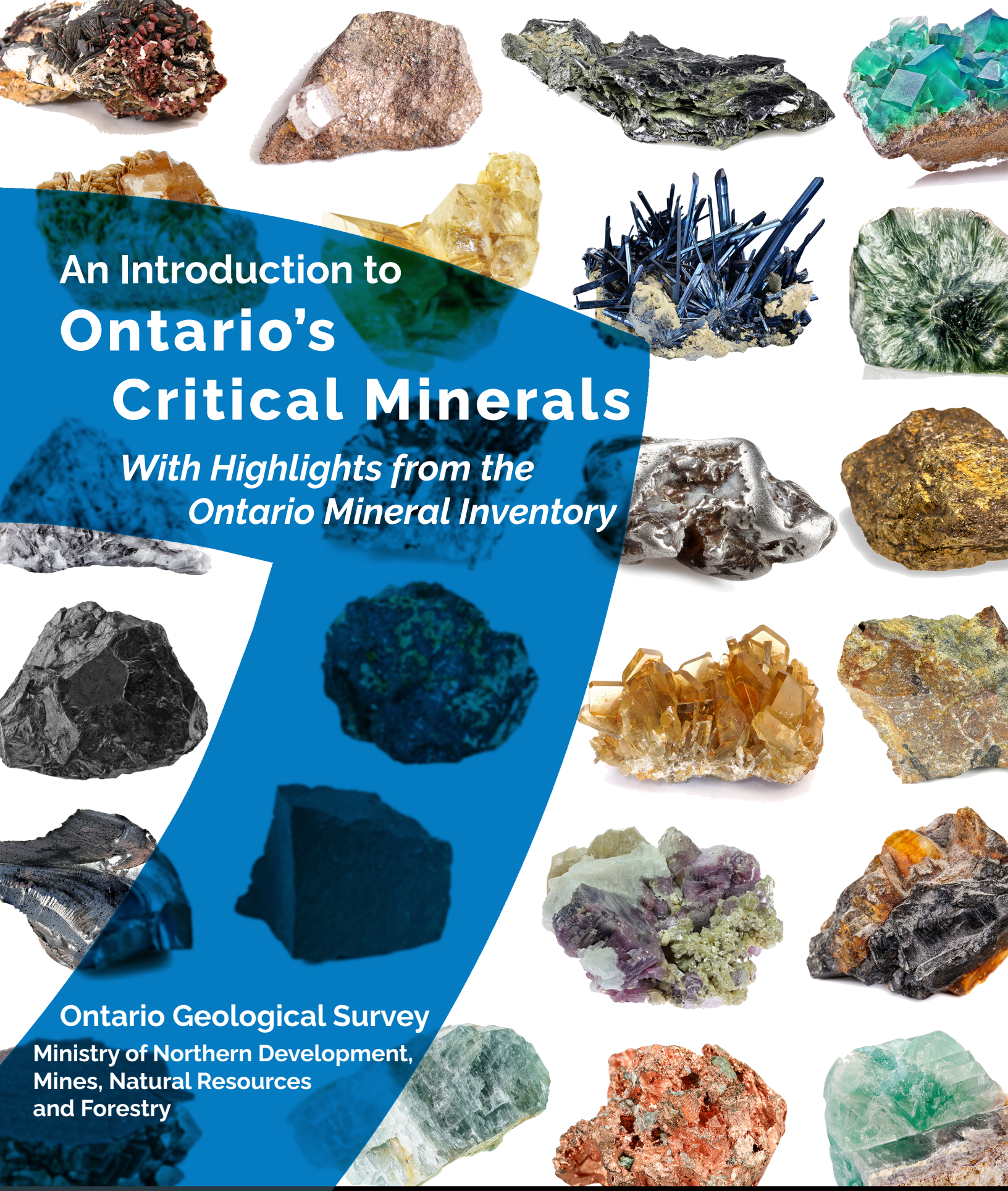


An Introduction to Ontario's Critical Minerals

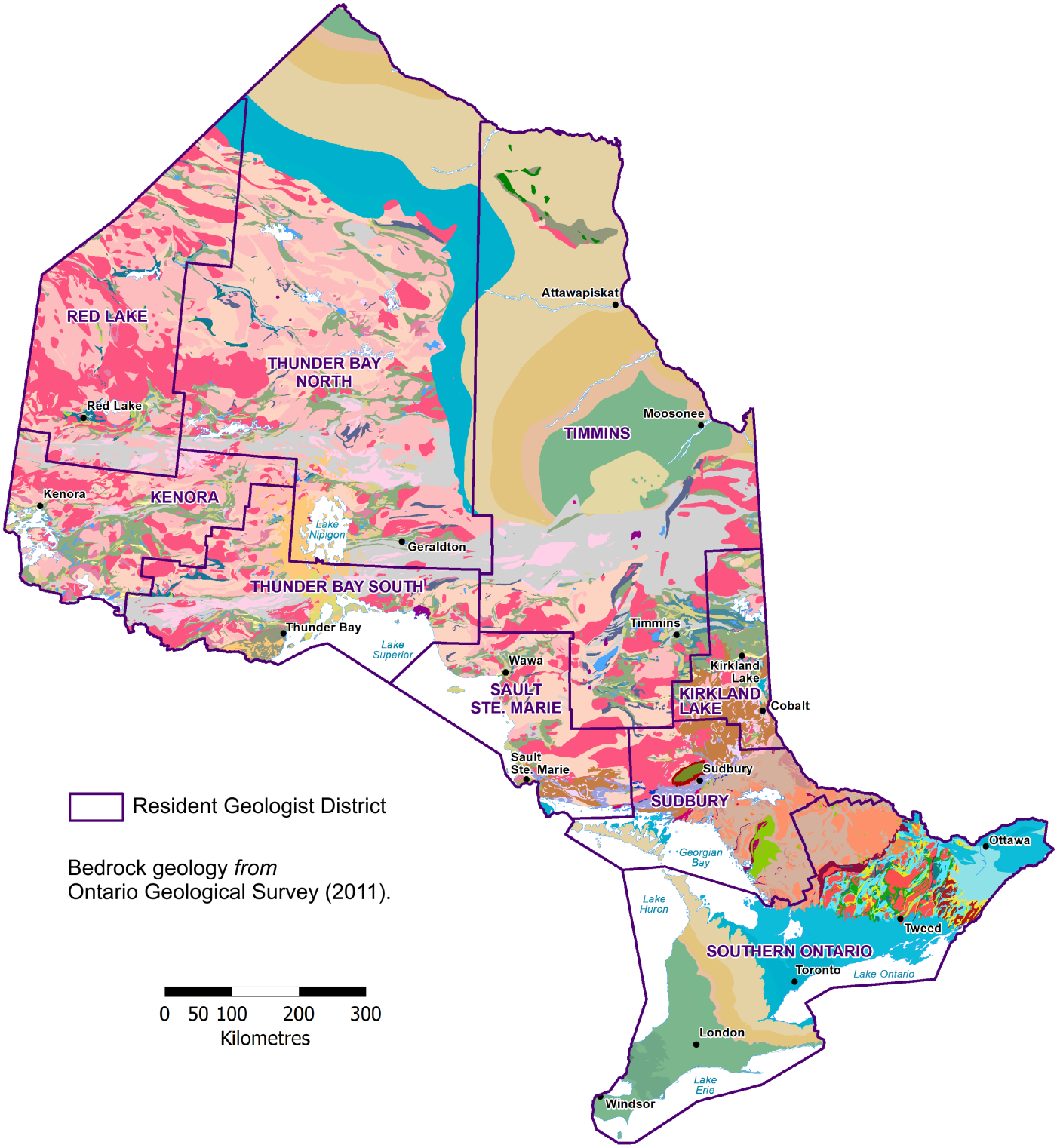
With Highlights from the Ontario Mineral Inventory

Ontario Geological Survey

Ministry of Northern Development, Mines, Natural Resources and Forestry

ONTARIO CANADA

Ontario


RED LAKE
THUNDER BAY NORTH
TIMMINS
KENORA
THUNDER BAY SOUTH
SAULT STE. MARIE
KIRKLAND LAKE
SUDBURY
SOUTHERN ONTARIO
Attawapiskat
Red Lake
Moosonee
Kenora
Lake Nipigon
Geraldton
Thunder Bay
Lake Superior
Timmins
Wawa
Kirkland Lake
Cobalt
Sault Ste. Marie
Sudbury
Georgian Bay
Lake Huron
Ottawa
Tweed
Toronto
Lake Ontario
London
Lake Erie
Windsor
Resident Geologist District
Bedrock geology *from* Ontario Geological Survey (2011).
0 50 100 200 300
Kilometres

Contents

An Introduction to Ontario's Critical Minerals, With Highlights from the Ontario Mineral Inventory

Ontario Geological Survey
Resident Geologist Program

Over the last 20 years, there has been a gradual shift in the global economy. New technologies and high-growth sectors, such as renewable energy, electric vehicles, high-end consumer electronics and information and communications technologies, have transformed our everyday lives. From smartphones and laptops, to drones and battery-run electric cars, demand is rising—so is the need for the raw materials used to build these products. Many of these raw materials fall into a category known as critical minerals, and exploration for these commodities is capturing increasing worldwide exploration interest.

The minerals that a jurisdiction deems "critical" depends on its geology, as well as its own domestic and economic priorities. It is commonly accepted that critical minerals have specific industrial, technological and strategic applications for which there are few viable substitutions. These minerals are economically important and are subject to supply risk because of geopolitical considerations and market demand. In alignment with these considerations, Ontario has developed the following critical minerals list.

Ontario Critical Minerals List[1]		
Antimony	Graphite	Scandium
Barite	Indium	Selenium
Beryllium	Lithium	Tantalum
Bismuth	Magnesium	Tellurium
Cesium	Manganese	Tin
Chromite	Molybdenum	Titanium
Cobalt	Nickel	Tungsten
Copper	Niobium	Uranium
Fluorspar	Phosphate	Vanadium
Gallium	Platinum Group Elements[2]	Zinc
Germanium	Rare Earth Elements[3]	Zirconium

[1]*Information related to the Ontario critical minerals list is available at www.ontario.ca/page/critical-minerals. Ontario's Critical Mineral Strategy 2022–2027 is also available to download.*

[2]*Platinum Group Elements include platinum, palladium, rhodium, ruthenium, osmium and iridium.*

[3]*Rare Earth Elements include lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium and yttrium.*

Ontario's varied geology provides tremendous opportunities for critical mineral exploration. In fact, Ontario is already a producer of several critical minerals (either as primary commodities or by-products). For other critical minerals, there has been past production in Ontario or these minerals occur in deposits that are currently being developed for possible future production. The remaining minerals that are included on Ontario's Critical Minerals List (along with the ones in the production, past-production and development categories) are all considered to have exploration potential. Ontario's Critical Minerals are grouped into these 3 categories, which are represented by different page colours in this publication:

- production (blue): cobalt, copper, indium, nickel, platinum group elements, selenium, tellurium, zinc;
- past-production history and/or under development for future production (orange): barite, beryllium, chromite, fluorspar, graphite, lithium, magnesium, molybdenum, niobium, phosphate, tungsten, uranium;
- exploration potential (green): antimony, bismuth, cesium, gallium, germanium, manganese, rare earth elements, scandium, tantalum, tin, titanium, vanadium, zirconium.

This publication provides information about the geological characteristics and economic importance of each of the critical minerals on Ontario's list, along with an introduction to the wealth of information about the occurrence of these minerals in Ontario that can be obtained from the Ontario Mineral Inventory (OMI) database, formerly the Mineral Deposit Inventory (MDI) database.

The OMI records include information on the location, geological environment, and exploration history of metallic and industrial mineral showings. Deposits are categorized according to their significance and production status (e.g., occurrences, prospects, mines). Where available, current and historical production and mineral resource data are also included. The OMI data are maintained by staff of the Resident Geologist Program (RGP) and are compiled by the Regional Mineral Deposit Compilation Geoscientists with assistance from District Office staff.

To complement this publication, the OGS is also pleased to provide a new OGSEarth layer (www.geologyontario.mndm.gov.on.ca/ogsearth.html#ontarios-critical-minerals) that provides online map-based access to all of our OMI records for each of the commodities on Ontario's Critical Minerals List.

If you wish to learn more about the occurrence of critical minerals in Ontario or the Ontario Mineral Inventory database, feel free to contact a geoscientist in one of our RGP Regional or District offices.

Mark Puumala
Senior Manager, Resident Geologist Program
Ontario Geological Survey

April 2022

About the Ontario Geological Survey Resident Geologist Program

The Ontario Geological Survey comprises 3 business sections:

- the Earth Resources and Geoscience Mapping Section conducts geoscience surveys and mapping
- the GeoServices Section provides analytical services through the Geoscience Laboratories, and editorial, publishing and library services through Publication Services
- the Resident Geologist Program provides a variety of client services.

The Resident Geologists are the stewards of public geological and mineral exploration information for their districts. They provide a broad range of advisory services on geological topics of interest to the public, to municipal governments and to the mineral industry. They are the local experts on why geoscience information is important, what information is available and what is happening in exploration.

The program provides primary client services through a network of 8 field offices strategically located across the province.

Our services include

- collecting and maintaining geological data, including the Ontario Mineral Inventory*, Ontario Assessment File and Ontario Drill Hole databases
- monitoring mineral exploration activity
- conducting property visits to evaluate geology and mineralization
- providing geological and exploration advice
- providing geological field trips.

We provide geoscience information to support

- public safety
- environmental planning
- land use planning
- mineral sector investment and economic development.

We provide information and training to First Nation Communities regarding prospecting, mineral exploration and mining.

For more information about the Ontario Geological Survey and the Resident Geologist Program, please visit the following Web sites: Geoscience in Ontario at www.ontario.ca/page/geoscience-ontario and Geology and Geoscience at www.ontario.ca/page/geology-and-geoscience.

*Note: The Resident Geologist Program has implemented upgrades to the data entry and online posting components of the renamed Ontario Mineral Inventory (formerly Mineral Deposit Inventory) database. These upgrades are intended to provide users with more frequent updates and will allow for ongoing data quality improvements. The OMI is now available through the GeologyOntario (www.geologyontario.mndm.gov.on.ca/index.html) and OGSEarth (www.geologyontario.mndm.gov.on.ca/ogsearth.html#mineral-inventory) Web sites. Users of OGS publications may continue to find the database referenced by its former name, Mineral Deposit Inventory or MDI.

Terms Used

TEXT

deposit: Mineral deposit classifications follow those previously published by the Ontario Geological Survey (*see* Rogers et al. 1995).

primary commodity: Primary commodities are defined in the Ontario Mineral Inventory as those that meet Ministry cut-off grades and could be extracted economically.

secondary commodity: Secondary commodities are defined in the Ontario Mineral Inventory as those that may be present but have non-economic grades or they may be commodities and/or elements that could be used as geochemical pathfinders.

by-product: Many ore deposits contain commodities known as by-products. These could not be extracted economically on their own, but occur with another commodity that can be mined profitably (e.g., indium can be produced as a by-product of zinc mining).

production: Commodities listed under the production category are extracted from Ontario ore deposits that are being mined at the time of publication.

past production: Commodities with past-production are not currently being extracted from Ontario ore deposits, but have been produced in the past based on information available from the Ontario Mineral Inventory database.

under development: Commodities identified as being under development have active projects at the economic analysis stage at the time of publication, but these commodities are not currently being extracted from Ontario ore deposits.

exploration potential: All commodities on Ontario's Critical Minerals List have exploration potential. However, the exploration potential category in this publication is focussed on those commodities that have no production history and do not have projects in the economic analysis stage at the time of publication.

TABLES

reserves: Reserves represent an estimate of the quantity of economically mineable minerals in an ore deposit. Reserves may be reported as Proven or Probable, with Proven reserves having been determined with the highest degree of confidence.

resources: Resources represent an estimate of the quantity of minerals that are present in a mineral deposit that has reasonable prospects for eventual economic extraction. Resources are listed in this publication as Measured, Indicated, Inferred or Historical.

- Measured, Indicated and Inferred resources have been calculated in accordance with current standards (CIM 2014).
- Measured resources have been calculated with the highest degree of confidence, whereas Inferred has the lowest.
- Historical resources have been published, but were not calculated in accordance with current standards.

production: Total mineral production from an ore deposit that was being mined at the time of publication.

past production: Total mineral production from an ore deposit that was not being mined at the time of publication.

historical: *see* explanation under Resources.

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This publication is released in conjunction with the Ontario Geological Survey publication *Recommendations for Exploration Special Edition: Critical Minerals Compilation 2000–2022.*

Every possible effort has been made to ensure the accuracy of the information contained in this publication; however, the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry does not assume liability for errors that may occur. Source references are included in this publication and users are urged to verify critical information.

Users of OGS products should be aware that Indigenous communities may have Aboriginal or treaty rights or other interests that overlap with areas of mineral potential and exploration.

Cette publication est disponible en anglais seulement.

Ontario Geological Survey 2022. An introduction to Ontario's critical minerals, with highlights from the Ontario Mineral Inventory; Ontario Geological Survey, 69p.

or, for partial Content

Ontario Geological Survey 2022. Chromite; *in* An introduction to Ontario's critical minerals, with highlights from the Ontario Mineral Inventory; Ontario Geological Survey, p.11-12.

Notes

Sb ANTIMONY

Antimony – is a silvery white, brittle metalloid that is mainly found in nature as the sulphide mineral stibnite (Sb_2S_3). Antimony compounds, such as antimony trioxide (Sb_2O_3), are known to have been used in medicine and cosmetics since ancient times. Antimony occurs in Ontario both as primary and secondary commodities.

Stibnite is a trisulphide mineral and is the main source of antimony.

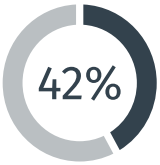
Geological Environment and Sources: Antimony is present in many types of deposits worldwide; however, in Ontario, antimony typically occurs in the same types of quartz-carbonate vein systems associated with lode gold deposits.

Host Minerals: Antimony is found in Ontario mainly as stibnite.

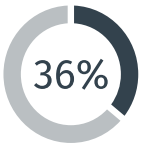
Total World Production 2021: Worldwide production of antimony in 2021 was approximately 114,500 tonnes.

Notable Ontario Localities: Howells Lake.

How Is Antimony Used?



Antimony trioxide is used mainly for flame-retardant materials. The flame-retarding effects do not come from the antimony trioxide itself, but, when combined with halogenated materials, they form halogenated antimony compounds that delay the spread of flames.



Antimony forms an alloy with lead that increases its hardness and mechanical strength. Antimony is also used in anti-friction alloys.

Antimony is also used in the production and manufacturing of non-metal products, for example plastics, ceramics, paints and rubber.

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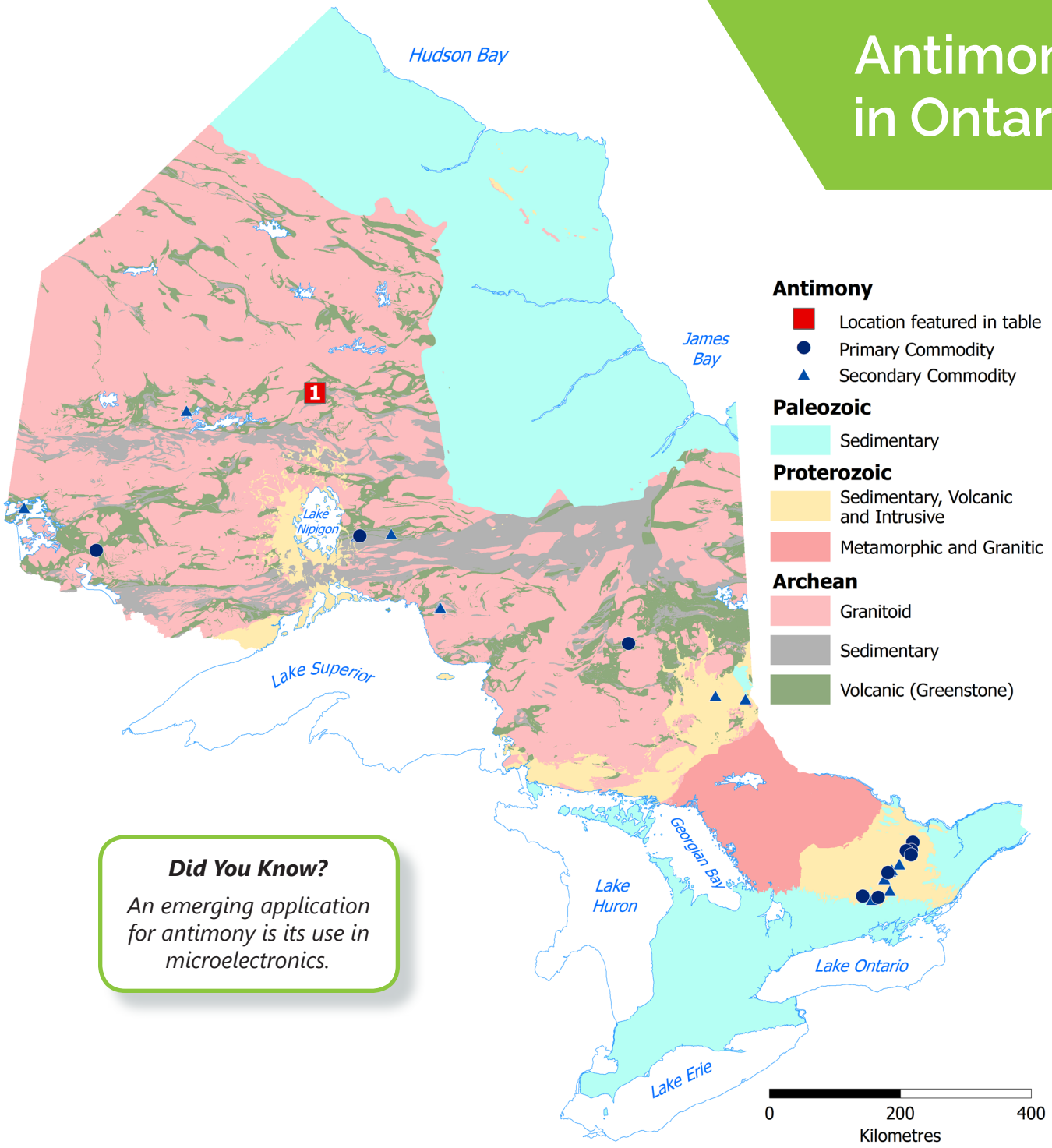
Antimony in Ontario



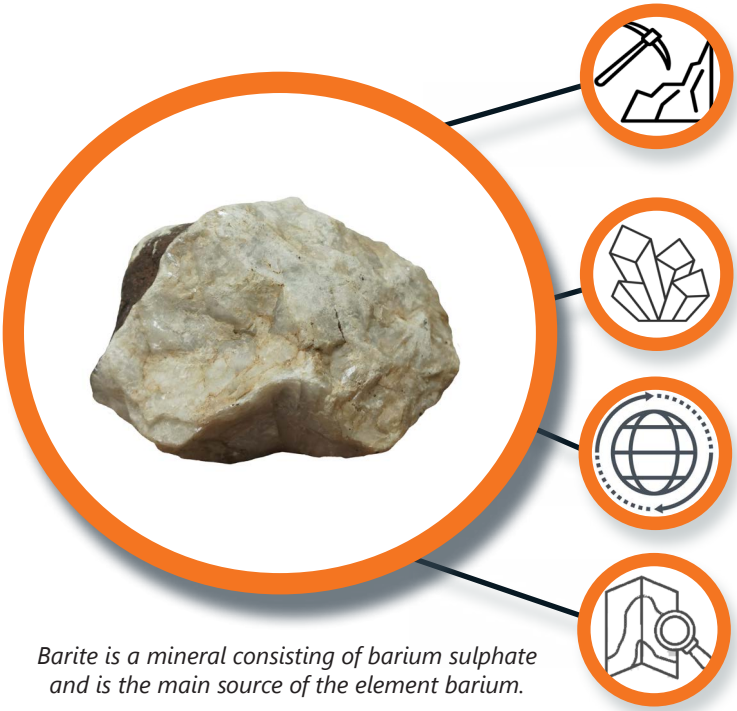
Did You Know?

An emerging application for antimony is its use in microelectronics.

Location	Name	Resources
1	Howells Lake prospect	Historical: Eastern zone: 660,000 tons @ 3.1% Sb; Western zone: 83,000 tons @ 1.27% Sb + 1 other commodity

Ba BARITE

Barite – is a white, pink or colourless non-metallic mineral consisting of barium sulphate ($BaSO_4$), and is the main source of the element barium. The high specific gravity of barite makes it suitable for a wide variety of industrial, medical and manufacturing uses. Barite occurs in Ontario as both primary and secondary commodities.



Barite is a mineral consisting of barium sulphate and is the main source of the element barium.

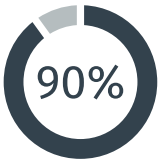
Geological Environment and Sources: Barite occurs in various vein-hosted depositional environments. In Ontario, barite occurs in association with sedimentary exhalative (SEDEX) mineralization, Mississippi Valley–type (MVT) mineralization, and in amethyst and polymetallic veins.

Host Minerals: Barite ($BaSO_4$) occurs naturally in Ontario.

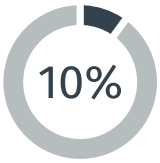
Total World Production 2021: Worldwide production of barite in 2021 was approximately 8.8 million tonnes.

Notable Ontario Localities: Southeastern Ontario, Thunder Bay, Matachewan (North Williams property).

How Is Barite Used?



Barite is an industrial mineral used primarily as a weighting agent, which is a key constituent in drilling mud used for drilling oil and gas wells.



Other minor uses of **barite** include its use as an additive for friction materials, paints, plastics, rubbers, and other products; feedstock for chemical manufacturing; and shielding in X-ray and gamma-ray applications.

