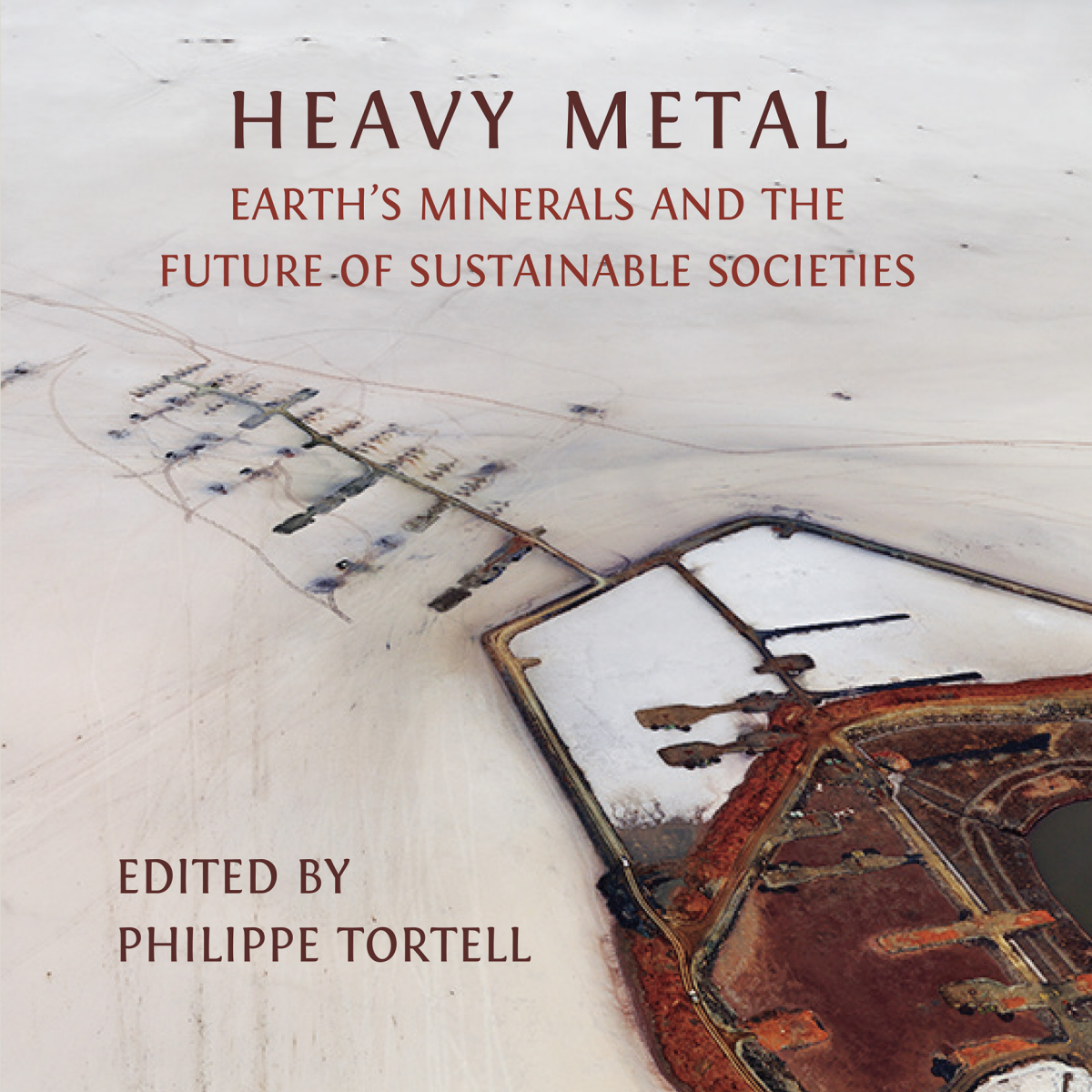
HEAVY METAL

EARTH'S MINERALS AND THE FUTURE OF SUSTAINABLE SOCIETIES



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Mining in Icy Worlds

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As the global economy transitions from fossil fuels to renewable energy, the search for 'critical minerals'—copper, lithium, cobalt and others—has pushed us to explore the remotest and most extreme environments on Earth, from the driest deserts to the depths of the ocean floor. In this global resource race, the coldest and iciest parts of our planet, the Arctic and the Antarctic, have also become the subject of much interest. These two regions, often assumed to be similar, but polar opposites in many ways, could play a large role in shaping the future economics and geopolitics of global mineral resources.

