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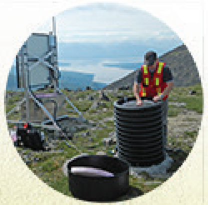


Geological Survey of Canada
Scientific Presentation 150

User-friendly toolkits for geoscientists: how to bring geology expertise to the public

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2022

Canada

Presented at: GAC-MAC-IAH-CNC-CSPG Halifax 2022

Date presented: May, 2022

Permanent link: https://doi.org/10.4095/331220

This publication is available for free download through GEOSCAN (https://geoscan.nrcan.gc.ca/).

Recommended citation

Bécu, V., Sappin A.-A., and Larmagnat, S., 2022. User-friendly toolkits for geoscientists: how to bring geology expertise to the public; Geological Survey of Canada, Scientific Presentation 150,1 .pdf file. https://doi.org/10.4095/331220

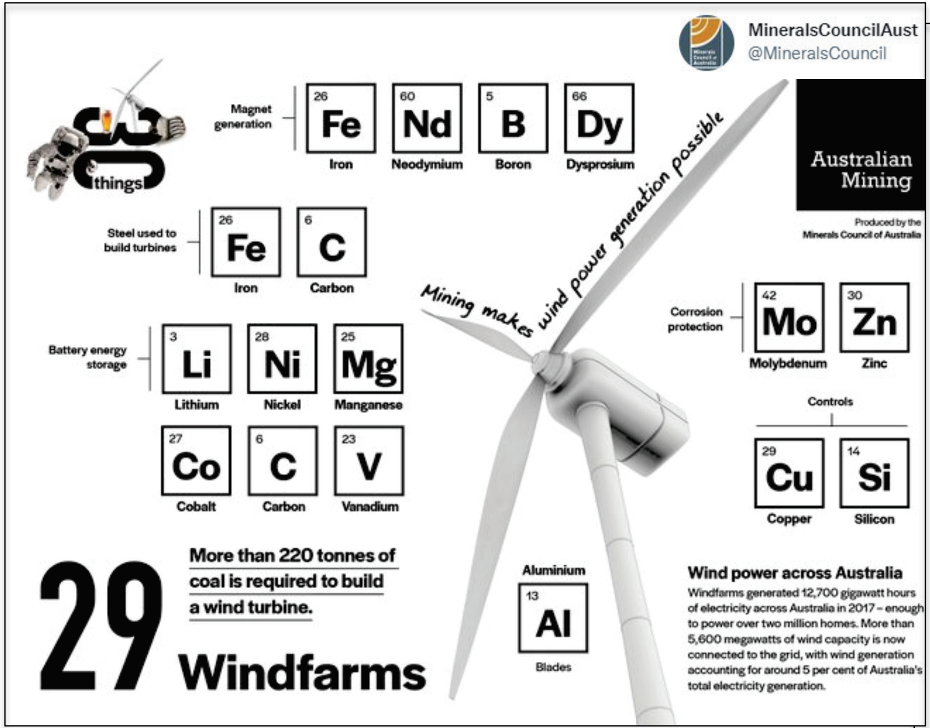
Publications in this series have not been edited; they are released as submitted by the author.

