

## Metal Mining

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Metal mining refers to only those mining operations which primarily recover metallic commodities from the earth's surface. This series of maps depicts metal mines and selected metal-production facilities. Mines are classed by their primary metal product. Production facilities are classed according to their primary capabilities.

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### Metal Mines

This section describes the relationship between metal mining and the geological provinces of Canada and reviews the classification of metal mines found on the maps.

#### Distribution of Metal Mines

The most significant geological formation associated with metal mining in Canada is the Canadian Shield. The shield is the largest and oldest geological region in Canada. It was formed 4 billion to 570 million years ago, and is composed of igneous and sedimentary rocks that have been heavily metamorphosed over the hundreds of millions of years of its existence.

The Canadian Shield represents about half of the land area of Canada. The shield comprises the Bear, Slave, Churchill, Superior, Southern, Grenville and Nain geological provinces. It forms a great circle around Hudson's Bay, extending from the eastern Northwest Territories and southern Nunavut, through northeastern Alberta, northern Saskatchewan and Manitoba, western and central Ontario, and most of Quebec north of the St. Lawrence River, to Labrador and Baffin Island.

The majority of Canada's metal mines are on the Canadian Shield. They are found in an arc stretching southeast from the gold mines of Yellowknife, through Flin Flon, Red Lake, Timmins, Sudbury, Rouyn-Noranda, Val d'Or and Chibougamau, to the iron mines of Labrador City.

The remaining areas of metal mining are found within the mountains along the western and southeastern coasts. The shifting of the Earth's tectonic plates has caused Canada's coasts to undergo intense geological activity over millions of years. These periods of mountain building, or orogeny, have produced complex structures of igneous, sedimentary and metamorphic rocks.

British Columbia's Cordilleran Orogen covers all but the northeast tip of the province. Although some of the rocks in the Cordillera are over 700 million years old, the most recent round of mountain building occurred between 185 and 50 million years ago. The Cordillera represents the Canadian part of a massive chain of overlapping

mountain ranges stretching from Alaska to the very end of the South American continent.

The older Appalachian Orogen was formed over a 300 million year period that ended roughly 250 million years ago. Mountains were formed during at least three distinct periods corresponding to the expansion and contraction of the Atlantic Ocean. The Appalachian Orogen covers the provinces of New Brunswick and Nova Scotia, and the island of Newfoundland. This mountain range starts at the southeastern edge of the Canadian Shield and extends southwest for about 3000 km to the state of Georgia.

## **Metal Mine Classification**

Most mines have more than one exploitable metallic resource contained in the recoverable ore. Metal mines have been classified, based on their most important exploitable commodity, as ferrous, precious and base metal.

- Ferrous-metal mines produce primarily iron and metals, such as niobium and tantalum, that are alloyed with steel.
- Precious-metal mines produce primarily gold, silver, palladium and uranium.
- Base-metal mines include all the remaining metallic commodities, the most important being nickel, copper, zinc, lead, molybdenum, magnesium and cobalt.

On the maps, each mine symbol represents the approximate geographic centre of the mine and related ore-processing facilities. They are shown for the year in which they operated for any period. A mine may include multiple access points between the surface and the underground orebody or multiple open pits. Associated mine buildings may house the crushing and milling machinery, concentrators, tailings containment or any other processing facilities located near the mine. Mines may be owned and operated by more than one company.

## **Metal-production Facilities**

This section provides a brief overview of metal-production facilities, describes where they are found and reviews the classification found on the maps.

### **Overview**

After ore has been brought to the surface, crushed and processed to produce a finely ground concentrate, it is sent to a metal-production facility. These facilities use heat and chemical processes to extract the valuable metal from the ore concentrate. Some facilities also recycle metal scrap from automobiles, consumer electronics or batteries. Others refine and alloy metals for specific manufacturing purposes. The

actual process used by a particular plant varies according to the metal being produced and the kind of minerals or scrap material that are being processed.

