Opportunities in Global Mineral Resources

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Azurite & Malachite, Ely, NV (J. Scovil photo)
Round Mountain, NV (2007)
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Demand is high.

Resources are global, but China is #1.

The trends will help guide exploration and development.
Data from USGS, USBM, & CIA, to 2018

- Copper production: ~42X more than in 1900
- World population: 4.5X more than in 1900
- Per capita consumption: 9.3X more than in 1900
Global copper production in 2018 (21 million metric tons) exceeded over 100 years of production from the Bingham Canyon mine (~17 million metric tons).
Demand is high for nearly every mineral resource.

Data from USGS, USBM, & CIA, to 2018
Global gold production in 2018 (3,260 metric tons) exceeded the cumulative production from the Carlin trend in Nevada (~3,000 tons), one of world’s top regions.
We are in the midst of the biggest gold-mining boom in history.
Coal has recently become an exception. Global demand has fluctuated; per capita consumption is steady.
Annual global coal production (~7.6 billion metric tons in 2017) equals approximately 5.2 km³ of coal, or ~1,840 km² of land with an average coal thickness of 3 m.
The amount of CO$_2$ released from burning of coal in 2017 would have been enough, without natural reduction from plant growth, rain, and other processes, to raise the concentration of CO$_2$ in the atmosphere by ~2.8 ppmv, a bit more than the recent global trend of CO$_2$ increasing ~2.2 ppmv per year.

\[
\text{(7.585x10}^{15}\text{ g coal burned in 2017)} \times (\sim 0.8 \text{ g C/g coal}) \times (3.6642 \text{ g CO}_2/\text{ g C})/(5.15x10^{21} \text{ g air in the atmosphere}) \times (28.97 \text{ g air})/(\text{mole air}) \times (1 \text{ mole CO}_2)/(44.0095 \text{ g CO}_2) \times 10^6 \text{ ppmv CO}_2/(\text{mole CO}_2/\text{mole air})
\]

= ~2.8 ppmv CO$_2$ potentially added to the atmosphere
The number of mineral commodities in demand for products in society has increased markedly in the last 100 years.
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From 1997 to 2018, China’s production increased by 8.2X; India’s increased by 4.6X.
Resources are global, but China is Number One.
World's leading producer

Countries with 4% or more of global production

Other countries with production or major reserves

Data source: USGS

China imports iron from Australia & Brazil.
Coal

Resources are global, but China is Number One.

World's leading producer
Countries with 4% or more of global production
Other countries with production or major reserves

Data source: USGS
India has been increasing its coal use, while China & USA cut back.
China has been the #1 gold-producing country since 2007.
World's leading producer

Countries with 4% or more of global production

Other countries with production or major reserves

Resources are global, but China is Number One.
China has ~19% of the world population.

Data from CIA.
Selected commodities for which China produced >19% of the global total

- Aluminum* (54%)
- Arsenic* (68%)
- Cadmium* (36%)
- Fluorspar (63%)
- Gypsum (50%)
- Lime* (66%)
- Molybdenum (45%)
- Aluminum ore (23%)
- Barite (39%)
- Cement* (59%)
- Germanium* (>50%)
- Indium* (43%)
- Magnesium (67%)
- Nitrogen (31%)
- Rare Earths (81%)
- Selenium* (28%)
- Steel* (49%)
- Tin (34%)
- Vanadium (54%)

- Antimony (73%)
- Bismuth* (79%)
- Coal (45%)
- Graphite (65%)
- Lead (51%)
- Mercury (80%)
- Phosphate (53%)
- Salt (24%)
- Silicon* (65%)
- Tellurium* (67%)
- Tungsten (83%)
- Zinc (39%)

Data from USGS in 2017, except coal from IEA in 2016.
In production of 44 mineral commodities, China ranks well above all others.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of commodities for which this country is the #1 producer</th>
<th>Number of commodities for which this country is among the top 3 producers</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>USA</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>South Africa</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Australia</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Chile</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Congo</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Russia</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Canada</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Brazil, Mexico, &amp; Indonesia</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Data for 2017, except coal, oil, and gas (2016)
Number of selected mineral commodities (among 44) for which these countries are among the top three global producers (with percentage of land area in parentheses).
Our consultant will tell us how we can secure a long-term supply of rare earth metals for our products.

