Box 5.3)

It is highly unlikely that current governments would have agreed to the terms of the treaty if they had fully understood the repercussions of that decision.[*] It was made during the period of the so-called Washington Consensus, when multilateral development agencies were imposing reforms on developing countries as part of a systematic process to improve governance and promote the role of the private sector. Governments have either ignored or tried to finesse the FPIC requirements by subverting or simply ignoring the consultation process.[99]

The most obvious attempt to circumvent the FPIC process was organised by the Bolsonaro administration, which proposed a law in 2019 that would establish a consultation process controlled by government

[*] Neither the United States nor Canada have ratified the convention, whose large native populations have permanent use rights to extensive geographic areas that formally belong to the state.

Text Box 5.3: Indigenous and Tribal Peoples Convention
International Labour Organization, C-169

Article 6

1. In applying the provisions of this Convention, governments shall:

(a) consult the peoples concerned, through appropriate procedures and in particular through their representative institutions, whenever consideration is being given to legislative or administrative measures which may affect them directly;

(b) establish means by which these peoples can freely participate, to at least the same extent as other sectors of the population, at all levels of decision-making in elective institutions and administrative and other bodies responsible for policies and programmes which concern them;

(c) establish means for the full development of these peoples' own institutions and initiatives, and in appropriate cases provide the resources necessary for this purpose.

2. The consultations carried out in application of this Convention shall be undertaken, in good faith and in a form appropriate to the circumstances, with the objective of achieving agreement or consent to the proposed measures.

Article 15

1. The rights of the peoples concerned to the natural resources pertaining to their lands shall be specially safeguarded. These rights include the right of these peoples to participate in the use, management and conservation of these resources.

2. In cases in which the State retains the ownership of mineral or sub-surface resources or rights to other resources pertaining to lands, governments shall establish or maintain procedures through which they shall consult these peoples, with a view to ascertaining whether and to what degree their interests would be prejudiced, before undertaking or permitting any programmes for the exploration or exploitation of such resources pertaining to their lands. The peoples concerned shall wherever possible participate in the benefits of such activities, and shall receive fair compensation for any damages which they may sustain as a result of such activities.

Ratified by national legislatures: Bolivia (1991), Brazil (2002), Colombia (1991), Ecuador (1998), Peru (1994); Venezuela (2002).

Source: https://www.ilo.org/global/lang--en/index.htm

agencies rather than the communities themselves.* Bolsonaro lost his bid for re-election but his party still remains a formidable electoral force that controls numerous local and regional governments. Regardless, wildcat mining in Brazil has always been a lawless phenomenon, and FPIC was used only by corporate miners.

* Projeto de Lei (PL-191-2020) mineração em terras indígenas: https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=1855498

Text Box 5.4: An Oxymoron: Sustainability in the Extractive Industries

> Mineral resources are non-renewable and, once they are extracted from the bowels of the Earth, they are gone. Yet almost all the corporations in the extractive industries have a division dedicated to *sustainability.* How can that be?
>
> One way is to evaluate the life cycle of the commodities themselves. Some minerals are converted into an infrastructure asset that will function over several decades, but most are transformed into a consumable good with a limited lifespan. Oil and gas are consumed over the short term while creating a climate legacy that will span millennia. In the best of cases, mineral commodities may be part of a supply chain, such as aluminium, copper or steel, that fosters recycling. Regardless, only a fraction of these metals is actually recycled, and that process is not managed by the mining companies.
>
> In reality, the extractive industries have a one-time opportunity to convert the mineral wealth of the Amazon into some form of 'sustainable capital', which may be material (infrastructure), financial (investment), social (institutions) or human (education). If this capital is wisely invested and equitably shared, then the exploitation of the region's mineral wealth represents a net benefit for society. However, if those economic resources are stolen or squandered or inequitably shared, then it is a tragedy – particularly considering the very significant environmental costs associated with mining and oil field development.

In April of 2022, the *Tribunal Constitucional* court of Peru declared that FPIC was not a fundamental right enjoyed by Indigenous groups, a decision that opened the way for Pedro Castillo to propose the concept of rentabilidad social (social profitability), which expressly balances the national interest, as perceived by the central government, with local demands made by civil society.[100] The Peruvian president, who was deposed in January 2023, nominally supported the concept of FPIC, but contended that local communities would support mineral development when it is in their interest.[101]

Successive governments of Ecuador have attempted to sidestep FPIC by insisting that a consultation was not equivalent to consent, while recruiting Indigenous leaders to support mineral production in exchange for compensation packages linked to individual projects.[102] That strategy was made inviable by the *Corte Constitucional* when it reaffirmed the primacy of consent.[103] The administration of Guillermo Lasso remains committed to expansion of the mineral sector, but now it will be done while respecting the FPIC process.[104]

Investment and Sustainability

The irreversible impacts caused by mineral extraction and the financial liabilities imposed by legal systems in the advanced economies have forced companies to embrace environmental management as a core component of their business models. Cadres of employees work diligently to show that their employers are dedicated to preserving the environment and improving the welfare of local communities. They are supported by consultants, non-governmental organisations and government functionaries who are all committed to improving the practices of the extractive sector. Some companies define their development projects and operations as 'environmentally and socially responsible', while promoting the 'wise use' of non-renewable resources. Increasingly, the term 'sustainability' is being used to describe these corporate policies – despite the obvious cognitive dissonance inherent when the word is used to describe the extractive industries (see Text Box 5.4).

The regulatory process that governs the environmental and social impacts caused by the exploration and exploitation of minerals is organised via a technical study known as an environmental impact analysis (EIA). The objective of an EIA is to identify, describe and quantify all the potential impacts. The environmental impacts of the mining industry are well known and are the probable origin of the mitigation hierarchy, summarised as: (1) avoid, (2) minimise, (3) remediate and (4) offset.

Occasionally, an EIA can lead to the cancellation of a project, but more often it motivates the developer to modify some particularly noxious aspect of a project, or to provide more generous compensation to impacted communities. There are two broad classes of impacts:

(1) Direct impacts, which stem from the construction and operations of the mine, oil well or associated infrastructure asset, such as a waste treatment facility or pipelines where a failure caused by a design flaw, human error or an act of nature (e.g., earthquake) can lead to catastrophic harm to natural ecosystems and nearby communities.

(2) Indirect impacts, which are more remote and harder to quantify; for example, deforestation on landscapes with key transportation assets or aquatic degradation caused by recurrent leaks and spills that can alter ecological processes far downstream from mine sites and oil fields. Sometimes referred to as secondary impacts, they are real and significant, particularly when they harm long-established communities whose livelihoods are dependent on natural ecosystems.

Assuming the project moves forward, EIAs are developed in parallel with an environmental action plan (EAP), which has four basic objectives that adhere to the mitigation hierarchy.[105]

Both instruments incorporate consultation processes and, when properly executed, can materially improve the profitability of a mine, in part by limiting the costs of environmental mitigation and avoiding conflict with communities. In spite of progress in using the EIA as a risk-management protocol, the mining industry is populated by old-school engineers and geologists that view EIA as a public relations document. They are often driven by short-term cost considerations and timelines that reflect upon their reputation as project managers. Consequently, the EIA is often used as a checklist of tasks that must be completed before the initiation of mining operations.

In contrast, progressive companies use the regulatory and consultation processes to improve their operations and protect their investments. A controversial project can be challenged by civil society organisations in the court of public opinion; regulatory agencies may be populated with allies, but functionaries will react to controversy by delaying decisions. A poorly executed EIA or a dishonest consultation process can paralyse a project and destroy financial capital. Worse still, the unforeseen consequences of a catastrophic event can lead to bankruptcy when aggrieved citizens take legal action though civil suits or when governments levy fines and damages caused by negligence.

Since about 2015, companies have become cognisant of investors' demands that they comply with ESG principles, which include commitments to adopt 'best management practices'. Not surprisingly, these are almost a mirror image of the mitigation hierarchy. Following are some examples of the environmental and social impacts associated with the extractive sector in the Pan Amazon.

Environmental Liabilities Are Also Economic Liabilities

Although new mines use state-of-the-art technology, the industry also has a legacy of ageing containment dams at older mines, particularly shuttered mines that no longer generate revenues to finance improvements in the technology surrounding tailings storage facilities (TSF).* Their failure can result in the release of millions of cubic metres of toxic sludge into river systems. In populated areas, this can impact the water supplies of communities, wreak havoc on the local economy and endanger the health of thousands of inhabitants. In remote landscapes, a failed containment structure will contaminate (tens of) thousands of hectares of aquatic and riparian habitat, threaten wildlife and disrupt the livelihoods of Indigenous families.

Although mining companies have fully embraced the need to improve their environmental management, they tend to focus on new mines where state-of-the-art technology could be incorporated into the design of new projects, often with additional benefits that reduce operating costs and conflicts with nearby communities. Until recently, less attention was focused on the older and decommissioned mines and their associated environmental liabilities. That changed after two recent incidents in Minas Gerais (Brazil)

* Tailings refer to pulverised rock waste after the extraction of all valuable minerals; depending upon the ore and the milling technology, tailings range from being mildly to extremely toxic.

where legacy dams constructed using a flawed engineering design failed with disastrous consequences.

The first event occurred at the Mariana iron ore complex in 2015 when a dam failed and released ~44 million metric tonnes of mud and effluent into the Río Doce.* The operating company, a joint venture between two of the largest and most experienced mining corporations (Vale SA and BHP), agreed to a remediation plan estimated to cost R$6 billion (~US$1.2 billion). That is only a fraction of the financial cost of the disaster, however, because lost operating income forced the operating company (Samarco) to default on US$13.4 million in corporate bonds. Yet to be determined are costs associated with civil action in the UK and Australia where BHP is being sued on behalf of individuals impacted by the incident.

The second event was even worse. In 2019, the Brumadinho tailings dam collapsed at another Vale-operated iron ore mine, releasing twelve million metric tonnes of tailings that triggered a flood which swept across the mine's operations centre and adjacent agricultural landscape.† The tailings facility, which had closed in 2014 after thirty years of operations, was classified as a low-risk small dam and, allegedly, was monitored twice a week for cracks and filtration. In February 2021, the government of Minas Gerais and Vale agreed on a remediation plan with an estimated cost of US$7 billion,[106] while reaching individual settlements with families impacted by the disaster at a cost of $US 630 million.[107] The Securities and Exchange Commission (SEC) sued Vale in April 2022 for deliberately misleading investors as to the safety of its tailings management systems.[108]

Corporate Shenanigans

The ongoing attempts by companies to isolate themselves from environmental liabilities highlight the legal challenges when those liabilities were created by corporate actors that no longer exist as legal entities. This behaviour has long been practised by both mining and oil companies that permutate their legal identity via complex transactions that exploit legal manoeuvres available to companies that have participated in mergers, acquisitions or sale of corporate subsidiaries that exist as distinct legal entities.

For example, the Oroya metallurgical complex in Central Peru has operated as an industrial mill for more than a century. It was owned by a private company between 1920 and 1980, when it was nationalised and ran as a state-owned corporation until 1997. It was sold to the RENCO Group of the United States, which maintains that it has legal liability only for the

* Twenty people died and the toxic sludge forced municipalities to shut down water systems along 600 km of the river; the impact of the disaster extended 600 km to the coast, causing harm to coastal and estuary ecosystems within a globally important protected area.

† Two hundred and seventy people died, farmers lost crops and livestock and municipalities shut down water systems.

period since it acquired the facility.[109] In 2005, an environmental monitoring study revealed that 97 per cent of the children in nearby communities suffered from lead poisoning caused by inhalation of dust that originated in the Oroya tailings heap.[110] Almost immediately, RENCO spun off its Peruvian operations into a separate corporate entity to protect the holding company from the financial liabilities of remediation, estimated at ~US$5 billion.[111] The dispute revolves around a claim and counterclaim: the government maintains that RENCO failed to eliminate toxic emissions, while the company argues it is not responsible for clean-up obligations that the Peruvian state had explicitly assumed during the privatisation process.[112]

The lengthy legal contest highlights a reality of the mining business. Depreciating assets are spun off into subsidiaries, which are sold to low-cost operators seeking to extract the last bit of value from a mineral deposit. Legal action to hold a corporate entity liable for events occurring decades after the closure of a mine is not likely to succeed, a fact highlighted by companies in their declarations to the Security and Exchange Commission.* The inability to make a defunct corporation pay for remediation forces the state to assume the full cost of remediation. Unfortunately, governmental budgets are constrained and solutions expensive. The most likely outcome is that elected officials will ignore the problem and let their citizens suffer the impacts of environmental degradation.

The same strategy is being used to escape (or limit) legal and financial liability in the Peruvian oil industry after five decades of negligence and mismanagement. The corporation that pioneered investments in Northern Peru in the 1970s, Occidental Petroleum, transferred operations in its principal concession to Pluspetrol in 2000. By coincidence, Pluspetrol had assumed operational control of an adjacent field in 1996 from the state-owned company Petroperú, replacing Occidental, which was a junior (rather than senior) partner. In both instances, Occidental was the operating partner and, presumably, liable for any accidents that might have occurred during its legal tenure.

Both concessions were located within the ancestral lands of the Achuar, who are equally displeased by the practices of Occidental, Pluspetrol and Petroperu. Occidental was sued by the communities in a US court and reached an (out-of-court) settlement; the company did not accept, however, any responsibility for oil spills in the concession they had operated for

* Buenaventura Mining Co Inc, a Peruvian mining company listed on the New York Stock exchange filed a Form 20-F, Securities and Exchange Commission (Filed 05/02/16) that states: 'Insurance against certain risks (including certain liabilities for environmental pollution or other hazards as a result of exploration and production) is not generally available to us or to other companies within the industry.' Source: http://www.otcmarkets.com/edgar/GetFilingPdf?FilingID=11352178

forty years.[113] Pluspetrol operated both concessions for slightly more than twenty years and, allegedly, continued many of the substandard practices of their predecessors.

Like all oil companies, Pluspetrol operates via subsidiaries and joint ventures, a deliberate strategy to manage the risks associated with their business. Pluspetrol declared one of its Peruvian subsidiaries bankrupt in December 2021, a not-illogical corporate manoeuvre considering those oil fields were well past their productive prime. However, it also represents a brazen attempt to avoid legal liability by arguing that the operator is not responsible for the contamination that occurred previous to its tenure. In its announcement, the company blamed the Peruvian environmental supervision agency (OEFA) for holding it responsible for the contamination that occurred in previous years when other companies (e.g., Petroperú and Occidental) were operating the block.[114]

Occidental and Pluspetrol will probably escape legal and financial liabilities; however, Petroperú has fewer legal options. As a state-owned company, it can neither pull up stakes and leave, nor declare bankruptcy, which is a political decision reserved for either the President or Congress (or both). Its legal liability is complicated by the *Oleoducto Norperuano*, a key infrastructure asset managed by Petroperú since its construction in 1973 – and the source of the vast majority of the oil spills that have contaminated the region. The regulatory agency that oversees the oil industry (OSINERGMIN) contends that Petroperú should not be held liable, however, because over eighty per cent of the incidents have been caused by sabotage.

The company's fiercest critics are the Awajún and Huambisa ethnic groups, who occupy the land transected by the pipeline. Although they oppose the pipeline, they are not the primary suspects in the recurring sabotage that plagues the financial health of Petroperú and exacerbates the environmental liabilities that afflict their communities. Those criminal acts are assumed to be caused by individuals who benefit economically from clean-up efforts, including the service companies that are contracted to remediate the spills and provide compensation to impacted communities in the form of health care and basic infrastructure

Petroperú may get stuck with the tab, but it has effectively ignored almost all judicial or regulatory mandates to remediate the impact from more than a thousand spills that have contaminated forest and aquatic habitats across Northern Peru. The price tag for that remediation, if it ever materialises, has been estimated at US$1 billion; that number, although large, is probably an underestimate and the reality is likely to be at least one order of magnitude greater.[115]

Environmental, Social and Governance Investing

There are now very few global corporations that deny climate change. Senior executives have finally realised their future as profit-making enterprises depend on their ability to make money on a planet radically different from the one they knew as children. Their long-overdue enlightenment is the product of three decades of educational campaigns waged by civil society, academia and multilateral organisations. Those campaigns forced these corporate behemoths into action in the last half of the 2010s, when institutional investors, which provide companies with the financial capital they need to grow their business empires, demanded change (Figure 5.14). It was also clear that a successful strategy needs to be holistic, which led to a consensus that the solution should incorporate criteria encapsulated by three words: Environmental, Social and Governance (ESG).[116]

Under previous iterations of sustainability programmes, companies sought to manage the environmental and social impacts from their operations in order to limit any potential legal or financial liabilities. The goal was to protect the corporate image and avoid angering consumers or provoking

Figure 5.14: A summary of selected institutional investments in Brazilian mining ventures in 2021. The total value of $US 31 billion includes loans, bonds, underwriting fees and equity shares of corporate entities that report financial information. Brazilian fund managers prefer to invest in Vale, the country's largest publicly traded corporation, while the capital allocation of fund managers in the USA and Canada reflect legal obligations to diversify investment portfolios according to market capitalisation and industrial sector.

Data source: APIB (2022).

key stakeholders (i.e., local communities). According to the new paradigm, ESG strategies pro-actively support the planet and societal well-being in order to maximise profits over the short and long term. The goal is to align a company's strategies and operations with the growing demand for the sustainable production of goods and services. Coincidentally, reformed corporate behaviour will support the energy transition and save the planet.

Because ESG guidelines are being mandated by a board of directors, they are being integrated into strategic development plans at the corporate equivalent of the speed-of-light. Task forces have reviewed existing sustainability initiatives and repackaged their environmental and social components according to the new (slightly different) nomenclature of ESG investing, while linking them to an expanded (pre-existing) set of standards conceived to ensure ethical behaviour on the part of corporate officers. The changes are subtle but significant. They are also controversial.

Critics on the left brand ESG investing as greenwashing, arguing that corporations view it through a public relations lens rather than as a true reform of business models. Their scepticism is based on the participation of corporations with a history of climate change denial and the ability of corporations to inundate ESG platforms with a myriad of data that de-emphasises more fundamental measurements of environmental performance. Supporters contend the emerging ESG schemes are different in both scope and scale from previous sustainability initiatives, where the power of consumers was dispersed via complex supply chains and political processes. In contrast, investors will use ESG ratings to constrain (or enhance) the provision of financial capital, which is essential for corporate growth.

Critics on the right contend that ESG criteria distract from the fundamental purpose of a corporation, which is to create wealth for shareholders, while arguing that ESG evaluation systems are a hodgepodge of good intentions with no demonstrable economic benefits.[117] Supporters, including the CEOs of the world's largest financial services companies, respond by observing that successful companies have always invested in the capacity of their employees, suppliers and clients. Regardless, the Security and Exchange Commission (SEC) of the United States has proposed rules to obligate publicly listed companies to report climate-related information, essentially mandating the inclusion of ESG metrics in corporate reports.[118]

The creation of the ESG evaluation and reporting system is an ongoing process with overlapping schemes composed of a bewildering assortment of metrics, guidelines, criteria, standards, frameworks, scores and benchmarks.[*] At the corporate level, the scale pertinent for evaluating investments in the

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[*] Standards: European Financial Reporting Advisory Group (EFRAG); Global Reporting Initiative (GRI); International Sustainability Standards Board (ISSB); Sustainability Accounting Standards Board (SASB).
Frameworks: Climate Disclosure Standards Board (CDSB – initiative of CDP);

extractive industries in the Pan Amazon, ten financial rating agencies have launched schemes that combine information from corporate reports with independent data that, allegedly, provide an objective measure of ESG performance.* The competing schemes often provide radically different scores for the same company depending upon what metrics are collected and the weights applied to different algorithms that pool hundreds of separate measurements into a single summary score. These scores are derived from thousands of data points, organised into hierarchical subcategories, which are compiled into sub-scores for E, S and G. System complexity causes ESG scores to be poorly correlated: a company may fare well in one scheme but be ranked as mediocre in another.[119]

ESG in the Pan Amazon

Evaluations are compiled at the global scale and encompass many corporate attributes that are not relevant to the specific facilities and operations located in the Amazon. A very large company may have a good score overall, but a poorly conceived project in the Pan Amazon. Moreover, the global corporations that participate in ESG initiatives are not representative of the dozens of domestic mining companies that operate in the Pan Amazon. With few notable exceptions, domestic companies do not participate in ESG scoring schemes; those that do tend to be highly dependent on foreign capital or on foreign markets to commercialise their production.

There are at least 250 corporate entities operating or actively developing a mine, oil or gas field, or a logistical facility (pipeline, port, manufacturing) with a presence in Brazil, Ecuador, French Guiana, Guyana, Peru and Suriname.† Of these, only a fraction (~18 per cent) can be found in the databases compiled by S&P-ESG (47), Refinitiv (46) or Sustainalytics‡ (44).

The companies with the best scores are all global mining or oil giants whose ratings are due, in part, to their ability to build comprehensive monitoring programmes that collect massive volumes of ESG data. Well

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International Integrated Reporting Council (IIRC); Task Force on Climate-Related Financial Disclosures (TCFD).

* Rating agencies: ESG-Analytics; MSCI (previously KLM); S&P Global ESG (previously RobecoSAM); Sustainalytics (Morningstar); Moody's ESG (previously Vigeo Eiris); Fitch Ratings ESG; Bloomberg-ESG, RepRisk, and Refinitiv, FTSF Russe.

† The enumeration of operating companies was extracted from public databases listing mines, oil fields and concessions made available online at government ministries (Brazil: Agência Nacional de Mineração, Agência Nacional do Petróleo, Gás Natural e Biocombustíveis; Peru: Ministerio de Energía y Minas, Instituto Geológico, Minero y Metalúrgico; Ecuador: Ministerio de Energía y Minas; Colombia: Agencia Naciomal de Mineria).

‡ The Sustainalytics score is designed to reflect risk; higher scores reflect greater ESG risk; in contrast, most other systems provide a rank score between 0 (worst) and 100 (best). See https://www.sustainalytics.com/esg-ratings

managed companies use the data to identify pressure points and bottlenecks, which can be modified at a reasonable cost to improve efficiency and profitability; it also allows them to flood rating systems with 'positive' data, while reaping additional points for data transparency. Companies that participate half-heartedly are penalised by blank data fields.

Among the high-scoring corporations are the mining giants Vale, Alcoa and Norsk Hydro, which operate massive strip mines near the Amazon River, as well as Glencore, BHP and Rio Tinto, which operate equally massive open-pit mines in the High Andes of Peru. The poorest scoring companies are the China National Petroleum Company and Sinopec, oil companies operating in Peru and Ecuador, and junior mining companies operating on frontier landscapes in Pará, Brazil. Following is a brief overview of selected corporations and their ESG scorings.

Vale SA[*]

Brazil's second most valuable company is also the fifth largest global mining corporation. In 2022, it was as ranked by the Refinitiv ESG framework as best in its class of 'diversified miners' (1 out of 615).[†] This score is remarkable considering Vale is being sued by the SEC for deliberately misleading investors of its ESG-related risks prior to the tailings pond disasters at Brumadinho in 2019.[120] Ironically, this high ranking is a direct consequence of that disaster, which led to a fifty per cent drop in its share price and the dismissal of its CEO. The company subsequently invested in multiple high-profile ESG initiatives, particularly the enhanced monitoring of tailing storage facilities, accelerated remediation of environmental liabilities and the creation of compensation programmes for communities impacted by its operations.

Vale operates the world's second largest iron ore mine in the Carajás district of south-central Pará. Even before Brumadinho, ESG concerns had motivated the company to develop a dry-tailings management system at the S11D iron ore mine at the Carajás Serra Sur complex. Other sustainability-linked features at the site include a spatial layout that placed 97 per cent of its industrial facilities in previously deforested pasture outside the forest reserve where the mining concessions are located. Industrial innovations include an ore-hauling system that eliminates the use of diesel-powered trucks, which reduces carbon emission by ~50 per cent. According to

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[*] Vale SA ESG scores: S&P-ESG 67/100; Refinitiv 90/100; Sustainalytics 36.1 [high risk].

[†] Financial analysts groups miners into categories and subcategories; diversified miners is a broad class that includes non-ferrous metals (Al, Cu, Ni, Zn, etc.), iron and steel (Fe, Mn, Ni, etc.), and precious metals (Au, Ag, Pt, etc,). Source: Refinitiv, https://www.refinitiv.com/content/dam/marketing/en_us/documents/quick-reference-guides/trbc-business-classification-quick-guide.pdf

Google Earth

Brazil's largest privately held company, Vale SA, operates the Carajás Serra Sur iron ore mining complex, which is located within the Carajás National Forest. The company started operations in 2016 at the S11D pit mine (a), which is part of an integrated system that eliminates the use of trucks to move ore to the processing mill (b) and a dry tailings management system (c). Ore and waste rock are moved via conveyer belts (d and d′), while concentrated iron ore is moved to the export terminal via the Estrada de Ferro Carajás. The company presents the Carajás Serra Sur mining complex as an example of responsible mining based on the principals of ESG investing, in part because of reduced GHG emissions and the elimination of water-based tailing management systems.

Data source: Vale SA.

corporate reports, the S11D mine is a template for how Vale will meet its commitment to be net carbon zero by 2050.[121]

As part of its broader ESG strategy, Vale is implementing water-conservation strategies and investing in renewable energy across all its operations. This includes purchasing electricity from the controversial Belo Monte hydroelectric dam on the Rio Xingu and the Estreito hydrodam on the Rio Tocantins (see Chapter 2). There are no plans to abandon water-dependent tailing management systems or the truck-based ore hauling systems at iron ore pits at Carajás Serra Norte or the copper mines at Salobo and Sossego (Annex 5.1). The company inspected all its tailing dams and reported engineering flaws at only one site in the Carajás mining district: an abandoned gold mine known as Igarapé Bahia that was subsequently decommissioned and de-characterised in 2021.[*] Other environmental actions taken by the company include the conservation of one million hectares of native forest, which it manages in coordination with the Brazilian national park service (ICMBio), and a commitment to assist local landholders reforest 100,000 hectares of degraded pasture by 2030.[†]

Social controversies accompanied the recent US$1.5 billion expansion of the company's 1,000-kilometre railway, which runs adjacent to Awá, Guajajara and Ka'apor Indigenous communities in Maranhão. Accusation of water pollution at the Onça Puma nickel mine led to legal action on behalf of the Kayapo ethnic group. Vale has responded to these and other complaints with a legal strategy that denies liability, while negotiating compensation agreements with the aggrieved parties.[122]

Vale holds the right to explore for minerals in hundreds of concessions acquired via public auctions over several decades.[123] In many cases, their below-ground mineral rights overlapped with above-ground rights of formally constituted indigenous territories. This contradiction became a serious public relations problem when the Bolsonaro administration attempted to weaken the legal protection of Indigenous lands. In 2021, Vale formally relinquished its rights to any concession that overlapped with Indigenous lands and reaffirmed its commitment to the concept of FPIC.[124] (see Figure 5.4)

Mineração do Rio Norte (MNR)[‡]

A sustainability initiative that predates ESG investing is the restoration of rainforest habitat at the Trombetas bauxite mine in Oriximiná, Pará, which is operated by MNR, a joint venture between Vale and four other companies: South32, Rio Tinto, Companhia Brasileira de Alumínio and Norsk Hydro (5%).[125] The consortium has avoided much of the controversy surrounding the Carajás mine by committing to an ambitious forest-restoration project.

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[*] De-characterisation refers to the endpoint of a remediation protocol for tailing ponds, which must be de-watered, de-commissioned (rendered harmless) and de-characterised (restored to a quasi-natural habitat). Source: Vale (2022), 'Mine Tailings Disclosure table', http://www.vale.com/esg/pt/Documents/disclosure_on_tailings_dams_PT.pdf

[†] Laws governing activities in conservation units allow mining operations in forest reserves (FLONA) established prior to 2000, a so-called grandfather clause that protects Vale's ten concessions located within the FLONA Carajás.

[‡] As of December of 2022, the major shareholders of MNR were the following corporations with their individual ESFG metrics :
Vale SA: S&P-ESG 67/100; Refinitiv 90/100; Sustainalytics 36.1 [high risk]
South 32 Ltd (ex-BHP); S&P-ESG 55/100; Refinitiv 69/100; Sustainalytics 23.0 [medium risk]
Rio Tinto Ltd: S&P-ESG 73/100; Refinitiv 81/100; Sustainalytics 30.7 [high risk]
CBA SA: S&P-ESG na/100; Refinitiv 48/100; Sustainalytics n.a
Hydro NV: S&P-ESG: 67/100; Refinitiv 87/100; Sustainalytics 19.7 [low risk].

Over the past four decades, MNR has restored ~7,000 hectares of land reclaimed from a massive strip mine that has consumed ~15,000 hectares of natural rainforest habitat. The mine is scheduled to cease operations in 2025 and presumably will eventually restore about 75 per cent of the total impacted area.

Other claims to sustainability include an industrial mill that recycles eighty per cent of its water-use and tailings management protocols via a concatenated series of ponds covering ~1,300 hectares. Individual ponds have been designed to be de-watered and decommissioned as the mine ages;[126] however, it is unlikely any of the ponds will be amenable to the cultivation of trees, much less the restoration of a natural habitat. Following the Brumadinho tragedy, the company reviewed their containment dams and reported that all were structurally sound and designed to withstand a 10,000-year rain-event. If they were to fail, they would impact adjacent natural forest habitat but not pose a threat to nearby communities.[127]

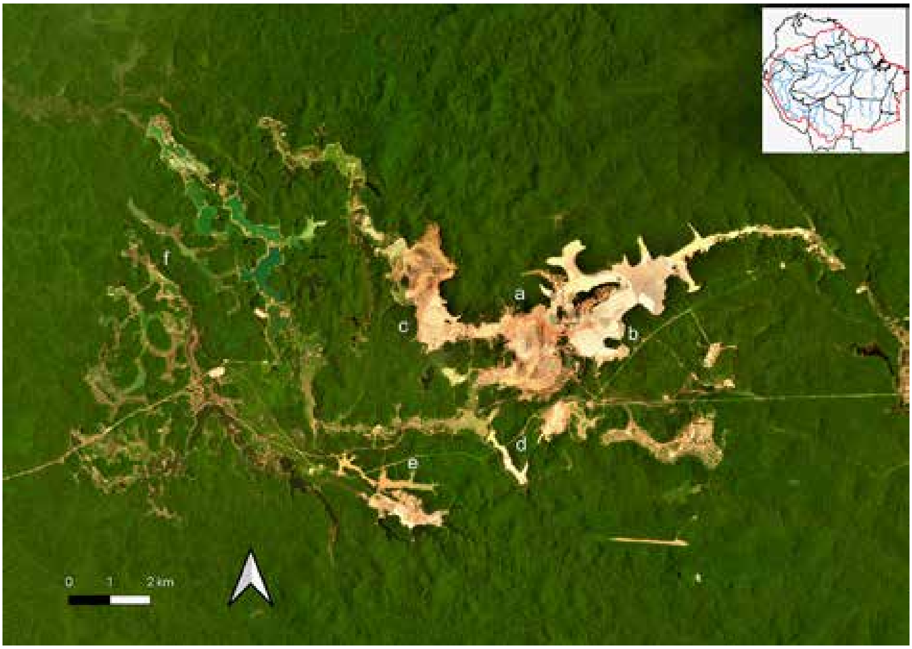
Mineração Taboca SA[*]

The Pitinga mine, owned by *Mineração Taboca* SA, in Amazonas state exploits the richest tin deposit in the world. It operated as a subsidiary of the Paranapanema Group from 1979 to 2009, when it was acquired by Minsur SA, a medium-sized company that runs several polymetallic mines in the Peruvian Andes. Minsur adheres to international sustainability standards and provides a relatively detailed overview of its practices in its annual reports. The company is large enough to warrant the attention of the ESG rating agencies with scores that reflect its efforts to report and monitor its environmental and social impacts of its Peruvian operations (157 out of 615). However, these scores may not accurately reflect the very significant environmental and social liabilities of the Pitinga mine.

The mine was operated for the first three decades using placer mining technologies that destroyed thousands of hectares of riparian forest on land that once belonged to the Waimiri–Atroari Indigenous nation. This iconic Indigenous tribe survived a genocidal attack by the military in the 1960s only to be dispossessed of a third of their territory by the mining concessions granted to *Mineração Taboca* (see Chapter 11). Following its purchase, Minsur abandoned placer mining operations and shifted production to an open-pit hard-rock mine. Rather than remediate the legacy tailings and isolate the tailings produced from the open pit, the new owners converted the abandoned placer mines into an *ad hoc* water-treatment facility. The abandoned placer mines/tailing ponds are located on the headwaters of the Rio Alaluá watershed, which drain westward into Indigenous lands.

The Waimiri–Atroari have filed complaints with environmental authorities questioning the efficacy of the tailings management regime

[*] Minsur SA: S&P ESG: 53/100; Refinitiv: 60/100 Sustainalytics: NA.



The tailing ponds at the Pitanga cassiterite mine in Amazonas are the legacy of placer and open-pit mining operations spanning five decades. The current operator, Minsur SA of Peru, purchased the mine in 2005 and assumed legal responsibility for the ponds' remediation and, eventually, decommission. Key: Open pit mine (a) and large tailing pond (b) that drains east towards the Balbina reservoir. Tailing ponds associated with secondary pits and mill facilities (c, d, e) that drain into catchment reservoirs occupying legacy placer riverscapes (f) situated upstream from the the Waimiri–Atroari Indigenous Territory.

and have provided factual evidence of leaks of noxious substances.[128] The company has responded by attesting to the structural integrity of fifteen dams that are the major components of its waste-management system, which channels water through a concatenated series of ponds with decreasing levels of suspended sediments. Satellite images show there are at least sixty interconnected ponds covering more than two thousand hectares, all of which are located in floodplains that were previously destroyed by placer mines. Presumably, when the Pitinga mine is closed, 25 years in the future, all these ponds will be dewatered, decommissioned and de-characterised.

Potássio do Brasil Ltd.

Potássio do Brasil Ltd. touts its ESG credentials by asserting that its future operations will displace carbon-intensive fertiliser imports from Russia, Belarus and Canada. The company, which is incorporated in Brazil, is the

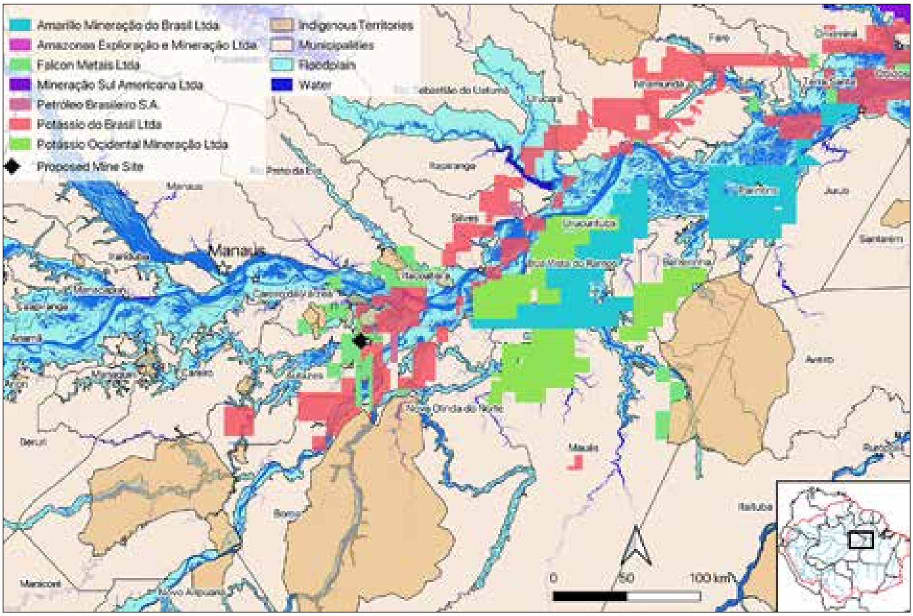


Figure 5.15: The discovery of potash deposits underneath and adjacent to the Amazon river plain has motivated mining companies to acquire concessions for their eventual development. The first such endeavour in the Municipality of Autazes hopes to initiate operations in 2024, but must contend with opposition from environmental and social advocates who have questioned the validity of its social consultation process.
Data source: RAISG (2022).

creation of Forbes and Manhattan, a Canadian investment bank that provides venture capital to greenfield-mining enterprises. If successful, the promoters will open an industrial-scale potash mine at Autazes near the junction of the Madeira and Amazon rivers (Figure 5.15)

The domestic potash mine's environmental benefits are largely based on estimates of GHG-emission reductions achieved by replacing fertiliser imports from fossil-fuel-based production systems with fertiliser manufactured using the Amazon's abundant hydropower energy.* These GHG reductions, which are significant, would be augmented by reductions from

* Annual reductions of 1.3 million tonnes CO2 by displacing imports; domestic potash would have a 79% lower carbon intensity compared to imported fertiliser; there would be 21,000 tonnes annual offset by linking local communities to the national grid (diesel replaced by hydropower); biodiversity would be enhanced by planting 20,000 trees. Communities have benefitted from a vaccination programme and food to needy families. The company would support gender diversity by appointing at least 20% females on its board. Source: Brazil Potash, https://brazilpotash.com/esg/

decreased transportation emissions and the displacement of diesel-based generators used by local communities because of the expansion of the regional electrical grid.[129]

Opponents object on environmental and social grounds arguing the mine site is on an ecologically fragile area (Amazon floodplain) and would impact nearby Indigenous and *ribeirinho* villages. The company claims the spatial footprint will be minimised because tailings will be returned to underground shafts and water will be recycled to reduce impacts to floodplain habitats. A major point of contention is agreements with local communities. The company maintains it has complied with Brazilian regulations by obtaining the consent of individual communities, but Indigenous organisations maintain that consent was not obtained via an open and informed process. The company has not chosen, apparently, to participate in any of the ESG evaluation initiatives despite its ostentatious claims of incorporating ESG principles into the heart of its proposed development strategy.

