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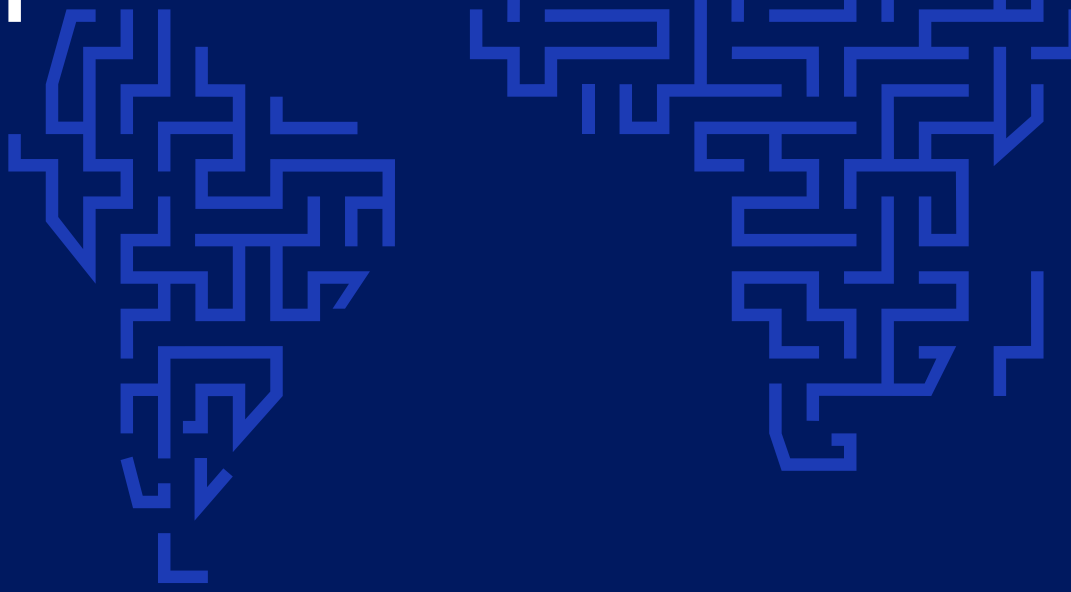
OPEN PIT MINING ACROSS NORTH AMERICA

AN ILLUSTRATIVE ATLAS



BECAUSE IT WORKS

INTRODUCTION

From the expansive deserts of the American Southwest to the forested shield of Northern Canada, the landscapes of North America have long held immense geological wealth beneath their surfaces. This book is a visual and narrative journey into one of the most powerful engines of that wealth: Open pit mining.

Open pit mining has shaped not only the terrain of this vast continent but also its economy, its workforce, and its historical trajectory. These immense excavations—some visible from space—reveal more than ore; they uncover stories of human ambition, technological evolution, and the relentless pursuit of progress. From copper in Arizona to gold in British Columbia, iron in Minnesota to diamonds in the Northwest Territories, open pits are both industrial sites and modern-day monuments to extraction.

This atlas aims to chart that dual reality. Through detailed maps and thematic illustrations, we explore the geological richness hidden in North American soil and its profound impact on modern life. We consider the economic role of mining, not just in terms of raw materials but in the employment of hundreds of thousands, the development of remote communities, and the infrastructure that sustains industries and cities alike.

We also examine the broader implications of open pit mining—from environmental challenges and land reclamation to Indigenous land rights and technological innovation. Open pit mines are both symbols of opportunity and subjects of debate, reflecting the tensions inherent in natural resource extraction.

In doing so, this book does not aim to romanticize mining nor to vilify it. Instead, it seeks to illustrate its full complexity: the scale, the beauty, the science, the disruption, and the human endeavour behind every ton of earth moved.

Welcome to the open pits of North America.

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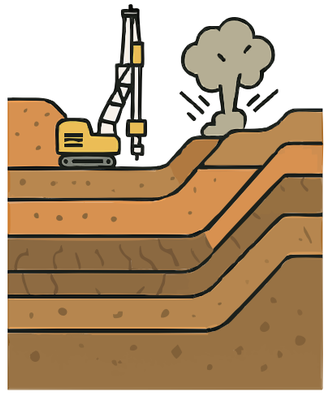

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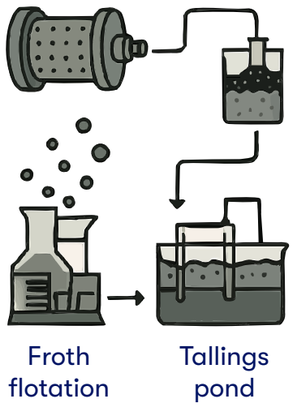
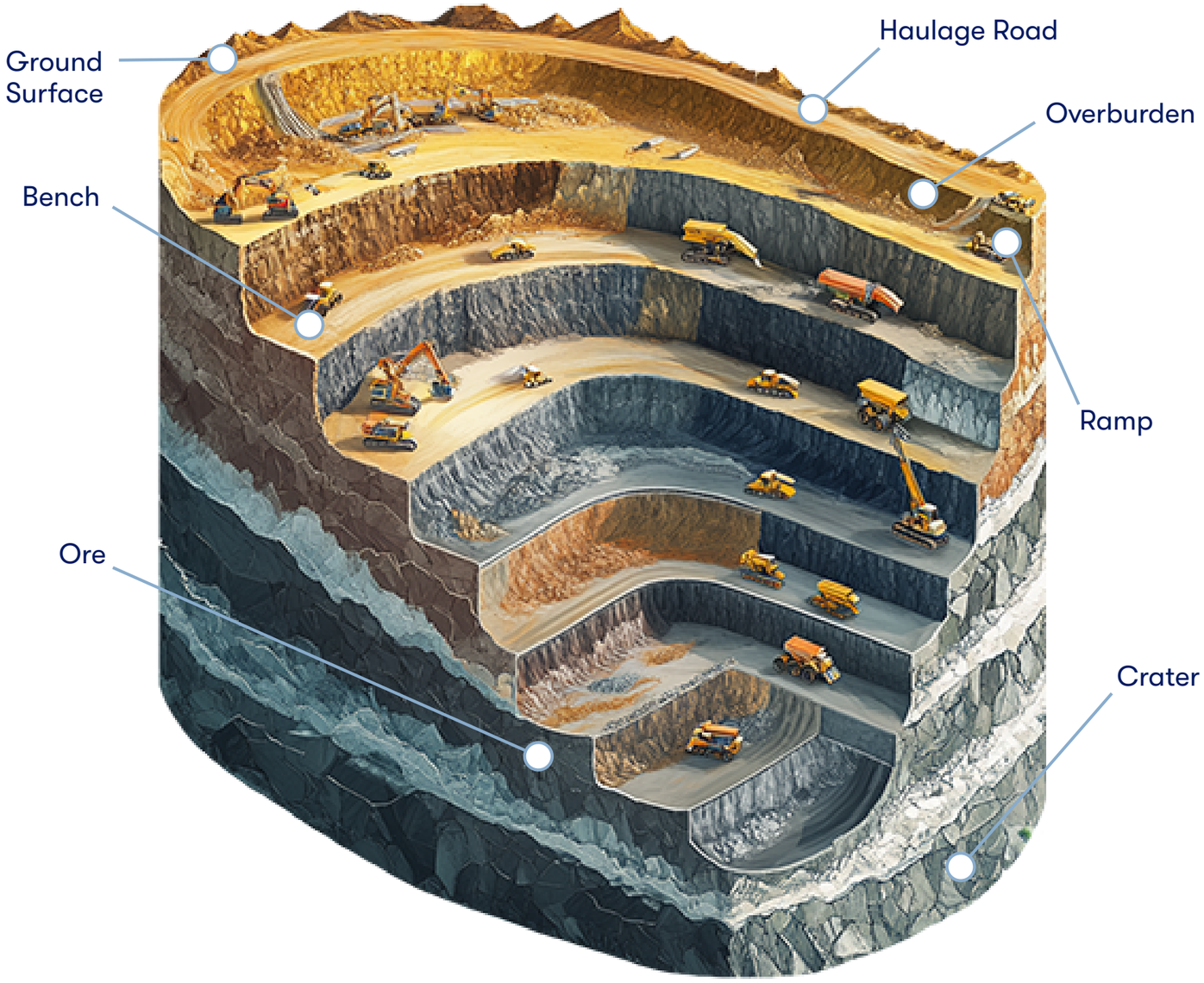




VEHICLES USED IN OPEN PIT MINING

Haul truck
Massive dump truck used to transport mined material from therpn to processing areas.

Excavator
A versatile digging machine with a long articulated arm and bucket for material loading.

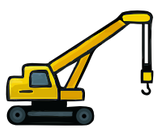
Wheel Loader
Front-mounted bucket vehicle used for scooping and loading loose material.

Bulldozer
Heavy-duty crawler machine equipped with a wide front blade for pushing earth and rock.

Drill Rig
Precision machine that bores deep holes for blasting operations in rock and soil.

Grader
Blade-equipped vehicle used for leveling and maintaining haul roads within the mine.

Water Truck
Large tank vehicle used to spray water for dust suppression on roads and working areas.



Crane
Lifting equipment used for assembling, maintaining, or relocating heavy machinery.

Scraper
Self-loading earthmover that cuts, collects, and deposits soil over short distances.

Electric Rope or Hydraulic Shovel
High-capacity loading machine designed for rapid material excavation in tough conditions.

HOW DOES AN OPEN PIT MINE WORK?

In short, open pit mining is a surface method to extract minerals near the Earth's crust. Over time, the pit grows wider and deeper, forming a terraced, pyramid-like shape that aids access and keeps the site stable. Open pit mining is ideal for shallow, spread-out deposits with enough minerals to make the effort worthwhile. Unlike underground mining, it uses giant machines and is highly visible, leaving an enormous environmental impact and, therefore, drawing attention from regulators and locals.

Open pit mining began thousands of years ago as ancient groups dug shallow pits with basic tools like antler picks and stones to recover flint, copper, and ochre. Sites like Grimes Graves in England (approx. 3000 BC) are a good example, as are Egyptian quarries for stone and metals. Open pit mining at that time was brutally hard work and on a very small scale, limited by simple tools and know-how.

The Industrial Revolution in the 1700s and 1800s changed everything. Steam-powered machines let miners excavate bigger areas and refine more material. Dynamite, invented by Alfred Nobel in the mid-1800s, made breaking rock easier, leading to the huge pits we see today. By the 1900s, advances in surveying, heavy gear, and transport turned open pit mining into a major industry.

The open pit mining process itself is complex, with carefully planned steps that turn a mineral deposit into an economically usable resource. Let's examine these steps in detail now.

Exploration and Feasibility Studies

The open pit mining process starts with locating and studying deposits. These days, geologists spot promising candidates using satellite images, aerial photos, and ground surveys. However, drilling for rock samples provides proof of the deposit's real size, depth, and mineral content, supported by seismic and magnetic surveys mapping the underground. Next, a feasibility study checks if it's worth mining—looking at ore quality, grade, costs, market prices, infrastructure, and regulations. Environmental and community impacts are reviewed, too, as laws often require it. If it the commercial risks are approved, engineers plan the pit's size, steps, and roads for safety and output.

Site Preparation and Overburden Removal

Once approved, the site gets ready. Vegetation is cleared, wildlife is moved if needed, and infrastructure like power, water, and roads are built for big trucks and machines. Then, the overburden—the dirt and rock covering the ore—is removed. Soft soil is scraped away with bulldozers; hard rock needs explosives to break it up. Excavators load the waste into trucks that haul it to dumps. The stripping ratio (overburden vs. ore) matters—a low ratio means less waste and cost, while a high one means more effort and impact.

Drilling and Blasting

Drilling and blasting are used to free the ore from rock. Special rigs drill exact holes into the ore, guided by computer maps of the deposit. These holes get filled with explosives like ammonium nitrate fuel oil (ANFO), which is strong and affordable. The blast is controlled to break the rock into pieces without wasting it or harming the ore. Engineers plan the blast based on rock type, pit shape, and safety—too big a blast could weaken the pit walls, too small leaves big chunks. Sensors and monitoring keep it safe for workers and gear.

Excavation and Ore Extraction

After blasting, excavation starts. Giant shovels or draglines scoop up the broken rock and load it into huge haul trucks—some carry over 400 tons. These trucks take the ore to a processing plant or storage. The pit is dug in benches, like steps 30 to 50 feet high, making it safer and easier to reach deeper ore. This stepped design also prevents the walls from collapsing by spreading the pit's weight. The pit grows wider and deeper, following the ore's path, with workers adjusting based on data and what they see.

Ore Processing

Raw ore needs processing to flush the valuable minerals out. First, it's crushed into small pieces with jaw or cone crushers, then ground into powder in ball mills. Different methods separate the minerals: copper uses froth flotation with chemicals and bubbles, while gold often uses cyanide leaching to pull out tiny bits. This usually happens near the pit, though some ore goes to bigger plants elsewhere. The leftover waste, called tailings, is ground rock and chemical scraps. Storing tailings in ponds or dams is tricky, and a close watch is needed to avoid spills or breaks.

Haulage and Waste Management

During the open pit mining process, tons of waste rock from overburden and low-value materials that are not worth processing are being produced. This waste gets hauled to dumpsites, usually near the mine, and stacked into stable piles. Sometimes, it's used to fill old pit sections, saving space. Efficient transport keeps things moving—trucks are common, but some mines use conveyor belts or rails to cut fuel use and emissions. Waste management isn't just about moving stuff; it's about protecting the environment. Badly managed dumps can leak harmful stuff into soil and water.

Reclamation and Closure

When the ore runs out, or mining stops making money, reclamation begins. The aim is to make the land safe, stable, and habitable for the environment. Workers reshape the pit, flattening steep edges to stop erosion and slides. Saved topsoil is spread back, and native plants are added to bring life back. Some pits get flooded into lakes for recreation or nature. Law often requires reclamation, but how well it's done varies. In places with weak rules, old pits remain ugly scars; with good funding, they can become useful for locals.

NORTH AMERICA'S MINERALS

MINERALS MINED IN 2023:

WORLD | CANADA | USA

Silver

- 25.790 Tons
- 300 Tons
- 1.000 Tons

Coal

- 8.165 Mio. Tons
- 48.6 Mio. Tons
- 524 Mio. Tons

Gold

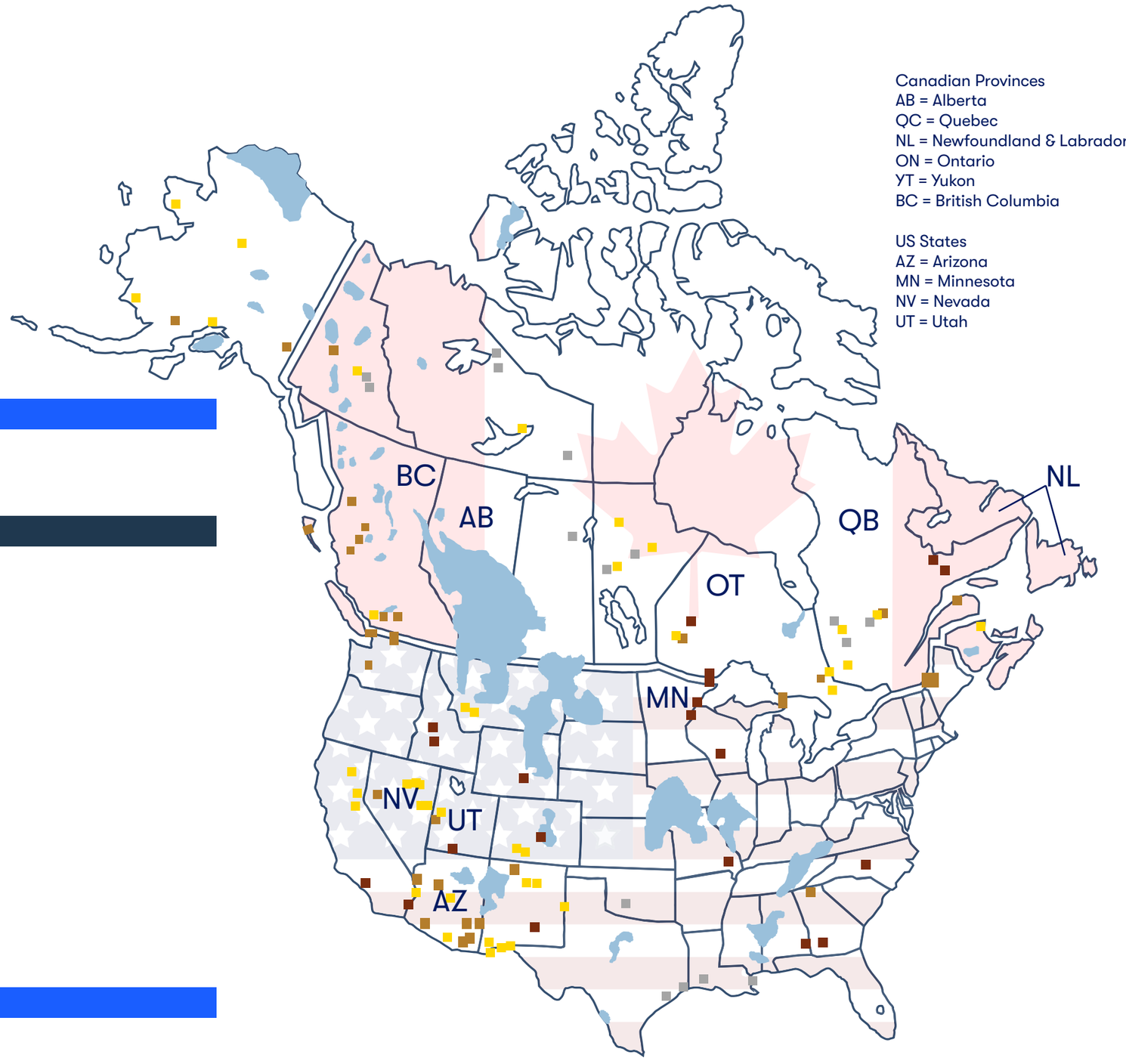
- 3.644 Tons
- 220 Tons
- 170 Tons

Copper

- 22 Mio. Tons
- 0.62 Mio. Tons
- 1.1 Mio. Tons

Iron

- 2.500 Mio. Tons
- 54 Mio. Tons
- 48 Mio. Tons



Canadian Provinces
AB = Alberta
QC = Quebec
NL = Newfoundland & Labrador
ON = Ontario
YT = Yukon
BC = British Columbia

US States
AZ = Arizona
MN = Minnesota
NV = Nevada
UT = Utah

THE SCALE OF OPEN PIT MINING IN NORTH AMERICA

In North America, open pit mines play a major role in the economy and resource production. Both, the United States and Canada, host significant mines supplying global industries with metals and minerals. As seen previously, open pit mining effectively extracts low-grade ores in large volumes and dominates the production of key minerals such as copper, gold, iron, and coal, fueled by the continent's rich geological diversity and insatiable global demand.

