Between a rock and a hard place;
How sustainable is critical metal supply?

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British Geological Survey
Critical metals

• What do we mean by ‘critical’?
• What’s so special about critical metals?
• How sustainable is supply?
• Conclusions
How do we define ‘critical’?

• Critical – defined in various ways for different purposes / countries

• Different assessments use different criteria, different results

• EU and US usage
  – value to the economy
  – potential for an international supply shortage

Supply risk

Economic importance to EU

Most critical
Results of EU analysis

Proportion of global production from: China, South Africa, Brazil in 2009

Source: BGS World Mineral Statistics Database
Key characteristics of critical metals

• Volumes produced much smaller than industrial metals
• Consumption rates rising quickly from a very low base
• Low aggregate value compared to other metals
• Often ‘co-metals’ or ‘daughter’ metals
• Difficult extractive metallurgy
• Vital function but often low critical metal content per unit – dispersive technologies
• Critical in delivering a low carbon economy
• Recycling rates relatively low compared to industrial metals
• Vulnerable to production concentration and price volatility
Increasing global demand for critical metals

Platinum group metals (75% since 1980)
Lithium minerals (70% since 1980)
Tantalum and niobium concentrates (75% since 1980)

Source: British Geological Survey
Looking ahead - emerging technologies (ET) and increasing demand

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Forecast increase in ET demand by 2030 (x2006 level)</th>
<th>Emerging technologies (selected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallium</td>
<td>x22</td>
<td>Thin layer photovoltaics, IC, WLED</td>
</tr>
<tr>
<td>Neodymium</td>
<td>x6</td>
<td>Permanent magnets, laser technology</td>
</tr>
<tr>
<td>Indium</td>
<td>x8</td>
<td>Displays, thin layer photovoltaics</td>
</tr>
<tr>
<td>Germanium</td>
<td>x8</td>
<td>Fibre optic cable, IR optical technologies</td>
</tr>
<tr>
<td>Tantalum</td>
<td>x3</td>
<td>Micro capacitors, medical technology</td>
</tr>
<tr>
<td>Cobalt</td>
<td>x2</td>
<td>Lithium-ion batteries, synthetic fuels</td>
</tr>
<tr>
<td>Palladium</td>
<td>x3</td>
<td>Catalysts, seawater desalination</td>
</tr>
<tr>
<td>Niobium</td>
<td>x3</td>
<td>Micro capacitors, ferroalloys</td>
</tr>
</tbody>
</table>

Source: EU Critical Raw Materials Report 2010
Threats to supply sustainability

- Physical depletion
- Human factors/ access
- Developmental and ethical issues
- Environmental limits
Fear of physical scarcity

Post 2000: Neo-Malthusian thinking

- Essay on the principle of population as it affects the future improvement of society (Malthus 1798)

- The Coal Question … and the Probable Exhaustion of our Coal Mines (Jevons, 1865)

- President’s Material Policy Commission (1950-1952)

- The Limits to Growth (The Club of Rome, Meadows et al. 1972)

  - “only 550 billion barrels of oil remained and that they would run out by 1990”

Earth’s natural wealth: an audit (Cohen, 2007) New Scientist

Countdown – are the Earth’s mineral resources running out? (2008) Mining Journal

- Rare metals getting rarer (Ragnarsdottir, 2008) Nature

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What is the geological resource base?

<table>
<thead>
<tr>
<th>Metal</th>
<th>Concentration in continental crust (g/t)</th>
<th>Tonnes in upper km of total land area</th>
<th>Tonnes in upper km of EU land area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>63000</td>
<td>$2.53 \times 10^{16}$</td>
<td>$7.52 \times 10^{14}$</td>
</tr>
<tr>
<td>Cu</td>
<td>28</td>
<td>$1.13 \times 10^{13}$</td>
<td>$3.34 \times 10^{11}$</td>
</tr>
<tr>
<td>Co</td>
<td>17.3</td>
<td>$6.96 \times 10^{12}$</td>
<td>$2.07 \times 10^{11}$</td>
</tr>
<tr>
<td>In</td>
<td>0.056</td>
<td>$2.25 \times 10^{10}$</td>
<td>$6.69 \times 10^{8}$</td>
</tr>
<tr>
<td>Nd</td>
<td>27</td>
<td>$1.09 \times 10^{13}$</td>
<td>$3.22 \times 10^{11}$</td>
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<tr>
<td>Pt</td>
<td>0.005</td>
<td>$2.01 \times 10^{9}$</td>
<td>$5.97 \times 10^{7}$</td>
</tr>
<tr>
<td>Te</td>
<td>0.001</td>
<td>$4.02 \times 10^{8}$</td>
<td>$1.19 \times 10^{7}$</td>
</tr>
<tr>
<td>Re</td>
<td>0.0002</td>
<td>$7.97 \times 10^{7}$</td>
<td>$2.36 \times 10^{6}$</td>
</tr>
</tbody>
</table>

(data from P. Weihecd)
Resources, reserves and the appliance of science

- Science and technology key to massive increase in efficiencies in exploration and extraction
- Major production from deposit types unknown or unworkable 50 years ago
- Reserves are economic

Data sources: USGS, BGR database, 2009
Where will metals come from in the future?

• ‘New’ terranes
  • Central Asia
  • Arctic
• Old targets in ‘old’ terranes – Reappraisal of Cu-Co in Zambia/ DRC, Hemerdon tungsten deposit, Devon
• deposits in SW Pacific Seabed – polymetallic massive sulphide
• The ‘urban mine’?
How important is the ‘urban mine’ in supplying critical metals?