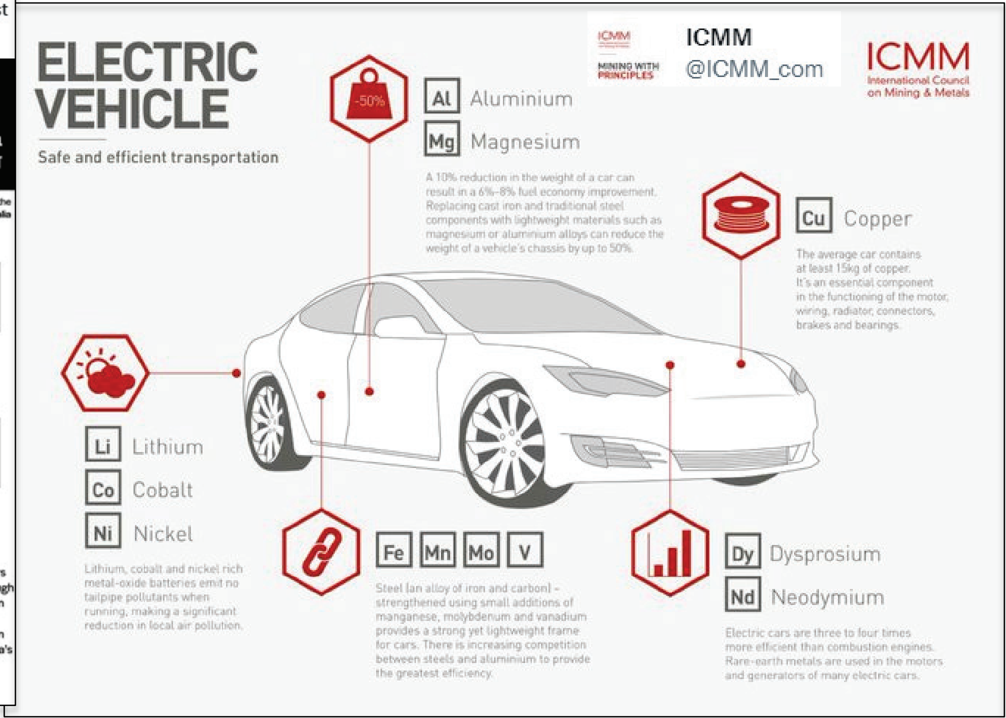
Abstract

A growing number of countries are committed to reduce their carbon emissions and are transitioning towards renewable and clean energy sources, leading to an increase in demand for metals and minerals. This is especially the case for a short list of what are called “critical minerals” which are considered essential to economic development, including the transition to a low-carbon economy and national security. The reliability of their supply chain raises concerns considering geological scarcity, difficulty to extract and/or political factors influencing their availability. At the same time, public awareness and perception of geoscience are eroding and there is more and more reluctance towards mining projects, even from traditionally favourable communities. To face this challenge, promote public interest and outline the contribution of geological science to society, geoscientists of the Geological Survey of Canada (GSC-Québec) have designed and put together a portable display that includes a suite of mineral and metal samples considered critical for the sustainable success of Canada’s transition towards a clean and digital economy. The display is a user-friendly toolkit that can be used by any GSC geoscientists during outreach activities, in classrooms as well as during public open houses. It comes with straightforward pedagogic material and content, along with presentation scenarios. To broaden and adapt the workshops to specific expectations, additional toolkits were developed and all are contained within easy to carry travel cases. These cover a variety of topics and can be presented as stand-alone displays or be used complementary to one another. For example, the “Mines and minerals” collection may serve as a supplement to the “Critical minerals” display to present everyday objects in which minerals are used as well as ore samples from active mines to illustrate the intertwining between mining activities and our everyday lives. Another display covers the ever-popular fossils thematic with the “Sedimentary rocks and fossils” collection and gives an opportunity to address key geoscience themes such as life evolution and biological crisis along with groundwater reservoirs and resources. The “Magmatic rocks” display touches on the formation of rocks from magmas, the different types and active processes of volcanoes, and discusses the risks and benefits related to volcanic activity. Hopefully, these four ready-to-use portable displays will encourage more GSC geoscientists to engage in public oriented activities to make geosciences more accessible, change perceptions and offer an overall tangible scientific experience for people.

To reach a net-zero emission objective, federal and provincial governments have launched various programs and incentives to facilitate the energy transition from fossil fuel towards renewable energies and clean technologies. But this transition to a low-carbone economy will ultimately rely on natural resources.

For example, wind turbines harness energy from the wind, a clean and renewable energy source, buy using mechanical power to create and store electricity, a process that relies heavily on mineral resources. Much like the manufacturing of electric vehicles that require the input of specific metals and elements.



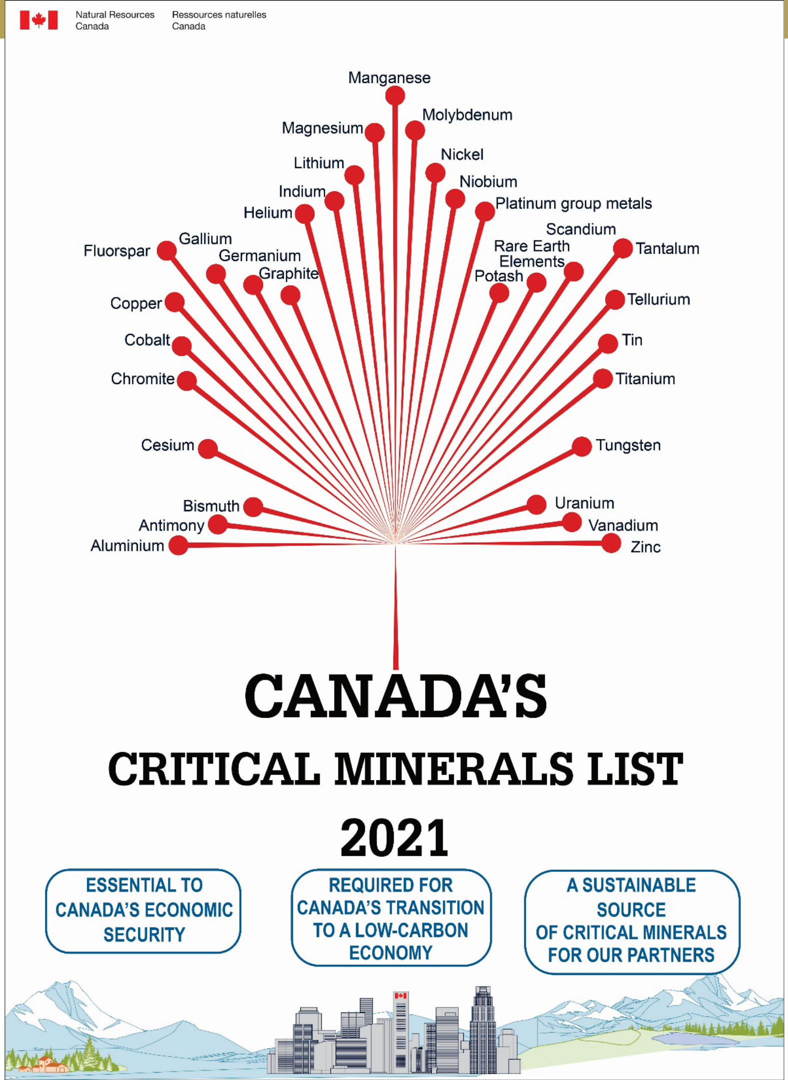


Electric vehicles typically require six times the mineral inputs (Cu, Li, Ni, Mn, Co, graphite) of conventional light vehicles

– *The Role of Critical Minerals in Clean Energy Transitions.* International Energy Agency (2021)

Most low-carbon-emission technologies require more raw materials than traditionnal technologies. Resulting in an increase in mineral resources intake.

The same IEA 2021 report also stated that, in order to reach net zero by 2050, the world's production of critical minerals and metals would also need to be multiplied by a factor of six.



