Geoscience Perspectives on Technology Development in Energy Storage and Implications for Strategic Mineral Exploration*

Edith Newton Wilson¹ and Jesse R. Edmondson²

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¹Rock Whisperer LLC, Tulsa, Oklahoma (edith@rockwhispererllc.com)
²Critical Resources Consulting, LLC, Fayetteville, Arkansas

Abstract

In May, 2018, the US Department of Interior released its list of 35 critical mineral commodities, most of which are used in energy storage or electronics. As the cost of lithium ion batteries drops, electric vehicles are becoming the preferred new purchase of car-buyers in Europe, China and parts of the US. Lower cost of operation will accelerate this trend and enhance the need for new batteries and their mineral components. Storage associated with the dramatic growth in off-grid baseload power, such as solar, wind, and hydro, will also increase the pressure on battery manufacturers. Minerals such as cobalt, graphite, lithium and vanadium, along with rare earth elements, are seeing an uptick in demand. Economic geologists are needed to explore for and sustainably extract them in ever increasing volumes. A review of the landscape of mineral exploration and extraction reveals similarities to the fossil fuel production business. A small group of major multi-national integrated corporations are supported by a plethora of “junior” exploration companies who provide a feedstock of leases and prospects.

Mining geologists use 3D geologic models to explore for and assess reserves of metals and are now expanding the use of geophysical techniques, including 3D seismic. The concept of ore trends, similar to petroleum play fairways, can be adapted and refined to better predict exploration corridors and future areas of extraction. Data employed by economic geologists are similar to those used to find hydrocarbons and include borehole records, surface geologic maps, rock mineralogy, and size statistics. Predictive models of ore accumulation rely on mass transport calculations at assumed heat, pressure, brine composition and mineral equilibria. As exploration geoscientists, we can readily transfer our skills from one hunting ground to the other. Geoscientists can also maximize energy efficiency for development of new mineral deposits via the use of low carbon energy resources. We can apply our environmental experience to minimize the footprint of the mine itself. We can utilize our industry strengths in risk assessment, environmental remediation, social license, and greening the oil field to become leaders in sustainable mineral development. As with all disruptive technologies, the plates will likely shift rapidly. Battery innovations will continue to redefine our concept of strategic minerals.
Selected References


Dominish, E., N. Florin, and S. Teske, 2019, Responsible minerals sourcing for renewable energy: Report prepared for Earthworks by the Institute for Sustainable Futures, University of Technology Sydney.

Doninger, J.E., and G. Economo, 2019, Cycling characteristics of silicon enhanced and boronated Lac Knife natural flake graphite from Quebec, Canada in lithium ion batteries: 36th International Battery Seminar and Exhibit, Fort Lauderdale, Florida, March 25-28, 2019.

https://www.eia.gov/maps/layer_info-m.php


Maps are shown on the World Ocean Base (Esri, dELorme, GEBCO, NOAA, NGCD and other contributors) or overlain on World Imagery (Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.


http://www.mining.com/web/much-will-cost/


https://www.sierrametals.com/Home/default.aspx

https://pubs.er.usgs.gov/publication/pp1802
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Edith Newton Wilson and Jesse Edmondson
AAPG ACE, May 20, 2019

Photo courtesy of Ty Dinwoodie
What’s driving this?
Growth in storage for battery-backed wind and solar set to dwarf EV demand.