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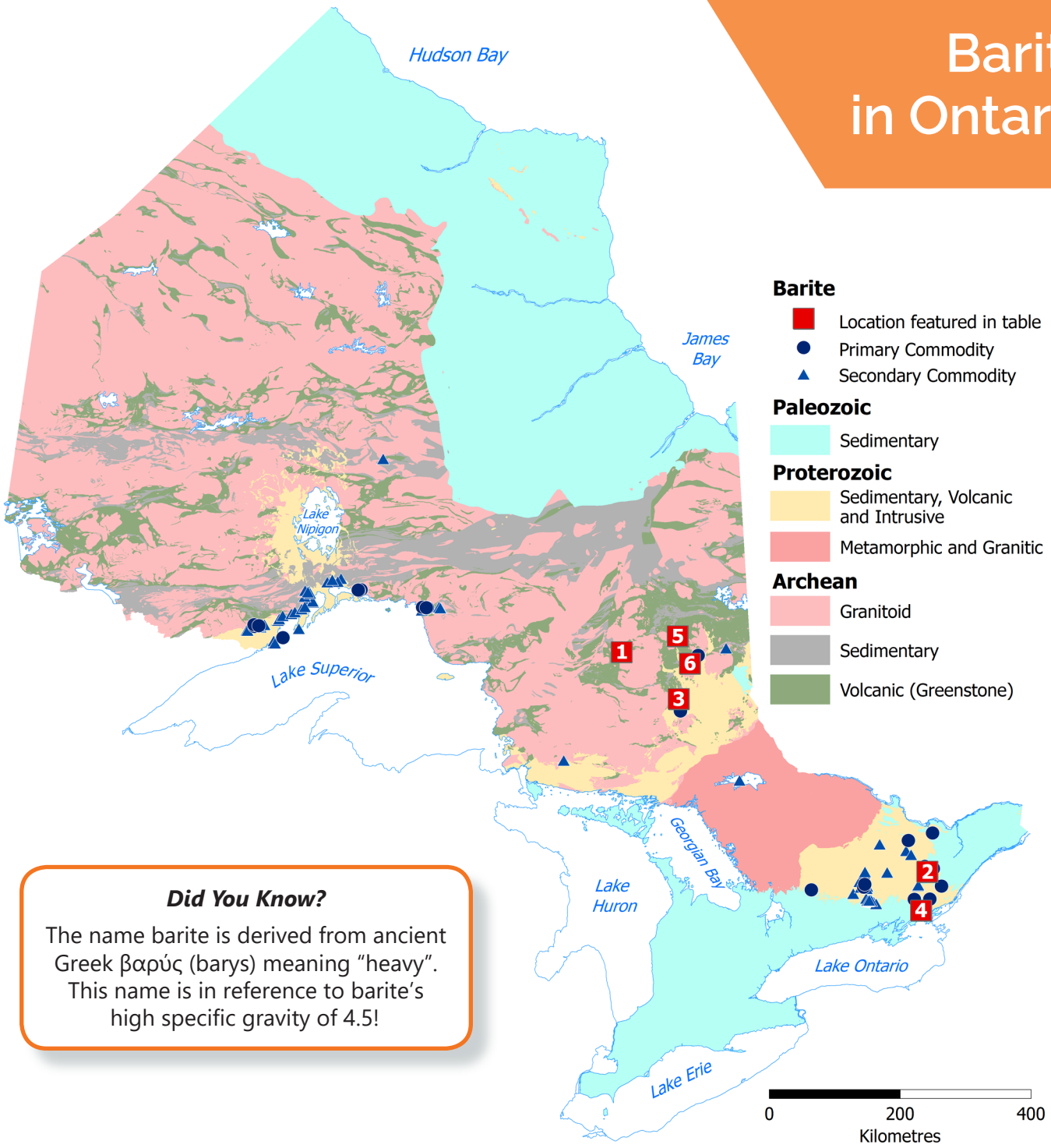
Barite in Ontario



Did You Know?

The name barite is derived from ancient Greek βαρύς (barys) meaning "heavy". This name is in reference to barite's high specific gravity of 4.5!

Location	Name	Resources and Past Production (t = tonne)
1	Ravena	Historical: 90,710 t @ 95% barite; Past Production (1923–1986 intermittently): 820 tons barite
2	H.C. Bellew	Past Production (1921): 363 t
3	North Williams barite property	Past Production (2000–2013): 10,000 t
4	Woodruffe	Past Production (1890s): 100 t
5	Premier Mine	Past Production (1918–1947 intermittently): 1,828 t
6	Ontario Barium	Past Production (1969–2002): minimum 55,000 t

Be BERYLLIUM

Beryllium – is a steel-grey, strong, brittle and lightweight alkaline-earth metal. Beryllium is primarily used in aerospace and defence applications because of its light weight, stiffness and resistance to a wide temperature range. Beryllium occurs in Ontario as both primary and secondary commodities.

Beryl is a beryllium aluminum cyclosilicate and is the main source of beryllium.

Geological Environment and Sources: In Ontario, beryllium occurs mainly in rare-element pegmatites.

Host Minerals: Beryllium is found in Ontario mainly as beryl.

Total World Production 2021: Worldwide production of beryllium in 2021 was approximately 260 tonnes.

Notable Ontario Localities: Quadeville (Beryl pit and Rose quartz quarries).

How Is Beryllium Used?

- 24% Aerospace and defense applications
- 23% Industrial components
- 12% Automotive electronics
- 11% Consumer electronics
- 9% Energy applications
- 1% Semiconductor applications
- 20% Other

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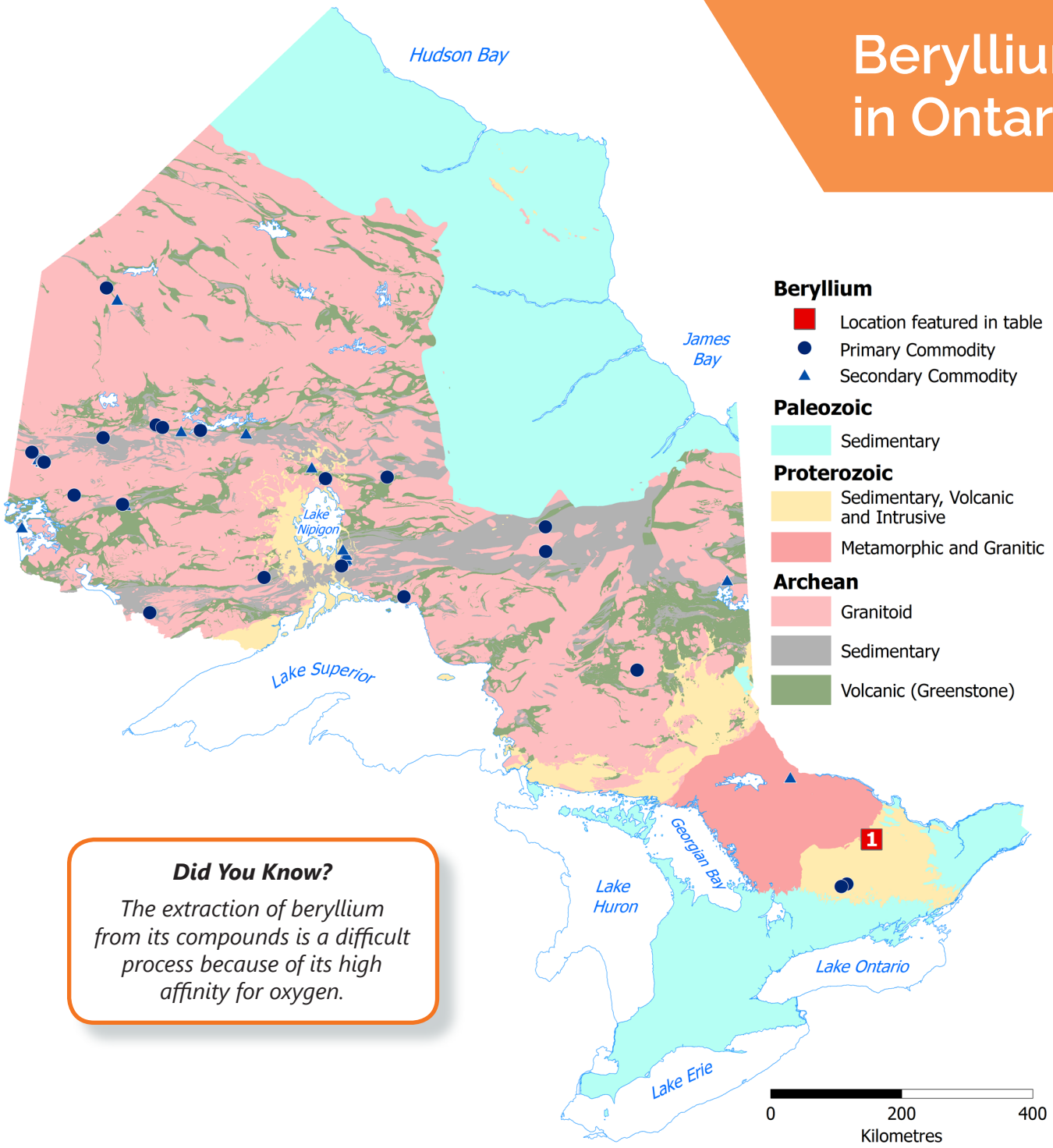
Beryllium in Ontario



Did You Know?

The extraction of beryllium from its compounds is a difficult process because of its high affinity for oxygen.

Location	Name	Past Production (t = tonne)
1a	Beryl pit	Past Production (1926–1950 intermittently): 208 t
1b	Rose quartz	Past Production (1936): 26 t

Bi BISMUTH

Bismuth – is a brittle post-transition metal that is silvery white on fresh surface, but often, surface oxidation creates numerous iridescent characteristics. Bismuth is the heaviest heavy metal and the only non-toxic one. Bismuth occurs in Ontario as both primary and secondary commodities.

Bismutite is a bismuth carbonate mineral and is one of the main sources of bismuth.

Geological Environment and Sources: In Ontario, bismuth occurs generally in association with lead and forms in five-element veins (silver-cobalt-nickel-bismuth-arsenic).

Host Minerals: Bismuth is found in Ontario mainly as bismutite and bismuthinite.

Total World Production 2021: Worldwide production of bismuth in 2021 was approximately 19,000 tonnes.

Notable Ontario Localities: Bismuth occurs in association with the silver ores that were mined historically in the Cobalt and Gowganda areas.

How Is Bismuth Used?

Bismuth is used in cosmetic, industrial, laboratory, and pharmaceutical applications, and metallurgical applications (non-toxic lead replacement, specialized bismuth alloys).

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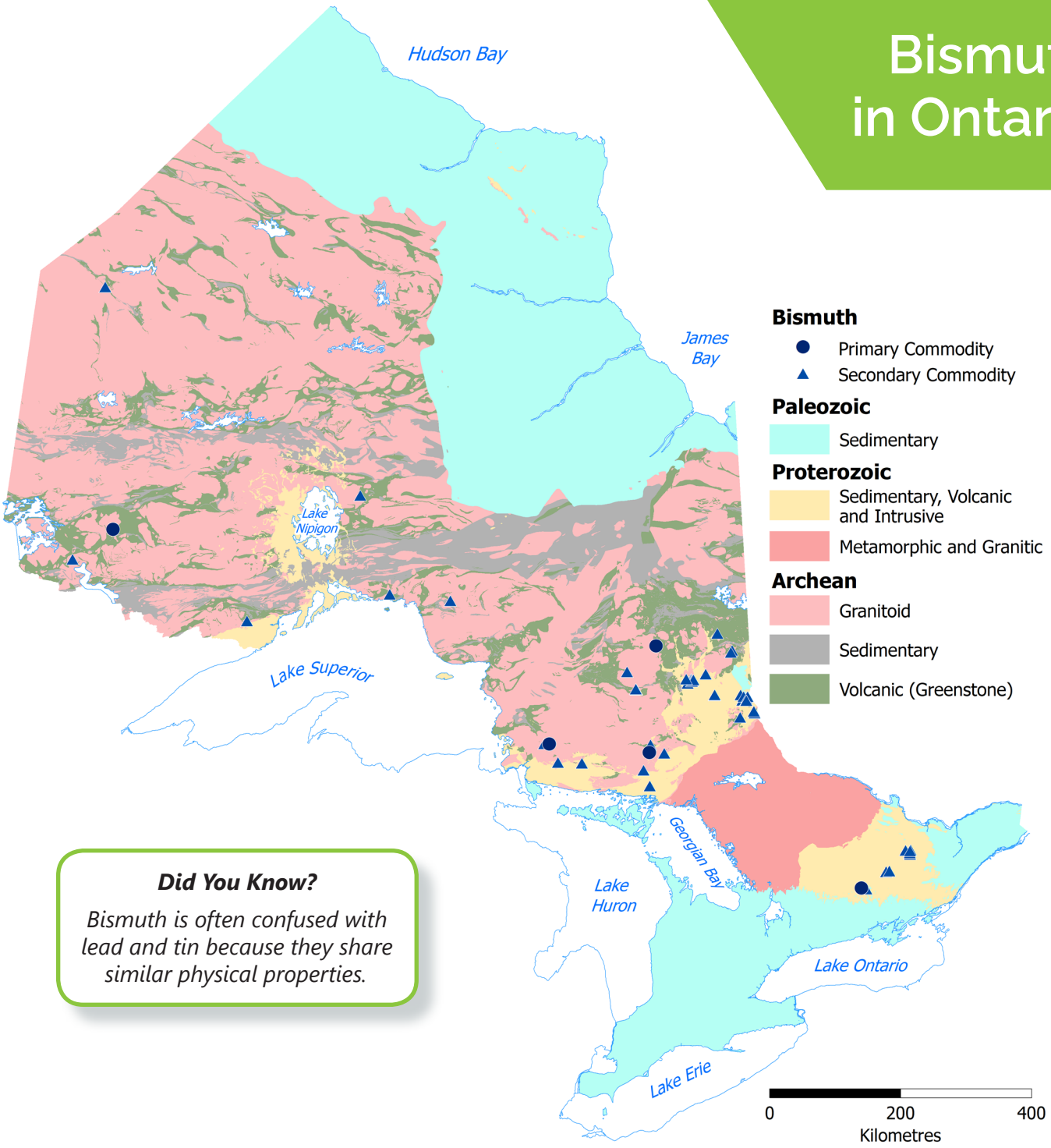
Bismuth in Ontario



Did You Know?

Bismuth is often confused with lead and tin because they share similar physical properties.

No resources or reported production.

Cs CESIUM

Cesium – is a naturally occurring alkali metal. Historically, the most important use for cesium has been in research and development in both chemical and electrical applications. Cesium occurs in Ontario as both primary and secondary commodities.

Pollucite is a zeolite mineral and a significant source of cesium.

Geological Environment and Sources: In Ontario, cesium occurs mostly in rare-element pegmatites.

Host Minerals: Cesium is found in Ontario mainly as pollucite.

Total World Production 2021: Worldwide production of cesium in 2021 was unknown.

Notable Ontario Localities: Separation Rapids, near Fort Hope (Pollucite dike).

How Is Cesium Used?

Cesium is used by the oil and gas exploration industry for high-pressure, high-temperature well drilling. Cesium isotopes are used as an atomic standard in atomic clocks. Cesium compounds are used worldwide and could potentially be used in photoelectric cells.

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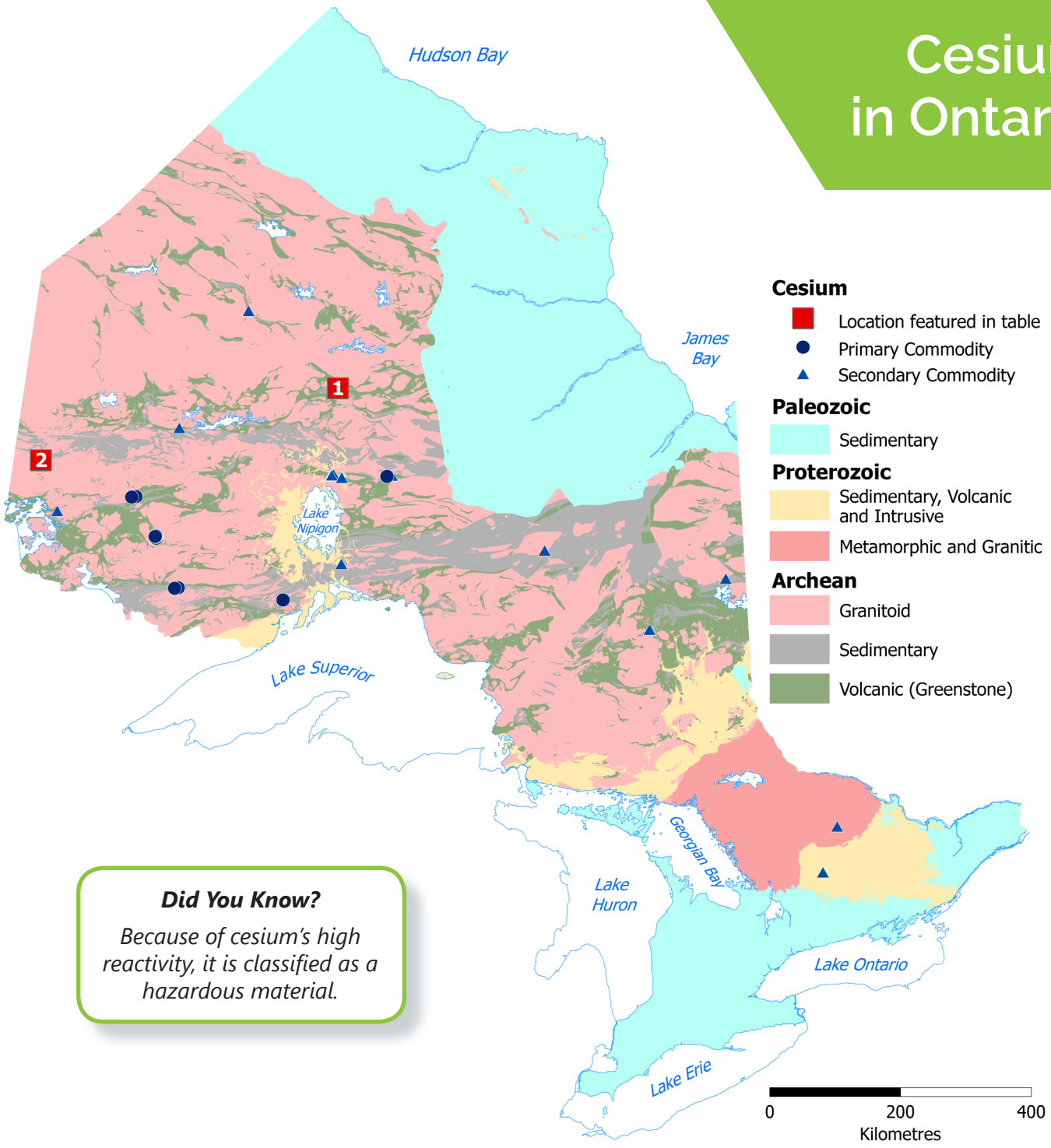
Cesium in Ontario



Did You Know?

Because of cesium's high reactivity, it is classified as a hazardous material.

Location	Name	Resources (Mt = million tonnes; t = tonne)
1	Pollucite dike	Inferred: 340,000 t @ 2.29% Cs_2O + 1 additional oxide
2	Separation Rapids	Measured & Indicated: 8.40 Mt @ 0.015% Cs_2O + 3 additional oxides; Inferred: 1.79 Mt @ 0.018% Cs_2O + 3 additional oxides

Cr CHROMITE

Chromite – is the chromium ore mineral. Chromium is a steel-grey, lustrous, hard and brittle transition metal. Chromium is valued for its high corrosion resistance and hardness. Chromium occurs in Ontario as both primary and secondary commodities.

Chromite is a crystalline oxide mineral and is the main source of chromium.

Geological Environment and Sources: In Ontario, chromium occurs in mafic to ultramafic magmatic stratiform chromitite–type deposits.

Host Minerals: The mineral chromite ($FeCr_2O_4$) is the main source of chromium in Ontario.

Total World Production 2021: Worldwide production of chromium in 2021 was 41 million tonnes.

Notable Ontario Deposits: McFaulds Lake area ("Ring of Fire") (Blackbird, Black Horse, etc.), Chrome Lake.

How Is Chromium Used?

Chromium is used to produce stainless steel and non-ferrous alloys, as well as in plating of metals, pigments, leather processing, catalysts, surface treatments and ceramic (refractory) materials.

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Chromite in Ontario

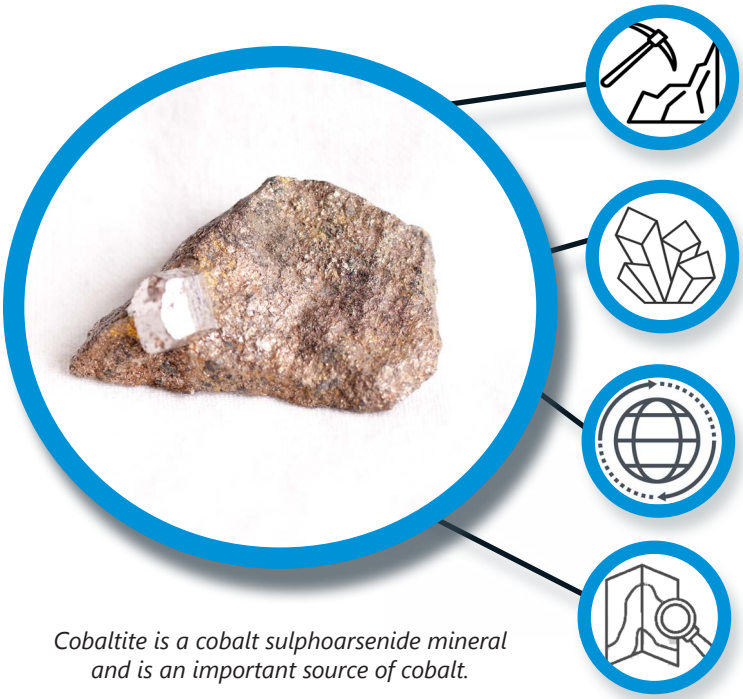
Did You Know?

The colour of many gemstones is derived from trace amounts of chromium contained within it.

Location	Name	Resources and Past Production (Mt = million tonnes; t = tonne)
1a	Blackbird 1 & 2	Measured & Indicated: 20.5 Mt @ 35.8% Cr_2O_3; Inferred: 23.5 Mt @ 33.1% Cr_2O_3
1b	Black Horse	Inferred: 85.9 Mt @ 34.5% Cr_2O_3
1c	Big Daddy	Measured & Indicated: 29.1 Mt @ 31.7% Cr_2O_3; Inferred: 3.4 Mt @ 28.1% Cr_2O_3
1d	Black Creek	Measured & Indicated: 8.645 Mt @ 37.4% Cr_2O_3; Inferred: 1.6 Mt @ 37.8% Cr_2O_3
1e	Black Thor	Measured & Indicated: 137.7 Mt @ 31.5% Cr_2O_3; Inferred: 26.8 Mt @ 29.3% Cr_2O_3
1f	Black Label	Measured & Indicated: 5.4 Mt @ 25.3% Cr_2O_3; Inferred: 0.9 Mt @ 22.8% Cr_2O_3
2	Chrome Lake Mine	Historical: 25,000 t @ 12% Cr_2O_3; Past Production (1936–1937): 8,000 t

Co COBALT

Cobalt – is a bluish grey, shiny, brittle metallic element. The leading use of cobalt is in rechargeable lithium-ion batteries and in the manufacture of wear-resistant and high-strength alloys. Cobalt occurs in Ontario as both primary and secondary commodities.



Cobaltite is a cobalt sulphoarsenide mineral and is an important source of cobalt.

Geological Environment and Sources: In Ontario, cobalt occurs in magmatic sulphide ore deposits and in five-element veins (silver-cobalt-nickel-bismuth-arsenic).

Host Minerals: Cobalt is found in Ontario mainly in base metal sulphide and arsenide silver-cobalt assemblages.

Total World Production 2021: Worldwide production of cobalt in 2021 was 170,000 tonnes.

Notable Ontario Localities: Cobalt is currently being produced in Sudbury. The Town of Cobalt derives its name from the cobalt mineralization that occurs there in five-element veins.

How Is Cobalt Used?

- 43% — Superalloys; mainly in aircraft gas turbine engines
- 31% — Chemical applications
- 16% — Metallic applications
- 10% — Cemented carbides for cutting and wear-resistant applications

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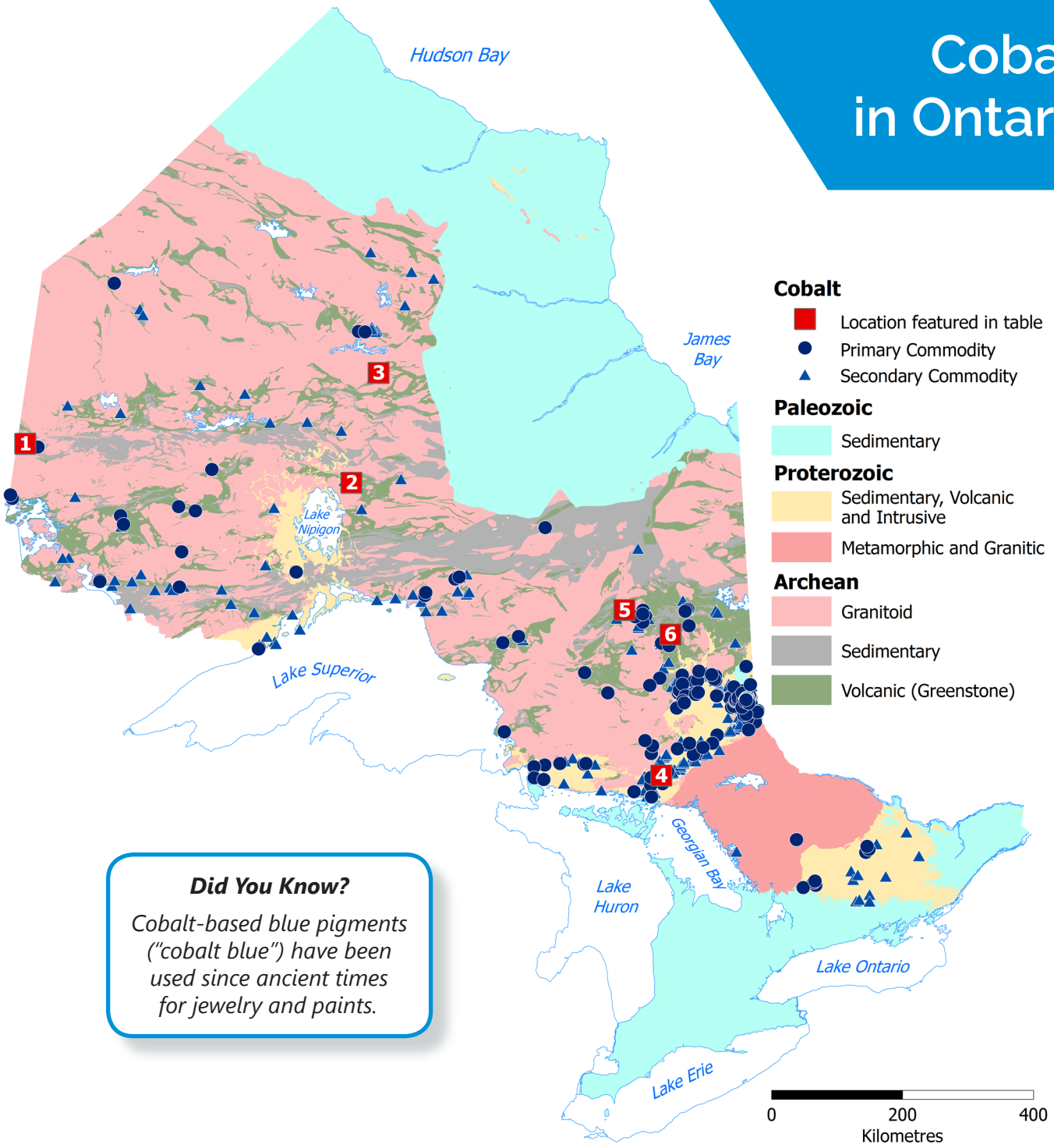
Cobalt in Ontario



Did You Know?

Cobalt-based blue pigments ("cobalt blue") have been used since ancient times for jewelry and paints.

