Critical raw materials: what, why and how?

Éimear Deady
British Geological Survey

GIFT WORKSHOP – 2015: MINERAL RESOURCES
Vienna, Austria, 12-15 April 2015
Security of supply of mineral resources

- Recurring theme in history is the availability of mineral resources
  - Rev. Thomas Malthus (1766 – 1834)
  - World War II – W mining in SW England, material stockpiles in the US
  - Cold War – ferroalloys, U availability
Security of supply of mineral resources

- Late 20th / early 21st Century UK and EU public attitudes overwhelmingly hostile to domestic mineral extraction
- Poor past record
- Socio-economic change and a rise in environmental ‘consciousness’ has resulted in a challenging domestic minerals sector
- Reinforced by post-Cold War ‘market will provide’ paradigm which conceals the true impact of conspicuous consumption
Globalisation: market efficiency or out of sight, out of mind?

- The EU now has a strong negative mineral trade balance
- In post-Cold War global free-market, both primary and manufactured goods flowed from producers with lower marginal costs
- Mineral industry benefitted from economies of scale
- As well as enjoying the economic benefits, to what extent have we moved our environmental impacts and obligations out of Europe?

Bayan Obo REE mine, China

© Éimear Deady
Mineral Resources: ‘supercycle’ and the new world order 2000-2010

• Booming World economy and double digit growth rates in the BRIC countries drive a sustained minerals ‘supercycle’

• Concentration of global production in a few countries, e.g. rare earth elements in China

• As a result, old concerns about mineral resource security start to re-emerge in the West
Mineral criticality – what should we be worried about?

• EU is heavily import dependent on most metals including those used in high-tech. and green technologies

• This has led to the classification of some minerals as “at risk” to supply disruption

• Criticality shortlists are important for informing policy and prioritising research on security of supply issues
The concept of criticality

- Criticality is a matter of degree not state (Gunn, 2014)
- A mineral is neither critical or non-critical, moreover it has a criticality level based on the following criteria:
  - Supply risk
  - Economic importance
  - (Environmental impact (Graedel et al., 2015))
EU criticality assessment - 2014

Assessed mineral raw materials based on importance to the EU economy and the likelihood of supply disruption

54 metals and minerals

Supply Risk
- Production concentration
- Governance in producer countries
- Environmental standards in producer countries
- Recycling rates
- Substitutability

Economic Importance
- End-use applications
- Gross Value Added (GVA) of ‘megasectors’ of EU economy

20 critical raw materials

Critical raw materials for the EU (2014)

The EU critical 20

7 Industrial Minerals
- Graphite
- Fluorspar
- Borate
- Phosphate rock
- Silicon metal
- Magnesite
- Coking coal

13 Metals
- HREE
- LREE
- Magnesium
- Niobium
- Germanium
- Indium
- Gallium
- Cobalt
- Beryllium
- PGM
- Antimony
- Tungsten
- Chromium
Supply risk: Concentration of production

Global production total 2013: 267,000 t

Ta-Nb concentrate

- Brazil: 93.53%
- Canada: 4.56%
- Rest of world: 1.91%

Global production total 2013: 198,142 kg metal content

Palladium

- USA: 42.4%
- Canada: 38.4%
- Russia: 8.1%
- Zimbabwe: 6.3%
- Other (6): 3.0%

Global production total 2013: 100,172 t

REE as oxides

- China: 94.8%
- Russia: 1.4%
- Malaysia: 2.4%
- Other (5): 0.2%
- USA: 1.0%
- Australia: 0.1%

Data from British Geological Survey 2015, World Mineral Statistics database
Supply risk: geopolitics
Supply risk: environmental standards in producer countries

A new age of sustainability for South Africa's mining industry

Contributing 19 percent to its GDP, mining is essential prospects of South Africa. Chris Griffiths, CEO of Anglo Platinum, tells World Finance how platinum can be in a sustainable way.
Supply risk: recycling – a complementary source of supply

MAJOR benefits of recycling:

• Mitigation of environmental impact of mining
• Extends the lifetime of primary resources
• Reduces geopolitical dependency
• Reduces the overall environmental burden e.g. emissions from discarded products, landfill, land use
• Reduces supply risk
• Supports ethical sourcing of raw materials
• Improving the ‘balance-problem’ between supply and demand
• Employment potential

Hagelüken, 2014; In: Gunn, 2014
Supply risk: recycling in practice

However...

How many of you have an old mobile at home??

