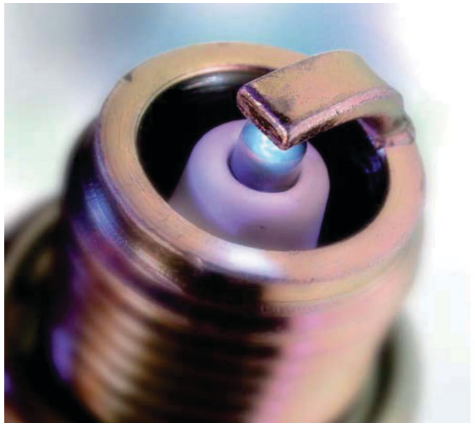
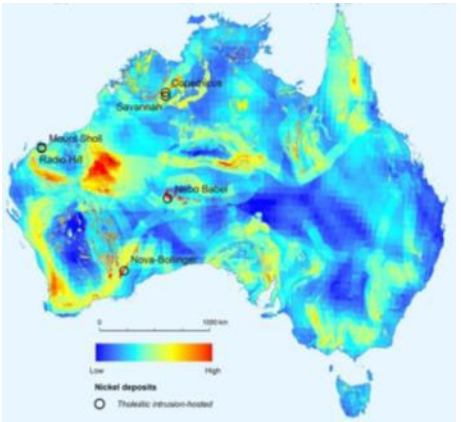
Australian Government
Geoscience Australia

Critical mineral potential in the Tasman Element, eastern Australia (eCat 146428)





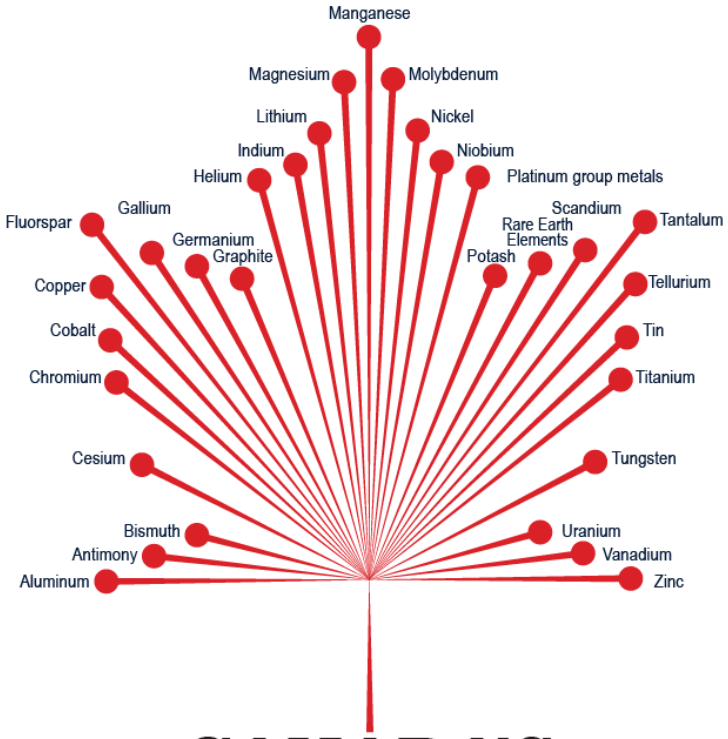
David Huston, Zhehan Weng and Evgeniy Bastrakov

What is a critical mineral?

Mineral resources that are essential to economic and/or technological development but are at risk of supply disruptions due to limited sources of supply and/or political-economic factors

- “Critical minerals” is a misnomer: of 45 identified “critical minerals”, 37 are solid elements, one is a gaseous element, two are rocks, one is a chemical and only four are minerals
- The term “critical minerals” is useful though to differentiate critical commodities produced by the extractive industries from those produced by agriculture and other industries (e.g. urea, neon)
- “Criticality” is in the eye of the beholder