China has most of the rare earth metals. Try dying and reincarnating. There’s a 20% chance that you’ll be born Chinese.

What’s plan B?

If the only part that goes wrong is the Chinese part, you can try dying again.
So what?

And who cares?
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The trends will help guide exploration and development.
• Which commodities does a country need to sustain or grow its economy?

• For which commodities is more research needed on models of formation and methods for extraction?

• For which commodities should a company explore?
49 selected commodities

Data for 2017 (coal, oil, gas 2016)
Data for 2017 (coal, oil, gas 2016)
Commodities for which China accounts for >19%
Commodities with global annual markets > $1 billion & for which China does not account for > 19%
Elements with (a) high prices relative to their abundances, (b) large markets, and (c) limited production from China are likely to be most attractive. These include

- Gold
- Platinum-group elements
- Uranium
- Lithium
- Cobalt
- Niobium
- Titanium
- Potassium
- Iron
"Forget gold. Strategic metals are where it's at."
Consider exploring for mineral resources that will likely be in higher demand in the future.
Energy-critical elements (ECEs) are a class of chemical elements that currently appear critical to one or more new energy-related technologies. A shortage of these elements would significantly inhibit large-scale deployment, which could otherwise be capable of transforming the way we produce, transmit, store, or conserve energy. We reserve the term ECE for chemical elements that have not been widely extracted, traded, or utilized in the past, and are therefore not the focus of well-established and relatively stable markets.
Some ECEs today
CuIn$_x$Ga$_{(1-x)}$Se$_2$, CdTe, GaAs, Ag, and Si$_{1-x}$Ge$_x$ for solar panels

Fe$_{14}$(Nd,Dy)$_2$B, SmCo$_5$, and Sm$_2$Co$_{17}$ for magnets, e.g., in wind turbines

Li, Co, La, Ni, and V for batteries

Pt, Pd for catalysts in fuel cells

Tb, Eu in fluorescent lights
World's leading producer

Countries with 4% or more of global production

Other countries with production or major reserves

Lithium is needed in batteries for electric cars, etc.

Data source: USGS
Cobalt is also needed in batteries for electric cars.
Potash (potassium) is used mostly in fertilizer.
Uranium is used mostly in generating electricity.
China’s economy will likely drive up the demand for those commodities for which it can’t mine enough domestically.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>% from China</th>
<th>% from Canada</th>
<th>% from US</th>
<th>Leading Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platinum</td>
<td>~0</td>
<td>6</td>
<td>3</td>
<td>South Africa (69%)</td>
</tr>
<tr>
<td>Potash</td>
<td>13</td>
<td>29</td>
<td>1</td>
<td>Canada (29%)</td>
</tr>
<tr>
<td>Chromium</td>
<td>~0</td>
<td>~0</td>
<td>~0</td>
<td>South Africa (44%)</td>
</tr>
<tr>
<td>Copper</td>
<td>8</td>
<td>3</td>
<td>6</td>
<td>Chile (28%)</td>
</tr>
<tr>
<td>Nickel</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>Indonesia (24%)</td>
</tr>
<tr>
<td>Cobalt</td>
<td>2</td>
<td>3</td>
<td>0.4</td>
<td>Congo (64%)</td>
</tr>
</tbody>
</table>

For example, the leading producers of nickel are Indonesia (24% of mine production), Philippines (15%), New Caledonia (9%), Russia (9%), Australia (7%), and Canada (7%).

Mount Keith Ni mine, Western Australia: 323 million metric tons @ 0.56% Ni

Spinifex texture in serpentine, Honeymoon Well nickel deposit, Western Australia - indicator of bladed crystals of olivine, from quenching of an ultramafic lava flow.