Aço Verde do Brasil (Grupo Ferroeste)

The world's first producer of 'green steel' is the family-owned company, *Aço Verde do Brasil*, which uses biomass as a source of thermal energy and charcoal as a reducing agent in the steel-making process. The company's steel mill is located in Açailândia (Maranhão) and sources its biomass charcoal from 15,000 hectares of eucalyptus plantations located in surrounding municipalities. The company was awarded the ESG Breakthrough Award (Global Metals Category) at the S&P Global Platts conference in 2021 in recognition of its production of steel with (almost) zero GHG emissions. Aço Verde, which translates as 'green steel' comercialises a variety of steel with a GHG footprint of 0.02 tonnes CO_2 per tonne of steel compared to a conventional coal-powered plant with 1.85 tonnes of CO_2 per tonne of steel.[130]

While billed as pioneer accomplishment, the use of biomass charcoal by the metallurgical industry in Brazil has been commonplace for decades, particularly at pig-iron mills that concentrate raw iron ore into cast-iron ingots. In the last half of the twentieth century, the conversion of 'waste wood' into charcoal for steel companies was an important revenue stream for landholders who were clearing natural forest to create cattle ranches.[131] This quasi-legal market ended in 2005 when government policies led to a dramatic reduction in deforestation and forced companies to switch energy feedstocks into a mixture of coal and cultivated biomass.

Aço Verde's corporate predecessor (Gusa Nordeste) was a major consumer of deforestation charcoal, but the parent company (Grupo Ferroeste) foresaw the end of uncontrolled deforestation and started planting eucalyptus plantations as early as 1993. The steel mill and its associated plantations are located in a heavily deforested municipality where less than thirty per cent of the original natural forest is conserved.* Nonetheless, the company attests that all charcoal feedstock originates on landholdings with ~40 per cent natural forest, and that all providers comply with the *Codigo Florestal* and the required allotment of *Area Permanente de Preservação* (APP). The company also reports an impressive portfolio of community-development programmes in sports, health and education, including the establishment of a technical school in the industrial arts.[132]

Newmont Corporation†

The world's largest gold miner, Newmont Corporation, operates two industrial-scale mines in the Pan Amazon: Yanacocha in Cajamarca, Peru and Merian in the Sipilwini District of Suriname. Newmont is domiciled in the United States and has an ESG ranking of five (of 615) in the class of diversified miners and seven (of 120) in the class of miners of precious metals. It has leveraged its exalted ESG status by issuing a US$1 billion 'green' bond that will pay a premium interest rate if the company fails to track an explicit pathway of GHG reductions: ~30 per cent reduction by 2030.[133]

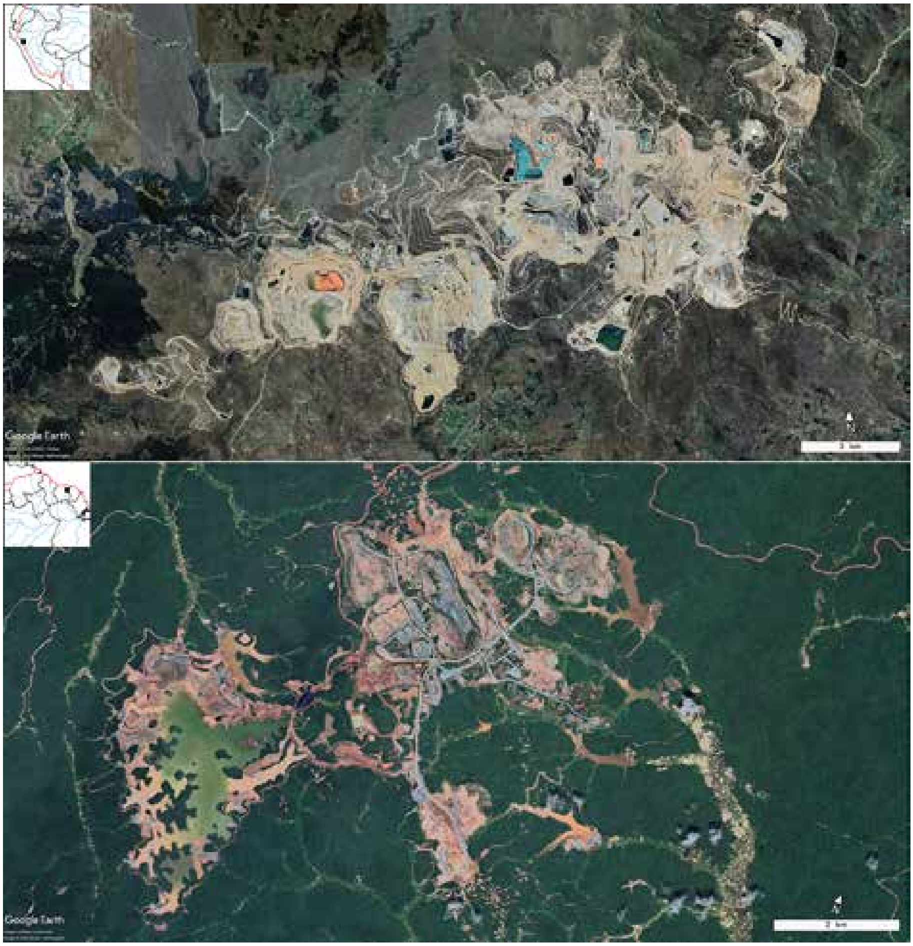
The Yanacocha mine is a sprawling multi-pit complex spanning more than 5,000 hectares in the semi-arid highlands of the Central Andes. It was opened in 1993 and suspended operations in 2022. The mine site is notable for the absence of tailing ponds, a consequence of the heap-leach technology used to extract gold. The Merian mine was opened in 2016 and covers only ~500 hectares; however, it is surrounded by catchment ponds covering an additional 1,000 hectares, which reflect the tank-leaching technology used at high-rainfall industrial mills.[134] Despite the differences in technology, both mines adhere to international standards regarding cyanide management; the company reports it recycles ~77 per cent of the water used in its processing plants.

Both mines are essentially money machines, and they provide considerable economic benefits to their host countries (see Table 5.7). As a high-profile gold miner, Newmont is particularly attuned to the reputational risk associated with social conflict and, in keeping with its ESG commitments, allocates significant resources to community development. Nonetheless, it occasionally needs to be reminded of the limits of its power.

In 2016, the company abandoned more than a decade of planning to extend the lifetime of the Yanacocha complex; known as the Conga Project, the company had plans to excavate a series of open-pit mines on an adjacent mountain. These plans were derailed by a subsistence farmer, Máxima Acuña

* Açailândia: Forest: 169,034; native non-forest: 302; plantation: 15,840; misc. crops: 11,860; pasture; 338,141; soy: 42,052. Source: MapBiomas 2020.

† Newmont Corporation: S&P ESG: 83/100; Refinitiv 87/100; Sustainalytics 20.3 [medium risk].



Google Earth

Newmont Corporation operates two massive gold mines in the Amazon. Top: The ~5,000 hectare complex at Yanacocha in the semi-arid Andes near Cajamarca, Peru, uses a cyanide heap-leach technology to concentrate gold. Instead of large-scale tailings ponds, the complex has a dozen smaller cyanide recycling ponds that are situated adjacent to heap-leach pads. Bottom: The Merian mine in Suriname spans about 2,000 hectares and includes a 750 hectare tailings pond required by the cyanide tank-leach technology. In addition, the company has constructed five catchment reservoirs to isolate the mine from the surrounding watershed.

Data source: Newmont Mining.

Table 5.7 The financial benefits of Newmont Mining Corporation's industrial-scale gold mines to the economy of Peru (Yanacocha) and Suriname (Merian); all values are in US$ millions for the 2021 calendar year.

	Operating costs	Wages & benefits	Capital investment	Interest & dividends	Royalties & taxes	Community investments	Total
Yanacocha	340	55.1	156.6	6.5	176.0	6.2	741.0
Merian	231	62.5	46.1	0.1	136.9	0.8	477.5

Source: Newmont Corporation. 2021. *Climate and Sustainability Summary*: https://s24.q4cdn.com/382246808/files/doc_downloads/sustainability/2021-report/2021-climate-sustainability-summary.pdf

de Chaupe,* who refused to surrender her small family farm to the mining giant and its powerful Peruvian partner (*Compañía de Minas Buenaventura*).†

Newmont's subsidiary company forcibly evicted her family and took her to court for illegally squatting on her own land. Ms Acuña was found guilty, received a 'suspended' prison sentence and was fined US$2,000. The Peruvian Supreme Court overturned her sentence and restored her property rights. This lesson in humility cost the company at least US$1 billion and disrupted an investment valued at US$12 billion.[135] It also showed why a properly executed consultation process (FPIC) is in the best interest of a mining corporation, because it will protect the company from the incompetence and malfeasance of its own employees, or in this case, business partner.

Eneva SA‡

The fastest growing diversified energy company in Brazil, Eneva SA, is seeking to access ESG financial markets by offering solutions to support the energy transition. It has a growing portfolio of solar projects, but most of its revenues are derived from assets that rely on coal, gas and hydropower. In the Amazon, it generates revenues via a 'reservoir to wire' supply chain that converts natural gas from proprietary wells into electricity generated at its own utility plants; it commercialises the electricity directly to retail and industrial consumers through the public power grid. This strategy is complemented by liquified natural-gas (LNG) technology to connect isolated gas fields with urban and industrial markets not yet integrated into pipeline networks.

* Ms Acuña was awarded the Goldman Environmental Prize in 2016. Source: https://www.goldmanprize.org/recipient/maxima-acuna/

† Buenaventura: S&P ESG: 39/100; Refinitiv: 41/100; Sustainalytics: 47.1 [very high risk]. Nemont bought out Buenaventura's stack in the joint venture in 2021.

‡ Eneva SA: S&P ESGL 15/100; Refinitiv: 63/100; Sustainalytics: 37/6 [high risk].

Top: Liquified Natural Gas (LNG) technology has come to the Amazon. Eneva, which operates gas fields at Azulão (Amazonas) and Paranaiba (Maranão), recently acquired the undeveloped Jurua gas field near Urucú. Bottom: Petrobras has commercialised its Liquid Petroleum Gas (LPG) from Urucú using fluvial transport systems since initiating operations at the Couari Terminal in in 1990.

In the last five years, Eneva has acquired six energy assets in the Brazilian Amazon, including the Paranaíba energy complex in Maranhão (Santo Antônio dos Lopes), the Azulão gas field in Eastern Amazonas (Silves) and the Juruá development concessions in the Solimões basin in central Amazonas (Tefé). In February 2022, it inaugurated the Jaguatirica-II power plant in Roraima (Boa Vista), which is supplied with LNG from the Azulão gas field.

Eneva's investment in LNG transport systems is a first for Brazil, which imports LNG to meet energy demand when the county's hydropower resources are stressed during periodic droughts. Viewed from this perspective, the natural gas assets of the central Amazon are an increasingly valuable asset, which explains the company's acquisition of the Juruá concession in 2020. The Juruá concession has an estimated 700 billion cubic feet (bcf) of natural gas that was discovered by Petrobras in the 1990s.

Mineral Hotspots in the Pan Amazon

The mineral resources of the Pan Amazon are not randomly distributed across the region but are located on landscapes with specific geological histories. There are three conspicuous macro regions:

A. The Amazon Craton is the term used to describe the complex of ancient rocks that form the heart of the continent, which was created via the serial accretion of continental plates between one to three billion years ago. Each such orogenic event was accompanied by magmatic intrusions that are imbued with the mineral resources.

B. The Andean Cordillera was formed after the Amazon Craton collided with the Nazca plate starting about 500 million years ago; this massive orogenic process occurred in phases with subregional variations characterised by volcanisms and magmatic intrusions that are impregnated with mineral deposits of global importance.

C. The Sedimentary Plain of the Western Amazon can be subdivided into basins that are the repository of significant hydrocarbon reserves, which were formed in what was once a shallow sea located between the Amazon Craton and the Andean Cordillera. Older sedimentary rocks that overlie parts of the Craton hold globally important reserves of bauxite and potash, while the upper horizons of multiple landscapes are rich in alluvial gold.

There are two superficial manifestations of the Amazon Craton: the Brazilian Shield and Guiana Shield, which were separated about 500 million years ago (Ma) by a deformation zone in the Earth's crust. The deformation zone is known as the Huancabamba Deflection / Amazon Mega-shear and extends

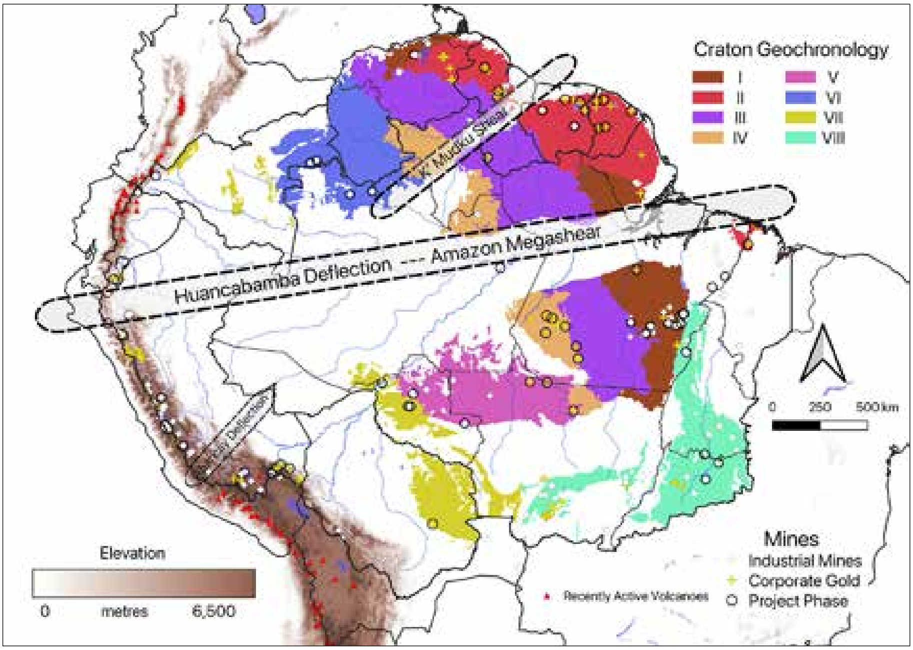


Figure 5.16: The distribution of corporate mines among the Tectonic Provinces of the superficial exposure of the Amazon Craton: (I) Carajás–Imataca, (II) Transamazon–Guiana Coast, (III) Central Amazon, (IV) Tapajós–Parima, (V) Rondônia–Juruena, (VI) Rio Negro, and (VII) Sunsas / Macarena, as well as Proterozoic formations of the Atlantic Shield (VIII). The stippled rectangles show the major deflection and shear zones that have influenced the tectonic history of the Amazon Craton and the Andean Cordillera.

Data source: Santos et al. (2001) and Porter Geo (2022).

from the floor of the Pacific through the Andes, across the Amazon Craton and into the Atlantic Ocean. A fundamental structural feature of the South American continent, it is responsible for creating a biologically important low spot in the Andean Cordillera (Huancabamba Gap) and the creation of Amazon Rift Valley. Sediments eroding off the two shield formations were deposited into the Proto-Amazon River and are the source of the bauxite and potash resources of the Central Amazon.

Geophysicists are still debating the details of the geological history of the Amazon Craton, but they all agree that it was created and has been modified repeatedly by tectonic forces over billions of years. A recent interpretation recognised six provinces linked to chronological age, tectonic origin and the types of rock formations found within them (Figure 5.16 and Table 5.8).[136]

Table 5.8: A recent hypothesis that describes the geological history of the Amazon Craton.

#	Province	Geological History	Active Mines	Age (Ga)	Era	Eon
I	*Carajás*	The oldest rocks on the continent with porphyries and magma intrusions linked to ancient tectonic rearrangements	Fe, Mn, Cu, Ni, Au, Ag	3.1 – 2.5		Archean
II	*Transamazon (Guianas)*	Formed when a smaller continental plate was accreted to the Carajás block along the northeast coast and creating the greenstone belt of the Guiana Coast	Au, Diamonds	2.3 – 2.0		
III	*Central Amazon*	Orogenic belt composed of granitic rocks with multiple magmatic intrusions; overlaid by table mountains (*tepuis*) with sedimentary rocks (~400 million years)	Au, Cu, diamonds	2.1 – 1.9	Paleo-	Proterozoic
IV	*Tapajos – Parima*	Orogenic belt caused by the collision between the Craton with an oceanic plate; produced a magmatic arc of dikes and porphyries.	Au, Cu	1.9 – 1.7		
V	*Rondônia – Juruena*	The collision of the Craton with a smaller continental plate,* causing the accretion of 'juvenile' crust to the Craton	Au, Sn, Mn, diamonds	1.8 – 1.5	Meso-	
VI	*Rio Negro*	An 'over-thrust' belt created when the crust from a subducting plate was 'recycled' and relocated along the margin of the Craton; metamorphic and igneous rocks are predominant.	Ni, Au	1.8 – 1.5		
VII	*Sunsas*	An 'over-thrust' belt that overlies the Rondônia – Juruena portion of the Craton with magma plutons and dikes	Au, Cu, diamonds	1.3 – 1.0		
VIII	*Tocantins Province of the Atlantic Shield*	Orogenic fold belt accreted to the São Francisco Craton between 0.6 and 1.0 Ga (Neo-Proterozoic), with Archean rocks and ancient sedimentary rocks that extend into Mato Gross.	Au, Cu, Mo, Nb, Ni	0.6 – 1.0	Neo	
IX	*Western Amazon Plain*	Multiple layers of sedimentary deposits overlaying the Amazon Craton, extending west to the Andean subduction zone.	Hydrocarbons	< 0.5	Paleozoic	Phanerozoic
X	*Eastern Amazon Valley*	Ancient plains with highly weathered soils uplifted or isolated by subsequent erosional events located on both sides of the Amazon floodplain	Bauxite, Kalium, Potash Hydrocarbons	< 0.25	Mesozoic	

Source: Modified from Santos et al. 2000.

* Proto-Laurasia, a super continent which included the North American Craton that collided with the Amazon Craton to form to Pannotia, which was the precursor to Gondwana and Laurasia.

The Andean orogeny started in the Jurassic soon after the breakup of Gondwona (~140 Ma)* with key structural stages occurring in the Cretaceous (70–100 Ma) and the Miocene (5–23 Ma) when most of the vertical uplift ensued. The Andes are organised into parallel mountain ranges, referred to as *cordilleras;* the western cordilleras were formed by volcanic and magmatic phenomena linked to the subduction zone of the colliding continental plates, while the eastern cordilleras are composed of uplifted blocks of sedimentary and metamorphic rocks that originated on the western margin of the Amazon Craton.† Magma intrusions invaded the eastern slope of the Cordillera Occidental and the western slope of the Cordillera Oriental to create the polymetallic porphyries, which are the foundation of the Peruvian mining industry.[137]

The distribution of economically important industrial metals, as well as gold, is a function of this geological history and the future of the mining industry is well-known among professional geologists and the investors that finance their industry (Annexes 5.1, 5.2, 5.3 and 5.4)

The rapid uplift of the Andes during the Miocene contributed to a continental-scale change in climate, which created orographic rainfall that dramatically increased erosion off the Andes and filled the hydrocarbon-rich sedimentary basins located in the subsidence zones immediately adjacent to the western Cordillera. A shallow sea between the Andes and the Amazon Craton eventually filled with sediment and forced a reversal in the direction of the Proto-Amazon River,‡ which began to flow from west to east only about ten million years ago.[138] In the Pleistocene (< 2 Ma) the cyclical advance and retreat of glaciers pulverised the highly mineralised peaks of the western Cordillera adjacent to the Altiplano. Glaciation released thousands of tonnes of gold into the fast-flowing sediment-laden rivers of the Andean foothills and created the alluvial gold fields on the piedmont and adjacent alluvial plain.

The Sedimentary Basins of the Pan Amazon were created by the ongoing phenomena of orogeny and erosion (Figure 5.17). Several are located within the Andean foredeep where the western reaches of the Amazon Craton are being subducted underneath the Andean Cordillera. Individual basins are separated by 'arches,' underground ridges that roughly corre-

* Gondwana was a large landmass derived from the original supercontinent Pangea; it split during the Jurassic to form South America, Africa, Antarctica, Australia and the Indian subcontinent. See http://homepages.see.leeds.ac.uk/~eargah/Gond.html

† There is a second shear zone similar to the Huancabamba Deflection in the Central Andes; referred to as the Abancay deflection, it is linked to tectonic rotations that gave rise to the Altiplano and the orientation of the Rio Madeira, which flows along the western edge of the Brazilian Shield.

‡ The name Proto-Amazon is used to refer to the river that flowed from east to west.

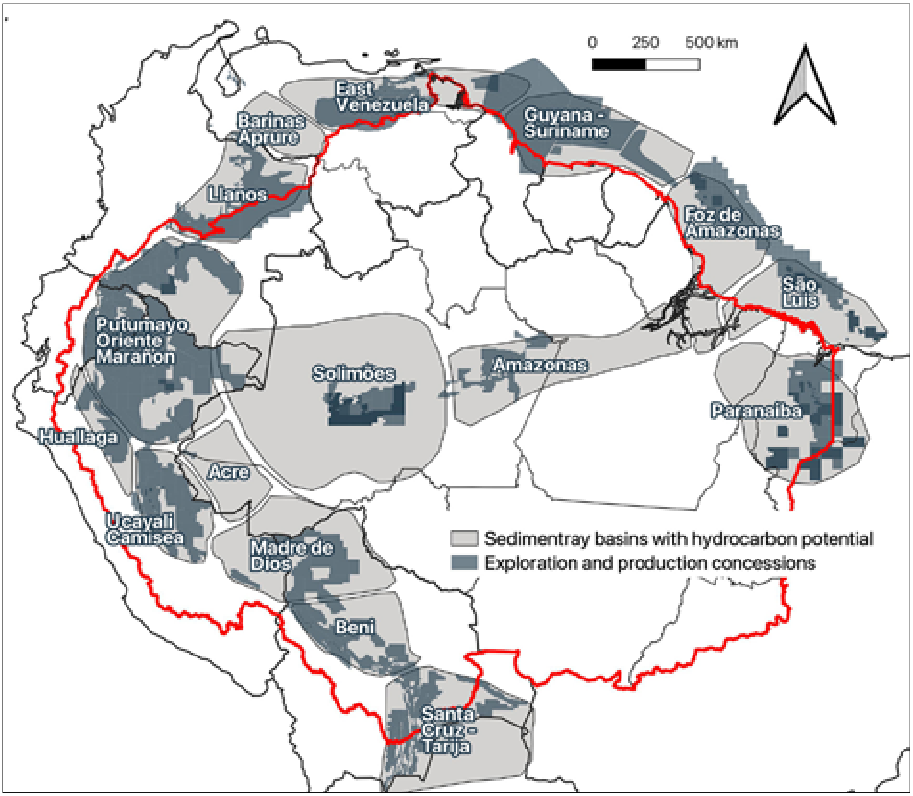


Figure 5.17: The sedimentary basins in the Pan Amazon.
Data sources: Schenk et al. (1999) and Codato et al. (2019).

spond to modern hydrological basins. To the North and East, sedimentary basins are arranged along the outer margins of the Guiana Shield where they have accumulated sediments and fossil fuels over hundreds of millions of years. There are two sedimentary basins in the middle of the continent, both formed when the Proto Amazon flowed from East to West within the Amazon Rift Valley.[139] All these basins, to different degrees of importance, are the source of the region's oil and gas reserves, which are the fossilised remains of photosynthetic microorganisms that once dominated the shallow water ecosystems above the continental shelves of the Amazon Craton in the Mesozoic* (100–250 Ma) and Paleozoic† (250–450 Ma).

* The Mesozoic Era is divided into three periods: Cretaceous (50–145 Ma), Jurassic (145–200 Ma), Triassic (200–250 Ma) and Jurassic (150–250 Ma).

† The Paleozoic Era is divided into six periods: Permian (250–300 Ma), Carboniferous (300–360 Ma), Devonian (360–420 Ma), Silurian (420–440 Ma), Ordovician

The Geography of Industrial Metals

There are a multitude of mineral ores used to produce industrial metals, which can be organised into four major groups with similar geological histories

Iron (Fe) and manganese (Mn) are essential components to steel and, as such, are in constant demand by manufacturers and the construction industries. Ferro-manganese ores are found within the ancient sedimentary rocks that were created when the first photosynthetic organisms were transforming the Earth's atmosphere during the Archean Eon as oxygen reacted with dissolved iron in primaeval oceans to create ferrous oxides, hematite and magnetite (FeO, Fe_2O_3, Fe_3O_4). These ancient sedimentary rocks were uplifted during the ancient orogenies that moulded the Amazon Craton and occur in three separate landscapes of the Eastern Amazon: the Carajás province in Eastern Pará, a similar area across the Amazon River in Amapá and the Imataca formation just south of the Orinoco River in Venezuela.

Base metals, particularly copper (Cu), zinc (Zn), molybdenum (Mo), nickel (Ni) and lead (Pb), are used by a wide range of industries, but are particularly important for electrical devices and industrial alloys. These industrial metals tend to occur in polymetallic ores associated with magma that originated deep within the Earth's crust; ore bodies are found along the margins of magmatic intrusion or within fissures in the surrounding matrix rock. On the Amazon Craton, intrusions are associated with ancient orographic events and their idiosyncratic distribution reflects the complex geological evolution of the Precambrian Era. In the Andes, intrusions exist as 'porphyries' that are linked to relatively recent volcanic events in the western Cordillera, or as plutons embedded in sedimentary rocks of the eastern Cordillera that were uplifted during the Mesozoic.*

Porphyries are also a source of precious metals, such as gold (Au) and silver (Ag), but also platinum (Pt) and palladium (Pd), which are important inputs to electronic devices; less common metals include niobium (Nb), titanium (Ti), tungsten (W) and tantalum (Ta). Typically, polymetallic miners seek to harvest multiple elements extracted at specialised smelters from concentrates that are the principal export commodity of polymetallic mines.

High-quality bauxite ores, such as those found in the Amazon, have elevated concentrations of gibbsite [$Al_2(OH)_3$], which make them particularly economical for the production of aluminium. Bauxite ores are found on upland plateaus, which were created by sedimentation along the mar-

(445–485 Ma) and Cambrian (445–485 Ma).

* A copper porphyry occurs when water interacts with the cooling magma causing the mineralisation of metal-bearing ore bodies along the margins of the porphyry; if the surrounding matrix is a carbonate rock, then it is referred to as a porphyry skarn. Source: http://www.portergeo.com.au/database/mineinfo.asp?mineid=mn1556

gins of the Brazilian and Guiana Shields during the Mesozoic Era. These landforms were uplifted during the Pleistocene when the Amazon River carved a deep passage through the Amazon Rift Valley; subsequently, they were subject to the extreme weathering typical of high-rainfall regions with tropical climates that leached most of the silica out of what are essentially paleo-soils.

The Carajás Mining District

The Carajás mountains and surrounding landscapes contain some of the most remarkable mineral deposits in the world (Figure 5.18). The oldest and largest mine was opened in the Serra Norte de Carajás (Parauapebas municipality) in 1984 by the Companhia Vale do Rio Doce to exploit an ore-body with the highest concentration of elemental iron on Earth (67 per cent).* In 2022, that facility consisted of eight separate pits covering 4,500 hectares and producing more than 150 million tonnes of iron ore each year. Production doubled in 2016 when Vale started production at Serra Sul de Carajás (Canaã de Carajás), about sixty kilometres south of the original mine. Vale operates a third iron-ore mine at Serra Leste (Curionópolis municipality) located just a few kilometres from Serra Pelada, the notorious wildcat gold mine of the 1980s. In addition, there are two manganese mines: Azul (Parauapebas municipality), which is operated by Vale, and Buritirama (Marabá municipality), which is owned by Buriti Group, Brazil's largest manganese producer.

Under current rates of exploitation, the original mines at Vale's facility in the Serra Norte will produce for another ten years. However, there are several additional ore-bearing structures nearby that should extend the life of the industrial mill for decades. Serra Sul has even larger reserves and can maintain current levels of production for ~110 years (Annex 5.1 and Annex 5.5). The southern facility, also known as S11D, is a classic example of a brownfield investment. Vale was able to mobilise large capital resources due to the limited risk associated with a fully explored mineral deposit, unwavering government support and minimal local opposition.

That investment, reported at US$14.7 billion, including US$6.4 for the new open-pit mine and a semi-automated, conveyer-belt processing mill with a state-of-the-art 'dry' tailings storage facility. An additional US$7.6 billion was invested in logistic infrastructure, which included a two-track expansion of the *Estrada de Ferra do Carajás*, its extension to the Serra Sul and an increase in the capacity at the export terminal at São Luís

* The original discovery was made by US Steel in the 1960s, which entered into a joint venture company with the state-owned Companhia Vale do Rio Doce (CVRD). US Steel withdrew from the joint venture in 1977, CVRD was privatised in the 1990s and is now known as Vale SA. As of 2022, Vale was the third largest mining company in the world with a market capitalisation of US$92 billion. Source: S&P Global.

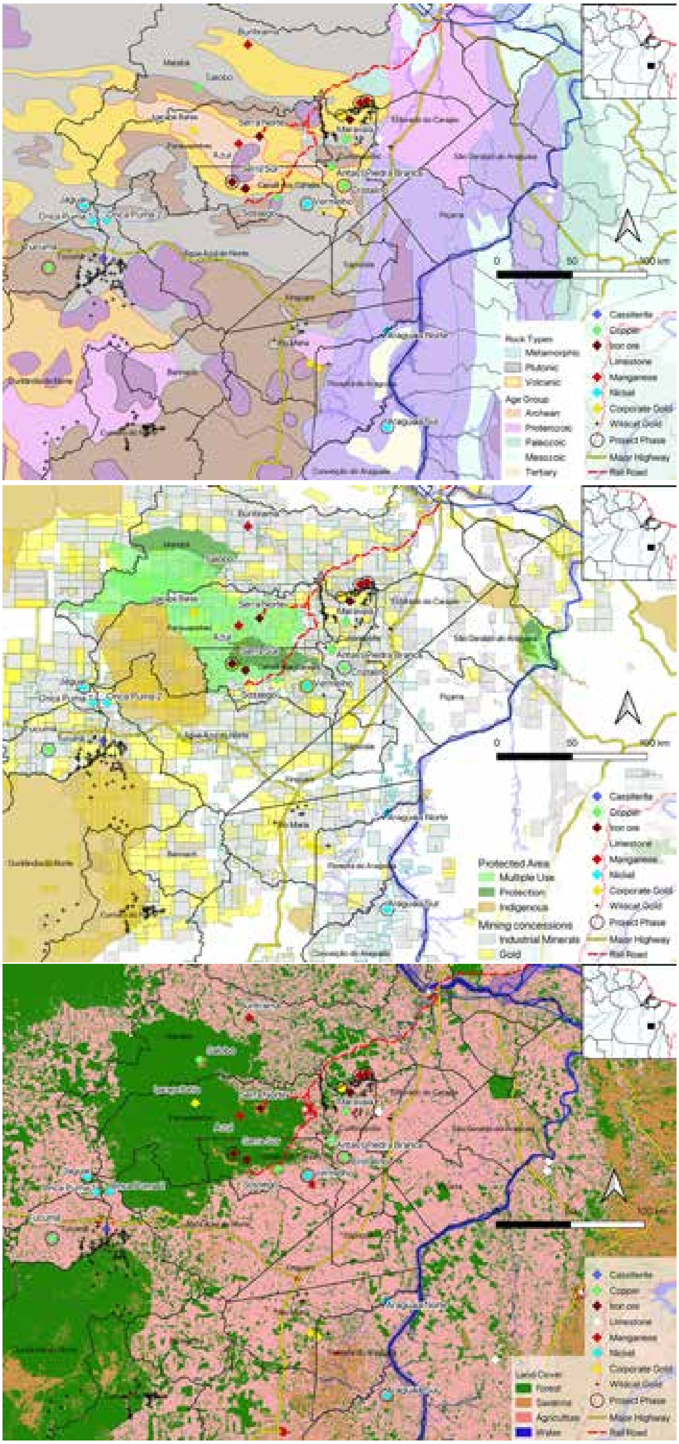


Figure 5.18: The Carajás Mining District. Top: Existing and project phase mines in the context of geological history. Middle: Existing and project phase mines in the context of mining concessions and protected areas. Bottom: Existing and project phase mines in the context of land cover. Data sources: RAISG (2022), MapBiomas (2022) and ANM (2022).

do Maranhão (see Chapter 2).[140] Annual exports of iron ore from the three facilities approached 200 million tonnes in 2020, which were valued at ~US$28 billion, an increase of fifty per cent in volume and 150 per cent in value when compared to 2015, the year before the inauguration of S11D.[141]

Although most of the iron ore is exported or transhipped to steel mills in Southern Brazil, a significant portion is processed a few kilometres from the mine at pig-iron plants and a steel mill near Açailândia in the state of Maranhão.* These plants are unique because they use charcoal, both as a source of energy and as the reducing agent in the steel-making process (instead of coke). In the 1980s and 1990s, pig-iron producers sourced their charcoal from landholders who were clearing natural forest to establish cattle ranches.[142] Since about 2000, however, they have used charcoal produced by eucalyptus plantations that were grown on land deforested in the previous decades. They now proudly proclaim their ESG credentials and aggressively market their production as green steel.†

The Carajás mining district is also remarkable for ore bodies associated with magmatic intrusions referred to by geologists as 'iron-ore, copper and gold' (IOCG) deposits. Vale has developed several of these polymetallic mines on the landscapes surrounding the Serra de Carajás. The oldest, Igarapé–Bahia (Parauapebas), was opened as a gold mine in 1990 and only operated for twelve years. However, a copper ore-body was discovered underneath the exhausted gold resource, which eventually will be exploited when market conditions justify the investment.[143]

The first large-scale copper mine in the Brazilian Amazon was opened by Vale in 2007 at Salobo (Marabá). It started production in 2012, doubled its capacity in 2014 and expanded again in 2020 (Figure 5.19). In 2019, it generated about US$500 million in gross revenues on an investment estimated at US$7 billion. Salobo is expected to produce copper and gold for another thirty years. Vale expanded and diversified its mining operations in the Carajas district with an even larger copper mine at Sossego in 2012 (Canaã de Carajás), copper and nickel mines at Onça Puna in 2011 (São Felix do Xingu and Ourilândia do Norte).

Other companies are opening new polymetallic mines in the Carajás district. These include Antas, a copper mine owned by the Australian

* The town of Açailândia is a major producer of pig iron, with an annual production capacity of 1.7 million tonnes; the steel mill has a capacity of 600,000 tonnes per year. The mills claim to provide about 3,500 direct jobs and more than 10,000 indirect jobs.

† Aço Verde do Brasil, claims to be the world's first carbon neutral steel plant, a claim certified by SGS according to the GHG Protocol. It was awarded the ESG Breakthrough Award in 2021 by the S&P Global Commodity Insights Global Metals Awards: https://www.spglobal.com/commodityinsights/global-metals-awards/winners

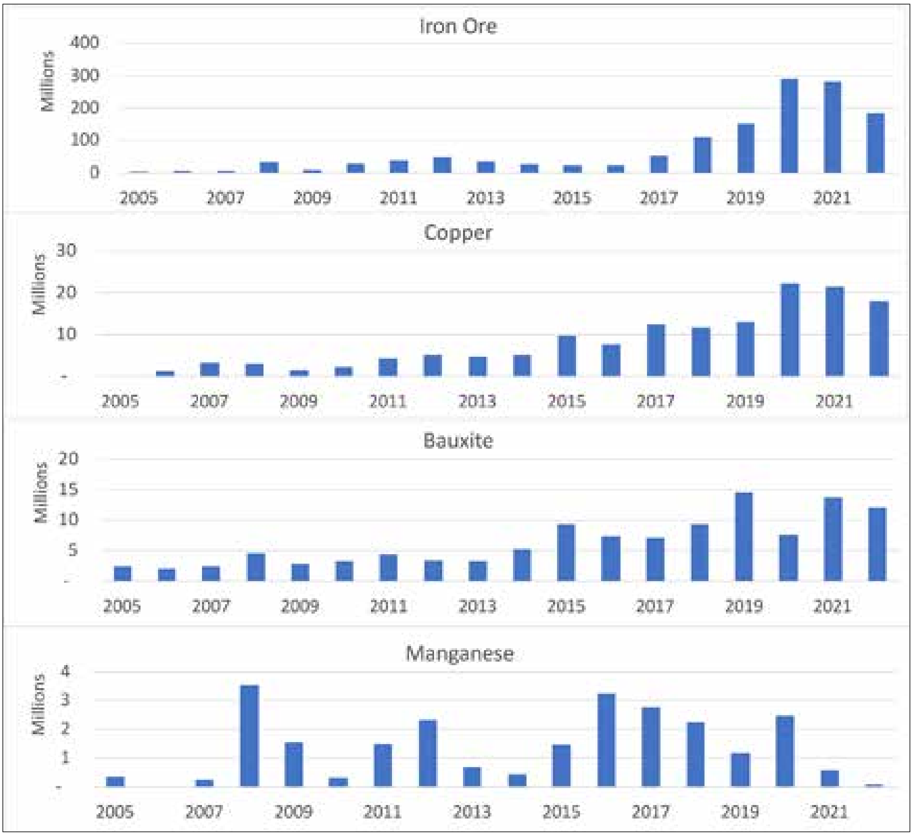


Figure 5.19: Royalty income (Compensação Financeira pela Exploração Mineral in $R) reported for four industrial minerals in Pará. The increase in CFEM revenues from iron ore followed the opening of the S11D pit at Carajás Serra Sur (Vale). The first copper mine was opened in 2006 at Sossego (Vale), which was followed in 2020 at Salobo (Vale). CFEM Revenues from bauxite production reflects production from Trombetas (MNR), Juruti (Alcoa) and Paragominas (Norsk Hydro). CFEM revenue from manganese reflects both price volatility and production at Buritirama (Buritipar Group), which paused mining operations in 2020.

