Mining—Metals

Metal mining extracts ores from the Earth, which are then processed into industrial or precious metals. The global mining industry has undergone changes since the global economy intensified its integration and reach in the early 1990s. These changes, including increasing technological efficiency and investment in the third world, have challenged sustainability and generated controversy. In response, global civil society is organizing to police the industry.

Mining is the extraction of minerals or other valuable geological materials from the Earth. These minerals serve as the primary inputs for much of the matter that makes up our industrial society. Important nonmetallic minerals include salt, clays, sand, gravel, and industrial materials. Gemstones such as rubies, diamonds, and emeralds are also mined, although they are predominantly used for jewelry or as a way to store wealth. Other mined materials include fuels such as petroleum, coal, natural gas, and uranium ores. Finally, metal mining involves the extraction of ores that are then processed into industrial or precious metals such as iron (steel), bauxite (aluminum), laterites (nickel), cassiterite (tin), copper (bronze), lead, gold, and silver.

The stages of metal mining include reconnaissance, prospecting, general and detailed exploration, and extraction. Exploration, an important stage, refers to the identification of zones that potentially contain mineral deposits of sufficient concentration to be profitably mined, and to the use of drilling to sample the prospective deposit at the depth where geologists presume the ore exists. Usually mineral geologists carry out exploration by using remote sensing, topography, and surface indicators to pinpoint potential zones of mineralization, the geological activity that occurs over time in which rocks are transformed into ores containing economically valuable minerals in significant concentrations. Extraction is the process of removing ore from the ore body, and the subsequent metallurgical processing to remove the metal from the ore. Generally, metal is removed from ore by heating or leaching (dissolving ore in a chemical solution). For some ores, heating this solution separates the target metals from other compounds. For others, such as gold, chemicals are added to the solution, which attract the target elements away from other substances, allowing for easier recovery.

The two basic types of metal extraction are underground mining and surface mining. The type of mineralization determines the type of extraction. Ore bodies that occur in underground veins, hundreds to thousands of meters below the surface, must be mined using underground techniques in which shafts (vertical tunnels) and drifts and stopes (horizontal or inclined tunnels) are constructed to access the ore body. Alluvial metal deposits, also known as placer deposits, are loose, surface mineral concentrations generally created by rivers. These are mined using surface mining techniques.

Open-pit mining is the most common type of surface extraction. Historically, underground mining has been predominant; however, in the twenty-first century, as commercially rich underground ore bodies have become ever scarcer, surface mining has become more common than underground mining. Newer processing techniques (such as cyanidation in the case of gold) and the economies of scale associated with large equipment allow for the profitable mining of lower-grade, more diffuse surface deposits.

Human civilizations have always mined metals, although the scale and scope has increased dramatically since the dawn of the Industrial Revolution in the 1840s. The Bronze Age marked the first widespread adoption of metallic minerals for human use. The earliest occurrence of bronze alloys was in the Middle East during the third millennium BCE. The Bronze Age gave way to the Iron Age approximately in the twelfth century BCE. Centuries later, the Romans developed the first large-scale mining techniques, complete with complex tunneling systems and mechanisms to remove overburden (layers of dirt and rock above the mineral deposit). Mining techniques were refined in Europe throughout the Middle Ages (c. 500–1500 CE). With the onset of the Industrial Revolution, the United States entered into large-scale mining. The three most important developments for industrial mining since the 1800s are the inventions of explosives, wire rope, and the internal combustion engine. Mining drove westward expansion in the United States in the late nineteenth century. San Francisco, California, and Denver, Colorado, for example, were originally settled as mining outposts.

Since the 1970s, we have entered a new era of metal mining characterized by the movement of mining investment from traditional investment targets (e.g., the United States, Canada, and Australia) toward emerging economies in the developing world (Bridge 2004). Four factors brought about this shift: (1) new technologies that allow for more diffuse deposits of minerals to be profitably mined, (2) the exhaustion of many deposits in traditional mining countries, (3) the opening of many developing economies to the world economy, and (4) the increased demand for metals as a product of industrial growth in Brazil, India, China, and Russia. In Latin America and Africa, investment in mining has tripled since 2000. With these changes, metal mining has become increasingly contentious regarding economic and environmental sustainability around the world.

In the twenty-first century, mining occurs in most countries through licenses—or concessions—that governments grant to mining companies. Generally, governments grant separate exploration and extraction licenses, and mining companies must meet certain technical, environmental, and social requirements in order to receive their licenses. In much of the developing world, a country's push to attract foreign investment in the economic sectors where it has a comparative advantage results in looser regulatory frameworks for metal mining. These frameworks may be less than ideal for protecting the natural environment and the host community. The mineral industry's corporate culture tends to marginalize community-relations personnel and to prioritize reducing production costs at the expense of transparency and environmental standards (Rees 2009; Dobra 2002).

