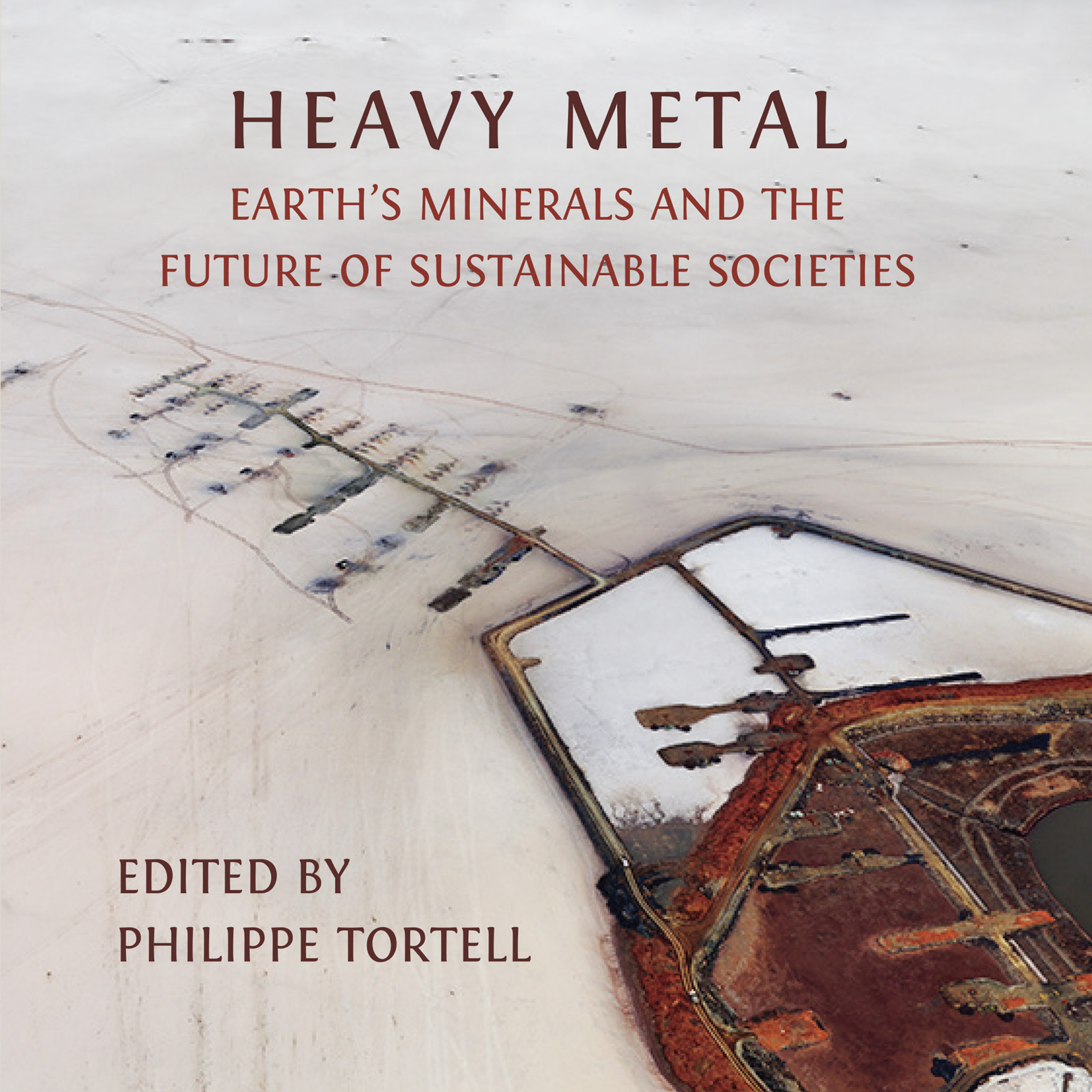

HEAVY METAL

EARTH'S MINERALS AND THE FUTURE OF SUSTAINABLE SOCIETIES

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Can Small Mining Be Beautiful?