Efficiency at each stage

End-of-life products

Collection

Dismantling and pre-processing

Smelting and refining

Reuse

Final waste

Separated components and fractions

Unusual metal combinations

Efficiency at each stage:

- Collection: 30%
- Dismantling and pre-processing: 60%
- Smelting and refining: 95%

Result: 17% Recycled metals

Adapted from Hagelüken, 2014; In: Gunn, 2014
Supply risk: end-of-life recycling rates

The reality...
Supply risk: substitutability

‘Necessity is the mother of invention’

Substitution status

Few known substitutes in some applications

Unique properties that make substitution difficult

Alternatives available but result in poorer performance

Alternatives have been developed

Alternatives available but developing technology has kept the critical material in use

Critical Metals

REE, Re

Be, Ta, Nb, W

Co, Sb, Ga, Li, Mg, PGMs

Ge

In
Geological considerations

• Physical availability of mineral deposits is not the issue but...need to continue to find more deposits

Technology for exploration, mining, processing, etc. all need to be developed. Deposits are frequently concentrated in one country and supply needs to be diversified

• Difficult to predict the future demands – criticality assessment tends to be a “snapshot” of the current situation

<table>
<thead>
<tr>
<th>Element or element group</th>
<th>Symbol</th>
<th>Relative supply risk index</th>
<th>Leading producer</th>
<th>Top reserve holder</th>
</tr>
</thead>
<tbody>
<tr>
<td>rare earth elements</td>
<td>REE</td>
<td>9.5</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>tungsten</td>
<td>W</td>
<td>9.5</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>antimony</td>
<td>Sb</td>
<td>9.0</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>bismuth</td>
<td>Bi</td>
<td>9.0</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>molybdenum</td>
<td>Mo</td>
<td>8.6</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>strontium</td>
<td>Sr</td>
<td>8.6</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>mercury</td>
<td>Hg</td>
<td>8.6</td>
<td>China</td>
<td>Mexico</td>
</tr>
<tr>
<td>barium</td>
<td>Ba</td>
<td>8.1</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>carbon (graphite)</td>
<td>C</td>
<td>8.1</td>
<td>China</td>
<td>China</td>
</tr>
<tr>
<td>beryllium</td>
<td>Be</td>
<td>8.1</td>
<td>USA</td>
<td>Unknown</td>
</tr>
<tr>
<td>germanium</td>
<td>Ge</td>
<td>8.1</td>
<td>China</td>
<td>Unknown</td>
</tr>
<tr>
<td>niobium</td>
<td>Nb</td>
<td>7.6</td>
<td>Brazil</td>
<td>Brazil</td>
</tr>
<tr>
<td>platinum group elements</td>
<td>PGE</td>
<td>7.6</td>
<td>South Africa</td>
<td>South Africa</td>
</tr>
<tr>
<td>cobalt</td>
<td>Co</td>
<td>7.6</td>
<td>DRC</td>
<td>DRC</td>
</tr>
<tr>
<td>thorium</td>
<td>Th</td>
<td>7.6</td>
<td>India</td>
<td>USA</td>
</tr>
<tr>
<td>indium</td>
<td>In</td>
<td>7.6</td>
<td>China</td>
<td>Unknown</td>
</tr>
<tr>
<td>gallium</td>
<td>Ga</td>
<td>7.6</td>
<td>China</td>
<td>Unknown</td>
</tr>
<tr>
<td>arsenic</td>
<td>As</td>
<td>7.6</td>
<td>China</td>
<td>Unknown</td>
</tr>
<tr>
<td>magnesium</td>
<td>Mg</td>
<td>7.1</td>
<td>China</td>
<td>Russia</td>
</tr>
</tbody>
</table>
Measurement of economic importance of a raw material to the EU

End uses of a raw material

Use 1
Use 2
Use 3
Σ=100%

GVA of each EU end use ‘megasector’

Megasector A
Megasector B

Assign end uses to ‘megasectors’

Multiply each % end use by GVA of ‘megasector’ to build weighted sum

Economic importance

∑=100%
So, what is the EU doing to address security of supply?

Raw Materials Initiative (2008-2011)

European Innovation Partnership (2014-2020)
EU Raw Materials Initiative (RMI) 2008 – 2011 – securing sustainable supplies

- Increasing raw material demand, especially for new/green technologies, and increasing risk of supply disruption
- Launched in 2008, consolidated in 2011
- Non-energy, non-agricultural raw materials
- Integrated strategy built around 3 pillars, linking EU internal and external policies

Ensure level playing field in access to resources outside EU

Foster sustainable supply from European sources

Boost resource efficiency and recycling
European Innovation Partnership on Raw Materials, 2014 - 2020

• Major new policy initiative (EIP) building on the RMI

• Overall aim to ensure the sustainable supply of raw materials to the EU economy, while increasing benefits for society as a whole

• Specific objectives:
  ➢ reducing import dependency
  ➢ improving supply conditions in EU
  ➢ diversifying raw materials sourcing
  ➢ improving resource efficiency (including recycling)
  ➢ finding alternative raw materials