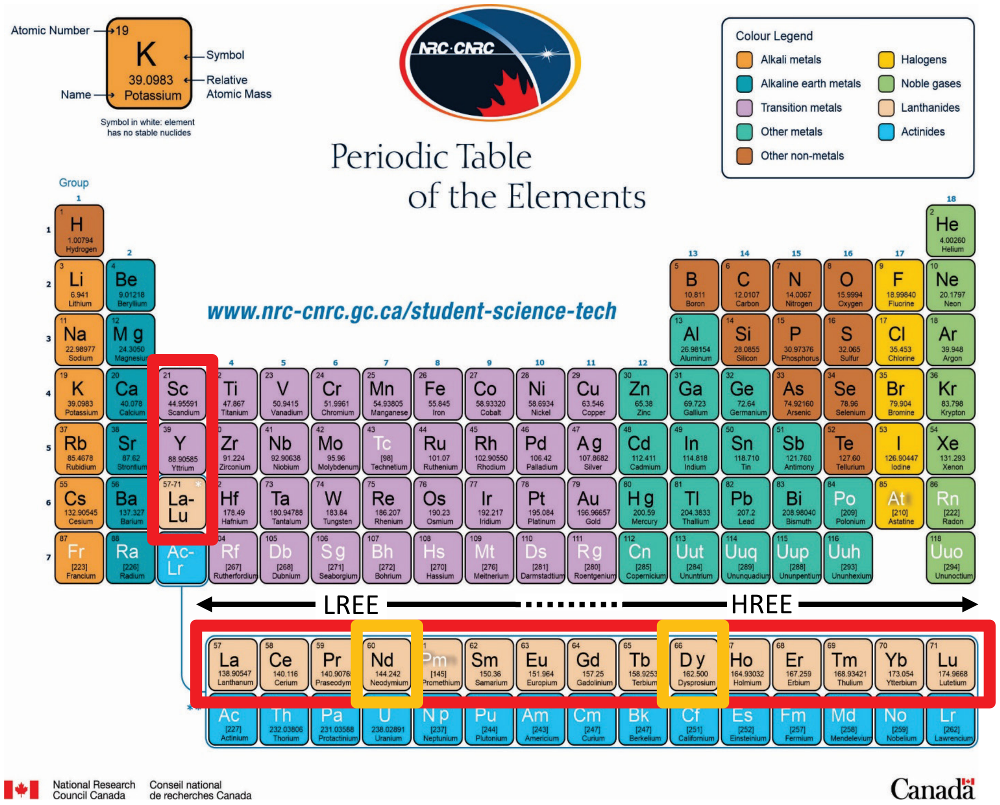
Considering their vital role in the energy transition, the Governement of Canada, with the help of the provinces and territories, compiled a list of 31 critical minerals/elements. The factors considered were:

- Critical minerals are essential to economic development, including the transition to a low-carbon economy and national security.
- The reliability of their supply chain raises concerns considering geological scarcity, difficulty to extract and/or political factors influencing their availability.
- Canada is a recognized leading mining nation:
  - Key global producer for copper, nickel, cobalt, and others;
  - Advanced mineral projects for rare earth elements, lithium, graphite and vanadium.

Source: Minerals and Metals Facts (nrcan.gc.ca)

Canada

Rare earth elements



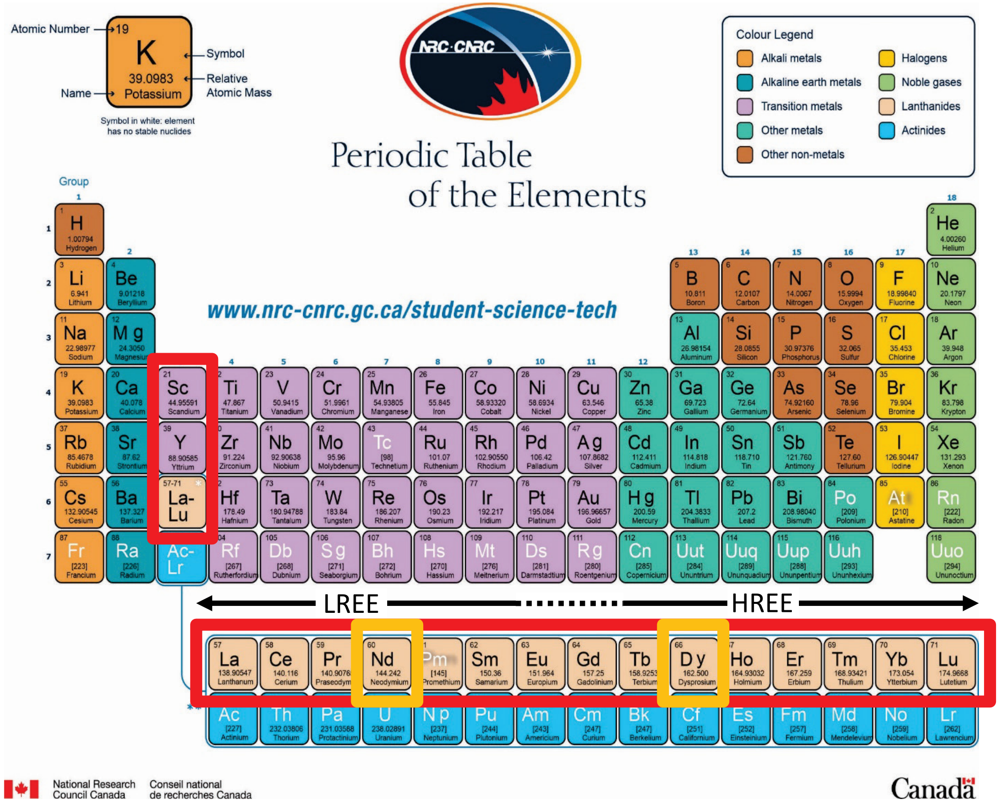
Let's have a closer look at a group of elements considered as "critical", namely the REE. As geoscientists we tend to forget that not everyone is familar with the REE designation, as recently pointed out in an outreach activity with post-secondary science students...

- Rare earth elements (REE) are a series of chemical elements found in the earth's crust. They are subdivided in light (LREE) and heavy (HREE) rare earth elements, mainly based upon their atomic weights.

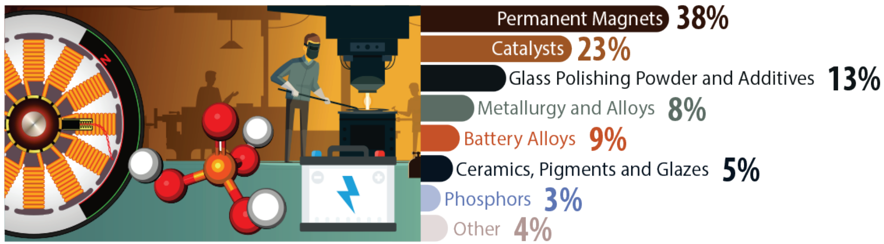
- While REE aren't rare, ore bodies containing sufficient concentrations to make processing economically viable are exceedingly rare

- Extensive processing is required to separate rare earth elements from mined ore