Power plant data from https://www.eia.gov/maps/layer_info-m.php

45 % growth
There’s antimony, arsenic, aluminum, selenium,
And hydrogen and oxygen and nitrogen and rhenium,
And nickel, neodymium, neptunium, germanium,
And iron, americium, ruthenium, uranium.
Europium, zirconium, lutetium, vanadium,
And lanthanum and osmium and astatine and radium,
And gold and protactinium and indium and thorium.
And iodine and thorium and thulium and americium.
There’s yttrium, ytterbium, actinium, rubidium,
And boron, gadolinium, niobium, iridium, strontium and silicon and silver and thallium.
And bismuth, bromine, lithium, beryllium, and barium.
There’s holmium and helium and hafnium and erbium,
And phosphorus and francium and fluorine and terbium,
And manganese and mercury, molybdenum, magnesium, Dysprosium and scandium and cerium and cesium.
And lead, praseodymium, and platinum, plutonium, Palladium, promethium, potassium, polonium,
And tantalum, technetium, titanium, tellurium,
And cadmium and calcium and chromium and curium.
There’s sulfur, californium, and fermium, berkelium,
And also mendelevium, einsteinium, nobelium,
And argon, krypton, neon, radon, xenon, zinc, and rhodium,
And chlorine, carbon, cobalt, copper, tungsten, tin, and sodium.
These are the only ones of which the news has come to Harvard,
And there may be many others, but they haven’t been discovered.

- Tom Lehrer, 1959 (102, nobelium)
Global demand for graphite for battery storage alone forecast to grow from about 300,000 MT in 2018 to 1 million MT by 2023.
### Global Cobalt Deposits and Production

#### Mine Production (MT)

<table>
<thead>
<tr>
<th>Location</th>
<th>Production (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>140,000</td>
</tr>
<tr>
<td>DRC (Congo)</td>
<td>90,000</td>
</tr>
<tr>
<td>Russia</td>
<td>5,900</td>
</tr>
<tr>
<td>Cuba</td>
<td>4,900</td>
</tr>
<tr>
<td>Australia</td>
<td>4,700</td>
</tr>
<tr>
<td>Philippines</td>
<td>4,600</td>
</tr>
<tr>
<td>Canada</td>
<td>3,800</td>
</tr>
<tr>
<td>Madagascar</td>
<td>3,500</td>
</tr>
<tr>
<td>PNG</td>
<td>3,200</td>
</tr>
<tr>
<td>China</td>
<td>3,100</td>
</tr>
<tr>
<td>Morocco</td>
<td>2,300</td>
</tr>
<tr>
<td>South Africa</td>
<td>2,200</td>
</tr>
<tr>
<td>USA</td>
<td>500</td>
</tr>
</tbody>
</table>

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Global demand for cobalt for battery storage alone forecast to grow from about 100,000 MT in 2018 to 300,000 MT by 2023.
Global demand for lithium for battery storage alone forecast to grow from about 300,000 MT (LCE) in 2018 to almost 1,000,000 MT (LCE) by 2023.
Hachured countries are home to significant lithium processing while orange dots indicate countries that manufacture batteries.
Crude oil needs to be refined. And industrial minerals require processing. Geology required here.
Common Elements

Technical
- Resource estimation, asset valuation
- Hydrodynamic modeling of mass balance and transfer
- Tectonic element mapping and structural restoration
- Mineralogy and petrophysics
- Core, log and well analysis
- 3D seismic imaging
- Geochemistry

Strategic
- Secondary production
- Looking deeper in old basins
- Plethora of “juniors” feeding majors
- Future of ML, AI and sustainability supporting creative geologists
USING 3D SEISMIC

Using Geochemical Data

150-500 ppm lithium in coal, water, and rock samples

Data from the USGS National Geochemical Database
Reserve assessments are rigorously controlled and regulated according to national standards in three steps, PEA, PFS, and FS, and require an independent report and third-party monitoring.
Oil and Gas Model
Permian HZ project
16 wells on 1280 acres
Per well EUR 500,000 barrels
Capital investment ~$175 M
Payback after first year
Project life 5 years
NPV10 ~175M
Mine Model
Open pit mine
5,000 tonnes per day
Capital investment ~$20 M
Payback after 3-5 years
Project life 10 years
NPV10 ~150M
Dominish and others, 2019, Responsible Minerals Sourcing for Renewable Energy

BUT IS IT CLEAN AND SUSTAINABLE?
Critical minerals - a new energy frontier

Worldwide market demand
Global distribution trends
Basin to play to prospect
Exploration technology
Valuation and economics
Sustainable development

U.S. Senate moves forward on plan to develop electric vehicle supply chain

Ernest Scheyder