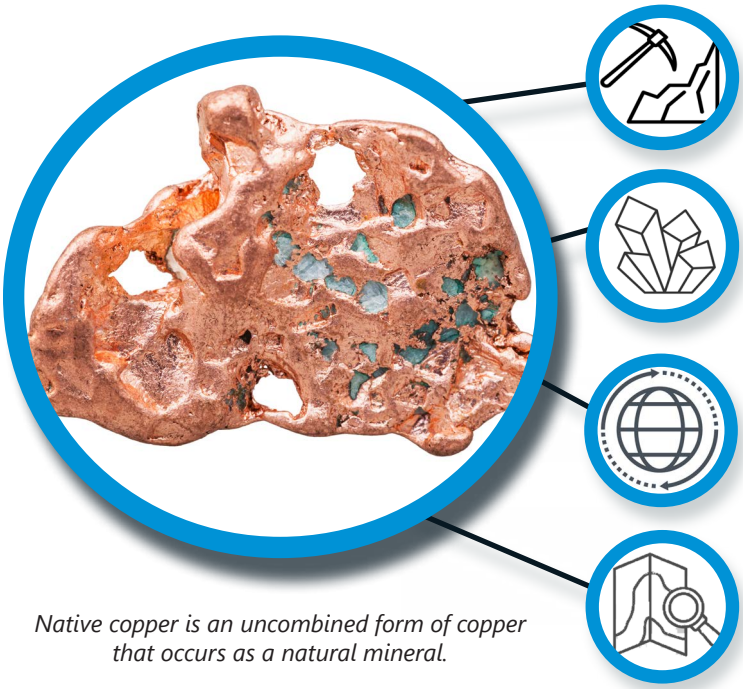
Location	Name	Resources and Past Production (kg = kilogram; Mt = million tonnes; t = tonne)
1	Werner Lake	Indicated: 57,900 t @ 0.51% Co; Inferred: 6,300 t @ 0.48% Co
2	Junior Lake	Indicated: B4-7 zone: 3.16 Mt @ 0.05% Co; Indicated: VW zone: 1.084 Mt @ 0.02% Co
3	Norton Lake	Measured & Indicated: 2.26 Mt @ 0.03% Co
4	Sudbury	Past Production (to 2020): 100.35 million kg Co as by-product of the copper-nickel mines
5	Montcalm Mine	Past Production (2004–2009): 1,421 t Co
6	Redstone Mine & McWatters Mine	Past Production (2010–2011): 18.68 t Co

112,967 tonnes of cobalt were produced in Ontario between 1904 and 2018.

An estimated 1,064 tonnes of by-product cobalt were produced in Ontario in 2018 (30% of Canada's cobalt production).

Cu COPPER

Copper – is a natural mineral generally associated with sulphur, but it can also occur as native copper. Copper occurs in Ontario as both primary and secondary commodities.



Native copper is an uncombined form of copper that occurs as a natural mineral.

Geological Environment and Sources: In Ontario, copper occurs in magmatic sulphide ore deposits and volcanogenic massive sulphide (VMS) deposits or is vein hosted.

Host Minerals: Chalcopyrite is the primary copper ore mineral in Ontario. Native copper also occurs in some volcanic rocks near Lake Superior.

Total World Production 2021: Worldwide production of copper in 2021 was approximately 21 million tonnes.

Notable Ontario Deposits: Sudbury, Timmins (Kidd Creek).

How Is Copper Used?

Copper is used in a variety of industries, such as specialized copper alloys (marine and anti-microbial applications), and electronics (wiring, semi-conductor manufacturing, electric motor components).

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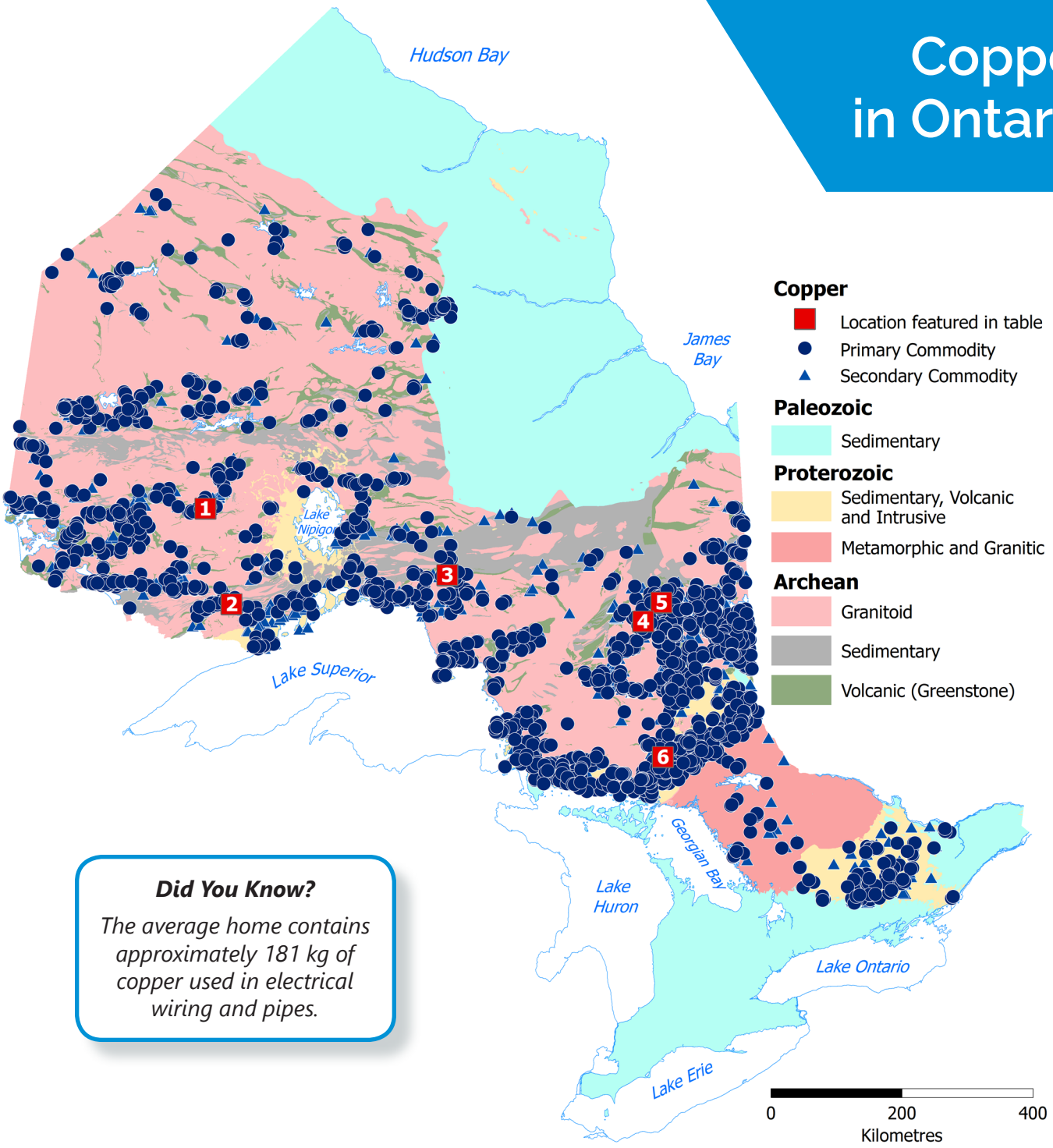
Copper in Ontario



Did You Know?

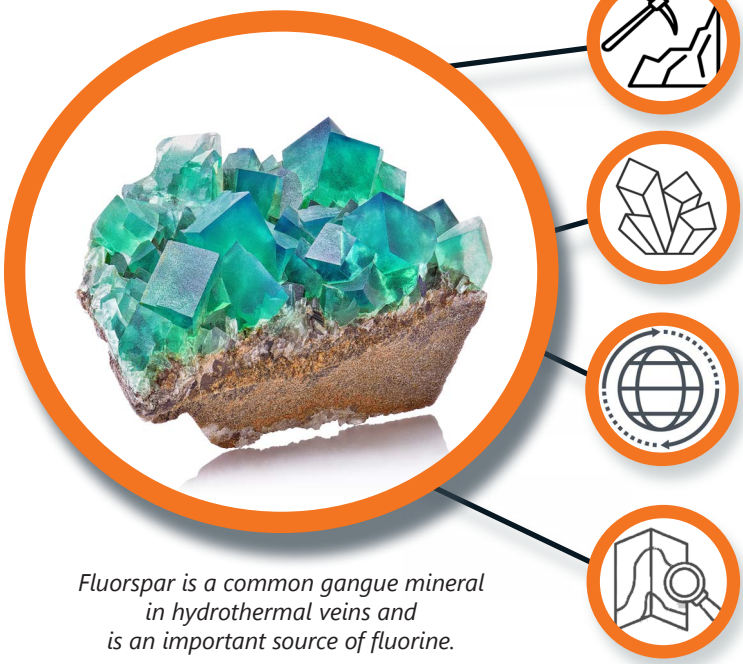
The average home contains approximately 181 kg of copper used in electrical wiring and pipes.

Location	Name	Resources, Production and Past Production (kg = kilogram; Mt = million tonnes)
1a	Mattabi	Past Production (1972–1988): 91,245,000 kg Cu
1b	Sturgeon Lake	Past Production (1974–1980): 50,052,000 kg Cu
1c	F Group	Past Production (1981–1984): 50,052,000 kg Cu
2	Shebandowan Mine	Past Production (1972–1998): 83,101,000 kg Cu
3	Geco Mine	Past Production (1955–1995): 1 billion kg Cu
4	Kam Kotia Mine	Past Production (1943–1971): 61,833,299 kg Cu
5	Kidd Creek Mine	Proven & Probable: 5.0 Mt @ 1.8% Cu; Past Production (1966–2020): 3.68 billion kg Cu
6	Sudbury	Production (since 1883): 12.2 billion kg Cu from the Sudbury camp. Glencore: Proven & Probable: 28.2 Mt @ 0.87% Cu + 4 other commodities; Vale: Proven & Probable: 51.1 Mt @ 1.63% Cu + 5 other commodities

In 2019, Ontario produced 158,200 tonnes of copper (21.9% of total Canadian copper production).

F FLUORSPAR

Fluorspar – also called fluorite, is transparent, but impurities usually make it a colourful mineral. Fluorspar has both industrial and ornamental and/or lapidary uses. Fluorspar occurs in Ontario as both primary and secondary commodities.



Fluorspar is a common gangue mineral in hydrothermal veins and is an important source of fluorine.

Geological Environment and Sources: In Ontario, fluorspar occurs in hydrothermal vein deposits.

Host Minerals: Fluorspar is a halide mineral with the chemical formula CaF_2.

Total World Production 2021: Worldwide production of fluorspar in 2021 was approximately 8.6 million tonnes.

Notable Ontario Localities: Most of Ontario's historical fluorspar production occurred from deposits in the Madoc area of Hastings County. Some production also occurred near Harcourt in Haliburton County.

How Is Fluorspar Used?

Fluorspar is used directly or indirectly to manufacture a variety of products, such as aluminum, gasoline, insulating foams, refrigerants, steel, uranium fuel, cement production, enamels, steelmaking flux, glass manufacturing, iron and steel casting, and welding rod coatings.

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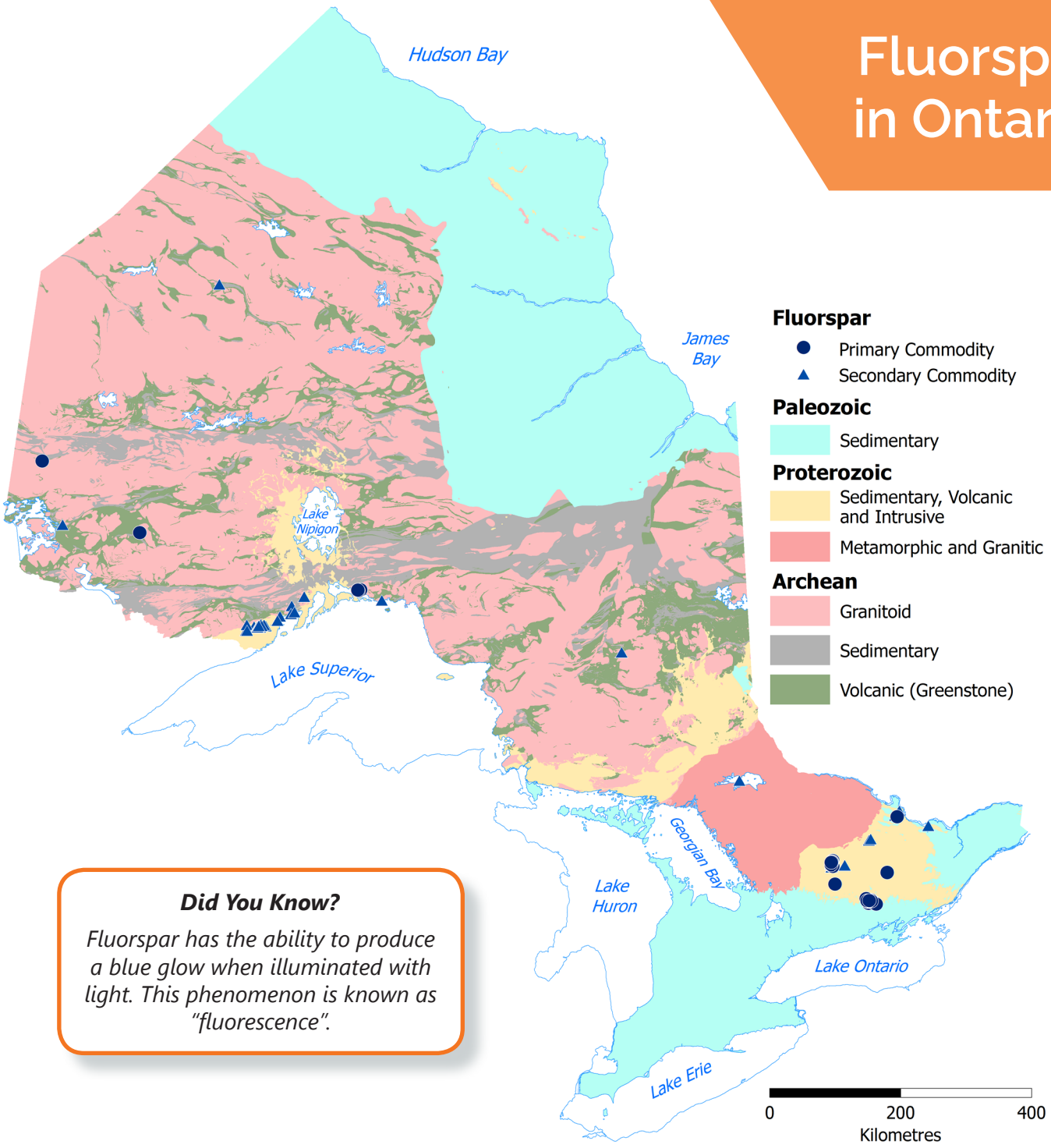
Fluorspar in Ontario



Did You Know?

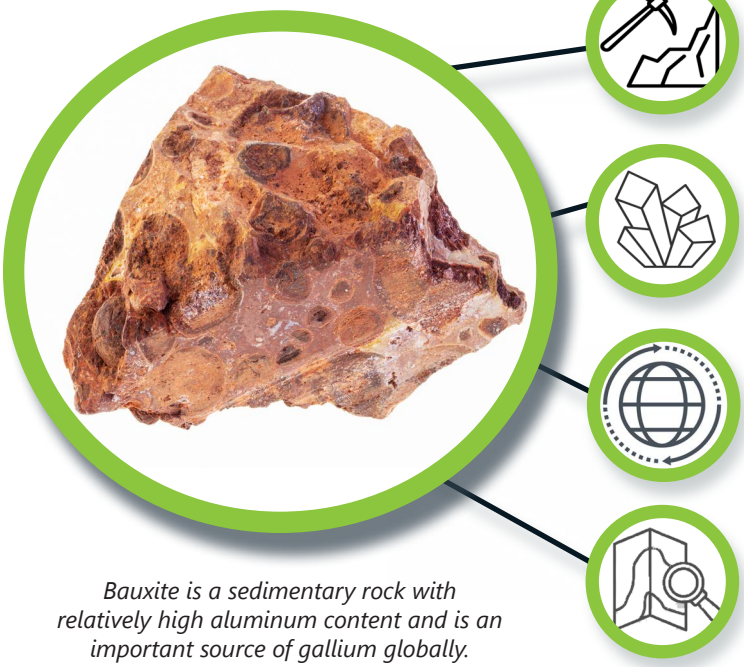
Fluorspar has the ability to produce a blue glow when illuminated with light. This phenomenon is known as "fluorescence".

Several small-scale vein-hosted deposits in southern Ontario produced 144,535 tons of fluorspar between 1905 and 1961.

Ga
Ge

GALLIUM & GERMANIUM

Gallium – is a silvery, soft metal that does not occur as a free element in nature, but occurs as gallium compounds in trace amounts in zinc ores. **Germanium** – is a greyish white, lustrous, hard and brittle metalloid. Gallium and germanium occur in Ontario as secondary commodities.



Bauxite is a sedimentary rock with relatively high aluminum content and is an important source of gallium globally.

Geological Environment and Sources: In Ontario, gallium and germanium can be associated with zinc ore, which has primarily been mined from volcanogenic massive sulphide (VMS) deposits.

Host Minerals: In Ontario, gallium and germanium can occur as a minor constituent of zinc sulphide minerals (e.g., sphalerite).

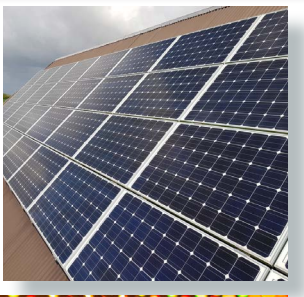
Total World Production 2021: Worldwide production in 2021 was 430 tonnes gallium and 140 tonnes germanium.

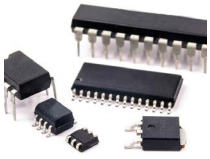
Notable Ontario Locality: Little data are available about the occurrence of gallium and germanium in Ontario.

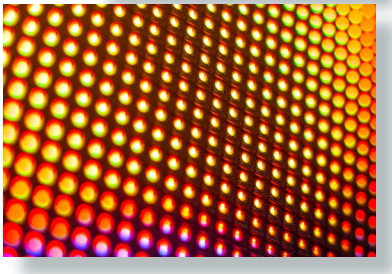
How Are Gallium and Germanium Used?

Gallium arsenides (GaAs) are used in laser diodes, light-emitting diodes (LEDs), photo detectors, solar cells, specialized integrated circuits, semiconductors and transistors (computers, smart phones). Gallium nitride (GaN) is used principally in the manufacture of LEDs and laser diodes, power electronics and radio-frequency electronics.

Germanium is used in electronic devices, flat-panel display screens, LEDs, night-vision devices, optical fibres, optical lens systems and solar power arrays.







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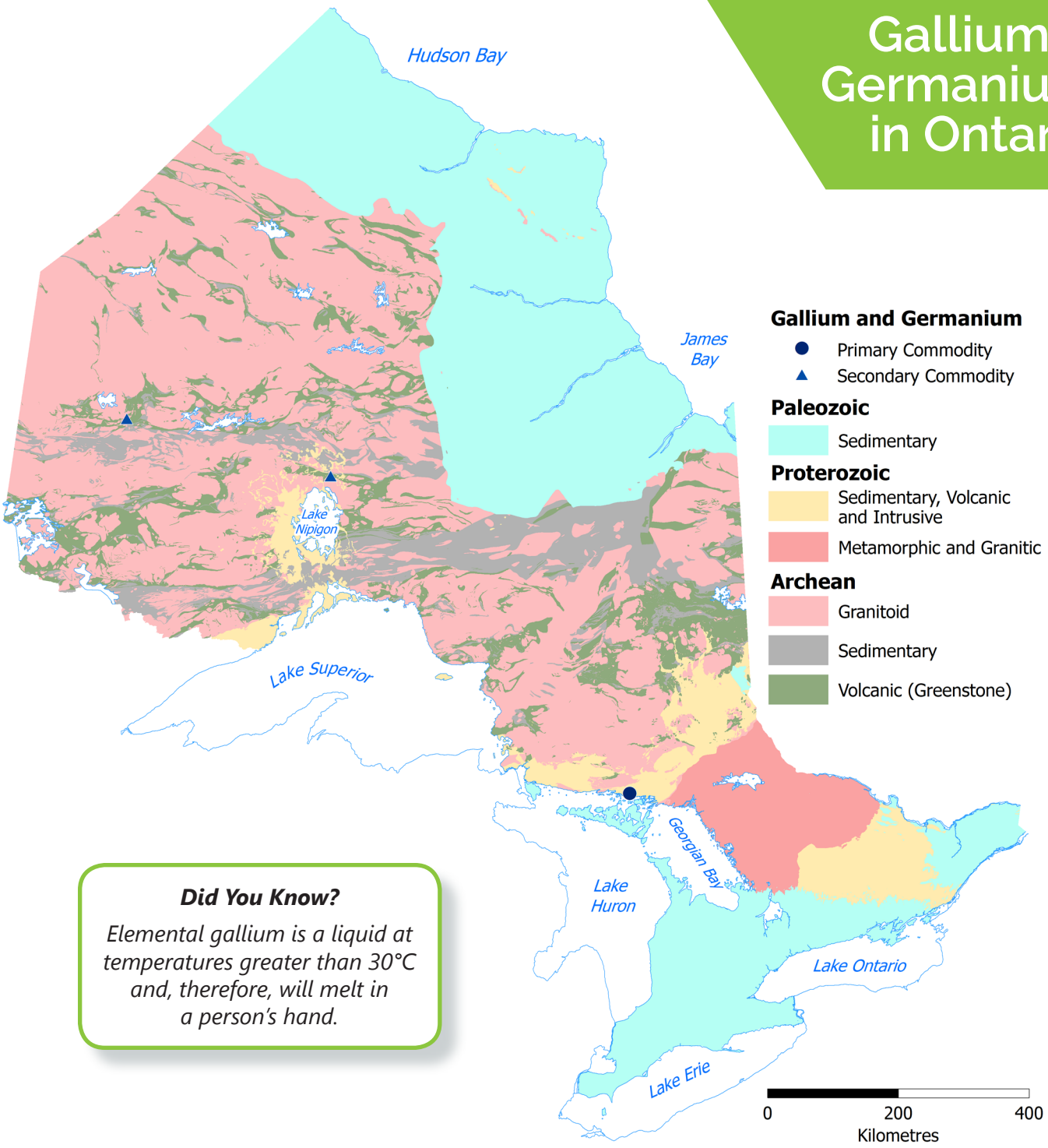
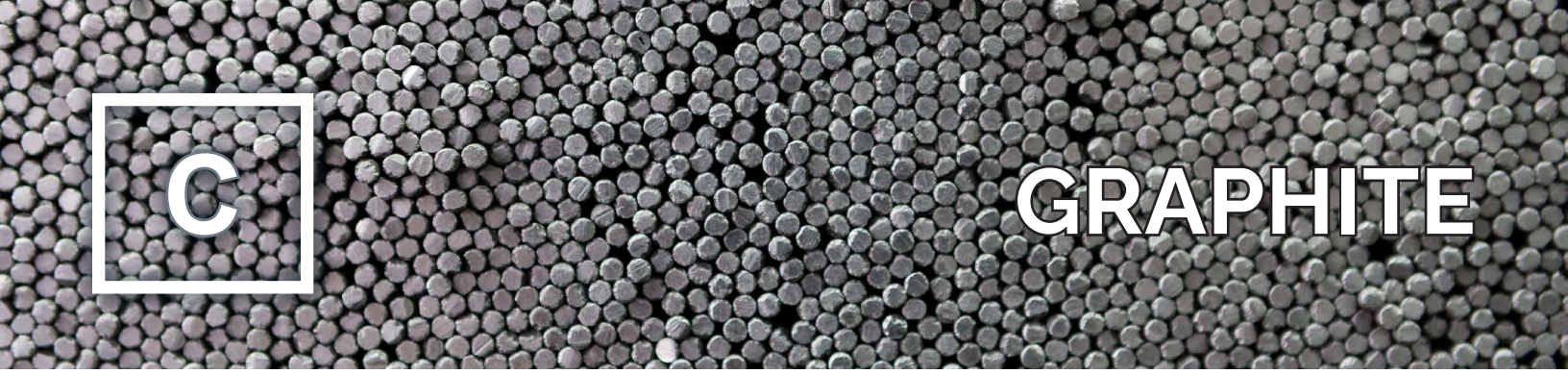
Gallium & Germanium in Ontario



Did You Know?

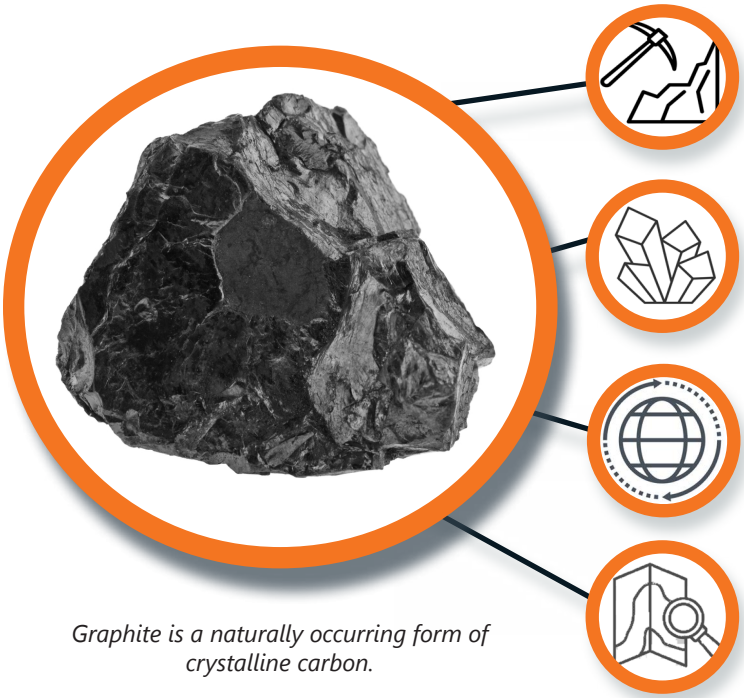
Elemental gallium is a liquid at temperatures greater than 30°C and, therefore, will melt in a person's hand.

No resources or production.



C GRAPHITE

Graphite – is a crystalline form of the element carbon that occurs as isolated, plate-like structures with hexagonal edges. Graphite occurs in Ontario as both primary and secondary commodities.



Graphite is a naturally occurring form of crystalline carbon.

Geological Environment and Sources: In Ontario, graphite occurs in metamorphic environments and in breccia pipes.

Host Minerals: Graphite occurs naturally in Ontario.

Total World Production 2021: Worldwide production of graphite in 2021 was 1 million tonnes.

Notable Ontario Localities: Hearst (Albany Graphite), Bisset Creek.

How Is Graphite Used?

Graphite is used in batteries, fuel cells, brake linings, lubricants, powdered metals, refractory applications and steelmaking.