At the top of the globe, the ice-covered Arctic Ocean spreads across the circumpolar North. This body of water is the smallest and shallowest of the major oceans. It covers an area of about fourteen million square kilometers, surrounded by many islands and archipelagos, and the northern parts of the North American and Eurasian continents. Humans have lived on these lands for thousands of years. At the other end of Earth, nearly twenty thousand kilometers away, the southern polar region is dominated by the ice-covered landmass of Antarctica. This is the fifth largest continent (covering about the same area as the Arctic Ocean), and also the coldest and windiest place on Earth. It has a harsh climate, with average annual temperatures ranging from -10°C on the coast to -60°C at the highest parts of the interior. Most of Antarctica is covered by

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a four-kilometer-thick ice sheet, and has much lower terrestrial biodiversity than the Arctic, with no indigenous human population.

Since the early 1960s, human activity and governance arrangements in Antarctica have been subject to an international framework called the Antarctic Treaty System (ATS). This system regulates scientific research, environmental management and conservation, but does not recognize national sovereignty over any portion of the continent. Nonetheless, seven countries have made territorial claims to parts of the Antarctic, based on their roles in exploration and early scientific endeavors. The geopolitical situation is entirely different in the Arctic, which comprises eight nation states—Canada, the United States, the Russian Federation, Iceland, Norway, Sweden, Finland and the Kingdom of Denmark, which includes Greenland. Since 1996, these nations have (mostly) cooperated on matters of governance through the Arctic Council, an intergovernmental, consensus-based forum concerned with environmental protection, conservation and sustainable development. Arctic Council activities have been on hold since Russia's invasion of Ukraine in February 2022, although some work is beginning to resume under the auspices of the Council's working groups.

If there is one Arctic region that is closest to Antarctica, at least geographically and climatically, it is Greenland. Although Greenland is not a continent (it is attached to the North American tectonic plate), it is the world's largest island, covering about 2.2 million square kilometers. Average temperatures in the small town of Qaanaaq, in the northwest, range from around 5°C in July to -25°C in January, while Nuuk, the country's capital in the southwest, experiences an average temperature of 10°C in July and around -10°C in January. Greenland is a self-governing territory, with a population of around fifty seven thousand—of which 80% are of Inuit descent. The population is concentrated in towns and smaller settlements along the island's coastal stretches, mainly on the west coast. Most of the island, some 80% of its land mass, is covered by the world's second largest ice sheet. This ice sheet—known as the inland ice (or *Sermersuaq*, the 'great ice' in Greenlandic)—is over three kilometers thick in parts. A weather station on the topographic summit of the inland ice recorded a temperature of -69.6°C in December 1991—the lowest ever recorded in the Northern Hemisphere.

While there are probably more differences than similarities between Antarctica and Greenland, they are both subject to significant speculation about their resource potential. As global demand for critical minerals rises sharply, and supply chains become precarious and volatile, securing mineral supply has become a matter of economic importance and national security. What this means for Antarctica and Greenland will likely be very different. In the case of Antarctica, any future mining would not probably happen for at least another quarter century due to existing international agreements. On the other hand, the circumpolar North has a long history of extractive resource ventures, with major industry operations in Alaska, Canada, Russia and northern Fennoscandia, as well as the Norwegian archipelago of Svalbard. In these regions, hydrocarbon extraction and mining have had significant environmental impacts and lasting social and economic consequences, especially for Indigenous communities. Increasingly, Greenland is now also being seen as a resource frontier for critical minerals, and many around the world see the island as a new and important source of the materials needed for decarbonization and electrification.

A key motivation underlying Greenland's push for mining is a political desire to reduce its dependency on Denmark, while forging an independent sustainable economy and enhancing its global stature.[1] The self-rule government has affirmed its priority to develop a mining industry, and significant efforts have been put into attracting international investors. The recent focus on mining in Greenland is not entirely new. The history of mineral exploration on the island stretches back to the beginning of the nineteenth century, when geologists first surveyed the potential mineral wealth of the west coast and southern areas. Cryolite, a mineral used in the production of aluminum, was first mined at Ivittuut in southwest Greenland starting in the 1850s, with production continuing for over a century until 1987. In the early 1900s, Danish administrators laid down plans for the industrialization of Greenland's natural resources. Subsurface resource exploitation was included in those plans, even though Danish economic interests were more focused on the trade of marine mammal products, fish and furs. Other early mining ventures included coal extraction at Qullissat on Disko Island from 1924 until 1972, and lead, iron and zinc mining at the

Black Angel Mine at Maamorilik in the northwest Uummannaq district from the late 1930s until 1990. In more recent decades, several exploratory mining and hydrocarbon operations have occurred, and specific government policies have been developed to support mining as a critical component of Greenland's economy. These efforts have intensified since Greenland achieved a greater degree of self-government in 2009. As part of the new self-rule agreement with Denmark, Greenland acquired ownership of its subsurface resources in January 2010, with full authority over the decision-making process concerning mineral resource activities.

