The Importance of Mineral Resources in a National-International Context

Jonathan G. Price
State Geologist Emeritus
Nevada Bureau of Mines and Geology

Azurite & Malachite, Ely, NV (J. Scovil photo)

jprice@unr.edu
775-329-8011
The Importance of Mineral Resources in a National-International Context

• Demand for mineral resources will continue to grow.

• We are unlikely to run out of mineral resources (globally).

• Nonetheless, there are challenges for the United States.
Demand is high for nearly every mineral resource, due to rising population and average standard of living.
Demand is high for nearly every mineral resource.

Copper

~34X more production than in 1900

~8X more per capita consumption than in 1900

Source: USGS, CIA
Global copper production in 2012 (17.0 million metric tons) equaled over 100 years of production from the Bingham Canyon mine in Utah (17.0 million metric tons).
Demand is high for nearly every mineral resource. 

- Gold: ~same per capita consumption for the last 100 years.
- ~7X more production than in 1900 (historical high in 2012).

Source: USGS, CIA
The number of mineral commodities in demand for products in society has increased markedly in the last 80 years.

Source: USGS data
Economic geologists have been quite successful in finding more ore deposits in known areas.

The Round Mountain gold mine in Nevada (volcanic-rock-hosted deposit) discovered in 1904, has yielded 13 million ounces of gold from 1977 to 2012 – continuous record of discovery around the initial deposit.
Gold production, 1835-2012

- **United States**
- **Nevada**

The current boom (1981-2012) = 247M oz Au

mostly Carlin and other Nevada deposits = 174M oz

Goldfield (NV), Black Hills (SD), Cripple Creek (CO), porphyry Cu (AZ & UT) = 95M oz Au

’49ers = 29M oz Au

Discoveries continue to feed the biggest gold boom in US and world history.
Discoveries continue to be made in traditional terrains, such as Precambrian cratons, throughout the world – limits are political and economic, not technical.
We have barely started to explore the oceans – political and legal challenges are probably more important than technical challenges.

Jurassic to Recent oceanic crust – potential for ore deposits of manganese nodules (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
Economic geologists have been quite successful in finding more ore deposits in known areas, deposits in new areas, and new types of deposits.
Examples of some **new types** of ore deposits recognized and brought into production in the last 55 years.

<table>
<thead>
<tr>
<th>Deposit type</th>
<th>Type locality (year discovered) and new features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlin Au</td>
<td>Carlin, Nevada (1961): disseminated gold in sedimentary rocks</td>
</tr>
<tr>
<td>Roll-front U</td>
<td>Wyoming, Kazakhstan (1960s): redox boundaries in sandstones</td>
</tr>
<tr>
<td>Granite-hosted U</td>
<td>Rössing, Namibia (1960s): U-rich granite</td>
</tr>
<tr>
<td>Unconformity U</td>
<td>Rabbit Lake, Saskatchewan (1968): high-grade U near unconformities</td>
</tr>
<tr>
<td>Iron oxide Cu-Au</td>
<td>Olympic Dam, S. Australia (1975): iron-oxide-rich ores in huge regional alteration systems</td>
</tr>
<tr>
<td>Intrusion-related Au</td>
<td>Fort Knox, Alaska (1980s): Au in granitic rocks, without Cu</td>
</tr>
<tr>
<td>Ion Absorption REE</td>
<td>South China (1980s): low-grade REEs with kaolinite in weathered granites</td>
</tr>
</tbody>
</table>

More new types of ore deposits will be discovered in the future…
We may not need to worry about mining on the Moon, Mars, or asteroids for some time.

Though thinking about how ore deposits might form on such bodies could help us be more imaginative on Earth!
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Challenges for the United States

China is #1 in terms of mineral-resource production.
Iron

With 19% of the population, China produces ~43% of the world’s iron ore and ~48% of the world’s steel.

China’s economy continues to boom, although 2012 iron-ore production suggests a slowdown.
Copper

China produces only ~9% of the world’s copper but is aggressively seeking resources elsewhere.
Gold

China has been the #1 gold producing country since 2007.
In production of 46 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>24</td>
<td>31</td>
</tr>
<tr>
<td>USA</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Australia</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Russia</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Canada</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Chile</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>South Africa</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Brazil</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Congo</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

2012 production statistics from USGS, EIA for coal and uranium in 2011
China

Leading world producer (24 commodities)
#2 or #3 (7 commodities)

Abundance (ppm, grams of element/tonne of Earth's crust)

Price ($/kilogram)
China has 19% of the world’s population.

Selected commodities for which China produced ≥19% of the world’s total in 2012:

- Aluminum*, 42%
- Barite, 48%
- Cement*, 58%
- Fluorspar, 61%
- Gypsum, 32%
- Lead, 50%
- Mica, 69%
- Rare Earths, 94%
- Tungsten, 85%
- Antimony, 83%
- Bismuth, 81%
- Coal, 45% (2011)
- Germanium*, 70%
- Indium*, 58%
- Manganese, 19%
- Molybdenum, 42%
- Steel*, 48%
- Vanadium, 37%
- Arsenic, 57%
- Cadmium, 30%
- Diatomite, 21%
- Graphite, 68%
- Iron ore, 43%
- Mercury, 75%
- Phosphate, 42%
- Tin, 43%
- Zinc, 35%

* refined or processed, not mined
Rare Earth Elements (REEs)

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.
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, La, Ni, and V for batteries

Pt, Pd for catalysts in fuel cells

Tb, Eu in fluorescent lights
Critical and strategic minerals do change with time.
What minerals will be critical for the country?
Will the USA be a major producer of mineral resources in the future?
Will the USA be a major producer of mineral resources in the future?

Or will we, perhaps by default, practice “environmental imperialism” – export the negative environmental, health, safety, aesthetic, and cultural aspects of mining to other countries?
Artisanal mining outside the US will likely continue as a health, safety, and environmental challenge for society, governments, and industry worldwide.

Four artisanal miners (galamsey) work unsafely, without personal protective equipment or ground support, near Kyereboso in Ghana in 2008.
Gold mill in Sulawesi (Larry James photo)
Recent reports (Science Oct. 2013) state that 70% of Hg pollution worldwide is from artisanal mining.

Using blowtorch to remove mercury from amalgam, Sulawesi (Larry James photo)
Will the US government invest in research needed to discover, extract, and process mineral resources in an environmentally responsible manner?
Will the US government invest in research on improving the rate of recycling of mineral resources, and on finding substitutes for mineral resources that become too expensive for commercial or other applications?
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).
Do we have, and are we training, the people needed to ensure the US can meet its mineral and energy needs?
Will the US and other governments support the basic research, including geologic mapping, needed to understand where resources are likely to be found?
Will the US and other governments support the preservation of geological data and collections that stimulate discovery?
What may be the unintended consequences of new mineral resource production?
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