## Distribution of Metal-production Facilities

The majority of the steel and aluminum production facilities are found in Quebec's Saguenay region, south along the St. Lawrence River and along the shores of Lake Ontario and Lake Erie. This area provides plants with access to energy and industrial infrastructure, the St. Lawrence Seaway and land-transport connections to the eastern United States. The primary raw material in steel making is iron. Iron-ore production is centred in Labrador City, Newfoundland and Labrador.

The most common precious metals produced in Canada are gold and uranium. Gold is found across the Canadian Shield, British Columbia and the island of Newfoundland. Precious metals are usually smelted to a nearly pure state in facilities at the mine. Final refining is carried out in more specialized, centrally located facilities. Uranium, used as a fuel for nuclear reactors, is presently mined in northern Saskatchewan and refined in Ontario.

The largest base-metal facilities in Canada involve the production of nickel, copper, zinc and lead. The large size and cost of constructing and operating these facilities encourages economies of scale, so a plant usually processes the concentrates produced by several mines. Base-metal smelters usually produce small amounts of precious and other metals in addition to their primary product. The largest base-metal processing facilities are found in Trail, British Columbia; Flin Flon and Thompson, Manitoba; Sudbury and Timmins, Ontario, Rouyn-Noranda, Quebec; and Belledune, New Brunswick.

## Classification of Metal-production Facilities

The classification of production facilities is designed to show the distribution of primary metal production (that is, the smelting and refining of ore to produce metal), as opposed to the secondary activity of manufacturing of products from metal.

Metal-production facilities have been classed according to their primary metal product and capabilities. Facilities may produce more than one primary metal product or they may produce nonmetallic materials as a byproduct. Some base-metal facilities may process both base and precious metals. Some steel facilities may combine primary metal production with secondary manufacturing capacity.

The list below details each class of metal-production facility. These classes should be considered as only a summary of a particular plant's production capability.

- **Aluminum Smelter:** Facility used to refine aluminum metal and produce aluminum alloys. All of Canada's aluminum smelters use imported raw materials.

- **Agglomerate Plant:** Facility that converts iron concentrate from a mine into iron pellets suitable for use in the first step of steel making.
- **Steel Mill:** Facility that produces steel and alloyed steel using iron pellets or concentrate, pig iron, direct-reduced iron, recycled scrap steel or a combination of these inputs.
- **Ferroalloy Plant:** Facility producing specialty alloys used in the manufacture of high-performance steel. Inputs may be from mine concentrates or imported materials.
- **Smelter:** Facility that primarily produces an unrefined base-metal product using ore concentrate, metal scrap or a combination of both. The output is usually sent to a refinery.
- **Refinery:** Facility that primarily produces refined metals and alloys using the output of a smelter, metal scrap, metal concentrates or a combination of these inputs.
- **Foundry:** Facility that recovers base metals from scrap or concentrates to produce refined metals, alloys and cast-metal products.
- **Recycling Plant:** Facility specializing in the recovery of metals and plastics from used electronics, car batteries or other post-consumer products.
- **Complex:** Combines the capabilities of a smelter, refinery, recycling plant or other specialized metal-recovery process into one integrated facility.
- **Converter:** Uranium-processing facility that converts refined uranium trioxide into uranium hexafluoride and uranium dioxide to be used as fuel in nuclear reactors.

## Metallic Commodity Reviews

This section reviews the individual metallic commodities which are produced by Canada's metal mines and metal-production facilities. Commodities are divided into ferrous metals, precious metals, base metals and aluminum.

### Ferrous Metals

The ferrous-metal group is dominated by the production of iron ore, the primary raw material in steel making. It also includes the production of ferroalloys and other metals commonly used in producing high-performance steel alloys. Almost all of the iron ore produced in Canada is used to produce steel.

#### Iron

Most of Canada's iron-ore production is located in Quebec and Newfoundland and Labrador, around Labrador City. A small amount is produced as a byproduct of base-metal smelters in British Columbia.

Iron mines are dependent upon ship and rail to move their raw materials economically. Crushed ore concentrate is transported by rail to agglomeration plants

to produce iron-rich pellets, which are then shipped to be used as the raw material in steel making. Iron concentrates with sufficiently high iron content can also be directly used in steel making.