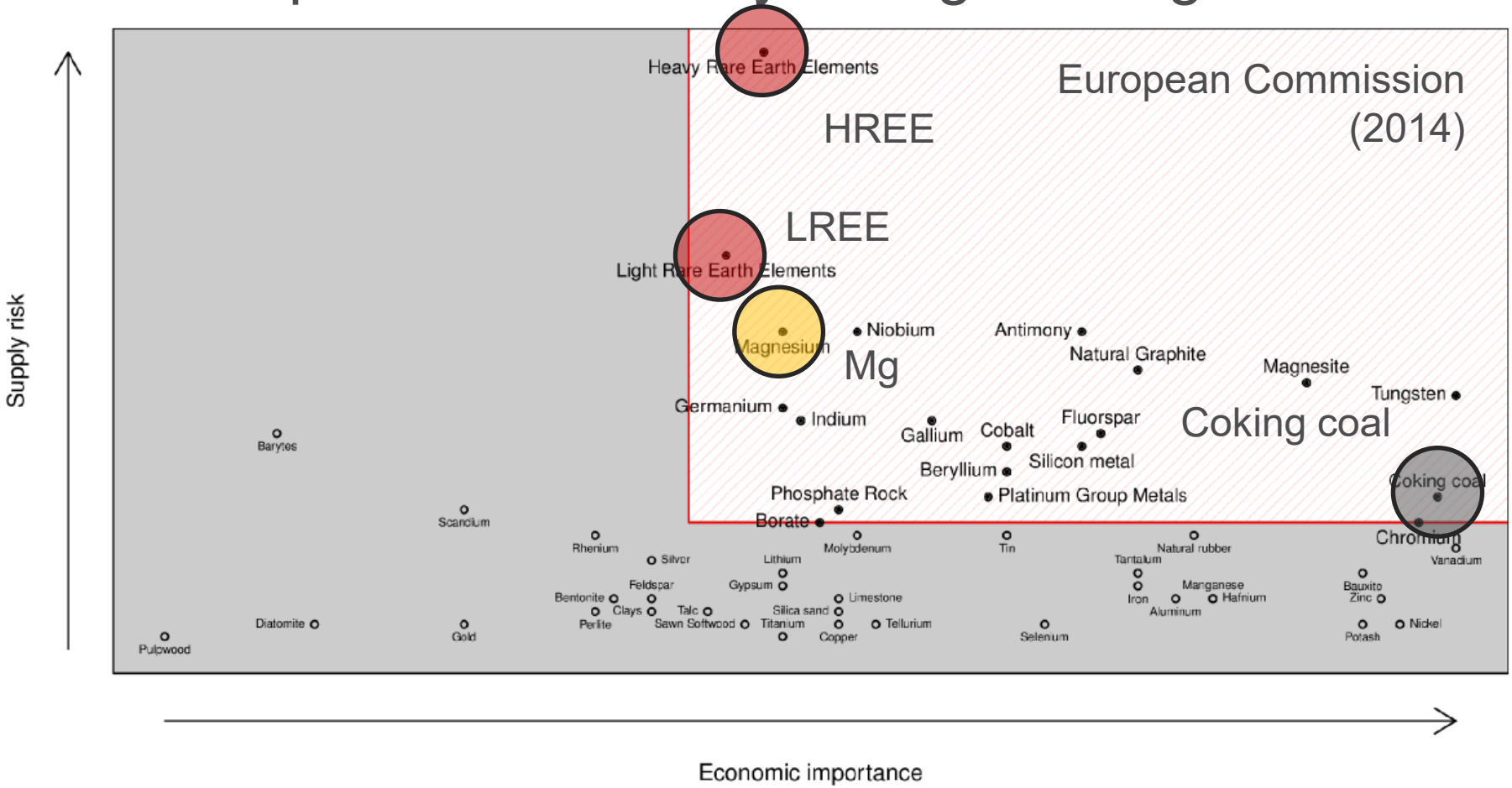
Critical mineral lists



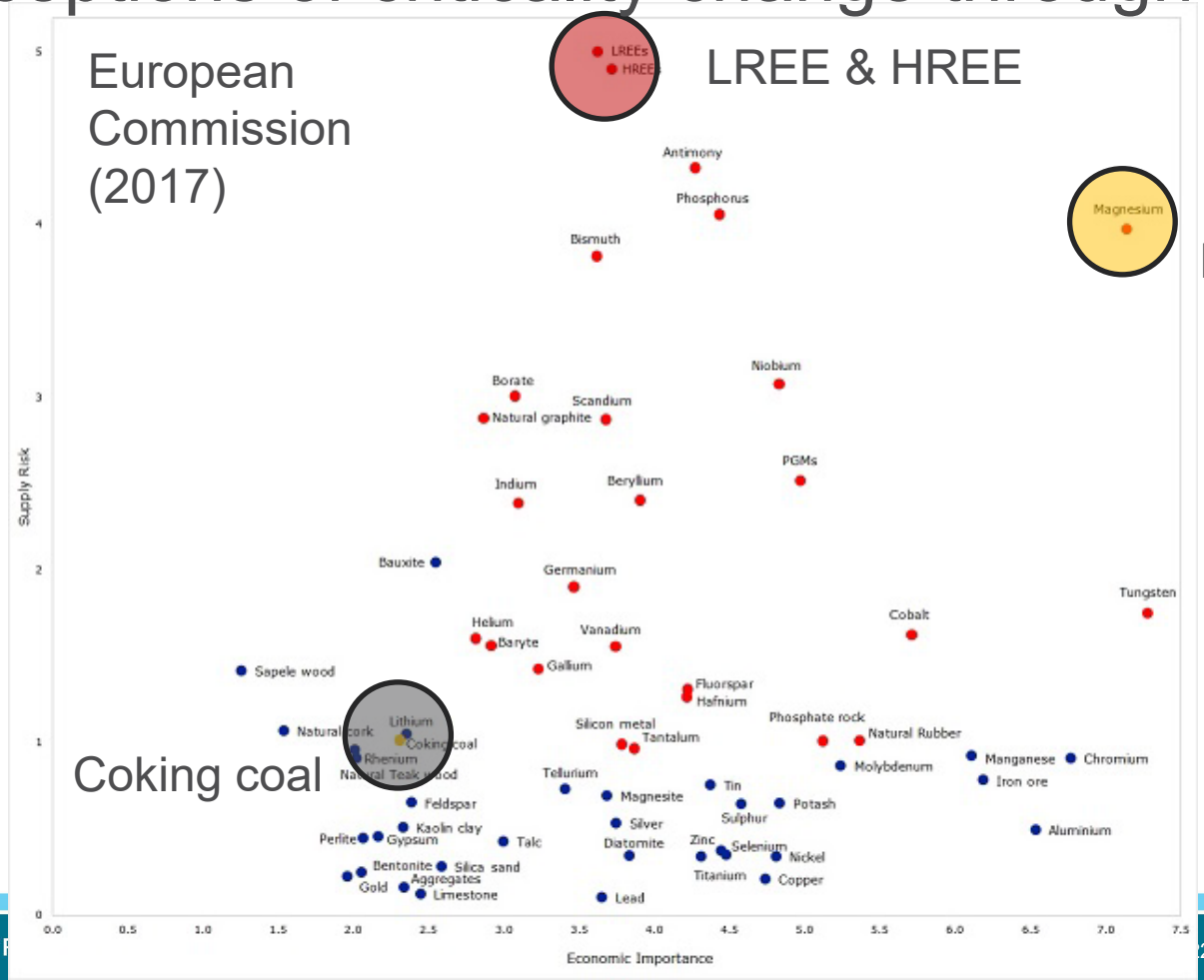
Source: Natural Resources Canada

- Most developed economies (including Australia) have identified commodities considered critical for their economies
- Australia's main role – reliable supplier of critical minerals to other economies
  - Our list is based on this role as our economy consumes few critical minerals
  - Critical minerals for Australia's economy are mostly needed by agriculture – phosphate and potash

Perceptions of criticality change through time



Perceptions of criticality change through time



Critical mineral markets

- Generally much smaller than major commodities

Commodity	2017 production (Mt)	2017 market value (US$billion)
Iron ore	2400	180.0
Gold	0.00315	127.6
Copper	19.7	121.6
Zinc	13.2	37.0
Rare earths	*0.130*	*24.3*
Platinum/palladium	*0.000391*	*11.4*
Cobalt	*0.110*	*6.0*
Tellurium	*0.000420*	*0.0015*

Source: USGS mineral commodity summaries; Mudd et al. (2018)

- Can grow rapidly – lithium market is projected to grow from US$526m in 2021 to US$1400 in 2026 (BCC Publishing)

Production of critical minerals

As main or co-product – REEs, phosphate rock, chromite, tin, tungsten, graphite, antimony, niobium, lithium, beryllium

- Value of critical mineral determines viability of development
- Economic viability highly dependent on critical mineral price