Data source: ANM (2022).

company Oz Minerals, and Vermelho, a nickel-cobalt project operated by the UK-based holding company Horizonte Minerals, both of which were opened in 2022 (Curionópolis). A separate subsidiary of Horizonte Minerals, Araguaia Nickel, will open two pits in 2024 in the municipalities of Rio Maria and Conceição de Araguaia. The expansion and diversification of the mining industry in the greater Carajás district is being driven by the market for strategic metals necessary for the transition to renewable energy.

A review of mining concessions in different stages of exploration and development shows that investors have identified a base metal as the mineral of primary interest in more than 530 concessions in the five municipalities surrounding the Carajás mineral district.

Google Earth

Vale operates two massive copper mines in the Carajás mining district. Both concentrate the ore using copper sulfide flotation technology. Consequently, both have highly toxic tailing ponds. Salobo, which was opened in 2012, has a downstream containment dam, while Sossego, which was opened in 2007, has a dam with a centre-line design.
Data source: Vale (2020).

Several of the mines operated by Vale are located within Floresta Nacional (FLONA) de Carajás, a multiple use protected area that is strictly off limits to settlers. Its formal designation as a protected area was part of a policy compromise that allows mining in FLONAs created prior to 2000, while prohibiting it in FLONAs established thereafter. In 2017, part of the FLONA de Carajás was declared a national park (PARNA Campos Ferruginosas), a decision intended to protect the endemic flora unique to these iron-rich soils. Nonetheless, the map of mineral concessions continues to show the existence of numerous claims within the national park, all of which predate the creation of the park.

Amapá and the RENCA

Industrial mining began in the Amazon in 1953 when a joint venture between an influential Brazilian entrepreneur* and Bethlehem Steel opened the Serra do Navio manganese mine in what was then the federal territory of Amapá. It is an example of 'enclave' mining where an isolated complex of facilities operates as a quasi-autonomous entity that typically include the mine, a company town, railroad, industrial plant and port facilities.† Over its forty-year life span, Serra do Navio produced forty million tonnes of high-quality manganese, exporting about fifty per cent to Europe and North America with the rest supplying a key input to a nascent steel industry in Southern Brazil. The main mineral resource was eventually exhausted, but the industrial infrastructure continues to exploit a low-grade iron ore deposit (< 45% Fe) that would not otherwise be economically viable.

Amapá is not without additional mineral resources. Western Amapá and adjacent areas of Northern Pará are located within geological formations not unlike the Carajás mineral district. Most of this area was incorporated into the *Reserva Nacional de Cobre e Associados* (RENCA) by the military government in 1984 (Annex 5.2). A proposal to open the RENCA for exploitation was considered in 2017 during the government of Michel Temer. The proposal was vociferously opposed by environmental and social advocates intent on protecting two regional conservation units, Floresta Estadual do Paru (Pará) and Reserva de Desenvolvimento Sustentável de Rio Iratapuru (Amapá), as well as two Indigenous territories, Waiãpi (Amapá)

* Augusto Trajano de Azevedo Antunes was the principal shareholder of the Indústria e Comércio de Minérios S.A. (ICOMI), which evolved into Companhia Auxiliar de Empresas de Mineração (CAEMI), Brazil's largest private mining company until the privatisation of Vale, which acquired CAEMI in 2006. Antunes was arguably Brazil's most influential corporate executive and, allegedly, played a key role in fostering the military coup of 1964. He died in 1996. Source: https://pioneiros.fea.usp.br/augusto-trajano-antunes/

† The original Carajás mine started as an enclave mine, but development of the adjacent landscapes due to highway development and agricultural policies ended its isolation.

and Rio Paru d'Este (Pará). The proposed change in status of the RENCA was blocked by a Brazilian court;[144] nonetheless, mining interests seek to reopen the RENCA as part of a policy to promote mining throughout the Amazon. It was a fundamental component of the development strategy of the Bolsonaro administration.

The Arco Minero of Venezuela

Further north, a cluster of world-class iron-ore deposits is located along the extreme northern edge of the Amazon Craton where it borders the Orinoco flood plain in the Venezuelan State of Bolivar. Geologists have christened this the Imataca formation, but it is understood to be a disjunct portion of the same ancient formation that occurs in Serra de Carajás with similarly high mineral grades of iron ore (60–65.5%).

The Imataca deposits were discovered prior to the Carajás formations, and the first mine (El Pao) was opened by Bethlehem Steel in 1951. The mine and associated industrial infrastructure were nationalised in 1978 by the government of Carlos Andrés Pérez when he launched an aggressive development programme fuelled by the exploitation of the nation's mineral resources. The El Pao mine was decommissioned in 1998, but not before the regional development corporation (*Corporación Venezolana de Guayana* – CVG) had initiated production at four additional sites (Los Barrancos, San Isidro, Las Pallas and Altamira). Production declined from about 20 million tonnes in 2007 to less than five million tonnes in 2015; the mines were shut down at the height of the economic crisis in 2019. The government periodically announces new investment plans and projects future annual production levels as high as 40 million tonnes.

The country's total iron-ore reserves are estimated at 2.2 billion tonnes, which would have an approximate value of US$330 billion at international prices in 2022. Investors from China are reported to be engaged in these efforts as part of a plan to retire the approximately US$30 billion in outstanding loans made to the government of Nicholas Maduro.[145] Landscapes adjacent to the Imataca have globally important reserves of gold and bauxite, and Venezuelans refer to the northern sectors of the states of Bolivar and Amazonas area as the *Arco Minero*.

The Copper Porphyries of the Peruvian Andes

The mines located within the High Andes are seldom mentioned when discussing the extractive industries in the Pan Amazon. Nonetheless, the ore-processing facilities of these mines extract water from, and discharge wastewater into, tributaries of the Amazon River (Annex 5.4 and Annex 5.6). Altogether, they represent about fifty per cent of Peru's formal mining industry and are a core component of the national economy.* Peru has a long history of industrial mining, and there are hundreds of active and derelict underground mines, particularly near the city of Cerro de Pasco, the centre of Peru's mining industry in the twentieth century.

The recent history of Peru's mining industry is characterised by the transition from underground mines, which exploit localised ore bodies with higher mineral grades and lower waste-rock production, to open-pit mining operations, which exploit voluminous ore bodies with lower mineral grades that create massive amounts of waste rock and tailings. Open-pit mines require very large amounts of financial capital, but they are less risky than an underground mine when evaluated on operational criteria. However, their environmental and social impacts are not fully appreciated by investors, particularly the long-term risk inherent in many tailing-storage facilities (see Text Box 5.2).

Prior to 2007, there were seven open-pit mines operating in the Amazonian portion of the Peruvian Andes; since 2010, however, six more have opened and another fourteen are in different stages of development. Four of the original seven were operated by companies controlled by Peruvian companies, two by large multinationals and one by a Canadian gold-mining specialist (Annex 5.4 and Annex 5.6). Of the fourteen new projects, all but four are controlled by foreign capital, including three from China.

The infusion of investment capital, typically between US$ 1.5 to 3.5 billion per mine, has transformed the Peruvian economy over the last two decades. The fifteen operating mines generated about $US5 billion in 2015, of which about 25 per cent was captured by taxes and royalties. Mines located within Amazonian watersheds represent about forty per cent of Peru's mining industry; they support ~30,000 direct jobs and perhaps double that number of indirect jobs. Each mine has a lifespan of between fifteen and thirty years, but most are adjacent to ore bodies with similar or slightly lower mineral content. The potential for continued growth in the mining sector remains strong.

The mining sector is credited for the relative health of the Peruvian economy, which had the highest mean growth rate in GDP in Latin America between 2005 and 2020. Peru is not a wealthy country and the unprecedented economic growth allowed it to reduce its poverty rate from 58 per cent to twenty per cent between 2005 and 2019. Unfortunately, extreme poverty increased again to thirty per cent in 2020 due to the COVID-19 Pandemic,[146] and the economic prospects for the Peruvian mining industry have become

* The rest of the mining industry is located along the Pacific West of the Continental divide or within the Altiplano / Lake Titicaca watershed.

less certain due to an uptick in social conflict. Successive governments have failed to meet the expectations of its populace.

Google Earth

The evolution of the Antapaccay copper mine between 2005 and 2020. During its 40 year lifetime; the complex expanded from one to five pits, with the oldest now apparently functioning as a tailings storage facility. One of the original tailings ponds (see inset) has been dewatered, decommissioned and de-characterised. The mine was opened in 1985 by the Magma Copper Company, which was acquired by BHP Billiton in 1996, who sold it to the Xstrata Corporation in 2006, which in turn was acquired by Glencore in 2013.

The Cordillera del Condor

The mineral resources that characterise the High Andes of Peru are conspicuously absent north of the Huancabamba Gap, the altitudinal low point in the Andes linked to the deflection zone that created the Amazon Rift Valley. There is, however, an unusual mountain range located east of the Cordillera Oriental on the border between Peru and Ecuador. The Cordillera del Condor is a fold and thrust belt created in one of the earlier phases of the Andean orogeny when magmatic plutons were intruded into older sedimentary strata that created copper porphyries with significant mineral resources (Figure 5.20).

There are several mines under development, but the most advanced is the *Mirador Project*, which will exploit an estimated 3.1 million tonnes of copper, 3.2 million ounces of gold and 25 million ounces of silver. This is Ecuador's first industrial-scale open-pit mine and will include a processing facility that will convert the ore into a concentrate. The mine, which has a projected lifespan of thirty years, is being developed with Chinese capital and will generate billions of dollars in royalty and tax revenues, while contributing to the balance of payments equation that motivates finance ministries. There are four other copper mines and two industrial-scale gold mines under development (Annex 5.7). On the Peruvian side of the border, wild-cat gold miners are active, but there are no economically significant reserves of copper or other base metals.

The Copper Porphyries in the Northern Andes

Ecuador and Southern Colombia are renowned for their volcanoes that are commonly associated with copper and gold porphyries. Recent exploration has revealed the existence of copper-rich formations near the border between Ecuador and Colombia. On the Ecuadorian side, the *Empresa Nacional Minera del Ecuador* (ENAMI EP) is in the early stages of developing La Bonita, a copper deposit first discovered in the 1990s where exploratory drilling extracted samples with copper concentrations between 0.35 per cent and 0.86 per cent, with similarly attractive potential for gold, molybdenum and lead. La Bonita encompasses three large concessions covering 13,500 hectares that border (and slightly overlap) lands claimed by the Cofan Indigenous people.[147]

Approximately 300 kilometres to the north, a similar copper-gold porphyry, known as the Mocoa Copper-Molybdenum Project, is being developed by a Canadian junior mining company. The initial discovery was made in 1978 by the Colombian Geological Service (*Ingeominas)* but

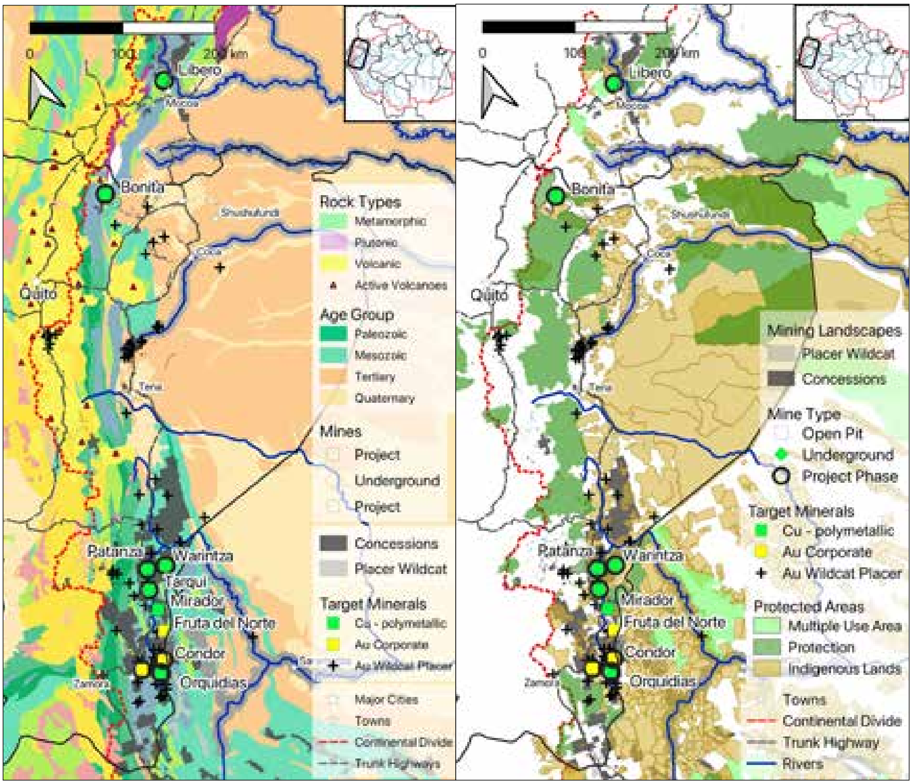


Figure 5.20: The mining landscapes of the Cordillera del Condor in Ecuador and the upper reaches of the Putumayo watershed on the border with Colombia. Left: Industrial and wildcat mines in the context of geological history. Right: Industrial and wildcat mines in the context of protected areas and indigenous lands.

Data sources: Gomez et al. (2019), RAISG (2022) and ENMI EP (2022).

wasn't seriously explored until 2004 when a Canadian junior acquired the concession, who eventually sold it to the current holder (Libero Copper Corporation). In a recent report for investors, the developer estimates the ore body has approximately 2.1 million tonnes of copper and 231,818 tonnes of molybdenum, which would be valued at approximately US $20 billion at current market valuations for copper. The mine, if it is developed, would be located only fifteen kilometres north of the city of Mocoa, the capital of Putumayo Department; the ore-body overlaps with the Reserva Forestal Alto Rio Mocoa and is adjacent to the Resguardo Indígena Yungillo.[148]

Amazonian Bauxite

Brazil produced more than 35 million tonnes of bauxite in 2020. This is about ten per cent of global demand and represents a level of production that could be maintained for ~100 years based on estimated reserves of 2,700 million tonnes. There are three operating bauxite mines located in three municipalities in the state of Pará, which generated approximately US$935 million in gross revenues in 2020.[*]

The largest mine was opened in 1979 by the *Mineração Rio Norte* (MNR), a joint venture involving five multinational and Brazilian corporations.[†] It is located on the north bank of the Amazon River in the municipality of Oriximiná. Just across the river on the south bank is a mine operated by Alcoa in the municipality of Juruti that initiated operations in 2010. Both mines are enclave mines surrounded by natural forest with dedicated industrial mills, a rail line and port facilities. The third mine was established in 2007 by Norsk Hydro in Eastern Pará (Paragominas) on a landscape that has been heavily impacted by deforestation. Two additional bauxite mines are under development by the *Companhia Brasileira de Alumínio*, both of which are located a few kilometres from the existing mine in Paragominas.[‡]

The bauxite deposits in Western Pará are located on old sedimentary plains (peneplains) that were created between fifty and sixty million years ago in what is essentially the former floodplain of the Proto-Amazon River when it flowed from the east to the west.[149] The mines in Eastern Pará have a different geological history but were formed by similar weathering processes on what was once an expansive coastal plain situated east of the Amazon Craton.[§] Interest in future bauxite development is revealed by the number of concessions solicited by investors and mining companies (<1000), which

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* The actual revenues are difficult to know because a significant proportion is transformed to alumina and aluminium within corporate supply chains; this estimate is based on levels of production reported by the Ministério de Minas e Energia and mean import prices to the United States as reported by the USGS.

† Vale (Brazil), Norsk Hydro (Norway), Votorantim/CBA (Brazil), Rio Tinto (UK) and South32 (Australia).

‡ CBA is Brazil's largest manufacturer of aluminium products; it holds at least ten concessions that have been approved for development at two sites in eastern Pará (Rondon do Para and Ulianópolis) where recent satellite images show extensive exploratory drilling.

§ Kalium, a type of clay used to make high-quality ceramics, is often found on land forms similar to (and nearby) bauxite ore bodies.

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Programa de Aceleração do Crescimento (PAC), CC BY-SA 2.0 , Flickr.com

Norsk Hydro operates an integrated vertical aluminium supply chain in Pará, which extends from its bauxite strip mines (top) and concentration plant (middle) in Paragominas, to its Alunorte refinery, Albras aluminium smelter and port facilities in Barcarena (bottom). It relies on the Tucuruí hydroelectric facility and the Amazon waterway to receive ore and ship aluminium ingots to global markets.

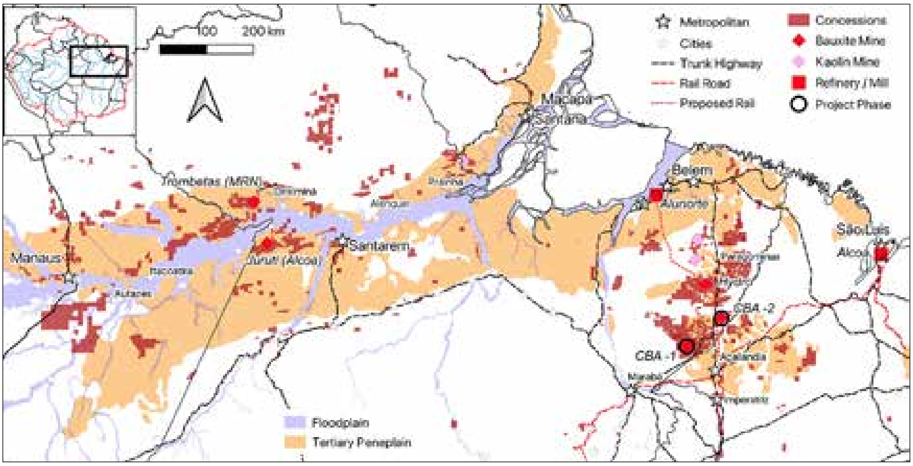

Figure 5.21: The Bauxite reserves of the Brazilian Amazon are concentrated on the upland terraces of the lower Amazon rift valley and on adjacent Tertiary peneplains. Bauxite is exported via the Amazon waterway or transformed into aluminium at refineries and smelters in Barcarena and São Luis do Maranhão. There are three working mines and two under development by the Companhia Brasileira de Alumínio (CBA), as well as refineries and smelters in Barcarena and São Luís de Maranhão.

Data source: RAISG (2022).

reflects the potential in the landscapes around existing mines but also in the municipalities of Nhamundá, Urucurá, Borba, Autazes and Careiro in Amazonas state (Figure 5.21).

Throughout most of the twentieth century, Guyana and Suriname were global leaders in production and export of bauxite; however, the easily exploitable mineral deposits in the two countries were exhausted in the first decade of the twenty-first century (Annex 5.8). Guyana exports only a small fraction of its former production,* while Suriname closed its last mine and processing facility in 2016. Both countries still have considerable bauxite reserves, but their exploitation is not, apparently, cost-effective in today's global mining industry. Venezuela has very large, high-quality reserves and the installed capacity to exploit them; however, its mineral sector has collapsed due to economic mismanagement and structural constraints linked to its socialist economic model.

The Cassiterite Mines of the Brazilian Amazon

Cassiterite is a conglomerate ore with high concentrations of tin-oxide [SnO_2]; it exists both as a 'primary' deposit in hard rock formations asso-

* The Bauxite Company of Guyana is a subsidiary of Rusal, which is part of the conglomerate controlled by Oleg Deripaska, an oligarch with close ties to Vladimir Putin.

ciated with magmatic intrusions in metamorphic rocks and as 'secondary' deposits in depositional landscapes located adjacent to the primary ore body. Brazil has about fifteen per cent of the global reserves of cassiterite and has been a major producer of tin since the 1960s when it was part of an international tin cartel.[*] High prices (~$35,000 per ton) fuelled a mining boom that targeted the alluvial deposits which were particularly abundant in northwest Rondônia (municipalities of Porto Velho and Ariquemes), as well as selected landscapes in Pará (São Félix de Xingu) and Amazonas (Presidente Figueroa) (Annex 5.1 and Annex 5.2).

Market dynamics eventually prevailed and a precipitous drop in the price ($5,000 per ton) led to the collapse of the cartel in 1985 and, shortly thereafter, the end of the small-scale cassiterite mines in the Brazilian Amazon. The price of tin recovered in the commodity super cycle between 2007 and 2012 (US$15,000 and US$20,000), but its exploitation is now restricted to corporations with the capital resources needed to exploit hard rock deposits.[†] In 2022, two Canadian companies signed a joint venture to exploit the tailing dumps and abandoned placer mines in Arequimes and surrounding municipalities.[‡]

The largest and longest operating corporate mine is located near the northern border of Amazonas state in the municipality of Presidente Figueroa (Annex 5.2). Known as the Pitinga mine, it is infamous for its history of environmental damage and social conflict. The mine was opened in 1982 when the military government was pursuing a 'development at all costs' strategy that discounted the impact of environmental degradation and ignored the rights of Indigenous people (see Chapter 6). The mineral resource was located within the traditional lands of the Waimiri–Atroari, a tribe that had been brutally suppressed in the 1960s when they resisted the construction of the highway between Manaus and Boa Vista.[§] Their reserve, which had been created in 1971 as a form of compensation for the

[*] Belgian Congo (Democratic Republic of Congo), Ruanda-Urundi (Rwanda), Bolivia, Indonesia, Malaysia, Nigeria and Thailand. The demand for tin declined due to an increasing use of aluminium and plastics on the consumer goods packaging industry and over-supply from Malaysia. See Chandrasekhar 1989.

[†] Bom Futuro / Merdian Mining (Ariquemes), Estanho do Rondônia, São Lourenço (Porto Velho); Projected new development: Metalmig Mineração Indústria (Campo Novo de Rondônia),

[‡] Meridian Mining and Orosur propose to spend $US 3 million in evaluating the mineral potential of legacy mines owned by local mining associations and families. Source: https://www.orosur.ca/projects/brazil/

[§] At least 600 individuals were killed by direct action by the military and the total death toll is estimated at > 2,000 when including communities impacted by diseases that were deliberately introduced into the region; an estimated 80% of the population was eliminated when military engineers were building the BR-217. Source: Prazeres 2013.

brutality of the previous decade, was unilaterally reconfigured in 1981 to exclude the land for the proposed mine site.[150]

That mine is now operated by *Mineração Taborca*, a subsidiary of a Peruvian mining company, MINSUR, that acquired the 130,000-hectare concession and associated processing facilities in 2008.[*] Although the mine had already begun its transition into a modern open-pit operation, the new owner continued to use placer mining technology until 2012. Placer mining is particularly noxious because it selectively targets, and destroys, riparian habitats, and its use within the Pitinga concession has created a massive long-term environmental liability that threatens the health of the mine's Indigenous neighbours.

The Pitinga open-pit mine continues to be highly profitable and the hard-rock ore body is considered to be the world's largest tin reserve (500,000 tonnes of refined tin). In 2020, the mine produced about 7,400 tonnes of enriched cassiterite with estimated gross revenues of ~US$220 million.[151] More importantly, the processing mill has started recovering both niobium and tantalum, strategic minerals with reserves estimated at 775,000 and 106,000 tonnes of refined mineral, respectively.

Niobium, Tantalum and Rare Earth Elements

Niobium (Nb) is used in the steel industry to manufacture specialised (stainless) steels that are used in the construction, shipbuilding, automotive and oil and gas industries. Tantalum (Ta) is similarly resistant to corrosion, but is used in the manufacture of miniaturised electronic devices, including cell phones, medical equipment and aerospace applications. Both elements tend to be found together in a mineral ore known as coltan, which is, apparently, present on landscapes long renowned for their cassiterite deposits.[152]

Revenues from niobium and tantalum at the Pitinga tin mine now represent about fifty per cent of the gross mine revenues, contributing another US$200 million dollars to corporate revenues in 2020. The diversification of production and revenues may undergo yet another transition in the near future, because the mine would appear to be a globally important source of a strategically significant class of mineral known as rare earth elements (REE).

Rare earth elements[†] are the elements in the lanthanide series of the periodic table; with atomic numbers that range from 57 (lanthanum) through

[*] MINSUR also acquired the Mamoré metallurgical tin mill for $US400 million. Source: https://www.internationaltin.org/minsur-completes-taboca-acquisition/

[†] Rare earth elements (REE): lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu). Scandium (Sc) and yttrium (Y), which are not rare earth (they occupy the third column in the periodic table of elements

71 (lutetium), they are grouped together because they all have a valency of +3 and share certain chemical properties that influence their distribution in nature. In spite of their name, they are not particularly rare, although the mining and commercialisation of REE has been dominated by China for about two decades. Geopolitics and high-stakes competition spawned by the energy transition has motivated investors in Western economies to prioritise the development of alternative sources of these strategic minerals. After China, Brazil has the second largest known reserve of REE, estimated at approximately 22 million tonnes. Most of the known reserves are located at a single mine in Goiás: Catalão.[*] There are three areas in the Amazon that have potentially significant reserves of niobium, tantalum and REE.[153]

Mineração Taborca has yet to start separating and processing the potential REE minerals within the Pitinga concession; apparently, they are present not only in the primary ore body but also in the more than 6,000 hectares of tailings ponds that contain more than 100 million tonnes of waste rock. The ongoing discoveries at the Pitinga mine, particularly the association of REE with cassiterite, niobium and tantalum, have stimulated renewed interest in the abandoned mining landscapes in Rondônia and elsewhere.

In January 2022, Auxico Resources Canada Inc, which was established specifically to discover and develop REE deposits, signed an agreement with the *Cooperativa Estanífera de Mineradores da Amazônia Legal Ltda* (CEMAL) for the exploitation and commercialisation of REE from the legacy tailings in the municipalities of Ariquemes and Monte Negro in Rondônia. The holdings are estimated to contain thirty million tonnes of tailings from previous alluvial and colluvial mining operations. Samples provided by CEMAL were analysed by a Canadian research institution and revealed total REE oxides content in excess of 63 per cent; these were particularly rich in cerium (35.9%), lanthanum (15.2%) and yttrium (1.14%). As at the Pitinga mine, the potential to exploit the unremediated mine tailings would be a unique (and unexpected) opportunity that could provide the resources needed to resolve a long-standing environmental hazard.[154]

Morro dos Seis Lagos and Adjacent Regions in Colombia and Venezuela

The Moro de Seis Lagos is a remote mountain in Northern Amazonas state with geological features similar to the Catalão mine in Goiás. Long before it was recognised as a potential source of rare earth elements, it had been flagged as a world class deposit of niobium (236 Mt @ 2.81% Nb_2O_5) with economically significant reserves of titanium and manganese.[155] The still

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where the REE also sit), are included because they occur in the same mineral deposits and have similar chemical properties (valence). Source: https://www.visualcapitalist.com/rare-earth-elements-where-in-the-world-are-they/

* *Companhia Brasileira de Metalurgia e Mineração* – CBMM. In 2015, CBMM formed a joint venture with *Empresa Brasileira de Pesquisa e Inovação Industrial* (EMBRAPII) to develop the technical capacity to refine REE from Brazilian ores.

poorly mapped ore body is known to contain monazite, florencite, rhabdophane and pyrochlore, minerals that are known sources of rare earth oxides. Preliminary surveys suggest there are ~43 Mt of ore with concentrations of rare earth oxides that average about 1.5 per cent.[156] This would make the Morro dos Seis Lagos one of the main REE deposits of Brazil.

Despite its mineral potential, there are numerous obstacles to its development, most importantly, its location within the boundaries of *Parque Nacional Pico da Neblina,* a high profile protected area created in 1979. Moreover, the surrounding landscapes are within the traditional foraging grounds of several Indigenous groups, including the Yanomami, who inhabit the forest landscapes to the northeast, and the Baniwa, Baré, Desana, Makú, Tariana and Tukan peoples, who reside along the Rio Negro to the south. The area has been further protected by the creation of a biological reserve within the national park that circumscribes the mountain itself.

Over the border in Colombia, there might be about 1,000 million tonnes of REE-bearing mineral ores in the departments of Guainía, Vichada and Vaupes. The national database of mining concessions shows numerous requests for exploration licences, many of which are deep within established Indigenous reserves. The government has been clear it will not grant any of these requests; nonetheless, a clandestine trade in coltan has existed for more than a decade. The only legal activity is a proposed mine near the village of Puerto Carenõ (Vichada) by the Canadian company, Auxicos Resources, which has also expressed interest in a geological formation that extends into the Amazon's State of Venezuela near the existing Pijiguaos bauxite mine.[157]

Agricultural Minerals

The ongoing expansion of Brazil's industrial farms has created a robust market for the mineral feedstocks used for the manufacture of chemical fertilisers. Historically, demand was met largely by imports, but a combination of cost and geopolitical considerations has motivated agribusiness and government to invest in domestic fertiliser production. Most of this investment will be in mines and manufacturing plants in other parts of Brazil; however, the Brazilian Amazon has mineral resources that are cost-competitive and strategically vital. Andean countries also rely on imports and, although there is interest in Peru to enhance domestic sources, fertiliser feedstocks would not be of Amazonian origin. The Guianas do not have agricultural economies sufficient to justify investment in fertiliser factories, nor, apparently, sufficient mineral reserves to create an export industry.

Potash: A New Mineral Resource in the Heart of the Amazon

Brazil is the world's largest single importer of potash fertiliser and it is almost entirely dependent (95 per cent) upon imports from three countries: Canada, Belarus and Russia.[158] The fertiliser supply chain is about to undergo radical change, however, because of an ongoing effort to develop a world-class potash reserve located directly underneath the Amazon River floodplain (see Figure 5.15).

The potash was discovered by Petrobras geologists when they were exploring for oil in the Amazon and Solimões basins in the 1980s. The deposit consists of a 400-kilometre-long band of sedimentary rock that is one to four metres thick buried 650 to 900 metres below the surface of the Amazon floodplain. The ore body is a salt and clay mineral, known as 'sylvinite,' which is located within the *Nova Olinda* stratum formed during the Cretaceous Era about 100 million years ago. It is essentially a layer of salt that formed in a shallow-water marine habitat located in an estuary of the Proto Amazon River during a period with a strong evaporative climate.* The deposit is estimated to contain at least 250 million tonnes of ore with an average purity grade of 31.5 per cent potassium chloride (KCl).[159]

These resources are being developed by a subsidiary of a Canadian merchant bank, Forbes and Manhattan, which specialises in greenfield mining ventures.† The company, Brazil Potash, acquired the mineral rights in 2010 and has since documented the dimensions of the mineral resource, while conducting feasibility and environmental studies. The project proposal is based on an underground mine that will employ conventional room and pillar methods to extract an estimated 8.5 million tonnes of ore per year. The extracted ore will be concentrated in an adjacent 'hot leaching' processing facility to yield 2.5 million tonnes of commercial potash, about thirty per cent of projected domestic consumption.

The primary commercial market will be the industrial farms in Mato Grosso and potash will be delivered via the Madeira waterway to Porto Velho and BR-364 trunk highway. The mine is located upriver from the grain terminals at Itacoatiara and Santarem, which will allow agribusiness companies to use the otherwise empty grain barges and trucks returning to farm landscapes.

The mine is slated to initiate operations in 2023 with a life-of-mine estimated at 34 years; the developers are confident that additional resources will be located and developed over the medium-term. The total investment is reported at US$2.1 billion, with estimated gross revenues of about US$1.4 billion per year. As of June 2022, investors have allocated US$100 million to its project development.[160] The company estimates cost savings of approximately US$80 per ton, about fifteen per cent of the total cost of

* This sedimentary stratum lies below the Alter de Chão stratum when the mouth of the Proto Amazon was located from 20° to 30° below the equator.

† Forbes and Manhattan is also the investment bank that is underwriting the Belo Horizonte mining project at the Volte Grande of the Río Xingu.

potash shipped from Canada,* which translates into a savings of between US$200 million and US$300 million annually for Mato Grosso farmers.

Allegedly, the project developers are adhering to the Equator Principles† and will recycle water to avoid discharge of wastewater from processing facilities and return all waste rock to the abandoned mine shafts and galleries. According to the company, the proposed mine will generate 2,600 direct jobs during the construction phase and 1,300 direct jobs during the operational phase.[161]

Environmentalists oppose the mine because of its negative impacts to the seasonally flooded *várzea* forests and backwater habitats that characterise the Amazon floodplain. Opposition from Indigenous leaders is based on longstanding, and unfulfilled, claims by the Mura people for additional territories; although the proposed mine is not in or underneath a legally constituted *Terra Indigenas* (TI). Nonetheless, since one of their reserves is adjacent to the proposed mine, their approval is still required under the FPIC‡ conditions enshrined in Brazilian law.[162] The mine has the overwhelming support of the local, state and federal governments, as well as the agribusiness sector, who contend the mine can be developed with safeguards to minimise and offset any unwanted impacts, while fairly compensating Indigenous communities for any negative impacts.[163]

Phosphorus

Unlike potash, Brazil is nearly self-sufficient in the production of rock phosphate (P_2O_5); eight corporations operate mines in seven states to meet about eighty per cent of national consumption. Most production is based in Minas Gerais (70%),[164] but two companies (Itafos Inc and Rialma Fertilizantes) have opened strip mines in Tocantins, and a third is planned to open in southeast Pará.[165] As of 2022, there were 938 concessions that identified phosphate as the target mineral within the Legal Amazon. However, only eight had been approved for exploitation, all of which belong to the two previously mentioned companies.[166]

Agricultural Lime

Limestone, dolomite and gypsum are the primary sources of agricultural lime (*cal agrícola)*, which is not generally considered to be a fertiliser, but a soil amendment that resolves the chemical and physical constraints common to many tropical soils. The active component is calcium carbonate ($CaCO_3$), which is essentially pulverised rock mined from calcium-rich

* All of the Andean countries import their potash from Russia or Canada.

† The Equator Principals are a predecessor to ESG schemes and is specific for the banking industry; they consist of guidelines that are meant to voluntarily regulate investments in infrastructure projects and the extractive industry. Source: https://equator-principles.com/about-the-equator-principles/

‡ Free Prior and Informed Consent.

sedimentary formations. Calcium carbonate acts by changing the pH of the soil from acidic to slightly alkaline, which eliminates aluminium toxicity and facilitates the uptake of all three essential macronutrients (nitrogen, phosphorus and potassium: NPK), as well as most key micronutrients. The change in soil chemistry also transforms the soil biota, leading to an increase of soil-organic matter, and an improvement in soil water holding capacity over the medium-term.

Both the Cerrado and Amazon biomes are characterised by acidic soils and it was commonly assumed that industrial crops could not be cultivated in the Brazilian Amazon.[167] Starting in the 1980s, however, soil scientists at EMBRAPA[*] showed that application of large quantities of agricultural lime would reduce soil acidity, and turn these previously infertile soils into highly productive farm landscapes. By the late 1990s between fourteen and sixteen million tonnes of lime were being spread on Brazilian fields each year as the large-scale cultivation of soy, maize, cotton and other industrial row crops came to dominate the rural economy of Mato Grosso. The most sought-after land was on the flat tablelands (*planaltos)* of the Cerrado biome, which had deep well-drained friable soils; however, industrial farmers were soon expanding operations onto landscapes dominated by humid forest.

The expansion of industrial agriculture has motivated many landholders to convert their cultivated pasture to row crops, or to rent their holdings to industrial farmers in joint ventures that would begin with the application of agricultural lime. The benefits of soil management are now motivating ranchers to restore degraded pastures as part of a livestock–crop rotation business model that has expanded into Pará and Rondônia (see Chapter 3).

The EMBRAPA recommendation calls for an initial application of between five and nine tonnes of agricultural lime per hectare. High rainfall, however, will eventually wash the alkalinity from the soil profile and, unless there is a periodic application of calcium carbonate, soils will gradually lose their productive capacity. Consequently, there is a constant and growing demand for limestone. Approximately thirty million tonnes were used in 2019 by agroindustry in Mato Grosso. Much of the agricultural lime used in the state is mined in adjacent states but the cost of transportation has motivated producers to seek supplies closer to home. In 2022, there were 24 active limestone, dolomite and gypsum quarries[†] where the rock is mined and pulverised for immediate use without any industrial concentration process. A few limestone quarries have been operating for several decades as a source of the feedstock for Portland cement but most have been opened recently to respond to the needs of the country's industrial farms. As of

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[*] Empresa Brasileira de Pesquisa Agropecuária is the federal agricultural research service.

[†] A quarry is essentially a small-scale open-pit mine; Portuguese: pedreira; Spanish: cantera.

2022, there were 1,800 mining concessions that listed limestone, dolomite or gypsum as the target mineral; of these 222 have been granted a licence to operate.