Rare earth elements – uses



Rare earth elements uses, 2020



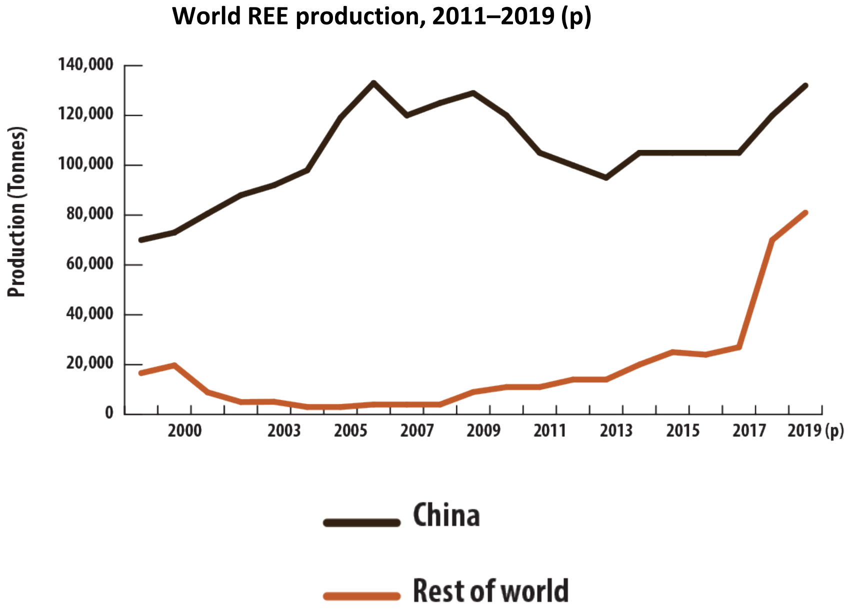
Permanent magnets are used in wind turbines, motors, cars, hard drives, generators, televisions, phones, headphones, speakers, transducers, sensors, etc.

Source: Minerals and Metals Facts (nrcan.gc.ca)

Rare earth elements – supply chain

World production of REE, by country, 2020 (p)

Ranking	Country	Thousand tonnes	Percentage of total
1	China	140.0	57.5%
2	United States	38.0	15.6%
3	Burma (Myanmar)	30.0	12.3%
4	Australia	17.0	7.0%
5	Madagascar	8.0	3.3%
-	Other countries	10.3	4.2%
-	**Total**	**243.3**	**100.0%**



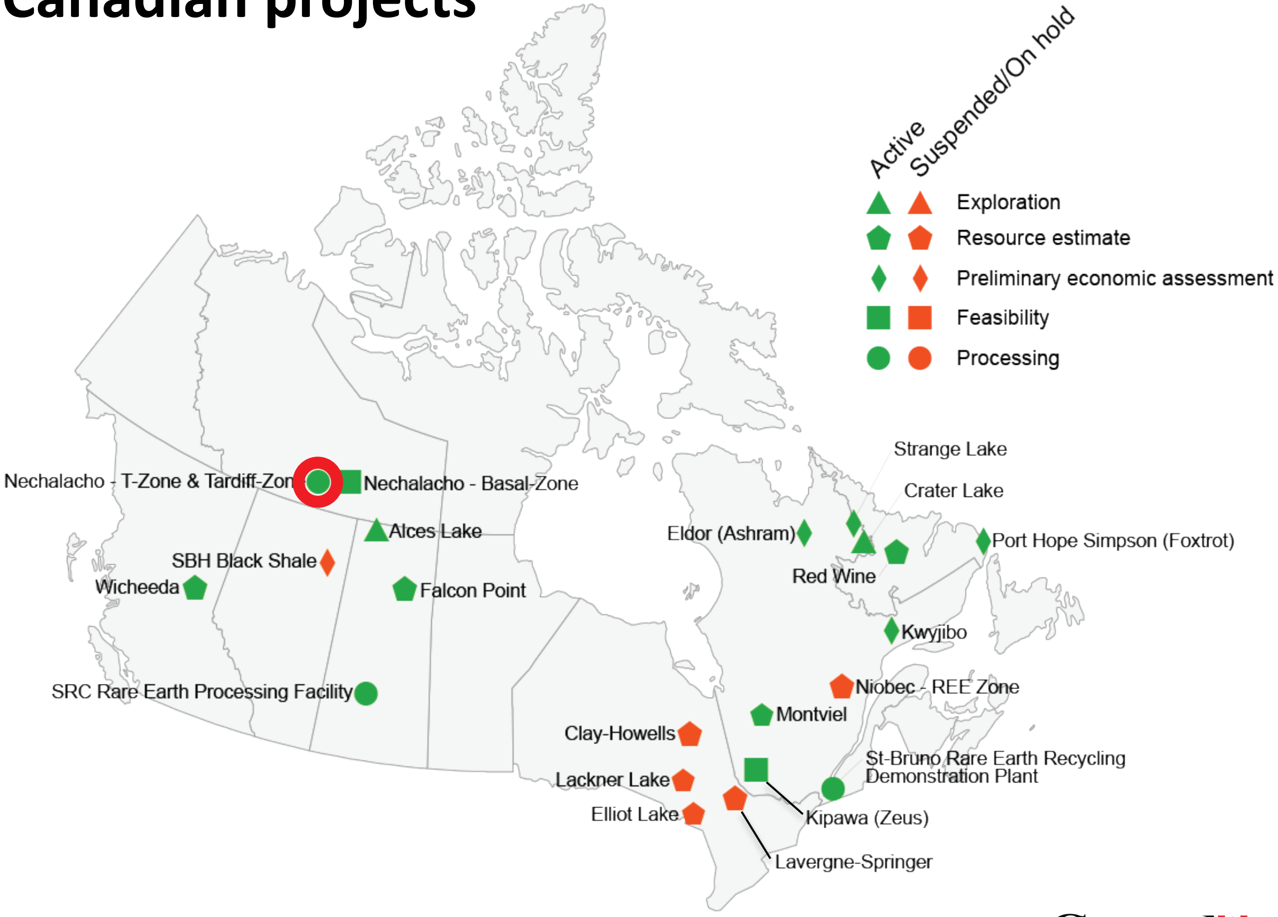
Source: Minerals and Metals Facts (nrcan.gc.ca)

Rare earth elements – Canadian projects

The Nechalado mine, located in the NWT, opened in June 2021 and is the first and only REE producing mine in Canada, and only the second in North America. Resources are estimated at 94.7 Mt at 1.46% TREO (total rare earth oxides).