As by-product – cobalt, vanadium, indium, germanium, bismuth, gallium, rhenium, selenium, cadmium, tellurium

- Value of major commodity determines viability of development
- Economic viability largely independent of critical mineral price
- Supply not as price sensitive

Both as main/co- and by-product – molybdenum, PGEs

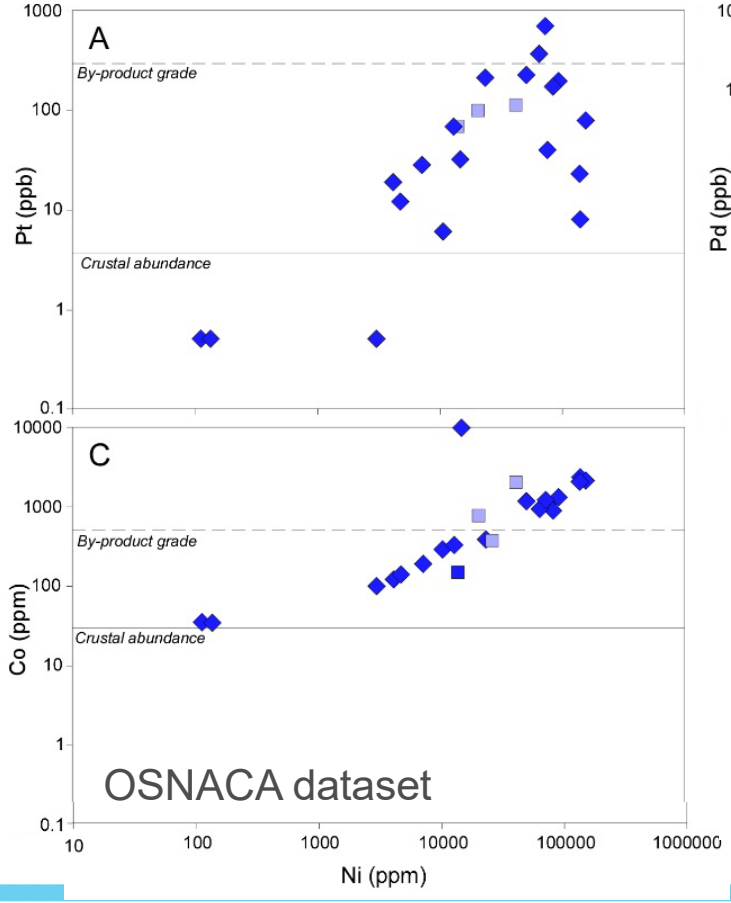
Government support for critical minerals

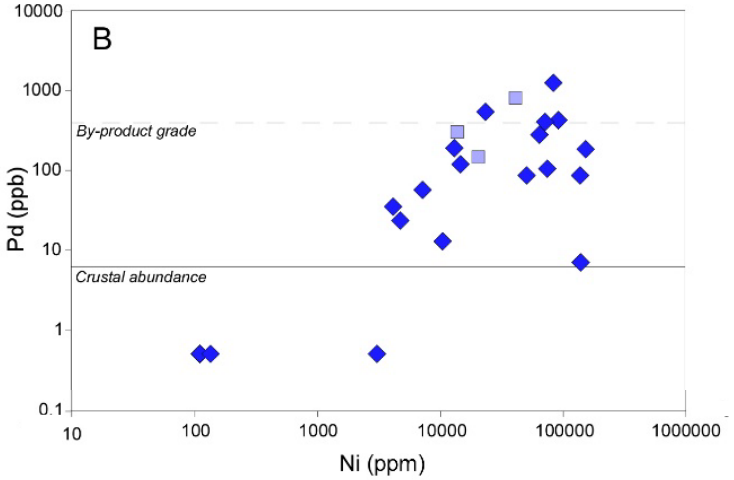
- New South Wales government – *Critical Minerals and High-Tech Metals Strategy*
- Queensland government – *New Economy Minerals*
- Commonwealth government
  - Critical Minerals Facilitation Office
  - Geoscience Australia – *Exploring for the Future*
- Government consortia
  - National – GA-State/Territory Surveys
  - National – ANSTO-CSIRO-GA – *National Critical Minerals Research and Development Centre*
  - International – GA-GSC-USGS – *Critical Mineral Mapping Initiative*