From the arid deserts of the American Southwest to the rugged northern reaches of Canada, open pit mines dot the terrain, their immense pits serving as testaments to human engineering and resource extraction prowess. Together, these operations produce billions of tons of material annually, supporting everything from infrastructure development to advanced technology.

In the United States, open-pit mining is a powerhouse of mineral production, with some of the world's largest and most iconic operations. The Bingham Canyon Mine in Utah stands out as the deepest open pit globally, plunging over 1.2 kilometres into the Earth and stretching nearly 4 kilometres wide. This copper giant, alongside Nevada's sprawling gold mines and Arizona's copper-rich pits, underscores the Southwest's dominance in the industry.

Meanwhile, the Midwest contributes through massive iron ore operations like the Hull-Rust-Mahoning Mine in Minnesota, which has shipped over 800 million tons of iron since the late 19th century. These mines collectively employ thousands, drive local economies, and supply a significant portion of the US's metal and mineral needs.

Canada, too, boasts an impressive array of open pit mines, leveraging its vast landmass and mineral wealth. The oil sands of Alberta represent some of the continent's largest surface mining projects, with operations like the Millennium and Horizon mines producing millions of metric tons of bitumen annually. In the east, Quebec and Labrador form an iron ore hub, while Ontario's gold and base metal mines thrive amid the Canadian Shield's ancient geology. The Yukon and British Columbia further extend Canada's reach into gold production, with remote pits carving through northern wilderness. These operations highlight Canada's role as a global leader in mineral exports, particularly in gold, copper, and iron.

The scale of open pit mining in North America is not just a matter of physical size but also economic impact. In 2024, the industry contributed tens of billions of dollars to the GDP of both nations, with the US and Canada together accounting for a substantial share of global copper, gold, and iron ore output.

Gold

Gold mining in North America, particularly in the United States, remains a significant industry. 2022 U.S. gold mine production was estimated at 170 metric tons, valued at approximately $10 billion. Production occurred at over 40 lode mines across 11 states, with Alaska and Nevada being prominent contributors. Canada is pivotal in North America's gold mining industry, ranking as the world's fourth-largest gold producer. In 2023, Canadian mines produced approximately 198 metric tons of gold, marking a 2% increase from the previous year. This output rose to an estimated 200 metric tons in 2024.

Silver

In the United States, silver production in 2023 was about 1,000 metric tons, valued at $760 million. Silver was extracted from four primary silver mines and as a byproduct from 31 other operations across 12 states. Alaska led production, followed by Nevada. In Canada, silver production has experienced fluctuations over the years. In 2021, the country produced approximately 325 metric tons of silver. Ontario was the leading silver-producing province in 2022, contributing around 129.93 metric tons.

Notable silver mines in Canada include the Keno Hill mine in Yukon, which produced an estimated 1.5 million ounces of silver in 2023, and the Kidd Creek Mine in Ontario, also yielding approximately 1.5 million ounces. Other significant operations are the LaRonde Mine in Quebec and the Lalor Mine in Manitoba.

Copper

Copper mining remains a vital component of North America's mineral industry, with both the United States and Canada contributing significantly to global output. In the United States, copper production in 2024 was estimated at approximately 1.1 million metric tons of recoverable copper, representing a slight decline from the previous year. Arizona continued to dominate the sector, accounting for nearly 70% of total domestic output. The value of U.S. copper production for the year was estimated at around $10 billion, underscoring its economic importance.

Canada, meanwhile, produced approximately 485,375 metric tons of copper in 2023, making it the world's 12th-largest copper producer and accounting for about 2.4% of global supply. The leading provinces for Canadian copper production were Ontario and British Columbia. Ontario alone produced over 221,000 metric tons, valued at more than CA$2.2 billion, which equated to around 43% of the national total.

Iron ore

In the United States, iron ore production in 2023 was estimated at 44 million metric tons, marking a 13% increase from the previous year's 39 million tons. This production was valued at approximately $7.5 billion. The majority of U.S. iron ore comes from mines in Michigan and Minnesota, which together account for nearly all domestic production. The United States produced about 1.6% of the world's iron ore output in 2023.

Canada, meanwhile, produced approximately 70 million metric tons of usable iron ore in 2023, with an iron content of 42 million metric tons. This positioned Canada as the world's seventh-largest iron ore producer. The country's iron ore production is primarily concentrated in Quebec, Newfoundland, and Labrador.

Coal

In the United States, coal production has been on a declining trend since its peak in 2008. In 2023, the U.S. produced approximately 578 million short tons of coal, less than half of the 2008 peak. This decline is attributed to the increasing competitiveness of natural gas and renewable energy sources, which have reduced coal's share in electricity generation.

Canada's coal industry, while smaller in scale, remains an important contributor, particularly in producing metallurgical coal used for steel manufacturing. In 2023, Canada produced 47 million tonnes of coal, with 66% being metallurgical coal. The majority of Canada's coal production occurs in Alberta and British Columbia, accounting for 85% of the country's output. Canada exports about half of its coal production, primarily to Asian markets. In 2023, Canadian seaborne coal exports increased by 9.6% year-over-year to 49.9 million tonnes, with Japan, South Korea, and China being the largest importers.

BIGGEST U.S. OPEN PIT MINES

1 North Antelope Rochelle ~ 259 km²

2 Carlin Gold Mine ~ 227 km²

3 Henderson Mine ~ 105 km²

4 Morenci Mine ~ 52.61 km²

5 Coeur Rochester Mine ~ 40.45 km²

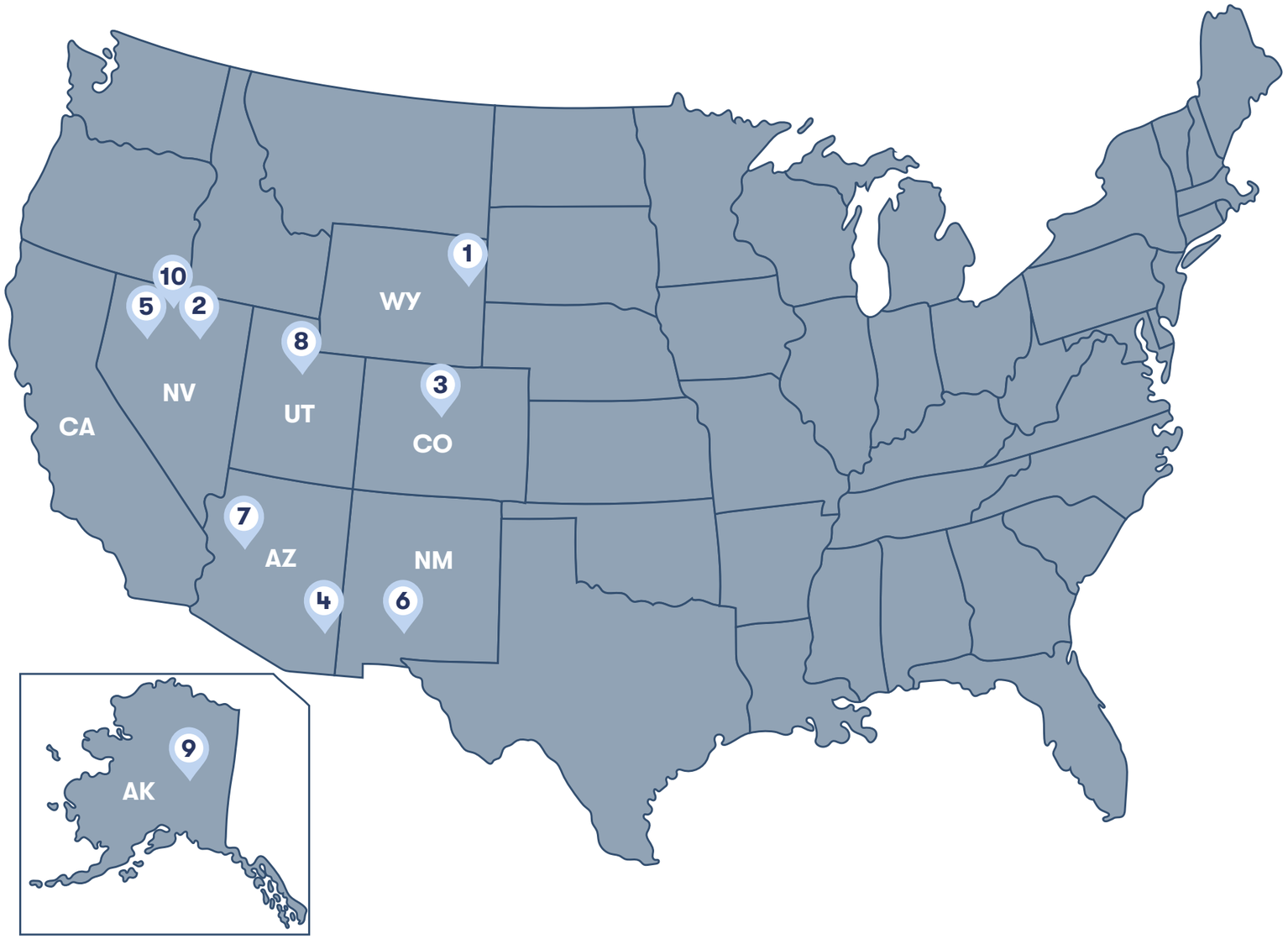
6 Chino Mine ~ 36.42 km²

7 Bagdad Mine ~ 24.28 km²

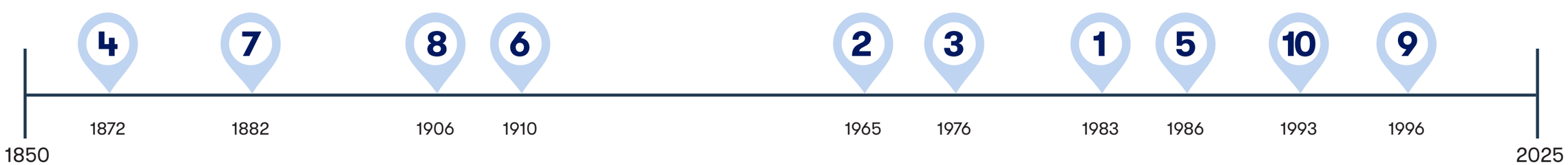
8 Bingham Canyon Mine ~ 7.69 km²

9 Fort Knox Gold Mine ~ 4.05 km²

10 Twin Creek Mine ~ 4 km²



MINE OPERATIONS STARTED:



THE BIGGEST OPEN PIT MINES IN THE UNITED STATES OF AMERICA

Open pit mining is a major US industry with a century-long legacy of extracting critical minerals like copper, gold, and molybdenum.

The **North Antelope Rochelle Mine (NARM)**, operated by Peabody Energy, is located in the Powder River Basin of Wyoming, approximately 65 miles south of Gillette. It stands as the largest coal mine in the United States and one of the most productive globally. The mine is renowned for its substantial coal reserves and high-quality output. As of December 2012, the recoverable coal reserves at NARM were estimated to be more than 2.3 billion tonnes. The coal seams at the mine are notably thick, ranging from 60 to 80 feet, and are located 100 to 400 feet below the surface.
NARM employs surface mining techniques, utilizing draglines and truck-and-shovel methods to extract coal. The extracted coal is then transported via a network of conveyors and rail lines to various customers.

The **Bingham Canyon Mine**, also known as the Kennecott Copper Mine, is an open-pit mining operation located southwest of Salt Lake City, Utah. Recognized as one of the largest man-made excavations globally, the mine measures over 0.75 miles deep and 2.5 miles wide. Since its inception in 1906, it has produced more copper than any other mine in history, exceeding 19 million tons. Operated by Rio Tinto's Kennecott Utah Copper, the mine also yields significant quantities of gold, silver, and molybdenum.
In 2020, it produced 140,000 tons of copper, 171,200 ounces of gold, 2.2 million ounces of silver, and 20,400 tons of molybdenum. The mine's operations are supported by a concentrator, smelter, and refinery, all located on-site. Notably, in 2013, the mine experienced a massive landslide, one of the largest non-volcanic landslides in North American history, which temporarily halted operations but resulted in no injuries due to advanced monitoring systems. Efforts are ongoing to extend the mine's life beyond 2032 through proposed expansions.

The **Fort Knox Gold Mine**, located near Fairbanks, Alaska, is a large open-pit operation owned by Kinross Gold Corporation. Since commencing production in 1996, it has become Alaska's largest gold producer, surpassing 8 million ounces by 2019. The mine employs both carbon-in-pulp milling and heap leach processing, with a daily capacity of up to 45,000 tons of ore. In 2024, Fort Knox began processing high-grade ore from the Manh Choh project, significantly boosting its output. During the third quarter of 2024, the mine produced over 149,000 ounces of gold, reflecting the enhanced production from this new source. The integration of Manh Choh ore is expected to sustain annual production levels of approximately 500,000 ounces over the next four years, extending the mine's operational life into the 2030s.

The **Chino Mine**, also known as the Santa Rita Mine, is an open pit copper mining operation located near Silver City, New Mexico. Recognized as one of the world's oldest active open-pit copper mines, it began large-scale operations in 1910 under the Chino Copper Company. Currently owned and operated by Freeport-McMoRan, the mine has been a significant contributor to copper production in the United States.

Over the years, the mine has undergone various operational changes, including the introduction of solvent extraction and electrowinning (SX/EW) processes in 1988, which have enhanced its production capabilities.

The **Henderson Mine**, located near Empire, Colorado, is North America's largest primary producer of molybdenum. Owned by Freeport-McMoRan through its subsidiary Climax Molybdenum Company, the mine commenced operations in 1976 and has since produced over a billion pounds of molybdenum. The underground operation employs block-caving techniques to extract ore from a porphyry molybdenum deposit situated beneath Red Mountain.

The extracted ore is transported via a 10-mile conveyor tunnel beneath the Continental Divide, followed by a 5-mile surface conveyor, to a mill near Parshall, Colorado. The mill processes approximately 32,000 metric tons of ore per day, yielding molybdenum concentrate that is primarily shipped to Freeport's facility in Fort Madison, Iowa, for further refinement. As of the end of 2024, the mine's proven and probable reserves are estimated at 44 million metric tons of ore with a molybdenum grade of 0.16%, containing approximately 0.14 billion pounds of recoverable molybdenum. The Henderson Mine is projected to remain operational until at least 2038.

The **Hull–Rust–Mahoning Open Pit Iron Mine**, located in Hibbing, Minnesota, is one of the largest open-pit iron ore mines in the world. Established in 1895, it played a pivotal role in the U.S. steel industry, especially during World Wars I and II, supplying up to a quarter of the nation's iron ore during peak production periods. The mine measures over three miles in length and two miles in width and reaches depths of 535 feet. Its vast output led to the relocation of the northern section of Hibbing between 1919 and 1921 to accommodate expansion.

Today, the mine is operated by the Hibbing Taconite Company, producing millions of tons of taconite pellets annually. Designated a National Historic Landmark in 1966, the site features the Hull Rust Mine View, offering visitors panoramic views of the massive excavation and insights into over a century of mining history.

Looking ahead, these mines face the challenge of sustaining production as ore grades decline, prompting investments in underground expansions and renewable energy integration to ensure long-term viability.

THE GOLD RUSH IN WESTERN USA

1 Donlin Gold Project (AK)

2 Coeur Rochester Mine (NV)

3 Twin Creeks Mine (NV)

4 Carlin Complex/ Mine (NV)

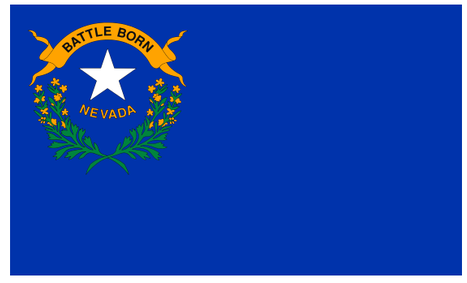
5 Mesquite Mine (NV)

6 Cortez Gold Mine (NV)

7 Mesquite Mine (CA)

CALIFORNIA (1848–1855)

Gold at Sutter's Mill sparked the Forty-Niner rush. Sierra Nevada mined for $2B in gold; statehood in 1850.



COMSTOCK LODE NEAR VIRGINIA CITY, NEVADA

It yielded gold and silver worth over $300M. Deep mining innovations led to statehood in 1864.

NEVADA - THE CAPITAL OF THE GOLD MINING INDUSTRY

Nevada is the undisputed leader in US gold production, with about 75% of the nation's total output. The state produced 5.46 million ounces (170 metric tons) of gold in 2023, the US Geological Survey (USGS) says, a quantity that places it in the ranks of the world's leading gold-producing regions, alongside nations like South Africa (110 MT) and Australia (330 MT). The Carlin Trend, a 50-mile geological belt in northeastern Nevada, is the centre of this dominance.

This formation contains some of the richest gold deposits in the world, with mines like Newmont's Carlin operation yielding 927,000 ounces (28.8 MT) in 2023 alone. The advent of heap leach technology—a process involving chemical solutions like cyanide to extract gold from low-grade ore—has been a game-changer, making enormous reserves that were once uneconomically viable. This technology has increased Nevada's production by 15% in the last ten years, solidifying its position as an international player.

The **Carlin Gold Mine**, situated in northeastern Nevada, is part of the Carlin Trend, one of the world's richest gold mining districts. Discovered by Newmont in the early 1960s, the mine commenced production in 1965, pioneering large-scale extraction of low-grade, "invisible" gold using heap leaching and autoclave processing. Today, it operates as the Carlin Complex under Nevada Gold Mines—a joint venture between Barrick Gold (61.5%) and Newmont (38.5%)—and encompasses multiple open-pit and underground operations, including Gold Quarry, Leeville, and Pete Bajo. The complex has produced over 50 million ounces of gold to date, making it the most prolific gold-producing district in North America.

The **Twin Creeks Mine,** situated in Humboldt County, Nevada, is a prominent open-pit gold and silver mining operation. Established in 1993 through the merger of the Chimney Creek and Rabbit Creek mines, it now forms part of the Turquoise Ridge Complex, managed by Nevada Gold Mines—a joint venture between Barrick Gold Corporation (61.5%) and Newmont Corporation (38.5%).

The mine encompasses the expansive Mega and Vista pits, with the Mega Pit spanning approximately three miles in length, one mile in width, and reaching depths exceeding 1,000 feet. Twin Creeks employs conventional open-pit mining methods, including drilling, blasting, loading, and hauling. Ore processing involves both heap leaching and milling techniques, utilizing facilities such as the Juniper Mill for oxide ores and the Sage autoclave for refractory sulfide ores. Historically, the mine has been a significant contributor to gold production in Nevada. Between 1993 and 2002, Twin Creeks produced over 6.6 million ounces of gold and 1.8 million ounces of silver. As of December 31, 2016, the mine reported 4.9 million ounces of attributable gold reserves.