The ore mainly contains LREE and, at a concentration of 2.2% NdPr, is one of the highest grade REE deposits in the world.

Around 80% of the workforce comes from local native communities.



Sources:
https://vitalmetals.com.au/
https://www.aptnnews.ca/

Source: Minerals and Metals Facts (nrcan.gc.ca)

Canada

“If you can't grow it, you have to mine it”

– Anonymous

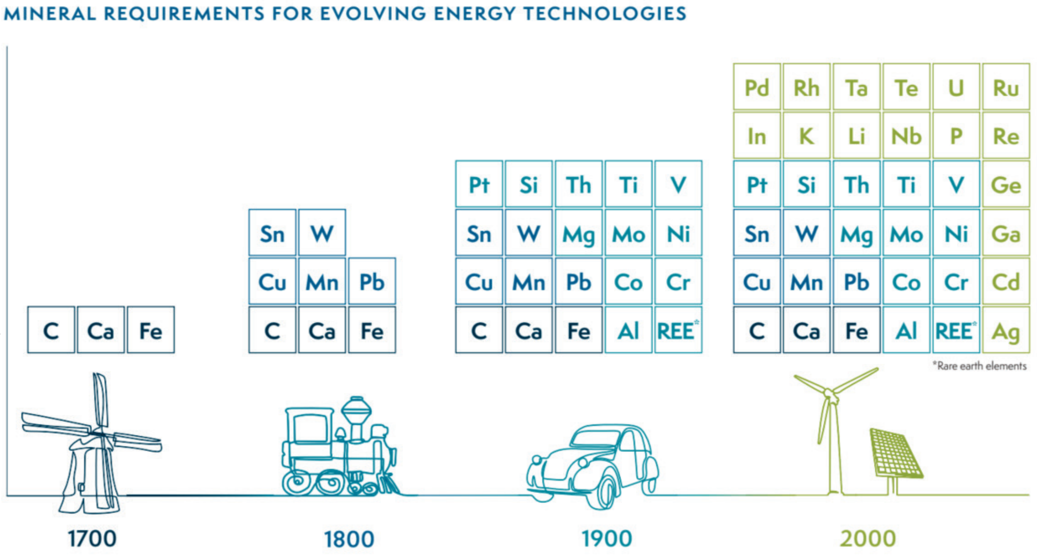
… and try to recycle it!

Rare earth elements – Minerals

To obtain REEs concentrate that can be incorporated into permanent magnets, then into-manufactured goods, they have to be extracted through mining operations.

Example of bastnaesite, a fluoro-carbonate (CO_3F) that contains LREE. It is the main ore at the Nechalado mine.

Eudialyte, from the Kipawa advanced exploration project in Quebec, is a cyclosilicate enriched in HREE, Y and Zr.



Bastnaesite

Eudialyte

Source: https://vitalmetals.com.au/

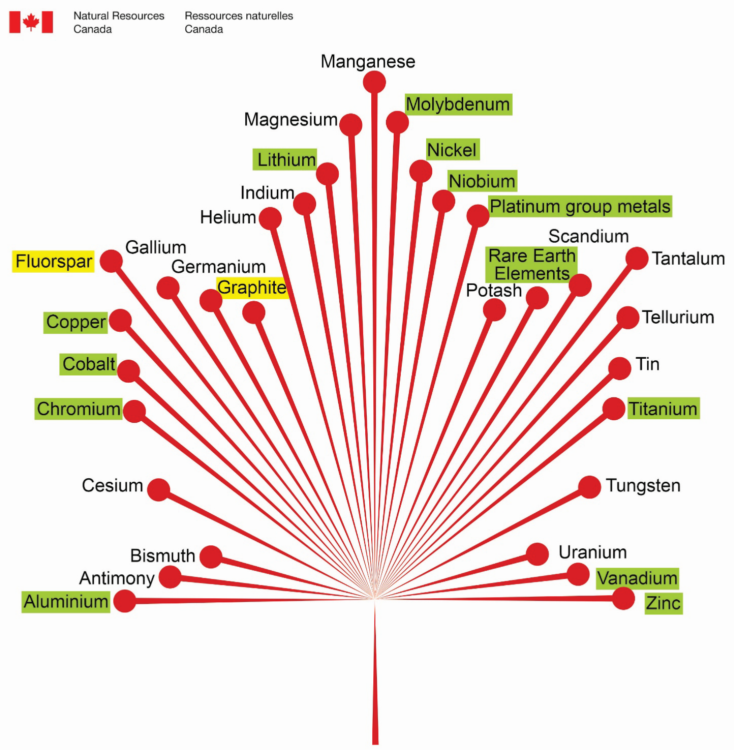
As illustrated in this graphic, society's mineral requirements steadily increased over the past centuries with evolving technologies. An increasing variety and quantity of metals and elements is now required to support broaden technology access and overall population growth.

Source: Pan-Canadian Geoscience Strategy brochure (www.geologicalsurveys.ca), adapted from Zepf et al., 2014. Materials critical to energy industry – An introduction (2nd edition).

“Critical Minerals” Case

In an effort to promote public interest and outline the contribution of geological science to society, we assembled a « Critical Mineral » educational case.

It is a user-friendly toolkit containing a collection of 16 samples that include critical minerals and/or metals (elements). This helps to create a tangible link between the critical minerals, their mineral hosts and ultimately the geological environments from which they have to be extracted to feed the manufacturing chain and end-up in our electronic devices, electric cars or as energy producing technologies (e.g. wind turbine, solar panels).



“Critical Minerals” Case – User guide

The samples are contained in a sturdy case that’s easy to handle, transport and store.

There is also a « user guide » that accompanies the sample collection. It contains a sample inventory and biligual identification cards with mineral names and chemical formulae highlighting the « criticial element » within the minerals. The guide, available in both English and French, also gives a general overview of what are critical minerals.