Critical minerals in Australia – opportunities

- Deposits associated with (ultra)mafic magmatism
  - Ultramafic/mafic-associated Ni sulfide deposits
  - Lateritic Ni-Co-Sc deposits
- Deposits related to granitic magmatism
  - Intrusion-related rare metal (Sn-W-In-Mo-Re) deposits
- Rare earth element deposits
  - Magmatic deposits
  - Hydrothermal (IOCG and unconformity-related) deposits
  - Deposits related to basin formation (phosphorites)
  - Deposits related to weathering (ionic adsorption) and erosion (placers)
- By-products of processing of major commodities

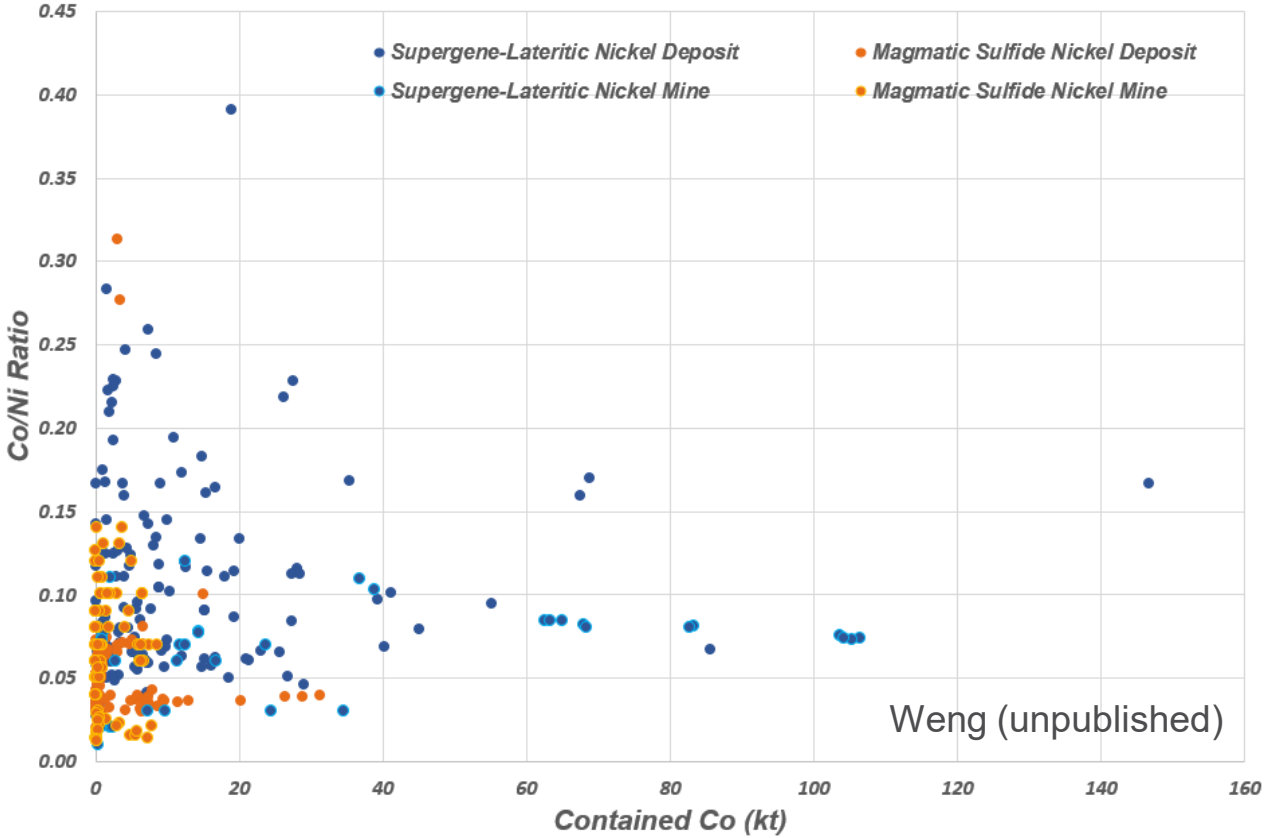
Critical minerals in (ultra)mafic intrusion-related systems