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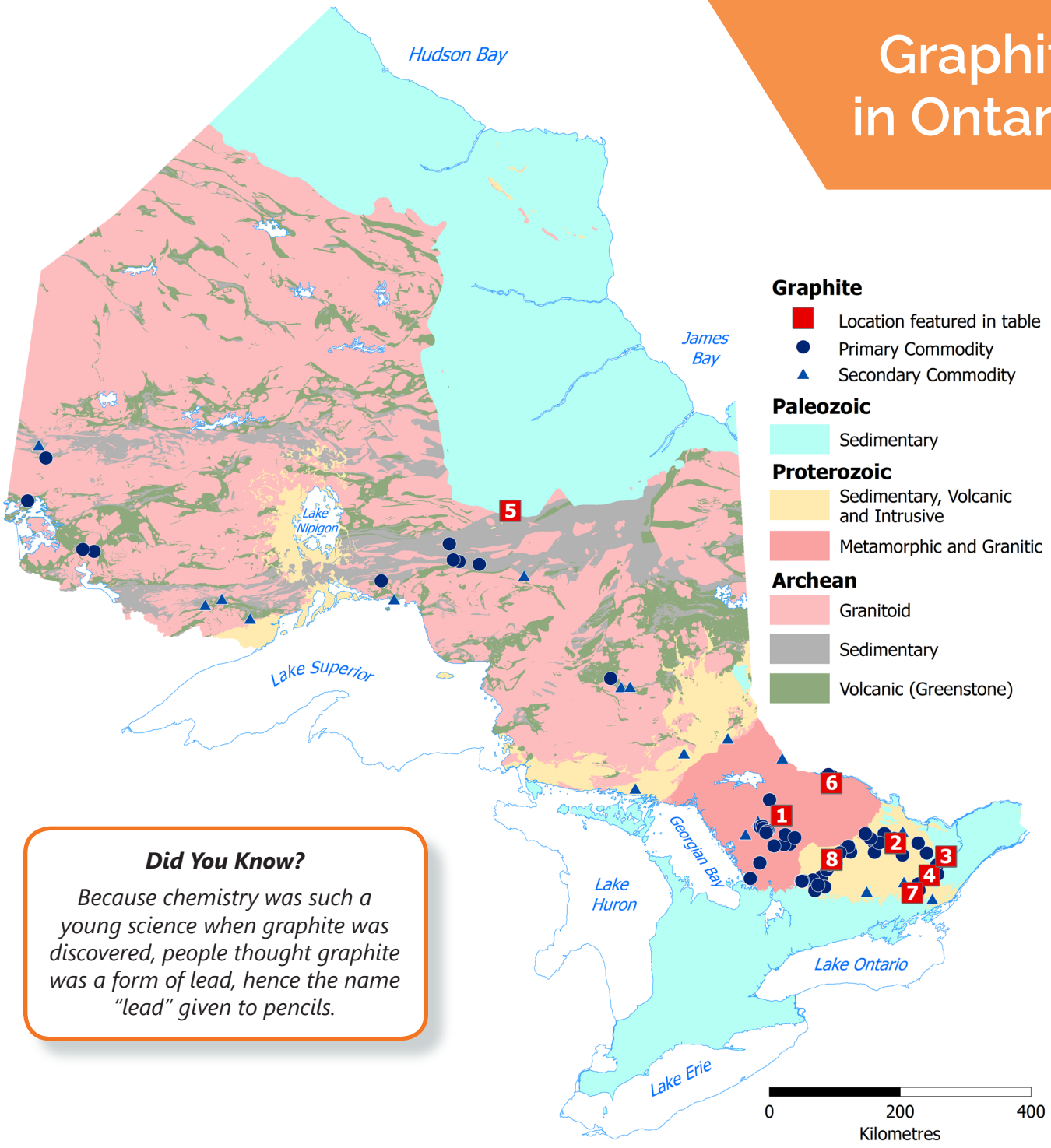
Graphite in Ontario



Did You Know?

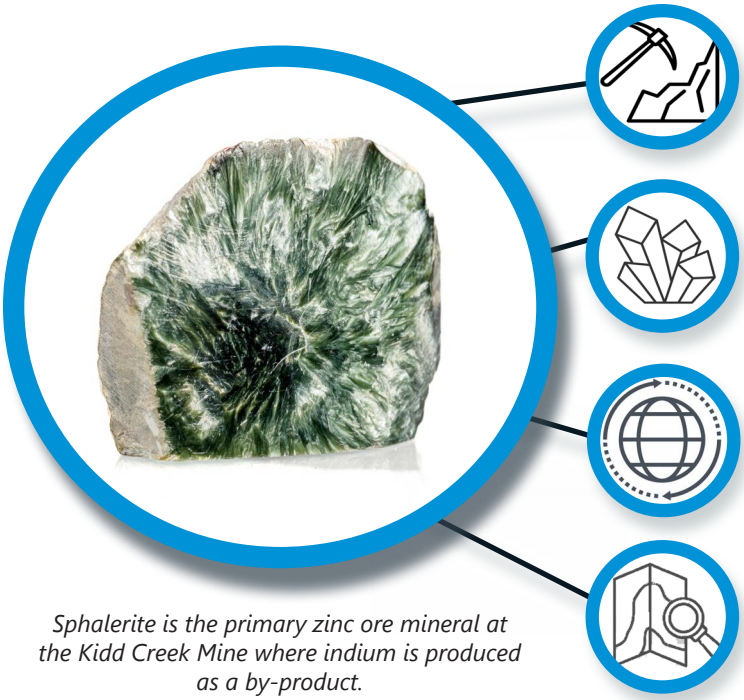
Because chemistry was such a young science when graphite was discovered, people thought graphite was a form of lead, hence the name "lead" given to pencils.

Location	Name	Resources and Past Production (Mt = million tonnes; t = tonne)
1	Kearney graphite mine	Indicated: 51.5 Mt @ 2.0% Cg; Inferred: 46.8 Mt @ 2.0% Cg*
2a	Black Donald Mine	Past Production (1896–1954): 77,259 t graphite
2b	Beidelman–Lyall	Historical: 525,000 t @ 8% Cg
3a	Globe graphite mine	Historical: 50,000 t @ 7% Cg
3b	Portland graphite	Historical: 295,000 t @ 6% Cg
3c	Meadow Lake zone	Historical: 1.70 Mt @ 3.44% Cg
4	N.A. Timmins Mine	Historical: 1.0 Mt @ 8% Cg
5	Albany graphite deposit	Indicated: 24.3 Mt @ 3.98% Cg; Inferred: 16.9 Mt @ 2.64% Cg
6	Bissett Creek	Measured & Indicated: 69.8 Mt @ 1.74% Cg; Inferred: 24.0 Mt @ 1.65% Cg
7	Stewart Lake	Historical: 1.48 Mt @ 9.5% Cg
8	National Graphite Ltd.	Historical: 1.4 Mt @ 4.1% Cg

** "Cg" is a calculated value: graphite as carbon = total carbon less the amount of carbon present as CO_2.*

In INDIUM

Indium – is a silvery white, post-transition metal. Indium is a by-product of zinc ore processing. Indium occurs in Ontario as a secondary commodity.



Sphalerite is the primary zinc ore mineral at the Kidd Creek Mine where indium is produced as a by-product.

Geological Environment and Sources: In Ontario, indium occurs in volcanogenic massive sulphide (VMS) deposits.

Host Minerals: Indium is found in Ontario mainly in association with sphalerite or as an impurity.

Total World Production 2021: Worldwide production of indium in 2021 was 920 tonnes.

Notable Ontario Locality: Timmins (Kidd Creek).

How Is Indium Used?

Indium is used in fusible alloys, solders, electronics, liquid-crystal displays (LCDs), fire sprinkler systems, heat regulators and thin-film applications. Indium wire is used as a vacuum seal and thermal conductor in cryogenics and ultra-high vacuum applications.

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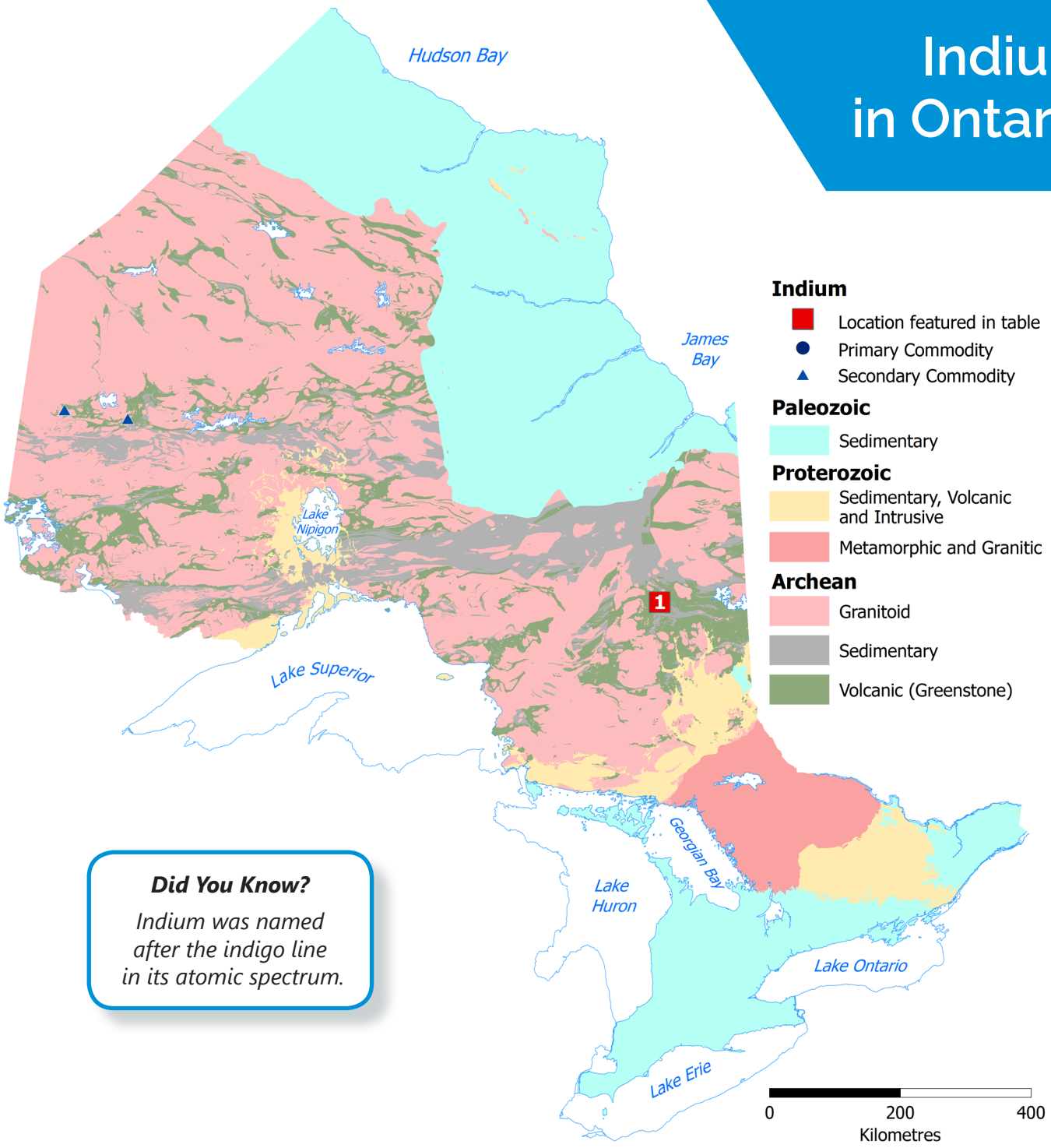
Indium in Ontario



Did You Know?

Indium was named after the indigo line in its atomic spectrum.

Location	Name	Resources (Mt = million tonnes; t = tonne)
1	Kidd Creek Mine	Indium is produced as a by-product

Li LITHIUM

Lithium – is a silvery white to grey alkali metal and does not occur in elemental form in nature because of its reactivity. Lithium occurs in Ontario as both primary and secondary commodities.

Lepidolite is the most abundant lithium-bearing mineral.

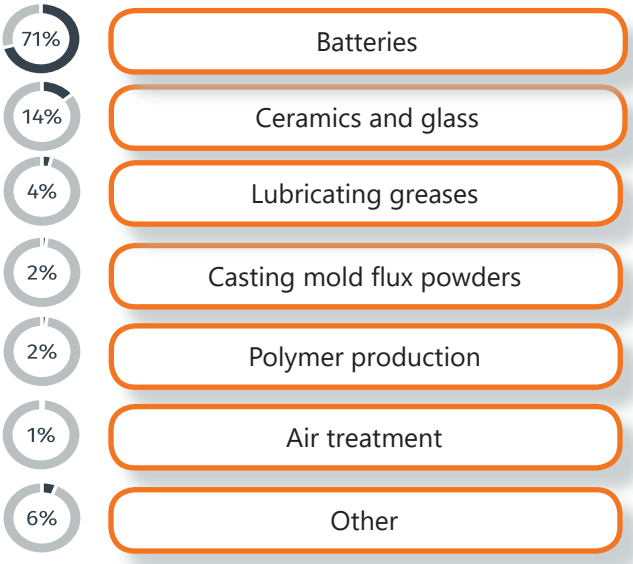
Geological Environment and Sources: In Ontario, lithium deposits occur in rare-element pegmatites.

Host Minerals: Lithium is found in Ontario mainly as spodumene, petalite and lepidolite.

Total World Production 2021: Worldwide production of lithium in 2021 was 100,000 tonnes.

Notable Ontario Deposits: Separation Rapids, Pakeagama Lake, Georgia Lake (Nama, Vegan, etc.), Seymour Lake (North and South Aubry).

How Is Lithium Used?



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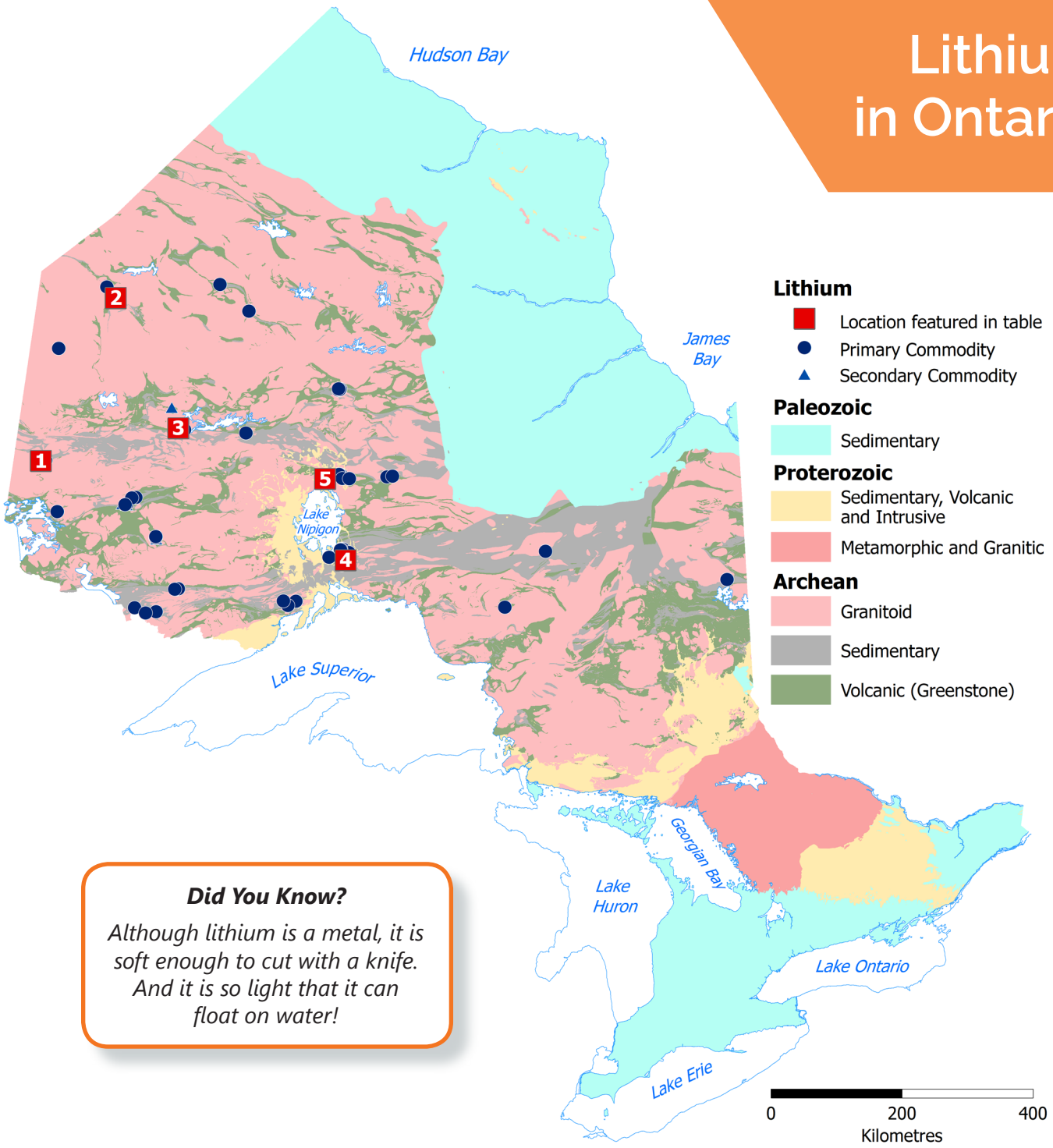
Lithium in Ontario



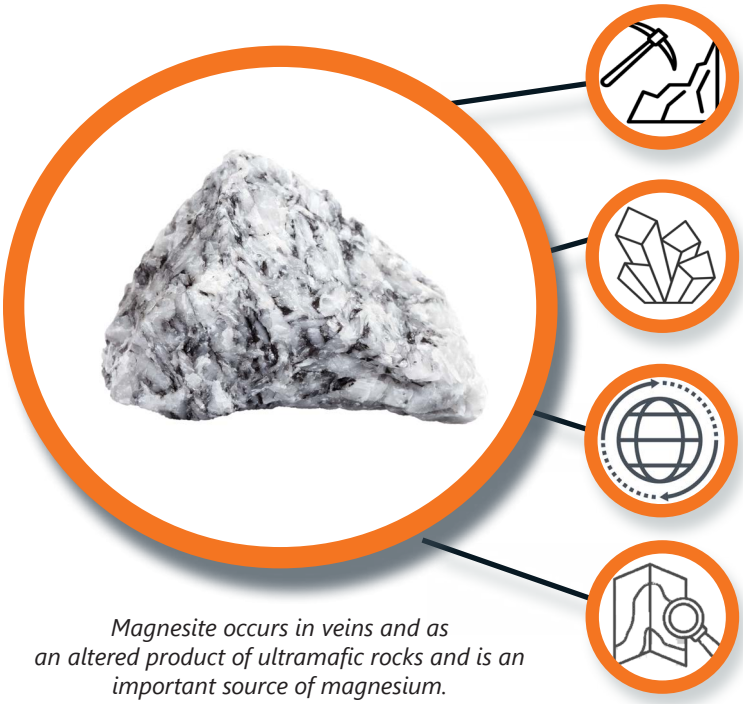
Did You Know?

Although lithium is a metal, it is soft enough to cut with a knife. And it is so light that it can float on water!

Location	Name	Resources (Mt = million tonnes; t = tonne)
1	Separation Rapids	Measured & Indicated: 8.40 Mt @ 1.408% Li_2O + 3 additional oxides; Inferred: 1.79 Mt @ 1.349% Li_2O + 3 additional oxides
2a	Spark pegmatite	Indicated: 14.414 Mt @ 1.40% Li_2O; Inferred: 18.118 Mt @ 1.37% Li_2O
2b	Pakeagama Lake pegmatite	Measured & Indicated: 5.964 Mt @ 1.81% Li_2O + 3 additional oxides; Inferred: 0.68 Mt @ 1.75% Li_2O + 3 additional oxides
3	McCombe	Historical: 1.3 Mt @ 1.3% Li_2O
4a	Nama	Indicated: 4.18 Mt @ 1.01% Li_2O; Inferred: 6.31 Mt @ 1.0% Li_2O
4b	Vegan	Historical: 750,000 t @ 1.38% Li_2O
4c	Jackpot	Historical: 2 Mt @ 1.09% Li_2O
4d	Jean Lake	Historical: 1.689 Mt @ 1.30% Li_2O
4e	Aumacho	Historical: 759,475 t @ 1.65% Li_2O
5a	North Aubry	Indicated: 2.13 Mt @ 1.29% Li_2O + 1 additional oxide; Inferred: 1.7 Mt @ 1.5% Li_2O + 1 additional element
5b	South Aubry	Inferred: 1.0 Mt @ 0.8% Li_2O

Mg MAGNESIUM

Magnesium – is a silvery white alkaline-earth metal. Magnesium is used as a metal or as a constituent in a number of compounds, such as magnesium oxide. Magnesium occurs in Ontario as both primary and secondary commodities.



Magnesite occurs in veins and as an altered product of ultramafic rocks and is an important source of magnesium.

Geological Environment and Sources: In Ontario, magnesium occurs in ultramafic rock–hosted and marble-hosted deposits.

Host Minerals: Magnesium is found in Ontario mainly as dolomite, magnesite, brucite, carnallite and olivine.

Total World Production 2021: Worldwide production of magnesium in 2021 was 950,000 tonnes.

Notable Ontario Localities: Timmins (talc-magnesite deposits), Renfrew (Timminco Metals).

How Is Magnesium Used?

Magnesium metal is primarily used for castings, automotive parts, desulphurization of iron and steel, and aluminum-based alloys.

Magnesium compounds (MgO) are used in agricultural, chemical, construction, de-icing, environmental and industrial applications.

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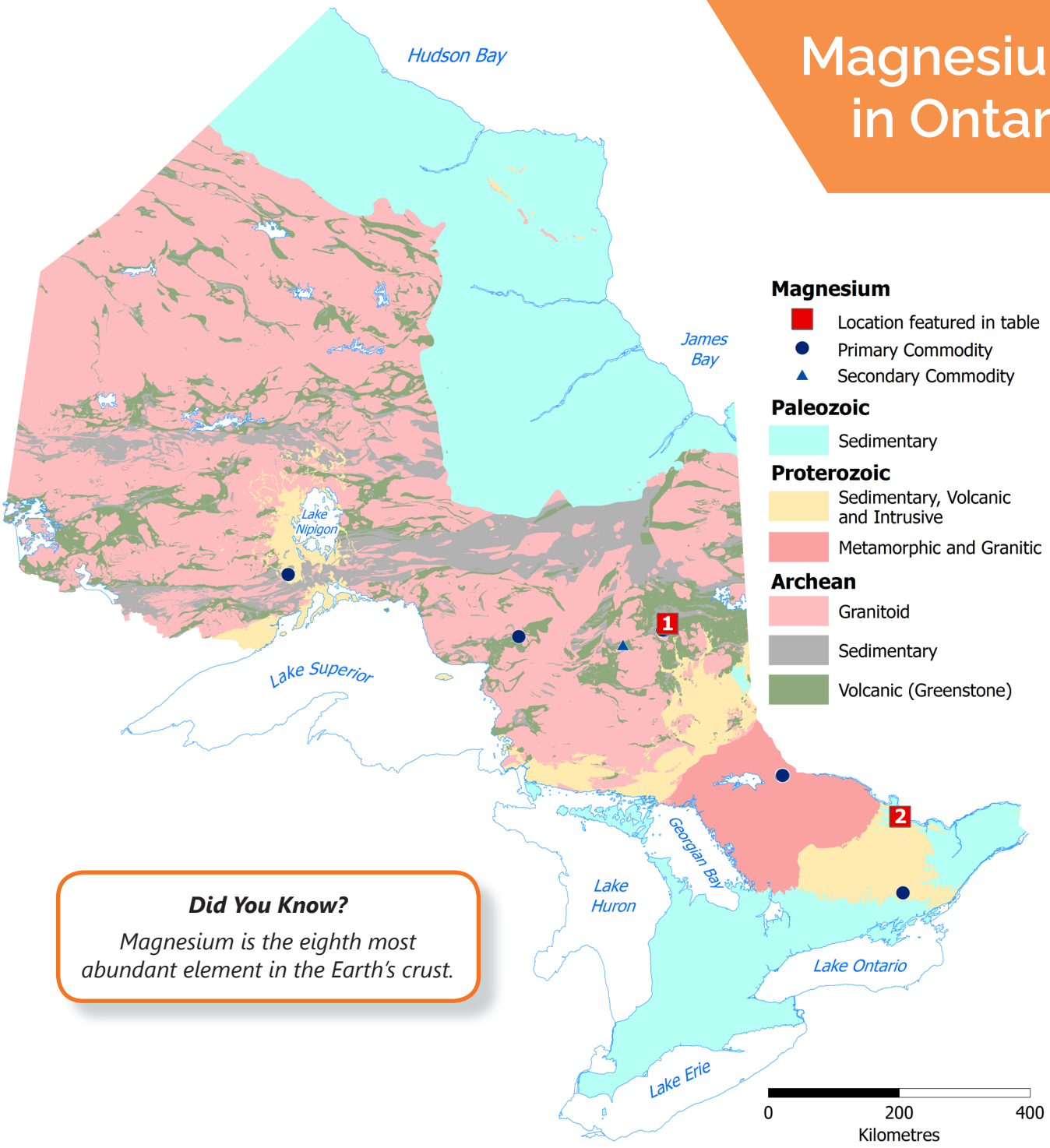
Magnesium in Ontario



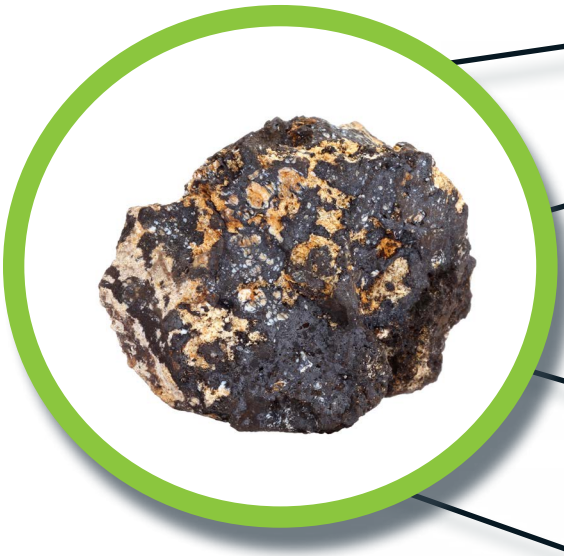
Did You Know?

Magnesium is the eighth most abundant element in the Earth's crust.

Location	Name	Resources and Past Production (Mt = million tonnes)
1a	Timmins talc-magnesite property	Indicated: 12.728 Mt @ 20% soluble MgO; Inferred: 18.778 Mt @ 20.9% soluble MgO
1b	Whitney talc-magnesite south zone	Measured & Indicated: 54.076 Mt @ 34.43% magnesite; Inferred: 43 Mt @ 34% magnesite
1c	Whitney talc-magnesite north zone	Historical: 6.3 Mt @ 33.3% MgO
2	Timminco Metals	Past Production (1941–1980): 475,056,312 pounds magnesium metal

Mn MANGANESE

Manganese – is a silvery, hard and brittle metal commonly found in combination with iron. Manganese is essential and irreplaceable in steelmaking. Manganese occurs in Ontario as both primary and secondary commodities.