The **Coeur Rochester Mine,** located in Pershing County, Nevada, is an open-pit, heap-leach operation producing silver and gold. Owned and operated by Coeur Mining, it is the company's largest mine and one of the world's largest open-pit heap-leach operations. In 2024, the mine completed a $730 million expansion, which included the construction of a new three-stage crushing facility, a Merrill-Crowe process plant, and a new leach pad.

This expansion increased the mine's annual throughput capacity to approximately 32 million tons, about 2.5 times higher than historical levels.
The Rochester Mine is now expected to be the largest source of domestically produced and refined silver in the United States. In 2024, the mine achieved commercial production at the end of the first quarter and is projected to produce between 4.8 and 6.6 million ounces of silver and 37,000 to 50,000 ounces of gold for the full year.

California, while not as preeminent as during its Gold Rush era, is also experiencing revived activity. According to USGS statistics, the state produced 17 metric tons (547,000 ounces) in 2023, with mines such as Imperial County's Mesquite Mine producing 135,000 ounces (4.2 MT). Rising gold prices—up 16.38% in early 2025 to $3,053 per troy ounce —have spurred investment in traditional mining regions like the Sierra Nevada. Alaska, in the meantime, adds further gravity to the Western surge, producing 21 metric tons (676,000 ounces) in 2023.

The Donlin Gold project, a world-class undeveloped gold deposit, has 39 million ounces (1,213 MT) in reserves, suggesting space for eventual expansion. Together, these states produced 208 metric tons in 2023—over 6.6 million ounces—accounting for 95% of US gold production.

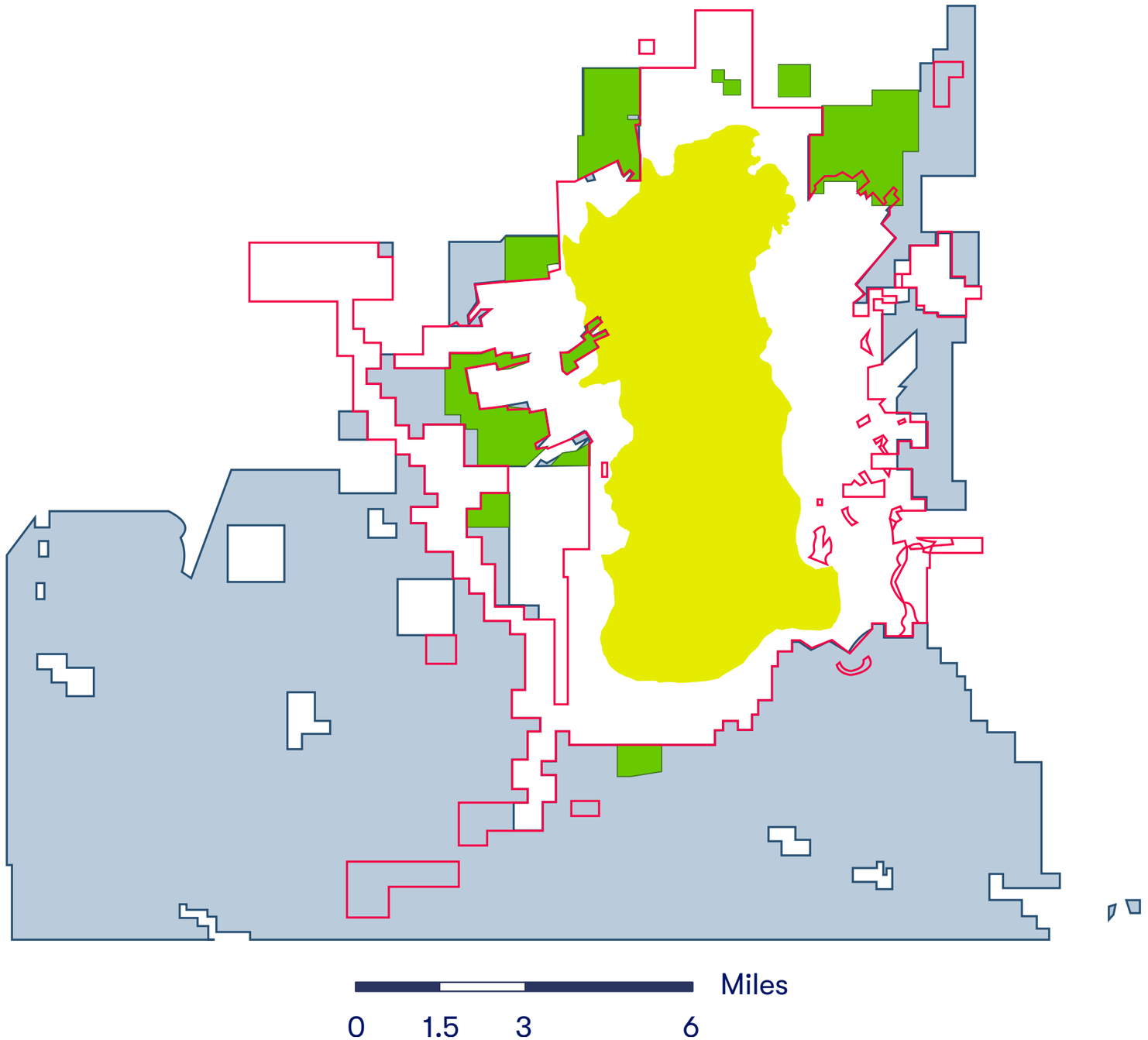
The boom has breathed life into local economies across the West. In Nevada, gold mining generated $9.2 billion in economic output and supported 12,000 direct jobs in 2023, with average annual wages exceeding $100,000. Rural communities like Elko and Winnemucca have seen tax revenues rise by 20% since 2020, funding schools, roads, and healthcare. Imperial County in California was given 1,500 mining jobs in 2023, and Alaska's industry contributed $600 million to its economy, the Alaska Miners Association says. The spin-offs include the creation of infrastructure, such as improved rail and power grids, to enhance connectivity in these remote areas.

The boom, though, comes with significant environmental challenges. Heap leaching in Nevada requires huge amounts of water—up to 100,000 gallons per ton of ore processed—in a state where drought has strained resources since 2018. Cyanide, used in 80% of Nevada's gold mining, poses risks of groundwater contamination.

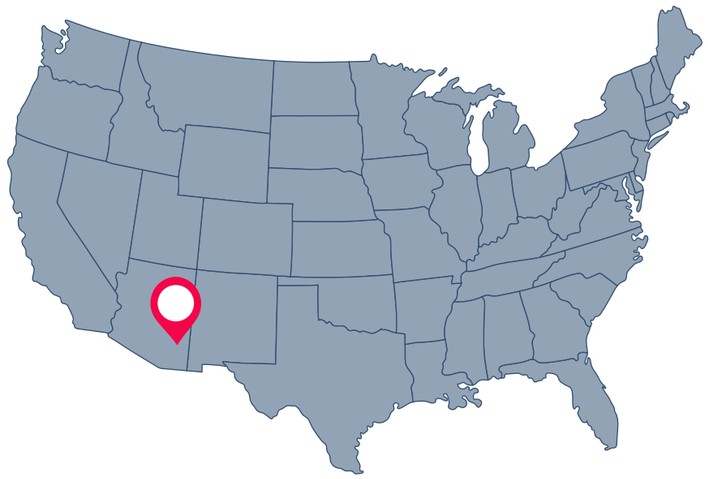
Mining companies are responding with large investments. At its Cortez Mine in Nevada, Barrick Gold invested $40 million in 2023 to install a new water treatment plant to meet Nevada Department of Environmental Protection standards for arsenic, antimony, and total dissolved solids. The 2 million gallons per day plant reduces impurities by 95%. In California, the Mesquite Mine installed a $15 million reverse osmosis system in 2024, recycling 70% of its water consumption. Alaska's Donlin project has invested $100 million to contain tailings and protect nearby rivers, but there is doubt from environmental groups like Earthworks, which tallied 12 small spills across the West in 2023.

The Western gold rush reflects a tenuous balance between economic growth and environmental sustainability. As global gold demand increased 4% in 2023 to 4,899 MT (World Gold Council) and prices climbed, the region's production—valued at over $20 billion—drives prosperity. Yet, as water shortages and pollution risks arise, the industry's future hinges on sustainable innovation, so the West's golden revival endures without compromising its natural legacy.

THE MORENCI MINE, ARIZONA



MORENCI MINE



Morenci Mine

Morenci Boundary

BLM Surface and Minerals

Unpatented Mining Claims

COPPER MINING GIANTS IN THE SOUTHWEST

The southwestern United States, particularly Arizona and Utah, is a staple of the nation's copper mining industry, driving both local economies and global supply chains. Iconic mines like the Morenci Mine in Arizona and the Bingham Canyon Mine in Utah embody the region's dominance, producing staggering volumes of copper—a metal essential to electrical grids, renewable energy gear, and infrastructure.

At Arizona, **Freeport-McMoRan's Morenci Mine** is North America's top copper producer. In 2023, the mine produced 399,100 metric tons (879 million pounds) of copper, as reported by GlobalData, which accounts for some 3% of the world's 28 million metric tons of mined copper. From its 1873 inception, Morenci has expanded from underground mines to a large open-pit complex, benefiting from innovations like heap leaching—a chemical extraction process that treats low-grade ore at 0.18% copper—to remain profitable. Two concentrators process 132,000 metric tons of ore daily at the mine, and four solvent extraction (SX) and three electrowinning (EW) plants produce 900 million pounds of copper cathode annually (Freeport-McMoRan).

Employing 3,300 workers in 2023, Morenci spent $1.5 billion in the Arizona economy, supporting rural Greenlee County with wages averaging $90,000 annually. In Arizona's arid climate, water is precious; 70% of process water from the mine is recycled—over 50 million gallons daily—and treated effluent is used, reducing freshwater use by 30% since 2015. Expansion plans will raise milling to 150,000 metric tons daily by 2026, and a $100 million solar power installation initiated in 2024 will reduce energy costs by 15% and carbon output by 50,000 metric tons annually.

The **Bagdad Mine**, located in Yavapai County, Arizona, is another significant open-pit copper and molybdenum mining operation owned by Freeport-McMoRan. Mining activities at this site commenced in 1882, with a transition to open-pit methods beginning in 1945. The mine boasts substantial reserves, with an estimated 873.6 million tonnes of ore grading 0.36% copper.

Its processing facilities include a concentrator with a capacity of 75,000 metric tons per day, a solution extraction/electrowinning (SX/EW) plant, and a pressure-leach plant for molybdenum concentrate. In 2003, Bagdad became home to the world's first commercial-scale concentrate leach processing facility. The mine operates continuously and remains a vital contributor to the U.S. copper industry.

The **Safford Mine**, located in Graham County, Arizona, is an open-pit copper mining complex owned and operated by Freeport-McMoRan. It began production in December 2007, marking the first major new copper mine in Arizona in over three decades. The operation includes the Dos Pobres and San Juan deposits, with current mining focused on the Lone Star deposit. Utilizing a mine-for-leach process, the mine produces copper cathodes through heap leaching and solvent extraction/electrowinning (SX/EW). In 2024, Safford produced approximately 249 million pounds of copper, with plans to increase output to 300 million pounds annually from oxide ores.

The site features a crushing facility with a design capacity of 103,500 metric tons per day and employs a fleet capable of moving over 400,000 metric tons of material daily. Recognized for its environmental stewardship, Safford is a zero-discharge facility awarded the Copper Mark for responsible production practices.

The **Lisbon Valley Mine**, located in San Juan County, southeastern Utah, is an open-pit copper mining operation managed by Lisbon Valley Mining Company (LVMC). Initiated in 2005, the mine employs heap leaching and solvent extraction-electrowinning (SX/EW) processes to produce high-purity copper cathodes. The operation targets copper-bearing sandstones, primarily within the Burro Canyon Formation. As of 2024, LVMC is pursuing an expansion to incorporate in-situ recovery (ISR) mining techniques, which involve injecting a solution to dissolve copper underground and then pumping it to the surface for extraction.

This proposed method has raised environmental concerns among local residents regarding potential impacts on groundwater quality. The mine's expansion plans are under review by the Bureau of Land Management and the Environmental Protection Agency. Despite facing operational challenges, including workforce reductions in late 2024, LVMC anticipates that the development of the Lone Wolf Pit could extend the mine's life by 15 to 20 years and increase employment opportunities in the region.

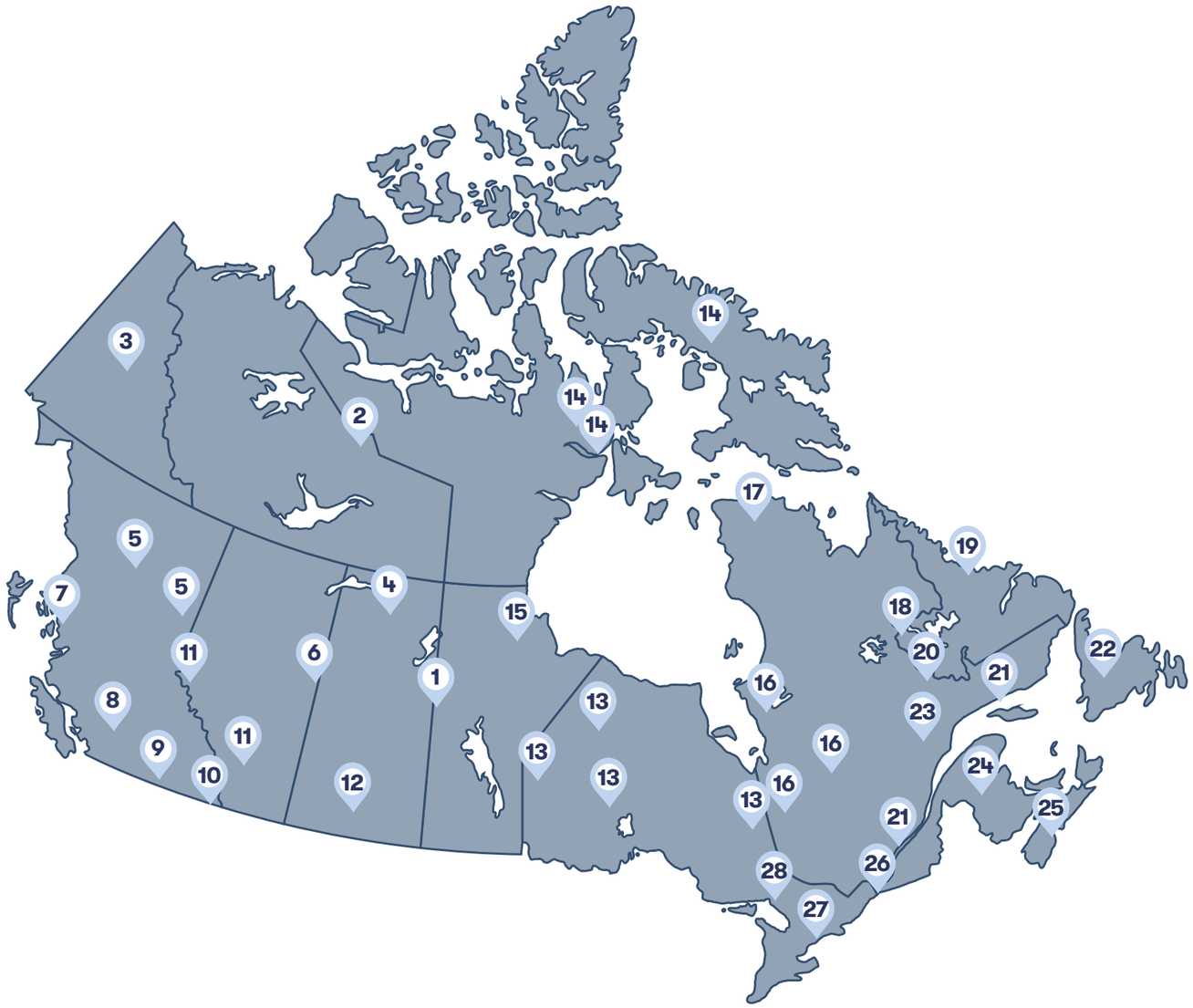
These Southwestern giants face obstacles like volatile copper prices—$4.25 per pound in Q1 2025 —wearing down high-grade ore and tight environmental regulations. Morenci's ore grade has dropped from 1% in the 1930s to 0.27% today, while Bingham Canyon's has fallen from 2% to 0.5%. Yet, innovation keeps them competitive. Morenci employs bioleaching, using bacteria to extract copper from waste rock, boosting recovery by 10% and adding 20 million pounds yearly.

Bingham Canyon's $50 million wind and solar renewable energy retrofit provides 25% of the operation and has cut emissions by 100,000 metric tons since 2022. Regulatory compliance costs have risen—Morenci has spent $40 million in 2023 to treat water to EPA standards for arsenic and antimony—but these investments pay long-term dividends.

Combined, Arizona and Utah provided 70% of US copper output—1.2 million metric tons—in 2023, valued at $9 billion.

With global demand for copper predicted to rise to 36.6 million metric tons by 2031, driven by electric vehicles (183 pounds per vehicle) and solar panels (12 pounds per kilowatt), these mines are essential. The Southwest's 2023 production met 17% of US demand (1.7 million metric tons), reducing reliance on imports from Chile and Peru.

MINERALS IN CANADA



1 FLIN FLON
(Copper, Zinc, Gold)

2 NWT
(Diamonds)

3 YUKON
(Copper, Gold, Silver)

4 NORTHERN SASKATCHEWAN
(Uranium, Gold)

5 NORTHERN BC
(Copper, Gold, Molybdenum, Metallurgical Coal)

6 FORT McMURRAY
(Oil Sands)

7 KITIMAT
(Aluminum)

8 SOUTHERN BC
(Copper, Golg, Molybcenum)

9 TRAIL
(Lead, Zinc)

10 ELK VALLEY
(Metallurgical Coal)

11 SOUTHERN ALBERTA
(Coal, Allied Industries)

12 SOUTHERN SASKATCHEWAN
(Potash, Coal)

13 NORTHERN ONTARIO
(Gold, Palladium, Platinium, Copper, Zinc)

14 NUNAVUT
(Gold, Iron)

15 NORTHERN MANITOBA
(Nickel, Cobalt, Gold)

16 ABITIBI & JAMES BAY REGION
(Gold, Copper, Zinc, Diamonds)

17 NORTHERN QUEBEC
(Nickel)

18 SCHEFFERVILLE
(Iron)

19 VOISEY'S BAY
(Nickel)

20 LABRADOR CITY & FERMONT
(Titanium, Scandium)

21 HAVRE ST. PIERRE & SOREL-TRACY
(Titanium, Scandium)

22 NEWFOUNDLAND
(Gold, Nickel Refining)

23 SAGUENAY REGION
(Aluminum, Niobium)

24 NEW BRUNSWICK
(Zinc, Lead, Salt)

25 NOVA SCOTIA
(Gold, Gypsum)

26 MONTREAL
(Aluminum)

27 TORONTO & SOUTHERN ONTARIO
(Salt, Uranium Refining)

28 SUDBURY
(Nickel, Copper, Cobalt)

OPEN PIT MINE OPERATIONS IN CANADA

Canada stands as a global leader in the mining industry, harnessing its natural resources through extensive open pit mining operations. The country's mineral wealth is extracted from its rugged landscapes, providing essential materials that fuel both domestic industries and international markets. Besides key minerals besides gold, iron, copper and coal, oil sands play a huge role in Canada's open pit mining.