In Greenland today, different perspectives are emerging around the future of the region's mineral resources. The increasingly accessible landscape, made possible by climate-driven retreat of the ice sheet, has inspired local politicians to promote the island's extractive industry sector. From an international perspective, this unearthing of mineral resources highlights Greenland's evolving geostrategic position, as various economic and political interests look to invest, establish business relations and forge diplomatic links. China, for example, has expressed interest in funding Greenlandic projects, while the United States and other countries have also been positioning themselves to take advantage of Greenland's resource potential. For its part, the European Union has identified Greenland as a major supplier for most of the critical minerals it needs, including rare-earth elements (REEs).

In July 2021, Greenland's new coalition government announced that it was suspending the granting of new licenses for oil exploration. This move was part of a broader commitment to develop strategies for renewable energy and tackle climate change. Whereas fossil fuels were to be phased out, mining companies were reassured that mineral extraction would be a pillar of Greenland's future economy. Indeed, Greenlandic politicians have declared that the country is open for the mining business, actively welcoming bids for prospecting and exploration licenses. And the world has taken notice. Significant international interest is evident in the numerous ongoing mineral exploration and mining projects, with a focus on cobalt, graphite, niobium, platinum-group metals (PGMs), REEs, tantalum, titanium and vanadium. Companies such as KoBold Metals, supported by billionaires Jeff Bezos and Bill Gates, are also

initiating exploratory projects, while the Tanbreez mining project in south Greenland aims to unlock the area's REEs. Other resources such as rubies, pink sapphires and uranium have also become objects of value for the future economy of this increasingly important Arctic country.[2]

Not all mineral exploration ventures in Greenland have been smooth or without controversy. Energy Transition Minerals—an Australian company formerly known as Greenland Minerals—faced a major setback when the Greenland government refused its 2019 application for an exploitation license for uranium and REEs. The proposed project, at Kuannersuit near the town of Narsaq in south Greenland, was subject to considerable public opposition, highlighting concerns over inadequate social and environmental impact assessments, and insufficient consultation with potentially impacted communities. Across Greenland, other mining projects have increasingly provoked highly charged political and social debates about the nature, and even desirability, of resource development. The government decision to deny permits to Energy Transition Minerals could indicate a significant policy shift towards greater scrutiny and stronger regulatory control over the environmental and social impacts of mining. But there can be no doubt that the emerging mineral industry in Greenland illustrates a broader global reimagining of the Arctic as a resource frontier.

Antarctica presents a rather different case study of mining in a frozen world. It is the only continent without a history of mining, and no mineral deposits of commercial interest have yet been identified there. But this has not stopped significant speculation about the mineral resources that might be locked up underneath the vast mass of Antarctic ice. About two hundred million years ago, Antarctica was part of an ancient continent, Gondwanaland, that comprised land masses including present-day Australia, Africa, India and South America. Because of this shared geological history, it has been hypothesized that Antarctica may host large mineral deposits, similar to those found in its ancient continental neighbors. But, even if such mineral deposits were discovered, Antarctica's geography and climate would prevent economically viable and environmentally safe mining. Any consideration of potential mineral exploration

would be limited to only a few areas of the continent with exposed rock, such as the Prince Charles Mountain range, where iron deposits have been identified.[3] Things could change, however, under a rapidly warming climate. The Antarctic Peninsula is amongst the fastest warming parts of the planet, and glacier melt across the Antarctic continent is predicted to increase by 25% by the end of this century.[4] Much of this new ice-free area will emerge in the North Antarctic Peninsula, significantly enhancing access to potential mineral resources.

A significant complexity around potential mining in Antarctica arises from the unsettled question of its sovereignty. The continent and its surrounding waters belong to no one. They are governed collectively by a group of fifty-six countries that are signatories to the Antarctic Treaty of 1959. But seven of these countries (Argentina, Australia, Chile, France, New Zealand, Norway and the United Kingdom) claim Antarctic territory, even though the treaty neither recognizes nor denies these claims. Furthermore, three of these territorial claims (Argentina, Chile and the UK) overlap with one another in the potentially mineral-rich Antarctic Peninsula. The United States and Russia do not recognize any of these claims, but both reserve the right to make a claim in the future if the Antarctic Treaty were to collapse.

The Antarctic Treaty was a product of its time. Negotiated at the height of the Cold War, the key and most pressing need was to ensure that Antarctica did not become a stage for war or nuclear testing. Suspending the issue of territorial claims was thus a pragmatic move when the nuclear stakes were so high. The principal provisions of the treaty focused on the use of the continent for peaceful scientific purposes only, prohibiting military activities, nuclear tests and radioactive waste disposal. More than half a century after the signing of the original Antarctic Treaty, there are now around forty-one year-round and thirty-nine seasonal scientific stations in the Antarctic, operated by thirty-three national government agencies. Each year, over ten thousand scientific and logistics personnel work on the continent during the Antarctic summer, and around one thousand in the winter.[5] Tens of thousands of tourists also travel there annually, mainly on cruise ships—just over 100,000 visited the continent during the 2023–24 season.