Production statistics from USGS
Watch for competition in the regions of resource-rich Precambrian cratons, which are major sources of iron, manganese, nickel, chromium, titanium, copper, cobalt, zinc, gold, palladium, platinum, and uranium. This includes parts of Africa, Australia, South America (particularly Brazil and Venezuela), Russia, and Canada.
Precambrian cratons

- **Archean** (2.5 to 4.0 Ga) – Au, Ni, U
- **Proterozoic** (542 Ma to 2.5 Ga) – Fe, Mn, V, Pt, Pd, Cr, Ni, Au, Cu, Co, U, Ti, diamonds

Source for geologic map: www.OneGeology.org
Jurassic to Recent oceanic crust – potential for ore deposits of manganese nodules & crusts (Mn, Ni, Co, Cu), massive sulfide deposits & seafloor vents (Cu, Zn, Pb, Au, Ag), and phosphate nodule deposits (P)

Source for geologic map: www.OneGeology.org
World's leading producer

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Other countries with production or major reserves

Nickel is used mostly in steel.

Data source: USGS
Pt

(USA = 2.6%)
(Canada = 6%)
(Russia = 13%)
(Zimbabwe = 9%)
(South Africa = 69%)

Platinum is used mostly in catalytic converters.

Data source: USGS
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Chromium is used mostly in steel & other alloys.
Titanium has a variety of uses, including aerospace.
Niobium is used mostly in steel & other alloys.

Data source: USGS
Critical and strategic minerals will change with time.
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\[ \text{CuIn}_x\text{Ga}_{(1-x)}\text{Se}_2 \text{ or CIGS, for solar panels?} \]
\[ \text{CdTe, GaAs, and Ge for solar panels?} \]
\[ \text{Nd for magnets for wind and other electrical turbines?} \]
\[ \text{Li, Co, and V for different types of batteries?} \]
More recycling can be accomplished by increasing collection rates of various products, better product design with recycling in mind, and improvements in recycling technologies. - Reck and Graedel (2012).
Social and cultural concerns are part of mining today.

- Sustainability and sustainable development – environment, economy, social and cultural structure
- International Standards Organization environmental management (ISO 14001)
- International Cyanide Management Institute
- Community Outreach and Economic Security
- World Bank
- Stockholder demands
- Governmental regulations
Mark Twain (1872) described a classic scheme involving an unscrupulous assayer (Fig. 17): (a) “Assaying was a good business, and so some men engaged in it, occasionally, who were not strictly scientific and capable. One assayer got such rich results out of all specimens brought to him that in time he acquired almost a monopoly of the business. But like all men who achieve success, he became an object of envy and suspicion. The other assayers entered into a conspiracy against him, and let some prominent citizens into the secret in order to show that they meant fairly. Then they broke a little fragment off a carpenter's grindstone and got a stranger to take it to the popular scientist and get it assayed.”

Scams happen.
“In the course of an hour the result came---whereby it appeared that a ton of that rock would yield $1,284.40 in silver and $366.36 in gold! Due publication of the whole matter was made in the paper, and the popular assayer left town 'between two days.'

The **Bre-X hoax** of the **mid-1990s** led to the development of **Canadian National Instrument 43-101**, **Standards of Disclosure for Mineral Projects**. The Calgary-based junior mining company supposedly discovered a major gold deposit at Busang, Indonesia. The assayed samples were salted, and investors lost $2 billion.
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Thank you!

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Artisanal mining will likely continue as a health, safety, and environmental challenge for society, governments, and industry.

Four artisanal miners (galamsey) work unsafely, without personal protective equipment or ground support, near Kyereboso in Ghana in 2008.
Using blowtorch to remove mercury from amalgam, Sulawesi (Larry James photo)
Why explore in Nevada?

Among many other reasons, Nevada is the US leader in gold, barite, and lithium; a significant historical producer of copper, silver, and zinc; and a key source of industrial minerals for construction (gypsum, cement resources, aggregate).

Lithium-brine evaporation pond, 2008, Clayton Valley (Silver Peak), Nevada
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We are in the midst of the biggest gold-mining boom in history.
Thank you!

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