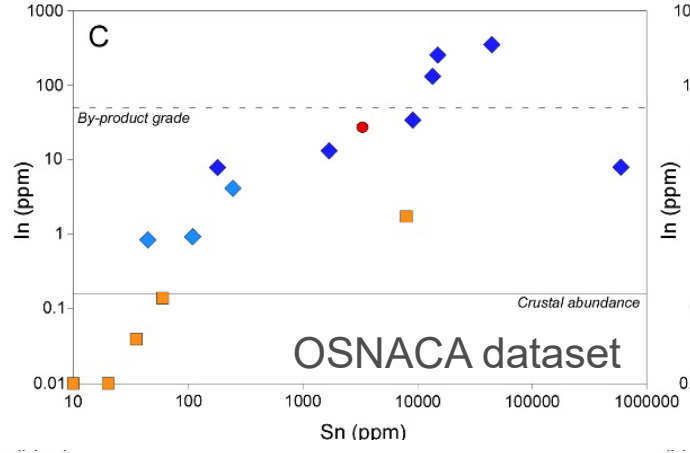
- Komatiite-associated and intrusion-hosted Ni sulfide deposit (mostly Yilgarn)
- Co and PGEs produced as by-products
- Te and Se also enriched

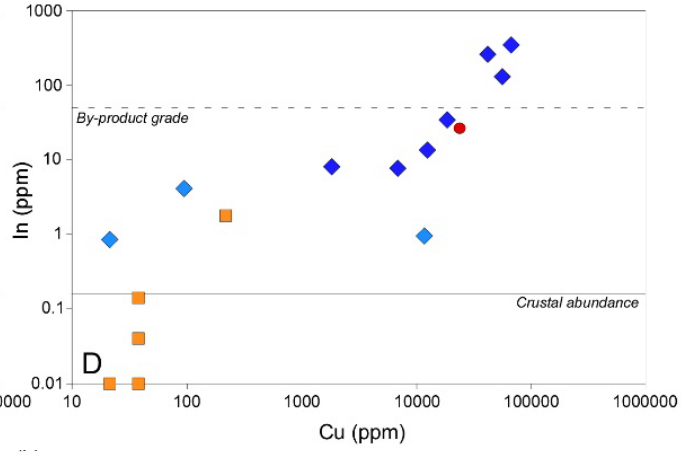
Critical minerals in lateritic Ni deposits

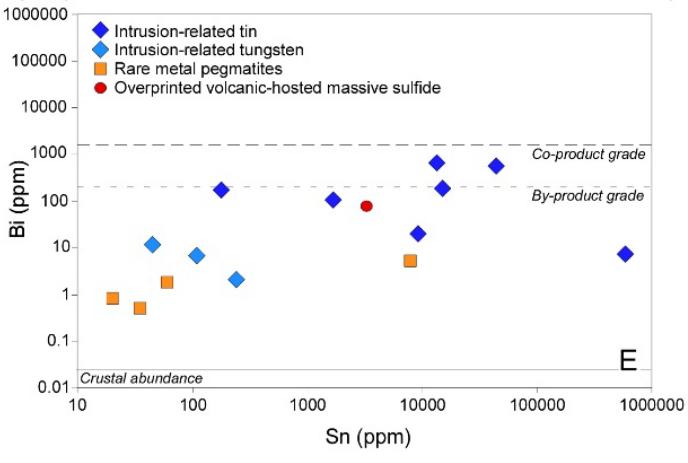


- Lateritic Ni deposits relatively Co-rich compared to Ni-sulfide deposits
- Lateritic Ni deposits can also contain significant Sc