- Knowledge of resource flow, distribution/dispersion and composition is sparse
- Recyclable resources are limited to EOL material – most is unavailable as still in use
- Access to metals from urban mine governed by product design/life, extraction technology, environmental regulation and social factors – all heavily influenced by economics
- Growth in demand means that primary material still needed
High volume consumption + low unit content = major dispersion

- 1.6 billion mobile phones and 350 million PCs/laptops manufactured globally in 2010

Equates to:
- 189 000 tonnes Cu (<1% global production)
- 750 tonnes Ag (4% global production)
- 115 tonnes Au (4% global production)
- 42 tonnes Pd (19% global production)
- 17 800 tonnes Co (23% global production)
Mobile devices as a polymetallic ore body

- Although 95% of Cu and precious metals recovered, less than 50% of total metal content captured during smelting.
- Most of CM content is dispersed below cut off grade and/or extractive metallurgy too difficult.
- Price of CM determines cut off grade.

Li, Co, Cu, Ta, Pd, Au, Al, Fe, etc, W, REEs, Mg, Al, C, H, Cr, Si, Al, Na, In.
The role of recycling

- Recycling has a major role to play in supply and reducing environmental footprint.

- But with increasing consumption over the lifetime of the products, there is a ‘gap’.

Modified from Steinbach and Wellmer, 2010
Human factors/ access

- Resource nationalism and geopolitics
- Skill shortages
- Inertia and business models
Resource nationalism and geopolitics

- As competition forces up prices, governments try to boost revenues through direct control of natural resources
- Burgeoning demand + uneven resource distribution + fewer, larger mines concentrates supply = increased tension between ‘haves’ and ‘have nots’
- China controls about 97% of global rare earth supply (germanium 95%, tungsten 80%, antimony 93%)

The Telegraph

China blocked exports of rare earth metals to Japan, traders claim

China blocked exports of rare earth metals to Japan days before Tokyo’s decision on Friday to free a Chinese boat captain whose detention sparked the worst diplomatic row between the sides in years, traders said.
Concentration of supply

1960

- China: 29%
- South Africa: 23%
- U.S.S.R.: 11%
- Bolivia: 10%
- Turkey: 3%
- Austria: 2%
- Yugoslavia: 4%
- Mexico: 8%
- Czechoslovakia: 3%
- Peru: 1%
- Others: 4%

2010

- China: 97%
- Russia: 2%
- Others: 1%
- Ceylon: 15%
- Other Republics: 19%
- Brazil: 47%
- Malaya: 2%
- Australia: 16%
- Others: 1%

Rare earth oxides

Antimony

Source: British Geological Survey
Skills shortages

- Major demographic challenge to industry where many workers are near retirement or left sector during recent downturn
- Projects cancelled or deferred due to labour shortages
- Increased level of industrial disputes
- Australian minerals industry needs additional 86,000 workers in next decade to maintain market share
Business models and inertia

• With some exceptions, low level of interest in CM from major mining companies to date
• Some developments may move toward vertically-integrated mode (analogous to fluorochemical industry)
• Many CM developments will need to supply niche products ‘engineered’ for niche markets
• Requires close relationship with customers and high level of investment in process technology (analogous to some industrial minerals)
• From discovery to mine to market can take at least 10 years – speed of technological developments + inertia can lead to short/medium term shortages

Okorusu fluorspar mine, Namibia (owned by Solvay Fluorine Industries)
CM, ASM and the ‘resource curse’: environmental, developmental and ethical issues

• Shortages and price volatility can encourage artisanal/ small-scale mining (ASM) for a restricted group of CMs
• ASM activities are labour-intensive but capital and technology-poor
• Spectrum between small, informal, subsistence mining and small, organised commercial activity
• Usually (but not always) focus on high-value, easily identifiable/ extractable and portable commodities such as Au, Ta-Nb, W, Sn, gemstones, coal
Artisanal mining impacts

• Corruption and conflict – coltan, ‘blood’ diamonds
• Social disruption – population movement
• Habitat destruction and pollution
• Child labour
• Poor health and safety
• Land access/ title – disenfranchised underclass
• Poverty-driven at bottom end of spectrum therefore likely to continue
• Can be catalyst for other livelihoods and community benefits
Toward ethical sourcing of CMs

- Dodd-Frank requires US companies and those that trade with US to report use of ‘conflict minerals’ in products and components
- ‘Conflict minerals’ = Sn, W, Ta, Au mined in DRC or neighbouring countries
- NGOs campaign to pressure manufacturers to ethically source raw materials
Environmental limits?

- Extracting metal currently requires a lot of energy
- Lower grade deposits = more energy expended
- Innovation in extraction needed to break link between metal use and greenhouse gas emissions

Low energy bio-extraction of copper, Chile
Living in a material world

- Sustainable supply of critical metals is not certain
- Physical exhaustion is not an issue: primary resources and ‘urban mine’ together comprise an abundant resource although access is a major challenge
- Human factors such as resource nationalism, geopolitics, skill shortages and development inertia present an immediate supply risk
- Environmental and developmental issues which arise from artisanal mining of a small group of CMs present an ethical challenge
- Environmental limits (particularly GHGs) represent ultimate constraint on resource use
- Investment in science, better resource diplomacy, supply diversification, better extractive metallurgy, ethical sourcing, supply chain dialogue, reduced dispersion, efficient recycling, appropriate design and ‘doing more with less’ will help address these issues
Thank you

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