Oil sands

Canada's oil sand industry is one of the largest and most significant sources of crude oil in the world, centred primarily in Alberta. The region holds the third-largest proven oil reserves globally, after Venezuela and Saudi Arabia. Unlike conventional oil extraction, oil sands production involves mining or in-situ techniques to extract bitumen, a heavy, viscous form of petroleum. Surface mining is used when deposits are close to the surface, while deeper reserves require steam-assisted gravity drainage (SAGD) or other thermal methods.

The industry contributes substantially to Canada's economy, providing thousands of jobs and billions in revenue through exports—most notably to the United States, which remains Canada's largest oil customer. Despite its economic benefits, the oil sands sector has drawn significant environmental scrutiny. It is carbon-intensive, requires large volumes of water, and impacts local ecosystems and Indigenous lands. However, ongoing investments in carbon capture, water recycling, and land reclamation are aimed at mitigating these effects.

In recent years, the industry has faced challenges, including global price volatility, pipeline constraints, and increasing pressure to transition to cleaner energy sources. Nevertheless, oil sands production continues to grow in efficiency and output, with many companies setting net-zero emissions targets by 2050. As global energy demand evolves, the future of Canada's oil sands will likely hinge on its ability to balance environmental responsibility with energy security and economic value.

Gold

Gold is among Canada's most precious mineral commodities, with Canada being the world's fourth-largest producer in 2023, producing 198 metric tons (6.37 million ounces). These mines extract gold from near-surface deposits using large-scale earth-moving equipment to remove overburden and access ore bodies. Open-pit methods are favoured when deposits are extensive and relatively shallow, allowing for high production volumes at lower operational costs compared to underground mining.

Canada hosts several world-class open-pit gold mines, including Detour Lake in Ontario—the country's largest by reserves—and Canadian Malartic in Quebec, one of North America's most productive gold mines. These sites typically operate year-round and contribute significantly to local economies through employment, procurement, and royalties. Technological advancements, such as autonomous haul trucks and real-time data monitoring, have improved efficiency and safety across many operations. Environmental management remains a key focus, with mine operators required to submit detailed reclamation plans and implement water treatment, tailings management, and land rehabilitation measures.

Despite fluctuating gold prices, demand remains strong, supporting continued investment in exploration and expansion. As Canada maintains its position as one of the world's top gold producers, open-pit mining continues to play a central role in meeting global supply and advancing mining innovation.

Coal

Open-pit coal mining in Canada is primarily concentrated in the western provinces, especially Alberta and British Columbia, where large surface-accessible coal deposits are abundant. The industry focuses on two main types: thermal coal, used for power generation, and metallurgical (coking) coal, essential for steelmaking. Canada is one of the world's leading exporters of metallurgical coal, with most shipments destined for Asia.

Open-pit methods are favoured for coal extraction due to the relative ease of accessing layered seams near the surface. Operations typically involve removing large volumes of overburden, followed by drilling, blasting, and hauling of coal to processing facilities. Major open-pit mines, such as those in the Elk Valley region, are among the most productive in North America, operated by companies like Teck Resources. Some provinces, like Alberta, have placed restrictions on new thermal coal projects, reflecting the shift toward cleaner energy sources. Nonetheless, metallurgical coal remains in high demand globally, ensuring that open-pit coal mining continues to be a significant—if evolving—part of Canada's resource economy.

Potash

Potash mining in Canada is centred almost entirely in Saskatchewan, which holds some of the richest and most extensive potash reserves in the world. While most potash is extracted using underground methods due to the deposits' depth, surface-accessible operations utilize solution mining—a hybrid approach that combines aspects of open-pit and subsurface techniques. True open-pit potash mining is rare in Canada, as the deposits are typically too deep for conventional surface excavation. In solution mining, water is injected into the ore body to dissolve the potash, which is then pumped to the surface and crystallized. This method reduces surface disruption compared to traditional mining but still requires substantial infrastructure and water resources. Major producers like Nutrien and Mosaic operate large-scale facilities in the province, supplying global agricultural markets with potash for fertilizer production.

The potash industry plays a crucial role in the Canadian economy, both as a leading export and as a source of employment in rural communities. Demand remains strong due to global population growth and the need for food security, positioning Canada as a long-term leader in potash production. Environmental regulations and water management continue to shape the development and expansion of operations.
 20,000 metric tons from its open pit mine. Valued at $4.5 billion, copper exports bolster Canadian trade, particularly with the U.S., which imported 300,000 metric tons in 2023.

Canada's open pit diamond mines in the Northwest Territories have placed it third globally after Russia and Botswana, with production of 16.3 million carats in 2023. Burgundy Diamond Mines' Ekati Mine produced 4.2 million carats from its Misery and Koala pits, and Rio Tinto's Diavik Mine produced 3.8 million carats at grades of 2.8 carats per ton. The mines provided employment for 2,500 individuals and added $2 billion to the northern economy, with 80% of diamonds exported to Europe and Asia. Proven reserves of 110 million carats ensure production through 2040.

MINING OPERATIONS 2024 - ONTARIO

1 Bell Creek Mine

2 Black Fox Mine

3 Borden Mine

4 Detour Lake Gold Mine

5 Eagle River Mine

6 Hollinger Mine

7 Hoyle Pond Mine

8 Island Gold Mine

9 Macassa Mine

10 Magino Mine

11 Musselwhite Mine

12 Rainy River Mine

13 Red Lake Mine

14 Sugar Zone Mine

15 Timmins West Mine

16 Williams Mine

17 Young – Davidson Mine

18 Kidd Creek Mine

19 McCreedy West Mine

20 Sudbury Operations

21 Fraser Mine,
Nickel Rim South Mine

22 Tomclid Iron Mine

23 Lac des Iles Mine

MINING OPERATIONS IN ONTARIO

Famous for its bountiful mineral resources, Ontario has been a resource extraction hub for a long time, and the tradition continues with the province dominating in the production of valuable minerals like gold, nickel, copper, and platinum group metals. In 2023, the mineral output from Ontario was worth $15.7 billion, a 50% growth over the last decade, the Ontario Mining Association (OMA) reported.

Currently, there are 35 producing mines, mainly located in Northern Ontario, and over 300 exploration projects are underway, reflecting the sector's magnitude and growth potential. The attention over the past few years has increasingly focused on such key minerals as lithium and cobalt, with demand from the renewable energy and electric vehicle sectors having accelerated.

Nickel, a key requirement for stainless steel and EV batteries, rounds out Canada's open pit portfolio, with 130,000 metric tons produced in 2023, ranking sixth globally. Ontario's Sudbury Basin is the standout, where Glencore's Onaping Depth project, an open pit transitioning underground, yielded 25,000 metric tons at 1.2% grade.

The Ontario government's Critical Minerals Strategy is aimed at connecting northern mines to southern manufacturing sectors, particularly for battery and electric vehicle manufacturing, reflecting the province's strategic position in facilitating the world's transition to sustainable technologies.

Ontario is a leading producer of platinum group metals (PGMs) in Canada, accounting for approximately 75% of the nation's PGM mine production in 2023. These metals—including platinum, palladium, rhodium, ruthenium, iridium, and osmium—are primarily extracted as by-products of nickel and copper mining, particularly in the Sudbury Basin.

Significant exploration and development projects bolster the province's PGM industry. Notably, the Marathon project near Thunder Bay aims to develop an open-pit mine to extract ore containing copper and PGMs, including gold, platinum, and palladium. Additionally, the River Valley project near Sudbury is recognized as Canada's largest undeveloped primary PGM resource, with substantial measured and indicated reserves.

Ontario's PGM production is integral to the global supply chain, especially for applications in the automotive and chemical industries. The province's mining sector generated $15.7 billion worth of minerals in 2023, with PGMs contributing significantly to this total. As demand for PGMs continues to rise, Ontario's role in their production remains crucial.

Ontario's open-pit copper mining industry is experiencing a resurgence, driven by significant projects and strategic developments. A notable initiative is the Marathon Palladium-Copper Project near Thunder Bay, which involves constructing and operating three open pits to produce copper concentrate. Over its 12.5-year mine life, the project is expected to yield approximately 3.6 million ounces of palladium equivalent, with copper contributing about 29% of the revenue.

The operation includes an onsite processing facility, and a comprehensive environmental assessment has been undertaken by federal and provincial agencies, Indigenous groups, and local communities.

In Sudbury, Vale Base Metals is revitalizing the historic Stobie Mine by developing a new open-pit copper-nickel operation. The project, with an investment of C$205 million over four years, aims to produce 1.5 million tonnes of ore annually by 2025. This initiative emphasizes collaboration with Indigenous businesses and local contractors, reflecting a commitment to sustainable and inclusive growth.

Ontario's mining industry has a rich history in silver production, particularly in the early 20th century. The town of Cobalt, Ontario, became a significant centre for silver mining following discoveries in 1903. At its peak in 1911, Cobalt's mines produced over 30 million ounces of silver, making it one of the world's largest silver-producing regions at the time. While large-scale silver mining has declined, the legacy remains, and exploration activities continue in the region.

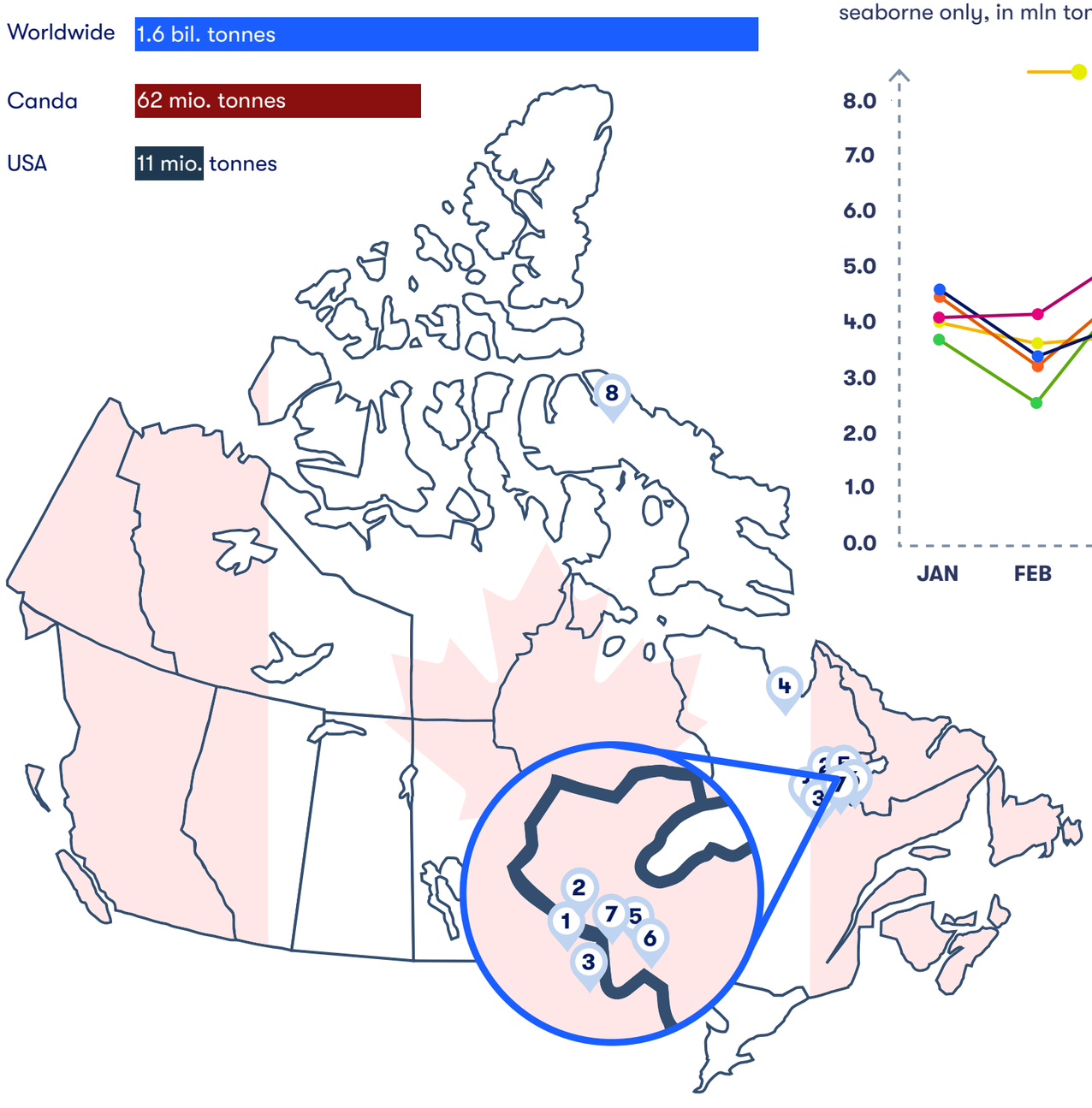
Regarding zinc production, Ontario contributes to Canada's output, though the majority comes from other provinces. The Kidd Creek Mine near Timmins is a notable operation that produces zinc, copper, and silver. However, overall, Ontario's zinc reserves have significantly declined over the past 25 years, decreasing by 95%, impacting the province's standing in zinc production.

While Ontario's prominence in silver and zinc mining has diminished compared to its historical highs, the province continues to play a role in Canada's mining sector, with ongoing exploration and development projects to revitalise these industries.

In the future, Ontario's mines face challenges as much as opportunities as they change in a more rapidly changing global world. The expanding demand for minerals associated with clean technologies offers significant opportunity for growth, with projections indicating that nickel demand could be 14 times higher by 2040 than it was in 2021 and cobalt seven times higher, according to the OMA. These are, however, weighed against prospects for volatility in commodity prices and stringent government regulation to reduce emissions. With ongoing investment in green technology and sustainable practices, the industry's ability to transition into a low-carbon economy will be critical.

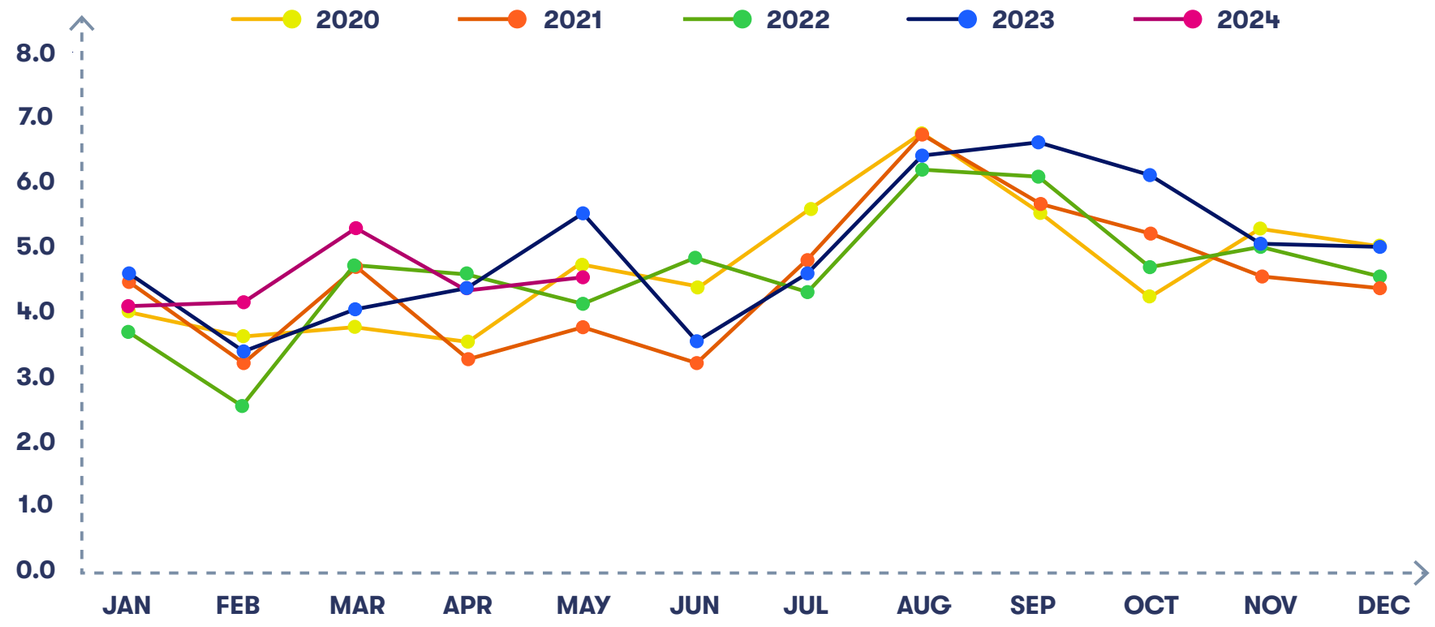
IRON ORE IN CANADA

IRON ORE EXPORT COMPARED IN 2024



CANADA'S MONTHLY IRON ORE EXPORTS - SEASONALITY

seaborne only, in mln tonnes, all bullkers



CANADA'S IRON ORE PROJECTS AND MINES

1. Bloom Lake
2. Mont-Wright
3. Fire Lake
4. Lac Otelnuk
5. Carol Lake (Larbrador City)
6. Scully Mine
7. Kami Project
8. Mary River Mine

CANADA'S IRON ORE POWERHOUSE

Canada's iron ore sector is an economic powerhouse worldwide, with Quebec and Labrador being the undisputed masters leading this sector. These provinces draw from the rich resources of the Labrador Trough—a mining goldmine bisecting the border between Quebec, Newfoundland and Labrador—to manufacture most of Canada's iron ore. In 2023, Canada's total iron ore production, pellets and concentrate, was 59.4 million tonnes.