Critical minerals in felsic intrusion-related systems

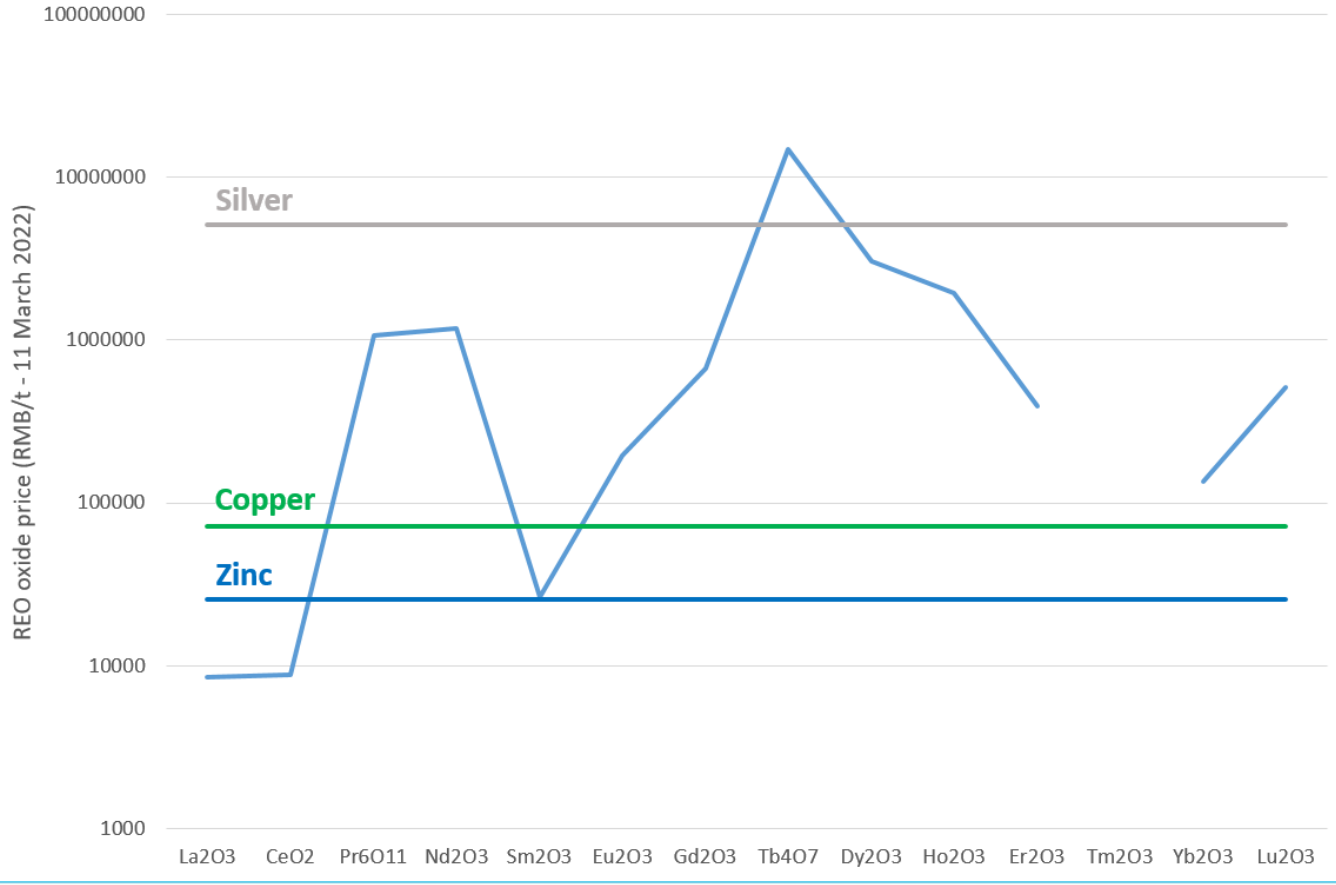






- Granite-related hydrothermal systems (skarn, carbonate-replacement deposits) – Sn, W, Mo, In, Bi
- Pegmatites – Li, Sn, Ta, Nb
- Porphyry copper deposits – Cu, Mo, Re, Se, Te

Rare earth elements - not all are valued equally



- Prices vary by three orders of magnitude
- Most REEs more valuable than common base metals
- Many highly valuable REEs have small markets

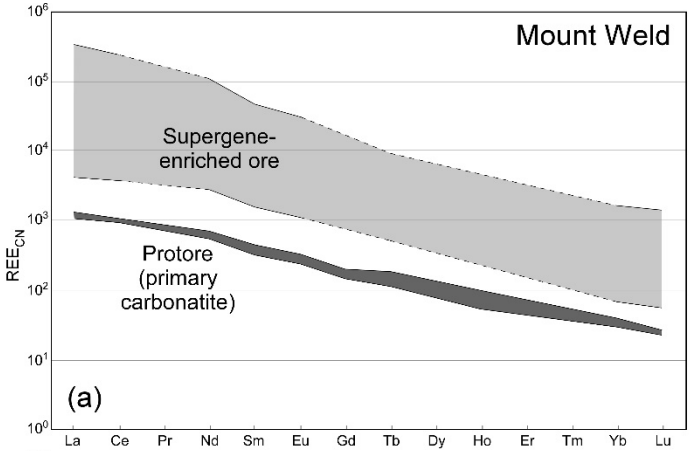
Rare earth element deposits – classification