The Geography of the Garimpo

Gold mining has been a feature of the Andean Amazon since pre-Colombian times and, along with silver, was the cornerstone of the economy in the colonial and republican periods. In Brazil, gold mining was a source of wealth for the Portuguese crown and a major diver in the colonisation of Mato Grosso and Rondônia during the eighteenth century. Guyana, Suriname and French Guiana all experienced nineteenth-century gold rushes, as did Venezuela in the first decades of the twentieth century. These historical events, however, have been dwarfed by the gold rushes of the modern era, all of which occurred after the United States ended the convertibility of the dollar in 1971.

The decision to untether international gold markets coincided with a decade marked by inflation that triggered an exponential increase in the price of gold. Coincidentally, Amazonian countries adopted policies to open their forest hinterlands to migration and development (see Chapter 6). The intent was to catalyse the expansion of the national economy via agricultural and mineral development. Structural obstacles and hubris doomed many initiatives, at least at first, but tens of thousands of families responded by migrating to the Amazon. Many headed for the recently discovered gold fields in Carajás, Tapajós, Roraima, Madre de Dios and the Guiana Coast

These wildcat miners soon became adept at discovering alluvial gold, which they exploited with the full support of their governments. Corporate miners eventually followed, armed with information from high-quality geological surveys published by national mining ministries. Those technical documents disseminate information at a relatively high level, but the presence of gold must be verified and validated by field work. This is the domain of junior mining companies, whose field geologists knew the best places to look for gold is to follow the lead of the wildcat miners.

Gold-bearing mineral formations typically are classified as primary (hard-rock) or secondary (alluvial / colluvial / saprolite) deposits. The presence of secondary deposits is an indication of the existence of a primary deposit. Wildcat miners extract 'free gold' from secondary deposits using placer-mining technology. This type of mining will eventually end in the Amazon – either when authorities limit its expansion or when wildcat miners discover and exploit all the accessible secondary deposits. Long before this occurs, however, the gold mining sector will have transitioned to the more lucrative hard-rock mining production model.

The gold rush of the 1980s was exemplified by the world's largest hand-dug open-pit mine at Serra Pelada, Pará, which attracted approximately 80,000 miners. The mine was closed in 1990 when the danger of landslides forced the government to shut it down; nonetheless, its unexploited (and underground) reserves are estimated at 100 tons of gold worth an estimated $US 5 billion in 2023.

Hard-rock deposits have two manifestations: (a) high-grade lodes and veins located in faults or shear zones within a rock matrix; and (b) low-grade ore bodies where gold is tightly bound in low concentrations within the mineral matrix of the rock. Some medium-scale miners have already made the transition to hard-rock mining using underground mines and cyanide to exploit the high-grade ores. Low-grade ores will be exploited by corporations operating open-pit mines within, or near, landscapes already blighted by the scourge of placer mining.

The Tapajós Garimpo

Gold mining started in southwest Pará in the late 1950s when *garimpeiros* discovered alluvial deposits on the Río Crepori, a tributary to the Rio Tapajós located about 500 kilometres south of the port city of Santarém (Figure 5.22). Access was limited by what small airplanes could ferry into remote airstrips or hauled upriver and ported around several sets of rapids. The earliest miners used the most rudimentary placer technology and cleared

Google Earth

The Tapajos gold fields have attracted several 'junior' miners, a term used for small entrepreneurial geologists and investors that discover and develop ore bodies, which are usually exploited by underground mines and cyanide leaching technology. The São Chico (top) and Palitos (bottom) gold mines are operated by Serabi Gold of Canada. See Annex 5.6.

~1,540 hectares of riparian forest by 1975.[168] Migration increased after the construction of the trunk highway (BR-163) that connected Cuiabá with Santarem in the late 1970s (see Chapter 2). Tens of thousands of *garimpeiros* poured into the region and, by 1984, the spatial footprint of the *Tapajós Garimpo* had tripled to 4,750 hectares and access to the region was improved

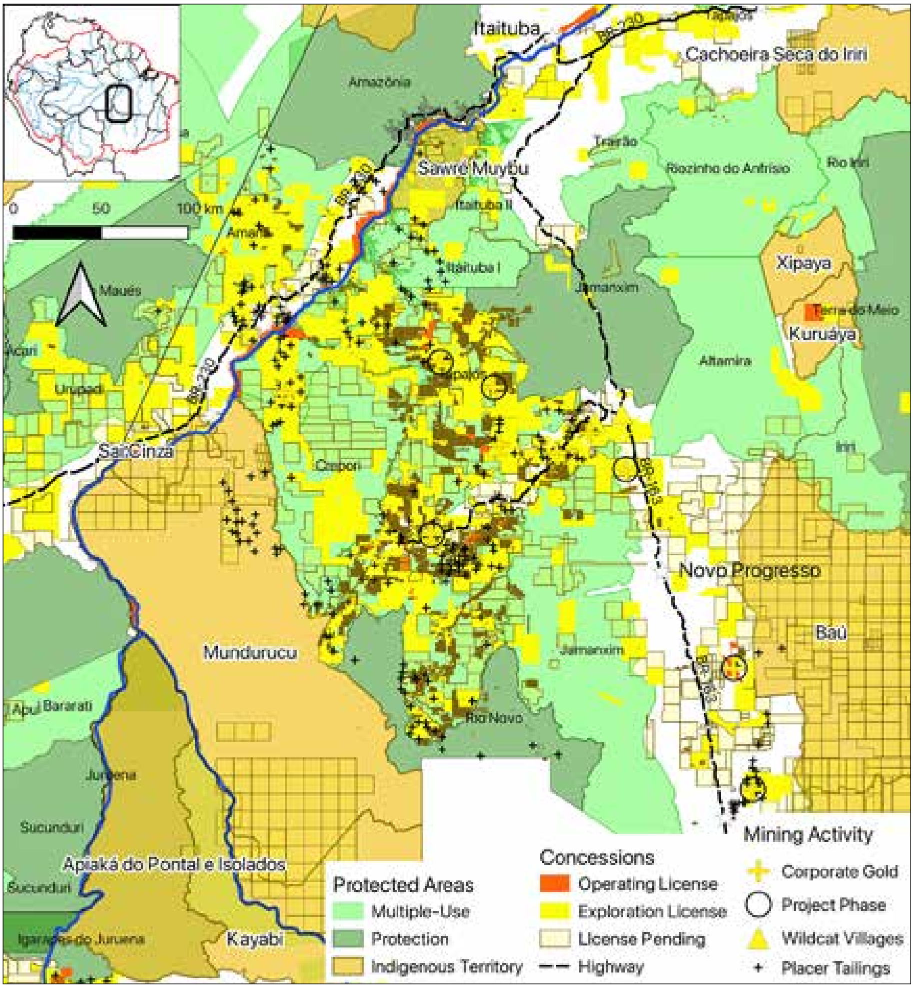

Figure 5.22: The gold fields of the Tapajos have been dominated by wildcat placer miners since the 1950s, but junior miners have documented the presence of several hard-rock gold deposits that are in different stages of development. Most of the mining activity occurs within the Área de Proteção Ambiental (APA) Crepori, a multiple-use protected area. Illegal mining also occurs within the FLONA Jamanxim and the Munduruku indigenous reserve.

Data sources: RAISG (2022) and corporate reports (see Annex 5.4).

by the construction of the *Estrada Transgarimpeira*,* which allowed miners to expand the scale of their activities with heavy equipment. The area of floodplain forest lost by 1993 surpassed 16,500 hectares.[169]

* Apparently, the road was built by the municipality of Itaituba with federal funds; maintenance was assumed by the state of Pará in 2009. Source: https://estradas.com.br/transgarimpeira-deve-virar-rodovia-estadual/

Top: Placer mining technology has destroyed tens of thousands of hectares of riparian forest habitat in the Tapajós watershed, within the Area de Proteção Ambiental (APA) Crepori, a multiple use protected area where mining is legal – IF its practitioners comply with environmental, labour and tax regulations. Tax compliance has improved dramatically over the last five years, but most miners continue to operate outside the law.

Middle: Wildcat miners have invaded the Yanomami Indigenous Territory repeatedly over its more than 40 years of existence in a constant game of cat and mouse with programmes organised by FUNAI, IBAMA and the Brazilian Armed forces. A deliberate decision by the Bolsonaro administration to defund those programmes led to a surge of incursions between 2018 and 2022 when an estimated 20,000 garimpeiros were once again encamped along its rivers exploiting one of Brazil's most notorious gold fields.

Bottom: The Indigenous territory most affected by illegal mining is home to the Kayapó nation, which borders several historic garimpos (gold fields) in Southeastern Pará.

Gold production increased from eight tonnes annually in 1970 to more than 26 tonnes by 1990, while the nominal value increased from US$7 million to US$175 million – a very large sum in the Amazon of the late 1980s.[170] The price of gold stagnated in the 1990s; nonetheless, miners still managed to produce between eight and twelve tonnes per year. The rebound of gold prices after 2007 led to another boom in mining activity, increasing the total spatial footprint to 26,170 hectares by 2015.[171] Compared to the deforestation caused by cattle ranching, this might appear not to be a particularly large area. However, the forest destroyed in the Tapajós gold fields is almost always floodplain forest.

In 2013, a newspaper in Santarem estimated the region had produced about 758 tonnes of gold over fifty years with a value calculated at ~R$79 billion (then ~US$25 billion).[*] The purpose of the newspaper article was to protest lost public revenues from gold miners that had only recently started paying royalties.[†] Gold production from the region in 2013 was reported at twelve tonnes, which would have had a nominal market value of ~US$447 million; however, only R$1.6 million were transferred to the municipality of Itaituba, roughly seven per cent of the putative amount actually owed (R$24 million).[‡] Annual receipts have improved steadily since, as medium-sized companies and cooperatives began operating within the formal sector.[172] In 2019, a total of R$64 million in royalties were transferred to the municipality corresponding to, perhaps, fifty per cent compliance with their obligations under Brazilian law (Figure 5.23).

In 2020, a regional news service estimated there were 2,700 active *garimpeiro* mine sites employing ~27,000 individuals.[173] Some are reworking pre-existing placer mines using more sophisticated technology, but the placer-mining footprint continues to expand up secondary and tertiary tributaries of the Crepori and Jamanxim. Satellite images reveal that between 3,000 and 4,000 hectares of floodplain forest were lost each year between 2010 and 2020.[174] At least some *garimpeiros* have evolved into small-scale hard-rock miners and are now exploiting the more easily accessible primary

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* The values reported by the newspaper are approximately equivalent to inflation-adjusted values; an alternative estimate based on the median price of gold when it was mined would place the total value at about US$9.5 billion. Source: Gazeta Santarém (2013) 'R$76 bilhões em ouro roubado do Tapajós', https://gemasdobrasil.blogspot.com/2015/12/r-76-bilhoes-em-ouro-roubado-do-tapajos.html

† Based on transfers executed by the federal government to municipalities. See Agencia Nacional de Mineração: https://sistemas.anm.gov.br/arrecadacao/extra/relatorios/arrecadacao_cfem_substancia.aspx

‡ Based on the reported production of 12 tonnes of gold (363,250 troy ounces) at US$1,200/ounce, an exchange rate of R$2.1839 per US$1.00) and 2.5% royalty tax known as the Compensação Financeira pela Exploração de Recursos Minerais (CFEM).

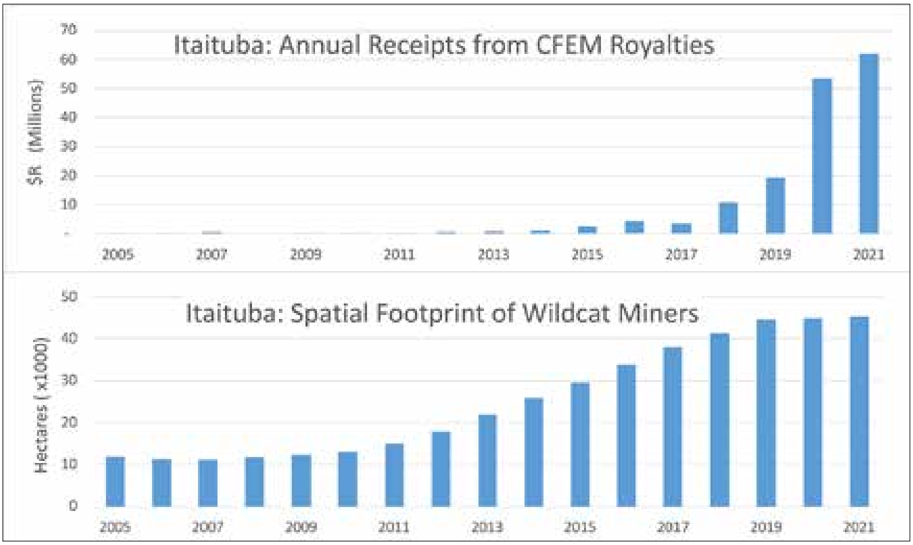

Figure 5.23: The Tapajós gold field, which is largely circumscribed by the municipality of Itaituba, has continually been the focus of wildcat miners since the 1950s, but the region experienced an upsurge in activity since about 2011, as evidenced by the increase in denuded river valleys characteristic of placer technology. Virtually all wildcat miners avoided paying taxes until about 2015 when the local government and state authorities started collecting royalty taxes to support local development.

Data source: ANM (2022).

gold deposits.[175] There were only two industrial-scale underground mines operating in the region in 2020, but junior companies were developing four underground and three open-pit mines (see Figure 5.22), while conducting exploration campaigns across the region.

Most of the mining has taken place within the *Área de Proteção Ambiental* (APA) *do Tapajós*, a conservation category that allows mining; nonetheless, most mines are considered illegal because they do not comply with environmental or fiscal regulations. The region also contains two national parks (*Jamanxim, Rio Novo*) where mining is not allowed, and five national forest reserves: *Floresta Nacional* (FLONA) *Itaituba I* and *II*, where mining is allowed, and FLONA Amaná and Jamanxim where it is not.[*] All are still in early stages of consolidation and are under pressure from settlers, land grabbers and wildcat miners. In 2017, the administration of Michel Temer

[*] Mining is allowed in FLONAs established before 2000. All but the Itaituba reserves were established in 2006 as part of a sustainable development initiative linked to the paving of BR-163 (see Chs 2 and 12).

Top: The Grupo Especializado de Fiscalização *(GEF) was a militarised branch of the environmental agency (IBAMA) that conducted periodic raids to interdict the operation of illegal mines operating within national parks and Indigenous territories; however, the unit was defunded during the Bolsonaro administration. Bottom: The scale of this strip mine in Parque Nacional Rio Novo demonstrates that illegal miners are often criminal operations with access to capital and technology*

Historically, the Rio Jamanxim was considered to be a 'clear water' river, a class characteristic of the Xingu and Tapajos watersheds of the Southern Amazon. Placer technology has changed the river into a sediment-laden waterway that is also heavily polluted by mercury.

attempted to reduce the size of and recategorise the FLONA *Jamanxim*, but the move was declared illegal by the Supreme Court of Brazil.[176]

Most of the mid sector of the Tapajós watershed was once the undisputed domain of the Munduruku, an Indigenous nation that has struggled to coexist with the *garimpeiros* and to protect the region's ecological integrity. A relatively numerous tribe, they now mainly reside in riverside communities in their legally constituted territories (TI Munduruku, TI Sai Cinza and TI Sawré Muybu), all of which are adjacent to the gold fields.[177] Their communities continue to suffer territorial encroachment, particularly along the Rio das Tropas and Rio Cabituto. In 2014, they created the *Movimento Ipereg Ayu*[*], a self-protection force, whose first act was to 'self-demarcate' their land and organise patrols to combat illegal mining and logging.[178]

Eastern Pará

The most famous gold mine in the Brazilian Amazon is Serra Pelada in Eastern Pará, the site of a gold rush that started in 1981 and ended with the closure of the world's largest hand-dug, open-pit mine in 1993.[†] At its peak in the mid 1980s, the population of miners reached 80,000 men and boys, while tens of thousands of women and children lived in adjacent settlements. Today, Serra Pelada is surrounded by farms and ranches, but in 1981 it was a forest frontier and, predictably, a chaotic and violent *garimpo.*

The gold rush occurred in the heyday of the military government that sent an officer familiar with the region to manage the mine, which was quickly becoming famous for its chaos and hellish working conditions.[‡] Sebastião Rodrigues de Moura, known by the sobriquet Major Curió, imposed order using a combination of coercion, persuasion and common sense.[§] The *garimpeiros* organised themselves into the *Cooperativa de Mineração dos Garimpeiros de Serra Pelada* (COOMIGASP). The concession was originally held by a subsidiary of the state mining company (*Companhia Vale do Rio Doce* – CVRD), which ceded ownership to COOMIGASP in 1982 once it was obvious that social conditions would make it impossible to develop an industrial mine.[¶]

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* 'I am strong, I know how to protect myself', in Murundukú.

† Miners were obligated to sell their gold to a state controlled bank (Caixa), which paid a premium above market prices to avoid the development of a black market.

‡ These were documented by the Brazilian photographer Sebastião Salgado

§ Curió was selected by the military government, in part, due to his role in the suppression of the Marxist guerilla campaign in neighbouring Araguaia. Subsequently, he was elected to Congress and as mayor in the municipality of Curionóplis, which was named in his honour, and assumed a leadership role in the COOMIGASP. Source: Gomes and Lopes 2009.

¶ Vale SA is the privatised successor of CVRD and has retained dozens of concessions in the area; it also operates the Serra Leste iron ore mine located five kilometres to southwest of Serra Pelada.

The tropical rains eventually surpassed the ability of pumps to keep the pit free of water, while its haphazard design and the unconsolidated lateritic soils (saprolite) led to multiple recurring landslides that killed dozens of workers. The mine was closed in 1992, even though there were abundant gold resources yet to be fully exploited.[179] The amount of gold that came out of the Serra Pelada is conservatively estimated at 42 tonnes, which at the time would have represented ~US$500 million. The true amount is presumed to be greater because the bank tasked with purchasing the miners' production only paid 75 per cent of the international market price.

The Serra Pelada ore body is known to extend several thousand metres below the surface and is estimated to contain an additional ~100 tonnes of gold as well as platinum (~35 tonnes) and palladium (~18 tonnes).[180] The *garimpeira* cooperative has neither the technical capacity nor the financial resources to develop the resource. However, in 2000, COOMIGASP entered into a joint venture with a Canadian company (Colossus Minerals) to install an industrial-scale underground mine. The initiative was not successful, due to the complex social dynamic that required the Canadian company to enter into a business venture with an unruly association of *garimpeiros*.[*]

The cooperative, which now boasts 45,000 members, continues to seek partners and opportunities to reopen the shaft sunk by Colossus between 2000 and 2014. In January 2022, COOMIGASP received a commitment from the Bolsonaro administration to reactivate the mine, a decision influenced by the memories of his father's experience as a *garimpeiro* at the mine in the early 1980s.[181]

Serra Pelada was just one of several *garimpos* that benefitted from federal programmes in the 1980s; direct subsidies included technical assistance, financial services, air transport, health care and food. The highest profile federally sponsored *garimpo* was the Projeto Cumaru, which was located on a remote forest landscape on lands inhabited by the Gorotire tribe of the Kayapó nation.[182] The surge of migrants overwhelmed the Gorotire, whose leaders originally sought an accommodation with the *garimpeiros* in exchange for a share of revenues and the delimitation of their territory.[†] The Kayapó quickly tired of the accommodation, once they experienced the impacts on their health and livelihoods – and realised they were being

[*] Colossus Minerals filed for bankruptcy in 2014, after investing US$125 million in an exploratory shaft 1.9 kilometres deep, following charges of bribery involving directors of the cooperative who approved a plan that would have defrauded 35,000 members of the cooperative and forced hundreds of families to abandon their homes. Source: http://projects.aljazeera.com/2015/07/brazil-gold-mine/

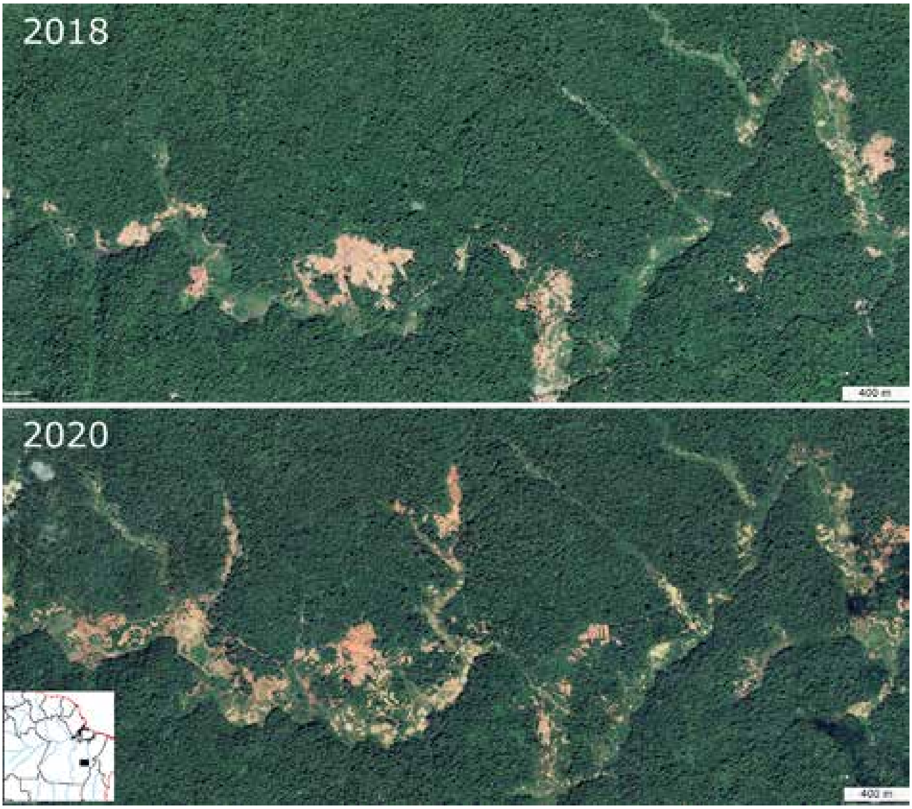
[†] The TI Kayapó was delimited in 1985 and legally formalised in 1991. Source: ISA– Instituto Socioambiental (2022) Terra Indígena Kayapó; https://terrasindigenas.org.br/pt-br/terras-indigenas/3731

Google Earth

This Kayapo village in the Xikrin do Catete Indigenous Territory is located approximately 40 kilometres downstream from Vale's Onça Puma nickel mine. The indigenous group sued Vale for damages and won a court order of $R 25 million in compensation for pollution originating from the mine. Vale has appealed the decision, as well as court orders to suspend operations. Data source: https://ejatlas.org/conflict/onca-puma-nickel-mining-project-in-ourilandia-do-norte-para-brazil

cheated out of revenues. Mining activity declined through the 1990s as the value of gold experienced a cyclical decline, but miners once again poured into the area after 2015 (Figure 5.24). The Kayapó are resolute in their opposition to mining, but they have been unable to protect their territory, despite assistance from the public prosecutor's office and civil society (see Chapter 11).[183]

The popular press emphasises the conflict between Indigenous people and *garimpeiros*, but the renewed expansion of placer mining has also negatively impacted communities residing on agricultural landscapes. Tens of thousands of *garimpeiros* were attracted to Eastern Pará during the 1980s and, although some relocated elsewhere, many settled in INCRA-sponsored settlements that characterise the region (see Chapter 4). This demographic reserve of *garimpeiros*, or their descendants, emerges when the price of gold spikes. Some invade Indigenous areas, but others reoccupy the abandoned



Google Earth

The recent surge in placer mines near Ourilândia do Norte, Pará, is one of many examples of illegal mining within the Kayapó indigenous territory.

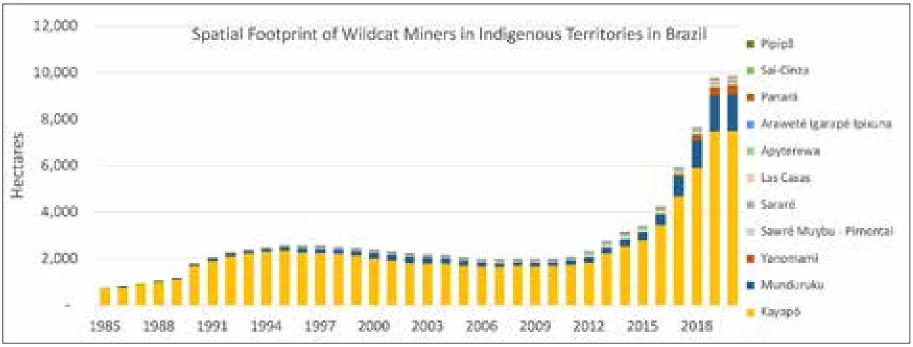


Figure 5.24: The increase in wildcat mining was well underway in the gold rush of the 2010s, when the Bolsonaro administration turned a blind eye to illegal miners who were invading indigenous territories. The most severely impacted were home to Kayapó, Murunduku and Yanomami indigenous people.

Data source: Mapbiomas (2022).

Google Earth

Public attention is focused on wildcat mining within indigenous lands and protected areas; however, operators of placer mines on private land are also guilty of avoiding taxes and violating environmental regulations, such as these mines near Curionópolis, Pará.

garimpos of the 1980s that are now surrounded by farms and ranches. Satellite imagery reveals new placer mines have destroyed thousands of hectares of riparian habitat and remnant gallery forest in the municipalities of Xinguara, Rio Maria, Curionópolis and El Dorado de Carajás.

As in the Tapajós, the success of the *garimpeiros* has attracted the interest of corporations, who know that alluvial gold is an indication of greater deposits locked away in the ore bodies of the Greater Carajás mineral province. Vale operated an industrial gold mine at Igarapé Bahia between 1990 and 2000 that produced ~100 tonnes of gold and about ~US$1.6 billion in gross revenues.[184] Today, corporate interest is focused on copper and nickel as the primary target minerals; nonetheless, these mineral (IOCG) deposits also produce gold.* In 2021, the Sossego and Salobo mines produced, respectively, two and ten tonnes of gold, representing about 25 per cent of their combined revenues of US$ 2.5 billion.[185] (Annex 5.1 and Annex 5.5).

Mato Grosso

Gold was central to the colonisation of Mato Grosso. Cuiabá was founded by *bandeirantes*† from São Paulo who discovered gold in 1719. As they explored the region, they found gold in the upper reaches of the Rio Guaporé, which led to the creation of the first capital of Mato Grosso at Vila Bela da Santíssima Trindade in 1731.[186] The easily exploitable placer deposits were soon exhausted, but the thirst for gold was reignited during the 1970s when *garimpeiros* rushed to exploit a region with both alluvial and saprolite deposits at four major *garimpos:* (1) Baixada Cuiabá, (2) Serra de Aguapei, (3) Novo Xavantina and (4) Alta Floresta–Juruena (Figure 5.25).

The gold rush of the 1970s and 1980s attracted tens of thousands of *garimpeiros* into previously remote regions. There are no reliable estimates of the quantity of gold they extracted, but it is widely assumed the demographic surge, and the capital derived from gold, accelerated the development of the state's agricultural economy. Many *garimpeiros* became small farmers and ranchers, particularly in northern municipalities where INCRA sponsored a half dozen settlement projects (see Chapter 4). As in Pará, they have retained both their knowledge and propensity to exploit alluvial gold, which has shown a resurgence of activity in the old *garimpos* located near Alta Floresta and Pontes de Lacerda.[187]

In the Baixada Cuiabá, a dozen moderately-large placer mines have transitioned into strip mining operations exploiting primary ore deposits that use cyanide to separate and concentrate elemental gold. There are three open-pit mines operating in the Aguapei belt near the Bolivian border, and one industrial scale gold mine is under development in the Alta Floresta–Juruena belt. There will likely be more in the near future, as several companies hold exploration permits in the region. As in eastern Pará, many hope to exploit both copper and gold. (Annex 5.9).

* IOCG refers to iron oxide, copper and gold and refers to mineral rich porphyries associated with magmatic intrusion in cratonic landscapes. Source: http://portergeo.com.au/tours/iocg07/iocg07deposits.asp

† The bandeirante were eighteenth-century fortune hunters that consolidated Portuguese control over central-west Brazil (Goiás, Mato Grosso and Mato Grosso do Sul). In addition to prospecting for gold and diamonds, they engaged in the Indigenous slave trade and were instrumental in disrupting the Jesuit system of missions that served as a geopolitical buffer zone between the Spanish and Portuguese colonies. Source: Hemming 1978.

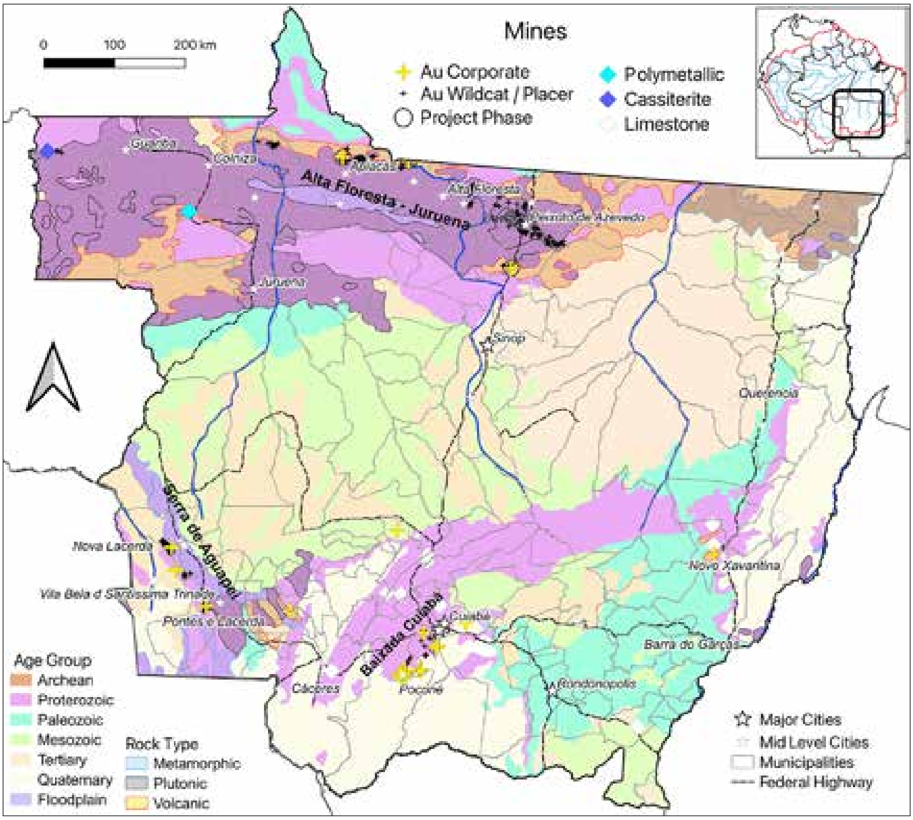


Figure 5.25: Mato Grosso was settled by wildcat gold miners (garimpeiros) in the seventeenth, nineteenth and twentieth centuries. The largest placer deposits, known as garimpos, were near the Baixada Cuiabá, Serra de Aguapei, Novo Xavantina and Alta Floresta–Juruena.

Data sources: da Costa and Rios (2022) and Gomez Tapia et al. (2019).

Rondônia and Amazonas

The geological formations that are the source of gold in northwest Mato Grosso extend into the border municipalities of Rondônia where several wildcat mines have encroached upon the Indigenous lands of the *Cinta Larga* (TI Roosevelt and TI Aripuanã). There were no mass gold rushes in this corner of the Amazon in the 1980s; however, the western portion of the state is riddled with hundreds of abandoned placer mines established in the 1960s and 1970s during the cassiterite boom. These abandoned mine sites are indistinguishable from placer gold mines; consequently, it is difficult to document the historical impact of small-scale gold miners.

The longest continuous *garimpeiro* district in Rondônia is the river channel of the Rio Madeira where placer dredges have exploited alluvial gold since the early 1980s.[188] This unique '*garimpo aquático*' is the consequence of the depositional forces of a massive sediment-laden 'white water river' and the extraordinary quantity of gold released by erosional processes unleashed during the Pleistocene that gave rise to the gold fields in the Madre de Dios and the La Paz Yungas. Prior to the construction of the dams at Santo Antonio and Jirau (see Chapter 2), dredges worked the river upstream from Porto Velho, producing an estimated 38.5 tonnes of gold between 1980 and 2010.[189] This area is now essentially off limits and the bulk of the dredge miners now operate downstream from Porto Velho.

The activities of placer dredges are most noticeable in Humaitá, which is the operating base for hundreds of these specialised river barges. Virtually all operate outside the law: neither paying royalties nor complying with environmental regulations. A series of police investigations in 2017 provoked a backlash from the *garimpeiros*, who burned the offices of IBAMA and ICMBio. This focused the attention of elected authorities on the demands of *garimpeiro* families who reside in more than 170 riverside villages. At the direction of the governor, the environmental authorities of Amazonas (SEMA – Amazonas) issued provisional licences and the dredges proceeded to expand their operations all the way to the mouth of the river.[190] By 2021, there were more than 400 barges operating in a series of 'chains' in the river channel in the municipality of Autazes. Another police action (*Operação Uiara)* confiscated and destroyed 130 barges in November of 2021. The garimpeiros responded by protesting to local authorities and their representatives in Congress and, once again, were allowed to regroup and return to the river.[191]

In March 2022, the administration of Jair Bolsonaro launched a programme specifically to support *garimpeiros*: the *'Programa de Apoio ao Desenvolvimento da Mineração Artesanal e em Pequena Escala'* (PROMAPE).[192] In a press release, the administration stated 'that artisanal and small-scale mining is a source of wealth and income for hundreds of thousands of people and it is essential that the government takes actions to recognize the conditions in which the small miner lives, the scope of its activity and the primary needs of the surrounding society'.[193] By July 2022, there were dozens of barges once again exploiting the alluvial gold on the Rio Madeira with the public support of prominent politicians from all major parties.[194]

Terrestrial *garimpos* are not common in Amazonas state because of its geological history. Nonetheless, there are a few active garimpos in border municipalities that share a geological province with an adjacent state or nation (Annex 5.1). The most prominent is the garimpo de Juma located near the village of Apuí, where a placer discovery triggered a gold rush in 2007.[195] A relatively small deposit, it ceased activities following a police

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Top: The frenzy for gold led to the proliferation of placer dredges that organised themselves into formal and informal cooperatives that worked the Rio Madeira between Porto Velho and the main stem of the Amazon River. Bottom: Dredges are known to operate on multiple rivers across Brazil, as well as in Bolivia, Peru and Colombia.

action in 2017 when SEMA–Amazonas intervened in an attempt to force the association of *garimpeiros* to comply with pertinent regulations.[196]

Barge-mounted dredges have been reported on several rivers in the western sector of Amazonas state. Those located south of the Rio Solimões (Purus, Jurau and Javari) are unlikely to host a gold rush because neither drain an area with gold-bearing geological formations. In contrast, the Solimões, Japaru (Caquetá) and Putumayo all drain portions of the Andes with known or suspected deposits of gold; dredges have been reported on these rivers, but not at levels sufficient to qualify as a gold rush. The watershed of the upper Rio Negro drains landscapes known to hold significant gold reserves, particularly in Roriama and along the border with Colombia. *Garimpeiros* have yet to successfully install either a river-based or terrestrial garimpo in the mid to upper reaches of the Rio Negro, presumably because the local authorities are closely affiliated with Indigenous people.

The Calha Norte: Roraima and Amapá

Roraima has experienced periodic gold rushes over several decades, beginning in the 1970s after the discovery of gold in the borderlands between Venezuela, Guyana and Brazil. The military regime facilitated migration into the region as a deliberate strategy to occupy its northern frontier (*Calha Norte*) and thousands of *garimpeiros* streamed into the region. Unfortunately, the borderlands were the homelands of several Indigenous tribes, notably the Yanomami to the west and the Macuxi in the East. The Yanomami are uncontacted forest dwellers, while the Macuxi had limited experience interacting with the military and ranchers. Neither group was prepared for the onslaught of *garimpeiros.*

As the gold rush increased in intensity, its impact on Indigenous people was intensified by the actions of Romero Jucá, an influential politician who migrated to Roraima as a young and ambitious public servant. He was appointed head of FUNAI in 1986 where he sought to dismember and reduce the extent of the Yanomami territory. In 1989, he was appointed as the first governor of the new state and adopted policies to facilitate the migration of thousands of *garimpeiros* into the borderlands. As in the Tapajós, the miners organised a logistical system that used light aircraft to supply their operations at more than eighty remote airstrips spanning more than eight million hectares.

The Yanomami resisted but the interlopers responded with brutal force and in one instance killed sixteen men, women and children in a massacre that was ruled an act of genocide.[*] Juca lost his election for governor

[*] The Haximú Massacre actually occurred in Venezuela in 1993; the transborder nature of the event complicated the prosecution of the crime, but five Brazilian miners were found guilty of murder in 1998. Human rights activists complained prosecutors had acted negligently by not treating the crime as an act of geno-

in 1990* and new leadership at FUNAI reconstituted the TI Yanomami to its original 9.6 million hectares.