Bécu et al., GIP 144e


“Critical Minerals” Case - Section 1

“Critical Minerals” Case

Assembled by Valérie Bécu, Anne-Aurélie-Sappin and Stéphanie Larmagnat, GSC-Quebec

The purpose of the educational case project is to facilitate scientific awareness and outreach activities by assembling simple materials and educational content as well as ready-to-use facilitation scenarios. All contained in sturdy cases with wheels and handles for easy handling, transport and storage This initiative received financial support from the Canadian Geological Foundation (Grant 19-26) as well as the Geological Survey of Canada, Quebec division (GSC-Quebec) in addition to several donations (samples and others) from several GSC-Quebec staff members and their entourage. The material assembled is intended to be a starting point that can be modified and adapted as presenters see fit for various scenarios and facilitation contexts. As such, the content of this guide should not be considered exhaustive and can easily be modified to reflect the resources available in each province or territory.

The minerals and their constituting elements are used in the manufacturing of various products or in industrial processes thanks to their physical or chemical properties. What would life be without metals or minerals: no steel, no electricity, no plumbing, no household appliances, no planes, and no vehicles? Were you also aware that minerals are used in making cosmetic products, medications, vitamins, electronic devices and played a key role in the transition to a digital and low carbon economy? The Government of Canada has compiled a list of the 31 minerals and/or elements that are considered critical to the economic prosperity of Canada and its allies and to position the country as a leader in the mining sector, as laid out in the Canadian Minerals and Metals Plan (CMMP). The “Critical Minerals” case shows some of the minerals that are deemed essential for the country's economic development.

Minerals contained in the “Critical Minerals” case

1

Bécu et al., GIP 144f


Mallette « Minéraux critiques » - Section 1

Mallette « Minéraux critiques »

Assemblée par Valérie Bécu, Anne-Aurélie-Sappin et Stéphanie Larmagnat, CGC-Québec

L'objectif du projet des mallettes éducatives est de faciliter les activités de sensibilisation et de vulgarisation scientifique en élaborant du matériel et du contenu pédagogique simple, ainsi que des scénarios d'animation prêts à être utilisés. Le tout est contenu dans des mallettes robustes, munies de roues et de poignées, pour faciliter la manutention, le transport et le rangement. Cette initiative a bénéficié de l’appui financier de la Fondation géologique du Canada (FGC) (*Canadian Geological Foundation Grant 19-26)* ainsi que de la Commission géologique du Canada, division de Québec (CGC-Québec), en plus de nombreux dons (échantillons et autres) de la part de plusieurs membres du personnel de la CGC-Québec et leur entourage. Le matériel assemblé se veut un point de départ pouvant être modulé et adapté à la guise des présentateurs selon les divers scénarios et contextes d’animation. En ce sens, le contenu de ce guide ne doit pas être considéré comme exhaustif et peut facilement être modifié pour refléter les ressources présentes dans chaque des provinces ou territoires.

Les minéraux et les éléments qui les constituent sont utilisés dans la fabrication de divers produits ou dans des procédés industriels grâce à leurs propriétés physiques ou chimiques. Que serait notre vie sans métaux ni minéraux : pas d’acier, pas d’électricité, de plomberie, d’appareils ménagers, d’avion et d’automobiles? Mais encore, aviez-vous déjà réalisé que les minéraux entrent également dans la confection de produits cosmétiques, médicaments, vitamines, appareils électroniques et jouent un rôle essentiel dans la transition vers une économie numérique et à faibles émissions de carbone? Le gouvernement du Canada a dressé une liste qui compte 31 minéraux et/ou éléments considérés comme critiques pour la prospérité économique du Canada et de ses alliés et pour positionner le pays en tant que chef de file de l’exploitation minière, comme mentionné dans le Plan canadien pour les minéraux et les métaux (PCMM). La mallette « Minéraux critiques » présente des exemples de minéraux jugés indispensables pour le développement économique du pays.

Minéraux contenus dans la mallette « Minéraux critiques »

1

MALLETTE « MINÉRAUX CRITIQUES »/ “CRITICAL MINERALS” CASE

Inventaire des minéraux/ Minerals inventory:

1. Graphite / Graphite
2. Pyrochlore / Pyrochlore
3. Molybdénite / Molybdenite
4. Malachite et cuivre natif / Malachite and native copper
5. Spodumène / Spodumene
6. Bauxite / Bauxite
7. Chromite /Chromite
8. Fluorite / Fluorite
9. Eudialyte / Eudialyte
10. Ilménite / Ilmenite
11. Titanomagnétite / Titanomagnetite
12. Chalcopyrite / Chalcopyrite
13. Sphalérite / Sphalerite
14. Pentlandite et chalcopyrite (Mine Raglan, Cap Smith, Qc) / Pentlandite and chalcopyrite (Raglan Mine, Cape Smith, Qc)

“Critical Minerals” Case – User guide

A detailed table of content is included in the guide.

Each individual mineral have its own description page that provides information about the mineral and the critical metal/element it contains. Following paragraphs mention the general applications in modern technology and give insights about the geological environments in which these minerals can be found.

(Bécu et al., GIP 144e)

“Critical Minerals” Case - Section 1

Content structure for the “Critical Minerals” case:

“Critical Minerals” Case - Section 2

EUDIALYTE

Figure 2.8: Sample of eudialyte (pink minerals) from the Kipawa deposit, located in Témiscamingue, Quebec (donated by V. Bécu and P. Mercier-Langevin). Eudialyte can contain rare earth elements, or REEs, which are essential for the manufacture of many common electronic products.

Eudialyte (Figure 2.8) is a rare, cyclosilicate mineral, comprising sodium (Na), calcium (Ca) and zirconium (Zr), with the chemical formula $Na_{15}Ca_6(Fe^{2+},Mn^{2+})_3Zr_3[Si_{25}O_{73}](O,OH,H_2O)_3(OH,Cl)_2$. In some cases, eudialyte can be enriched with rare earth elements (REEs) such as lanthanum (La), cerium (Ce) and neodymium (Nd) for example.

REEs are a group of 15 elements in the periodic table called lanthanides. Scandium (Sc) and yttrium (Y) tend to be associated with the same ore deposits because of their similar properties to lanthanides elements. REEs are essential components in numerous electronic devices that we use on a daily basis and that are used in various industrial applications, namely electronics, clean energy, aerospace, automotive and defence.