Metal Mining and Economic Sustainability

In the contemporary developing world, rather than serving as an engine for economic development, mining can actually make countries underperform economically. Metal mining was an important industry for early economic development in some of the world's most developed nations. The United States and Canada in particular benefited from vast, unexplored frontiers with significant mineralization that enabled them to develop large metal mining industries. These same countries, however, were industrializing simultaneously, and they were able to consume the metals they produced, which in turn fortified other industries. Also, the sheer expanse of these continental nations facilitated the emergence of complex rail systems to transport primary goods. Therefore, mining in these countries was an engine for industrial development and diversification. In the twenty-first-century Global South, or the developing countries that populate the Southern Hemisphere, however, foreign companies carry out the mining, and the extracted ore is largely exported (Power 2002). In contrast to the United States of the 1850s, most modern mining constitutes an enclave sector, which means that it does not meaningfully support other national industries. Further, in countries that are heavily mineral dependent, mining can create a "Dutch disease" effect. This refers to a process in which sudden growth in the mining sector (such as the discovery of a new large deposit or the passage of new mining legislation) siphons off labor and capital from more productive economic sectors such as manufacturing. When the mineral boom ends, economic sectors that lost out to mining are weakened. Finally, a mineral-dependent economy is very vulnerable to sudden changes, or "shocks," in the global prices of these minerals. Minerals are volatile commodities subject to sudden and dramatic price swings. When the prices for these minerals plummet in the world market, countries that are too dependent upon mineral exports can face serious economic crises. Much research in the social sciences supports this "resource curse thesis" (Auty 1993; Power 1996; Karl 1997; Auty and Mikesell 1998; Ross 2001).

Although large multinational corporations dominate world mining, substantial percentages of metals, particularly precious metals that are profitable in very small amounts, are produced in artisanal and small-scale mining operations. Many artisanal mines are little more than individuals panning for gold much the way "forty-niners" did during the California gold rush of the 1840s and 1850s. The difference is that many artisanal miners, including many children, may be exposed to the highly toxic chemicals, such as mercury, used to leach metals from the ore. Almost all artisanal mining takes place in Africa, Latin America, and Asia, often under conditions of extreme poverty and exploitation. Many advocates of sustainable development contend that artisanal mining has the potential to alleviate poverty and enhance well-being in marginalized regions because the poor themselves control the means of production. Others argue that artisanal mining is too informal to be adequately regulated, which leads to proportionally greater environmental and labor violations than corporate mining. New models that incorporate artisanal miners into corporate mining strategies offer a middle ground. An example is Goldlake Group's mines in Honduras, which partner with artisanal miners to produce alongside the commercial mines.

Metal Mining and Environmental Sustainability

Perhaps the biggest problem with metal mining is its potential to negatively affect the environment. This can be mitigated with the right technology and personnel, but because financing is so precious in the mining industry, many companies save money by not implementing optimal safeguards.

There are three chief sources of environmental damage from metal mining: (1) the removal of forest cover and overburden, (2) acid rock drainage, and (3) the storage and disposal of tailings (the by-products of extraction). To build a surface mine, miners must remove the surface vegetation and many tons of overburden to access the ore body. This generates large quantities of dust, contributes to desertification and ecosystem disruption, and increases the vulnerability to erosion in surrounding areas. Also, unless enough trees are planted elsewhere, the removal of the forest cover allows more carbon to escape into the atmosphere, thus exacerbating global climate change. Finally, the creation of these immense craters in the Earth, some so large that they are visible from space, can be aesthetically unappealing as well.

Acid rock drainage occurs when rocks, usually high in sulfides, are extracted from beneath the Earth's surface and left exposed. The exposure of sulfide minerals to the oxygen in the air and to iron-oxidizing bacteria catalyzes the rock's decomposition, which may generate sulfuric acid and release heavy metals such as manganese, lead, and arsenic. The acid and other toxins can then leach into the soil, and rainwater may carry them into the water system. If these heavy metals are permitted to leach into the soil, this can adversely impact agricultural production and human health in areas near the mine. Because some of these metals are carcinogenic, they can negatively impact soil fertility, which in turn, can adversely affect agricultural production. Further, the consumption of foods produced on soils with heavy metal contamination can transfer those toxins to the human organism and can cause serious illness. Mine operators usually prevent acid rock drainage by covering extracted sulfide minerals with clays to prevent their exposure to air and water, or by treating the rock with lime to neutralize its acidity.

Many metallic ores are leached with toxic chemicals to recover the target metal. When dangerous chemicals are used, tailings can be toxic. Mines produce large quantities of tailings, usually a slurry containing pulverized waste rock and thus the same heavy metals and other toxins present in acid rock drainage. Cyanide, a highly toxic compound, is commonly used in gold and silver leaching; therefore, tailings from gold and silver mines also contain potentially dangerous quantities of cyanide. Tailings must be stored and treated during the mining operation and renovated or reclaimed during mine closure. This is one of the most costly aspects of mining. High costs can drive financial managers to pressure mine managers to limit the size of the tailings storage facility and to use cost-effective designs that might increase the risk of adverse environmental outcomes. Tailings enclosures are highly engineered containment systems; nevertheless, if they are not properly contained, toxic substances can escape into the environment. In the case of dry, stacked tailings, airborne cyanide dust can be carried beyond the tailings storage facility. With wet tailings, toxins can leach into the soil and groundwater or dams can fail, resulting in environmental disasters. There have been hundreds of tailings dam failures around the world over the last century.