Shortly thereafter, a law-and-order campaign physically removed ~5,000 *garimpeiros* from Yanomami territories.[197] Known as *Operação Selva Libre*, the police action was organised by FUNAI in coordination with the public prosecutor (MPF) and specialised units of the army and federal police. Similar operations were conducted in 1997, 1998 and 1999 and periodically throughout the next decade.[198] In spite of these efforts, *garimpeiros* continue to invade the TI Yanomami, mostly on four tributaries to the Rio Branco (*Uraricoera, Mucajaí, Apiaú* and *Catrimani*) whose lower reaches are easily accessible by road from the populated areas of Roraima.[199]

The Roraima gold fields are different from the *garimpos* in Tapajós, eastern Pará and Mato Grosso where placer mining left conspicuous scars on landscapes, visible on satellite images decades after they were created.† It is unclear why this is the case. Perhaps they are exploiting hard-rock deposits with localised veins or are working very small placer deposits under the forest canopy. The inability to monitor their illegal activities using remote sensing technology requires a more intensive on-site monitoring effort that is both dangerous and more costly. The availability of high-resolution imagery will greatly facilitate monitoring efforts.[200] The inability to monitor the region effectively facilitated a renewed garimpeiro invasion during the Bolsonaro administration that defunded efforts to control illegal mines and support the health and well-being of the Yanomami Indigenous communities (Text Box 5.5).

Gold mining in Amapá dates from the last half of the nineteenth century with a gold rush in what are now the northern municipalities of Oiapoque and Calçoene. *Garimpeiros* were attracted by the rich gold deposits associated with the greenbelt formation that extends across the hills of the Guiana Coast. They have had a continuous presence at the Garimpo São Lourenço, which was also the site of the state's first underground gold

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cide and sued the Brazilian state in 1997 at the Interamerican Court of Human Rights (IACHR). The Brazilian Supreme Court eventually ruled in 2000 that the Haximú Massacre did indeed constitute genocide and the case before the IACHR was archived in 2011. Source: http://www.worldcourts.com/iacmhr/eng/decisions/2011.07.21_16_Indigenous_Yanomami_v_Brazil.pdf

* Juca was elected as a Senator from Roraima between 1995 and 2019. He was an unabashed supporter of *garimpeiros* and in his first year as a legislator he proposed the *Projeto de Lei* 1620/96 to create an expedited process to approve mining within Indigenous territories. He would periodically resubmit this bill until his retirement, and it is not materially different from a proposal submitted by Jair Bolsonaro in 2019. Source https://trabalhoindigenista.org.br/analise-pl-161096-e-mineracao-a-forc-2/

† Most attribute data in the RAISG database indicates the source was from Indigenous informants and field verification.

Text Box 5.5: The Yanomami Genocide of 2022

The Bolsonaro administration was accused of genocide in January 2023, when it became apparent that deliberate actions to defund agencies and terminate programmes had caused a dramatic upsurge in disease, malnutrition and death in Yanomami villages between 2019 and 2022. The new policies ended twenty years of coordinated action among federal agencies to combat illegal gold mining and protect the integrity of the Yanomami Indigenous Territory. Although imperfect, previous programmes had suppressed the number and size of illegal gold mines and allowed the Yanomami to live in relative peace within their ancestral territories. They were organised by *Fundação Nacional dos Povos Indígenas* (FUNAI) and *Instituto Brasileiro do Meio Ambiente* (IBAMA), who leveraged the prosecutorial powers of the *Ministerio Público* (MP) with the coercive action of the Armed Forces and police to uphold environmental and constitutional law. The tactics of the Bolsonaro administration, which were enacted in coordination with the Roraima state government, triggered a gold rush when ~20,000 *garimpeiros* invaded the Yanomami Indigenous reserve between 2019 and 2022.

Tragically, the invasion coincided with the onset of the COVID-19 pandemic, while a surge in *garimpeiro* populations triggered an outbreak of malaria within Yanomami villages. Severe illness overwhelmed the indigenous health service (SENSAI), which was likewise defunded during the Bolsonaro administration. The upsurge in severe illness impeded hunters from foraging in the forest and cultivating gardens, while fishing entailed risk because rivers were overrun by hostile wildcat miners. Famine soon stalked the ~30,000 Yanomami who reside on both sides of the Brazil–Venezuela border. It was particularly severe for the eldest and youngest members of one of the Amazon's most vulnerable ethnic groups. According to social advocates, at least 570 children and infants died between 2020 and 2022.

The departure of the Bolsonaro government led to an immediate relief effort, supported by all elements of the new administration. Presumably, police action will follow and the *garimpeiros* will be expelled from Yanomami territory. Obtaining justice for the Yanomami will take longer. Hopefully, illegal miners will be punished sufficiently, so that they abandon their erstwhile efforts to exploit the region's mineral wealth. That would be a good outcome, but it is not likely considering past experience. Nor would it constitute justice. True justice would require the perpetrators of the invasion and the architects of the famine to be held accountable in a court of law. This will require for the Brazilian judicial system to examine the facts and determine that a crime had been committed. That crime may – or may not – be genocide, which is a very specific criminal act defined by international law. The next step will be to decide who is responsible for the crime, or perhaps more accurately, determine the levels of culpability for the crime, which could include local agents, ministerial functionaries and, perhaps, an ex-president. If the Brazilian justice system fails to act, or if they are dissatisfied by the outcome, then the Yanomami can take their complaint to the Inter-American Court of Human Rights (IACHR).

mine (Salamagnone), which extracted ~20 tonnes of gold (~US$250 million) between 1984 and 1995.[201]

The next major development was an open-pit mine at Gaivota in 1991, although that company lost (part) of its investment when the concession was overrun by *garimpeiros* in 1997. The next corporate endeavour was at the Tucano mine, which benefited from the extensive geological explorations of its neighbour, the Serra de Navio manganese mine. The Tucano facility has opened eight open-pits and one underground mine since 2012. As of 2021, it had produced more than 44 tonnes of gold with a nominal value of ~US$2.5 billion.

Situated just east of these two industrial mines is the RENCA mineral reserve, which is believed to have one or more world-class deposits of gold, copper and other strategic minerals. The RENCA is closed to mining, but *garimpeiros* have been exploiting surface deposits at several localities, most notably in the Serra de Ipatinga, a low ridge located to the west of the Rio Jari in Northern Pará. Estimated at ~5,000, *garimpeiros* are operating between thirty and forty clandestine landing strips.[202]

Belo Sun and the Volte Grande

The most controversial corporate project in the Brazilian Amazon is located near the Volte Grande on the Xingu river just a few kilometres from the Belo Monte hydropower dam. The proposed mine would exploit a world-class gold deposit on a greenstone deposit that was first exploited by *garimpeiros* in the 1960s (*Garimpo Itatá*). The project developer, the Canadian company Belo Sun, acquired the concession in 2013.[*] The proposed open-pit mine has 'proven or probable' reserves of 3.8 million ounces of gold and is projected to generate profits of US$2 to US$5 billion over a seventeen-year lifetime. Opposition to the project has focused on the danger of a catastrophic failure of its cyanide ponds and tailing storage facilities that would contaminate the lower stretches of the Rio Xingu.[†] Concern over the potential impact is magnified by the reduced water flows caused by the Pimentel Dam which diverts about 75 per cent of the river's water flow to the Belo Monte hydropower plant (see Chapter 2).

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[*] Belo Sun is controlled by Forbes and Manhattan, an investment bank specialising in mining projects. It is also underwriting the development of Brazil Potash, another controversial mine located near the mouth of the Río Madeira in the municipality of Autazes (see above). Source: https://www.forbesmanhattan.com/portfolio/

[†] The Volte Grande is also the site of Brazil's second largest hydropower facility: Belo Monte. The proposed mine would be located approximately halfway between the diversion dam (Pimentel) and the powerhouse (see Ch. 2).

Opposition to the mine is led by Indigenous communities whose livelihoods depend on the natural fishery of the Xingu River.* The environmental impact analysis (EIA) has been accepted by the state environmental agency (SEMAS) but the operating licence was rejected by a federal court due to the failure of the company to obtain the free prior and informed consent of nearby Indigenous communities.[203] The company contends it has reached an agreement with the communities, a position validated by the functionaries at FUNAI during the Bolsonaro administration and the state Supreme Court.† Nonetheless, the project remains on hold until the resolution of a separate judicial case questioning the licensing process, arguing that the federal agency (IBAMA) has jurisdiction rather than the state agency (SEMAS). If it is allowed to move forward, Belo Sun will be the largest gold mine in Brazil.

The Greenstone Belt of the Guianas

Greenstone belts are zones of metamorphic and volcanic rocks that occur within ancient (Archean) formations dominated by granite and gneiss.‡ They are common to most of the cratons in the world and are often associated with world-class gold deposits. The most important greenstone belt in the Pan Amazon is Barama-Mazaruni supergroup, which occurs as a non-contiguous band of rocks in Eastern Venezuela and Guyana, then reappears in Suriname and French Guiana and then further south in Amapá (Figure 5.26). Altogether, this geological formation covers about thirteen million hectares.

Venezuela

Apparently, the richest portion of this geological province is in the Venezuelan state of Bolivar where small-scale placer mining began in the 1930s. The spike in gold prices in 1980 motivated thousands of adventurers to migrate into the region to work the surface (saprolite) gold deposits using hydraulic mining techniques. Most settled near two frontier towns: El Callão in the North and Las Claritas in the South.

The wildcat miners shared these landscapes with three state-owned concessions that were created in the 1970s to exploit the richest and largest deposits. The rights to develop these resources were auctioned in the 1990s to foreign companies, who developed plans to install large-scale open-pit

* Arara de Volte Grande (117 inhabitants) and Paquiçamba (95 inhabitants; both reserves are located downstream from the proposed mine site.

† Environmental and social advocates contend that the decision by FUNAI reflects the political agenda of Jair Bolsonaro who favours opening Indigenous territories to all forms of mining.

‡ Greenstones are dark-green metamorphosed basic igneous rock that owe their colour to the presence of chlorite, actinolite or epidote. Gold is found in associated magmatic intrusions. Source: USGS, 'Geologic Units Containing Greenstone', https://mrdata.usgs.gov/geology/state/sgmc-lith.php?text=greenstone

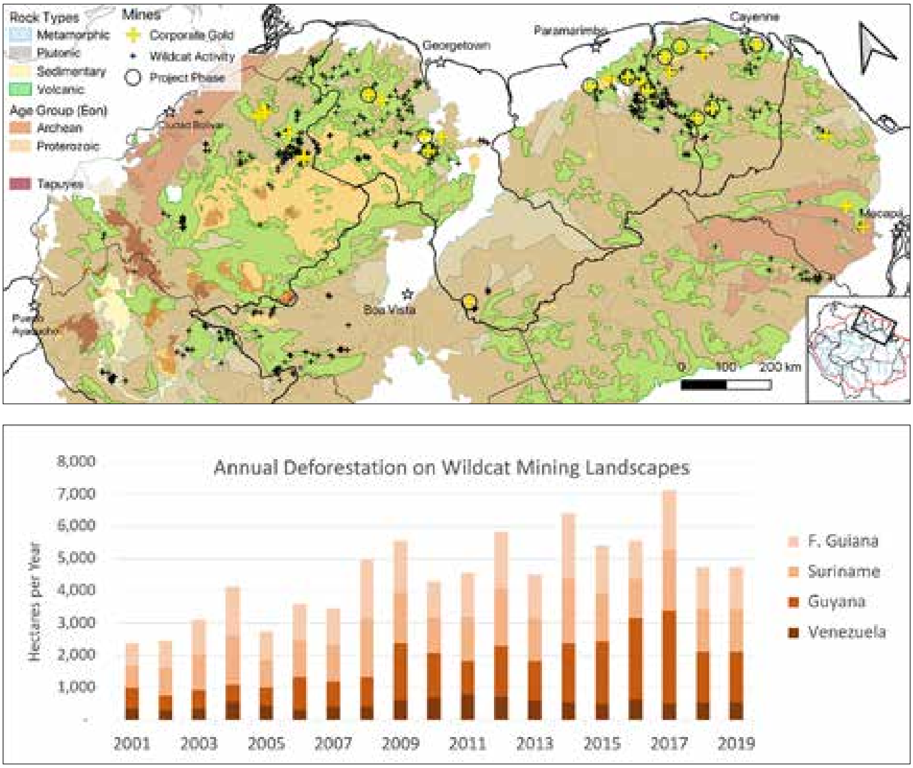

Figure 5.26: Top: The greenstone belt of the Guiana Shield is a discontinuous band of ultramafic volcanic rocks located within the Archean and Proterozoic formations of the Amazon Craton. They are the source of the extraordinarily rich gold deposits along the northern coast of the South American continent. Bottom: Annual rates of deforestation on wildcat mining landscapes in the jurisdictions of the Guiana Coast.

Data sources: Gomez Tania et al. (2019) and RAISG (2022).

mines. The mines were renationalised in 2008 by the government of Hugo Chavez and the companies, all domiciled in Canada, sued Venezuela for compensation in international courts.*

* The World Bank's International Centre for Settlement of Investment Disputes (ICSID) awarded Christalex US$1.2 billion (plus interest) and Rusoro US$2.2 billion. Rusoro is apparently controlled by Russian oligarchs and, allegedly, negotiated a settlement of US$1.28 billion. However, there is no evidence money was paid and both corporations are essentially bankrupt. Source: https://www.mining-technology.com/analysis/seizure-and-settlement-in-venezuela-the-story-of-rusoro-mining/

The administration of Nicolas Maduro has delegated the administration of the gold fields to the army, which controls dozens of joint ventures between the state-owned mining corporation (CVG Minerven) and private companies owned by politically influential individuals.[204] There are no large-scale open-pit operations and concessions are exploited using a combination of strip and underground mining technology. Large mines use cyanide and tank-leaching technology to concentrate the gold, while small miners use placer technology and mercury. The gold fields in Venezuela are characterised by thousands of poorly engineered tailings ponds.

In 2017 and 2018, the government reported production from all sources at 8.4 tonnes and 10.5 tonnes, respectively. However, an entity that tracks the international trade in gold bullion places that value at 23 and 26 tonnes.[205] Analysts associated with civil society groups estimate that Venezuelan miners produce about eighty tonnes per year, which would have a nominal value of ~US$ 42 billion.[206] The vast majority of gold leaves the country via clandestine routes, but it is not clear how much is exported by individuals and criminal gangs avoiding taxes and how much is due to the government seeking to avoid international sanctions.*

Guyana

Artisanal gold miners have long dominated gold mining in Guyana and, unlike other Amazonian countries, most operate as formal companies with legal concessions registered with the government. Nonetheless, thousands of small-scale miners work under informal agreements for the legally constituted mid-sized companies. Some middle-sized companies allegedly abuse these informal arrangements and expel their subcontractors if they discover a significant gold resource.[207] Despite the evident imperfections in the sector, the government has made a commitment to improve management via its concessionaires and to eliminate the use of mercury by 2025. The goal is to create a niche within the international market for jewellery and bullion that can be certified as sustainable.[208]

The first large-scale corporate investment in Guyana was the Omai open-pit mine, which operated between 1993 and 2005, despite a major disaster in 1997 caused by the failure of its tailings storage facility. The mine was shut when low gold prices made operations unprofitable (~US$500/oz), and may be reopened to exploit what are, apparently, still large gold reserves.[209] The rebirth of Omai is indicative of government policy to facilitate investment by foreign corporations. As of 2022, there were two industrial mines operating, one under construction and four in different

* The Treasury Department of the United States sanctioned CVG Minerven for organising and laundering trade in illicit gold in Venezuela as part of an integrated strategy to force political change in Venezuela. Source: https://home.treasury.gov/news/press-releases/sm631

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Wildcat miners in Guyana are largely registered with mining authorities. Nonetheless, they routinely violate environmental regulations that, theoretically, should mitigate and remediate the impact of their placer mining operations.

stages of development (Annex 5.3 and Annex 5.9). Total gold production in Guyana in 2020 was twenty tonnes per year (~US$1 billion) with about 65 per cent produced by the approximately 15,000 individuals who labour for domestic companies.[210] If all the industrial mines under development come to fruition, the country will produce in excess of forty tonnes of gold per year.

Suriname and French Guiana

Suriname has a gold mining sector not unlike Guyana. There are approximately 20,000 small-scale miners who produce about half the gold that is exported each year. Rather than a legalised system administered by the government, however, the gold fields are controlled by individuals of the Maroon* community who subcontract undocumented Brazilian *garimpeiros* to exploit surface gold deposits.[211] As in Guyana, investment in corporate mines has increased over the last decade; there are two active open-pit mines in operation and several more under development (Annex 5.9).

French Guiana shares the tradition of Maroon communities that dominate the small-scale mining sector, which likewise entails the participation of thousands of *garimpeiros*. The stable legal environment has attracted several corporate investors including both multinational giants and a French company seeking to open an industrial mine in a concession that once housed a placer mine (Annex 5.9).

Madre de Dios

One of the most remarkable placer gold fields in the world is found in the Andean piedmont in the department of Madre de Dios in southern Peru (Figure 5.27). Gold was discovered in the 1970s on the banks of the Huaypetue,† a small stream that empties into the Río Inambari, approximately twenty kilometres downstream from the narrow gorge where the Inambari exits the Andean foothills.‡ The current channel did not exist until a few tens of thousands of years ago, because it was blocked by a low ridge that deflected the main channel 90º west into the precursor of the Huaypetue. This diversion created a near-perfect sediment trap for the gold being carried out of the Andes. Eventually, the river eroded a channel through the outlying ridge and created a depositional plain south of Madre de Dios, creating a mega gold field that stretches from the Río Colorado (West) to the city of Puerto Maldonado.

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* The Maroons are a traditional people descended from escaped slaves who intermarried with Indigenous people in the eighteenth and nineteenth centuries (see Ch. 6).

† Pronounced ‘why-pay-two’.

‡ This Inambari gorge was the site for the 2,000 MW hydropower facility proposed by Alain Garcia and Luiz Inácio Lula da Silva in 2009, which was rejected by Peruvian society (see Ch. 2).

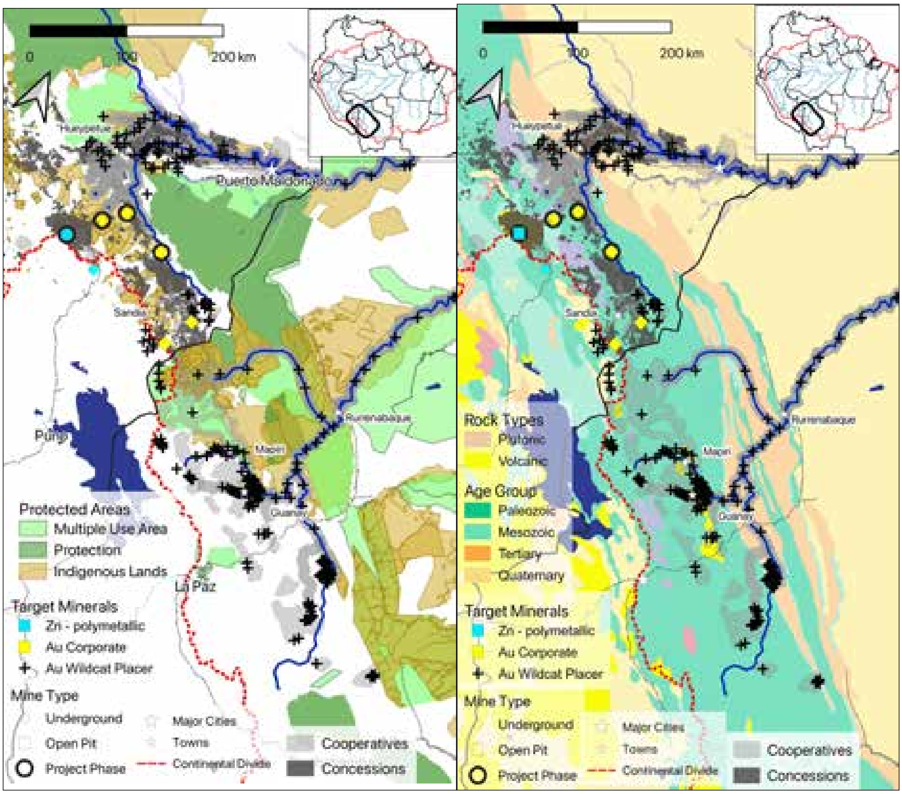
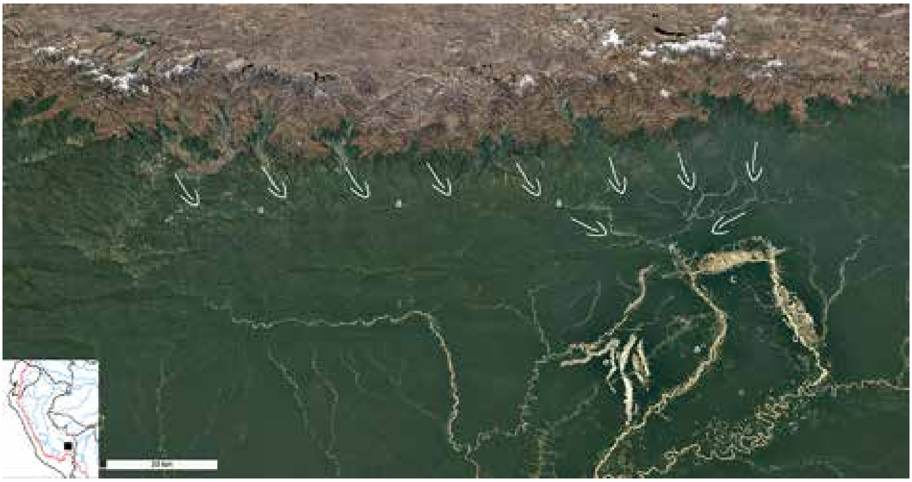


Figure 5.27: The gold mining landscapes of Southern Peru and the Bolivian Yungas. Left: Industrial and wildcat mines in the context of geological history. Right: Industrial and wildcat mines in the context of protected areas and indigenous lands.
Data sources: Gomez Tania et al. (2019), RAISG (2022) and MINEM (2020).

Enormous amounts of alluvial gold have been funnelled into the Inambari due to the tectonic peculiarities of the Altiplano and the climatic history of the Quaternary Period. The headwaters span a 260-kilometre swath of the Andean highlands that constitute the northern border of the Altiplano, which was formed by a process known as ‘crustal shortening’ where a section of the South American plate was chipped off (rather than subducted) and relocated on top of the South American plate. Essentially an exaggerated phase of the Andean orogeny, this phenomenon was associated with magmatism that created numerous gold-bearing ore bodies in the eastern cordillera.[212] Subsequently, this section of the Andes was completely



Google Earth

The upper Río Inambari (a) collects sediments from multiple tributaries that drain the Cordillera Oriental between the Cordillera de Apolobamba (b) and the Cordillera de Vilcanota (b′), where past glaciation released mineral gold from multiple ore bodies over several million years. The lower Inambari (a′) acts a funnel, which concentrated gold in the Huaypetue valley (c) where a low ridge once deflected the Inambari into adjacent drainages (d and e). Eventually, the river carved a channel through the Huaypetue ridge to create the lower Inambari (a″). The alluvial fan of the Inambari spans approximately 500,000 hectares and has estimated gold resources of approximately 2,500 tons.

Data source: OAS (2021).

glaciated during the Pleistocene, causing massive amounts of gold-bearing rocks to be pulverised and released into the Inambari watershed.*

Climate also played a role. This region is often referred to as the ‘Elbow of the Andes,’ because it is oriented west to east, rather than north to south, which ensures the Amazon-facing slopes experience exceptionally high levels of rain because they sit astride a low-level jet stream flowing along the base of the Andes.[213] Mean annual precipitation exceeds 10,000 mm per year, leading to high rates of erosion in the cloud forest section of the Inambari watershed where colluvial gold is associated with paleo-placers located within Tertiary conglomerates.[214]

In synthesis, the gold fields of the Madre de Dios are remarkable because they receive gold from multiple different primary sources and concentrate it in the sediments in the Huaypetue Valley and the adjacent

* On the other side of the continental divide is La Rinconada, a placer gold field of approximately the same dimensions as the Madre de Dios; together the two gold fields cover between 25% to 40% of Peru’s total gold production. Source: OAS 2021.

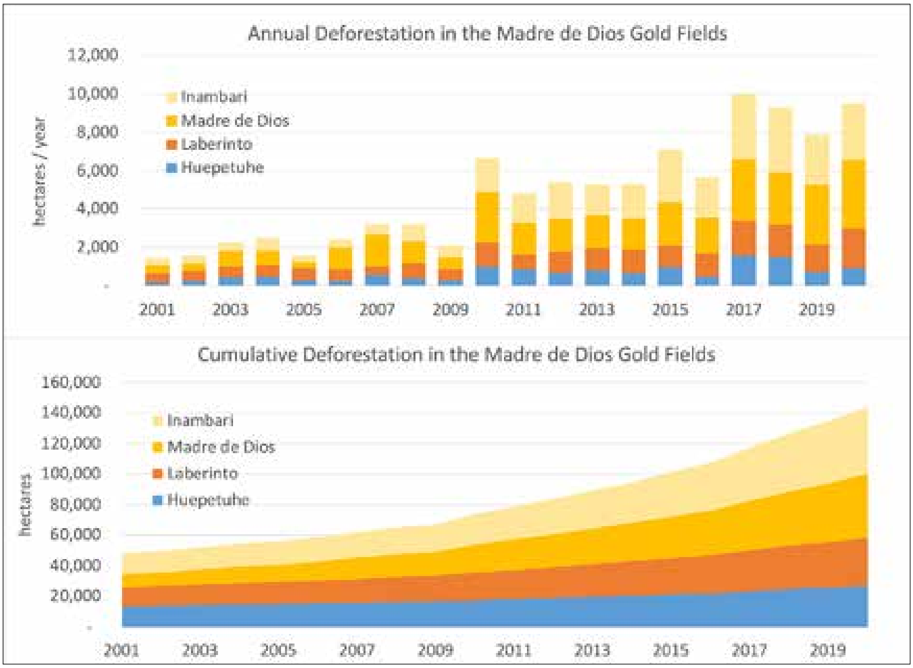


Figure 5.28: Top: Annual rates of deforestation in the three mining districts Madre de Dios (Peru). Bottom: Cumulative deforested area in the three mining districts Madre de Dios (Peru).

Data source: Geobosques (2020).

alluvial fan of the Río Inambari. There is no published estimate of total gold reserves in Madre de Dios, but the alluvial fan covers about 500,000 hectares and if the average gold concentration is 5 kg/ha,* then the region should have contained about 2,500 tonnes of gold.[215] Assuming miners have exploited the richest deposits, then perhaps half of that total has been extracted, which would value the remaining reserves at ~US$75 billion, a conservative estimate.

By 2020, the total area of placer-mine tailings in Madre de Dios exceeded 150,000 hectares with annual increments that vary between 4,000 and 10,000 hectares (Figure 5.28).[216] Estimates of the amount of gold extracted from the region range between 15 and 35 tonnes per year, which translates into equally imprecise estimates of gross revenues between ~US$500 million in 2015 to more than US$1.6 billion in 2019. Placer gold mining is the most

* Based on the 50% share of estimated annual gold production (OAS 2021) and mean annual deforestation for the three gold mining districts in Madre de Dios (Geobosque 2022).

important economic activity in southeast Peru. By way of comparison, the nearby coca fields in the cloud-forest region generated between US$60 and $US100 million annually over the same period, while the total value for legal farming is a mere US$4 million per year.* The estimated number of individuals working or providing services to the gold fields varies between 50,000 and 75,000.[217]

The government initiated an effort to establish a legal and regulatory presence in 2014 with the creation of the *Fiscalía Especializada en Materia Ambiental* (FEMA), which are prosecutors charged with enforcing environmental law. As in Brazil, they work via periodic 'law and order' campaigns that mobilise multi-agency task forces, which also include environmental agents, police and the military. The first campaign in 2015 destroyed 86 mining camps that had encroached upon the Tambopata y Amarakaeri protected areas.[218] This was followed by the *Operación Harpia* in 2018 to collect data and display their technological prowess;[219] and the *Operación Mercurio*, which expelled 25,000 miners from Tambopata Reserve in 2019.[220] Subsequent efforts by wildcat miners to invade the reserve have been similarly shut down and included the confiscation and destruction of their machinery and vehicles.[221]

Authorities are less inclined to confront illegal mining on public lands not located within a protected area. They have started collecting royalties, however, and in 2020 the ministry for mines and energy reported that 245 concessionaires produced 1.1 tonnes of gold, up from about 500,000 kilograms in 2015 and 10,000 kilograms 2011.[222] Although greatly improved, these numbers represent less than five per cent of the estimated production from the Madre de Dios.

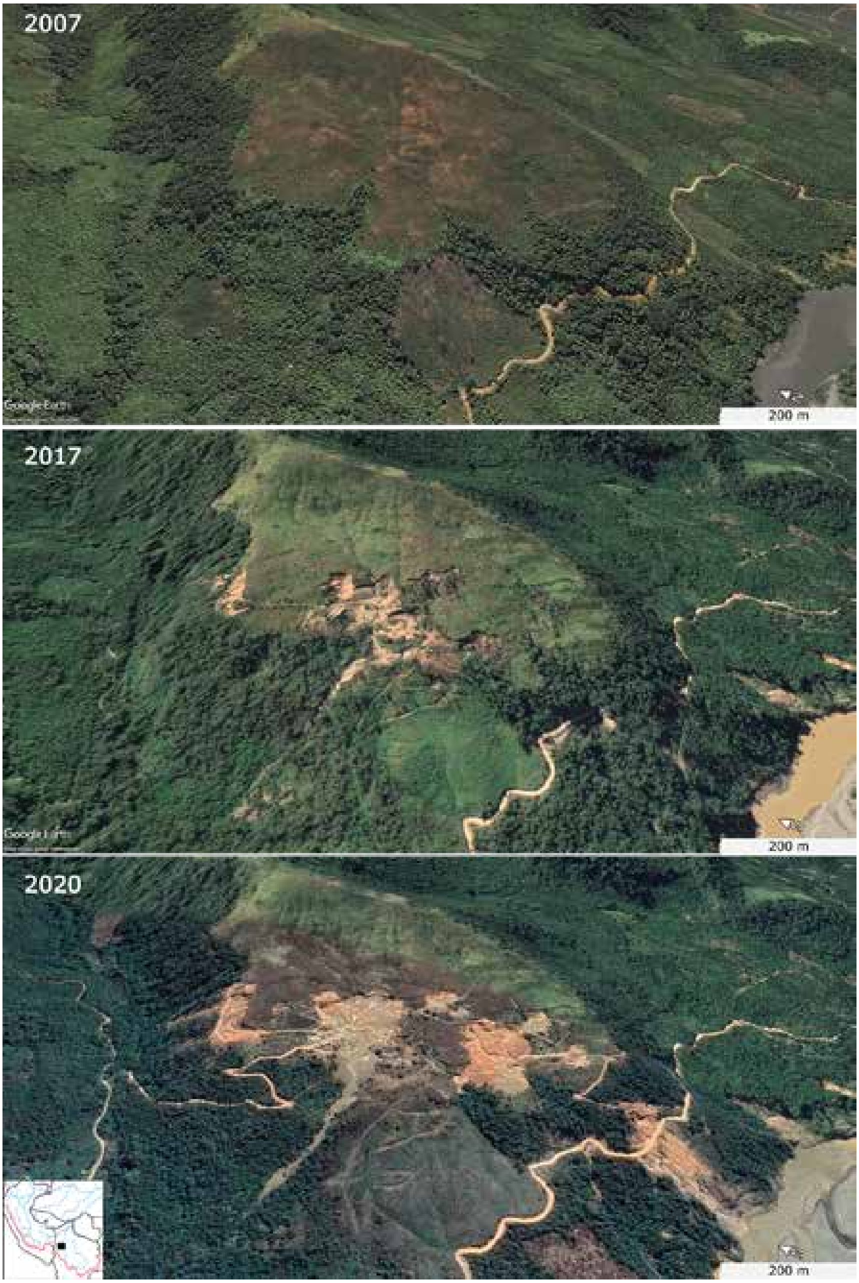
The La Paz Yungas and the Río Beni

The gold fields of the Bolivian Yungas are similar to the Inambari system.† They are linked to primary magmatic intrusions located in glaciated terrain of the Cordillera Real and paleo-placer deposits in the foothills.[223] Gold has been mined in the foothills for decades, but a gold rush has exploded across the intermontane valleys that have functioned as logistical corridors between the Altiplano and the Amazon lowlands since before the Inca Empire. The Yungas is traditionally divided into two subregions: Nor Yungas and Sur Yungas, each of which are drained by half a dozen rivers that all feed into the Río Beni, which, like the Inambari, exits the Andes through a narrow gorge.‡

* Includes the cultivation of maize, rice, cocoas, coffee and cattle.

† The Quechua and Aymara languages use the term Yungas to describe the humid valleys of the eastern Andes.

‡ Also, like the Iñapari, this gorge is the proposed site of 2.5 GW hydropower facility (see Ch. 2).



Google Earth

In the La Paz Yungas of Bolivia, wildcat miners use high-pressure hoses to strip way the overburden and expose gold bearing deposits using standard placer technology. Because of topographic shade and the preexisting abundance of non-forest land cover, most of this mining is not being captured by remote sensing monitoring initiatives.

Apparently, the depositional landscape of the alluvial plain created by the Río Beni is not conducive to the formation of a sediment trap and, as of 2022, placer mining below the gorge has been limited to dredges mounted on barges. The use of dredges was introduced into Bolivia from Brazil in the 1980s and, in addition to the Río Beni, are a common sight on the Madre de Dios, as well as the Orton and Manuripi rivers, both of which are paleochannels of the Madre de Dios.

The Bolivian gold-mining industry is almost completely dominated by miners operating as cooperatives.* However, the use of this identifier disguises a sector that is actually dominated by unscrupulous individuals who use the associative framework to avoid the labour and environmental regulations applied to the private sector. The sector is highly decentralised and democratically organised: an estimated 140,000 miners are employed by 1,300 cooperative-affiliated enterprises that are incorporated into four separate federations.[224] Altogether they produce 94 per cent of Bolivia's gold; 76 per cent originating in the Yungas of La Paz and 21 per cent from the dredge barge operations in the department of the Beni and Pando.[225]

Starting in about 2010, the government and the mining cooperatives organised a process to register miners and collect mineral royalties, which are returned to local governments to finance infrastructure and basic services. The devolution of royalties explains, in part, the willingness to report production values that obligate them to pay the four per cent royalty tax. Nonetheless, the system continues to tolerate other forms of tax evasion and ignores environmental regulations. Despite numerous commitments to control the importation and use of mercury, the government has failed to act because authorities are reluctant to antagonise a group of highly organised and militant cooperative miners.[226] Like other mining landscapes across the Pan Amazon, murder, extortion and armed robbery are common, as are multiple different forms of social and labour exploitation.[227]

In 2021, the Bolivian mining ministry reported production of 45 tonnes of gold with an estimated value of US$ 2.5 billion, up from two tonnes and US$94 million in 2010 (Figure 5.29). Bolivia's economy benefited from the formalisation of gold exports by creating a significant new source of foreign exchange at a time when the country's balance of payments was suffering from a decline in revenues from the export of natural gas (see below).[228] It is unlikely, however, that 100 per cent of the gold harvest is being reported to authorities and independent analysts estimate that as much as fifty per cent of the gold produced in Bolivia is sold via intermediaries from Peru.[229]

* Federación Regional de Cooperativas Mineras Auríferas (Ferreco), Federación de Cooperativas Mineras Auríferas del Norte de La Paz (Fecoman) and the Federación Departamental de Cooperativas Mineras (Fedecomin).

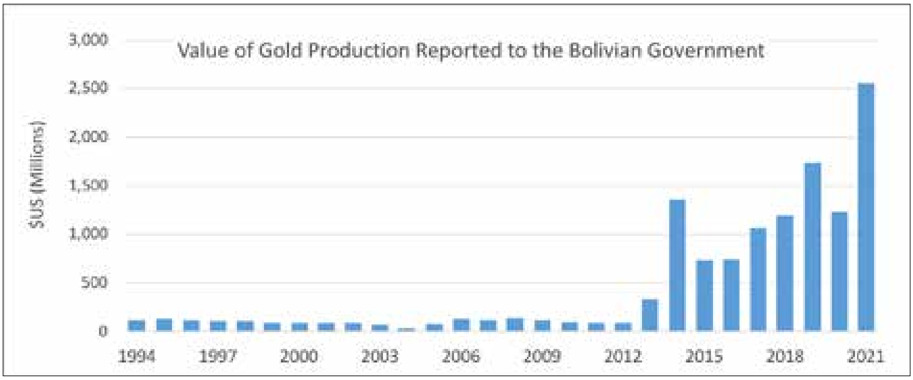


Figure 5.29: Wildcat miners have been active in the Bolivian Yungas for at least four decades but the government only began to obligate miners to report their production and pay royalty taxes since about 2014.

Data source: MMM (2022).

The Alto Marañon

There are multiple reports in the Peruvian press about illegal gold mining in the highlands and valleys of the Andes, particularly in the upper valley of the Río Marañon where gold mining has existed since before the Inca empire. The most heavily impacted section is a 100-kilometre stretch in the department of La Libertad* where miners have exploited gold veins using underground and surface mining technology for about 100 years.[230] In 2022, three Peruvian companies were operating several underground mines with others under development; they produced ~20 tonnes of gold with a nominal value of US$1 billion in 2022. Known as the Pataz mining district, it has numerous environmental liabilities, including eroded hillsides scarred by hydraulic mining, abandoned placer tailings, and cyanide-laced tailing storage facilities and leaching pads (Figure 5.30)

The Alto Marañón drains both the Cordillera Oriental, the source of most of its water, and the Cordillera Occidental, which is home to six massive open-pit gold mines that have initiated operations after 2005. All apply the heap-leach concentration technology that minimises the use of water and avoids the use of tailings ponds. Their production sums to about ten tonnes of gold, and they will probably operate for a couple of more decades by opening other pits in adjacent ore bodies and expanding via brownfield investments.