There are three agglomeration plants shown on the ferrous metal maps. The first is located at the Carol Lake mine near Labrador City. The remaining two are along the St. Lawrence River near Sept-Îles and Port Cartier, Quebec. Both are connected by rail to their parent mine sites near Labrador City.

### **Titanium**

Titanium is used primarily as a white pigment for paint and plastics. Titanium metal is used in aerospace applications, and as a ferroalloy in steel making. Titanium is mined north of Havre-Saint-Pierre, Quebec. The titanium is produced, in the form of titanium-dioxide concentrate, along with pig iron at a steel mill in Tracy, Quebec.

### **Ferroalloys**

There are two mines that produce tantalum and niobium. Tantalum is used to produce electronic components and as an alloy for steel. It is mined at Canada's only tantalum mine near Lac-du-Bonnet, Manitoba. Most niobium is used in steel alloys, usually in the form of ferroniobium. Niobium is mined near Saint-Honoré, Quebec and ferroniobium is produced at the mine's ferroalloy plant.

Ferroalloy plants produce alloys for use in the production of high-performance steels, the most important being ferrovanadium, ferromolybdenum, ferrosilicon and ferroniobium. With the exception of niobium, ferroalloy plants use imported raw materials. They are located near Saguenay and Bécancour, Quebec and outside Ottawa, Ontario.

### **Steel**

The largest steel producers, referred to as integrated steel mills, are found in Quebec and Ontario, along the St. Lawrence River and the shores of the Great Lakes. All have rated annual steel production capacities of over 2 000 000 tonnes.

Integrated mills use iron-ore concentrates or pellets and small amounts of scrap steel to produce pig iron as an intermediate product in steel making. This carbon-rich cast iron then has its carbon content reduced in a basic-oxygen furnace (BOF) in order to produce steel. There are four steel mills that produce steel in this way, all of them in Ontario: one in Sault Ste. Marie, two in Hamilton and one in Nanticoke.

There are two additional steel mills that use specialized processes to make steel. The first, in Tracy, Quebec, heats titanium and iron-rich ore in electric-arc furnaces (EAF) to produce titanium dioxide and pig iron. The pig iron is then made into steel using a basic-oxygen furnace.

The second specialized steel maker is located in Contrecoeur, Quebec. This steel mill first produces iron-rich pellets from iron-ore concentrate using a Direct Reduced Iron (DRI) process. The direct-reduction process uses significant amounts of natural gas and electricity, so plants must have access to inexpensive and reliable supplies. The iron-rich pellets are then heated in electric-arc furnaces to produce steel.

The remaining steel mills, called steel mini-mills, are found outside urban centres in Ontario and western Canada. These mills produce steel and steel alloys using electric-arc furnaces to heat steel scrap or direct-reduced iron pellets. The steel mills in this group have rated capacities of between 90 000 and 1 650 000 tonnes per year. Most of these plants include secondary manufacturing operations.

There are about 20 smaller steel plants found across southern Canada that are not included on the maps. These plants specialize in foundry-cast steel products. These plants generally remelt steel and most have annual productions of less than 10 000 tonnes.

## **Precious Metals**

Almost all of the precious metal mines in Canada are gold mines. The exceptions are the palladium mine near Thunder Bay, Ontario and the uranium mines of northern Saskatchewan.

### **Gold and Silver**

Gold is used primarily to manufacture jewellery and in electronics. Small amounts are also used to produce gold bullion coins. Gold mines may also recover silver and other precious metals in varying amounts. Small amounts of gold and silver are often associated with base-metal deposits and are recovered at base-metal smelters. Significant amounts of gold are also recycled.

Canada's gold mines are found predominately on the Canadian Shield and the Cordillera in British Columbia. The most important provinces in gold production are Ontario, Quebec and British Columbia.

Gold can often be separated from its host minerals more easily than the ores that host base metals. This can make it economical to build small-scale gold-production facilities. In general, gold mines have onsite facilities capable of producing a nearly pure gold bar called a doré bar.