Quebec and Labrador together produced a staggering 91% of this, indicating their supremacy. Quebec led the way with 33.6 million tonnes, or 57% of the nation's production, followed by Labrador with 20.2 million tonnes, or 34%. This overwhelming performance highlights the provinces' precious contributions and establishes Canada's position as a significant player in the global iron ore market. The backbone of this business lies in the gigantic mining ventures that define Quebec and Labrador's iron ore landscape. In Quebec, the Bloom Lake Mine owned by Champion Iron is the country's largest iron ore operation.

Alone in 2023, it produced nearly 40 million metric tons of high-grade ore, a testament to its strength and efficiency. Close behind was ArcelorMittal's Mont Wright Mine, propping up Quebec production with nearly 22 million metric tons, further establishing the province's reign over the sector. Across the border in Labrador, Rio Tinto's Carol Lake Mine remains a pillar of production.

With a planned capacity of 17.715 million tonnes per year—a record marked in 2020—this mine is typical of the region's industrial power. Supporting this endeavour are cutting-edge infrastructures, such as the Iron Ore Company of Canada (IOC), which Rio Tinto, Mitsubishi, and Labrador Iron Ore Royalty Income Corporation have joined forces with. IOC's vast network features a fully owned 418-kilometer railroad between its Labrador City mine and the Sept-Îles port in Quebec. Smooth transportation ensures an efficient supply of high-grade, low-impurity iron ore—a perfect raw material for the fast-emerging green steelmaking sector, focusing on sustainability and lower carbon content.

The financial importance of Quebec and Labrador's iron ore mines cannot be emphasized enough. Canada exported nearly 54 million tonnes of iron ore in 2021, with the sector earning a staggering $10.1 billion in revenue. The majority of the exports were from the mines in Quebec and Labrador, which are important contributors to Canada's resource-based economy and the trade surplus. Besides contributing to national wealth, the mining operations are a significant source of employment.

In 2022, the iron ore industry directly employed approximately 9,300 workers in 11 business units, mostly based in these two provinces. The employment provides thousands of employees with stable livelihoods and stimulates economic growth in the surrounding communities and even farther away. In addition, the industry's economic contribution is also in terms of the supply chain since it sustains auxiliary businesses such as transport, equipment manufacturing, and port facilities.

In addition to their economic contributions, Quebec and Labrador's iron ore mining operations contribute to sustainable and inclusive development. IOC's operations, for example, have encouraged close ties with First Nations peoples in both provinces through impact and benefits agreements that recognize economic inclusion, respect for culture, and environmental management. These alliances ensure Indigenous peoples a share in the prosperity generated by the mines, either through job opportunities, revenue sharing, or community initiatives. By incorporating sustainability into their operations, these companies are aligning with global demands for responsibly sourced materials—a concern that is increasingly important as industries worldwide shift toward greener business practices.

Quebec and Labrador iron ore is particularly well-positioned to meet such modern demands. Labrador Trough-mined high-grade, low-impurity ore is a high-quality product, making it the preferred choice for green-minded steel manufacturers who want to reduce their carbon footprint. While countries transition to cleaner technology, such as electric arc furnaces and hydrogen-based steel production, Canada's quality iron ore puts Quebec and Labrador at the forefront of market suppliers in the new environment. Their ability to supply consistent volumes of better-grade ore supports Canada's position as a reliable and innovative participant in the global resource economy.

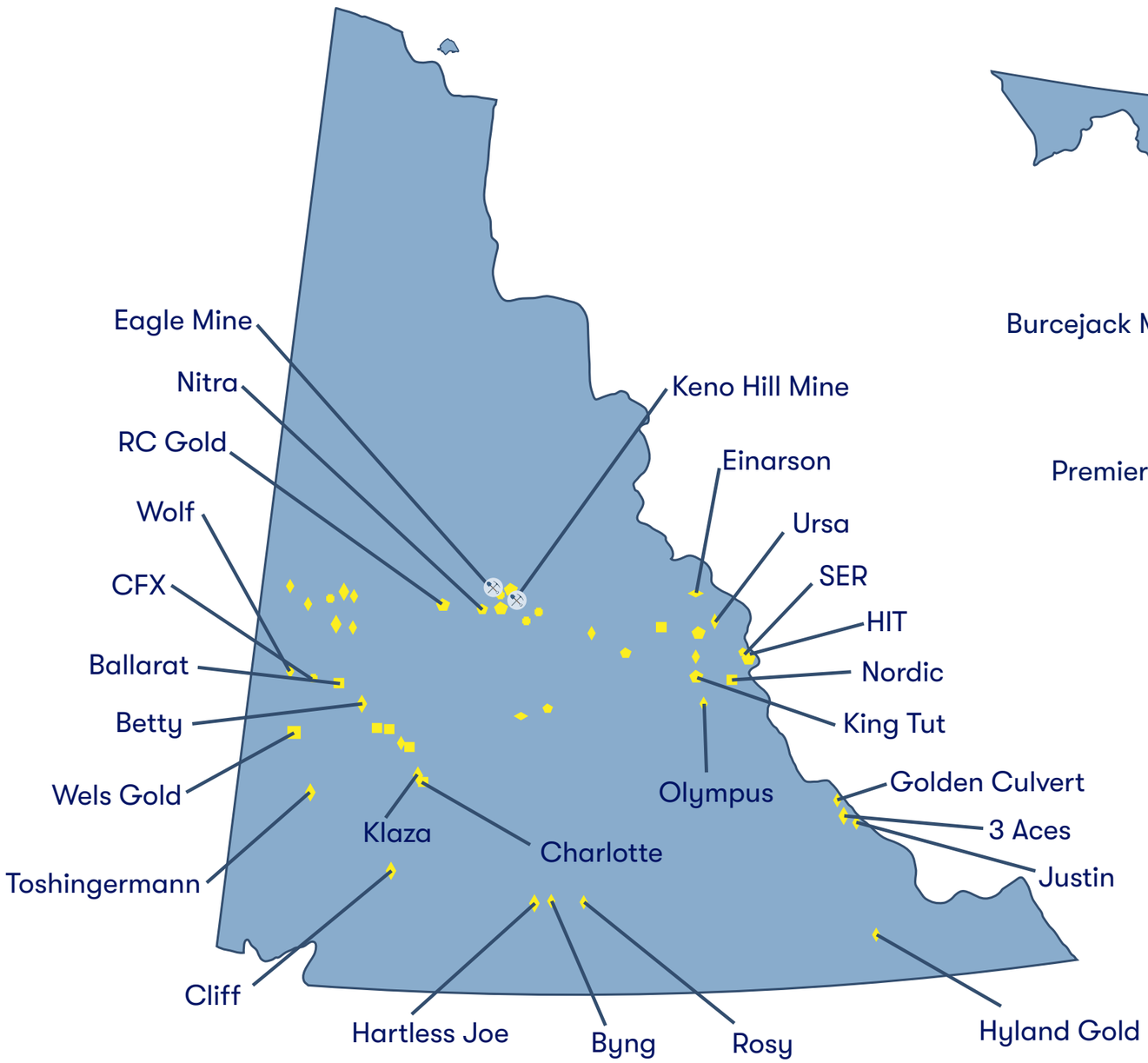
Beyond its prominent iron ore operations, Quebec hosts significant open-pit mining activities for various other minerals. A notable project is the Troilus gold-copper mine, located approximately 120 km north of Chibougamau. This venture is being developed as a conventional open-pit operation, with plans to produce an average of 244,600 ounces of gold and 17.3 million pounds of copper annually over a 22-year mine life.

In the Abitibi region, the Canadian Malartic mine stands as Canada's largest open-pit gold mine. Initially developed by Osisko Mining and operated by Agnico Eagle and Yamana Gold, the mine began commercial production in 2011 and has significantly contributed to the local economy. The Casa Berardi Mine, situated 95 km north of La Sarre, Quebec, also includes an open-pit component known as the East Mine Crown Pillar (EMCP). This development began in 2016 and is expected to contribute to the mine's production of approximately 2,300 tonnes of ore per day.

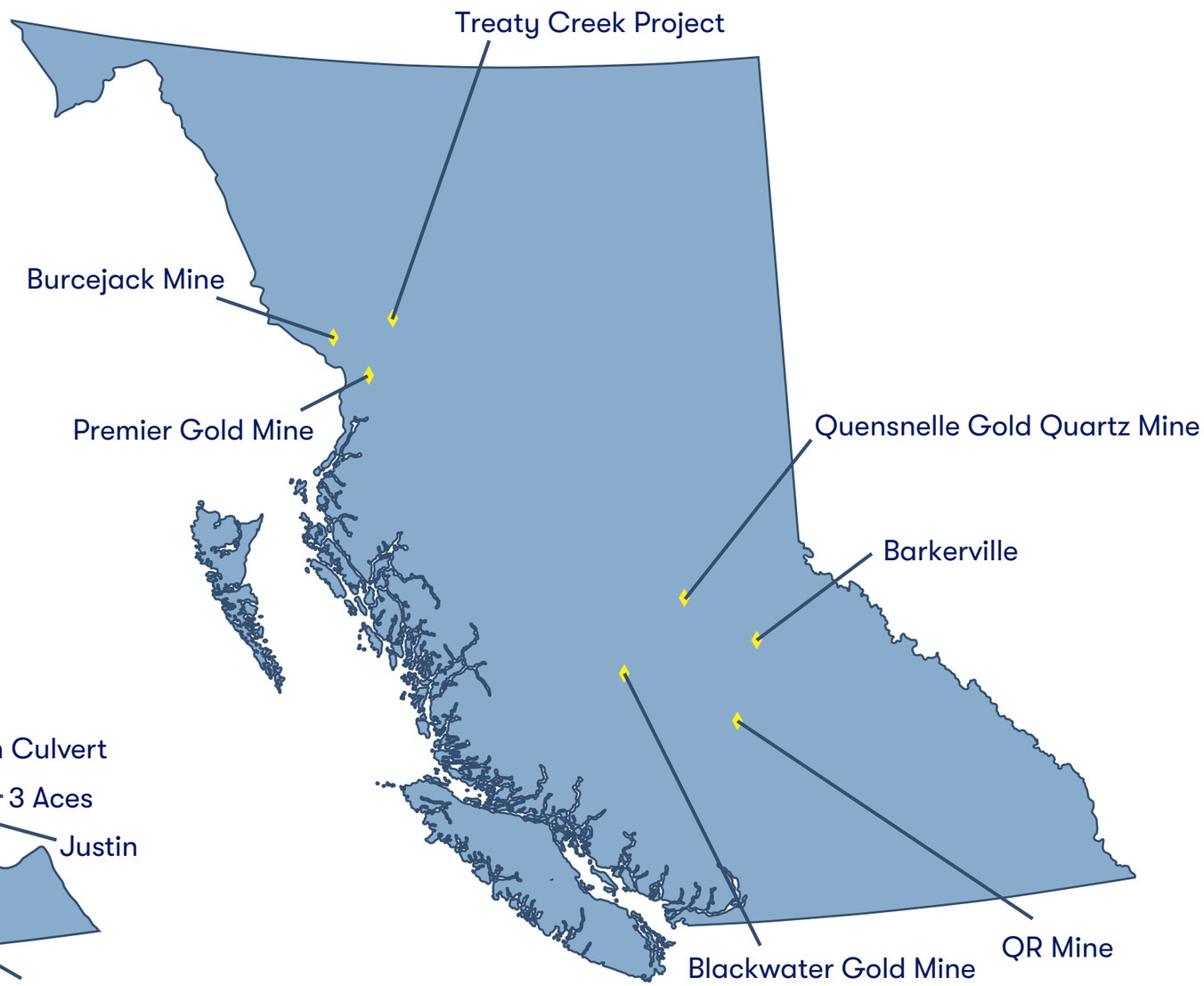
In Labrador, while iron ore dominates, there are emerging interests in other minerals. For instance, Torngat Metals is proposing an open-pit rare earth element mine near the Quebec-Labrador border. The project aims to transport the extracted materials via a 160 km seasonal road to Voisey's Bay, with further shipment to a processing facility in Sept-Îles, Quebec.

GOLD MINING IN YUKON & BRITISH COLUMBIA

YUKON



BRITISH COLUMBIA



GOLD MINING IN THE YUKON AND BRITISH COLUMBIA

Gold mining has profoundly impacted the Yukon and British Columbia, hitting Canada's northwest and north borders with a legacy of historic rushes and robust current production. These regions have been at the centre of the country's mining history for 200 years, blending rich historical heritage with today's operations that continued economic growth and expansion strong. From the crazy gold rushes of the 19th century through the advanced mining technology of today, the Yukon and British Columbia are perfect examples of Canada's long affinity with this commodity metal.

For Yukon, gold mining and the Klondike Gold Rush cannot be divorced. It is an eventful history that started when gold was found in Bonanza Creek in 1896, triggering this fundamental change. This find triggered a mad rush of migration, bringing an estimated 100,000 miners to the district between 1896 and 1899. The journey was difficult, with only 30,000 to 40,000 hardy men reaching the goldfields after surviving dangerous land and stringent climate. The influx of people transformed Dawson City into a prosperous hub overnight, which spurred work on the infrastructure that left a lasting legacy on the region.

One of these innovations was the White Pass and Yukon Route Railway, which was a vital lifeline that connected the Yukon to the Pacific coast. The railway facilitated the transportation of goods and human beings, opening the way for sustained economic activity. The Klondike Gold Rush might have faded into history, but its legacy endures in the Yukon's modern gold mining industry.

As of April 2025, the Yukon gold mining industry is experiencing a dynamic period marked by growth in placer mining and challenges in hardrock operations. Placer mining continues to thrive, with 156 active operations in 2024, up from 147 in 2023. The Dawson Mining District remains the most active, accounting for 70% of operations. Favourable gold prices and weather conditions contributed to record placer revenues between April and November 2024.

In contrast, the hardrock sector faced setbacks, notably the (temporary) closure of the Eagle Gold Mine after a heap leach pad collapse, one of the territory's primary producers, leading to a decline in mineral production. Despite this, exploration activities are robust. Sitka Gold's RC Gold Project reported significant mineralization in 2024, with plans for up to 30,000 meters of drilling in 2025. Similarly, Banyan Gold's AurMac Project expanded its resource base, with a 2024 drilling program identifying multiple high-grade gold intersections.

For British Columbia, the 1860s Cariboo Gold Rush was a turning point in its history. Motivated by the discovery of gold in 1861, the rush attracted thousands of fortune seekers to the Cariboo region, making it a bustling hub. At the centre of the boom was Barkerville, the town that reached a population of over 5,000 and was the largest city north of San Francisco and west of Chicago at its peak. The sheer population growth called for the construction of the Cariboo Wagon Road, a 650-kilometre engineering feat between Yale and Barkerville.

While it enabled the gold rush, it also opened up British Columbia's interior for settlement and business, paving the way for long-term growth. The province's gold mining industry remains a powerhouse today, being exemplified by mines like the Brucejack Mine, owned and operated by Newmont Corporation. In 2023, the mine produced over 300,000 ounces of gold, and it continues to keep British Columbia at the forefront of contributing to Canada's mining sector. Achievement in such operations highlights the province's ability to balance its historical past with a vibrant present.

As of April 2025, British Columbia's gold mining industry is navigating a transitional phase. While exploration spending declined by 14% in 2024 to C$552 million, this shift reflects the maturation of several flagship projects moving toward operational readiness. The Northwest region continues to lead in exploration expenditure, accounting for 63% of the province's total. Notably, two major gold mines commenced operations in 2024.

Ascot Resources' Premier Gold Mine near Stewart and Artemis Gold's Blackwater Gold Mine southwest of Prince George are now contributing to the province's gold output. Additionally, Osisko Development's Cariboo Gold Project is advancing, with recent drilling at the QR Mine yielding high-grade results of 13.6 g/t gold.

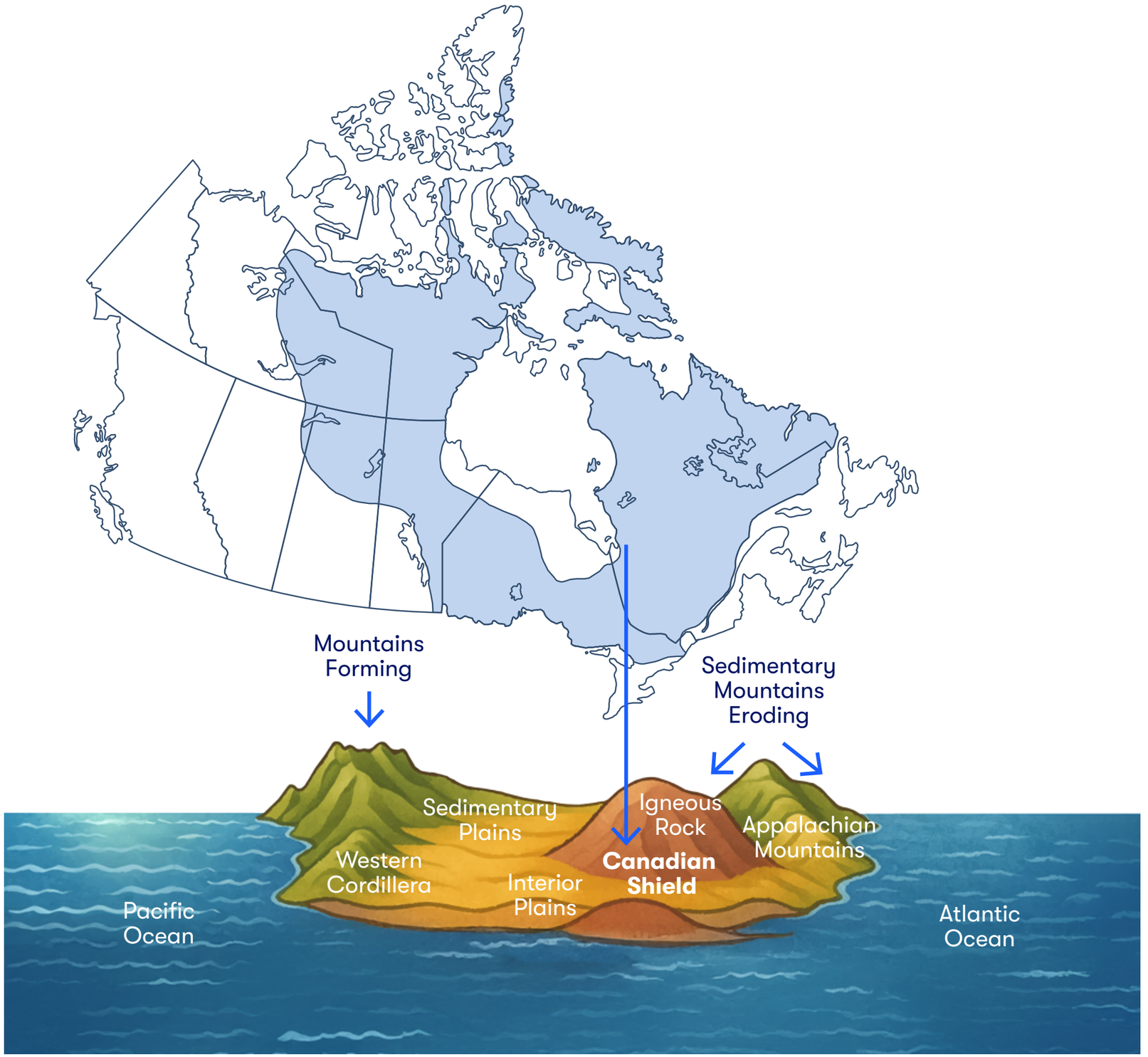
Exploration efforts remain robust. Golden Cariboo Resources reported promising findings at the Quesnelle Gold Quartz Mine Property, with samples indicating significant gold mineralization. Similarly, Tudor Gold's Treaty Creek Project in the Golden Triangle saw a 19% increase in its indicated gold equivalent ounces, highlighting the region's ongoing potential.