* Libertad is a coastal department (region) that is not included within Amazonian statistics, but its easternmost border incorporates approximately 175 kilometres of the Marañon River.

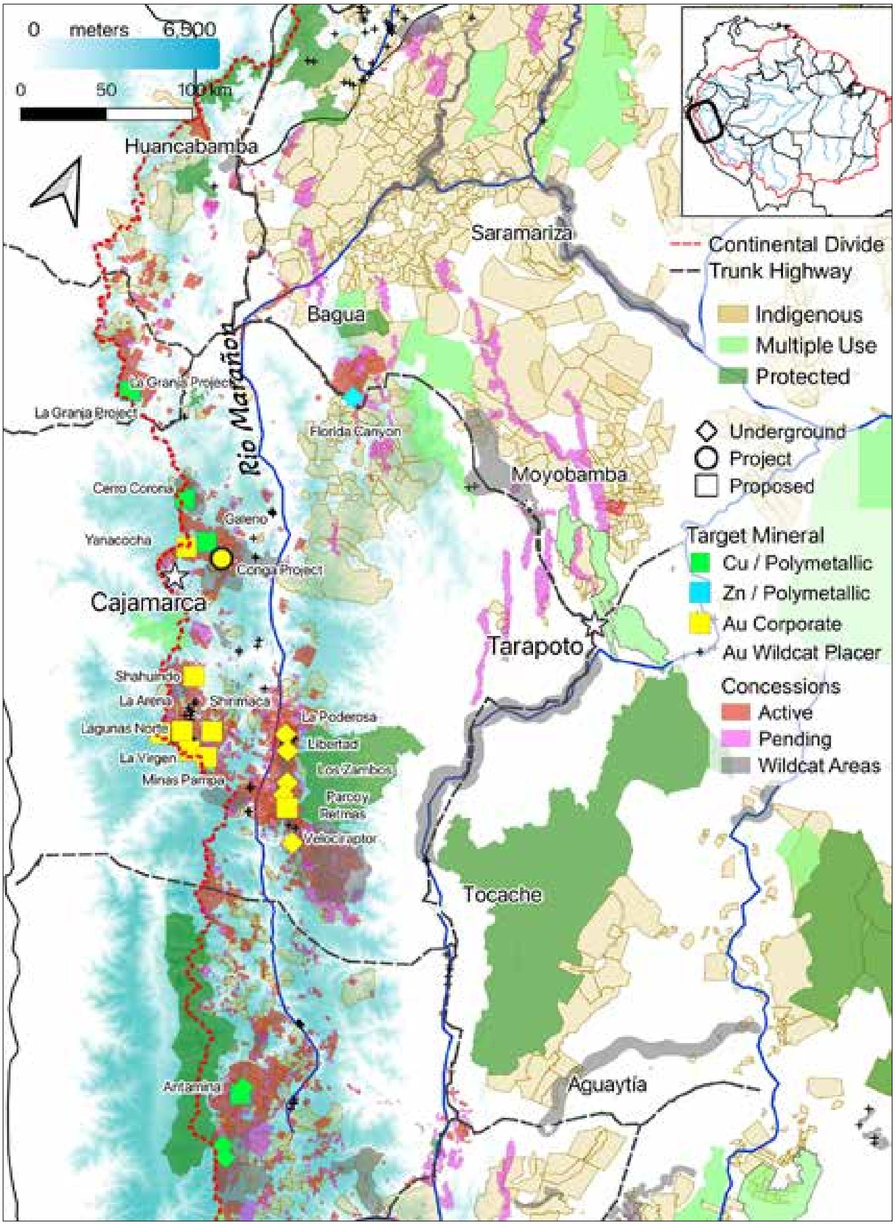


Figure 5.30: The Alto Marañon is a centre of Peru's formal gold industry. It includes massive open-pit mines located near the continental divide in the Cordillera Occidental and underground mines located on the lower slopes of the Marañon valley. Several of the open-pit mines are associated with copper-bearing ore bodies that are attracting the interest of corporate miners.

Data source: MINEM (2022).

Further north in Cajamarca is Yanacocha, the largest and most lucrative corporate gold mine in Peru, which has produced more than 1,200 tonnes of gold and 950 tonnes of silver over its thirty-year lifespan. The mine complex, which ceased operations in 2021, encompasses seven open pits, surrounded by hillocks composed of waste rock and tailing heaps that cover more than 3,000 hectares. The operator, Newmont Corporation,* had hoped to open a second facility on a nearby mountain (Conga Project); however, opposition by communities forced the company to abandon those plans.[231] Apparently, the US$1.2 billion spent on community development and the 1,600 jobs was insufficient to convince the region's inhabitants that a second similar mine would benefit the region. Although the gold-mining operation has closed, reclamation efforts are still underway with at least 5,000 hectares of area scheduled for some sort of active remediation.[232] Newmont is evaluating the feasibility of exploiting two copper-ore bodies with an underground mine, which could prolong operations for another 20 years.[233]

Cordillera del Condor and the Northern Andes

The Río Marañón also receives runoff from the Cordillera del Condor, a unique mountain range on the border between Ecuador and Peru that is home to a surprising number of endemic plants and animals.[234] The area was sheltered from development throughout most of the twentieth century due to a border conflict between the two countries. Upon resolution of that dispute, the area became the focus of conservation advocates and geological prospectors attracted by the region's mineral resources. Much of the area has been set aside as a protected area or Indigenous territory, but there are still large areas open to mining, particularly in Ecuador where multinational corporate miners are investing in both copper and gold mines (see Figure 5.20).

In Ecuador there are two dedicated gold mines: Fruta del Norte, which has been operating since 2015, and the Condor Project, which is still at the development stage. Together, they hold an estimated 320 tonnes of gold with a nominal value of about US$16 billion in 2022. In addition, several copper mines are operating (one) or under development (five); all six will produce significant amounts of gold (Annex 5.7). All are located on the western slope of the Cordillera del Condor where wildcat miners have exploited alluvial gold in the headwaters of the Río Zamora, a tributary of the Rio Santiago since about 2010.

* In 2022, Newmont Corporation (USA) bought out their long-standing partners, Sumitomo Corp (Japan) and Buenaventura. Source: Newmont Corporation. 2022: https://www.newmont.com/investors/news-release/news-details/2022/Newmont-Announces-Acquisition-of-Buenaventuras-Stake-in-Yanacocha/default.aspx

Nearby on the cloud forest slopes of the Andean Cordillera, is the Nambija gold district, a historical site dating from the Inca empire. An old Spanish mine was rediscovered in the 1980s, triggering a 'gold rush' when 25,000 wildcat miners poured into the area seeking their fortunes at one of 75 different mine sites. Chaos and *ad hoc* engineering led to an avalanche that killed 300 miners in 2000, while leaving a legacy of unstable underground mines and unremediated tailings heaps that are laced with mercury.[235] The area continues to be a locus for dozens of small and medium-scale mines, which are operated by domestic companies that are, apparently, registered with national mining authorities. Downstream, the Santiago flows north until it exits the cordillera through a narrow gorge and then back south into Peru where wildcat miners have been active since about 2016.

Wildcat miners also have been reported on the Río Cenepa, a tributary of the Marañón that drains the eastern slope of the Cordillera del Condor, where 39 placer mines were exploiting the river bed and adjacent beaches in 2021. This part of Peru falls within the territory of the Awajún, a well-organised Indigenous nation whose representative organisations have denounced the illegal activity. Not all Awajún are opposed to the activity, however, and many of the miners, perhaps most, are residents who view placer mining as a legitimate economic activity that can generate resources for the families.[236]

Both Ecuador and Colombia are renowned for their volcanos, and gold is commonly found associated with volcanic rocks. With the exception of Nambija, there are no industrial-scale mines operating on the Amazonian slopes of the Cordillera Oriental in either country – yet; nonetheless, there is undoubtedly gold in those mountains, otherwise there is no reasonable explanation for the alluvial gold that has been discovered (and exploited) on the floodplains of the Napo, Putumayo and Caquetá rivers. Further evidence is being gathered by corporate miners exploring copper porphyries in Mocoa Colombia and the Bonito project in Succumbios, Ecuador.

The Geography of Oil and Gas

Petroleum geologists explore for economically significant reservoirs of oil and gas using technologies that have evolved in sophistication as the industry grew to dominate the global economy in the twentieth century. They begin with geological surveys that identify the various rock formations that lie within, underneath or adjacent to a sedimentary basin capable of holding oil and gas reserves. Next, they conduct seismic surveys to create a three-dimensional image of the underground landscape that is augmented with data from magnetic and gravitational instruments. They process data using super computers and artificial intelligence to discover and describe what is referred to as a 'Total Petroleum System'.

This integrated analysis identifies the potential 'source rocks' with organic compounds that are the raw material of fossil fuels and unravels the tectonic history that provided the 'maturation forces' (heat and pressure) necessary to convert carbon-rich molecules into oil and gas. The methodological framework also identifies a pathway for hydrocarbons, which are buoyant, to 'migrate' through porous sedimentary rocks until they are contained by an impermeable rock layer that functions as a 'trap' where oil and gas accumulate to create a 'reservoir.' The methodological rigour required to develop a Total Petroleum System greatly improves the probability of discovering an economically significant hydrocarbon reserve. It remains a hypothesis, however, until an exploratory well verifies the existence of oil and/or natural gas.

Seismic surveys are first conducted at large scales using two-dimensional images collected along widely spaced transects; these are followed by higher-density studies that provide a three-dimensional image of the subterranean landscape. Most exploratory wells are so-called dry holes, but if they 'strike' oil or gas, then multiple (sometimes dozens of) production wells are drilled to exploit the resource. The whole process will span, at a minimum, a decade and demands the expenditure of hundreds of millions of dollars that may, or may not, yield a financial return.

There are several major sedimentary basins within the Amazon (Figure 5.17), but only five are actively being exploited for oil or gas.[237] Most are located along the margins of the Amazon Craton, but there are two in the middle of the continent associated with Paleozoic shales in the Amazon Rift Valley.[238] Currently, all the oil fields under active exploitation are conventional reserves, but the growing market for natural gas has motivated geologists to identify shales* that could be exploited using hydraulic fracking technology.[239]

Putumayo – Oriente – Marañón (POM) Basin†

The largest and oldest of the Amazonian oil fields is located in a sizeable sediment basin in the Western Amazon, which stretches from Southern Colombia (Putumayo sub-basin), across Eastern Ecuador (Oriente sub-basin) and into Northern Peru (Marañón sub-basin). Most of the reservoirs are located in Mesozoic sandstones overlying Paleozoic shales that are situated on top of the basement rocks of the Amazon Craton[240] Approximately eight

* Shale is a fine-grain sedimentary rock that is viewed as a source rock in a classic Total Petroleum System. Some shales can be exploited using hydraulic fracking, which creates millions of micro-cavities that accumulate 'shale gas', thus making shale both a source and reservoir of natural gas. Source: Environmental and Energy Study Institute, https://www.eesi.org/files/fracking_products_120111.pdf

† The name used by geologists combines the names given to each sub-basin in each country. Source: USGS (Higley 2001).

billion barrels of oil have been pumped out of the ground since Texaco drilled the first wells in Ecuador and Colombia in the 1960s and Occidental Petroleum in Peru in the early 1970s. More importantly, these two companies commissioned the construction of three roughly parallel pipelines that are the foundation of the oil industry: *Oleoducto Transandino Colombiano* (OTC) in 1969, *Oleoducto Norperuano* (ONP) in 1977 and *the Sistema de Oleoducto Transecuatoriano* (SOTE) in 1972. Texaco and Occidental surrendered their concessions in the 1990s, but they left behind an entrenched system operated and supervised by state-owned oil companies.[*]

Exploitation in the POM basin focuses exclusively on petroleum because fields do not yield sufficient volumes of natural gas to justify the investment in a gas pipeline.[241] Consequently, gas is either used locally to generate electricity, flared or re-injected. The areas under exploitation have declined over most of the last two decades. Nonetheless, the basin retains significant reserves of oil (Annex 5.10). The value of the oil extracted from the POM was approximately US$10 billion in 2020, but was twice that amount for most of the years between 2005 and 2015. All three countries (Colombia, Ecuador and Peru) are making a concerted effort to expand and prolong the productive life of an asset with a nominal value of ~US$200 billion. Investment is constrained by social pressure, particularly from Indigenous groups exasperated by the poor environmental performance of past and current operators.

The Marañón Sub-Basin – Peru

Located in the Department of Loreto, the Marañón sub-basin was the primary source of oil in Peru between 1980 and 2005. The seven blocks currently under contract have oil reserves of 156 million barrels with another five blocks in different stages of exploration.[†] An additional 25 blocks, covering more than ten million hectares are available for exploration, but social conflicts have limited interest in the public auctions that are organised periodically by Perupetro (Figure 5.31). The total reserves are estimated to exceed 500 million barrels of oil, which would have a nominal value of between US$50

[*] The corporate structure of these entities has changed over time. As of 2022, Peru: Petroperú operates strategic infrastructure such as pipelines, refineries and distribution networks, while Perupetro oversees the concessionaire system, which is dominated by the private sector; Ecuador: Petroecuador is a vertically integrated company that operates most of the concessions in the Amazon and one of two major oil pipelines, while the Viceministerio de Hidrocarburos (Ministerio de Energía y Minas) oversees the disposition of a limited number of concessions to the private sector; Colombia: Ecopetrol is a vertically integrated oil company with multiple subsidiaries, while the concessionaire system is managed by the Agencia Nacional de Hidrocarburos.

[†] Operating: Pluspetrol, Perenco Peru, Pacific Stratus, and Gran Tierra Energy; Exploration: Gran Tierra Energy, Repsol, Pacific Stratus, Perenco Peru. Source: https://www.perupetro.com.pe/

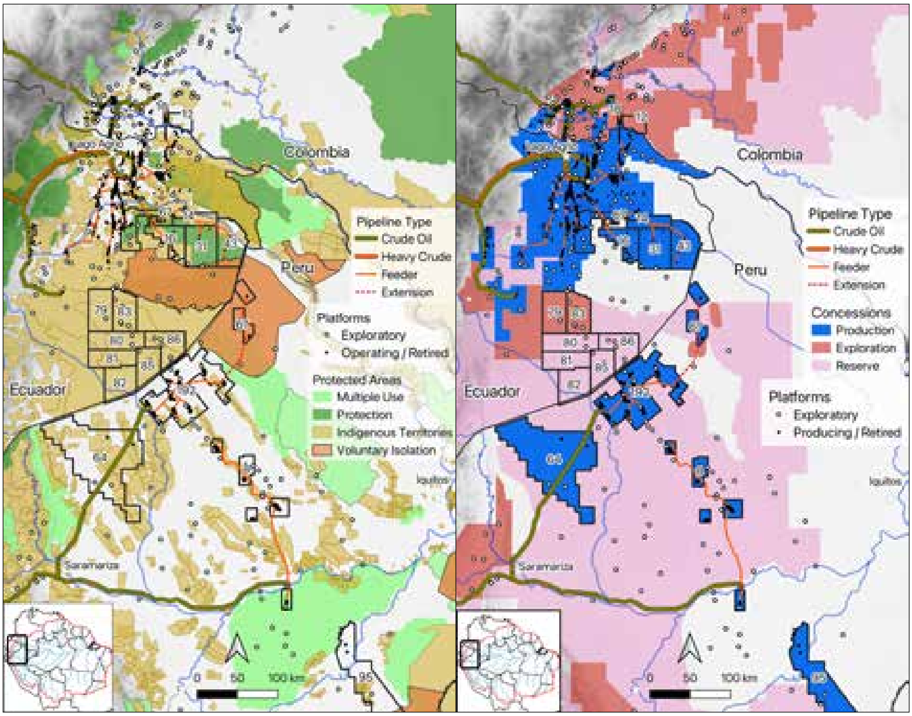


Figure 5.31: The most important sedimentary basin in the Amazon includes oil fields referred to as the Putumayo (Colombia), Oriente (Ecuador) and Marañon (Peru). Each nation constructed pipelines and logistical facilities to support hundreds of wells. Ecuador was the most successful operator and has extracted an estimated 6.6 billion barrels over the 40-year lifespan of its facilities. The most conflictive concessions are highlighted, as are the five Ecuadorian blocks with the greatest potential for discovering oil and generating conflict if they are developed (80, 81, 82, 85, 86).

Data source: Codato et al. (2022).

and US$100 billion.* Despite its potential, exploratory interest peaked in the 1970s when ~20 exploratory wells were drilled annually, but the number of wells declined subsequently with an average of only three per year between 1990 and 2010. There has been no exploratory activity since 2015.

Declining production is reflected in the volume of crude oil transported by the Oleoducto Norperuano. It was designed to transport up to 500,000 barrels per day (bpd), but at no time has it moved more than 160,000 bpd (1980–1985) when the two largest fields, Lote 192 and Lote 8, were at peak

* Total reserves include 'proven', 'probable', 'possible', and 'resources'. The price of oil has fluctuated between US$60 and US$120 per barrel in 2022 due to the disruption of oil markets caused by the war in Ukraine.

production. Pipeline flows declined linearly to less than 40,000 bpd in 2016 when a catastrophic failure caused the government to close the pipeline for repairs (see below). Operations were renewed in 2017, but volumes have not exceeded 20,000 bpd.

Underutilisation of the pipeline has contributed to its physical deterioration. Low revenues have caused Petroperú to underinvest in maintenance, while air in the pipeline has created an environment conducive to oxidation. The physical deterioration of the pipeline, and the subsequent oil spills, has exacerbated the social conflict of communities, who complain of the impacts caused by inadequate remediation of previous incidents during the 45-year lifetime of this ageing infrastructure asset. This has created a negative feedback loop that now plagues Peru's efforts to promote investment in the region. In the 2000s, major oil companies lost interest in the region, but they were replaced by second-tier companies, many privately owned, who are less exposed to the negative publicity that accompanies investment in the Amazon. Even these companies, however, are losing interest in the region.

There are two legacy concessions and both are beset with difficulties: Lote 192 and Lote 8 were operated by PlusPetrol Norte* from 1996 to 2015, but an extended legal dispute with the environmental regulator (Organismo de Evaluación y Fiscalización Ambiental – OEFA) caused PlusPetrol to abandon the Marañón sub-basin and to liquidate its subsidiary in an attempt to evade legal liability for forty years of poor environmental management.[242] Both concessions will be operated by Petroperú over the near term, presumably by service providers working as contractors.[243] Production in the two areas has fallen from about 25,000 bpd in 2015 to less than 3,000 bpd in 2020. The proven reserves are reported at ~80 million barrels.[244]

There have been three greenfield discoveries. One is located in Lote 64 where seismic and exploratory wells predict a reservoir with 160 million barrels of crude oil. Two companies have taken and abandoned the concession due, in part, to their inability to obtain a FPIC agreement with Indigenous organisations.† Perupetro insists the resource will be developed and has delegated the task to Petroperú. Apparently, the two state-owned companies are confident they can reach FPIC agreements with individual Indigenous communities, regardless of the opposition from their umbrella

* PlusPetrol Norte is a subsidiary of PlusPetrol Resources that was declared insolvent in 2020 by the holding company and its partner in the joint venture, the China National Petroleum Corporation. Source: https://www.bnamericas.com/en/company-profile/pluspetrol-norte-sa

† The companies are Talisman (Canada) and GeoPark (Colombian/Chilean). The Indigenous groups represent both Ashuar and Awajún communities. Source: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/oil/121621-petroperu-to-restart-200000-bd-oil-pipeline-following-settlement-with-protesters-official

organisations (see Chapter 11). In the meantime, however, there is no production from Lote 64.

A similar, but quite different, issue has impeded the development of Lotes 39 and 67, which are being developed by Perenco, an Anglo-French independent that discovered an ~200-million-barrel reserve between the Napo and Tigre rivers near the Ecuadorian frontier. The company has plans to establish eighteen drilling platforms that would sink 200 wells, requiring the construction of a 200-kilometre feeder pipeline to connect with the Oleoducto Norperuano. Development at this scale would produce about 100,000 bpd and provide the Oleoducto Norperuano with sufficient volume to justify continued operations, while generating between US$2.5 and 3.5 billion in annual revenues.[245] The uncertainty in its future operations stems from evidence that the area is home to a group of Indigenous people living in voluntary isolation.* A proposal to create an Indigenous territory was first tendered in 2003 and passed an important milestone in July 2017 when the Ministry of Culture approved the content of a study verifying the existence of a population of uncontacted Indigenous groups. Perenco asserts that the tribe does not actually exist and has filed an injunction to impede the establishment of an Indigenous reserve.[246]

The only discovery moving forward is Lote 95, which has been a site of interest since an exploratory well revealed the presence of oil in 1974. Exploration was initiated in 2005 in a joint venture by companies specialising in high-risk projects in Latin America. They eventually sold their project in 2017 to PetroTal, a Peruvian company that was incorporated to develop this and other resources being abandoned by international oil companies. Lote 95 would appear to be a small reserve (20 million barrels) that the company will exploit using thirteen wells to produce 20,000 bpd by 2025.[247] At that rate the proven reserves will be exhausted in a little more than a decade, while generating between US$500 and US$750 million in gross revenues. PetroTal has developed multiple logistical pathways for exporting its oil, all of which depend on barge transport. Some of the production will go to the refinery in Iquitos, but the lion's share will be shipped to the river terminal that connects to the Oleoducto Norperuano or exported to refineries in Manaus, Brazil.

Despite its progress in moving the project to production and commercialisation, the operators of Lote 95 have not been immune to social conflict. The production platform is located on land occupied by a community of the Kukama Kukamiria ethnic group, who filed an (as yet) unsuccessful formal territorial claim in 2013. The company and the community remain

* The claims are supported by 172 testimonios (witness accounts of campsites and sightings) and a photograph taken from a small airplane in 2019. Source: http://www.orpio.org.pe/orpio-presenta-nuevas-evidencias-para-el-reconocimiento-de-la-reserva-indigena-napo-tigre/

in conflict and, apparently, the community itself is divided regarding the benefits from the company's operations, which include a compensation fund. The conflict led to violence in 2020 when police officers assigned to provide security shot and killed a protestor.[248]

Iquitos, the regional capital, is a major logistical staging area for the oil industry. It hosts a small refinery and several service companies that provide services to the oil and gas sector, particularly in the transportation subsector, which connects the refinery to population centres such as Pucallpa and Yurimaguas in Peru, but also Leticia in Colombia and Tabatinga in Brazil. The regional government, once heavily dependent upon oil royalties (*Canon Petrolero*), is very supportive of the industry.

The Oriente Sub-Basin – Ecuador

Ecuador has enjoyed considerably more success in discovering and developing Amazonian oil resources, but has also underutilised the capacity of its pipeline infrastructure. Annual production doubled from ~200,000 in 1980 to ~300,000 bpd in 1991 when Petroecuador[*] assumed operational control of the Texaco concessions. Production approached the maximum transport capacity in 2000 when it reached 350,000 bpd, as new discoveries by private companies were yielding a type of petroleum that was classified as 'extra heavy'.

As the name implies, the molecular composition of this type of petroleum makes it more difficult to transport, which Petroecuador manages by mixing the heavy oil with lighter crude to pump via the *Sistema del Oleoducto Trans Ecuatorian* (SOTE). This became more problematic as the proportion of heavy crude increased and, in 2001, the private companies formed a joint venture to build and operate a second pipeline: the *Oleoducto de Crudos Pesados* (OCP).[†] It was financed by loans from multilateral agencies[‡] and essentially doubled the country's capacity to transport its Amazonian oil to its refinery and export terminal on the Pacific coast.

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[*] The company was first incorporated as Corporación Estatal Petrolera Ecuatoriana (CEPE) and was subsequently restructured as Empresa Estatal Petróleos del Ecuador (Petroecuador) when it became the country's largest producer after Texaco ceased operation in 1991. It was restructured again as the Empresa Pública Petroecuador (EP Petroecuador).

[†] The owners of the OCP have changed over time as companies bought and sold their Ecuadorian assets. In 2022 the owners were China National Petroleum (19.5%), China Petrochemical (16.32%), Repsol (29.6%), Pampa Energia (15.9%) Occidental (14.2%) and Perenco (4.02%); source: Offshore Technology (1 Aug. 2022), https://www.offshore-technology.com/marketdata/oleoducto-de-crudos-pesados-oil-pipeline-ecuador/

[‡] Construction costs for the OCP were financed by loans from the World Bank ($US 425 million) and the Inter-American Development Bank ($US 625 million). Source: Global Energy Monitor, https://www.gem.wiki/Crudos_Pesados_Oil_Pipeline

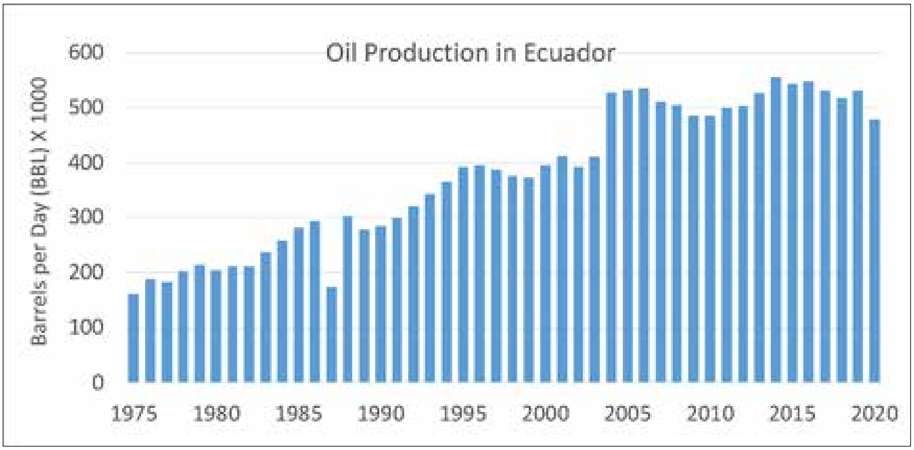

Figure 5.32: Ecuador has successfully increased production over more than four decades. Although it has enlisted investments from the private sector, more than 80% of its current production is managed by the state-owned oil company Petroecuador. Data source: CountryEconomy.com (2022).

By 2015, production had increased to 471,000 bpd, of which about eighty per cent was produced by Petroecuador and twenty per cent by private companies (Figure 5.32).* Geologists estimate that only about half of the recoverable reserves have been exploited and, at current rates, the proven and probable reserves should last another 47 years.[249] If estimated 'resources' are located and verified, however, the oil industry in Amazonian Ecuador could function for another century.† Between 2013 and 2015, Ecuador invested between US$2.5 and US$3.5 billion annually in the exploration of new production, a figure that fell to about US$1.5 billion in 2020.[250] The government's goal is to increase production to 800,000 bpd by 2027.[251]

Ecuador's relations with the private sector have been fraught with legal and political uncertainty. Its legal battle with Texaco (now Chevron) over past environmental liabilities is just one example (see Chapter 7). It has also nationalised the operations of other well-known international corporations or unilaterally modified contracts causing some operators to abandon the country. Companies from China have acquired these operations

* In 2022 these numbered 15 companies, from: Ecuador (5), Argentina (2), China (2) Chile, Canada, Spain, United Kingdom and France. Source: Ministerio de Energía y Minas, https://www.recursosyenergia.gob.ec/mapa-de-bloques-e-infraestructura-petrolera-del-ecuador/

† The oil industry certifies 'reserves' as proven (1P), probable (2P) and possible (3P), but geologists also estimate potential 'resources' based on geology and statistical probability.

either directly by purchase or indirectly via a bidding process managed by the energy ministry. Reportedly, this is part of the government's strategy to amortise its US$18 billion debt with Chinese development banks.[252]

Despite the important role of private corporations and the state-owned companies from China, the largest developer of new fields is Petroecuador, which takes a lead role in exploration and expansion, particularly in controversial developments such as of Block 43, which is located on the northern edge of Yasuní National Park. [253] Also known as the *Ishpingo-Tambococha-Tiputini* (ITT) concession, the state-owned company continues to develop new production wells within the national park right up to the border of the *Zona Intangible*, an area that enjoys special status as both a protected area and Indigenous territory.[254]

Less media attention has focused on eight other blocks which overlap, or are adjacent to, Yasuní National Park. Totaling more than 1.5 million hectares, they are believed to have commercially exploitable oil fields.[255] The entire area is covered by primary forest and is home to dozens of Indigenous communities (see Figure 5.31). Two of these blocks (79 and 83) were awarded in 2016 to the Andes Petroleum Ecuador Ltd, a joint venture between China National Petroleum Corp (CNPC) and China Petrochemical Corp (SINOCHEM). However, the two companies abandoned the concessions when it became clear that the opposition by the Kichwa communities made the project unattractive, if not unviable.[256] The other six concessions (14, 16, 17, 31, 56, 67) have ongoing operations within either the park or Indigenous territories, a source of conflict with the government that is unlikely to be resolved.

Finally, there are an additional sixteen blocks in the provinces of Pastaza and Morona Santiago, referred to as the *Bloque Suroriental,* which have been held in reserve by the *Secretaria de Hidrocarburos*.[257] These concessions have long been viewed by the oil and gas sector as an expansion area that will, eventually, be made available via some sort of competitive bidding process. That process was put on hold by the administration of Guillermo Lasso in 2022, however, as part of a commitment to formalise the regulatory process so that it adequately reflects the principles of free prior and informed consent (see Figure 5.31).[258]

The Putumayo Sub-Basin – Colombia

Oil production of the Putumayo has reached only a fraction of its potential due to the lack of investment caused by the civil conflict that has long plagued the region. The sub-basin, which extends northward through Caquetá, has enormous potential with perhaps six million barrels of recoverable oil. Successive governments have made the development of this region a priority, but the decades-long civil conflict impeded investment and damaged critical infrastructure.* Presumably, this period in Colombia's development has ended, at least as it concerns the development of its energy assets.

There are currently eleven concessions operated by four companies.† However, an additional 49 blocks have been taken up by an additional eighteen companies.[259] Most of the oil reserves are believed to be a heavy crude similar to that found in Ecuador, and, in 2016, one of the four concessionaires built the *Oleoducto Binacional Ameriser* (OBA) to connect its fields in Colombia with the OCP pipeline just over the border in Ecuador. Like most of the regional pipelines, the OBA remains underutilised with only ~10 per cent of its capacity used in 2021. Nonetheless, its construction in 2016 demonstrates a belief that the region will eventually produce greater volumes of oil. The rest of the current production is transported over the Andes via the *Oleoducto Transandino Colombiano*, which is likewise vastly underutilised (~20 per cent of its capacity of 85,000 bpd).

Approximately, half of this exploration is taking place on previously deforested ranchland in Putumayo and adjacent areas of Caquetá with the remainder occurring in nearby natural forest.[260] Dozens of Indigenous communities exist in the area, including highland populations displaced by the civil war and lowland tribes inhabiting lands situated between the Putumayo and Caquetá rivers.‡ All have legal recourse to the FPIC protocols, which are enshrined in the Colombian constitution, and all of the oil companies purport to comply with these norms. Nonetheless, communities living near existing oil wells and logistical facilities have long accused companies and regulatory agencies of ignoring their complaints and associated demands for remediation.[261]

Ucayali Basin and the Camisea Megacampo

Further south in Peru, the Ucayali Basin occupies a broad stretch of the Andean foothills and adjacent piedmont. It is a foreland basin located between the Contaya Arch in the North and the Manu arch in the South.§ Its most significant component is the Camisea gas field, which was discovered by Shell Oil in the mid 1980s, as well as a half dozen smaller production wells near the town of Aguaytía.[262] Camisea is located in the extreme southern margin of the Ucayali Basin in a unique area where the juxtaposition of several thrust-and-fold belts led to the geological entrapment of extraor-

* The Oleoducto Transandino was the object of repeated acts of sabotage in 2014 and 2015. Source: https://crudotransparente.com/2019/09/18/en-torno-a-la-actividad-petrolera-en-el-putumayo-2016-2019/

† Amerisur Exploration Colombia (now Geopark), EcoPetrol, Emerald Energy PLC, Gran Tierra Energy.

‡ Siona, Cofán and Huitoto, Coreguaje.

§ Arches are high spots in the basement rocks of the Amazon Craton that separate the various sediment basins from one another.

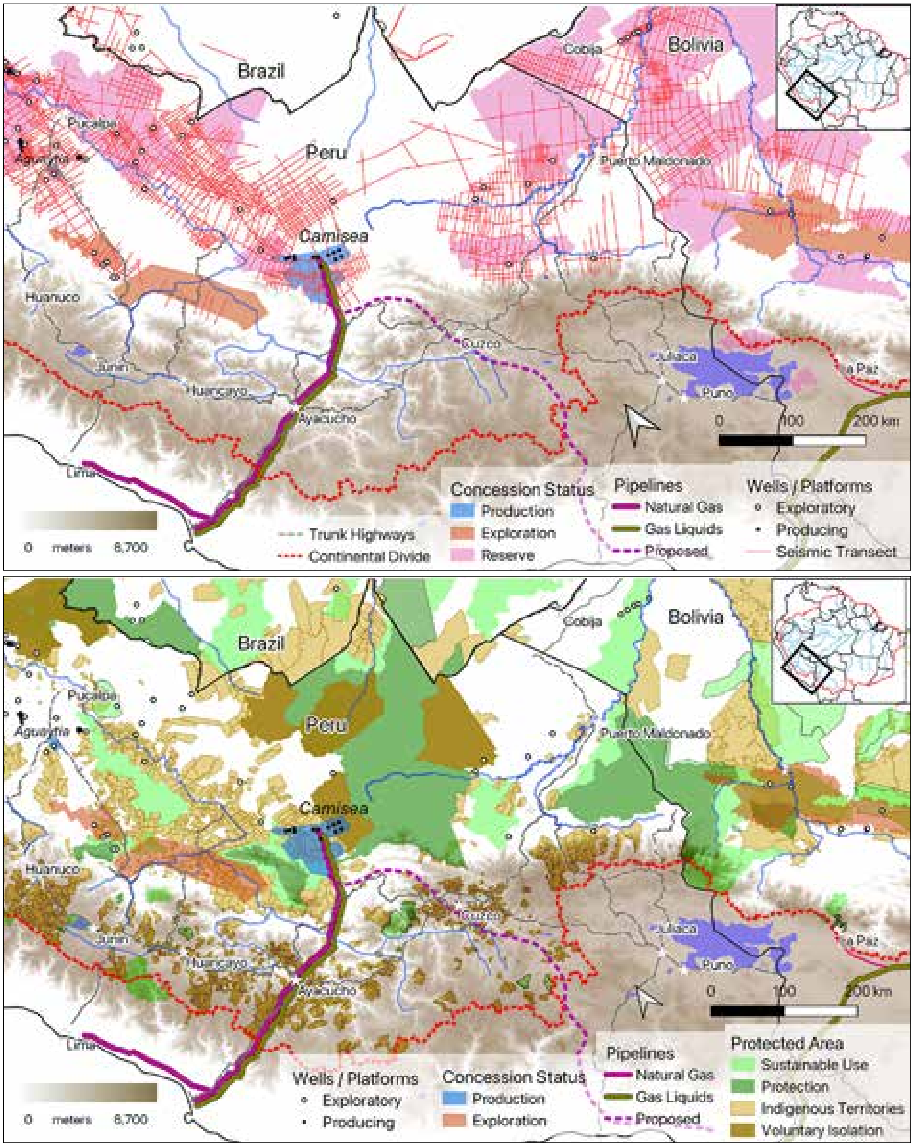

Figure 5.33: The Camisea field, which was discovered in the 1980s, is rich in both natural gas and gas liquids; these are separated near the well-head and shipped to the coast via two parallel pipelines. A third pipeline was under construction in 2016 when its operator, a subsidiary of Oderbrecht, filed for bankruptcy following the Lava Jato corruption scandal. The steel pipe remains in the country and proponents periodically promote the resurrection of the project as a strategic energy asset.