Metal Mining and the Host Community

While most mines are located in remote, rural areas with little surrounding infrastructure, in an ever more densely populated world, new mines are often near, or even upon, populated areas. The advent of large mines in small communities, therefore, can affect social relations (Tauxe 1993; Gaventa 1980). Mines tend to attract laborers from outside of the community, thus causing rapid population growth. Research shows that along with such growth come increased alcoholism, petty crime, and prostitution (Laite 2009). Further, operating mines create new jobs in poor areas, but because mineral deposits are finite, companies exhaust deposits and leave town, often leaving unemployment in their wake. Mine closure is responsible for many of the ghost towns littering the world, from Africa to the Rocky Mountain West.

Since the 1980s, international legal instruments, such as the International Labor Organization's C169 Convention concerning Indigenous and Tribal Peoples in Independent Countries and the United Nations Declaration on the Rights of Indigenous Peoples, have institutionalized the right of free, prior, and informed consent for indigenous peoples facing mining projects. According to these international norms, indigenous peoples must be substantively consulted, and they must grant consent before a mining project can begin in indigenous territory. The right to grant or withhold consent is not the same as the right to reject a mining project outright. Rather, indigenous groups have the right to shape the project, within reason, to maximize benefits and minimize adverse impacts for the host community. Increasingly, international institutions like the International Council on Mining and Metals and the World Bank are conceding to some level of consultation with indigenous peoples, but in most cases this falls short of the standards for free, prior, and informed consent established in international law.

In one case, the gold mining company Manhattan Minerals sought to locate a mine on top of the large town of Tambogrande in northern Peru. In 2002, the town's inhabitants, facing displacement, organized a municipal referendum to decide whether to allow mining in their territory. Ninety-four percent of the participants voted to prohibit mining (Muradian, Martinez-Alier, and Correa 2003). This model has been duplicated in other places, most notably in Guatemala where, since 2005, over 400,000 people in 42 municipalities have voted to prohibit mining in their territory ("Territorios indigenas y democracia guatemalteca bajo presiones" 2009). These votes are not legally binding, however, since the government usually owns subsoil rights, and mining is considered to be in the national interest. Nevertheless, they give a sense of the growing resistance to large-scale, high-tech mining in developing countries.

Because of the increased contentiousness of mining since 2000, an emphasis on sustainability in the mining sector has emerged, and attention from global civil society has grown considerably. The International Council on Mining and Metals, a mining industry association that seeks to improve sustainability within the industry, was established in 2001 with a set of best practices that include human rights, respecting indigenous culture, and promoting sustainable development. In 2001, the World Bank, under much pressure from activist organizations, commissioned an in-depth review of its involvement in extractive industries. The resulting report, the *Extractive Industries Review,* was published in December 2003 and recommended that the bank phase out funding for mining. In 2002, a coalition of governments, multilateral financial institutions, and civil society organizations formed the Extractive Industries Transparency Initiative (EITI) to audit participating governments according to standards of revenue transparency and good governance. This high-profile initiative is endorsed by most of the world's largest governments and multilateral institutions; however, many smaller nongovernmental initiatives also police the global metal mining industry. Oxfam America, for example, works to ensure that mining projects contribute to sustainable development and respect the rights of host communities. The nonprofit Earthworks, based in Washington, D.C., manages the "No Dirty Gold" campaign in which retailers express their concerns about the rights and environmental problems associated with gold extraction. Major retailers such as Walmart and Tiffany and Co. have signed the pledge.

Despite the many potential sustainability problems associated with mining, metals form the basis for our industrial society, and mines can create important economic opportunities in poor countries. Mines employ and train people and pay royalties and taxes into local and national coffers. Fourteen of the largest mineral firms in the world paid $29 billion to governments in 2007 (PricewaterhouseCoopers 2009). Increasingly, mining companies are also spending large sums of money on community development projects in affected areas to compensate residents for the adverse impacts of the mine's presence (McMahon and Remy 2001). This new trend in local philanthropy is known as acquiring a "social license to operate."

The growth of the global economy since 1990 has produced changes in the global metal mining industry, which have constrained economic and environmental sustainability as well as social justice. At the same time, increased attention to mining issues and the growth of global civil society has attempted to mitigate some of these effects.

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See also Aluminum; Chromium; Coltan; Copper; Electronics—Raw Materials; Gold; Heavy Metals; Iron Ore; Lead; Lithium; Minerals Scarcity; Mining—Nonmetals; Nickel; Platinum; Potassium; Rare Earth Elements; Recycling; Silver; Thorium; Tin; Titanium; Uranium; Wise Use Movement

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