Pyrolusite is a mineral consisting of manganese dioxide and is an important source of manganese.

Geological Environment and Sources: In Ontario, manganese occurs as a minor constituent of some iron deposits, and has been found in hydrothermal veins.

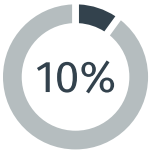
Host Minerals: Manganese is found in Ontario mainly as manganite and as pyrolusite.

Total World Production 2021: Worldwide production of manganese in 2021 was 20 million tonnes.

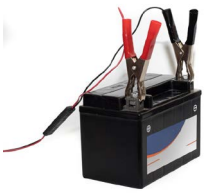
Notable Ontario Localities: Kapuskasing area (Clay–Howells). Manganese was also present as a minor constituent of the ore zone at the past-producing Steep Rock Iron Mine in Atikokan.

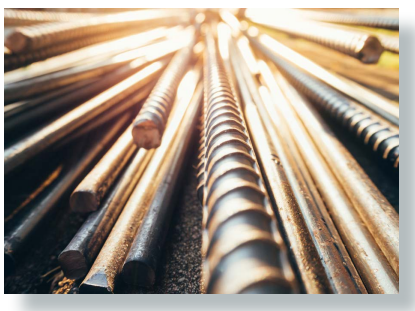
How Is Manganese Used?

As much as 90% of **manganese** consumption is accounted for by the steel industry. Manganese is a purifying agent in iron-ore refining and is an essential alloy that helps to convert iron into steel.



Other important non-metallurgical uses include battery cathodes and electronics.





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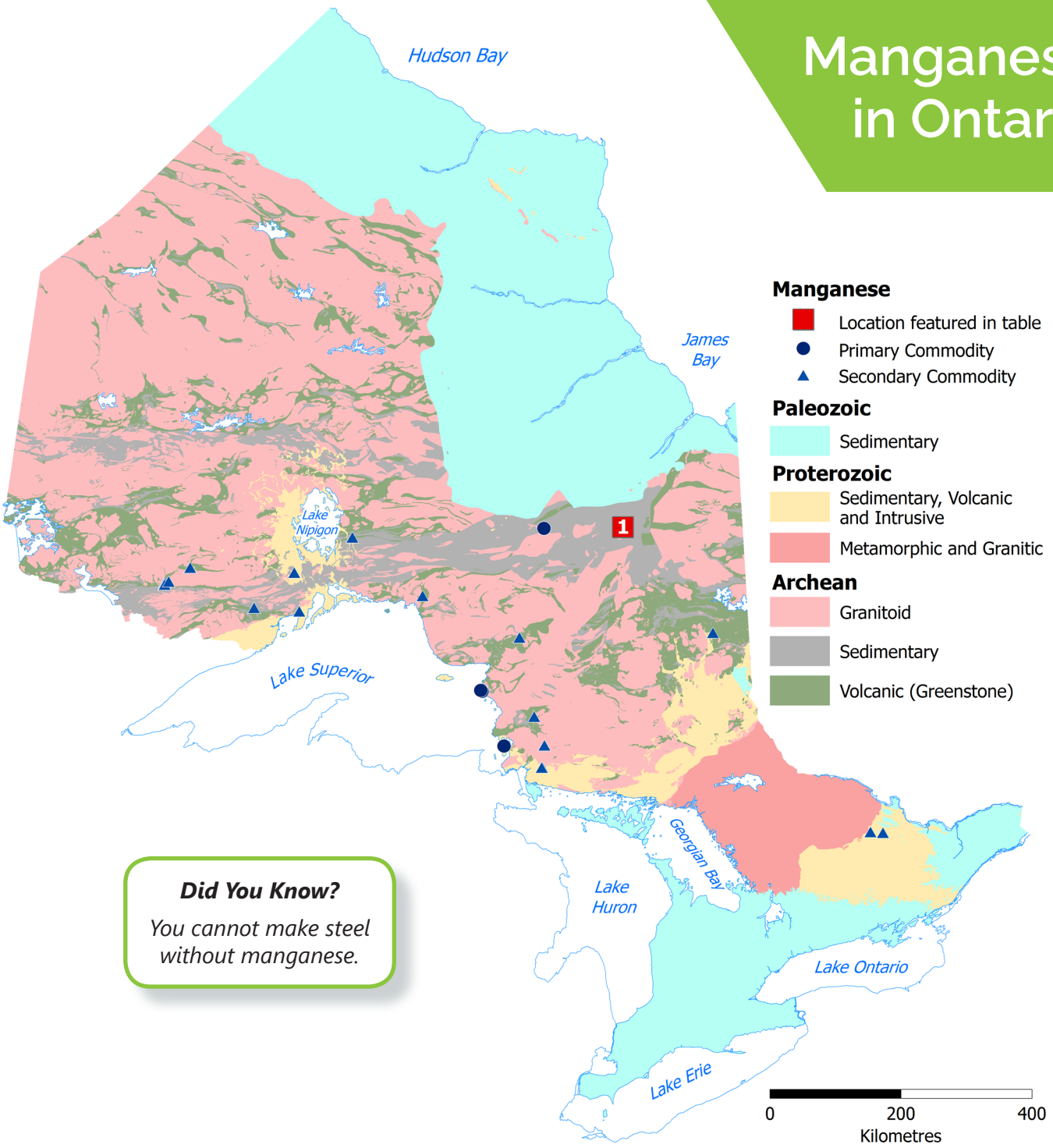
Manganese in Ontario



Did You Know?

You cannot make steel without manganese.

Location	Name	Resources (Mt = million tonnes)
1	Clay–Howells	Inferred: 8.477 Mt @ 2.20% MnO + 4 additional oxides

Mo MOLYBDENUM

Molybdenum – is a silvery grey transition metal. Molybdenite is a mineral composed of molybdenum and sulphur, with a chemical composition of MoS_2. Molybdenum occurs in Ontario as both primary and secondary commodities.

Molybdenite is a mineral of molybdenum disulphide and is an important source of molybdenum.

Geological Environment and Sources: In Ontario, molybdenum occurs in pegmatites, and in porphyry-type deposits.

Host Minerals: Molybdenum is found in Ontario mainly as molybdenite.

Total World Production 2021: Worldwide production of molybdenum in 2021 was 300,000 tonnes.

Notable Ontario Localities: Lake Nipigon area (Kilometre 61), Favourable Lake area (Setting Net Lake deposit).

How Is Molybdenum Used?

Molybdenum can withstand extreme temperatures, making it useful in aircraft parts, electrical contacts, industrial motors, supports for filaments in light bulbs, stainless steel, tool steel, cast iron and high-temperature superalloys. Finely ground molybdenite is used as a solid lubricant to reduce friction between sliding metal parts.

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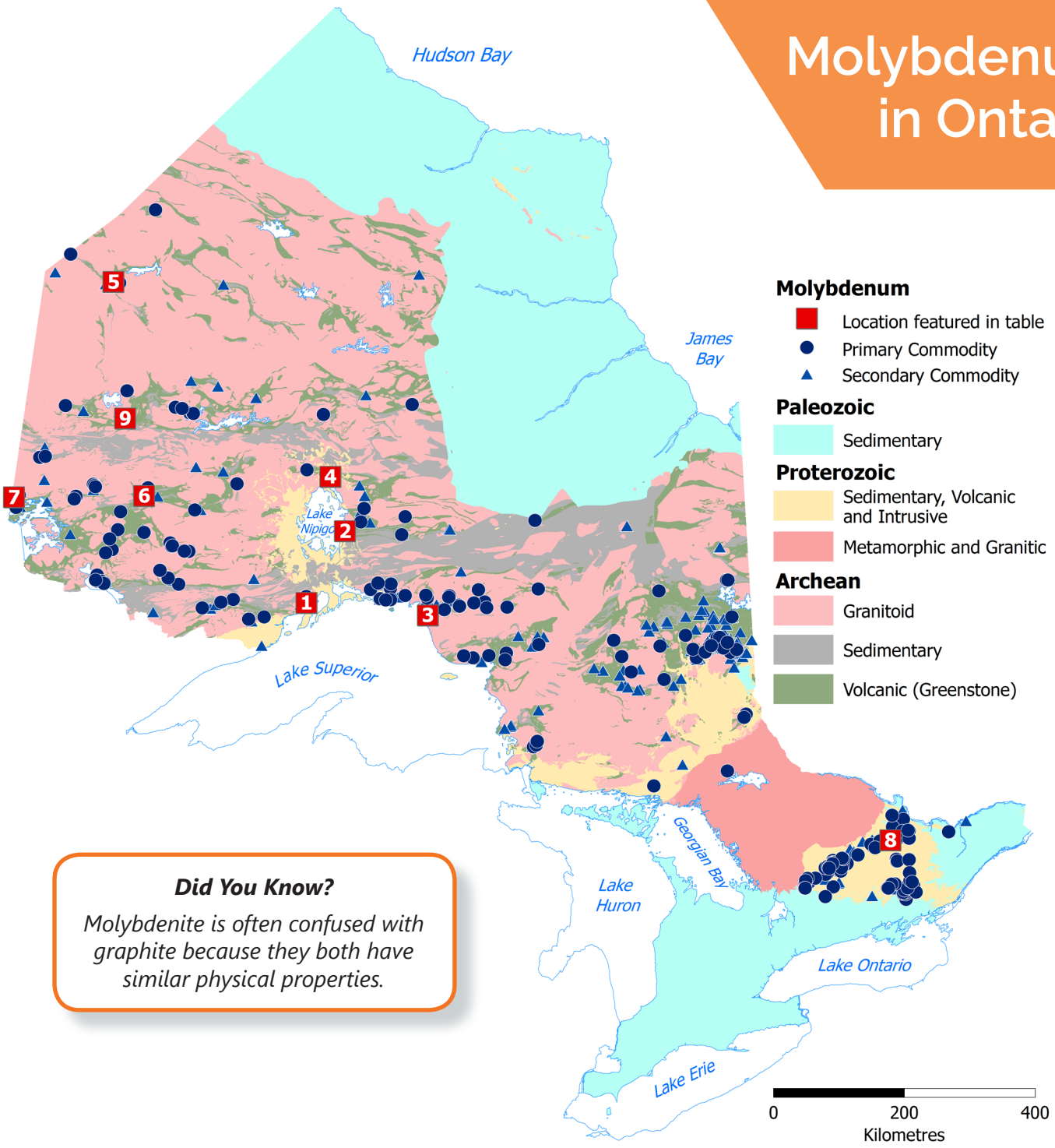
Molybdenum in Ontario



Did You Know?

Molybdenite is often confused with graphite because they both have similar physical properties.

Location	Name	Resources (Mt = million tonnes; t = tonne)
1	Anderson Lake	Historical: 1.346 Mt molybdenum-bearing rock
2	Nortoba–Tyson prospect	Historical: 72,000 t @ 2% MoS_2
3	Playter molybdenum-rhenium	Inferred: 874,410 t @ 0.25% MoS_2
4	Kilometre 61	Indicated: 66.6 Mt @ 0.05% MoS_2; Inferred: 38.9 Mt @ 0.05% MoS_2
5	Setting Net Lake	Historical: 101.6 Mt @ 0.09% MoS_2
6	Pidgeon molybdenum	Indicated: 2.657 Mt @ 0.117% MoS_2; Inferred: 12.391 Mt @ 0.083% MoS_2
7	High Lake–Evenlode	Historical: 200,000 t @ 0.63% MoS_2
8	Spain Mine	Historical: 18,140 t @ 1% MoS_2
9	Copperlode property	Historical: 100 t @ 0.84–2.52% MoS_2

Ni NICKEL

Nickel – is a silvery white, lustrous, hard transition metal with a slight golden tinge. Native nickel is always found in combination with iron. Nickel occurs in Ontario as both primary and secondary commodities.

Pentlandite is an iron-nickel sulphide mineral and is an important source of nickel.

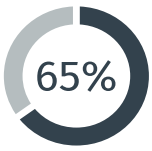
Geological Environment and Sources: In Ontario, nickel occurs in magmatic sulphide ore deposits hosted by mafic to ultramafic rocks.

Host Minerals: Nickel is found in Ontario mainly as pentlandite.

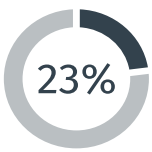
Total World Production 2021: Worldwide production of nickel in 2021 was 2.7 million tonnes.

Notable Ontario Deposits: Sudbury, McFaulds Lake area ("Ring of Fire") (Eagle's Nest).

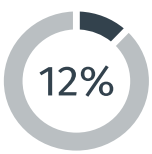
How Is Nickel Used?



Stainless steel



Metal alloys, coinage, electroplating, rechargeable batteries, non-ferrous alloys and superalloys



Other uses, including catalysts and chemicals

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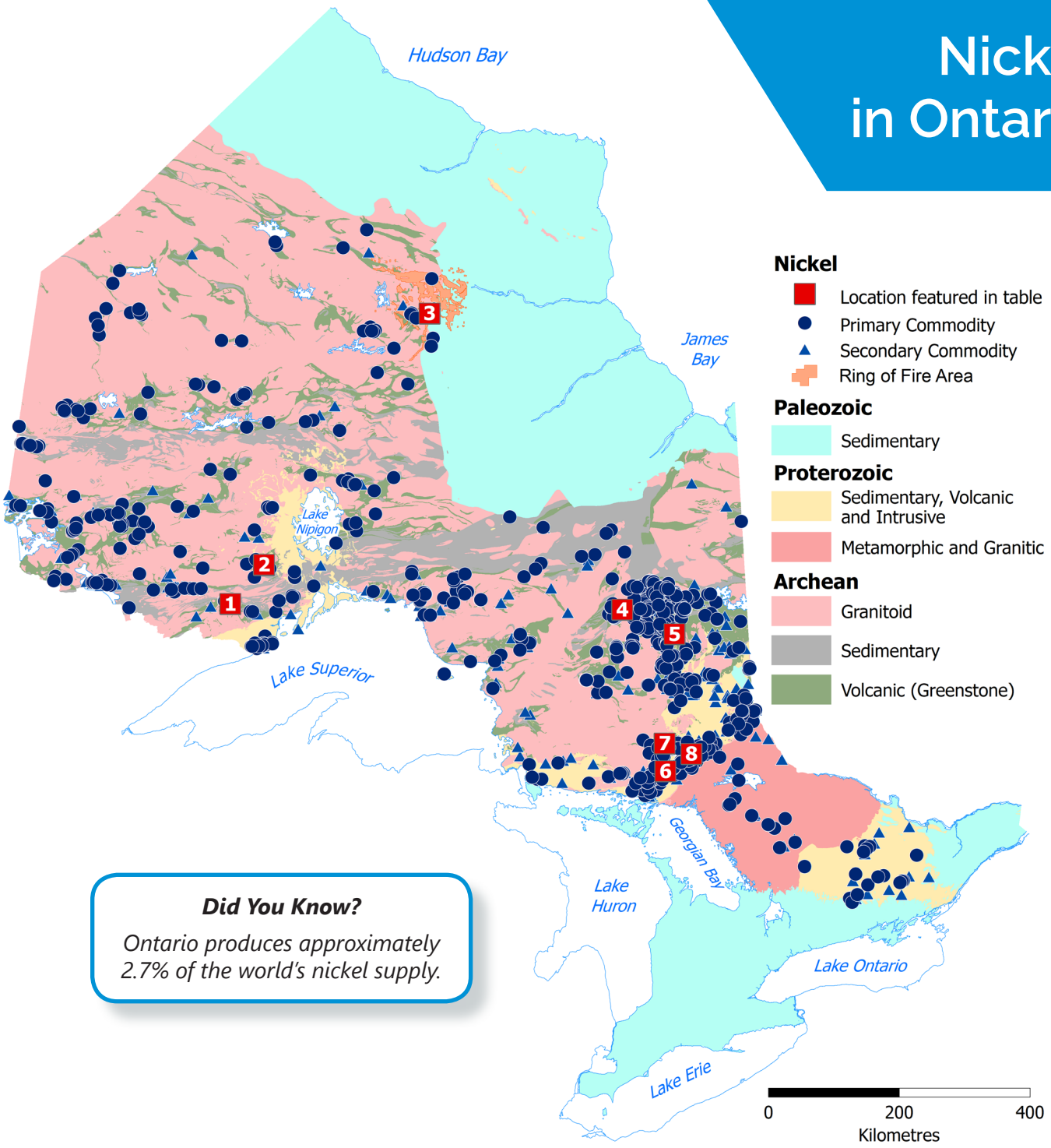
Nickel in Ontario



Did You Know?

Ontario produces approximately 2.7% of the world's nickel supply.

Location	Name	Resources, Production and Past Production (kg = kilogram; Mt = million tonnes)
1	Shebandowan Mine	Past Production (1967–1998): 162,575,000 kg Ni
2	Lac des Iles Mine	Production (since 1993): 16,973,182 kg Ni as a by-product of PGE production
3	Eagle's Nest	Proven & Probable: 11.131 Mt @ 1.68% Ni + 3 other commodities; Measured & Indicated: 11 Mt @ 1.78% Ni + 3 other commodities
4	Montcalm Mine	Past Production (2006–2009): 51,333,000 kg Ni
5	McWatters Mine	Past Production (2008–2011): 17,466,477 kg Ni
6a	Crean Hill Mine	Past Production (1905–2002): 195,200,000 kg Ni
6b	Lockerby Mine	Past Production (1970–2015): 17,568,000 kg Ni
7	Whistle Mine	Past Production (1988–1997): 54,245,000 kg Ni
8	Sudbury	Production (since 1883): 11.3 billion kg Ni from the Sudbury camp. Glencore: Proven & Probable: 28.2 Mt @ 2.21% Ni + 4 other commodities; Vale: Proven & Probable: 51.1 Mt @ 1.39% Ni + 5 other commodities

**These only represent current producers and the most significant past producers.*

In 2018, 65,710 tonnes of nickel valued at $1.11 billion were produced in Ontario (37% of Canada's nickel production).

Nb NIOBIUM

Niobium – is a light grey, crystalline and ductile transition metal. Niobium is known to oxidize in the Earth's atmosphere very slowly making it a good hypoallergenic alternative to nickel in jewelry. Niobium occurs in Ontario as both primary and secondary commodities.

Columbite is an ore of niobium.

Geological Environment and Sources: In Ontario, niobium occurs in carbonatite intrusions and rare-element pegmatites.

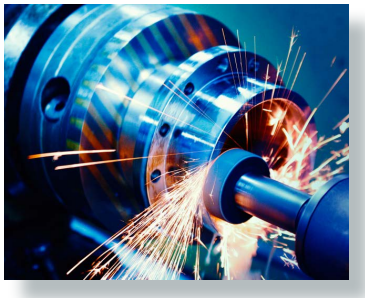
Host Minerals: Niobium is found in Ontario mainly as columbite and pyrochlore.

Total World Production 2021: Worldwide production of niobium in 2021 was 75,000 tonnes.

Notable Ontario Localities: Moosonee (James Bay Niobium), Hearst area (Martison Lake).

How Is Niobium Used?

Niobium is used in electrolytic capacitors in high-technology devices, for example, cell phones, computer hard drives and implantable medical devices. It is also used as an alloying element in steels and in superalloys.



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Niobium in Ontario

Did You Know?

Niobium was originally called columbium.

Location	Name	Resources (Mt = million tonnes; t = tonne)
1	James Bay Niobium project	Indicated: 29.7 Mt @ 0.52% Nb_2O_5; Inferred: 33.8 Mt @ 0.52% Nb_2O_5
2	Martison Lake	Indicated: 63.6 Mt @ 0.51% Nb_2O_5 + 1 additional oxide; Inferred: 89.8 Mt @ 0.45% Nb_2O_5 + 1 additional oxide
3	Clay–Howells	Inferred: 8.477 Mt @ 0.13% Nb_2O_5 + 4 additional oxides
4	Hawke zone	Historical: 8.16 Mt @ 0.482% Nb_2O_5
5a	Newman deposit	Historical: 2.962 Mt @ 0.69% Nb_2O_5 + 2 additional oxides
5b	Big Manitou Island ore zone	Historical: 24,494 t @ 0.38% Nb_2O_5 + 2 additional oxides
6	Prairie Lake carbonatite	Historical: 181,437 t @ 0.25% Nb_2O_5 + 1 additional oxide
7a	Multi-Minerals zones 3 and 4	Historical: 33.6 Mt @ 0.17% Nb_2O_5 + 1 additional commodity
7b	Multi-Minerals zone 8	Historical: 72.5 Mt @ 0.25% Nb_2O_5

P PHOSPHATE

Phosphate – is derived from sedimentary or igneous rocks that are rich in phosphate minerals. Inorganic phosphates are mined to obtain phosphorus for use in agriculture and industry. Phosphate occurs in Ontario as both primary and secondary commodities.

Apatite is the name of a group of phosphate minerals and is an important source of phosphate.

Geological Environment and Sources: In Ontario, phosphate occurs in carbonatite and alkalic intrusions.

Host Minerals: Phosphate is found in Ontario mainly as apatite.

Total World Production 2021: Worldwide production of phosphate in 2021 was 220 million tonnes.

Notable Ontario Localities: Kapuskasing (Kapuskasing Phosphate Operations (closed 2013)), Hearst area (Martison Lake).

How Is Phosphate Used?

Phosphate is used in fertilizers, steel production (phosphor bronze) and industrial chemical manufacturing, such as wet-process phosphoric acid and superphosphoric acid.

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Phosphate in Ontario

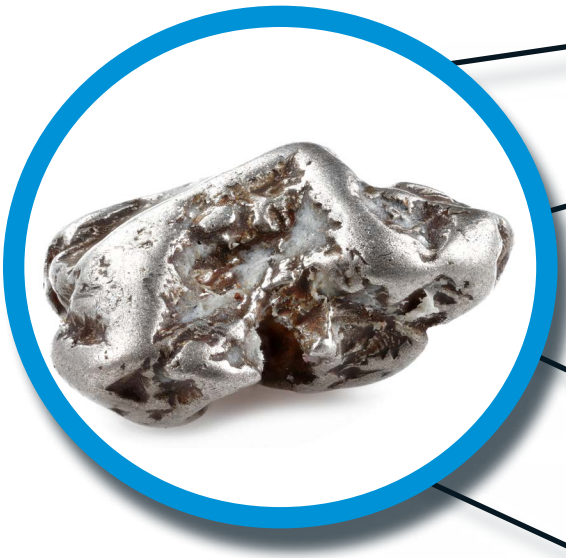
Did You Know?

Phosphates are found in all living organisms.

Location	Name	Resources and Past Production (Mt = million tonnes; t = tonne)
1	Martison Lake	Indicated: 63.6 Mt @ 21.03% P_2O_5 + 1 additional oxide; Inferred: 89.8 Mt @ 18.10% P_2O_5 + 1 additional oxide
2a	Multi-Minerals zone 6	Historical: 3.473 Mt @ 2.65% phosphate + 1 additional oxide
2b	Multi-Minerals zones 3 and 4	Historical: 33.6 Mt @ 21.3% apatite + 1 additional oxide
3	Big Manitou Island ore zone	Historical: 24,494 t @ 10% P_2O_5 + 2 additional oxides
4	Kapuskasing Phosphate Operations	Past Production (2000–2013): 9.899 Mt P_2O_5
5	James Foxton	Past Production (1886–1892): 4,535 t apatite
6	Otter Mine	Past Production (1870–1891): 1,814 t phosphate

Platinum Group Elements

Platinum Group Elements (PGEs) – comprising platinum, palladium, ruthenium, rhodium, osmium and iridium, are part of a subgroup of native metals that have similar physical and chemical properties and tend to occur together. PGEs have many industrial applications. PGEs occur in Ontario as both primary and secondary commodities.



Platinum nugget.

Geological Environment and Sources: In Ontario, PGEs occur in layered and unlayered mafic to ultramafic intrusions.

Host Minerals: PGEs occur in a variety of minerals, including sulphides, tellurides, arsenides, antimonides, bismuthinides, stannides and alloys.

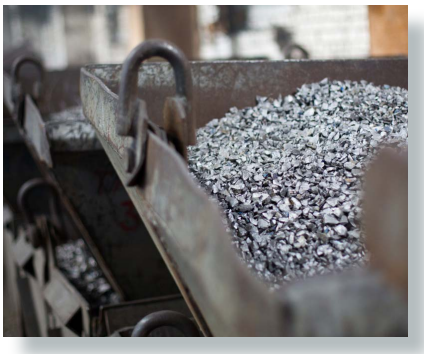
Total World Production 2021: Worldwide production in 2021 was 180,000 tonnes platinum and 200,000 tonnes palladium.

Notable Ontario Deposits: Sudbury, Lac des Iles.

How Are Platinum Group Elements Used?

PGEs are used in catalytic converters to reduce pollution in automobile exhaust (carbon monoxide, hydrocarbon, nitrous oxide), medical implants (e.g., pacemakers).

PGE alloys and catalysts are used by multiple industries in the manufacture and refinement of many products.



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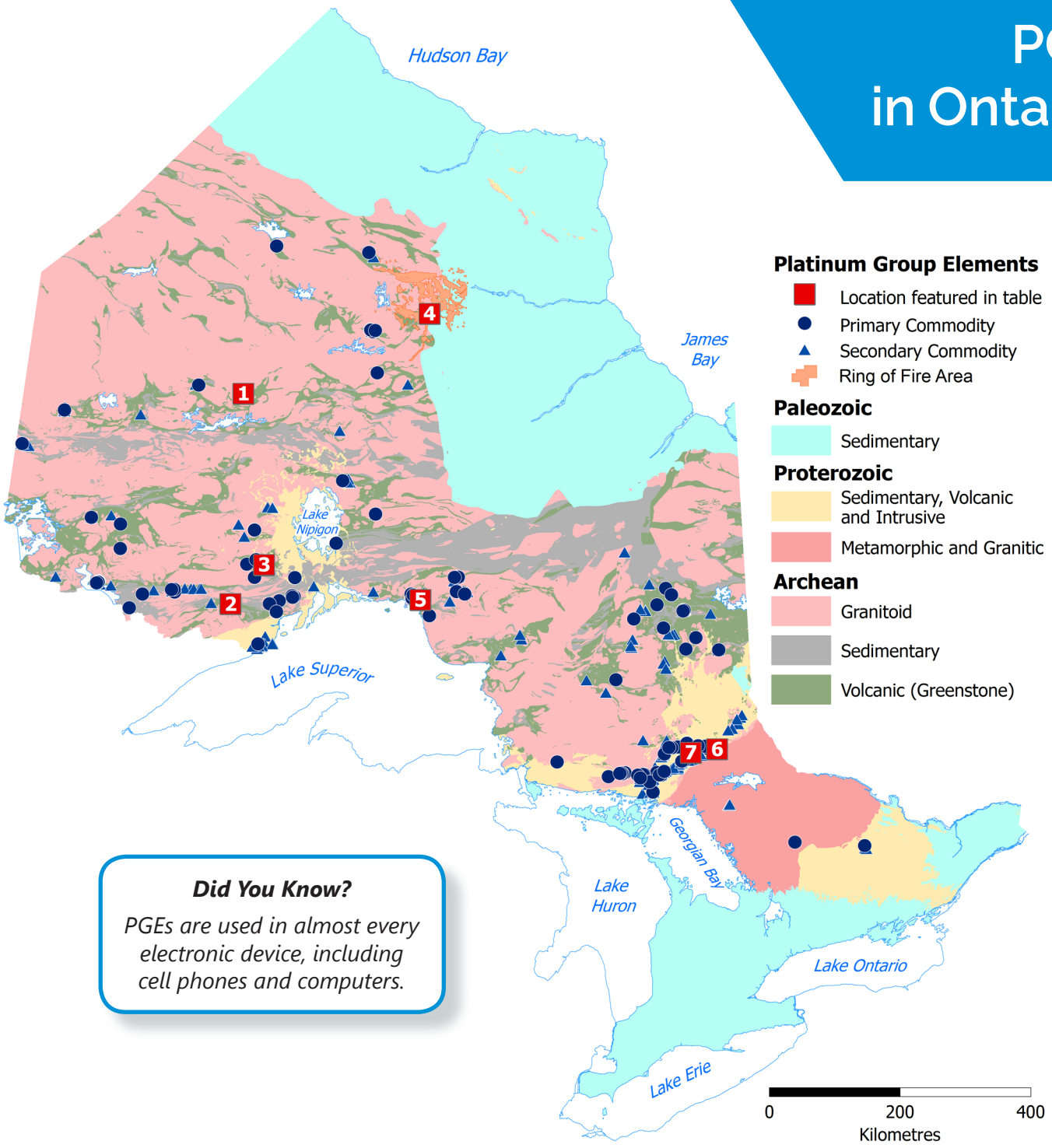
PGE in Ontario



Did You Know?