Data source: RAISG (2022) and Codato et al. (2019).

dinarily large volumes of natural gas and associated liquids, the latter of which are molecularly similar to gasoline and particularly valuable as an energy commodity (Figure 5.33). As of 2020, there were 32 production wells operating in three concessions (Lotes 56, 57, 88). The wells are run by the Camisea consortium, which is led by PlusPetrol, the same company that recently abandoned its concessions (and environmental liabilities) in Northern Peru.[*] Development of a fourth Camisea concession (Lote 58), which is held by the China National Petroleum Company (CNPC) is on hold while the company reviews its environmental impact statement and the logistical constraints that limit its ability to monetise the concession's hydrocarbon reserves.[263]

The Camisea wells are connected to a processing plant operated by *Transportadora de Gas del Peru* (TGP), which separates the liquids and gas prior to injection into two parallel pipelines.[†] Approximately sixty per cent of the natural gas is consumed domestically, while the rest is exported as liquefied natural gas (LNG). In 2020, Camisea produced about 619 billion cubic feet (17.5 billion cubic metres) of gas and 37 million barrels of oil with a combined nominal value of approximately US$2.8 billion (Figure 5.34).[264] This generated more than US$460 million in revenues for the state, of which about fifty per cent was returned to local and regional governments. Between 2012 to 2022, the Cusco Region and its constituent jurisdictions received ~US$1.7 billion via the canon system of revenue sharing (see above). Cusco shares the benefits of 1,681 direct jobs with Pisco where the export terminal is located, as well as of ~30,000 indirect jobs in Lima, the principal market for natural gas.[‡]

Project proponents highlight the benefits of domestic gas production, which has saved an additional US$10–20 billion in oil imports, while avoiding higher greenhouse gas emission when natural gas is compared to either oil or coal. Less appreciated is the role that Camisea has played in the demise

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[*] PlusPetrol is Latin America's largest oil company. It was founded in Argentina but moved its corporate offices to Amsterdam in 2000. Other members of the consortium include Repsol (Spain), Hunt Oil (USA) and the SK group (South Korea). Source: The Energy Year (24 Feb. 2015), https://theenergyyear.com/articles/10-years-of-camisea-the-natural-gas-revolution-in-peru/

[†] The pipeline system was built and operated by a consortium led by Hunt Oil and Repsol, but it was restructured in 2014 when it was acquired by Canada Pension Plan Investment Board (49.89%), Enagas (28.95%) and Sonatrach (21.18%). Source: https://www.tgp.com.pe/nosotros/

[‡] The construction phase (2000–2006) generated 8,000 direct and 30,000 indirect jobs. Source: OSINERGMIN - Organismo Supervisor de la Inversión en Energía y Minería. 2006. ¿Qué significa el Proyecto Camisea? https://www.osinergmin.gob.pe/seccion/centro_documental/Institucional/Estudios_Economicos/Documentos_de_Trabajo/Documento_de_Trabajo_23.pdf

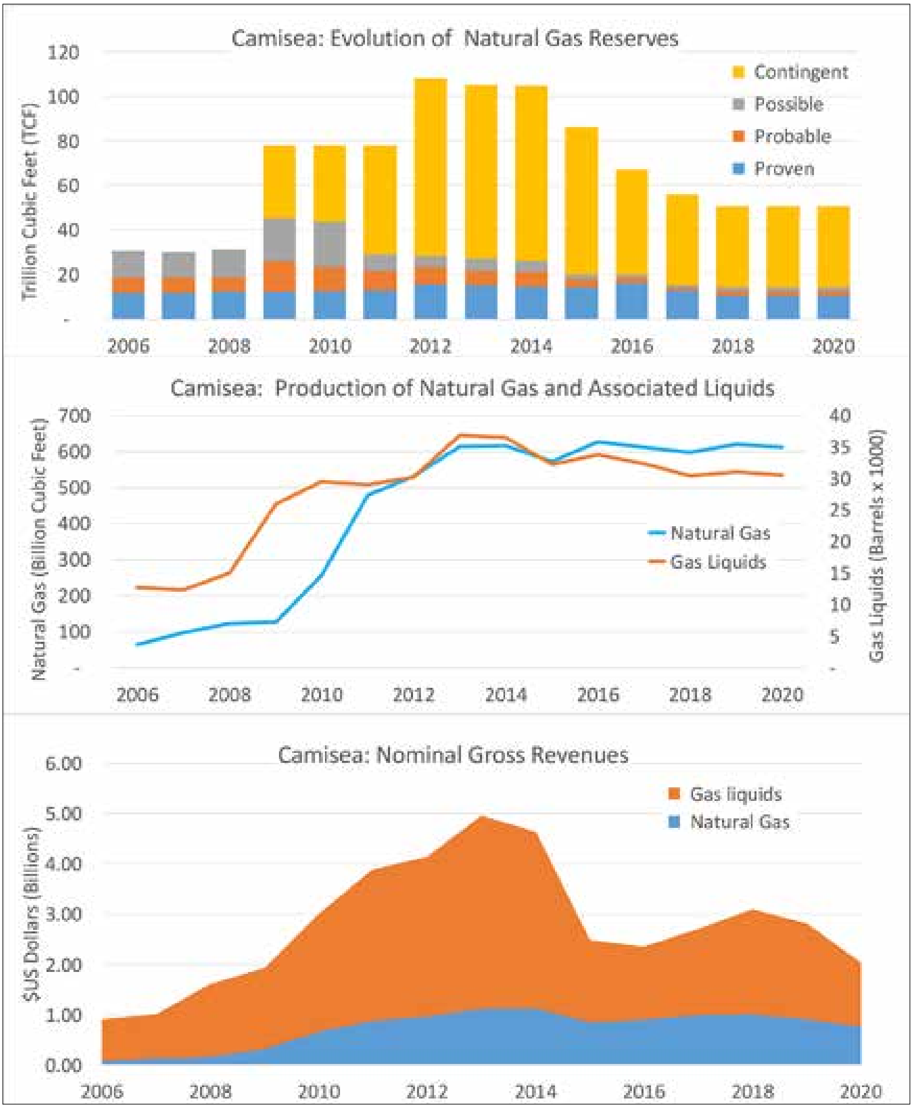

Figure 5.34: Statistics from Camisea. Top: Variation in the reserves of natural gas reflect data from exploratory wells and drawdown caused by production wells. Middle: Camisea produces 'wet gas' that is associated with liquid hydrocarbons that are commercialised separately. Bottom: The nominal value is based on production volumes and the price each commodity would bring in domestic and international markets.

Data source: Perupetro (2022).

Google Earth

A gas production platform in Lote 88 near Camisea, Peru. This platform has five operating wells and is connected to the Malvinas gas treatment plant by a feeder pipeline that is not discernable underneath the forest canopy. Referred to as the 'San Martin-Cashiriari conventional (non-shale) gas field', it is exploited by four additional platforms that have recovered ~50% of the field's proven reserves. Production began in 2004, peaked in 2016 and is projected to cease operations in 2048; the field is operated by Pluspetrol on behalf of a consortium that also includes Hunt Oil, SK Innovation, Sonatrach, Techint and Repsol.

Data source: Offshore technology (2021).

of several large-scale hydropower facilities that were abandoned because they were not economically competitive with natural gas (see Chapter 2).

Hydrocarbon development in the tropical landscapes of Cusco Region was opposed by Indigenous groups and environmental advocates because the gas fields are adjacent to territory known to be inhabited by several Indigenous tribes living in voluntary isolation. Their presence, and the need to ensure the development of Camisea, motivated the government to upgrade the status and improve the legal protection of the Kugapakori Nahua Nanty Indigenous reserve.* Regardless, the project has been beset by controversy because neither the Peruvian state nor the operators adhered to the principles of free prior and informed consent (FPIC) during the construction of the pipeline.[265]

Difficulties regarding FPIC likewise have impeded the development of Lote 58, which has an additional 2.3 trillion cubic feet of gas. A more

* The reserve was originally created by a ministerial resolution in 1991 based on a law passed in 1978; the presidential decree of 2003 upgraded the indigenous reserve (*Reserva Territorial del Estado*) by giving it dual status as an indigenous reserve and national protected area. Source: DECRETO SUPREMO N° 028-2003-AG.

The Urucú gas field is an example of the enclave model of hydrocarbon development where the concessionaire, in this case Petrobras, operates an isolated complex of wells and an industrial gas plant in the middle of the forest. Gas is transported to market, in this case Manaus, by a pipeline that was constructed with only a minimal disturbance to the forest canopy.

relevant constraint, however, is limited pipeline capacity because the current pipeline (TgP) is operating at capacity. A second pipeline (Gasoducto del Sur), which was under active development between 2010 and 2016, would have significantly enhanced Peru's export capacity and integrated its southern regions into a gas-dominated energy grid. Pipeline construction was halted in 2017, however, when the primary contractor, Oderbrecht SA, became embroiled in the *Lava Jato* bribery scandal that led to the bankruptcy of its pipeline subsidiary and the prosecution of two Peruvian presidents (see Chapter 6).[266]

The project was about 35 per cent complete when construction was halted and most of its component parts (steel pipe) are in Peru waiting for resolution of the project's bankruptcy proceedings. The spike in natural gas prices in 2022 has renewed efforts by its proponents to complete the project, which has been rechristened the Sistema Integrado de Transporte de Gas al Sur (SIT Gas). The current holder of Lote 58 (CNPC) would be a logical candidate to finance the completion of the pipeline. However, the inevitable production declines in the adjacent concessions will eventually create capacity within the existing TgP pipeline.[267]

Madre de Dios

The next sediment basin to the south includes most of the Madre de Dios in Peru as well as adjacent areas in Pando, Bolivia. It is broadly similar to the Ucayali Basin in structure and age with a fold-and-thrust belt close to the Andes. It has been the object of considerable exploration over the last twenty years, starting with seismic surveys and exploratory wells drilled by Mobile Oil (now Exxon Mobil) and Texaco (now Chevron) in the mid 1990s. The presence of oil-bearing deposits was verified but these were deemed non-economic due to low volumes and the high cost of transporting the oil to market.

Another potential natural gas deposit was identified in Block 76 with resources once estimated at 8.7 trillion cubic feet of natural gas.* The first exploratory well 'underperformed' expectations and the company, Hunt Oil, returned the concession to the state in 2018.[268] The decision to halt its development occurred during the slowdown in the hydrocarbon sector that followed the collapse of oil and gas markets in 2014. The depressed market, when combined with the paralysis of the *Gasoducto del Sur*, also froze the construction of a third gas pipeline that would have been required to develop the potential reserves believed to exist in the Madre de Dios.

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* Now listed on the PeroPetro database as 'Nuevas Areas de Promocion:SM53-19'. The 40-year concession was held by Hunt Oil until 2018 when it returned it to Perupetro. Source: https://elcomercio.pe/economia/dia-1/hunt-oil-renuncia-megaproyecto-gas-lote-76-410938-noticia/

The retreat of companies from Madre de Dios is characteristic of the travails that have characterised the sector in the rest of Peru where the total number of concessions under development fell from 87 in 2010 to 30 in 2020.[269] The rebound of global oil and gas markets in 2022 may change this financial calculus, but the investment case for developing more gas projects in Peru must be weighed with the risk of social conflict, environmental liabilities and the increased competitiveness of solar power on the coastal desert.[270]

The foreland-sediment basins in Bolivia have similar structural and stratigraphic attributes as their Peruvian counterparts. World-class gas reserves are being exploited in the Santa Cruz–Tarija Basin, which are located on the southern margin of the Amazon watershed.[271] It is widely assumed that there are similarly large hydrocarbon reserves in the adjacent Beni Basin, which is separated from the Madre de Dios by the Madidi Arch. Exploratory efforts by Texaco in the 1990s and PDVSA in the 2000 have failed to discover any significant reserves, but the state-owned oil company (YPFB) continues to explore for oil and gas.[*]

The Solimões Basin and the Urucú Gas Field

The Solimões sedimentary basin is an extensive geological province located in the centre of the continent (see Figure 5.18). In the West, it is bounded by the Iquitos Arch that delineates it from the POM basin and in the East by the Purus Arch that separates it from the Amazon sediment basin. The conventional reserves are located in a typical petroleum system: the source rocks are Devonian shales and the reservoir rocks are Carboniferous sandstones with traps that were formed during the Jurassic when tectonic forces warped the strata into anticlines.[272] The Devonian shales are relatively thick with significant quantities of organic carbon (2% and 5%), which makes them viable candidates for hydraulic fracturing and the production of shale gas.[273]

Urucú is the name used by Brazilian geologists for an oil and gas discovery within the Solimões. It is the largest onshore deposit of conventional oil and gas resources in Brazil (Figure 5.35). The total area spans 3.8 million hectares in the approximate centre of Amazonas state, which is subdivided into seven production blocks operated by Petrobras (83,000 ha) and sixteen exploratory blocks (3.7 million ha)[274] held by Rosneft, the

* In July 2019, the Bolivian state oil company (YPFB) repeatedly stated its intention to fully exploit the hydrocarbon potential in the protected areas of the country, including the four national parks in the Andean Amazon: Madidi, Pilón Lajas, Carrasco and Amboro; source: I. Paredes Tamayo. 19 Apr. 2022. Bolivia: 21 áreas protegidas amazónicas se superponen con lotes petroleros. Mongabay: https://es.mongabay.com/2022/04/bolivia-21-areas-protegidas-amazonicas-se-superponen-con-lotes-petroleros/

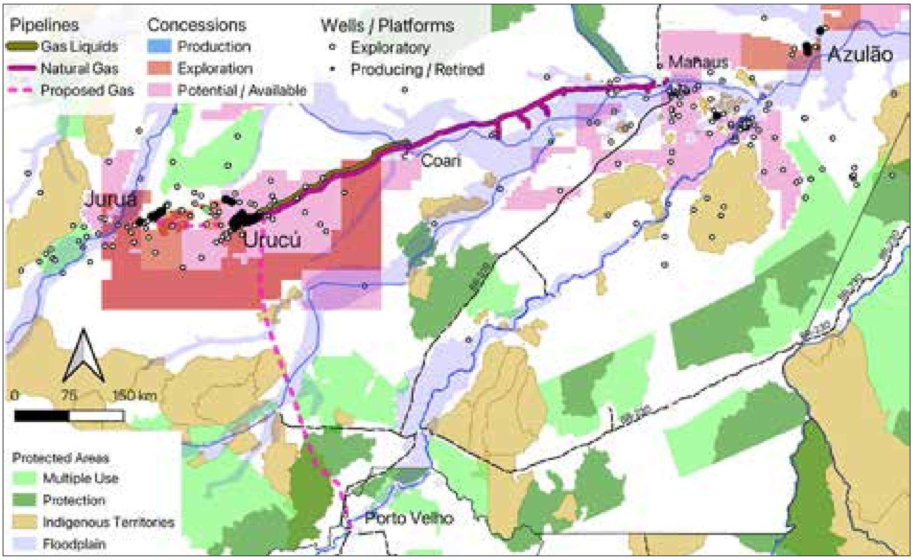

Figure 5.35: The natural gas field at Urucú is serviced by both gas and liquid pipelines. In the near future, production may start at the Juruá concessions, whose operators also manage the Azulão field where they use liquified natural gas (LNG) technology to supply a thermoelectric plant in Roraima.

Data sources: RAISG (2022) and Codato et al. (2019).

state-owned Russian oil company.* Estimates of the proven and probable reserves range between 1.1 and 5.2 trillion cubic feet of conventional natural gas,[275] while the potential recoverable resources of shale gas may be as high as 16.5 trillion cubic feet – approximately equivalent to those at Camisea.[276]

The first discovery was made in 1986 after more than a decade of exploration. Production started in 1989, but initial volumes were limited by a lack of transportation infrastructure. This was resolved in 1998 by the construction of a 280-kilometre pipeline between the Urucú separation plant and the river terminal near Coari (Amazonas) where liquids and compressed gas could be commercialised using river barges. In 2009, a second parallel pipeline was built and another that extended 360 kilometres to Manaus with seven branches supplying natural gas to thermoelectric plants that generate electricity in small municipalities on the north bank of the Solimões

* The CEO, Igor Sechin, is considered to be the 'right hand' man of Vladimir Putin. Source: Forbes (22 May 2022), https://www.forbes.com/sites/giacomo-tognini/2022/05/02/how-rich-is-putins-right-hand-man-inside-the-murky-fortune-of-igor-sechin-the-darth-vader-of-the-kremlin/?sh=6648b7fb5ddc

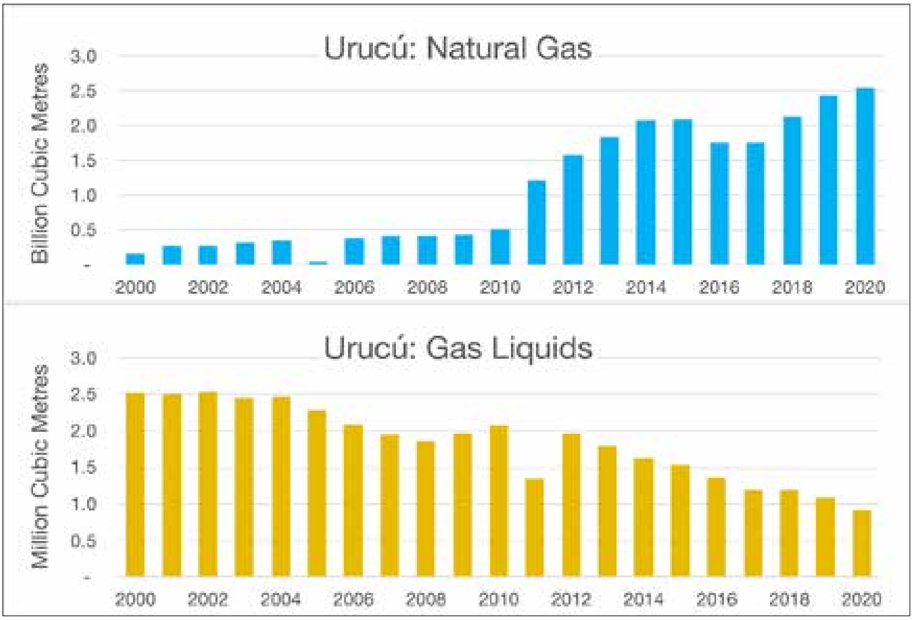

Figure 5.36: The Urucú field was discovered in 1986 and connected to a river port at Coari in 1998. Large scale commercialisation of natural gas did not begin, however, until the gas pipeline was extended to Manaus in 2009.

Data source: ANP (2022).

river.[277] Operations were managed by a Petrobras subsidiary, *Transportadora Associada de Gás* (TAG), until 2020 when it was sold to Engie Brasil.[*]

Production of liquids has declined steadily since 2000 (45,000 to 15,000 bpd) because Petrobras preferentially harvested gas-liquids. In contrast, production of natural gas has increased over the same period (245,000 to 530,00 cubic feet per day).[278] The two commodities are divided at the separation plant and excess gas is reinjected into the wells. This imbalance should have been resolved in 2009. However, Petrobras overestimated demand for natural gas in Manaus, and the pipeline has operated at about sixty per

[*] Engie Brasil is the country's largest independent energy company with an installed capacity of 8.5 GW electricity generating capacity. It operates 76 power plants, including eleven hydropower, two gas-fired and 64 renewable energy installations (biomass, solar, wind). It is a subsidiary of the French/Belgian energy company created by the merger of the Suez Company and Gaz de France. Engie is the world's largest operator of liquified natural gas (LNG) systems. Source: https://www.engie.com/en/activities/infrastructures/power-to-gas and https://www.engie.com.br/en/investors/

cent capacity[279] The nominal revenues are ~US$1.1– $US2.1 billion annually from the sale of natural gas and ~US$550 million from liquids (Figure 5.36).[*]

Despite the apparent lack of demand, Rosneft acquired the rights to all thirteen exploratory blocks in 2014 and mounted exploratory operations between 2017 and 2019. Eneva, a mid-sized Brazilian energy company, purchased the Juruá concession, which is located 100 kilometres west of Urucú, from Petrobras in 2019. Apparently, Eneva intends to develop the reserves that were discovered in the late 1970s either by building an extension of the Urucú-Coari pipeline or by developing a liquified natural gas (LNG) system.

Business groups in Manaus have long lobbied for an expansion in the Urucú pipeline system arguing that inexpensive gas will catalyse investment in the Manaus Free Trade Zone (see Chapter 6). They are joined in their boosterism by civic groups and politicians from Rondônia that seek to extend the pipeline system from Urucú to Rondônia.[280] Presumably both Rosneft and Engie are evaluating the feasibility of exporting liquefied natural gas (LNG) to export to overseas markets or to aluminium smelters in Belem. There is no shortage of reserves, particularly if the shale gas is exploited using fracking technology. Less certain is the profitability of the enterprise since the high prices for LNG in 2022 are dependent upon a war that will, eventually, come to an end.[†]

The development of the first phase of the Urucú complex occurred when the cultural and political environment was more open to fossil-fuel development in the heart of the Amazon. Indigenous groups and environmental advocates mobilised to oppose the second fleet of pipeline projects in the early 2000s. They were not able to derail the construction of the Ucurú–Coari–Manaus pipeline, but they were successful in stopping the pipeline to Rondônia. Petrobras had signed a contract with an international corporation in 2000 and obtained a licence from the environmental agency (IBAMA) in 2005.[‡] In 2006, however, a federal judge acting on a complaint filed by the public prosecutor invalidated the environmental licence and instructed Petrobras to comply with a series of protocols, including obtaining the free prior and informed consent of Indigenous communities.

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* Nominal revenues are based on reported volumes and mean price in 2019; in the case of gas, the benchmark was the mean price charged by Companhia de Gás do Amazonas (Cigas) and for liquids it is the international price for oil. Source: https://www.cigas-am.com.br/tabela-tarifaria

† The invasion of Ukraine by Russia has increased demand for LNG and consequently catalysed an increase in prices for LNG.

‡ El Paso Energy (USA) had signed an agreement to build the pipeline and operate a power plant in Porto Velho. Source: OGJ – Oil & Gas Journal. 2000. El Paso signs Brazilian power purchase Agreement:https://www.ogj.com/pipelines-transportation/article/17254364/el-paso-signs-brazilian-power-purchase-agreement.

The fate of these three pipelines reveals how infrastructure and energy projects might fare in the future, as well as suggesting the motive of past governments in allocating land rights in the Urucú region. The Urucú–Porto Velho project was rejected largely because it would have infringed upon Indigenous lands. In contrast, the Coari–Manaus segment only marginally impacted *Ribeirinho* (non-Indigenous) communities on the north bank of the Amazon River that benefitted from reliable and affordable electrical energy. Most remarkable is the absence of any Indigenous territories or conservation units near the Urucú complex. Most of the protected areas in the Brazilian Amazon were created in the 1990s and 2000s, while the potential of Urucú has been known since the late 1980s. Presumably, no Indigenous communities resided within or adjacent to this strategically important landscape. Otherwise, the national authorities would have been obliged to create a territorial entity that would have significantly impeded their ability to develop this non-renewable natural resource.

The Amazon Sedimentary Basin

The total petroleum system that describes the hydrocarbon resources of the Amazon Sedimentary Basin has many similarities to the Solimões Sedimentary Basin (see Figure 5.18). Source rocks date from the Devonian, and the reservoir of conventional gas and oil is located within Carboniferous strata deep in the Amazon Rift Valley between Manaus and the Ilha do Marajó.[281] The basin is delimited in the West by the Purus Arch and on the East by the Gurupá Arch, a geographic feature that once separated the Proto Amazon River from the Atlantic Ocean.[282] The traps that confine the conventional deposits are linked to extensional faulting and, apparently, a layer of salt in the *Nova Olinda* formation that is also the source of the Amazon's potash reserves.

The presence of fossil fuels was first discovered in 1998 and identified as a potential commercial deposit in 2004. The verification of exploitable reserves was confirmed in 2016 and production started in 2021. The discovery is not large, with proven reserves of only 7.1 billion cubic feet of gas.[283] Petrobras sold the concession, Campo de Azulão, as part of its corporate strategy to liquidate assets in order to reduce its debt load.[284] The concession was acquired by Eneva, the same company that recently came into possession of the Juruá concession near Urucú and the operators of the Paranaíba gas field in Maranhão. According to their corporate website, Eneva will commercialise the gas by shipping liquified natural gas (LNG) to Roraima in trucks or by generating electricity at Azulão and injecting electricity into to the Tucurí–Manaus high-tension line that was constructed in 2013 (see Chapter 2). The former is a business model that is viable only because the Waimiri Atroari Indigenous group has blocked the extension of the regional power grid to Boa Vista (see Chapter 11).

The limited current production from the Amazonas Sedimentary Basin belies its potential production. Estimates of shale-gas resources range from 21 to 37 trillion cubic feet,[285] which would have a nominal value between US$50 and US$200 billion when calculated at international prices before the war in Ukraine.[*] There are no evident plans to develop this hydrocarbon resource, all of which is located within fifty kilometres of the main stem of the Amazon River.

Offshore Deposits: Guiana, Suriname and the Foz de Amazonas

The presence of hydrocarbon deposits on the continental shelf of the Guiana Coast has been suspected by petroleum geologists for decades due to the theory of plate tectonics that posits northeast South America and northwest West Africa have a shared geological history.[†] In 2011, Tullow Oil, a UK-based oil and gas exploration company with experience in West Africa, discovered a large gas and oil reserve off the coast of French Guiana (see Figure 5.18). This discovery triggered a surge in exploration activity that has attracted dozens of oil companies, including the so-called super-majors who participate in exploratory activity only when the potential volumes meet the scale of their global market.[‡]

The Total Petroleum System of the offshore sedimentary basin is substantially different from those located within the interior of the continent. The source rock is a large marine mudstone deposited at the beginning of the Cretaceous, while the reservoir rocks are porous limestone and sandstone formations from the Paleogene (Eocene to Miocene). The area is characterised by abundant tectonic faults that created multiple traps, while maturation of the hydrocarbon molecules is believed to have occurred within both the migratory pathways and traps. In other words, the resources are not only massive but relatively recent in geological time-scales. The US geological service (USGS) estimated the basin might contain undiscovered conventional resources of more than fifteen billion barrels of oil and thirty trillion cubic feet of natural gas, which would make it larger than all of the conventional onshore Amazonian hydrocarbon reserves combined.[286]

As of August 2022, the largest discoveries were located offshore of Guyana where ExxonMobil has drilled 36 production wells with estimated reserves of eleven billion barrels.[287] Just over the border in Suriname, Total

[*] Prices vary depending upon market (USA: US$2–5 thousand per m3 versus Spain: US$5–10 thousand per m3).

[†] The same logic applies to the presence of greenstone belts and associated gold deposits on the corresponding shield rocks of the two continents, which split from Gondwana between 60 and 120 million years ago.

[‡] Guyana: ExxonMobil, CNOOC (China), Hess, EcoAtlantic, Repsol.
Suriname: Chevron, Hess, Statoil, Tullow, CEPSA, Kosmos, Noble and Petronas of Malaysia.
French Guiana: Total, Shell, Tullow Oil, Wessex.

Guyana, and most likely Suriname, have apparently won the petroleum lottery with the discovery of world class oil and gas reserves located offshore on their continental shelf. The discovery provides these countries with a unique opportunity to invest in sustainable industries – if they do not succumb to the so-called 'natural resource curse' and squander their endowment on non-viable projects driven by corrupt leaders.

has announced discoveries surpassing three billion barrels of oil equivalents, a term the industries use to report the combined energy potential of both gas and oil reserves.[288] These discoveries, and their dimensions, suggest that the USGS significantly underestimated the region's potential. Recent investment in the region, apparently, has surpassed investment in the Gulf Coast of the United States.

The development of hydrocarbons in Suriname and Guyana has the broad support of their citizens, in large part because these countries do not have an abundance of other development options. In contrast, opposition to the oil industry's operations in French Guiana reflects public opinion in that nation's European jurisdictions. In 2017, the national government promised to ban new oil and gas concessions as part of its commitment to renewable energies.[289] The French super-major, Total, ceased its exploratory operations in 2019 after drilling multiple exploratory wells without making a significant find.

A similar exploration boom is occurring off the coast of Amapá, Brazil, in a sedimentary sub-basin known as Foz de Amazonas. This area was the object of extensive exploration activities in the 1970s with discoveries described as 'shows'. However, none produced sufficient volumes to justify a commercial development. The discovery of oil in adjacent regions has stimulated a resurge in interest and new exploration efforts are underway.*

Environmental concerns may complicate the development of the offshore resources of Amapá because Brazilian scientists discovered an atypical reef-like ecosystem across 1,000-kilometre stretch of continental shelf off Amapá, which supports a unique community of organisms that have evolved to thrive in the sediment plume expelled from the mouth of the Amazon River. In September 2022, the public prosecutor's office in Amapá and IBAMA requested a court to suspend the company's operations, alleging it had failed to adequately consult four Indigenous communities on the coast who depend on the native fisheries for their livelihood. Petrobras has rejected the accusation stating that they did, in fact, conduct a public consultation as required by Brazilian law.[290]

What Comes Next in the Extractive Sector?

In January 2023, the federal government of the United States issued landmark decisions affecting two controversial projects to exploit mineral resources on public lands. One was an industrial-scale copper mine, the Pebble Mine in south central Alaska, and an oil drilling programme in the Willow Concessions on the North Slope of Alaska.[291] The Environmental Protection Agency (EPA) vetoed the Pebble Mine, citing its potential impact on an economically important population of salmon, while the Interior Department approved the environmental impact assessment (EIA) for drilling in the Artic Petroleum Reserve that will, coincidentally, prolong the useful life of the Trans Alaska Pipeline System.

In each of these decisions, the Biden administration balanced the advice of environmental scientists with the economic and political power of corporations, while taking the pulse of disparate stakeholder groups via a consultation process influenced by regulatory provisions and public relations campaigns. The veto was catalysed by a fight for Indigenous rights, while the oil drilling permit will favour a well-established industry that pays hundreds of millions of dollars in tax and royalty revenues to local and regional governments. If this type of regulatory and public relations confrontation is common in an advanced economy, such as the United States, then no one should be surprised that similar battles are being waged in the

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* Concessions in Amapá in 2020 were held by Total, Petrobras, BHP-Billiton, Brasil-Manati and Queiroz Galvão.

Pan Amazon. The specifics are different but the outcomes will probably be similar. Some will move forward and some will not.

Industrial Minerals and Corporate Mines

The investments most likely to proceed will occur in jurisdictions where corporations already have a large spatial and economic footprint. The Carajás Mining District, for example, is clearly the domain of corporate miners and it will remain so for the foreseeable future. The local population is dependent upon the industry for their livelihoods and elected officials at the state and local level unequivocally support brownfield mining investments. The mineral resources are so vast that mining will continue to expand over the short term and, in all likelihood, will remain the dominant economic activity for decades or, perhaps, a century or more (see Annex 5.5). Corporate miners can be expected to prosper in other municipalities in Pará, as well as in states with significant mineral resources such as Mato Grosso and Amapá. Elsewhere, particularly in Peru and Ecuador, the need for export revenues to support foreign exchange policies will place enormous pressure on central governments to favour an industry that is increasingly dominated by international giants.

Environmental and social advocates will oppose many (most) extractive investments, but they will confront corporations armed with abundant technical information provided by environmental specialists pursuing mitigation and compensation strategies devised by astute legal advisors. Regulatory systems are designed to allow projects to move forward after (allegedly) addressing impacts that critics argue should actually terminate a project. Nonetheless, opponents to industrial-scale mines have one, increasingly powerful, regulatory tool: the obligation to have the '*free prior and informed consent*' of communities with long-established '*customary rights*' as a precondition for obtaining an operating licence.

The full impact of FPIC on the regulatory process is still unfolding. Governments argue that mineral resources belong to the nation and should be monetised to finance economic development that benefits all sectors of society. In contrast, social advocates hope to expand the FPIC concept to include all types of local communities, including Indigenous communities who have yet to obtain legal recognition of their territories, as well as 'traditional' communities whose livelihoods depend on renewable resources but whose identities are not explicitly ethnically Indigenous. Societies have yet to decide which communities have the right to FPIC and governments are manoeuvring to maintain control over the consultation process. This is a major source of contention and it will be adjudicated in regulatory agencies and the courts and on the streets (and highways) of the Pan Amazon.

The other major factor that will influence the corporate sector is the emerging concept of ESG investing. Publicly traded mining companies are particularly exposed to this risk management framework because of their need for financial capital, particularly for greenfield projects that do not benefit from the cash flow from an existing operational asset. All three components of the acronym weigh heavily on the industry. Environmental and Social programmes are obvious components in the current system of 'responsible' mining, while legitimacy of their claims depends on transparency, a core criteria of corporate Governance. In contrast, Private companies, particularly closely held domestic companies, are non-transparent by design, while Chinese companies have demonstrated, repeatedly, that they have minimal concern for mitigating social and environmental impacts. ESG investing will not change the behaviour of these types of corporations, which highlights the importance of robust regulatory oversight.

The success of the corporate sector in organising greenfield projects will be determined, increasingly, by their ability to adequately compensate the communities impacted by their operations. This should include more generous royalty regimes and, in nearly all cases, a less corrupt distribution of royalty revenues and taxes (e.g., the Canon in Peru). Some companies have tried to overcome these systemic deficiencies by directly compensating communities without the mediation of the state; all too often, however, these efforts fall short, because the improvement of health and educational services, the most common programmes, alleviate but do not address the underlying grievances.

If companies actually listen to communities, they might learn that opposition to their projects is rooted in a deeply held resentment of the state. The most common complaint is usually about land. Corporate mines may exploit a below-ground resource but they also appropriate an above-ground landholding. A corporation's ability to obtain legal title lies in stark contrast to hundreds of thousands of families who lack formal recognition for their family landholdings. If the mine is a massive open-pit and tailings pond that infringes on what they perceive as pertaining to their community, the unfairness is provocative in the extreme. Companies that recognise this injustice have succeeded in advancing their projects;[*] in contrast, companies that resort to divide-and-conquer tactics, or intimidation, often suffer from regulatory fights that delay their project.[†] Projects overwhelmed by

[*] Alcoa played a pro-active role in helping the local *Ribeirinha* communities obtain land rights using the INCRA system to establish the Projeto de Assentamento Agroextrativista (PAE) Juruti Velho; the company then leased land from the community. Borges and Branford 2022.

[†] Potasio do Brasil has been accused of using pressure tactics to force individual families to sell (untitled) land holdings at below-market value while obtaining

public protest and civil unrest have been canceled after their promoters have invested tens of millions of dollars.*

Although mine start-ups attract the most attention, mine closure can reveal if corporations have fully embraced the concepts of responsible mining. Current regulations and ESG criteria obligate companies to develop an integrated closure plan; however, executives often underestimate the true cost of effective remediation. This practice, which some describe as creative bookkeeping, is actually a breach of corporate governance, because those obligatory future expenditures are a long-term financial liability that should be reported on corporate balance sheets. Most companies did not make mine closure a priority, nor did regulatory agencies pay close attention – until the tailings pond disasters at Mariana (2015) and Brumadinho (2019). Those two events demonstrated the very real financial risk of inadequate mine closure and, in the process, illustrated why ESG is good for business. Environmental activists would be well-advised to critically dissect the financial models associated with remediation and closure plans.

Peru is the only Pan Amazonian country that requires corporate miners to set aside funds to finance mine closure. Referred to as 'financial assurance', these can be bonds, insurance policies or other forms of financial securities.[292] Their value, however, is based on cost estimates reported by the company in its periodic filings to the government. Thus, if the company underreports the true cost of mine closure, they have every incentive to walk away from both their commitment to execute a responsible mine closure and their financial guarantee. When that happens, the state must assume the cost of remediation and, if the state reneges, communities near the mine will pay the price.

Wildcat Miners: Will Cyanide Displace Mercury?

The activities of wildcat miners in the Pan Amazon have become an increasing issue of concern over the past five years, in part because their numbers have exploded, but also because, as a group, they have flagrantly violated the land rights of Indigenous people, particularly the Yanomami, but also the Murunduku and Kayapó (Brazil), the Ese Eja and Harakmbut (Peru), and the Lekos (Bolivia). Efforts to 'tame' wildcat mining are a stated priority for governments and civil society.

Over the short term, most wildcat miners will be forcibly removed from formally recognised Indigenous territories. These efforts will be suc-

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the support of local and regional officials via consultancies and programs that channeled money to key individuals. Source: Bispo 2022.

* The Conga project was abandoned by Newmont mine due to a conflicts with small Indigenous landholders who refused to surrender their untitled family landholdings (see previous discussion).

cessful because the global media has determined this is a human rights issue that governments cannot ignore. It is less likely, however, that miners will be criminally prosecuted and, in some jurisdictions, they will be allowed to salvage their equipment. In some regions, they will be exiled from high-level protected areas; however, many will continue to have access to multiple-use protected areas. Unallocated public lands and waterways will remain exposed to their harmful practices, as well as unregulated mining operations on private landholdings.

Environmental advocates want them eradicated from all regions of the Amazon. Their view, one popularised by the global media, is they are illegal operators who avoid taxes, ignore labour laws and pollute the environment. Although this is literally true, many operate on landscapes where mining is, theoretically, legal. Some hold valid concessions and operating licences; nonetheless, virtually none are in full compliance with all the pertinent regulations. Unsurprisingly, wildcat miners do not consider themselves to be criminals, but members of an underprivileged economic class that has been traditionally exempt from the regulatory burden intended for corporate miners. In many jurisdictions, they are too numerous to eradicate by police action, which could lead to civil unrest and create a political backlash that weakens efforts to protect biodiversity, water resources and Indigenous rights.

Civil society groups working with wildcat miners have proposed an alternative strategy.[293] Short-term, the goals should be to bring them into a formal framework where they can be influenced by incentives to improve their practices. This could begin with a programme to register them into a national digital database and, simultaneously, legally recognise the *de facto* possession of their mining claims. In exchange, authorities could collect royalty taxes that materially benefit local government where miners actually reside. This procedure would allow authorities to identify large-scale miners for immediate registration as corporate miners, forcing them to pay royalties and income taxes, as well as to abide by labour and environmental regulations.

Formalisation of the sector should be accompanied by migration from mercury-based extraction technologies to other chemical and physical technologies. Wildcat miners use mercury because it is easy and cost effective; many (most) are unaware of its long-term toxic impacts. Although it is subject to regulations, the use of mercury in mining operations is not strictly illegal and it is widely available to miners via the black-market. The challenge, as always, is to organise policies and incentives that motivate miners to adopt different practices. Change can occur rapidly if the proposed solutions are more lucrative than the current system.

