The Resource Challenge of Going Green

Professor Richard Herrington

Surrey IET January 18th 2023
NHM Mineral Collection

- 80 million specimens in the NHM collections
- Includes >185,000 mineral specimens – many types
- Systematically collected
- Library of natural materials with variable chemistries and properties
- Actively studied and used as a reference collection

Gem form of the Li ore mineral spodumene

Ga-rich sphalerite ZnS

Meteorites
- Minerals
- Ore and rock collections

Kunzite LiAl(SiO₃)₂

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Advanced Mineralogical Analysis Infrastructure

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The Resource Challenge of Going Green

NHM Unlocked Programme

- NHM to be on 3 sites by 2026
- £182 million government support for Science and Digitisation Centre
- New facility to be delivered at the Thames Valley Science Park, Reading
- Opportunities to build closer science links with external partners (existing and new)
- Development of next generation analytical facilities

Natural History Museum to open major new research centre with the University of Reading

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Committee on Climate Change Challenge in 2019

Theresa May announces legislation for zero emissions by 2050

Electric vehicles. By 2035 at the latest all new cars and vans should be electric (or use a low-carbon alternative such as hydrogen). If possible, an earlier switchover (e.g. 2030) would be desirable, reducing costs for motorists and improving air quality. This could help position the UK to take advantage of shifts in global markets. The Government must continue to support strengthening of the charging infrastructure, including for drivers without access to off-street parking.

Leading scientists set out resource challenge of meeting net zero emissions in the UK by 2050

A letter authored by Natural History Museum Head of Earth Sciences Prof Richard Herrington and fellow expert members of SoS Minerals (an interdisciplinary programme of NERC-EPSRC-Newton-FAPESP funded research) has today been delivered to the Committee on Climate Change.

The metal resource needed to make all cars and vans electric by 2050 and all sales to be purely battery electric by 2035. To replace all UK-based vehicles today with electric vehicles (not including the LGV and HGV fleets), assuming they use the most resource-frugal next-generation NMC 811 batteries, would take 207,900 tonnes cobalt, 264,600 tonnes of lithium carbonate (LCE), at least 7,200 tonnes of neodymium and dysprosium, in addition to 2,362,500 tonnes copper. This represents, just under two times the total annual world cobalt production, nearly the entire world production of neodymium, three quarters the world’s lithium production and 12% of the world’s copper production during 2018. Even ensuring the annual supply of electric vehicles only, from 2035 as pledged, will require the UK to annually import the equivalent of the entire annual cobalt needs of European industry.
But it is bigger than that!

- Net Zero pledges worldwide are committed to ‘decarbonising’ all sectors of the economy

Press release

Plans unveiled to decarbonise UK power system by 2035

The plans will focus on building a secure, home-grown energy sector that reduces reliance on fossil fuels and exposure to volatile global wholesale energy prices.

Policy paper

Net Zero Strategy: Build Back Greener

This strategy sets out policies and proposals for decarbonising all sectors of the UK economy to meet our net zero target by 2050.
Decarbonising – what do we need to change?

Sources of anthropogenic CO₂

1. Switch to renewable generation of electricity
2. Decarbonise transport

Arif et al 2021
Carbon intensity of energy consumption for 2022

https://app.electricitymaps.com/map
Electricity needs to become renewable

However, all renewable technologies use significant mineral sourced materials....

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Transport needs to move from fossil fuels

Electric vehicles really do make sense if recharged with low-CO₂ electricity

ICE = internal combustion engine
BEV = battery electric vehicle

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But going completely green is a mineral hungry business
Increased demand for common bulk commodities as well as critical metals

Renewable energy needs more infrastructure

*Vidal et al 2013*
Human development generally has meant a much broader and deeper use of much of the periodic table.
A long list of ‘critical’ elements are needed for the energy transition.