The final step in the refining of gold occurs at internationally recognized refineries. They produce bars that are at least 99.99% pure gold and suitable for sale on international bullion markets. There are two gold and silver refiners shown on the maps, both in Ontario. The base-metal refinery in Montréal also refines precious metals. Precious metals are also recycled from used electronics at a plant in Brampton, Ontario.

## Platinum-group Metals

Platinum-group metals (PGMs) are a group of six precious metals (platinum, palladium, rhodium, ruthenium, iridium and osmium), which are commonly found together. Platinum-group metals are used to reduce pollution in automobile exhaust (autocatalysts), in the manufacture of electronics and to make jewelry.

Small amounts of PGMs are often found in association with copper and nickel ores and, like gold and silver, are collected at most base-metal smelters. Platinum-group metals are also widely recycled, usually from electronics and autocatalysts; several base-metal smelters process this scrap material.

Sudbury's mines are Canada's most important producers of PGMs, with a lesser amount recovered from the ores of Thompson, Manitoba. Canada's only palladium mine, near Thunder Bay, Ontario, also recovers gold, platinum and base metals. Canada's PGM production is refined outside the country.

## Uranium

Uranium is presently mined in northeastern Saskatchewan. Refining and conversion facilities, used to produce the fuel for nuclear reactors, are found in Blind River and Port Hope, Ontario. Saskatchewan's orebodies are located in the southwestern part of the Churchill geological province, where sedimentary rock overlies the Canadian Shield.

Uranium's high value encourages the exploitation of orebodies of even relatively low concentration. This requires that large amounts of ore be processed to produce a uranium concentrate. The primary crushing and concentrating facilities are centrally located to surrounding orebodies to process the ore from many mine sites. Only the final concentrate is moved to the fuel-processing plants.

Concentrate from the mines is sent to the refinery in Blind River, Ontario. The refinery produces high-purity uranium trioxide, which is then transported to the conversion facility in Port Hope, Ontario. The uranium conversion plant converts refined uranium trioxide into uranium hexafluoride and uranium dioxide to be used as fuel in nuclear reactors.

## Base Metals

Base-metal ores generally require a complex and energy-intensive process to recover their metallic content. In order to reduce costs, smelters are usually large and centrally located so they can process ore from as many surrounding mines as possible. For example, Sudbury's large metal-production complexes are supplied by the ore concentrates from almost 20 mines. Base-metal refineries and recyclers are usually found closer to urban areas, near sources of scrap, manufacturers and exporters. The most important base metals produced in Canada are nickel, copper, cobalt, zinc, lead, molybdenum and magnesium.

## Nickel

Nickel is one of the more valuable base metals. It is commonly used to produce steel alloys, primarily stainless steel. Significant amounts of nickel are recycled, usually from scrap stainless steel. Small amounts of this recycled nickel are processed in nickel smelters.

Canada's nickel is mined near Thompson, Manitoba; Sudbury, Ontario; and on the Ungava Peninsula of northern Quebec. Nickel is smelted and refined at large complexes in Thompson and Sudbury. There is also a nickel and cobalt refinery in Fort Saskatchewan, Alberta, although most of the concentrate it processes is imported from Cuba.

## Copper

Canada's copper production is mostly used in electrical transmission applications, primarily to make wire. Copper is commonly found associated with other base metals (zinc, nickel, molybdenum) and occasionally gold.

Copper-production complexes usually process the concentrate from several mines. British Columbia produces the most copper concentrate in Canada, although it has no copper-production facilities. British Columbia exports some of its concentrates directly and processes the rest at smelters in eastern Canada. Copper is also mined in Flin Flon, Manitoba; Sudbury and Timmins, Ontario; and near Rouyn-Noranda, Quebec. It is processed at complexes near all of these mining locations.

The smelter in Rouyn-Noranda also recycles copper scrap. The copper complex in Sudbury also produces nickel and the Timmins complex also produces zinc. Small amounts of copper are also recovered at the Belledune smelter in New Brunswick. There is copper refinery near Montréal, Quebec.