Technological change is already underway as medium-scale miners install cyanide based extractive systems similar to those used by corporate miners. This technology's biggest advantage is its ability to extract significant volumes of gold from low-grade ores, which also means operators can recover gold from the tailings created by previous miners who relied on rudimentary placer technology. The massive volume of placer tailings that characterise wildcat mining landscapes are (or soon will be) the site of the renewed gold rush.[294]

Cyanide is a well-known poison and comes with its own set of environmental liabilities and social challenges. It is lethal to fish and other forms of aquatic wildlife at low concentrations, which is why corporate gold miners invest significant financial resources in recycling systems, geomembranes, isolation ponds and catchment reservoirs. If they fail to insulate their operations from surrounding landscapes, particularly downstream portions of their watersheds, they will face the wrath of their neighbours, regulatory agencies and financiers.

Using cyanide to extract gold from mercury-laced tailings, however, brings its own suit of environmental and social impacts. The mechanical turnover of legacy tailings will mobilise trapped mercury, while cyanide will release other heavy metals from the pulverised ore and further amplify the toxicity of the residual tailings. Moreover, the chemical reaction that occurs between cyanide and mercury creates variants of methyl mercury that accelerate the phenomenon of bio-amplification, which is already a major health risk for Amazonian populations. The risks associated with cyanide and mercury motivated the Conference to the Parties of the Minamata Convention to characterise the unregulated use of cyanide to reprocess placer mining tailings as a 'worse practice'.[295] Regardless, cyanide based technologies will proliferate as the wildcat mining sector transitions into a formalised medium-scale domestic mining industry. [*]

Ironically, this transition offers an opportunity to remediate the toxic legacy of the previous gold rush, but only if a new generation of mining companies can be recruited (or coerced) into adopting a business model that fuses tailings remediation with gold recovery. The Minamata document that outlines the risks of cyanide technology also describes how those risks can be minimised by the removal of mercury from the tailings before the application of cyanide solutions. Options include a variety of physical and chemical techniques that should be economically and technologically viable. Ideally, wildcat miners would cease invasions of protected areas in exchange for unfettered access to the landscapes that have already been degraded. Theoretically, they could evolve into a responsible business sector generating good jobs and contribute to a stable and diversified Amazonian economy. Realistically, however, this win-win-win scenario will probably not

[*] The transition from mercury to cyanide-based artisanal systems has already occurred in the Philippines, Indonesia and Burkina Faso. Source: Verbrugge et al. 2021.

materialise, because current stakeholders are unable to make that transition due to economic constraints, deeply ingrained behaviour or an unwillingness to consider alternatives in a highly polarised political environment.

Oil and Gas: Stranded Assets or Strategic Resources?

Energy markets in 2022 were characterised by a shortfall in the supply of oil and natural gas due to Russia's war in Ukraine. Prior to the conflict, however, there was a surplus of both fossil fuels due to a combination of technological innovation in the United States (e.g., fracking and horizontal drilling) and excess-production capacity in countries that dominate global energy markets.* Although commodity markets are inherently cyclical, the pre-war surplus supported a hypothesis that the transition to renewable energy would suppress investment in fossil fuels. The anticipation that the 'age of oil' was coming to an end was particularly strong among environmental and human rights advocates who opposed the exploitation of hydrocarbons within the Pan Amazon based on philosophical and moral criteria. The potential for halting future development was no longer viewed as unrealistic.

This optimistic scenario has been called into question by the war in Ukraine and the subsequent commodity-driven inflationary cycle. Although the energy transition is now viewed as inevitable, the demand for fossil fuels, particularly natural gas, will remain robust over the next several decades. Consequently, global markets will continue to influence the hydrocarbon industry in the Pan Amazon, particularly those countries that are dependent on revenues derived from oil and gas (Bolivia, Colombia, Ecuador, Guyana) or which have legacy infrastructure assets that make investments financially attractive (Brazil, Ecuador, Peru).

Existing oil and gas fields will continue to operate over the medium-term. This means new production wells and feeder pipelines will be established on landscapes adjacent to existing production fields. Additional (greenfield) expansion is less certain. Attempts to drill within protected areas will be vigorously resisted by civil society, while Indigenous organisations will oppose any type of activity within their legally constituted territories. They will sue to halt operations in adjacent areas, arguing they enjoy customary-use rights to these lands and/or that impacts will extend into their territories.

Resistance to ongoing and expansionary investments is most likely to impact investment in northern Peru where pipeline failures and social

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* Referred to as OPEC+, this includes the 14 members of the Organization of Petroleum Exporting Countries, plus 10 nations that were excluded from the original cartel – the combined production represents 40% of global production. Source: OPEC, https://www.opec.org/opec_web/en/press_room/4052.htm

conflict threaten the industry's economic viability over the short term. The decision by several mid-tier companies to abandon concessions is an indication that they view the risk of failure to exceed the potential for an acceptable return on their investment. If the ageing infrastructure continues to suffer from mishaps, or if Indigenous groups successfully impede operations, then the region's hydrocarbon reserves will become a 'stranded asset', a term investors use to describe a thing of value that cannot be monetised.

Less likely is the demise of the oil industry in Ecuador, where the administration of Guillermo Lasso has repeated an electoral commitment to double national production. His government would appear to accept judicial restrictions that prohibit operations in protected areas, while recognising the obligation to consult Indigenous communities. This apparent contradiction might be partially resolved using technological solutions.* However, the viability of the petroleum industry in Amazonian Ecuador over the medium-term will depend on access to the unallocated concessions in Pastaza and Morona-Santiago (see Figure 5.31). This is unlikely to occur without considerable social conflict. Similar development conundrums confront the gas fields of southern Peru and the oil fields of the Putumayo in Colombia.

In contrast, there are extensive areas open for hydrocarbon development in Brazil, which has systematically avoided creating territorial constraints on the landscapes with the highest hydrocarbon potential. The Solimões Basin has significant shale-gas reserves that could be exploited using the existing infrastructure at Urucú whose useful lifetime can be prolonged using horizontal drilling and fracking technology. The recent sale of the Juruá concession to a company with expertise in LNG transportation systems could signal a move to commercialise the gas reserves of the Solimões Basin in overseas markets.

Exploiting the gas resources located underneath the Amazon River between Manaus and the delta (e.g., the Amazonas Basin) would require extensive exploratory drilling and, although there is no evidence this is being considered, there are few protected areas and Indigenous territories that might impede development on landscapes adjacent to the main stem of the Amazon River. Offshore development in Guyana and Suriname is a foregone conclusion. Less certain is the expansion of drilling along the continental shelf off French Guiana and Amapá where decisions will be made by central governments with minimal input from Indigenous communities.

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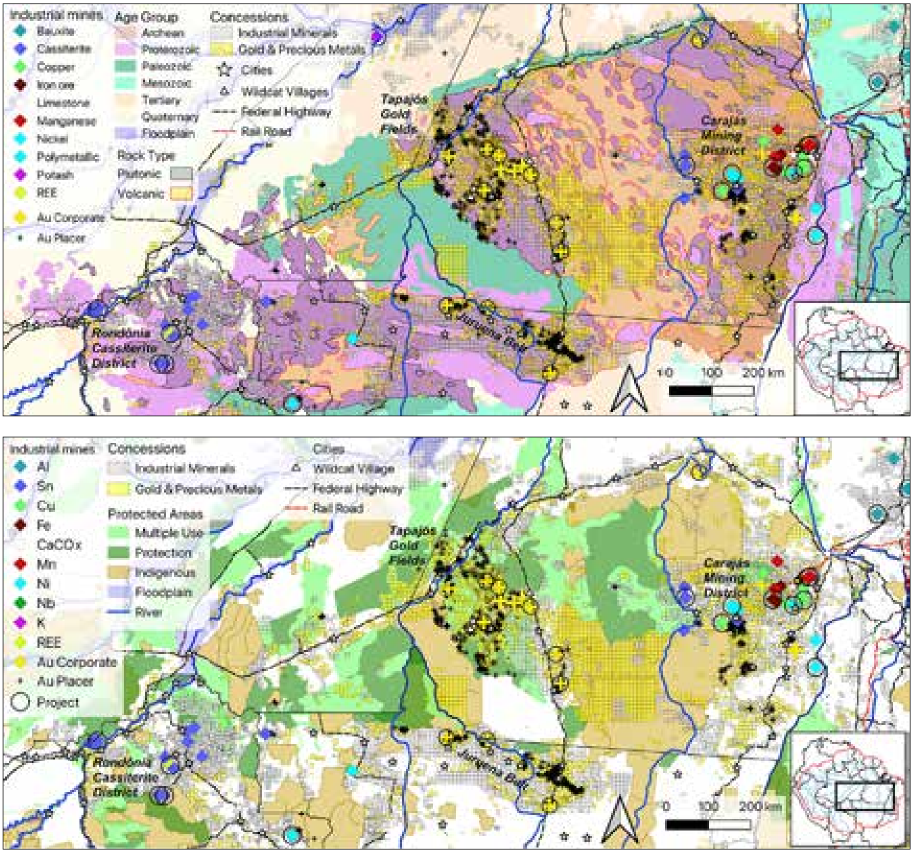
* President Lasso has stated that the oil underneath Yasuni National Park can be exploited from platforms established along the borders of the protected area using horizontal drilling technology. Source: Ecuador Chequea. 9 Mar. 2022. Guillermo Lasso dijo que no se puede dejar de explotar petróleo ni minerals: https://ecuadorchequea.com/guillermo-lasso-dijo-que-no-se-puede-dejar-de-explotar-petroleo-ni-minerales/

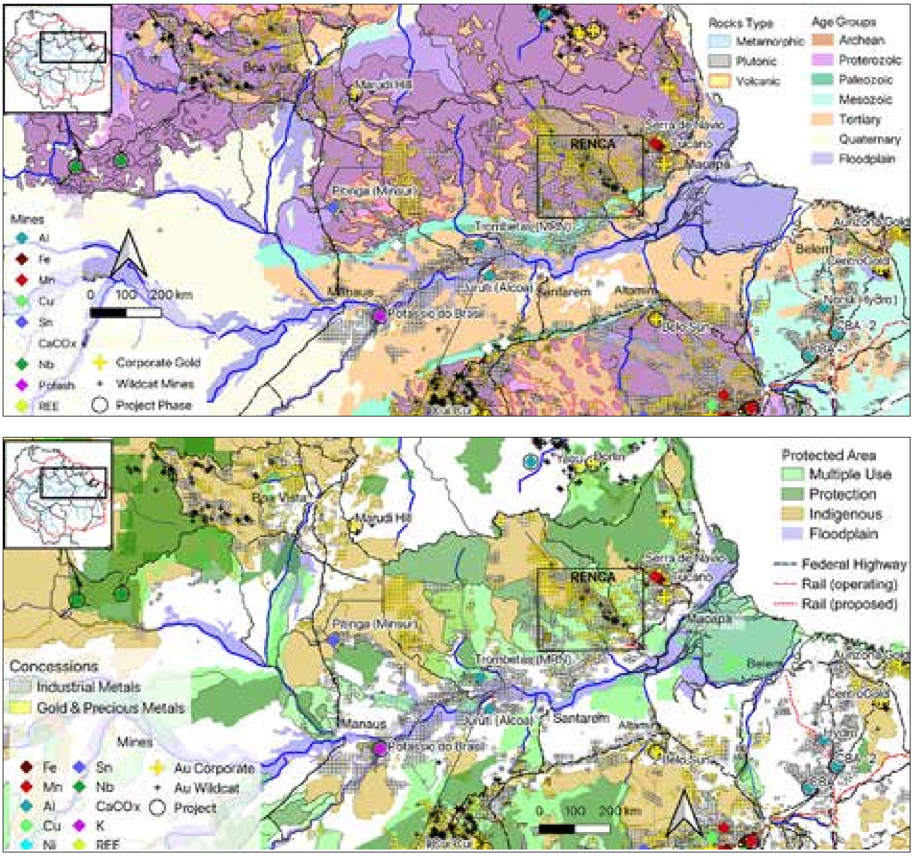
The views of environmental and human rights advocates predominate in international forums and, to a certain extent, within urban elites in Pan Amazonian countries. However, there are influential constituencies that believe it is in their country's interest to monetise their mineral resources. This view is greatest among service providers that benefit from the extractive sector but is mirrored by functionaries within agencies charged with regulating their activities. Mineral development is widely supported by the financial sector and the ministries that focus on macroeconomic criteria that measure economic health. Key private sector actors, such as the chamber of commerce, are deeply committed to the conventional economy. Many of these stakeholders also accept the reality of climate change but argue that-the failure to exploit the mineral resources of their countries would forgo the last opportunity to monetise a natural resource that should be used to invest in economic development that benefit the nation.

Annexes



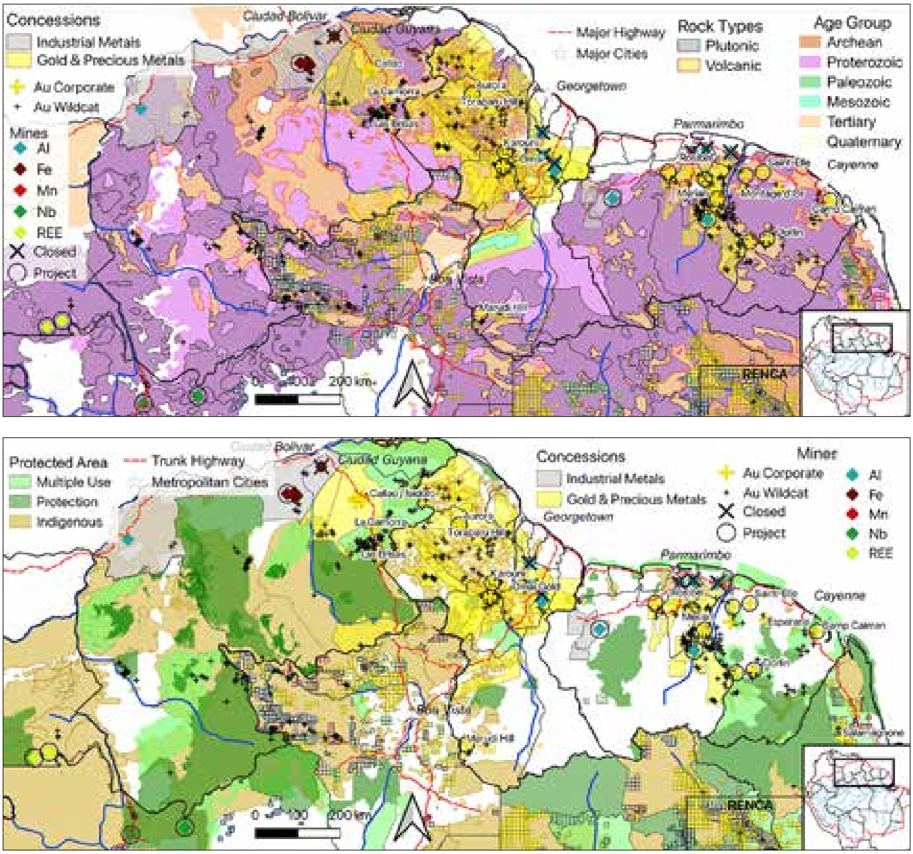
Annex 5.1: The mining landscapes of the northern sector of the Brazilian Shield: The Carajás Mining District; The Tapajós Gold Fields; the Juruena Belt of Mato Grosso; and (4) the Rondônia Cassiterite District. Top: mining data in the context of major geological features. Bottom: Protected areas and indigenous lands.

Data sources: Gomez et al. (2019) and RAISG (2022).



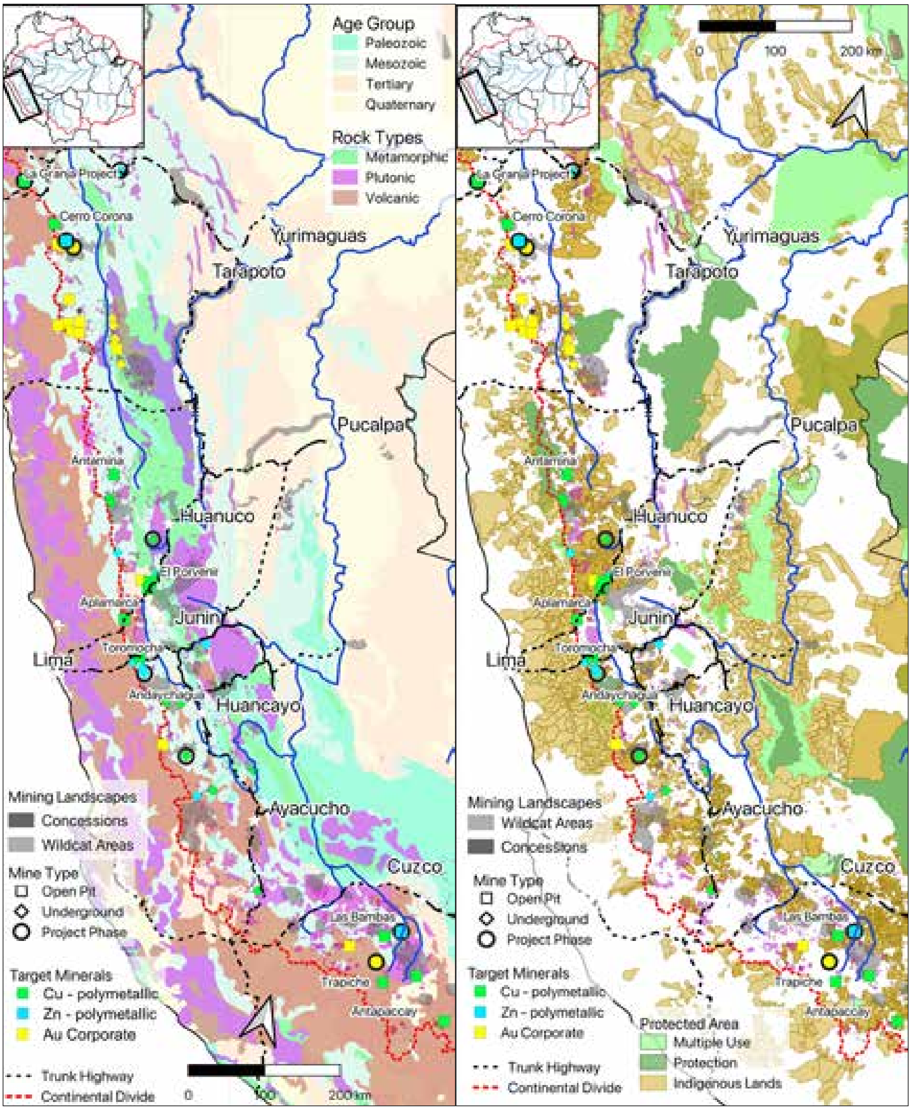
Annex 5.2: The mining landscapes of the Lower Amazon and adjacent areas of the Brazilian and Guiana Shield. Top: Mining data in the context of major geological features. Bottom: Mining data in the context of protected areas and indigenous lands. RENCA (Reserva Nacional do Cobre e Associados) is a mineral reserve created by the military government in 1984. Both the Temer and Bolsonaro administrations proposed opening it to mining.

Data sources: Gomez et al. (2019) and RAISG (2022).



Annex 5.3: The mining landscapes of the northeast sector of the Guiana Shield. Top: Mining data in the context of major geological features. Bottom: Mining data in the context of protected areas and indigenous lands.

Data sources: Gomez et al. (2019) and RAISG (2022).



Annex 5.4: The mining landscapes of the Central Peru. Most mines exploit polymetallic ore bodies located high in watersheds (Marañon, Ucayali, Madre de Dios) near the continental divide. Left: corporate mines and concessions in the context of selected geological features. Right: corporate mines and concessions in the context of protected areas and indigenous lands.

Data sources: Gomez et al. (2019), RAISG (2022) and MINAM (2022).

Annex 5.5: The open-pit mines of the Carajás Mineral Complex.

Mine complex	**Company**	**Domicile**	**Municipality**	**Mineral (concentration)***	**Start-up**	**Life of Mine (years)**	**Reserves Tonnes ($x10^6$)***	**Nominal value ($US million)†**
Serra Norte	Vale	Brazil	Parauapebas	Fe (65.8%)	1984	20	2,880	211,872
Azul	Vale	Brazil	Parauapebas	Mn (27%)	1985	2	13	83
Igarapé Bahia	Vale	Brazil	Parauapebas	Cu (0.8g/t)			170	16,017
Buritirama	Buritipar	Brazil	Marabá	Mn (45%)	1994	8	18	200
Sossego	Vale	Brazil	Canaã dos Carajás	Cu (0.6%) Au (0.19g/t)	2007	10	98	22,883
Serra Leste	Vale	Brazil	Curionópolis	Fe (64.8%)	2009	4	260	18,836
Onça Puma	Vale	Brazil	Ourilândia do Norte	Ni (1.36%)	2011		153	45,101
Salobo	Vale	Brazil	Marabá	Cu (0.5%) Au (0.1g/t)	2012	72	1,157	181,671
Antas	Avanco	Australia	Canaã dos Carajás	Cu (0.5%)	2015		5	69,786
Serra Sul (S11D)	Vale	Brazil	Canaã dos Carajás	Fe (65.7%)	2015	100	4,430	325,395
Tucumã	Ero Copper	Canada	Tucumã	Cu (0.86%)	> 2024	12	48	2,577
Jaguar	Centaurus	Australia	São Félix do Xingu	Ni (0.87%)	> 2024		108	24,786
Alemão	Vale	Brazil	Parauapebas	Cu (1.5%)	> 2024		170	19,898
Vermelho	Horizonte	Canada	Canaã dos Carajás	Ni (1.05%) Co (0.05%) Mn (11.2%) Fe (31%)	> 2024	38	146	38,604
						Total		**790,796**

* Source of data: Mining Data Solutions, https://miningdataonline.com; PorterGeo, http://portergeo.com.au/database/index.asp

† Nominal value calculated by multiplying (mineral concentration x ore reserve x 75% recent market value) in 2020.

Annex 5.6: The open-pit polymetallic mines located in the headwaters of the Amazon in Peru.

Mine	Holding Company	Domicile	River Basin	Minerals (concentration)*	Start-up	Life of Mine (years)	Reserves Tonnes (10^6)*	Nominal Value $US†
Atacocha	Nexa / Votoratim	Brazil	Ucayali	Cu (0.38%) Zn (3.45%) Pb (1.99%) Ag (66g/t)	1936	5	6.8	1,138
Cerro de Pasco	Volcan / Glencore	Switzerland	Ucayali	Zn (8.5%) Pb (3.2%) Ag (65.1g/t)	1950	12	3	811
Colquijirca	Buenaventura	Peru	Ucayali	Zn (1.25%) Cu (4.1%) Au (0.6g/t)	1974	12	76	15,149
Antamina	BHP Billiton / Glencore	UK, Swiss, Canada	Marañon	Cu (0.92%) Zn (2.03%) Mo (0.04%) Ag (14 g/t)	2001	30	335	42,070
Yauli	Volcan / Glencore	Switzerland	Ucayali	Zn (5.4%) Pb (0.9%) Cu (0.1%) Ag (89.9g/t)	2006	22	77	14,209
Cerro Corona	Gold Fields	Canada	Marañon	Cu (0.45%) Au (0.83 g/t)	2007	23	194	12,059
Coimolache	Buenaventura	Peru	Marañon	Cu (0.79%) Au (0.44g/t) Ag (7.2g/t)	2011	73	290	20,740
Antapaccay	Glencore	Switzerland	Ucayali	Cu (0.42%) Au (0.08 g/t) Ag (1.15 g/t)	2012		474	12,531
Alpamarca	Volcan / Glencore	Switzerland	Ucayali	Zn (1.13%) Cu (0.07%) Ag (40.3g/t)	2014	3	3	183
Constancia	HudBay	Canada	Ucayali	Cu (0.34%) Mo (0.01%) Au (0.04g/t) Ag (1.9g/t)	2014	27	483	13,315
Las Bambas	MMG	China	Ucayali	Cu (0.6%) Mo (0.02%) Au (0.03g/t) Ag (2.4g/t)	2015	18	13	573
Toromocha	Chinalco	China	Ucayali	Cu (0.47%) Mo (0.02%) Ag (5.8 g/t)	2016	40	1,412	55,676
Shahuindo	Tahoe resources	Canada	Marañon	Au (0.53 g/t) Ag (6.8 g/t)	2016	11	112	2,867
El Galeno	Minmetals	China	Marañon	Cu (0.64%) Mo (0.02%) Au (0.14 g/t)	2017		765	39,145

Mine	Holding Company	Domicile	River Basin	Minerals (concentration)*	Start-up	Life of Mine (years)	Reserves Tonnes (10^6)*	Nominal Value $US†
Corani	Bear Creek	Canada	M. de Dios	Zn (0.55%) Pb (0.9%) Ag (51.3 g/t)	2024		138	7,866
La Granja	Rio Tinto	UK Australia	Marañon	Cu (0.45%)	> 2024		3,500	120,914
Huaquira	First Quantum Minerals	Canada	Ucayali	Cu (0.45%) Mo (0.01%) Au (0.03 g/t) Ag (1.4 g/t)	> 2024		868	28,971
La Conga	Newmont	USA	Marañon	Cu (0.24%) Au (0.65 g/t)	> 2024		356	14,852
Trapiche	Buenaventura	Peru	Ucayali	Cu (0.42%) Mo (0.08%)	> 2024		722	39,191
						Total		**484,545**

* Source of data: Mining Data Solutions, https://miningdataonline.com; PorterGeo, http://portergeo.com.au/database/index.asp; annual reports of publicly held companies

† Nominal value calculated by multiplying (mineral concentration x ore reserve x recent market value) in 2020.

Annex 5.7: The open-pit copper mines operated or under development in Amazonian Ecuador and Colombia.

Mine	Holding Company	Domicile	River Basin	Minerals (concentration)*	Start-Up	Life time	Reserves Tonnes (10^6)*	Nominal Value $US million†
Mirador	Tongling / CRCC	China	Marañon	Cu (0.52%) Au (0.17g/t) Ag (1.3g/t)	2018		437	17,462
San Carlos - Panantza	Tongling / CRCC	China	Marañon	Cu (0.62%)	?		678	26,404
Orquidias	Luminex	Canada	Marañon	Cu (0.9%) Mo (0.66%)				
Tarqui	Luminex	Canada	Marañon	Cu Mo				
Warintza	Solaris	Canada	Marañon	Cu (0.59%)			579	21,457
Porvenir	SolGold	Canada	Marañon	Cu (0.44%) Au			396	10,944
Bonita	ENAMI – EP	Ecuador	Putumayo	Cu (0.9%)				
Mocoa	Libero Copper	Canada	Putumayo	Cu (0.33%) Mo (0,036%)			636	12,910
						Total		**89,178**

* Source of data: Mining Data Solutions, https://miningdataonline.com; PorterGeo, http://portergeo.com.au/database/index.asp; annual reports of publicly held companies

† Nominal value calculated by multiplying (mineral concentration x ore reserve x recent market value) in 2020

Annex 5.8: The Bauxite mines and unexploited reserves of the Pan Amazon.

Mine*	**Operator***	**Domicile**	**Jurisdiction**	**Content* Al_2O_3**	**Start-up**	**Life of Mine (years)***	**Reserves tonnes (10^6)***	**Value† $US million**
Trombetas	MRN‡	Multi-national	Oroximinas	48%	1979	10	416	1,000
Jurutí	Alcoa	USA	Juritî	48%	2010		700	2,815
Paragominas	Hydro Norsk	Norwegian	Paragominas	48%	2007	36	400	5,000
Alumina Do Rondon	Votorantim	Brazil	Paragominas	52%	< 2024	37	371	8,000
Onverdacht	Alcoa	USA	Suriname	50%	1941	closed		
Moengo	Alcoa / BHP	USA / UK	Suriname	50%	1916	closed	10	450
Bakhuis			Suriname	43%			325	1,625
Nassau, Lely & Bloomsberg			Suriname	54%			40	200
Linden-Ituni	Rusal§	Russian	Guyana		1916	closed		
Kurubuka-22	Rusal	Russian	Guyana		2015		30	
Tarakulli-6			Guyana	59%			1000	2,600
Essaquibo Group			Guyana	54%				
Blue Mountains			Guyana	50%				
Los Pijigüaos	C.V.G.	Venezuela	Bolivar	44%	1987	100	570	2,850
						Total		**24,255**

* Source of data: http://www.portergeo.com.au/database/index.asp

† Calculated by multiplying mineral content x reserve x 75% of market value of ore concentrate at export terminal (FOB) in 2015.

‡ MRN: BHP Billiton (14.8%), Alcoa (18.2%), Vale (40%), Rio-Tinto (12%), CBA (10%) and Norsk Hydro (5%).

§ Current operators of the Bauxite Company of Guyana.

Annex 5.9: A partial inventory of the corporate gold mines in the Pan Amazon.

Mine	Company	Domicile	Jurisdiction	Status	Type	Start up	Reserves (t oz)	Nominal Value* $US million
				BRAZIL				
Tucano	Great Panther	Australia	Serra de Navio (AP)	Operating	Open pit	2012	1,411	2,258
Novo Xavantina	Ero Copper	Canada	Novo Xavantina (MT)	Operating	Underground	2012	307	492
Ernest - Pau a Pique	Aura Minerals	Canada	Pontes e Lacerda (MT)	Operating	Open pit	2012	24	39
Sao Chico	Serabi Gold	Canada	Itaituba (PA)	Operating	Underground	2016	9	14
Aurizona	Equinox Gold	Canada	Godofredo Viana (MA)	Operating	Open pit	2019	1,660	2,656
Castelo de Sonhos	Tri Star Gold	Canada	Altamira (PA)	Project	Open pit		1,372	2,195
Volta Grande	Belo Sun	Canadian	Altamira (PA)	Project	Open pit		3,662	5,859
Tocantinzinho	G MINING	Canada	Itaituba (PA)	Project	Open pit		2,055	3,287
Crepori	Mineracao do Para	Brazil	Itaituba (PA)	Project	Strip		-	-
Coringo	Serabi Gold	Canada	Altamira (PA)	Project	Underground		164	263
Sao Jorge	Globestar Mining	Canada	Novo Progresso (PA)	Project	Underground		642	1,027
Palitos	Serabi Gold	Canada	Itaituba (PA)	Project	Underground		65	104
Cuiú Cuiú	Cabral Gold	Canada	Itaituba (PA)	Project	Underground		344	551
Cajuaeiro	Altamira Gold	Canada	Paranaíta (MT)	Project	Open Pit		227	364
São Francisco	Aura Minerals	Canada	Novo Lacerda (MT)	Suspended	Open pit		1	2
São Vicente	Aura Minerals	Canada	Santissima Trinidad (MT)	Suspended	Open pit		-	-
						Total	**11,944**	**19,111**
				GUYANA				
Karouni	Troy Resources	Australia	Cuyuni-Mazaruni	Operating	Underground	2017	91	145
Aurora - Gold	Zinjin Mining	China	Cuyuni-Mazaruni	Operating	Strip	2020	-	-

Mine	Company	Domicile	Jurisdiction	Status	Type	Start up	Reserves (t oz)	Nominal Value* $US million
Toraparu Hill	GCM Mining	Canada	Cuyuni-Mazaruni	Operating	Open pit	2022	4,237	6,779
Eagle Mountain	Gold-Source	Australia	Cuyuni-Mazaruni	Project	Strip		74	119
Omai - II	Omai Gold	Canada	Cuyuni-Mazaruni	Project	Open pit		962	1,539
Oko West	Reunion Gold	Canada	Cuyuni-Mazaruni	Project	Open pit		499	798
Marudi Hill	Golden Shield Resources	Canada	Upper Takutu	Project	Open pit		261	417
						Total	**6,123**	**9,533**
				SURINAME				
Rosibel Gold	Zinjin Mining	China	Sipaliwini	Operating	Open pit	2004	3,869	6,191
Merian	Newmont	USA	Brokopondo	Operating	Open pit	2016	3,994	6,390
Nassua project	79 North	Canada	Brokopondo	Project	Open pit		-	-
Brothers	Rhyolite	Canada	Sipaliniwi	Project	Underground		-	-
Suki Pass	Rhyolite	Canada	Para	Project	Underground		-	-
						Total	**7,863**	**12,581**
				FRENCH GUIANA				
Montage d'Or	Orea	Canada	F Guiana	Operating	Open pit	2022	-	-
Dorlin	Reunion / Auplata	France	F Guiana	Project	Underground		785	1,256
Esperance	CME / Newmont	France	F Guiana	Project	Underground		-	-
Camp Caiman	IAM-GOLD	Canada	F Guiana	Canceled	Open pit		-	-
						Total	**785**	**1,256**
				VENEZUELA				
Las Cristinas	MINER-VEN	Venezuela	Bolivar	Operating	Strip		8,217	13,146
Choco 10	MINER-VEN	Venezuela	Bolivar	Operating	Strip		4,467	7,148
Increible 6	MINER-VEN	Venezuela	Bolivar	Operating	Strip		560	896
Lo Increible	MINER-VEN	Venezuela	Bolivar	Operating	Strip		311	497
						Total	**13,554**	**21,686**

Mine	Company	Domicile	Jurisdiction	Status	Type	Start up	Reserves (t oz)	Nominal Value* $US million
				ECUADOR				
Fruta del Norte	Lundin Gold	Canada	Zamora Chinchipe	Operating	Underground	2020	6,125	9,800
Condor	Luminex	Canada	Zamora Chinchipe	Project	Open pit		2,496	3,994
						Total	**8,621**	**13,793**
				PERU				
Retamas	MARSA	Peru	La Libertad	Operating	Underground	1981	-	-
Yanacocha	Newmont	USA	Cajamarca	Operating	Open Pit	1993	1,856	2,969
Lagunas Norte	Boroo / Barrick	Australia	La Libertad	Operating	Open Pit	2005	3,948	6,316
Cori Puno	Cori Puno SAC	Peru	Madre de Dios	Operating	Underground	2007	-	-
La Zanja	Buenaventura	Peru	Cajamarca	Operating	Open Pit	2010	-	-
Anabi	Anabi SAC	Peru	Ucayali	Operating	Open Pit	2010	-	-
La Arena	La Arean SA	Peru	La Libertad	Operating	Open Pit	2011	1	720
Quicay	Centauro	Peru	Pasco	Closed	Open Pit	2011	-	-
Shahuindo	Pan American	Canada	Cajamarca	Operating	Open Pit	2016	10,633	17,013
Minas Pampas	Lida Resources Ltd	Canada	La Libertad	Project	Open Pit		-	-
Gaban & Yang	Winshear Gold	Canada	Madre de Dios	Project	Underground		-	-
Project Oyachea	Minera ITL	Canada	Madre de Dios	Project	Underground		866	1,386
						Total	**17,304**	**28,404**
				BOLIVIA				
San Simon	Stenmar	Bolivia	Beni	Operating	Underground	1985		
Golden Hill	Mantaro Goild	Canada	Santa Cruz	Project	Open Pit	2000		
Puquio Norte	Comsur	Bolivia	Santa Cruz	Closed	Open Pit	1995	0.32	0.520
						Total	**0.32**	**0.520**
					Grand Total		**66,194**	**106,365**

* The nominal value is based on the reported reserves and a market value of $US 1,600 per troy ounce. Reserves are reported in annual reports of publicly listed companies, where they are defined as proven and probable; italicised values are based on reported 'resources', which are defined as 'measured' and 'indicated'. Reserves from operating mines reflect future production; mines that report neither reserves nor resources are either at an early stage of exploration or privately owned domestic companies that are not obligated to report potential assets. Other sources of data include Mining Data Solutions, https://miningdataonline.com; PorterGeo, http://portergeo.com.au/database/index.asp

Annex 5.10: The major oil and gas reserves of the Pan Amazon.

	Reserves: Proven, Probable and Possible				**Resources: Contingent and Prospective**			
Sedimentary Basin	Oil (M BBL)*	Natural Gas (BCF)†	Gas liquids (M BBL)	Nominal value $US million‡	Oil (M BBL)*	Natural Gas (BCF)†	Gas liquids (M BBL)	Nominal value $US million‡
Putumayo-Oriente-Marañon								
Colombia	31			2,480	5,836			466,880
Ecuador	2,058	400		166,640	2,050			164,000
Peru	492			39,360	2,030	159		163,178
Ucayali (Selva Sur)								
Camisea		13,500	510	108,300	357	29,037	127	183,919
Brazil								
Solimões		1,245		6,225	574	23,127	625	211,555
Amazonas		207	1.8	1,180	369	6,648	259	83,480
Panaiba		956		4,780	2,972	17,759	1,088	413,595
Guyana-Suriname	11,000	10,000		930,000	13,608	21,000	863	1,262,680
Total	13,581	26,308	512	1,258,965	27,796	106,430	2,962	2,992,787

* million barrels
† billion cubic feet
‡ Nominal value calculated at $US 80 per barrel of oil and $US 5 per 1,000 cubic feet of natural gas, gas-liquids priced as oil.

Sources of data:
Colombia https://www.anh.gov.co/documents/18/Evaluating_total_Yet_to_Find_hydrocarbon_volume_in_Colombia.pdf ;
Peru http://www.minem.gob.pe/minem/archivos/LARH%202018.pdf ;
Ecuador https://www.recursosyenergia.gob.ec/wp-content/uploads/2022/07/Revista-Potencial-Anual-Hidrocarburi%CC%81fero-del-Ecuador-2021.pdf;
Brazil https://www.ibp.org.br/observatorio-do-setor/?ibp_pdados_do_setor_setor=petroleo;
Guyana & Suriname https://oilnow.gy/featured/worlds-largest-oil-reserves-by-country/;
Overview https://pubs.usgs.gov/fs/2012/3046/fs2012-3046.pdf

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