The Yukon and British Columbia blend their significance in the past into modern-day mining practices, emphasizing sustainability and community involvement. Contemporary gold mining in the region employs advanced techniques to minimize environmental impact, such as water recycling and minimizing waste. The approach reflects a broader industry shift toward sustainable resource extraction, responding to international demands for cleaner practices.

In addition, companies in both regions have signed impact benefit agreements with Indigenous people, such that economic achievement is shared and cultural heritage and traditional lands are respected. These agreements will likely include employment, revenue sharing, and community development elements, all directed towards the collaborative approach to resource development. By emphasizing sustainability and inclusiveness, Yukon and British Columbia's gold mining industries attempt to balance economic gain with social and environmental responsibilities.

Despite Yukon's and BC's dominance in gold mining, the Canadian Malartic Mine in Quebec is the biggest open pit gold mine, in Canada producing 689,000 ounces (21.4 metric tons) per day.

CANADIAN SHIELD



CANADIAN SHIELD

The Canadian Shield, one of the giant geological features in most of Canada and extending into the northern United States, is central to the mining universe as a factor in the suitability for open pit mining. The ancient stable platform of Precambrian rock formed a billion years ago and has a geological set that makes it remarkably advantageous in mineral recovery. Perhaps most crucial is the richness of Shield's mineral deposits, with huge reserves of valued resources such as gold, silver, copper, nickel, iron ore, and even diamonds.

The minerals frequently occur in veins or large bodies close to the surface and are ideal for open pit mining—a method that entails digging enormous, open pits to access resources in an economical way. The close proximity to the surface of these deposits is also helped by the Canadian Shield's relatively low overburden, the soil and rock layer covering the mineral-bearing horizons. With a lower overburden to be extracted than elsewhere, mines can access these valuable resources more quickly and at less expense, maximizing efficiency and profitability.

Other than its mineral accessibility, the Canadian Shield's geological composition offers some additional advantages for open-pit mining. The region is composed of hard, crystalline rock, which is extremely stable. This stability allows operators of mines to create vast, steeply sloped pits without the risk of structural collapse and with great safety for personnel and equipment, as well as with high ore density per unit location.

Moreover, much of the Shield is dominated by exposed bedrock that is exposed at the surface in most locations. Such exposure facilitates exploration because geologists are able to examine the rocks in hand to ascertain probable mineral deposits without relying on costly, deep exploratory drilling. The ease with which mining areas can be identified and pinpointed further contributes to the economic viability of operations in the area.

Water management, a key part of open pit mining, is another aspect in which Canadian Shield geology is beneficial. The region is replete with natural drainage systems, including numerous rivers and lakes, that facilitate control of water flow in and around mines. Such systems prevent pit flooding—a common issue in open pit mining—and provide channels for treating water that may get contaminated during mining.

Additionally, the Shield's environment, although harsh with lengthy cold winters, also has the possibility of delivering unsuspected advantages. Winter ground conditions of frozen surfaces can stabilize the ground, ease the passage of heavy equipment and maintain pit walls' structural support, thus permitting year-round mining in some situations.

Despite the remote positions it occupies, creating difficulties such as equipment and man movement logistics in some cases, the Canadian Shield's geology advantages are numerous compared to those problems. The integration of hard rock bases, easily accessible mineral deposits, shallow overburden, and effective natural water management systems makes it the ideal environment for open pit mining. The Canadian Shield is, therefore, now a pillar of Canada's mining industry and the world's leading destination for mineral extraction.

Several prominent open-pit gold mining operations are active in the Canadian Shield, a vast geological region rich in mineral resources. Besides the already mentioned Agnico Eagle's Detour Lake Mine in northeastern Ontario and Canadian Malartic in Quebec, there is Newmont's Musselwhite Mine in northern Ontario, while now an underground mine, began with surface operations and remains one of the key sites within the Canadian Shield. In northwestern Quebec, the Éléonore Mine—although primarily an underground operation—also had surface infrastructure developed for early stages, highlighting the region's hybrid mining potential.

The Rainy River Mine, operated by New Gold, is a relatively new operation that began commercial production in 2017. It features a large open-pit design supported by a processing plant capable of handling tens of thousands of tonnes per day, though the mine is gradually shifting toward underground development as the pit deepens.

The Young-Davidson Mine, owned by Alamos Gold, is primarily known for its underground operations today, but it was developed with an extensive open-pit phase. This allowed the company to build up cash flow and infrastructure while transitioning to long-term underground mining. Located in the southwestern Abitibi region of the Canadian Shield, Young-Davidson is considered a cornerstone asset for Alamos Gold due to its consistent output and long mine life.

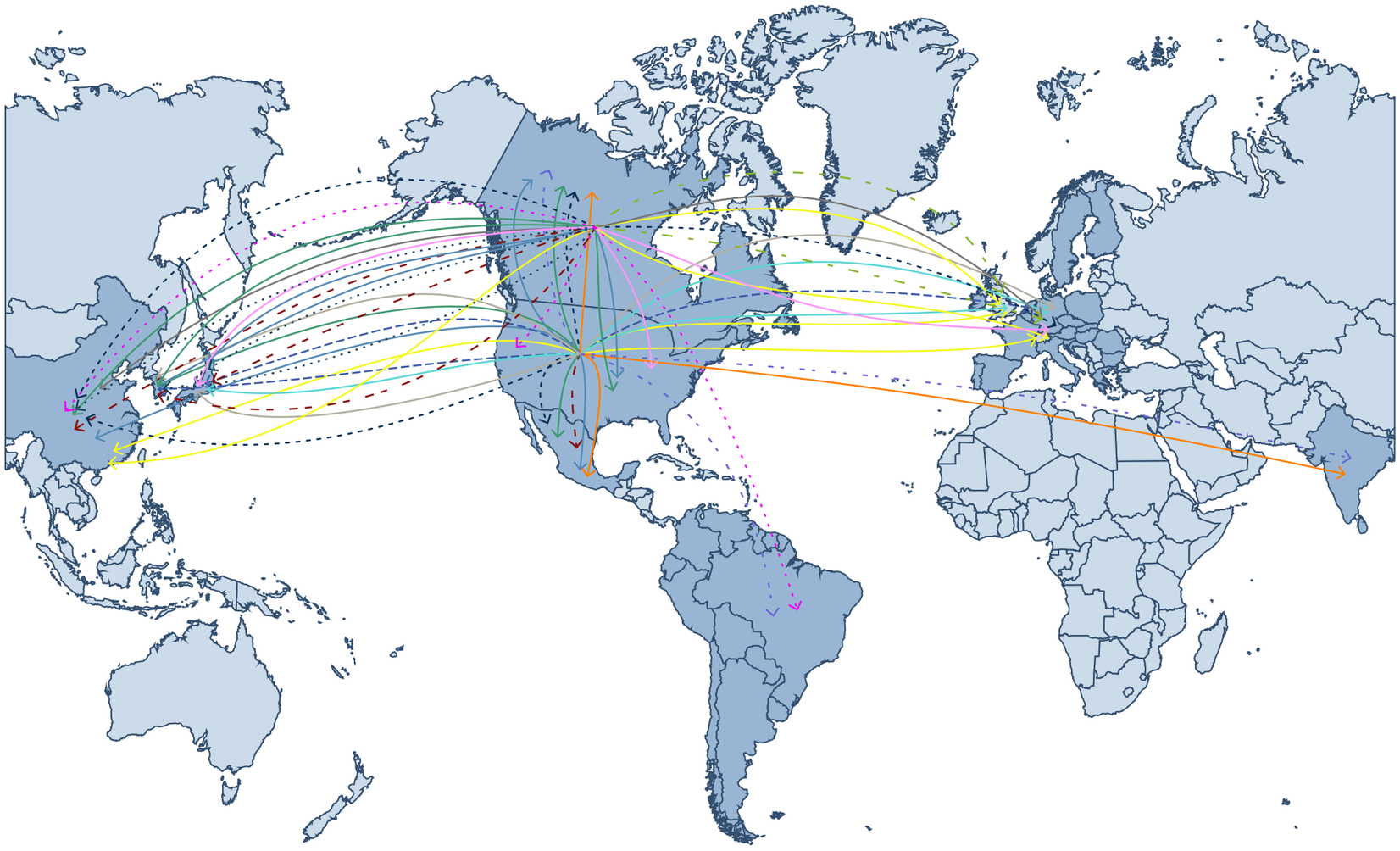
Farther north, the Meadowbank Complex in Nunavut, also operated by Agnico Eagle, includes several open-pit deposits and has played a pivotal role in developing the mining sector in the Canadian Arctic. Initially launched in 2010, Meadowbank's success paved the way for the nearby Amaruq satellite deposit, which began contributing ore through a long-haul truck route to the Meadowbank mill. Despite harsh conditions and logistical complexities, these sites underscore the viability and strategic importance of open-pit mining in remote areas of the Canadian Shield.

Even though the environmental concerns, i.e., land disturbance and loss of habitat, still apply, mining companies are currently embracing sustainable practices, i.e., rehabilitation of land after mining, to minimize their contribution. In essence, the Canadian Shield's unique geological character not only enables open-pit mining but also enhances its status as an integral part of the world's resource economy.

EXPORTING MINERALS FROM NORTH AMERICA

% OF ALL US MINERAL EXPORT GO TO

- **MEXICO** 11.2%
- **CANADA** 9.2%
- **CHINA** 7%
- **NETHERLANDS** 4.3%
- **GERMANY** 3.8%
- **JAPAN** 3.6%
- **SOUTH KOREA** 3.2%
- **UNITED KINGDOM** 3%
- **BRAZIL** 2.7%
- **INDIA** 2.4%
- **OTHER COUNTRIES** 49%



Coal
Gold
Uranium
Nickel
Lithium
Copper
Aluminum
Potash
Zinc
Iron
Silicon
Molybdenum
Rare Earth Elements
Posphate
Lead

% OF ALL CANADIAN MINERAL EXPORT GO TO

- **UNITED STATES** 56%
- **CHINA** 7%
- **UNITED KINGDOM** 6%
- **JAPAN** 4%
- **SOUTH KOREA** 3%
- **SWITZERLAND** 3%
- **HONG KONG** 2%
- **INDIA** 2%
- **BRAZIL** 2%
- **NETHERLANDS** 2%
- **OTHER COUNTRIES** 13%

EXPORT MARKETS FOR NORTH AMERICAN MINERALS

From copper and gold to potash and lithium, these materials fuel industries across continents. But where do these resources go? The export markets for North American minerals weave a complex narrative of trade shaped by geographic proximity, industrial demand, and geopolitical relationships.

Canada's mineral exports are dominated by its southern neighbour, which is its primary trading partner. In 2023, an impressive 56% of Canada's mineral shipments—valued in the tens of billions—crossed the border. This includes critical minerals such as nickel, cobalt, and uranium, alongside industrial mainstays like potash and aluminium. The U.S. depends heavily on Canada for these resources, with Canadian exports constituting 59% of its critical minerals supply in 2023, amounting to $29.8 billion.

Open-pit mines in Ontario and Quebec, which together handle 66% of Canada's mineral exports, process and ship massive quantities of copper, gold, and iron ore. These materials flow to American manufacturers, energy producers, and defence contractors, supporting everything from infrastructure projects to military hardware. The proximity of the two nations, combined with integrated supply chains fortified by the USMCA (United States-Mexico-Canada Agreement), ensures this trade relationship remains robust and efficient.

Beyond the U.S., Canada's minerals reach diverse international markets, reflecting the global appetite for its open-pit output. China, the world's manufacturing juggernaut, claims 7% of Canada's mineral exports, focusing on copper and iron ore sourced from British Columbia's open-pit mines, such as the Highland Valley Copper operation. These resources feed China's relentless industrial machine, producing everything from electronics to skyscrapers.

The United Kingdom, absorbing 6% of Canada's exports, imports gold and aluminium, while Japan, with 4%, seeks metallurgical coal and copper for its automotive and technology sectors. South Korea and Switzerland, each at 3%, complete the top six destinations, importing specialized products like lithium and refined metals for batteries, electronics, and precision manufacturing. Collectively, these six countries account for 79% of Canada's mineral exports, underscoring the far-reaching influence of its open-pit mining industry. Lesser but notable markets, such as India and Germany, also tap into Canada's mineral wealth, particularly for steel-making materials and fertilizers like potash from Saskatchewan's vast deposits.

The United States, while a net importer of many minerals, also plays a significant role as an exporter of its open-pit bounty. In 2020, U.S. mines produced $82.3 billion worth of minerals, with substantial volumes shipped overseas. Gold, copper, and molybdenum from massive operations like Arizona's Morenci mine—one of the world's largest copper producers—and Nevada's Carlin gold mines find eager buyers in Asia and Europe.

Japan and South Korea, key players in electronics and automotive manufacturing, import U.S. copper and rare-earth concentrates to power their high-tech industries.

Europe, meanwhile, takes in industrial minerals such as phosphate rock from Florida's open-pit mines and soda ash from Wyoming, which are essential for agriculture and chemical production.
Even amid trade tensions, China remains a significant purchaser of U.S. metallurgical coal and iron ore, illustrating the intricate and sometimes paradoxical nature of global mineral flows. Smaller markets, including Mexico and Brazil, also rely on U.S. exports for construction and industrial needs.

North American minerals are indispensable to global industries—construction, technology, renewable energy, and beyond. Canada's potash, almost entirely mined from Saskatchewan's open pits, dominates the world fertilizer market, supporting food security across continents. U.S. and Canadian aluminium, meanwhile, strengthens aerospace and automotive sectors in Europe and Asia. As demand for green technologies surges, minerals like lithium, graphite, and rare earths from these open-pit operations are increasingly targeted by export markets, particularly in Asia, where battery and renewable energy production is booming.

However, this trade is not without challenges. These challenges encompass infrastructure limitations, environmental and Indigenous rights concerns, competition from low-cost producers, and permitting delays.

The transportation infrastructure in North America, particularly ports and railways, is experiencing capacity constraints. Major container ports are grappling with congestion issues, which are anticipated to worsen over the next decade due to increasing cargo volumes. This congestion leads to delays in shipments and disrupts supply chains, affecting the timely export of minerals. Additionally, labour strikes in the rail sector have further exacerbated these disruptions, halting freight movement and causing significant supply chain interruptions across industries.

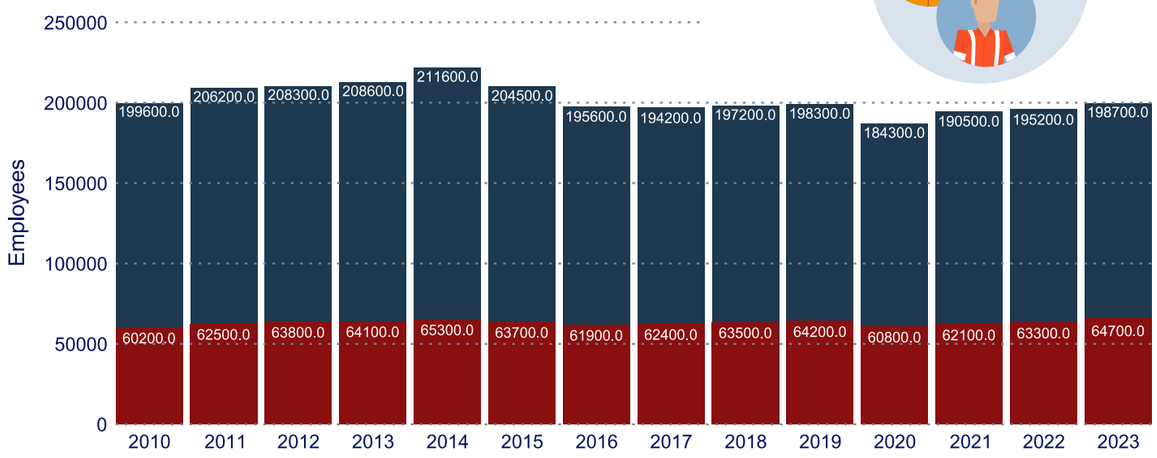
Mining activities have raised environmental and Indigenous rights issues. For instance, the Thacker Pass lithium mine in Nevada has faced opposition due to concerns over the destruction of sacred sites and the lack of free, prior, and informed consent from Indigenous communities.

North American mineral exporters face stiff competition from countries like China, Australia, and several African nations, which offer minerals at lower costs due to cheaper labour and less stringent environmental regulations. This competition challenges North America's ability to maintain market share, especially in critical minerals essential for technologies like electric vehicles and renewable energy systems.

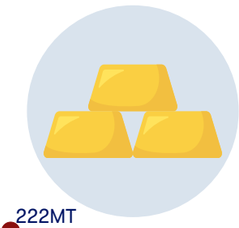
The permitting process for mining projects in the United States is notably lengthy and complex. On average, it takes seven to ten years to obtain the necessary permits, compared to two to five years in countries like Australia and Canada. These delays can diminish the value of mining projects by more than one-third, as prolonged timelines increase costs and deter investment. Efforts to streamline the permitting process, such as the FAST-41 initiative, aim to reduce these delays, but challenges remain in balancing expedited approvals with environmental and community considerations.