**Magnets in motors**
- Neodymium
- Dysprosium
- Praseodymium

**Alloys**
- Aluminium
- Niobium
- Magnesium
- Titanium
- Scandium?

**Batteries**
- Lithium
- Cobalt
- Graphite
- Nickel
- Manganese
- Vanadium

**Hydrogen**
- Platinum Group Metals

**Solar panels**
- Gallium
- Indium
- Tellurium
- Selenium

**Various uses**
- Copper
- Zinc
- Silver
- Chromium
- Steel alloys etc.

**Not just rare earths**

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Increasing demands very strong for a range of metals

Circular economy

What we need from recycling?
Can’t we just recycle? – no, there isn’t enough ‘stock’

Orange = percentage of commodity recycled at end-of-life

Blue = percentage of current demand satisfied by recycling

Authors figure from published data
Only by 2040 will recycling become significant for many of these materials.
Wastes should be looked at as a source for metals - but waste alone cannot feed the need

Estimated metal resources in European waste and landfill
World economic growth drives increased demand

- More mining is therefore needed
- But where from?
Growth demands more new materials to feed the circle
Problem 1 - geographic monopolies are stronger for minerals than they are for oil

Top three producers for each commodity shown – data as for 2020 (IEA 2021)

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Problem 2 – Opening a new mine often has a long lead time.
We need to expand the places we look for new minerals

Worldwide Exploration Spending 2014

Central Asia < 1%

Mining Association of Canada
Facts and Figures 2015

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It is still possible to find new deposit types

Jadar Li-B Deposit, Serbia

Inferred Resource
• > 110 Million tonnes
@ 1.8% Li$_2$O  13.1% B$_2$O$_3$
• 100Mt of an entirely new mineral discovered in 1994

Jadarite LiNaSiB$_3$O$_7$(OH)
We can look deeper in the earth

- We are learning to find deposits under cover..
- But, since 2000, only 9 out of 239 discoveries are deeper than 500m and 7 of those are ‘brownfields’
So we can go deeper at existing mines to find more

- Novel deep seismic exploration Navan Mine, Ireland
Mining could move onto the ocean floor?

Ocean versus terrestrial mining?
Deep oceans

**Seafloor sulfides**
- Global resource at least $6 \times 10^8$ tonnes sulfides
- Solwara 1 - $1.3 \times 10^6$ tonnes 7% Cu, 6g/t Au

**Polymetallic nodules**
- CCZ alone hosts $21 \times 10^9$ tonnes nodules
- 27% Mn, 1.3% Ni, 1.05% Cu, 0.2% Co
- This amounts to:
  - 10 years global Cu production
  - 300 years global Mn production
  - 450 years global Co production

*Hannington et al. 2011*
**Final frontier?**

**Asteroids**

Asteroid KU2
4.6km in diameter
Ni-Fe-Co + volatiles
Estimated value $80 trillion
Closest approach to earth 10 million km in 2069

www.asterank.com

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The debate about where our new minerals should come from is very complex

- However society is going to have to choose as there is no alternative if we want to hit the climate change targets!
Look for minerals closer to home?

- UK could supply significant W, Li, Sn +
- Europe could be a realistic supplier of many of the green technology metals
- Still a need to source many metals like Fe, Al and Cu from farther afield
SW England

- Pre-Roman Sn and Cu discovery
- Camborne-Redruth Sn-Cu ‘giant’ field produced 310,000 tonnes Sn, 850,000 tonnes Cu
- Minor base metal (Zn-Pb-Sb-Ag) production
- South Crofty mine alone has produced 115,000 tonnes Sn, 34,000 tonnes Cu
- Hemerdon W-Sn deposit is currently being reopened
- Current activity for lithium around granite systems
- Geothermal systems – Li in brine and hard-rock
Old mine – new minerals – Cornish lithium

Former kaolin workings

Li-rich granite phase

Lepidolite in UST

Li from micas?

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Mining looked on positively in some areas

Kiruna: How to move a town two miles east

Plymouth’s tungsten mine worth £415m as it prepares to reopen

Investors crowd in to fund Cornish Lithium

Cornish Lithium raises £6 million in new Crowdfunding Raise
But less welcome elsewhere

Portugal to scrap lithium mining project
Locals spent years fighting to halt the project, a cornerstone of Lisbon’s raw materials policy.