Magnet manufacturing represents the largest and most important end use of REEs, representing 38% of demand. Permanent magnets are an essential component in the modern electronic technologies used in cellphones, TVs, computers, vehicles, wind turbines, jets and many other products. REEs are also widely used in advanced and ecological products due their luminescent and catalytic properties.

Canada has some of the largest reserves and known resources of REEs (measured and indicated) in the world. However, the country only made the list of producers in the summer of 2021 with the Nechalacho Mine (Northwest Territories). In order to increase production, a certain number of mining projects are currently under development. In Quebec, the main rare earth deposits include the Strange Lake and Ashram deposits in Nunavik and the Kipawa deposit in Témiscamingue. The sample in our collection comes from the latter deposit. In the case of the Kipawa deposit, the rare earths are incorporated into the complex mineral structure of eudialyte, associated with units of syenite composing an intrusive peralkaline complex (magmatic rocks containing minerals rich in sodium and potassium).

Sources:
https://www.nrcan.gc.ca/our-natural-resources/minerals-mining/minerals-metals-facts/rare-earth-elements-facts/20522
https://mern.gouv.qc.ca/mines/industrie/metaux/metaux-exploration-terres-rares.jsp
See “Section 3- Supplementary Resources” for additional information and videos on rare earths.

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“Critical Minerals” Case – User guide

The mineral description sheets also contain a few interesting facts, for example, that graphite and diamonds are both polymorphs of carbon, i.e. they are both exclusively composed of carbon atoms but have different crystal structures and properties because formed under distinct pressure and temperature conditions.

(Bécu et al., GIP 144e)

GRAPHITE

Figure 2.10: Graphite sample (GSC-Quebec collection).

Graphite (C – Figure 2.10) is a soft mineral (hardness of 1.5 on the Mohs Scale) and its greasy and shiny lustre have made it an excellent substitute for lead, an element with which it was associated until the 18th century. The mineral was then called graphite in reference to its use in writing. Originally used in its raw state in the manufacturing of pencil leads, graphite is now mixed with ceramic clay, making it possible to vary the hardness of the lead based on what proportions of the two materials are used. The higher the proportion of ceramic clay, the harder the pencil lead and inversely, if there is more graphite, the pencil lead will be softer and provide a thicker and darker pencil mark. Today, manufacturers use numberings associated with the letters H (hard) and B (bold) to indicate the various degrees of hardness in their pencils.

Graphite is also an essential component in the manufacturing of lithium-ion batteries that power electric vehicles and most of our other electronic devices such as cellphones, laptops, smartwatches, etc. It is the main material in the making of anodes, the part of the battery that absorbs current. Interesting fact, lithium-ion batteries require 20 to 30 times more graphite than lithium. Thus 10 kg of graphite are required for a hybrid vehicle whereas an entirely electric vehicle needs 40-50 kg.

In Quebec, graphite is mined at the Stratmin Mine in the Lac-des-Îles sector south of Mont-Laurier. Graphite mineralization is associated with bands of dolomitic marble, calcitic marble*, quartzite and calc-silicate rocks found in the belonging to the Central Belt of metasedimentary rocks of the southwestern Grenville Province. The Matawinie Project is also under development in Saint-Michel-des-Saints, in Lanaudière (construction started in summer 2021). This project, spearheaded by the company Nouveau Monde Graphite, is looking to become the largest open pit mining operation (pit extending to 2.7 km long) that is entirely operated using electric vehicles. Graphite occurs in fine to coarse granules, disseminated in the biotite-graphite paragneiss in variable thicknesses (10-15 m). It is locally accompanied by iron sulphides (pyrrhotite, pyrite). (*see sample contained in the “Sedimentary Rock and Fossils” case)

Sources:
https://fr.canson.com/conseils-dexpert/le-crayon-mine-graphite
https://nmg.com/operations/
https://gq.mines.gouv.qc.ca/portail-substances-minerales/graphite/
For additional information regarding lithium-ion batteries, refer to “Section 3-Supplementary Resources”.

Graphite and diamonds are both polymorphs of carbon, i.e. they are both exclusively composed of carbon atoms, but they are crystallized based on different structures under distinct pressure and temperature conditions. The carbon in graphite forms hexagonal structures placed in layers one on top of the other (sheets), making the mineral very friable. In diamonds, the atoms are organized in a more tri-dimensional structure that is responsible for this mineral’s exceptional hardness (hardness of 10 on the Mohs Scale).

Diamonds are refractory xenocrysts (crystals that are foreign to the magma in which they are found), pushed up by kimberlite magma* to the sub-continental lithospheric mantle (Figure 2.11). Here, the magma is just a vehicle transporting the diamonds quickly to the surface under high-pressure and high-temperature conditions, preventing then from transforming into graphite. (*see sample of kimberlite contained in the “Magmatic Rocks” case)

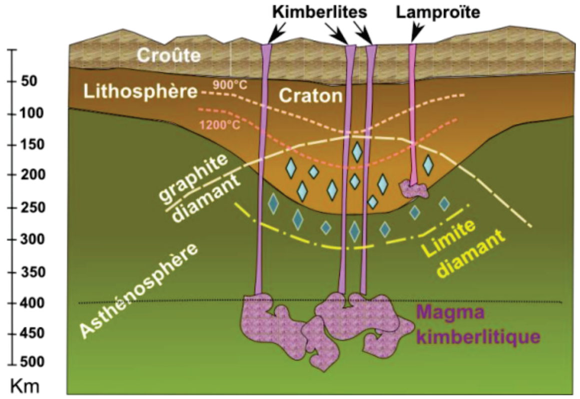


Figure 2.11: Diagram illustrating the various stability fields for graphite and diamonds as well as the mechanism for diamonds coming to rest in the continental crust when pushed up by the kimberlite magma, located at great depths in the earth's mantle. (source: https://www.pairform.fr/doc/17/138/500/web/co/grain2_1_2.html)

Educational Case Project – User-friendly toolkits for geoscientists

- Aims to provide user-friendly toolkits for GSC geoscientitsts, to use for outreach activities
- Educational content (User guide)
- Ready-to-use facilitation scenarios (PowerPoint presentations, semi-directed activities, supplementary resources and "Did you know?" fun facts)

This initiative received a grant from the Canadian Geological Foundation plus support from the GSC-Québec's office and the Canadian museum of Nature.