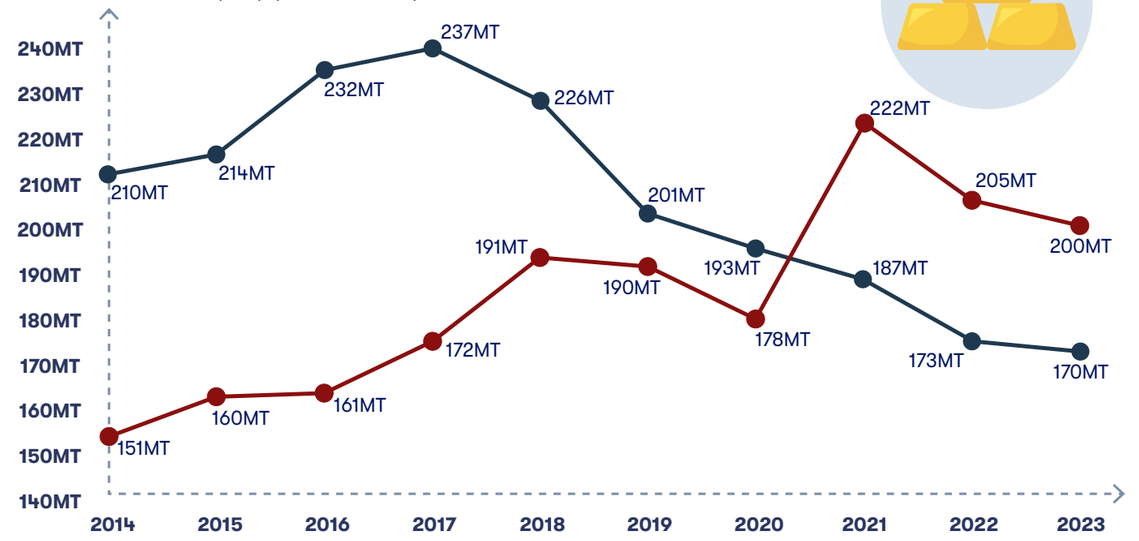
ECONOMY, EMPLOYMENT, SAFETY

EMPLOYEES IN MINING (2010–2023)



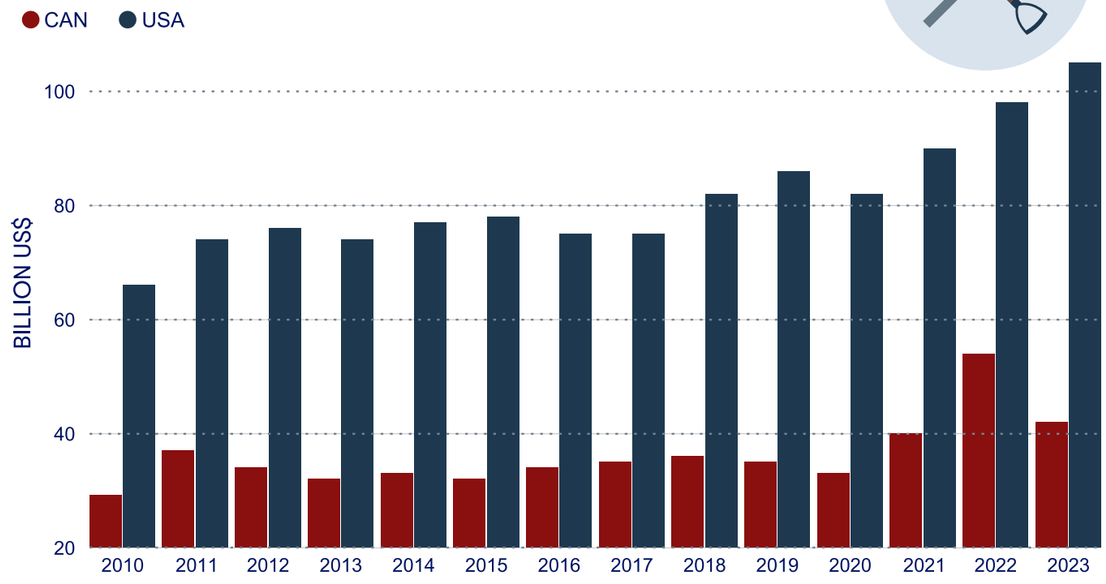
US AND CANADIAN GOLD MINE PRODUCTION IN METRIC TONES (MT) (2014 - 2023)





FATALITIES IN MINING (2010–2023)

TOTAL NONFUEL MINERAL PRODUCTION VALUE IN US$ (2010–2023)



JOBS AND ECONOMIC CONTRIBUTIONS

Employment
Open-pit mining is a pillar of employment in Canada, particularly in resource-rich provinces. In 2023, the mining sector directly employed over 80,000 people, and open-pit mines supplied a significant percentage of them. Ontario's Sudbury Basin and British Columbia's Highland Valley Copper mine, for instance, sustain thousands of high-paying jobs—miners, engineers, and equipment operators with mean salaries of over $80,000 annually.

Indirectly, the sector employs another 300,000 individuals in trucking, manufacturing, and services. In Saskatchewan, potash mining towns like Esterhazy thrive, with community businesses—from diners to hardware stores—relying on miners' pay. Nationally, mining contributed $71 billion to Canada's GDP in 2022, with open-pit mines driving exports that stabilize the trade balance.

The United States is no exception. In 2020, U.S. mines yielded $82.3 billion of minerals, with open-pit mines like Nevada's gold mines and Arizona's copper pits employing over 150,000 people directly. These jobs, typically in distant towns like Ely, Nevada, or Morenci, Arizona, pay upwards of $70,000 per year, significantly more than in the local community. The spillover is huge—each mining job generates two to three additional jobs in supply chains, from steel production to environmental analysis. Nationwide, mining added $280 billion to the U.S. economy in 2022, including tax payments and royalties that fund schools, roads, and healthcare. States like Wyoming, with its colossal open-pit coal mines, consider mining a saviour, contributing over 20% of state GDP.

Workplace Safety
Canada's mining industry reported an average of over 30 fatalities annually between 2011 and 2020, with more than 300 injuries reported each year. This places mining among the most hazardous occupations in the country. The fatality rate in the mining sector stands at 46.9 per 100,000 workers. While specific data distinguishing between open-pit and underground mining incidents is limited, it's recognized that underground mining poses higher risks due to factors like confined spaces and the potential for cave-ins. Efforts have been made to improve safety, with a 23% decline in the rate of fatal injuries per 10,000 employees from 2012 to 2021.

In the United States, the mining, quarrying, and oil and gas extraction industry experienced fluctuations in fatality numbers over the past decade. For instance, fatalities rose from 78 in 2020 to 95 in 2021, marking a 21.8% increase.

Between 1983 and 2020, the U.S. recorded 1,484 coal mining fatalities, with 62.6% occurring in underground mines and 37.4% in open-pit operations. This underscores the higher risks associated with underground mining.

Economic impact
Apart from jobs, open-pit mining injects capital into regional economies. In Canada's Yukon, the Minto mine revitalized the tiny Selkirk First Nation community, funding infrastructure and training programs.

In the United States, Utah's Bingham Canyon mine subsidizes Salt Lake County with millions in taxes and contributions. These investments have a tendency to cover holes left by declining industries like agriculture or manufacturing, so mining towns can ride out economic fluctuations.

Gold mining may serve as an example here. Economically, gold mining drives regional prosperity. In Nevada, it generated $9.2 billion and 12,000 jobs in 2023, while Canada's industry generated $37 billion in economic activity, including indirect effects. Their trade synergy—U.S. imports of Canadian gold grew from 41 MT in 2022 to 133 MT in 2023—strengthens North American supply chains.

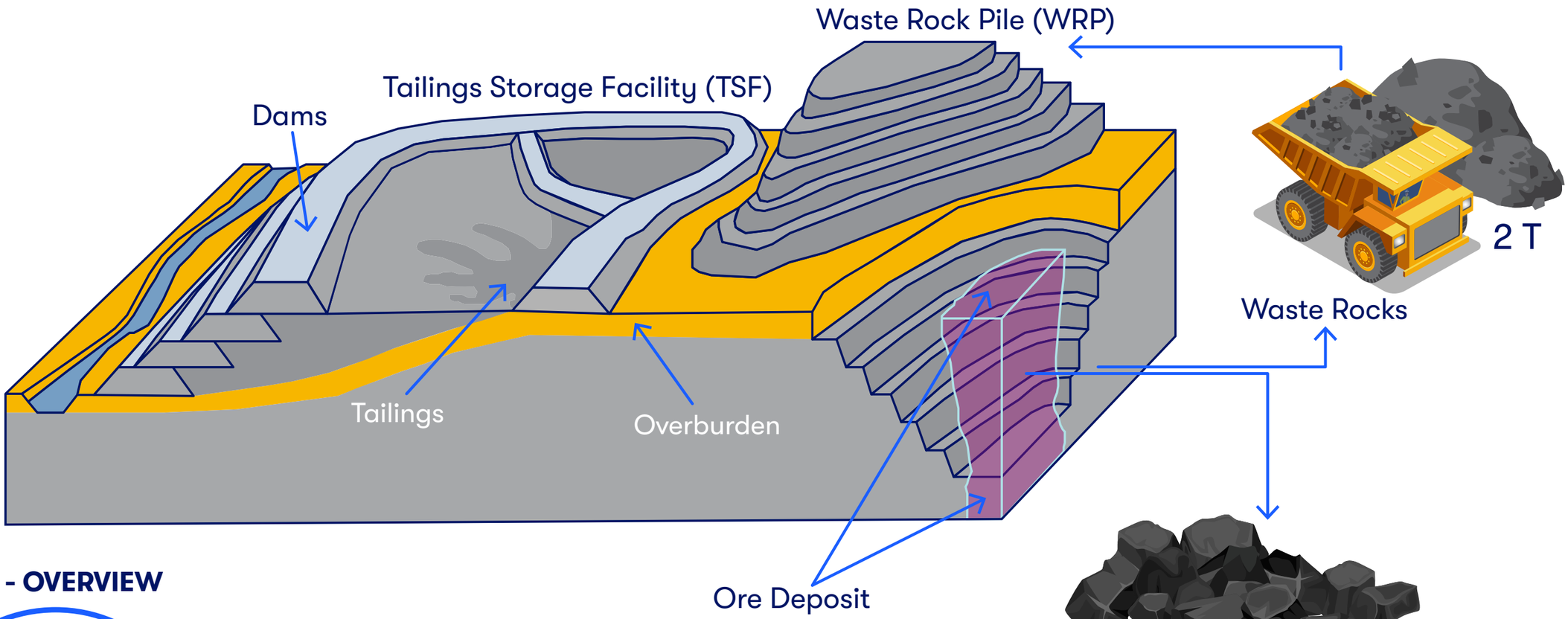
Together, their output defeats market fluctuation; in 2023, central banks bought 1,037 MT of gold, the second-highest annual amount in history, reports the World Gold Council, with United States holdings at 8,133 MT dwarfing the rest. As gold prices climb—by 16.38% in early 2025 to $3,053 an ounce—United States and Canadian production remains a foundation of economic might, pairing resource wealth with innovative brilliance to shape the world's gold sector.

Canada's gold production is supported by a stable political environment, strict regulations, and technological advancements, contributing $15.1 billion to its GDP in 2023. The industry also supported over 60,000 direct jobs, cementing its economic significance. Two-way trade amplifies their impact, with Canada exporting 133 MT of gold to the U.S. in 2023—a 221% increase from 2022—valued at over $10 billion, cementing North America's status as a gold-producing powerhouse.

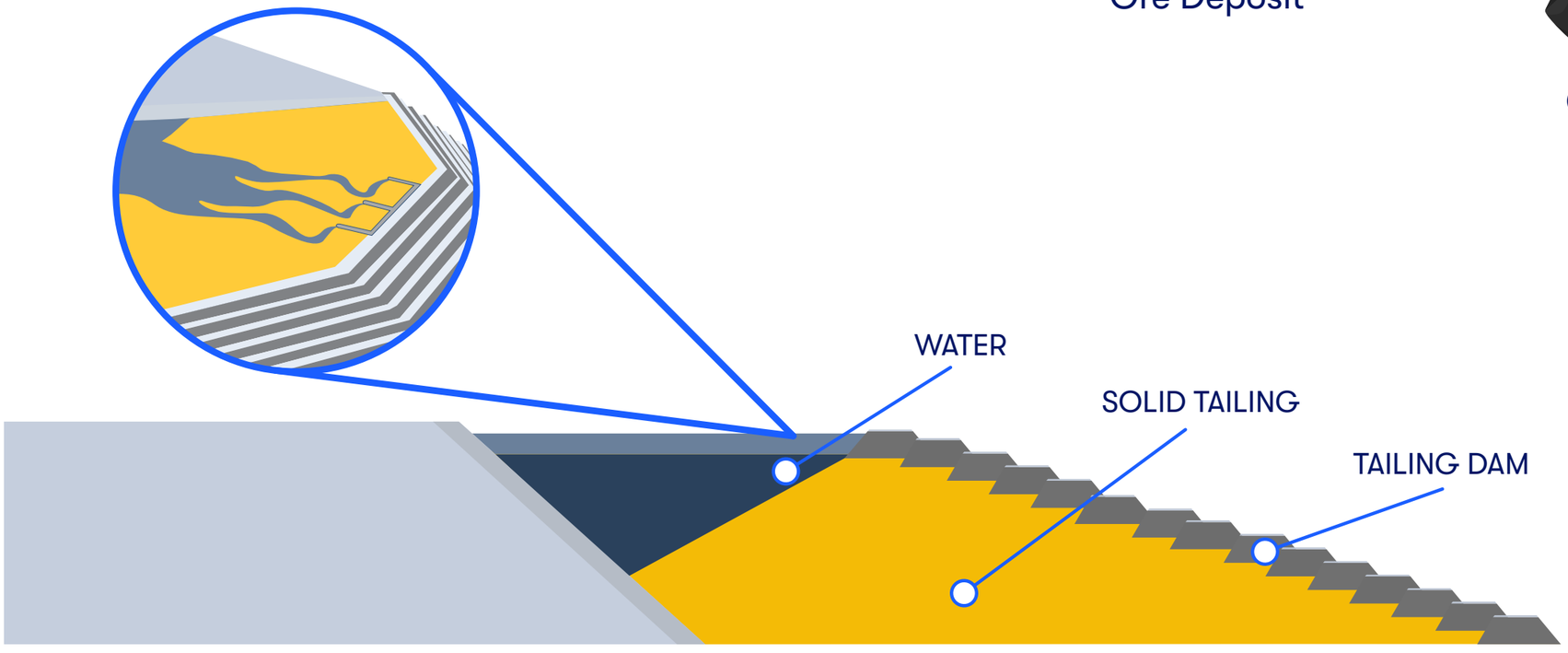
The U.S. produced 170 metric tons (MT) of gold in 2023, making it the fifth-largest producer globally. Nevada accounted for approximately 72% of this total alone, or roughly 122 MT, due to its rich deposits and established mining infrastructure, including large-scale projects like the Carlin Trend. This production supports domestic industry and serves to back the U.S. dollar as a reserve currency, with gold being utilized as a hedge against inflation—evidenced in 2023 when prices hit a high of US$2,029 per troy ounce.

Worldwide, the industry's influence is unchallenged. Canada's mineral exports—56% to the U.S. alone—generate foreign exchange, and U.S. production replaces import reliance, enhancing economic security. But risk exists: automation threatens jobs, and environmental costs create controversy over the long-term viability of mining. Still, today, open-pit mining remains a pillar of North American economies, with hundreds of thousands working, communities supported, and economic growth driven from the ground up. Its national and local contributions bear witness to its irreplaceable position in the economic fabric of the continent.

WASTE MANAGEMENT



TAILING DAM - OVERVIEW



TAILINGS AND WASTE MANAGEMENT

Tailings and waste management represent some of the most critical and controversial aspects of open-pit mining operations in North America and globally. These by-products of mineral extraction processes—especially tailings, the finely ground rock slurry left after valuable minerals have been separated—pose long-term environmental and safety challenges. Over the last century, the volume of tailings produced has increased exponentially as mining operations have scaled up and ore grades have declined, meaning more rock must be processed to extract the same amount of metal.

Tailings are not inert; depending on the type of ore processed, they may contain heavy metals, sulfides, arsenic, cyanide, and other harmful chemicals. These substances can leach into groundwater or be carried into surface water through overtopping, seepage, or dam failure, contaminating drinking water and disrupting aquatic ecosystems. Tailings in huge dams pose a significant risk, as dam failures can lead to catastrophic spills and flattening landscapes and communities. Overburden or waste rock can also create acid rock drainage when exposed to air and water, posing additional risks to water quality and biodiversity.

The primary problem with tailings is their storage. After separation from the ore, tailings are often mixed with water to create a slurry and stored in large impoundments called tailings ponds. These are usually held in place by earthen dams or embankments built around the edges. In theory, these dams are engineered to withstand extreme weather, seismic activity, and long-term erosion. In practice, they are often the most vulnerable part of any mining operation.

One of the most notorious incidents in the history of North American mining is the 2014 Mount Polley tailings dam breach in British Columbia. The dam, which contained waste from a gold and copper mine operated by Imperial Metals, failed catastrophically, releasing over 24 million cubic metres of contaminated water and tailings into Polley Lake and the Quesnel River watershed. The spill destroyed habitats, disrupted salmon spawning areas, and raised serious concerns about the adequacy of tailings dam design and regulation in Canada. A subsequent independent review concluded that the failure was due to design flaws and insufficient consideration of geotechnical risks.

Historically, the industry has seen numerous tailings-related incidents. The 1972 Buffalo Creek disaster in West Virginia, although involving a coal slurry dam rather than metallic mine tailings, is another tragic example. After days of heavy rain, a poorly constructed dam collapsed, unleashing a wall of coal waste that killed 125 people and left over 4,000 homeless. In the early to mid-20th century, environmental regulation was lax, and it was common for tailings to be dumped directly into rivers and lakes. For example, the Anaconda Copper Mine in Nevada, active for decades, left behind a legacy of contaminated groundwater and air, with arsenic and other metals persisting long after operations ceased.

Socially, tailings and waste management significantly affect neighbouring communities. The mining operations tend to encroach on indigenous areas or rural societies, leading to displacement and loss of livelihood strategies.

Waste heaps and tailings ponds alter scenery, impacting tourism and property values. Additionally, the possible menace of environmental disasters instils fear and mistrust among residents and mining organizations, raising social tensions.

The environmental challenges of tailings management extend beyond catastrophic failures. Chronic pollution is a quieter but more persistent issue. Tailings ponds can leak or overflow during heavy rainfall or snowmelt. In arid regions, the drying of tailings surfaces creates dust that can carry toxic particles over long distances, affecting both human health and ecological systems. Acid mine drainage is a particular concern when tailings contain sulfide minerals. Exposure to air and water leads to the generation of sulfuric acid, which then dissolves heavy metals from the surrounding material. These acidic, metal-laden waters can severely degrade aquatic habitats and require long-term treatment systems, often for decades or even centuries.