PGEs are used in almost every electronic device, including cell phones and computers.

Location	Name	Production and Past Production (g/t = gram per tonne; kg = kilogram; Mt = million tonnes)
1	Thierry Mine	Past Production (1976–1982): 1,564 kg PGE
2	Shebandowan Mine	Past Production (1967–1998): 17,000 kg PGE
3	Lac des Iles Mine	Production (since 1990): 118,579 kg Pd, 9,135 kg Pt Proven & Probable: 44.6 Mt @ 1.959 g/t Pd, 0.18 g/t Pt +1 other commodity
4	Eagle's Nest	Proven & Probable: 11.131 Mt @ 0.89 g/t Pt, 3.09 g/t Pd + 2 other commodities Measured & Indicated: 11 Mt @ 3.41 g/t Pd, 0.99 g/t Pt + 2 other commodities
5	Marathon	Proven & Probable: 91.447 Mt @ 0.832 g/t Pd, 0.237 g/t Pt + 3 other commodities Measured & Indicated: 179.2 Mt @ 0.56 g/t Pd, 0.18 g/t Pt + 3 other commodities
6	River Valley	Measured & Indicated: 89.64 Mt @ 0.54 g/t Pd, 0.21 g/t Pt + 6 other commodities Inferred: 94.268 Mt @ 0.35 g/t Pd, 0.16 g/t Pt + 5 other commodities
7	Sudbury	Production (since 1967): 945,209 kg PGE total from the Sudbury camp. Glencore: Proven & Probable: 28.2 Mt @ 0.54 g/t Pt, 0.99 g/t Pd + 3 other commodities; Vale: Proven & Probable: 51.1 Mt @ 1.19 g/t Pt, 1.39 g/t Pd + 4 other commodities

In 2018, 21,363 kg of PGEs were produced in Ontario (74% of Canada's PGE production).

REE Rare Earth Elements

Rare Earth Elements (REEs) – form a group of 15 chemical elements that occur together in the periodic table plus 2 adjacent elements (scandium and yttrium). The REEs are all metals that share similar properties, resulting in these elements being found together in geological deposits. REEs occur in Ontario as both primary and secondary commodities.

Bastnäsite is the most abundant of the minerals that contain REEs.

Geological Environment and Sources: In Ontario, REEs occur in carbonatite and alkalic intrusions.

Host Minerals: REEs are found in Ontario mainly as bastnäsite, monazite and xenotime.

Total World Production 2021: Worldwide production of REEs in 2021 was 280,000 tonnes rare earth oxides.

Notable Ontario Localities: Sturgeon Falls area (Lavergne), Elliot Lake (Eco Ridge), Lackner Lake (Multi-Minerals zone 6), Kapuskasing area (Clay–Howells).

How Are Rare Earth Elements Used?

REEs are used in electric motors of hybrid and electric vehicles, generators in wind turbines, and in fuel cells, nickel-metal hydride batteries, high-performance magnets, alloys, glasses and electronics.

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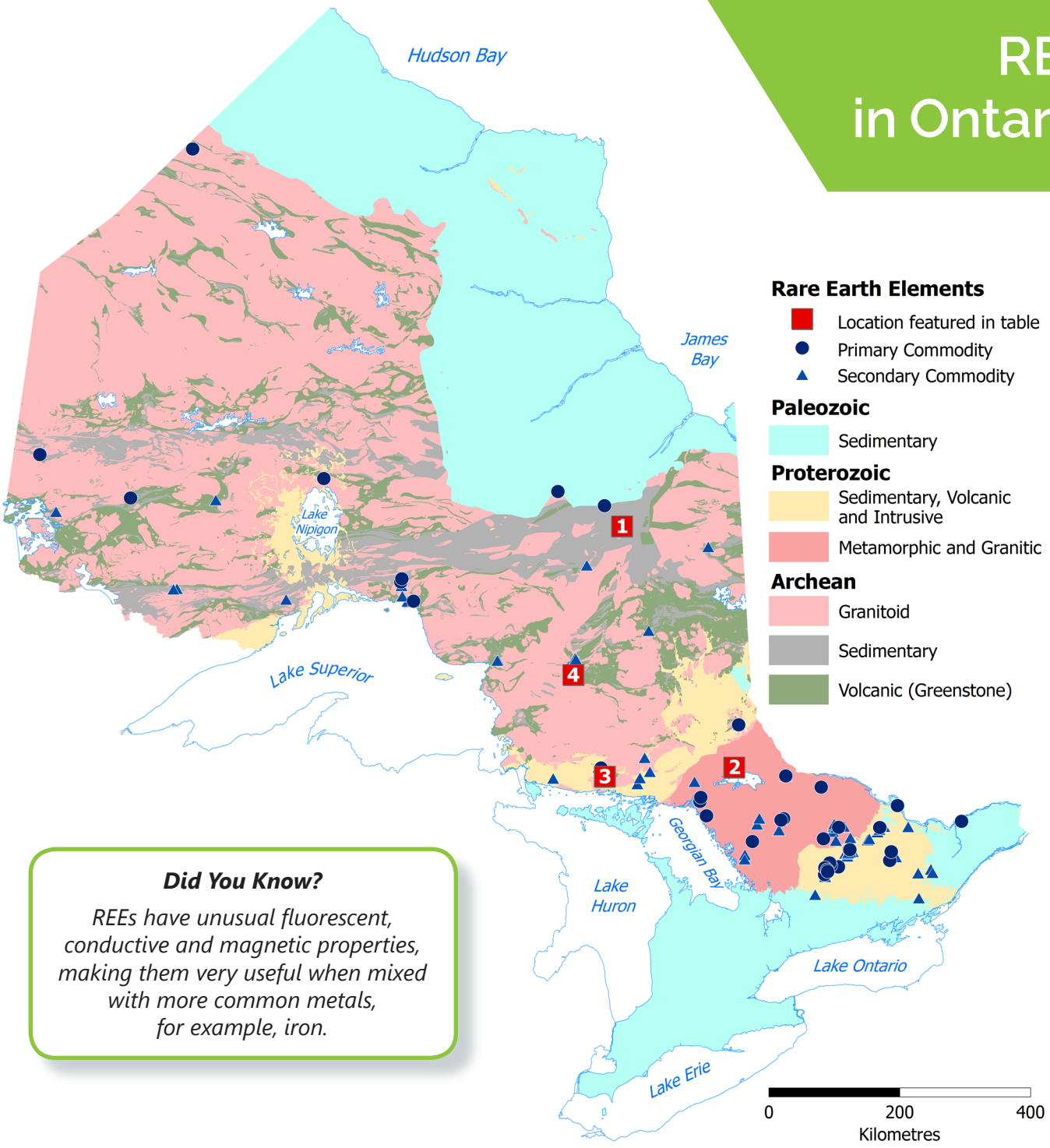
REE in Ontario

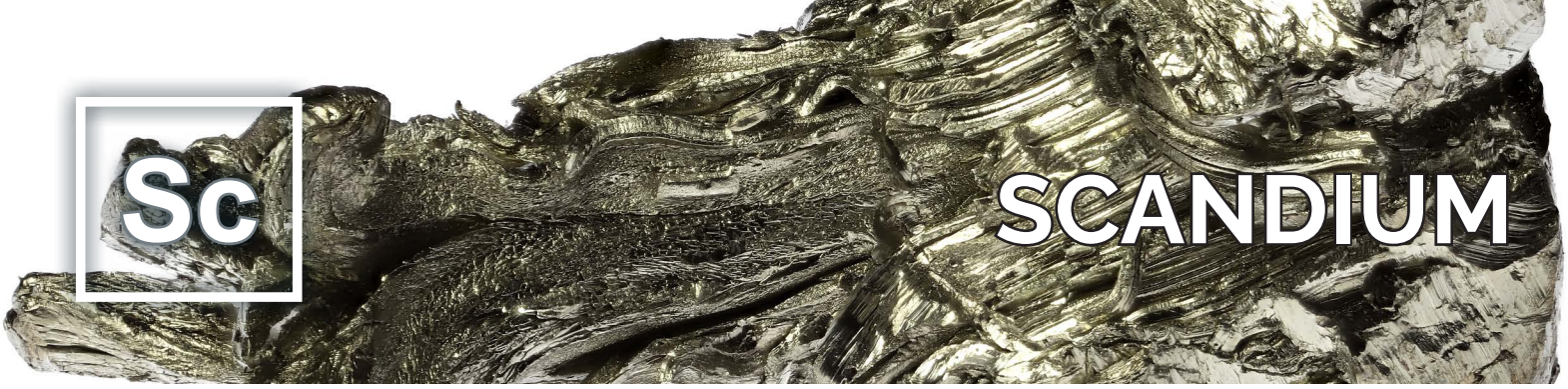


Did You Know?

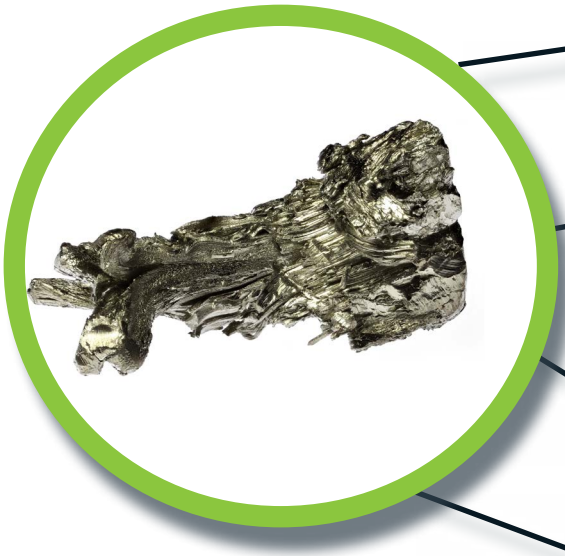
REEs have unusual fluorescent, conductive and magnetic properties, making them very useful when mixed with more common metals, for example, iron.

Location	Name	Resources (Mt = million tonnes; t = tonne; ppm = parts per million)
1	Clay–Howells	Inferred: 8.477 Mt @ 0.732% total rare earth oxides (TREO) + 4 additional oxides
2	Lavergne prospect	Indicated: 4.167 Mt @ 1.139% TREO; Inferred: 12.732 Mt @ 1.17% TREO
3	Eco Ridge	Indicated: 36.955 Mt @ 1560 ppm TREO + 1 additional oxide; Inferred: 22.306 Mt @ 1613 ppm TREO + 1 additional oxide
4	Multi-Minerals zone 6	Historical: 4.56 Mt @ 2.72% REE

Rare earth elements (REEs) are a group of elements from the lanthanide series of 15 elements. The REEs are subdivided into light REEs (LREEs), comprising lanthanum, cerium, praseodymium, neodymium, promethium, samarium and europium; and heavy REEs (HREEs), comprising gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium.



Scandium – is a silvery white element that is grouped with rare earth elements. Scandium is present in most rare earth element deposits. Scandium occurs in Ontario as a secondary commodity.



Scandium is a silvery white element.

Geological Environment and Sources: In Ontario, scandium occurs in layered ultramafic and mafic intrusions and in the same geological environment as REEs.

Host Minerals: Scandium occurs in the minerals euxenite, gadolinite and thortveitite.

Total World Production 2021: Worldwide production of scandium in 2021 was unknown.

Notable Ontario Localities: No notable stand-alone scandium deposits are known in Ontario, but scandium may be associated with some Ontario REE deposits.

How Is Scandium Used?

Scandium is used in solid oxide fuel cells, in lasers and lighting for stadiums or studios, and in aluminum-scandium alloys for the aerospace, defence and 3-D printing industries.

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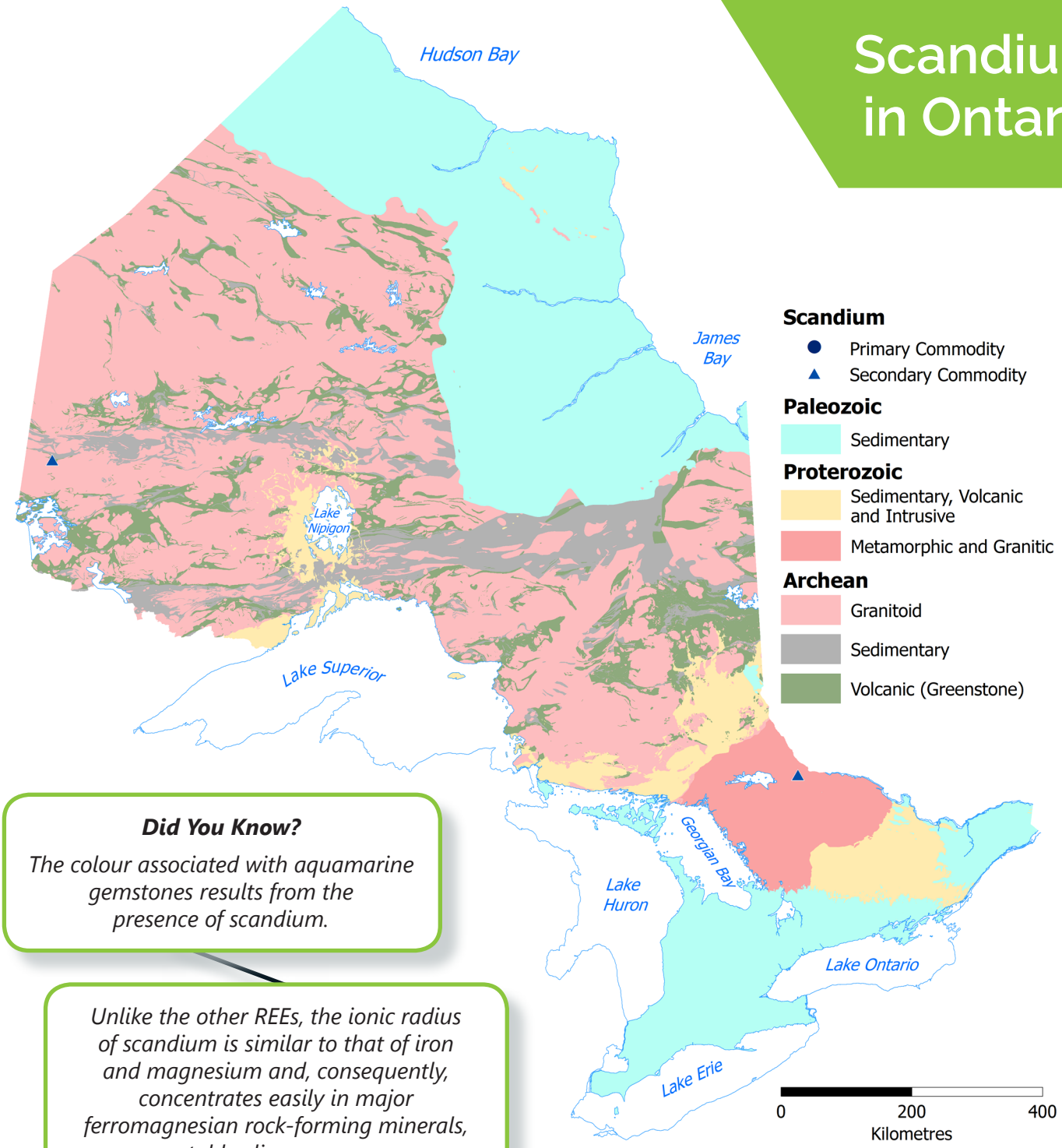
Scandium in Ontario



Did You Know?

The colour associated with aquamarine gemstones results from the presence of scandium.

Unlike the other REEs, the ionic radius of scandium is similar to that of iron and magnesium and, consequently, concentrates easily in major ferromagnesian rock-forming minerals, notably clinopyroxene .

No resources or production.

Although generally grouped with rare earth elements, scandium appears separately on Ontario's Critical Minerals List to allow for comparison with other jurisdictions.

Se SELENIUM

Selenium – is a relatively rare metalloid with diverse uses. Selenium is widely distributed within the Earth's crust, but not usually in economical concentrations suitable for extraction. Selenium occurs in Ontario as a secondary commodity.

Isolated selenium.
Selenium is a by-product of copper refining.

Geological Environment and Sources: In Ontario, selenium occurs as a minor constituent in magmatic sulphide ore deposits.

Host Minerals: No main mineral. Selenium is associated with sulphide minerals and is produced as a by-product of copper refining.

Total World Production 2021: Worldwide production of selenium in 2021 was 3,000 tonnes.

Notable Ontario Localities: Sudbury.

How Is Selenium Used?

Selenium is used in blasting caps to control delays; in copper, lead and steel alloys to improve machinability; in the electrolytic production of manganese to increase yields; in rubber compounding chemicals to act as a vulcanizing agent; in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells; as a human and livestock dietary supplement; and as a fertilizer additive.

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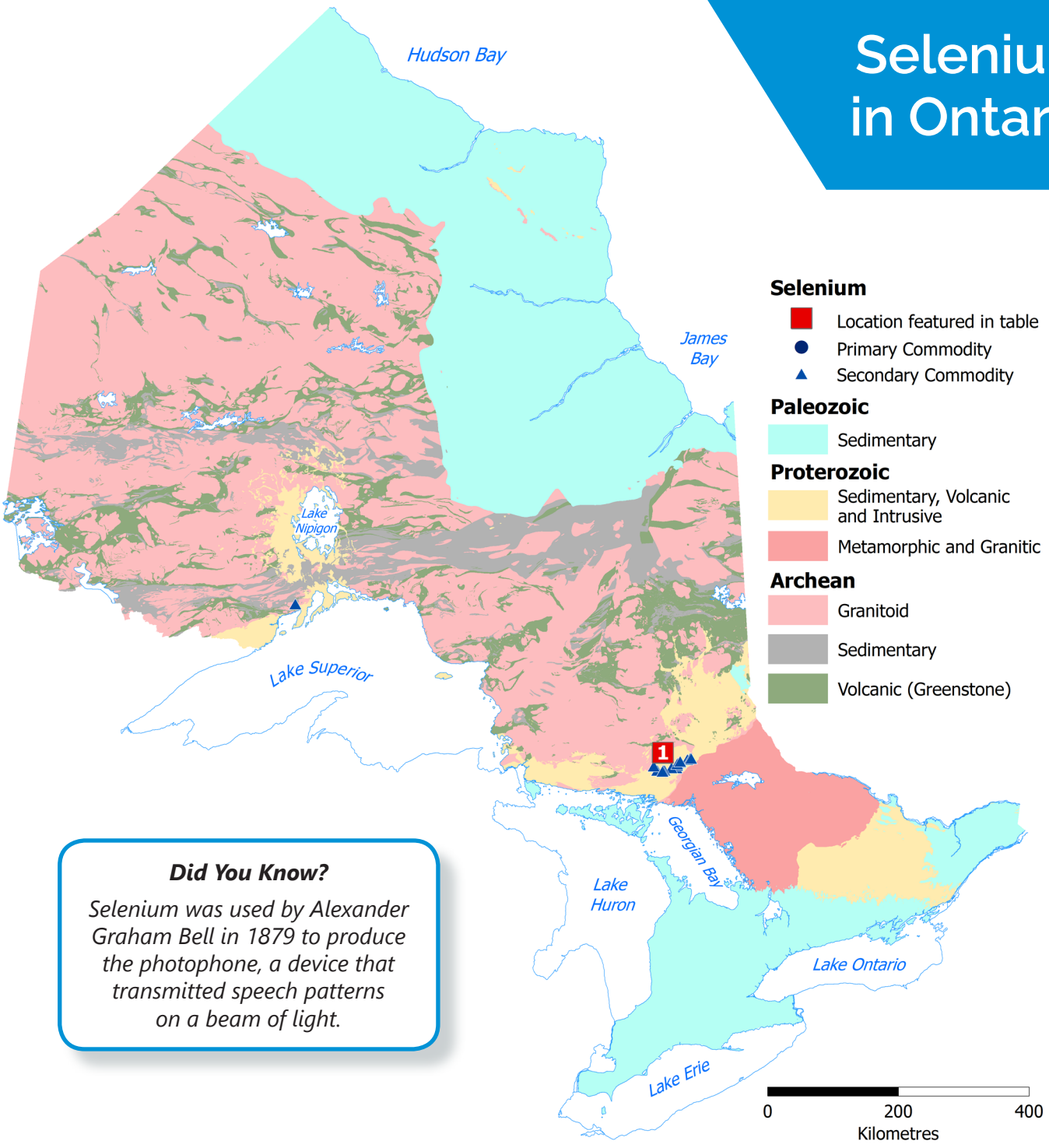
Selenium in Ontario



Did You Know?

Selenium was used by Alexander Graham Bell in 1879 to produce the photophone, a device that transmitted speech patterns on a beam of light.

Location	Name	Resources
1	Sudbury	Produced as a by-product of the copper-nickel mines in the Sudbury camp. No totals available.

Ta TANTALUM

Tantalum – is a rare, blue-grey, lustrous, hard transition metal. Tantalum occurs mainly in the mineral columbite-tantalite, which also contains other metals, including niobium. Tantalum occurs in Ontario as both primary and secondary commodities.

Tantalite is the primary source of the chemical element tantalum.

Geological Environment and Sources: In Ontario, tantalum occurs in rare-element pegmatites and carbonatite intrusions.

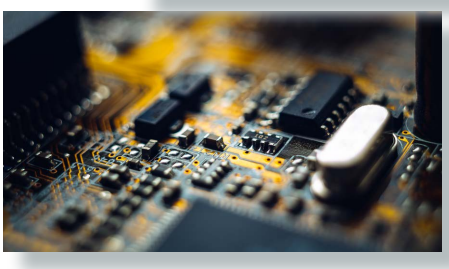
Host Minerals: Tantalum is found in Ontario mainly as tantalite.

Total World Production 2021: Worldwide production of tantalum in 2021 was 2,100 tonnes.

Notable Ontario Localities: Separation Rapids, Pakeagama Lake, Seymour Lake (North Aubry).

How Is Tantalum Used?

Tantalum is used in electrolytic capacitors in high-technology devices (cell phones, computer hard drives, implantable medical devices), medical applications (coatings on stainless steel implants), and aerospace and energy generation superalloys.



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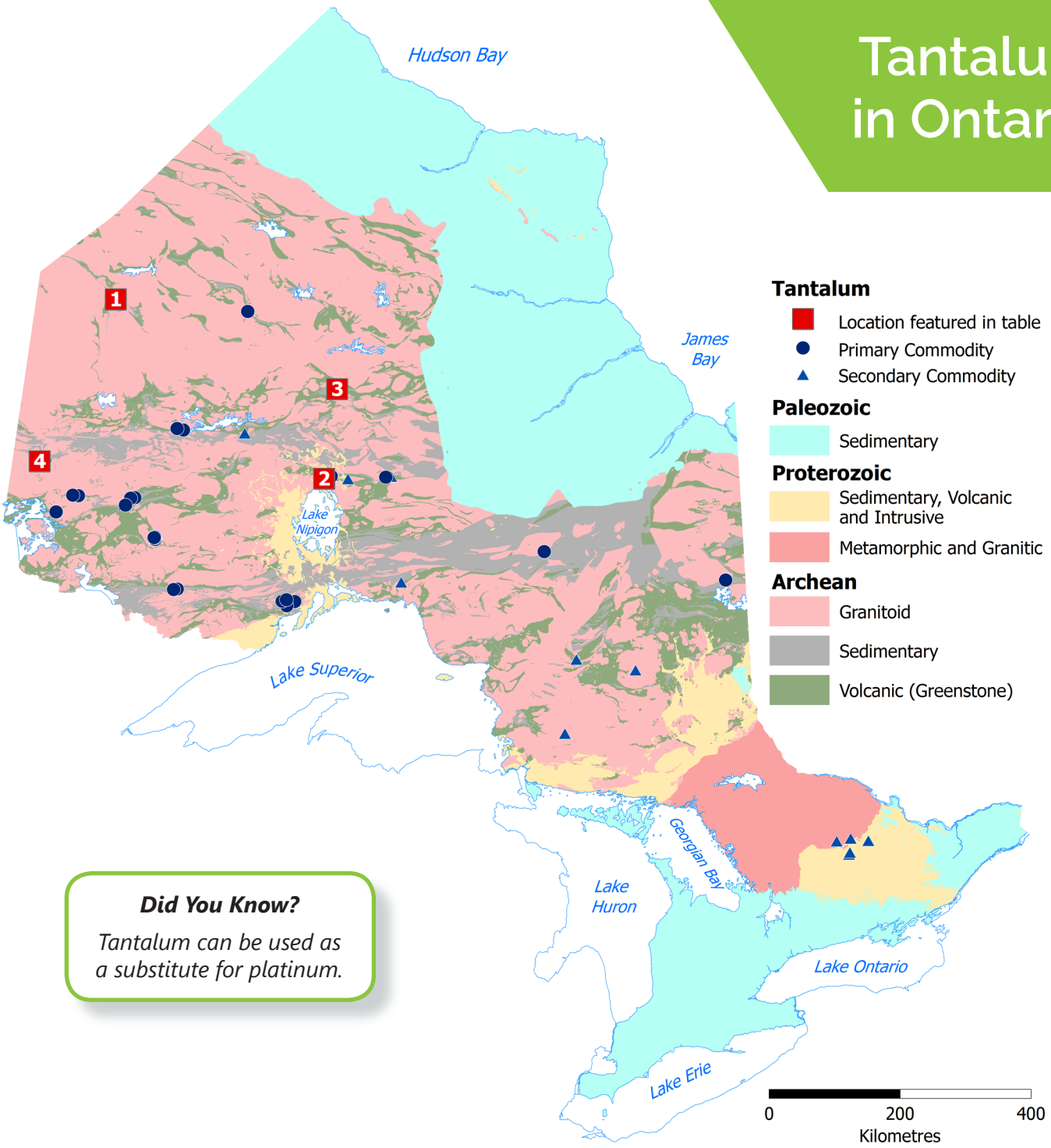
Tantalum in Ontario



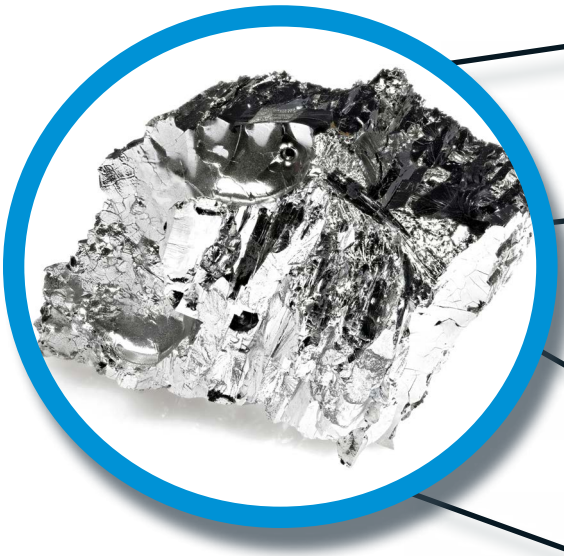
Did You Know?