Since the Antarctic Treaty entered into force in June 1961, the governance of Antarctica has evolved through various measures and conventions that regulate human activities and the conservation of living resources. By comparison, the attempted regulation of non-living resources has been less successful. Starting in the late 1970s, the Treaty parties spent over a decade negotiating the terms for future mining in Antarctica. These efforts culminated in the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA), which ultimately failed to be ratified by all the Consultative Parties (who are the ATS decision makers), and thus never entered into force. Among other nations, Australia, and France, both claimant countries, rejected the process, arguing instead to permanently prohibit mining in Antarctica.

The failure to ratify CRAMRA exposed serious divisions among the treaty parties, threatening to dissolve the ATS as it approached its thirtieth anniversary in 1991. In an effort to save the Treaty, the controversial CRAMRA was dropped in favor of a Protocol on Environmental Protection that came into force in 1998. This underscored the principle that the Antarctic must be regarded as a protected and globally unique wilderness to be utilized only for peaceful scientific purposes. The Protocol bans all mineral exploration activities. Like the Antarctic Treaty, the Protocol has no scheduled end in its text. But after 2048, fifty years following the date it came into force, any Consultative Party can request a formal review process, at which time the parties would have three years to ratify a modified or amended Protocol. If the Protocol is brought under review, any party can withdraw by 2051 if a new Protocol has not been entered into force. This would leave the future of its environmental regulations hanging in the balance.

The growing number of countries involved in Antarctic politics and scientific activities has led to concern over the management of human impacts. Today, there are twenty-nine Consultative Parties and twenty-seven Non-Consultative Parties to the Treaty, and the original signatories have been joined by emerging global powers like China and India as Consultative Parties. Each of these nations is attempting to exert influence over the regulation of Antarctica and striving to increase its scientific presence on the continent. Conducting science in Antarctica is expensive, and not all of it is done for intellectual curiosity alone; countries expect to capitalize on their

considerable investment. Resources and infrastructure created to enable science could also, one day, be used to support mineral exploration projects.

The main priority of the ATS has been to ensure that states avoid conflict in Antarctica. But it remains to be seen whether the shared values of scientific cooperation and peace can outlast future demands for strategically important minerals. The rapidly warming Antarctic Peninsula may prove to be an early test case, with its potential mineral deposits and the overlapping territorial claims of Argentina, Chile and the UK. For the moment, it does not appear that any nations are willing to give up their Antarctic claims for a greater common good. If anything, an increasing number of submissions to the Commission on the Limits of the Continental Shelf (CLCS), a body created by the 1982 Law of the Sea Convention, suggests that various nations are attempting to strengthen their territorial claims in preparation for a time when mineral exploitation might be feasible. It is difficult to predict what the global economy and demand for resources will look like in 2048, when the protocol banning mineral activities may face renewal.

The examples of Greenland and Antarctica underscore a critical dilemma. On the one hand, we face an urgent imperative to protect the integrity of environmentally sensitive polar regions, especially in the face of a rapidly warming climate. On the other hand, these regions are increasingly being viewed as current or, in the case of Antarctica, potentially future extractive zones for the mineral resources needed for renewable energy systems. Ironically, the effects of climate change are making these polar regions more accessible, and geopolitically significant for an overheating and more populated world. Continued scientific research in Greenland and Antarctica is crucial for understanding global climate change but increased human activity and interest in resource extraction also pose environmental risks.

Greenland is becoming firmly part of the 'planetary mine',[6] undergoing a process of state formation in which mineral resources have become central to a political and economic strategy for a prosperous, and possibly independent, future. In the face of economic and geopolitical pressures, the Greenland self-rule government must also

grapple with environmental and social concerns, seeking to balance prosperity and a drive for self-determination with the preservation of fragile and unique landscapes. Half a world away, the mineral resource potential of Antarctica may someday emerge to provide raw materials needed to support a future global economy. The future use of any Antarctic minerals will likely put significant strain on a unique form of international cooperation and environmental governance that has existed for more than half a century.

Both Greenland and Antarctica have growing strategic assets, with expanding scientific and technological expertise, and improving infrastructure, including harbors, airfields, research stations and ice transportation networks. These assets open new opportunities for current or potential future mineral exploration, putting Greenland and Antarctica at the forefront of geopolitical discussions about resource utilization and environmental conservation in an era of rapid climate change. And, more than ever, as we move toward a post-carbon Anthropocene future, we need both these regions to be at the forefront of global discussions about sustainability, environmental impact and the future of resource management.

Endnotes

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