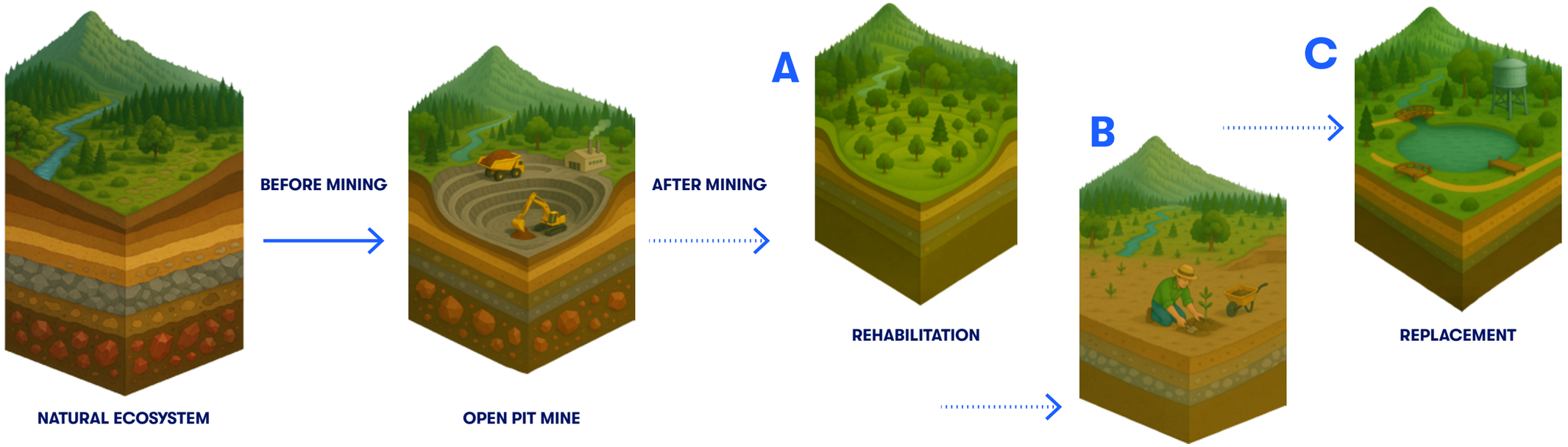
To address these risks, regulatory frameworks in both the United States and Canada have evolved significantly, particularly since the 1970s. In the U.S., the Environmental Protection Agency (EPA) and the Mine Safety and Health Administration (MSHA) regulate aspects of tailings storage under laws such as the Clean Water Act and the Resource Conservation and Recovery Act. State-level agencies also play a role, particularly in mining-heavy states like Nevada, Utah, and Arizona.

In Canada, tailings management is governed at the provincial level, with some of the most comprehensive regulations in British Columbia, Ontario, and Québec. The Canadian Dam Association has developed guidelines specifically for the design and management of tailings facilities, and after the Mount Polley disaster, the Mining Association of Canada revised its Towards Sustainable Mining standard to include more rigorous tailings protocols.

The mining industry applies different innovative technologies to solve these problems. One effective approach is dry stacking in tailings management. This involves dewatering tailings and stacking them in dry conditions, reducing the risk of dam failure as well as water usage. It also allows for easy land reclamation. Another technology is tailings utilization as backfill in underground mines, which reduces surface waste while increasing mine stability. For waste rock, strategically planned dumps—engineered to blend with a natural landscape and vegetatively stabilized—reduce visual and ecological impacts. Acid rock drainage treatment and monitoring in passive or active systems also prevent water pollution.

However, technologies may improve the situation. Bioleaching, using bacteria to leach metal from waste, can transform by-products into something of value. Artificial intelligence and machine learning can enhance waste handling, preventing and anticipating environmental accidents. Embracing circular economy principles—waste reduction and reuse—could further transform the practice of the industry.

RESTORING LANDSCAPES



WATER IN OPEN PIT MINING

16% of global mining occurs in water-stressed regions, increasing the risk of conflicts over water use.

In 2023, Canada's mining sector continued to prioritize water management, with 147 metal mines and 4 diamond mines operating under the Metal and Diamond Mining Effluent Regulations, ensuring effluent quality and environmental protection.

In 2023, the U.S. mining industry invested an estimated $1.19 billion in water management projects, reflecting the increasing importance of water reuse and conservation in mining operations.

ENVIRONMENTAL CHALLENGES

While economically vital, open-pit mining in North America has left a significant environmental footprint over time. The method is inherently invasive, removing vast amounts of soil and rock to expose ore bodies. This disturbance scale leads to a range of environmental challenges and, at times, ecological disasters.

Water

Water consumption is a significant issue. Open-pit operations require enormous volumes of water for mineral processing, dust suppression, and tailings management. In arid regions such as Nevada, Utah or Arizona, where many gold and copper mines operate, water use can exacerbate existing water scarcity problems, impacting agriculture and local communities.
In Nevada, gold mines on the Carlin Trend use up to 100,000 gallons of water per ton of ore processed, totalling over 7 billion gallons annually statewide. Groundwater use for this purpose threatens aquifer depletion, with the Humboldt River Basin—supplying 60% of Nevada's mining water—having dropped 20% since 2000 due to drought and withdrawal.

The 5,000 local agriculture workers earning $700 million annually are threatened by competition, while ecosystems such as the Lahontan Valley wetlands that hold 300 bird species dwindle, losing 85% of their original extent since 1900. The Morenci Mine in Arizona produced 399,100 metric tons of copper in 2023, consumes 50 million gallons a day, although 70% is recycled, according to Freeport-McMoRan. Nevertheless, the 30-year drought in the region escalates tensions over scarce resources.

Water pollution also comes with an equally dire danger in the form of mine tailings and runoff injecting heavy metals—arsenic, lead, mercury—and chemicals like cyanide into bodies of water. A key environmental hazard is acid mine drainage (AMD), a chemical reaction when sulfide minerals are exposed to air and water, forming sulfuric acid. This acidic runoff can leach heavy metals from surrounding rock, contaminating nearby streams, rivers, and groundwater. AMD has been a persistent problem in Canada and the U.S., with lasting impacts on water quality. The Berkeley Pit in Montana—a former open-pit copper mine—is a notorious example. Since its closure in 1982, it has been filled with highly acidic, metal-laden water, creating a toxic lake that poses long-term threats to the surrounding area and remains under active water treatment efforts.

The 2015 Colorado Gold King Mine spill is a good illustration: a century-old gold mine discharged 3 million gallons of acidic, metal-laced wastewater into the Animas River, elevating arsenic content to 300 times above safe levels and leaving the river mustard-yellow for 100 miles. The $150 million cleanup cost for the spill spoiled downstream Navajo Nation cropland and also killed 10,000 fish. Modern mines avoid such threats with dry stacking, dewatering tailings into solid heaps that lower water usage by 60% and decrease chances of dam failure, used in 15% of U.S. operations in 2023.

Advanced filtration, like reverse osmosis at Nevada's Cortez Mine, treats 2 million gallons of runoff daily, removing 95% of contaminants to Clean Water Act standards. Legacy sites, however, over 500,000 abandoned mines nationwide exist, with 40% seeping contaminants, the BLM reports.

Land restoration

Land degradation is one of the most immediate and visible impacts of open-pit mining. These mines often span several square kilometres and can reach depths of hundreds of meters, permanently altering landscapes. Natural ecosystems—forests, grasslands, wetlands—are cleared to access mineral deposits, leading to habitat destruction and biodiversity loss. The cumulative effect of decades of expansion in places like the Powder River Basin or British Columbia's copper belts has fragmented wildlife corridors and reduced population sizes for numerous species.

Land restoration, mandated by the 1977 Surface Mining Control and Reclamation Act (SMCRA), aims to restore mined ground, but the scale of open-pit mines—stripping millions of tons of rock—is daunting. Utah's Bingham Canyon Mine, which produced 169,300 metric tons of copper in 2023, has extracted 6 billion tons of material since 1906, filling a 2.5-mile-wide crater (Rio Tinto).

Reclamation involves regrading slopes, topsoiling, and replanting native vegetation for $50–$100 per acre. Montana's Anaconda Copper Mine, closed in 1982, is a case in point: its 3,000-acre scar is a wetland with 200 plant species, 150 bird species, and public trails, paid for by $120 million from Atlantic Richfield. Just 20% of U.S. mined lands were fully reclaimed as of 2023, however, with costs of $1.5 billion annually nationwide, keeping it slow. Nevada gold mines, processing 250 million tons of ore annually, restore only 10,000 acres annually against 1.5 million acres disrupted.

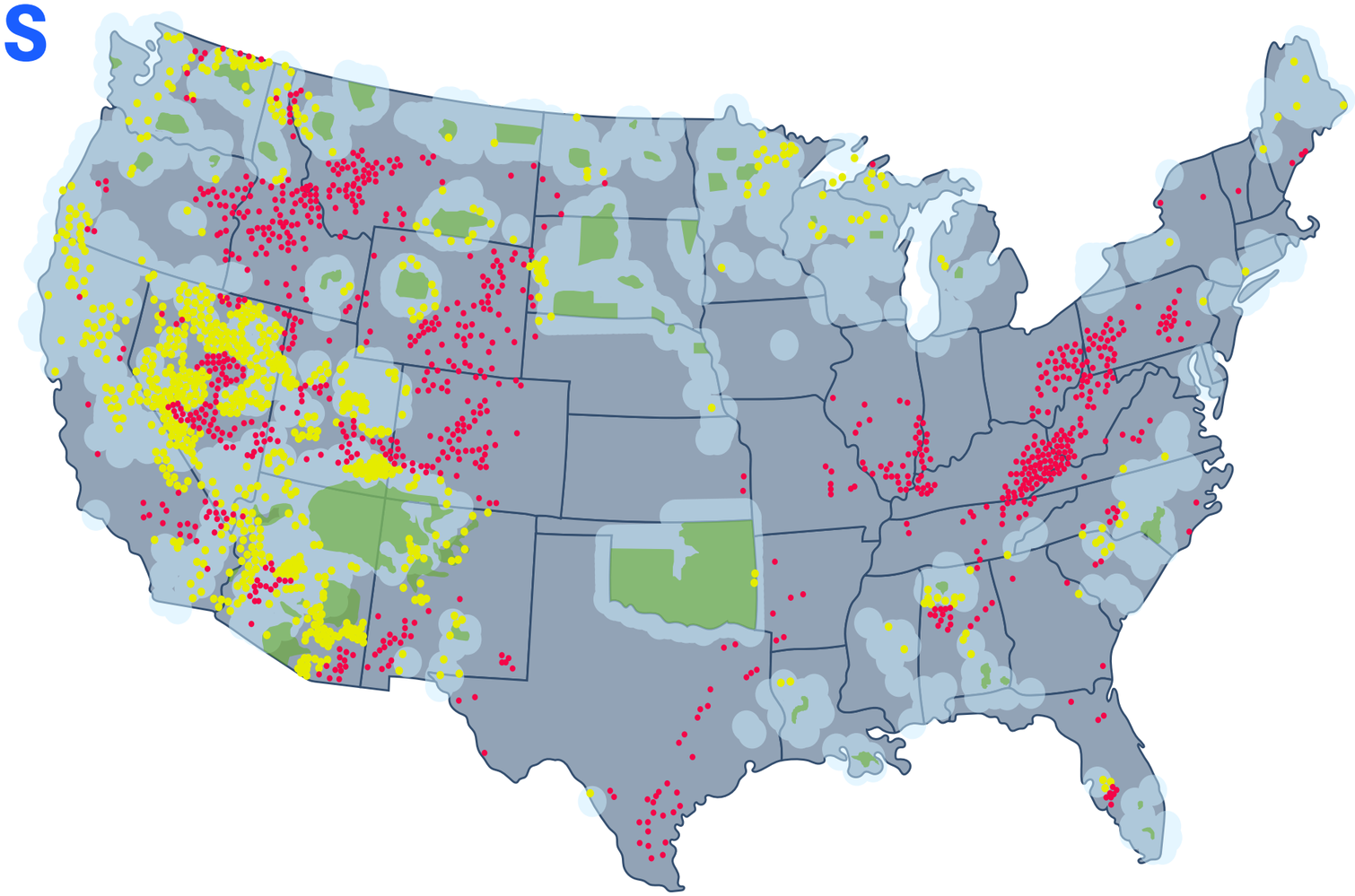
New technology is the solution. Drones monitor revegetation at 30% of Western mines, cutting costs by 25% and raising plant survival rates by 15%. The integration of renewable energy, such as Nevada's $40 million solar array at Cortez, which powers 20% of operations, replaces 50,000 metric tons of CO_2 annually. The EPA and Bureau of Land Management oversee compliance, levying $200 million in fines in 2023 for violations, although enforcement is intermittent; Arizona mines were inspected 50% more than Utah's due to water risks.

Air and ground pollution

Dust and air pollution are by-products of blasting, hauling, and crushing rock. Particulate matter from mine sites can contain silica and heavy metals, contributing to respiratory problems in nearby populations. Studies near operations like the Bingham Canyon Mine in Utah have documented elevated levels of fine particulate pollution, prompting regulatory interventions.

Pre-1977 or "legacy" pollution of $35 billion to remediate is still outstanding, with 80 Superfund sites linked to mining. Corporate commitments and public opinion—like Freeport-McMoRan's 2030 carbon neutral pledge—activate offsets for habitats (restoring Arizona's 5,000 acres) and imagination, but are a constant tightrope for balancing extraction and environmental health amidst booming metals demand.

NATIVE AMERICAN RESERVATIONS AND MINING OPERATIONS



NATIVE AMERICAN RESERVATIONS

35-MILE BUFFER AROUND RESERVATIONS

MINE INSIDE BUFFER

MINE OUTSIDE BUFFER

A HISTORY OF INDIGENOUS RIGHTS AND MINING IN NORTH AMERICA

1940s

Giant Mine built without indigenous consultation (Yellowknives Den)

Section 35

Canada's constitution act affirms indigenous rights

Oak Flat land swap

Apache protests and lawsuits

Canada adopts

UNDRIP in federal law

Today

Legal disputes and IBAs emerge as key tools

CANADA

USA

BOTH

COMMUNITY ENGAGEMENT AND INDIGENOUS RIGHTS

Mining has a troubled history of conflict with indigenous communities. In both Canada and the United States, many mineral-rich regions overlap with traditional or treaty lands of Indigenous peoples. In Canada, over 1,200 Indigenous communities live in areas where mining activity either exists or is proposed. While some First Nations and Inuit groups have negotiated benefit-sharing agreements or participate in the industry through employment and joint ventures, others strongly oppose the encroachment of mining on their lands, especially when consultation is inadequate or when the ecological risks are high.

Historically, mining development often proceeded without the consent—or even the knowledge—of Indigenous communities. During the 20th century, major mines were constructed in remote areas of the Canadian Shield and Arctic without meaningful engagement. For instance, the Giant Mine in Yellowknife (Northwest Territories), developed in the 1940s, left behind a legacy of arsenic contamination that continues to affect the Yellowknives Dene First Nation. The community was never consulted during the mine's construction or operation, and remediation remains a complex, government-led project costing over a billion dollars.

Various projects were previously imposed on or adjacent to Indigenous land without consent, leading to forced removal, contaminated environments, and the desecration of sacred ground. This experience has created a deep-seated suspicion that current mining activities must address historical injustices and pay homage to the rights of Indigenous communities.

In the United States, the situation is similarly fraught. The Oak Flat region in Arizona, sacred to the San Carlos Apache, has been at the centre of a prolonged dispute over the proposed Resolution Copper open-pit mine, which would cause the area to collapse into a crater due to block-cave mining techniques. Although the land was originally protected under federal law, a late-night land swap deal in 2014 transferred it to mining interests, igniting protests and legal challenges that continue to this day. The Apache Stronghold, a grassroots organization, has taken the case to federal court, arguing that the project violates religious freedom protections under the U.S. Constitution.

On the other hand, the Cortez Mine in Nevada, approximately 32 miles from the Battle Mountain Band of the Te-Moak Tribe, displays a successful partnership model. Operated by Barrick Gold, it has implemented training initiatives and hired tribal members preferentially, achieving economic empowerment while seeking to minimise environmental footprints through land stewardship and water conservation measures. This project is an excellent example of how mines can work together with tribes to gain economic benefits and coexistence with the environment.

Legal frameworks have evolved in recent decades to recognise Indigenous rights, but implementation remains uneven. In Canada, Section 35 of the Constitution Act (1982) affirms the rights of Indigenous peoples, and landmark Supreme Court decisions—such as Haida Nation v. British Columbia (2004) and Tsilhqot'in Nation v. British Columbia (2014)—have clarified that the government has a duty to consult and accommodate Indigenous communities before approving resource projects. The Tsilhqot'in decision went further by recognising Aboriginal title to a specific tract of land, giving the Nation legal authority over future development. Yet despite these rulings, many First Nations argue that consultation is often superficial, rushed, or non-binding.

In 2019, Canada adopted the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) into federal law, which includes the principle of Free, Prior and Informed Consent (FPIC). However, this does not yet grant communities a legal veto over projects; implementation varies by province, and interpretations of "consent" remain contested.

In the United States, the legal relationship is more complex. Tribes have some degree of sovereignty and often manage their own lands through tribal governments. However, federal agencies retain significant control over resource development, particularly on lands adjacent to reservations.

Under NEPA, federal agencies must prepare either an Environmental Assessment (EA) or a more comprehensive Environmental Impact Statement (EIS) for actions that could significantly affect the environment. If a proposed mining operation could impact tribal lands, resources, or sacred sites, the agency is legally required to consult with the affected Native American tribes.

The National Environmental Policy Act (NEPA) and the National Historic Preservation Act (NHPA) require that federal agencies consult with tribes about projects that may affect cultural sites, but, as the Oak Flat case shows, this does not always prevent conflict or project approvals. While it mandates consideration of tribal concerns, the final decision still rests with the federal agency, often leading to tension when economic interests conflict with Indigenous rights and environmental stewardship.

One helpful tool is the Impact Benefit Agreement (IBA), an agreement between indigenous communities and mining companies. IBAs can include guarantees of employment, training, conservation, and economic benefits, which can guarantee that benefits from mining accrue to communities. An IBA can, for example, guarantee that residents are employed or fund cultural festivals. IBAs need to be negotiated openly, with regular information sharing, and can only work if this is done.

The scope of mining extends beyond economics and ecology to the social fabric of communities. The industry remains a major employer, generating approximately tens of thousands direct jobs and indirectly sustaining another hundreds of thousands manufacturing and service jobs downstream. Mining operators have proceeded further in engaging Indigenous communities, forming agreements that respect original territory and have economic returns as a source of jobs and revenue-sharing arrangements.

As an example, the Ontario Mining Association states that Indigenous workers represent 12% of miners, although only 3% of all employees in Ontario are Indigenous. Training programs focusing on workforce development are also out in front, with training aimed at increasing diversity from historically underserved groups like women and Indigenous staff, generating a more representative industry. These efforts affirm the sector's role as a community ally in the face of highly complex social and cultural challenges.

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