Marcello M. Veiga and J. Alejandro Delgado-Jimenez

In the 1973 book, *Small Is Beautiful: A Study of Economics as if People Mattered*, the economist Ernst Friedrich 'Fritz' Schumacher outlined a vision for future sustainable development. He emphasized the use of local resources, and criticized the nascent process of globalization he saw unfolding around him. Schumacher embraced the use of small-scale technologies, and argued against the mainstream notion of 'bigger is better'.[1]

Half a century later, globalization, built on large-scale industries, has become the de facto economic imperative for the supply of all major commodities, including minerals needed for renewable energy and other technologies. But even before the 1970s, the discovery and extraction of mineral deposits was dominated by so-called Conventional Organized Mining (COM) companies, medium to large multinational corporations with operations spread around the globe. Today, COM companies employ as many as four million people globally, and have annual revenues between two and three trillion US dollars (on par with the gross domestic product (GDP) of Germany and France). Much of this profit is distributed among a small number of particularly large companies, some of which are among the biggest corporate entities in the world. One American company, Newmont Corporation, has about four thousand metric tons of gold reserves (almost 8% of the total global reserves).[2] The Brazilian company,

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Vale, has iron ore reserves of approximately thirteen billion metric tons (about 7% of the global total), producing 320 million metric tons in 2023.[3] With their significant market shares, COM companies control most of the mineral titles on Earth. For this reason, they exert a strong influence on global mining practices, directly impacting commodity prices and even geopolitics.

The dominant economic model for COM companies relies on the discovery or acquisition of large, 'word-class' ore deposits. The discovery and development of such deposits requires enormous up-front capital investments, and depends on an 'economy-of-scale' approach (the notion of *bigger is better* that Schumacher criticized). But increasingly, the main challenge to this economic model lies in finding large deposits, which are becoming rarer and more inaccessible, buried deeper underground.[4] Take gold, for example. In 2010, approximately five gold 'mega-deposits' with more than six million ounces (oz) of gold were discovered. In 2018 and 2019, no such large deposits were found, although many smaller deposits were identified, including thirteen new deposits ranging from 0.1 to 1 million oz of gold, and over three hundred deposits with less than 0.1 million oz.[5] Looking for 'elephants', the geologists instead found lots of 'mice', which are not large enough to justify large up-front investments of COM companies. And even with a significant investment in geological exploration, the discovery of potential mineral deposits often does not translate into a significant number of new mines entering into operation. On average, out of every 10,000 mineral exploration projects, only one becomes a large-scale working mine.[6]

In the face of dwindling mega-deposits, the COM companies have responded by putting their faith in technological innovation, and in market forces that keep commodity prices high. Most of these companies focus on technical approaches to develop new or improved methods for mining exploration and processing of complex ores. These include automated, deeper underground mining methods,[7] seafloor mining[8] and the use of microbes to access low-grade ore deposits.[9] Even asteroid mining has attracted the attention of COM companies.[10] These technological approaches are used to justify the strategies of the COM companies, but they don't necessarily address other environmental, social and geopolitical realities that might constrain large-scale mineral exploration and recovery. They also don't address the significant time-lag from the discovery of a large mineral deposit to the production phase. In some cases, this delay can range from fifteen to twenty years, and significantly longer if there are disputes with local communities. Such long delays make large COMs slower to respond to altered demand and potentially rapidly shifting market factors, with significant implications for commodity prices.

Sometimes, large proposed mining projects can be shut down all together, often over significant environmental concerns among potentially impacted communities. In the municipality of Tambogrande, Peru, for example, the Canadian company Manhattan Minerals obtained a reserve of close to fifty million metric tons of copper, zinc, gold and silver ore, proposing a mine to extract one billion dollars' worth of minerals. The community was concerned about insufficient revenue sharing and inadequate services associated with the proposed mine, and also about potential impacts on local lime and mango production (the region produces more than half of the country's limes). In addition, half of the 16,000 town inhabitants were to be displaced by the open pit. In a referendum, 93% of community members expressed opposition to the mining project, and the company left the town two years later with a sixty-million-dollar loss.[11]

All types of mining operations have potential negative impacts on the environment, and on the health and social fabric of local communities.[12] But the focus of most environmental groups has been on the COM operations, whose large-scale projects have the most significant potential impacts. In 2015, a tailings dam breach in Brazil released forty-four million cubic meters of iron ore waste rock, flooding the downstream villages of Bento Rodrigues and Paracatu de Baixo. The resulting pollution spread over more than six hundred square kilometers, and nineteen people lost their lives in the flooding. Four years later, also in Brazil, the failure of the Brumadinho tailings dam unleashed a mudflow that destroyed houses, roads and farms, killing 270 people and creating a devastating environmental catastrophe.[13] Such environmental impacts fall disproportionately on vulnerable communities in remote or developing regions. They are one of the most significant barriers to the acceptance of large-scale mining operations.