Canadian Geological Foundation 1968 Fondation géologique du Canada

CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

musée canadien de la nature nature canadian museum of nature

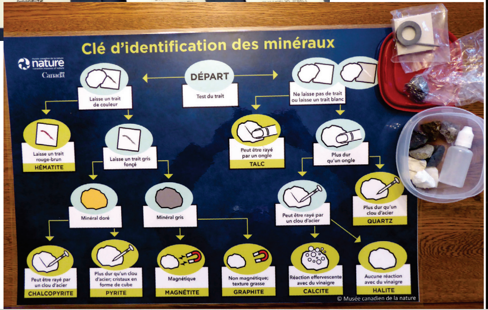
Educational Case Project – User-friendly toolkits for geoscientists

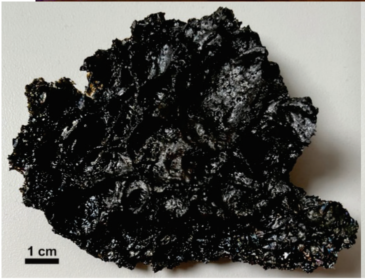
Additional toolkits were developed, and all are contained within easy-to-carry travel cases. These cover a variety of topics and can be presented as stand-alone displays or be used complementary to one another:

- "Mines and Minerals"
  - " Minerals in eveday objects "
  - Ore and mines
  - Physical properties of minerals activities
  - Supplementary resources (critical minerals, industry challenges and innovations, analytical techniques)

- "Sedimentary rocks and fossils"
  - Sedimentary rocks (hydrocarbons, caves and karsts)
  - Fossils (mass extinctions, origins of life of Earth)

- "Magmatic rocks"
  - Extrusive vs intrusive rocks (volcanic vs plutonic)
  - Volcanoes





The National Geological Surveys Committee (NGSC), which regroups Canada's 13 geological survey organizations, recently launched the Pan-Canadian Geoscience Strategy (PGS), that provides a framework for collaboration and coordination on shared geoscience priorities including two people-focused areas. These can be address by GSC scientists engaging in more public oriented activities with the help of the user-friendly toolkits for geoscientists presented here.

LONG-TERM VISION:

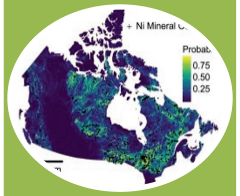
Provide geoscience information that underpins the responsible development of Canada's geological resources and serves the public good

MISSION STATEMENTS SUPPORT:

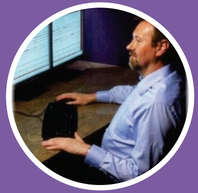
- Competitiveness
- Land use decisions
- Public safety
- Inclusivity

PRIORITY AREAS FOR COLLABORATIVE NATIONAL ACTION:

Advancing
FRAMEWORK GEOSCIENCE



Advancing
ENERGY & MINERAL POTENTIAL MODELLING



Facilitating
ACCESS TO ONLINE DATA

Technical-Focused Priority Areas

Supporting the training of
NEXT GENERATION GEOSCIENTISTS

Enhancing
PUBLIC LITERACY IN GEOSCIENCE

People-Focused Priority Areas

PGS People-focused priority areas for collaboration

Supporting the training of NEXT GENERATION GEOSCIENTISTS

Purpose:

Play an active role in attracting and training newcomers to geoscience in Canada

Problematique:

Availability of personnel; requirements for next-gen skillsets

Potential early actions:

Compile a list of hands-on training best practices

Leverage ongoing work under the CMMP regarding local procurement (particularly Indigenous procurement) to inform hiring practices

Develop an online national repository of geoscience training opportunities

Enhancing PUBLIC LITERACY IN GEOSCIENCE

Purpose:

Public awareness/trust of geoscience

Problematique:

Misinformation/misunderstanding

Potential early actions:

Build partnerships with existing science outreach organizations

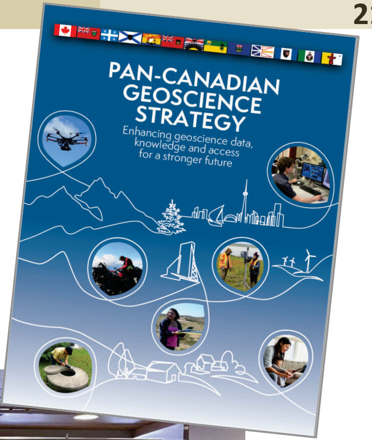
Continue to develop plain-language materials about geoscience projects

To learn more, visit the website

www.geologicalsurveys.ca | www.commissionsgeologiques.ca


Mine Raglan
« Ni-Cu-Co-ÉGP magmatique »
Cap Smith, Nunavik (Québec)
Pentlandite
($(Ni,Fe,Co)_9S_8$)+MGP
« Minéraux Critiques »
Chalcopyrite
($CuFeS_2$)
« Minéral Critique »
Ilménite
($FeTiO_3$)
« Minéral Critique »
Sphalérite
(ZnS)
« Minéral Critique »
Malachite
($Cu_2(CO_3)(OH)_2$)
« Minéral Critique »
Chalcopyrite
($CuFeS_2$)+MGP
« Minéral Critique »
Spodumène
($LiAlSi_2O_6$)
« Minéral Critique »
Eudialyte
($Na_{15}Ca_6(Fe^{2+},Mn^{2+})_3Zr_3[Si_{25}O_{73}](O,OH,H_2O)_3(OH,Cl)_2$) + ÉTR
« Minéraux Critiques »
Titanomagnétite
($FeV_{3-x}Ti_xO_4$)
« Minéraux Critiques »
Graphite
(C)
« Minéral Critique »
Pyrochlore
($(Na,Ca)_2Nb_2O_6(OH,F)$)
« Minéral Critique »
Fluorite
(CaF_2)
« Minéral Critique »
Bauxite
($AlO_x(OH)_{3-2x}$)
« Minéral Critique »
Molybdénite
(MoS_2)
« Minéral Critique »
Chromite
(Cr_2FeO_4)
« Minéral Critique »

Thank you!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