Value of criticality assessments to the EU

- Raise awareness and understanding among stakeholders, providing an ‘early warning’ of potential supply problems
- Help to prioritise requirements and actions
- Industry views ‘critical’ designation as implying scarcity and promoting substitution
- ‘Non-critical’ raw materials remain important to the EU economy

© NERC Wolframite, a major ore mineral of tungsten

© NERC All rights reserved
Security of supply – working together in Europe

- **Expert networks**
  - CRM InnoNet (substitution)
  - ERECON (rare earths)
  - ERAMIN (coordination of research in raw materials supply)

- **EU programmes** – numerous projects, part or fully funded by EC

Niobium metal, Araxá, Brazil
European Rare Earths Competency Network (ERECON) – towards EU supply security

- Three Working Groups (established 2013)
  - Opportunities and road blocks for primary REE supply from EU
  - REE resource efficiency and recycling in EU
  - REE current and future industrial demand and supply challenges

- Reports to deliver clear-cut policy recommendations across the REE value chain

EURARE - development of a sustainable exploitation scheme for Europe's Rare Earth ore deposits

- Aims to safeguard EU supply of REE raw materials
- Will characterise European REE resources and develop new ore beneficiation/extraction technologies
- 5-year project from Jan. 2013
- Budget 14 million euro (65% from EC)
- 23 partners, including researchers and industry
- [Link to EURARE website](http://www.eurare.eu/home.html)

REE occurrences in Sweden

Norra Kärr deposit

Map after Sadeghi et al. 2013
Blue Mining – deep-sea mining

- Aims to develop technical capabilities to discover, assess and extract mineral deposits at up to 6000 m water depth
- 4 years, 2014 – 2018
- 19 partners, 6 countries
- 15 million euro (10 million from EC)
- [http://www.bluemining.eu/](http://www.bluemining.eu/)
Minerals4EU

- Better information and analysis of EU’s mineral resources and industry
- Aims to develop a permanent EU Mineral Intelligence Network
- Onshore and offshore resources, primary and secondary
- 31 partners, including 25 national geological surveys
- 2 million euro, 2 year project, started Sept 2013
- Deliverables
  - Minerals data and products
  - European Mineral Yearbook
  - Analysis and foresight studies

http://www.minerals4eu.eu/
Security of Supply of Minerals
2012–2017 (UK)

- Understand environmental-technology element cycling and concentration in natural systems
- Understand how to predict and mitigate the environmental effects of extraction and recovery of environmental-technology elements
- £15 million – REE, Co, Te, Se and deep sea mineral resources

- [http://www.nerc.ac.uk/research/funded/programmes/minerals/#xcolapse3](http://www.nerc.ac.uk/research/funded/programmes/minerals/#xcolapse3)
Critical metal case study: Tungsten

- Tungsten is hard and very dense metal.

- It is resistant to corrosion, highest melting point of all non-alloyed metals, lowest coefficient of expansion and the highest tensile strength.

- Production of “hard metals” ~50% e.g. tungsten carbide, steel alloys <~40%, mill products – sheets, wire, etc (used in light bulbs, etc), specialist applications in electronics and pigments.

- Deposits are globally well distributed.

- ~83% of production (2013) from China.
Tungsten: global distribution
Tungsten global production 2013

- Mine production of tungsten 2013: 77,200t (BGS, 2015)
- Production dominated by China
- Need to diversify the supply and reduce reliance on Chinese supplies
Hemerdon tungsten-tin deposit, Devon, South West England

- Major, new secure UK supply of tungsten
- Sheeted vein greisen deposit located in the Hemerdon Ball granite
- 5th largest W deposit globally; reserve of 35.7Mt at 0.18% WO$_3$ and 0.03% Sn equalling 3% of global W supply
- Mine and processing facilities under construction
- Due to start production in 2015
Conclusions: security of mineral supply and critical raw materials in the EU

- Profile of mineral raw materials at all-time-high levels
- EU has defined those critical raw materials essential to the European economy
- Pan-EU criticality assessments provide early warning of potential supply disruption
- Useful tools for decision making by government and industry, and for prioritising research directions
- Research funding available from EC (and some MS governments) has grown rapidly
- Mining and recycling are both important to secure supply
- Begun to dispel the myth that physical depletion of resources is a threat:
  - Need to continue finding new deposits
  - While reducing the environmental footprint of extraction
Thank you!!
Economic Importance

End-use applications and Gross Value Added (GVA) of ‘megasectors’ of EU economy

- The end uses of critical materials are assigned to ‘megasectors’ of the European economy such as construction, electronics etc.

- The monetary value (GVA) of these ‘megasectors’ to the EU are calculated using Eurostat data

- The (weighted) value of each critical material to each ‘megasector’ is calculated to give a relative economic importance for the critical raw material of choice

- These values are plotted with supply risk to identify the ‘most critical’ raw materials to the European economy