Rio Tinto plans for Serbia lithium mine suspended after protests
Local authorities put $2.4bn project on hold after scale of opposition shakes country’s government

Le Télégramme
Manif anti-mines. L’avis en jeu

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ESG considerations are paramount for projects

**ENVIRONMENTAL**
Considers how a company performs as a steward of nature.
E.g., climate change, energy emission, waste management, and resource depletion

**SOCIAL**
Examines how a company manages its relationships with employees, suppliers, customers and the community.
E.g., health and wellbeing, building safety, employee relations, diversity, and impact on communities

**GOVERNANCE**
Deals with how a company is governed.
E.g., executive pay, shareholder rights, board diversity, and structure audits

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COP 26 had clear messaging relevant for minerals

The four main goals:

• Secure global net-zero by mid-century and keep limit of 1.5°C temperature increase “within reach”
• Adapt to protect communities and natural habitats
• Mobilise finance
• Collaborate to deliver

Agenda items:

• Mobilising public and private finance
• Accelerating the transition to clean energy
• Elevating the voice of young people and demonstrating the critical role of public empowerment
• Ensuring sustainable land use
• Adapting to climate hits and addressing the loss and damage
• Progressing meaningful participation by women and girls
• Looking at innovative science
• Driving towards zero-emission transport
• Promoting environmental action in cities
New types of mines?

- Less impactful and ‘net positive’ for the planet and people
- There is a clear need to protect and reconstruct the ecosystem
- Develop a ‘cradle to cradle’ approach to mining not a ‘cradle to grave’!

Flambeau mine, Wisconsin

Ellen MacArthur Foundation
New frontier exploration now needs to think **biodiversity**

Estimated Biodiversity Intactness Index – blue = intact; red = very degraded
Mining is energy hungry – this has to change

- As the grade of ore goes down, more ore has to be milled, more energy is consumed
- Mining needs to be decarbonized too

**Source:** Sandu & Syed, (2008) Trends in Energy Intensity in Australian Industry
New technologies can help - using microbes?

- Reduced ores (sulfides)
  - Fungal leaching
  - Abiotic (chemical) leaching

- Oxidized ores (laterites etc.)
  - Oxidative (bio)leaching
  - Reductive (bio)leaching
  - PLS
    - fungi
    - oxalate
    - CoC₂O₄
    - urea
    - CoCO₃
  - H₂S
  - SRB
  - CoS
  - Bio-nanomaterials
  - Direct reductive bio-conversion

- Low carbon extractive technologies
- Direct formation of functional downstream materials

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Deep eutectic solvents – new type of chemistry

- New field of chemistry applicable to complex ores

Selective leaching of rare earth elements from bauxite residue (red mud), using a functionalized hydrophobic ionic liquid

Paragiotis Davis, Efthymios Balomenos, Dimitrios Panias, Ioannis Paspalaris

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New ways of mining demands much better mineralogical analysis

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Revolutionising the way mining workflow is structured

- Mining projects too readily divided into separate ‘business units’
  - Exploration is a loss maker (*pressures to reduce costs*)
  - Projects may increase stock values (*not conducive to fully testing the potential negatives*)
  - Operations are what really makes the money (*tend to be milked dry for profit?*)
  - Closure plans have to pick up the pieces of short-cuts in operations plans
  - End users need to be a part of this too!

*Satarla 2021*
Cradle to Cradle mining?

Mining projects should be following the principle of ‘cradle to cradle’

- Mines are temporary interventions
- Mines should therefore be designed with built in
- Projects designed from the start to create net positive outcomes people and planet
There is a clear need to mine an increased volume of a range of metals in order to deliver the net zero pledge of decarbonisation.

This new sourcing must be done in a way that there is a net positive impact for both people and the planet.

Optimised recycling and use of waste a key component of the package but is not enough.

Mining is both inevitable and essential and it is for society to choose where that will happen.

Mining should follow ‘cradle to cradle’ principles.

It is prudent to source at least some of our new metals closer to home since:

- Regenerating old districts may have a lower impact.
- This could drive other social and economic benefits (localisation of industry, clean up of environmental legacies, positive biodiversity impacts, stronger supply chains etc.)