## Cobalt

Many of Canada's nickel and copper mines also produce cobalt in varying amounts. Some of this cobalt is recovered during the smelting of nickel and copper. Cobalt is used as an alloy in steel to increase its resistance to oxidation (rusting). Cobalt is recovered at the nickel-production complexes in Sudbury, Ontario and Thompson, Manitoba. Cobalt is refined in Port Colborne, Ontario and Fort Saskatchewan, Alberta. The Fort Saskatchewan refinery processes imported concentrates from Cuba.

## Zinc

Zinc is used primarily as a coating to help iron and steel resist oxidation, in a process called galvanizing. Significant amounts are also used in die-casting due to its low melting point and low viscosity when in liquid form. Zinc does not occur as a free metal on the earth's surface and it is commonly associated with copper and lead-bearing minerals.

Zinc is mined on Vancouver Island, British Columbia; around Flin Flon and Snow Lake, Manitoba; near Timmins, Ontario; near Rouyn-Noranda, Quebec; and near Bathurst, New Brunswick. The mine at Snow Lake only produces zinc. The mine at Bathurst produces zinc and lead, whereas the other mines produce zinc and copper.

Primary production facilities are in Trail, British Columbia; Flin Flon, Manitoba; and Timmins, Ontario. The Trail complex also produces lead and the Timmins complex produces copper. There is a zinc refinery in Valleyfield, Quebec that produces zinc metal and powders from concentrates. There is a zinc foundry near Hamilton, Ontario that recycles zinc scrap to produce refined zinc, alloys and castings.

### **Lead**

In Canada, most lead is produced in combination with zinc. Almost half of the refined lead produced uses recycled material as a feedstock. Most recycled lead is recovered from car batteries, the production of which is the leading use of refined lead. Primary lead processing facilities are usually able to smelt and refine lead, while recycling plants also recycle the plastic components of battery casings. Lead foundries produce refined lead, alloys and cast lead from scrap and concentrates.

Lead is mined near Timmins, Ontario and Bathurst, New Brunswick. In both mines, it is associated with zinc, which is the primary metal mined.

Lead-processing plants are found in Trail and Burnaby, British Columbia; near Toronto, Ontario; near Montréal, Quebec; and at Belledune, New Brunswick. The recycling plants in Montréal and Burnaby and the complex in Trail are integrated lead-recycling facilities. The Trail complex also produces zinc. The Belledune smelter refines lead and includes a battery-recycling plant. Foundries near Toronto and Montréal recover lead from scrap to produce refined lead, alloys and castings.

### **Molybdenum**

Molybdenum is used as an alloy in steel, as a catalyst in petroleum refining and as a lubricant. All of Canada's molybdenum is produced from three mines in British Columbia. Two of these mines, located in central and southern British Columbia, produce molybdenum as a byproduct of copper mining.

The remaining mine only produces molybdenum and includes an onsite refinery. Most of the mine's production is sold as a molybdenum-trioxide concentrate. The refinery produces molybdenum disulphide, an industrial lubricant.

### **Magnesium**

Magnesium is used as an alloy with aluminum, to increase strength and rigidity, and in die-casting. Magnesium, like zinc, does not occur as a pure metal in the Earth's crust, but it is found in over 60 minerals.

A complex in Danville, Quebec produced magnesium from asbestos mine tailings using a hydrometallurgical process. The complex closed in 2003. A complex near Haley, Ontario produces magnesium from a dolomitic limestone quarry. A third complex, in Bécancour, Quebec, produces magnesium metal from purchased magnesite and scrap magnesium.

### **Other Base Metals**

The remaining base metals are only produced in small amounts. They are usually recovered as a byproduct of primary base-metal smelting. They include cadmium, antimony, tin, bismuth, selenium, indium and tellurium. None of these metals are produced as the primary product of mines shown on the maps.

### **Aluminum**

Aluminum-bearing ore is not mined in Canada; it is only refined here. The raw material is shipped from around the world to Canada's refineries. The refined metal is likewise exported globally. The location of aluminum refineries is primarily determined by access to a consistent and inexpensive electricity supply, usually hydroelectric, and proximity to deep-water shipping lanes. All but one of Canada's aluminum refineries are found in Quebec; the other is in Kitimat, British Columbia and is accessible to Pacific shipping lanes.