Tantalum can be used as a substitute for platinum.

Location	Name	Resources (Mt = million tonnes; t = tonne; ppm =parts per million)
1	Pakeagama Lake pegmatite	Measured & Indicated: 5.964 Mt @ 98 ppm Ta_2O_5 + 3 additional oxides; Inferred: 0.68 Mt @ 89 ppm Ta_2O_5 + 3 additional oxides
2	North Aubry	Indicated: 2.13 Mt @ 210 ppm Ta_2O_5 + 1 additional oxide; Inferred: 1.7 Mt @ 189 ppm Ta_2O_5 + 1 additional oxide
3a	Pollucite dike	Inferred: 340,000 t @ 0.04% Ta_2O_5 + 1 additional oxide
3b	Rubellite dike	Inferred: 800,000 t @ 0.03% Ta_2O_5
4	Separation Rapids	Measured & Indicated: 8.40 Mt @ 0.007% Ta_2O_5 + 3 additional oxides; Inferred: 1.79 Mt @ 0.007% Ta_2O_5 + 3 additional oxides

Te TELLURIUM

Tellurium – is a silvery grey, lustrous, crystalline and brittle metalloid. Tellurium occurs in Ontario as both primary and secondary commodities.



Isolated tellurium.

Geological Environment and Sources: In Ontario, tellurium occurs in magmatic sulphide ore deposits and in association with gold deposits.

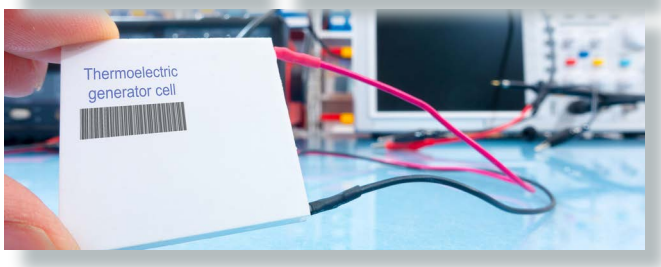
Host Minerals: The main host minerals for tellurium are tellurides. In Ontario, tellurium is produced as a by-product of the processing of magmatic sulphide ores in Sudbury.

Total World Production 2021: Worldwide production of tellurium in 2021 was 580 tonnes.

Notable Ontario Localities: Sudbury.

How Is Tellurium Used?

Tellurium is used as an additive to copper, lead and steel alloys. It is also used in thermoelectric cooling products, photovoltaic (solar) cells, integrated circuits, laser diodes and medical instrumentation.



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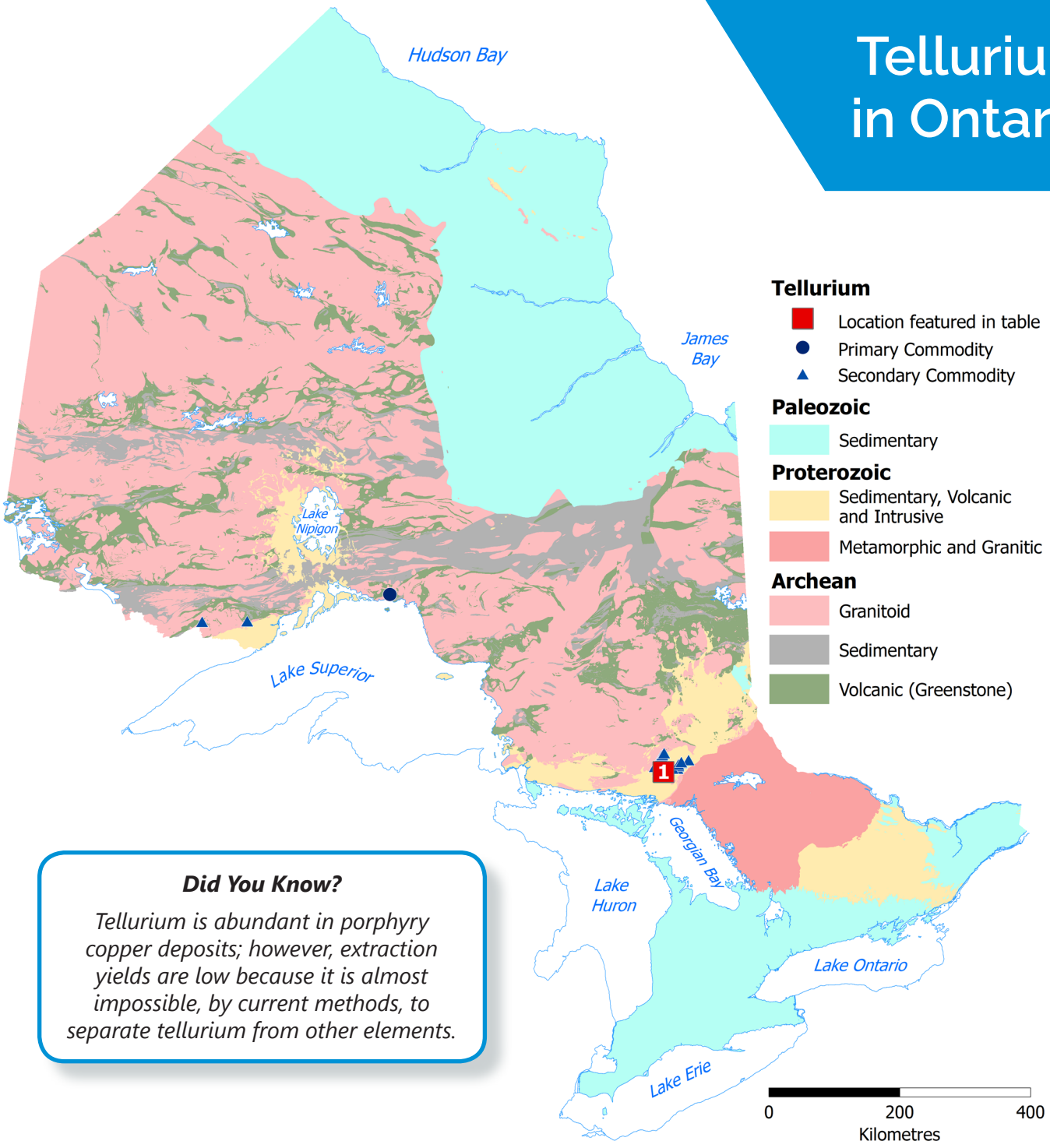
Tellurium in Ontario



Did You Know?

Tellurium is abundant in porphyry copper deposits; however, extraction yields are low because it is almost impossible, by current methods, to separate tellurium from other elements.

Location	Name	Production
1	Sudbury	Produced as a by-product of the copper-nickel mines in the Sudbury camp. No totals available.

Sn TIN

Tin – is a silvery post-transition metal. Tin is soft enough to be cut by little force. Tin occurs in Ontario as both primary and secondary commodities.

Cassiterite is a tin oxide mineral and is an important source of tin.

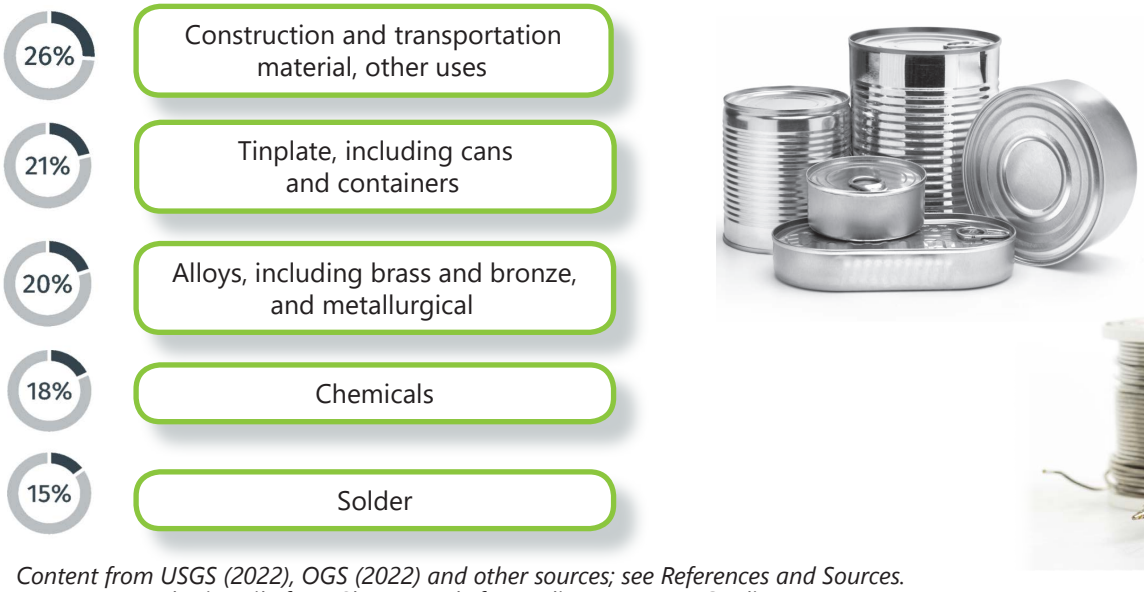
Geological Environment and Sources: In Ontario, tin occurs in volcanogenic massive sulphide (VMS) deposits and in pegmatites.

Host Minerals: Tin is found in Ontario mainly as cassiterite.

Total World Production 2020: Worldwide production of tin in 2021 was 300,000 tonnes.

Notable Ontario Localities: Tin has been identified as a secondary commodity in VMS orebodies at Timmins (Kidd Creek Mine) and Manitouwadge (Geco Mine).

How Is Tin Used?



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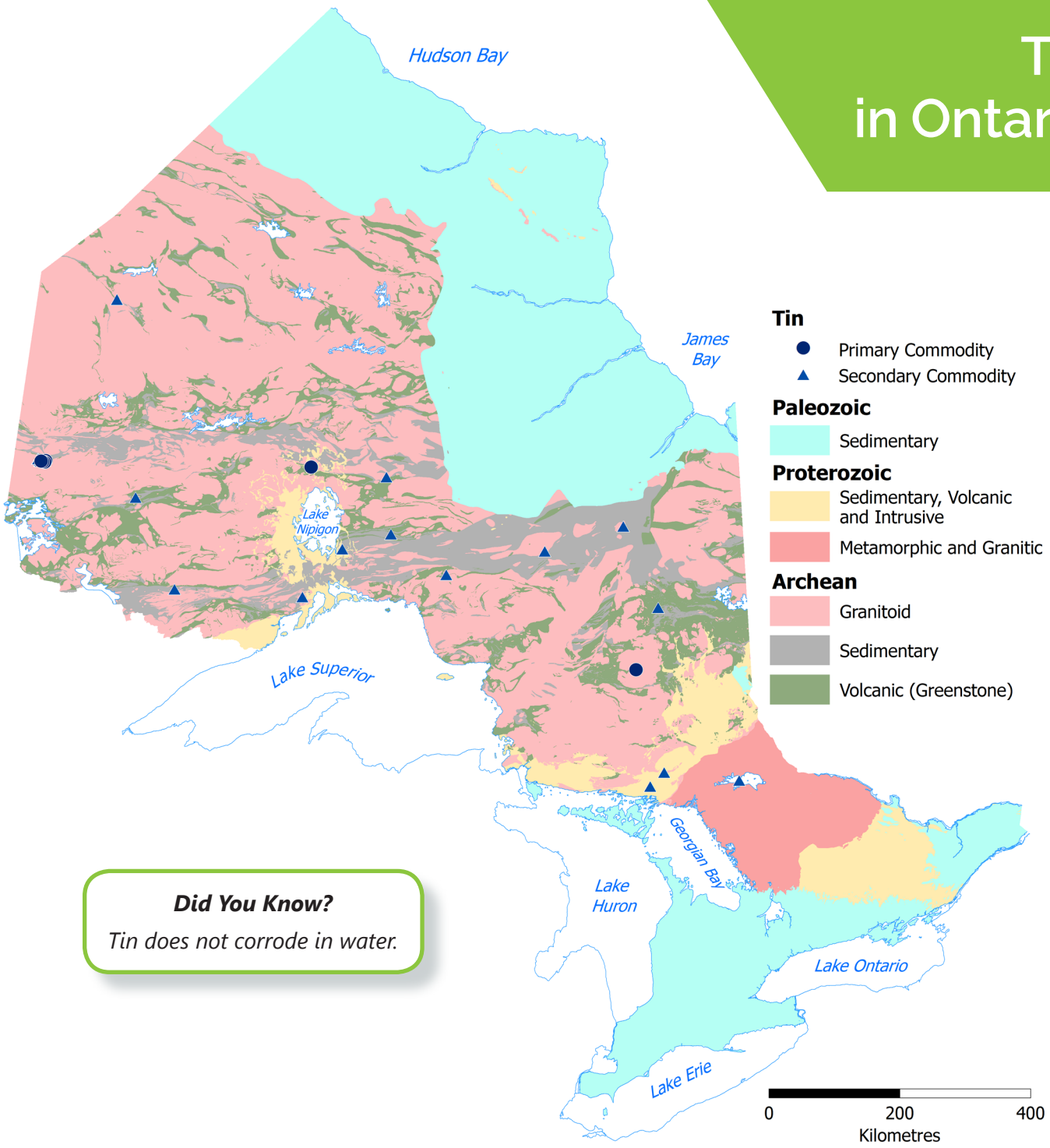
Tin in Ontario



Did You Know?

Tin does not corrode in water.

No resources or production.

Ti TITANIUM

Titanium – is a silvery, lustrous, low-density, high-strength transition metal. Titanium occurs in Ontario as both primary and secondary commodities.

Rutile is an oxide mineral composed of titanium dioxide and is an important source of titanium.

Geological Environment and Sources: In Ontario, titanium occurs in magmatic iron-titanium-oxide–rich deposits hosted by a complex suite of mafic rocks.

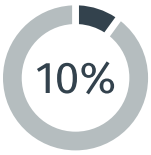
Host Minerals: Titanium is found in Ontario mainly as ilmenite, anatase and rutile.

Total World Production 2021: Worldwide production of titanium in 2021 was 9 million tonnes.

Notable Ontario Localities: North Bay area (Titan), Bad Vermilion Lake, Lackner Lake (Multi-Minerals zone 6).

How Is Titanium Used?

Domestic **titanium dioxide** (TiO_2) is used primarily for pigment producers.



Titanium is also used in welding rod coatings, carbides, alloying agent in aircraft parts and titanium metal.

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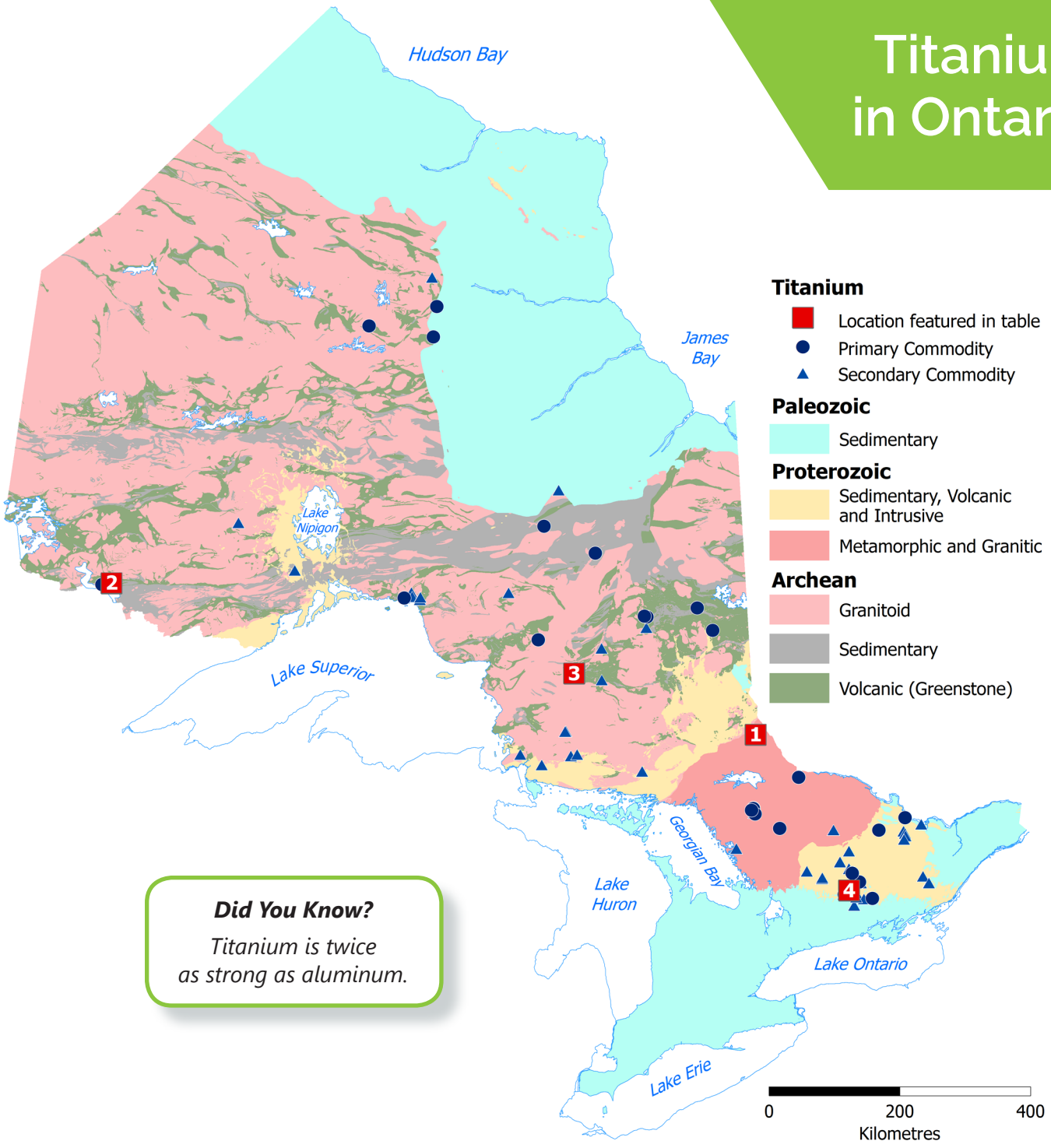
Titanium in Ontario



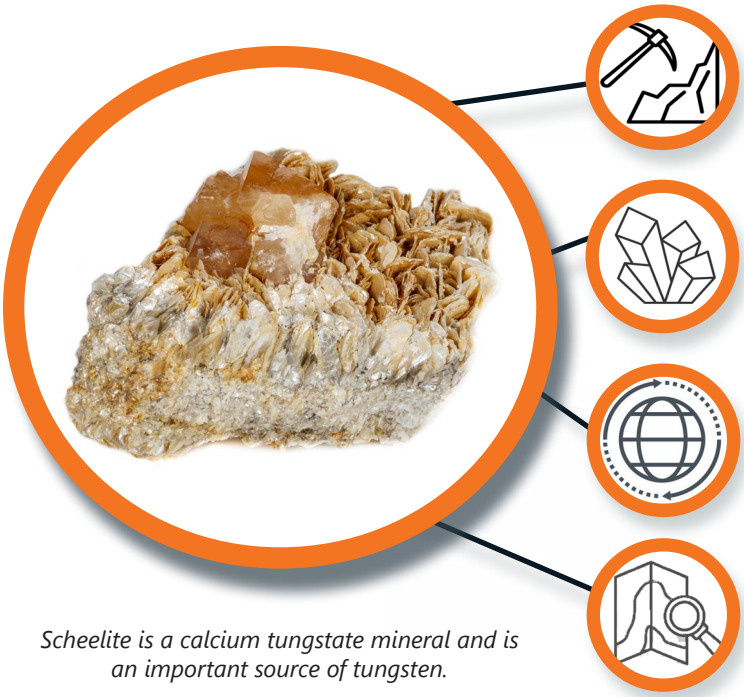
Did You Know?

Titanium is twice as strong as aluminum.

Location	Name	Resources (Mt = million tonnes)
1	Titan property	Inferred: 46 Mt @ 14.82% TiO_2 + 1 additional oxide
2	Bad Vermilion Lake	Historical: 1.2 Mt @ 15% TiO_2
3	Multi-Minerals zone 6	Historical: 3.473 Mt @ 6.40% TiO_2 + 1 additional oxide
4	Methuen Township ilmenite	Historical: 13.2 Mt @ 21.7% TiO_2

W TUNGSTEN

Tungsten – is a rare, robust transition metal found naturally on Earth almost exclusively as compounds with other elements. Tungsten occurs in Ontario as both primary and secondary commodities.



Scheelite is a calcium tungstate mineral and is an important source of tungsten.

Geological Environment and Sources: In Ontario, tungsten occurs in skarns, tungsten-bearing pegmatites, porphyry deposits and lode gold systems.

Host Minerals: Tungsten is found in Ontario mainly as scheelite and wolframite ore.

Total World Production 2021: Worldwide production of tungsten in 2021 was 79,000 tonnes.

Notable Ontario Localities: Espanola (Fostung), Sault Ste. Marie (Tribag Mine tailings), Timmins (Hollinger Mine).

How Is Tungsten Used?

Tungsten is used predominantly in the construction, metalworking, mining, and oil and gas drilling industries. The remaining tungsten is used to make various alloys and specialty steels for electrodes, filaments, carbides and wires in electronics, heating, lighting and welding applications. Crystal tungstates are used as scintillation detectors in nuclear physics and nuclear medicine.

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Tungsten in Ontario

Did You Know?

Tungsten is a substitute for gold in certain applications.

Location	Name	Resources and Past Production (kg = kilogram; Mt = million tonnes; t = tonne)
1	Fostung property	Inferred: 12.4 Mt @ 0.213% WO_3
2	Tribag Mine - west breccia	Historical: 100,000 t @ 0.6–1% WO_3 and 1 Mt @ 0.23% WO_3 estimated in the tailings
3	Pickle Crow Mine	Past Production (1943): 41 kg WO_3
4a	McIntyre Mine	Past Production (1941–1953): 505 kg WO_3
4b	Hollinger Mine	Past Production (1940–1953): 206,321 kg WO_3
4c	Coniaurum Mine	Past Production (1952–1953): 208 kg WO_3
4d	Preston Mine	Past Production (1941–1952): 1,593 kg WO_3
4e	Dome Mine	Past-Production (1941–1942): 32.5 kg WO_3

U URANIUM

Uranium – is a naturally occurring silvery-white metal that is weakly radioactive. Uranium is mostly used as fuel for nuclear power stations. Uranium occurs in Ontario as both primary and secondary commodities.

Uraninite is a major ore mineral of uranium.

Geological Environment and Sources: In Ontario, uranium occurs in paleoplacer deposits, pegmatites, and unconformity-type occurrences.

Host Minerals: Uranium typically occurs in Ontario as uraninite.

Total World Production 2021: Worldwide production of uranium in 2021 was an estimated 50,000 tonnes.

Notable Ontario Localities: Bancroft, Elliot Lake.

How is Uranium Used?

Uranium is used predominantly as fuel for nuclear power stations. Uranium is also used to produce isotopes for medical, industrial and defense purposes.