With its focus on finding mega-deposits, the COM sector does not take into consideration the mining of metals from a large number of small deposits found every year by geologists. The majority of these deposits are discovered by local prospectors or junior exploration companies, many of which are located in Canada. These small companies explore and drill small deposits using sophisticated geological expertise. They do not, however, typically move beyond the exploration phase, leaving the development and operation of mines to others. A number of these small deposits could be profitable given sufficiently high metal grades, but the low tonnage does not entice investors interested in large discoveries and financial windfalls. If large COM companies have interest only in large deposits (elephants), and if the junior companies are not interested in mining small deposits (mice), who will do it?

The answer may lie in artisanal mining. This informal economic activity, which directly involves forty-five million people,[14] is based on the use of rudimentary techniques to extract and process more than thirty different types of minerals, with a particular focus on gold, diamonds and other gemstones, but also increasingly on critical metals, such as cobalt, niobium, tin and tantalum. These practices go back thousands of years, to the time well-before European colonization of Africa and the Americas, but their contribution to the global economy has increased significantly in recent decades. Today, the sector employs approximately forty-five million workers in more than eighty countries around the world, with the greatest activity concentrated in developing countries in Africa, Asia and Latin America.[15] Artisanal miners represent about 90% of all mining-related employment in the world, with significant representation of both women and children.[16] In sub-Saharan Africa, artisanal mining is second only to agriculture as a contributor to local economies.

The involvement of child labor has underscored human rights concerns around artisanal mining, and these activities have often intersected, and perhaps even fueled, local armed conflict. During the five-year civil war in the Democratic Republic of

Congo (1998–2003), the region's minerals were used to finance rebel groups, foreign militias and the national army, leading to large-scale violence and human rights abuses.[17] Significant attention has also been focused on the potential environmental and health impacts of artisanal mining. These are particularly well studied in the case of gold extraction, which involves the burning of gold amalgams in open pans to evaporate the mercury.[18] The inhalation of highly toxic mercury vapors has been linked to neurological, kidney and autoimmune impairment, as well as respiratory failure and death, while environmental release of mercury leads to bioaccumulation across the food chain. Artisanal miners also face significant exposure to other potentially dangerous substances, including arsenic, lead, methane, sulfur dioxide, nitrous oxide, carbon monoxide and cyanide.[19] Biological health risks include increased exposure to sexually transmitted diseases, and other pathogens such as cholera, malaria and dengue fever associated with often poor sanitation and unsafe drinking water.[20] Physical risks include injury associated with over-working under conditions of high temperature and humidity, as well as the high prevalence of accidents, including landslides and the collapse of unstable mining tunnels. Typically, health services are either rudimentary (at best) or inaccessible in the vicinity of informal mining camps.

Despite its obvious challenges, the economic calculus and social context for artisanal mining is vastly different to that of COM operations, allowing it to potentially fulfill an important role in the global mining sector. Artisanal miners have very low up-front costs, allowing them to exploit small deposits, and rapidly shift their activities between sites. Following the collapse of the Tambogrande Mine project in Peru, for example, thousands of local artisanal miners began excavating the streets of the town to manually extract gold using mercury. This activity was accepted by the community as a means of providing socio-economic benefits for unskilled workers.

The broader question is how artisanal mining activities can be developed in a way that supports human and environmental well-being, while also supplying much needed raw materials. Many of the environmental and social challenges facing artisanal mining reflect the illicit nature of this sector, with few (if any) regulations and little (if any) oversight. Thus far, governments of developing countries have proved incapable of effectively regulating the methods used by artisanal miners, or even developing simple and expedited mineral legislations. This does not reflect a lack of interest or effort. In Ghana and Mozambique, for example, governments have attempted to formalize the practices of artisanal mining, yet these efforts have been hampered by limited financial and human resources, complex bureaucracy and ineffective enforcement regimes.[21]