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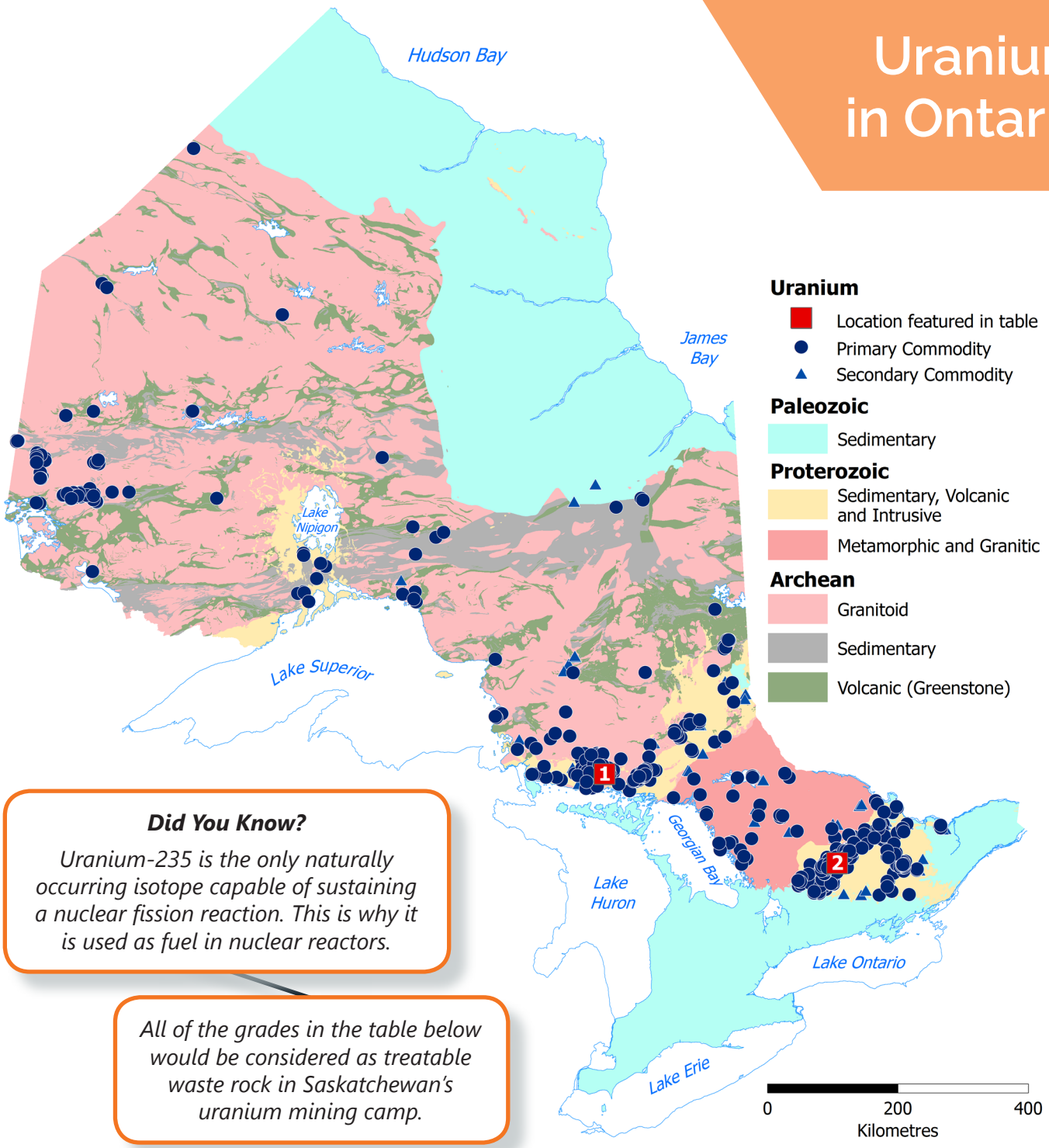
Uranium in Ontario

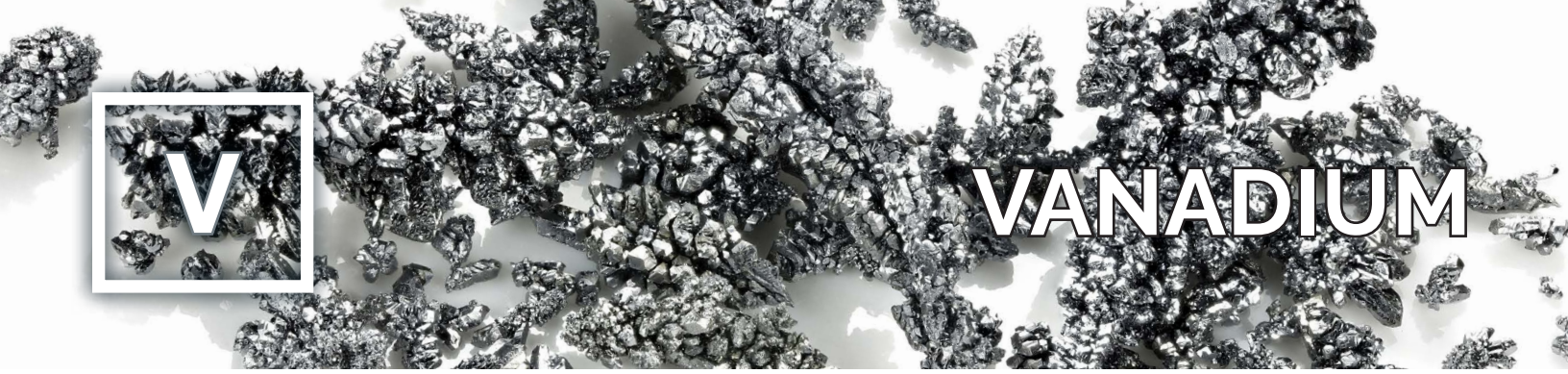


Did You Know?

Uranium-235 is the only naturally occurring isotope capable of sustaining a nuclear fission reaction. This is why it is used as fuel in nuclear reactors.

All of the grades in the table below would be considered as treatable waste rock in Saskatchewan's uranium mining camp.

Location	Name	Resources and Past Production (Mt = million tonnes; t = tonne)
1a	Elliot Lake	Past Production (1955–1990): 164,000 t of uranium metal
1b	Eco Ridge	Indicated: 36.955 Mt @ 0.046% U_3O_8 + additional set of oxides; Inferred: 22.306 Mt @ 0.045% U_3O_8 + additional set of oxides
1c	Denison Mine	Historical (undeveloped): 73.03 Mt @ 0.051% U_3O_8
2	Bancroft	Past Production (1954–1979): 3,414 t of uranium metal



V VANADIUM

Vanadium – is a silvery grey, hard, alkaline-earth transition metal. Vanadium compounds are used extensively as catalysts. Vanadium occurs in Ontario as both primary and secondary commodities.

Vanadinite is a mineral belonging to the apatite group of phosphates and is an important source of vanadium.

Geological Environment and Sources: In Ontario, vanadium occurs in vanadiferous titanomagnetite deposits.

Host Minerals: Titanium occurs in vanadiferous magnetite, as well as ilmenite, leucoxene and rutile.

Total World Production 2021: Worldwide production of vanadium in 2021 was 110,000 tonnes.

Notable Ontario Localities: North Bay area (Titan), Mattawa area (Brazeau).

How Is Vanadium Used?

Vanadium is used in vanadium-titanium alloys for aerospace applications, ceramics, electronics, and vanadium chemicals. Vanadium dioxide is used in the production of glass coatings that block infrared radiation. Vanadium redox-flow batteries (VRBs) are a major potential future use of vanadium.

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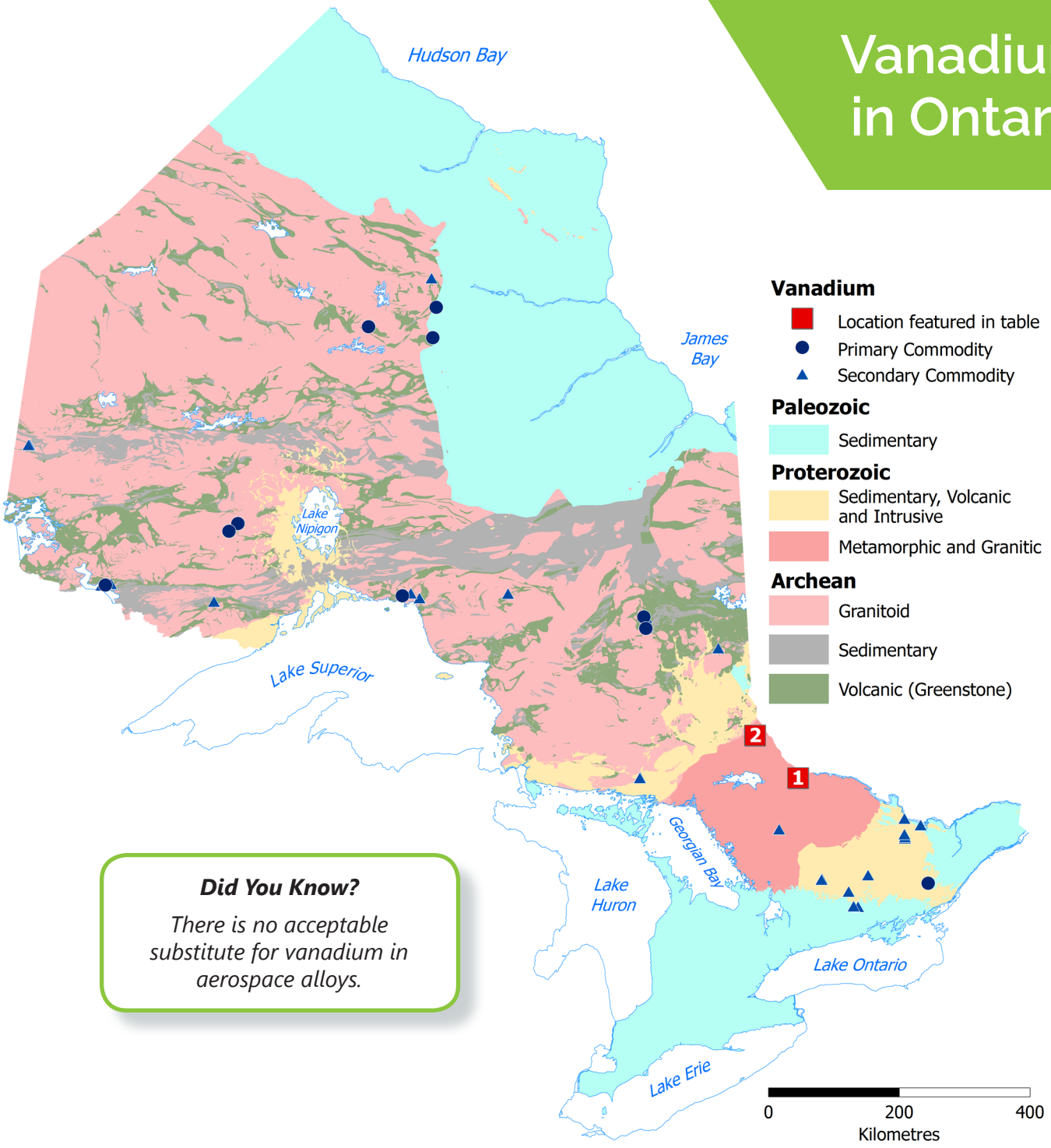
Vanadium in Ontario



Did You Know?

There is no acceptable substitute for vanadium in aerospace alloys.

Location	Name	Resources (Mt = million tonnes)
1	Brazeau prospect	Historical: 1.36 Mt @ 0.58% V_2O_5
2	Titan property	Inferred: 46 Mt @ 0.24% V + 1 additional oxide

Zn ZINC

Zinc – is a silvery grey, brittle metal. Zinc is most commonly used as an anti-corrosion agent. Zinc occurs in Ontario as both primary and secondary commodities.

Sphalerite is a sulphide mineral and is an ore of zinc.

Geological Environment and Sources: In Ontario, zinc occurs in volcanogenic massive sulphide (VMS) deposits, sedimentary exhalative (SEDEX) massive sulphide mineralization and polymetallic veins.

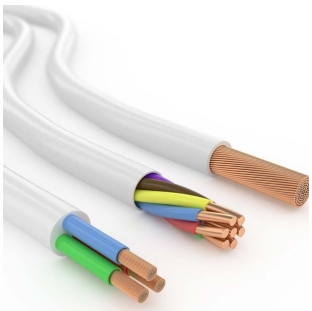
Host Minerals: Zinc is found in Ontario mainly as sphalerite (zinc sulphide mineral).

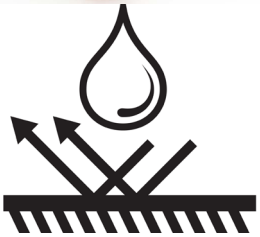
Total World Production 2021: Worldwide production of zinc in 2021 was 13 million tonnes.

Notable Ontario Localities: Timmins (Kidd Creek), Sturgeon Lake–Mattabi, Manitouwadge (Geco).

How Is Zinc Used?

Zinc is used as an anti-corrosion agent in lithium and alkaline batteries. Zinc alloys are used in the automotive, electrical and hardware industries. Zinc is also used in the rubber, chemical, paint and agricultural industries.





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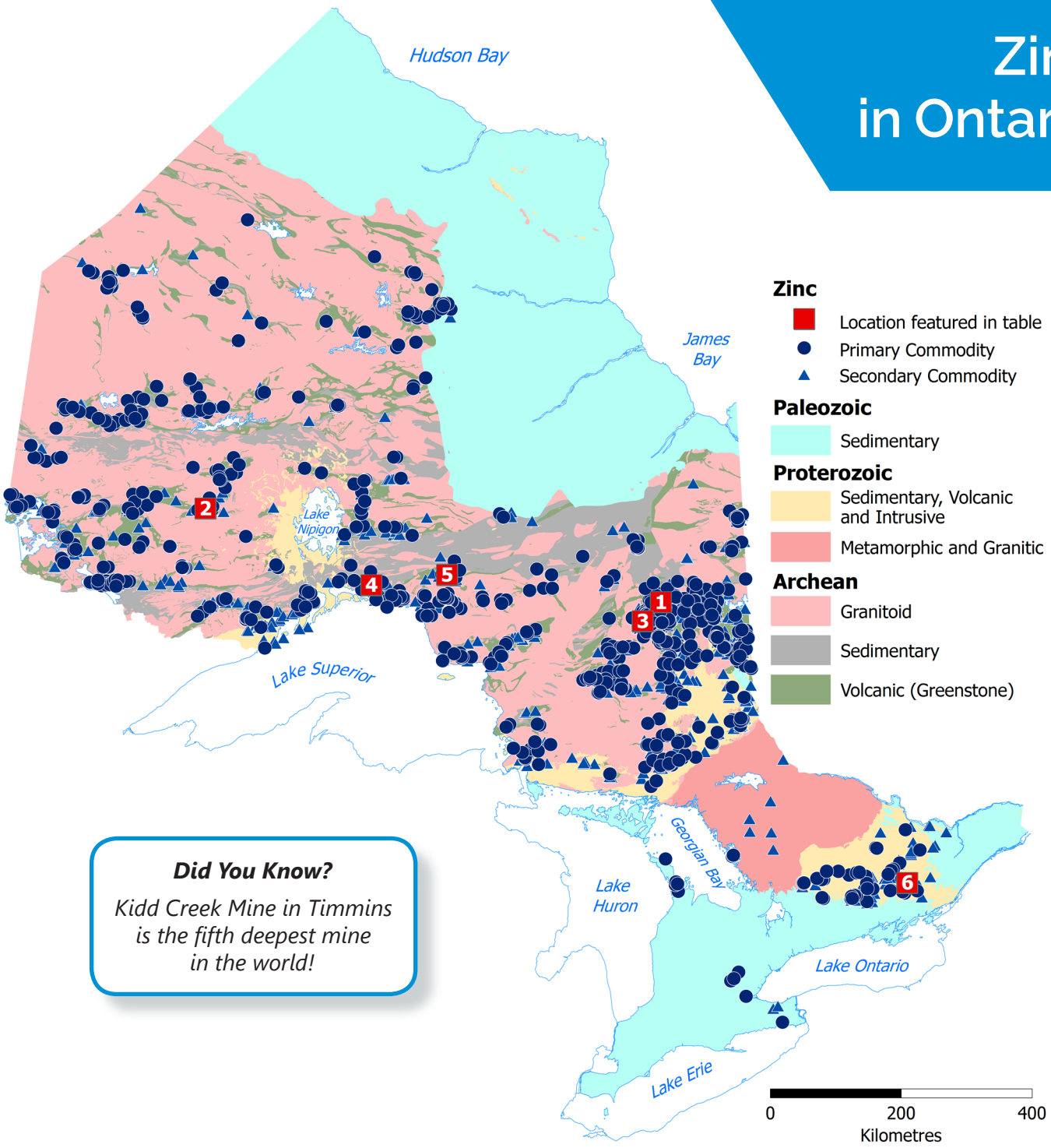
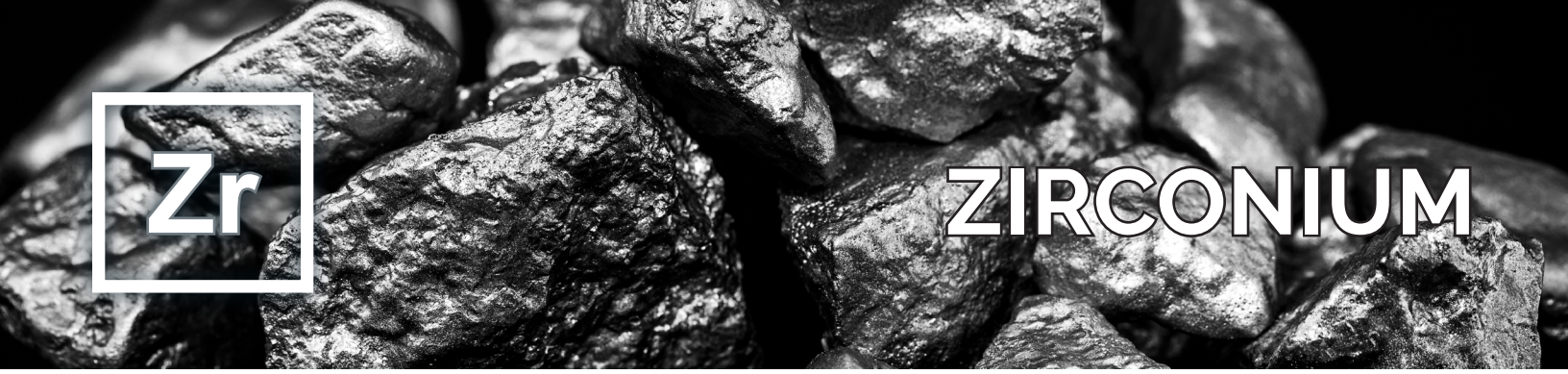
Zinc in Ontario



Did You Know?

Kidd Creek Mine in Timmins is the fifth deepest mine in the world!

Location	Name	Production and Past Production (kg = kilogram; Mt = million tonnes; t = tonne)
1	Kidd Creek Mine	Production (1996–2020): 9,751,528 t Zn, 3,685,645 t Cu, 349,729 t Pb, 12,168,281 kg Ag
2a	Mattabi	Past Production (1972–1988): 989,713 t Zn
2b	Sturgeon Lake	Past Production (1974–1980): 155,388 t Zn
2c	Lyon Lake	Past Production (1980–1991): 496,420 t Zn
2d	F Group	Past Production (1981–1984): 31,860 t Zn
3	Kam Kotia Mine	Past Production (1943–1944, 1964–1972): 70,200 t Zn
4a	Zenith	Past Production (1966–1970): 25,251 t Zn
4b	Winston Lake	Past Production (1988–1998): 435,747 t Zn
5a	Geco Mine	Past Production (1957–1995): 1.434 Mt Zn
5b	Willroy	Past Production (1957–1975): 264,557 t Zn
5c	Will Echo 1, 2	Past Production (1965–1977): 146,944 t Zn
5d	Will Echo 3	Past Production (1965–1977): 146,953 t Zn
5e	Nama Creek	Past Production (1968–1976): 10,214 t Zn
6	Long Lake	Past Production (1901–1974): 10,115 t Zn



Zr ZIRCONIUM

Zirconium – is a silver-grey, malleable and ductile transition metal. Zirconium and its alloys are very resistant to corrosion. Zirconium occurs in Ontario as both primary and secondary commodities.

Isolated zirconium.

Geological Environment and Sources: In Ontario, zirconium occurs in diatremes (volcanic vent or pipe) or pegmatites.

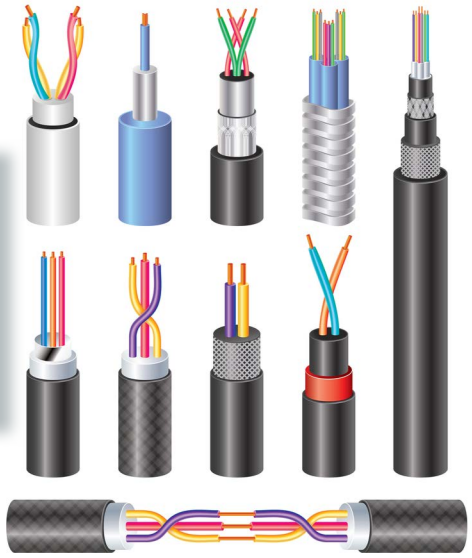
Host Minerals: In Ontario, zircon is the most common host mineral for zirconium.

Total World Production 2021: Worldwide production of zirconium in 2021 was 1,200 tonnes.

Notable Ontario Localities: The majority of Ontario's documented zirconium occurrences are found in eastern Ontario between Haliburton and Eganville.

How is Zirconium Used?

Zirconium is used in fibre-optic connector components, refractory coatings, engineering and structural ceramics, and alumina-zirconia abrasives.



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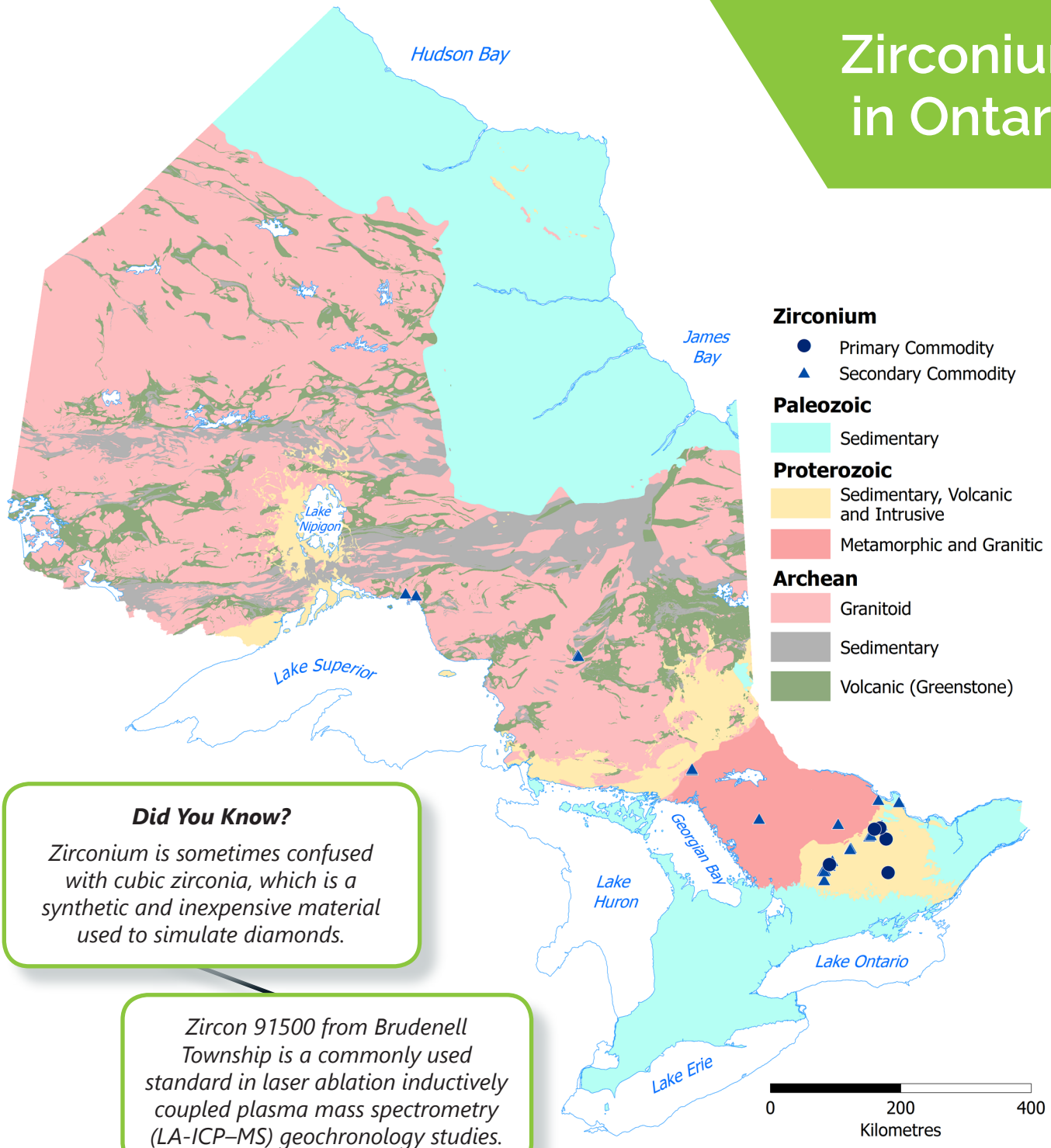
Zirconium in Ontario



Did You Know?

Zirconium is sometimes confused with cubic zirconia, which is a synthetic and inexpensive material used to simulate diamonds.

Zircon 91500 from Brudenell Township is a commonly used standard in laser ablation inductively coupled plasma mass spectrometry (LA-ICP–MS) geochronology studies.

No resources or production.

References and Sources

Canadian Centre for Occupational Health and Safety 2022. Workplace Hazardous Materials Information System (WHMIS) 2015 pictograms, www.ccohs.ca/WHMISpictograms.html [accessed March 24, 2022].

Canadian Institute of Mining, Metallurgy and Petroleum 2014. CIM definition standards for mineral resources & mineral reserves; CIM Standing Committee on Reserve Definitions, Canadian Institute of Mining, Metallurgy and Petroleum, 9p.

Hudson Institute of Mineralogy dba Mindat.org 2022. https://mindat.org [accessed February 27, 2022].

International Atomic Energy Agency 2022. Uranium production; International Atomic Energy Agency, www.iaea.org/topics/uranium-production [accessed March 25, 2022].

Mancini, L.A., Meek, R.D., Sabiri, N., LeBaron, P.S., Rodriguez Miguel, L.M., Hinz, S.L.K., Dorland, G. and Patterson, C. 2021. Historical production of fluorite – Southeastern Ontario District; Table 4 *in* Report of Activities 2020, Resident Geologist Program, Southern Ontario Regional Resident Geologist Report: Southeastern Ontario and Southwestern Ontario Districts and Petroleum Operations, Ontario Geological Survey, Open File Report 6376, p.19.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release—Data 126 – Revision 1.

——— 2022. Ontario Mineral Inventory; Ontario Geological Survey, online database, March 2022 update.

Rogers, M.C., Thurston, P.C., Fyon, J.A., Kelly, R.I. and Breaks, F.W. 1995. Mineral deposit models of metallic and industrial deposit types and related mineral potential assessment criteria; Ontario Geological Survey, Open File Report 5916, 241p.

Royal Society of Chemistry 2022. Periodic table (and associated links), www.rsc.org/periodic-table [accessed March 3, 2022].

Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II and Bradley, D.C., eds. 2017. Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply; United States Geological Survey, Professional Paper 1802, 797p. http://doi.org/10.3133/pp1802

Seal, R.R., II, Piatak, N.M., White, S.J.O. and Hayes, S.M. 2021. Mine waste as a potential source of critical minerals: The importance of understanding speciation and identifying synergies between resource recovery and environmental management; abstract *in* Critical minerals from discovery to supply chain, Program with Abstracts, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey, GeoFile 2021-14, p.17-18.

United States Geological Survey 2022. Mineral commodity summaries 2022; United States Geological Survey, 202p. https://doi.org/10.3133/mcs2022

Williams-Jones, A.E. and Vasyukova, O.V. 2018. The economic geology of scandium, the runt of the rare earth element litter; Economic Geology, v.113, p.973-986.

Wilson, A.C., Rowell, D.J., Seim, G.Wm. and Debicki, R.L. 2008. Procedural guidelines for provincially significant mineral potential mineral resource assessments; Ontario Geological Survey, Open File Report 6141, 91p.

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Back Cover—Contacts: images from the Resident Geologist Program, Ontario Geological Survey.

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	***Multiplied by***	***Gives***	***Imperial Unit***	***Multiplied by***	***Gives***
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	6.451 6	cm^2
1 m^2	10.763 9	square feet	1 square foot	0.092 903 04	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton(short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 9**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy) / ton (short)	1 ounce (troy) / ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights / ton (short)	1 pennyweight / ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors in **bold** type are exact. The conversion factors have been taken from or have been derived from factors given in the *Metric Practice Guide for the Canadian Mining and Metallurgical Industries*, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

Notes

Antimony | Barite | Beryllium | Bismuth | Cesium | Cobalt | Copper
Chromite | Fluorspar | Gallium | Germanium | Graphite | Indium | Lithium
Magnesium | Manganese | Molybdenum | Nickel | Niobium | Phosphate
Platinum Group Elements | Rare Earth Elements | Scandium | Selenium | Tantalum
Tellurium | Tin | Titanium | Tungsten | Uranium | Vanadium | Zinc | Zirconium

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