Little assistance is given to artisanal mining communities by the governments of developing counties. Rather, the presence of such primitive miners seems to be a source of embarrassment for the authorities, and most governments prefer to establish awkward and unenforced laws that stifle the development of this sector. In Colombia, for example, an artisanal miner seeking formal recognition from the government must work through 380 bureaucratic steps. As a result, less than 1% of artisanal miners operate legally in Latin America,[22] with unsanctioned miners often portrayed as bandits or criminals by local media. There is no doubt that money laundering and other illegitimate activities exist in artisanal mining (as in many other black-market economies), but the large majority of poor mining workers in rural areas are simply struggling to feed their families. A United Nations study concluded that much of the disorganization and pollution caused by artisanal miners is attributable to a lack of understanding, skills and equipment, and cumbersome legal and bureaucratic in developing countries facing dire economic circumstances. Nonetheless, there may be a path forward in transforming artisanal miners into small-scale operators adhering to acceptable environmental, safety and human rights standards.[23] And in this transformation, it may be that the COM companies can play a fundamental role, though a shift in their business models.[24]

Some progress is already evident. In Latin America there are an increasing number of local and foreign investors building small-scale, responsible mining operations. Chinese companies, in particular, have understood the profitability of these small mines, and have flocked to Africa, making significant economic contributions to local communities, but also generating conflicts with pre-existing artisanal miners.[25]

The model increasingly being developed is one of economic co-existence, in which artisanal miners sell their ores to COM operating plants, which have the capacity to process and refine these into higher-value metals. Such a model has already been implemented (albeit at a limited scale) in Colombia, Costa Rica, Ecuador, Nicaragua, Peru and other countries. In these countries, there are at least two dozen medium-sized COM companies either buying ores or tailings from artisanal miners, or allowing these small-scale miners to exploit part of the companies' mineral claims.[26] Through this cooperative model, the miners focus on extraction, while the companies focus on processing. The miners receive higher payments, and avoid the many health and environmental risks associated with low-tech extraction methods, including the use of mercury. This approach reduces environmental and health impacts, increases metal recovery and the overall profitability of the artisanal mining sector, with more economic benefits flowing directly to local communities. In addition, a more formalized artisanal mining sector can provide access to credit and more clearly defined property rights. Governments, in turn, can derive greater economic returns from their mineral resources.

There are other potential advantages of well-regulated artisanal mining, developed in partnership through mining companies and local communities. For one thing, new alternative technologies can be much more easily tested and implemented in small projects than in large operations. For example, using a liquid waste-product from cassava flour production, known as 'manipueira', it was possible to extract up to 84% of gold from an artisanal mining ore.[27] This home-made solution can be used as a substitute for mercury in artisanal gold mining, but would not be suitable to process hundreds of tons per day of ore from a large mine. And even if such technologies prove inviable, failure on a small scale results in a minor setback, as opposed to a major disaster. Other potential synergies with local communities include the use of traditional knowledge combined with modern prospecting methods to help focus exploration efforts.

The development of artisanal methods to exploit small ore deposits, using appropriate technologies and innovative business models, holds significant potential economic and social benefits for communities. Tangible benefits include direct employment and even ownership stake by locals, and the development of entrepreneurial initiatives. The small scale of these operations means that projects can start more quickly and experiment with the latest technological innovation. Depending upon the production rate, small-scale mines can remain viable for longer periods than rapidly exploited large mines, creating longer-term benefits. If adequately regulated, the environmental footprint of these small operations can be minimized, and they are likely to be much less energy intensive, with significantly lower carbon emissions.

The global mining sector is certainly different today than it was in 1973, when Schumacher published his famous book. It is likely that we have already located and mined most of the planet's easily accessible, large-scale deposits. With the growing scarcity of such deposits, large COM companies, and the global mining sector more broadly, will need to evolve quickly. No doubt, the development of new technologies and increasing commodity prices will support ongoing efforts to find and exploit ore deposits of various sizes and complexity. But in our ongoing search for elephants, we will surely find many more mice. These mice will not be able to meet our full demand for minerals, but if they are exploited responsibly—with appropriate oversight and regulatory frameworks—they can contribute significantly to the economic and social development of millions of people around the world. If we follow such a path forward, perhaps small can, indeed, be beautiful.

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