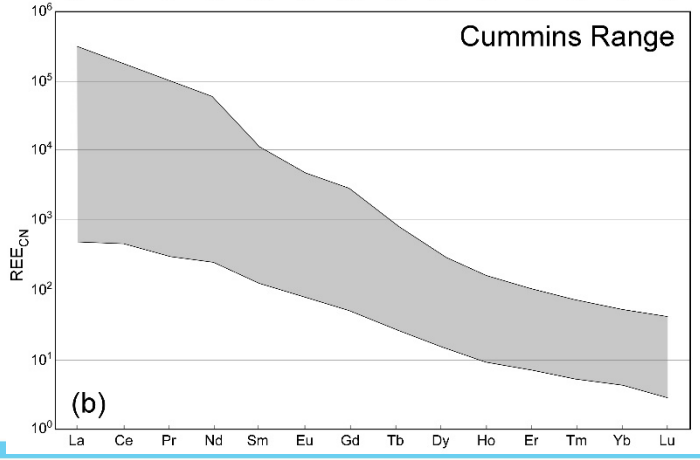
- Orthomagmatic and magmatic-hydrothermal deposits
  - Carbonatite and carbonatite-related
  - Peralkaline magmatic
- Hydrothermal deposits
  - Iron-oxide copper-gold
  - Unconformity-related
- Basinal and weathering-related deposits
  - Phosphorite
  - Ion adsorption clays
  - Supergene enrichment
- Placer deposits
  - Heavy mineral sands
  - Alluvial placers

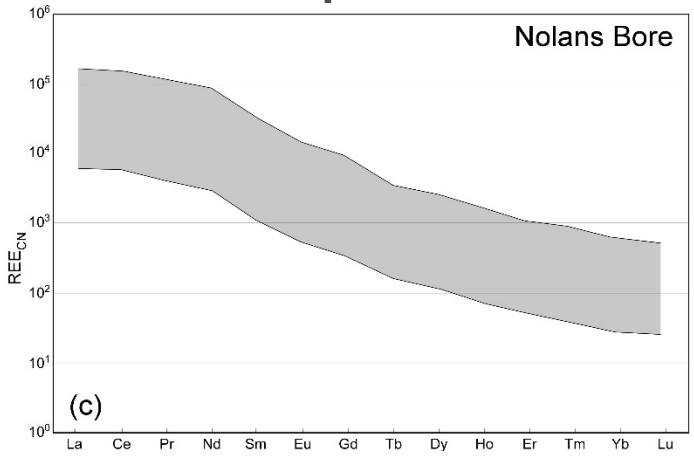
Rare earth element deposits – some terminology

- LnO – Lanthanide oxides
  - Lanthanum-lutetium suite of elements
  - Does not include yttrium or scandium
- Rare earth element (lanthanide) patterns
  - Normalised to chondritic values for comparison
  - Plotted on logarithmic scale
  - Patterns determine which lanthanide has most value

Carbonatite and related deposits

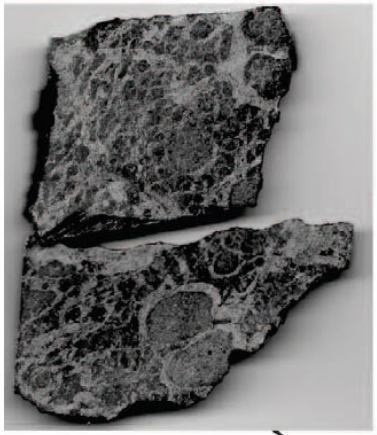


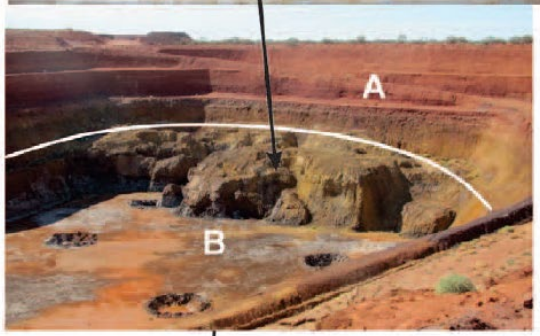


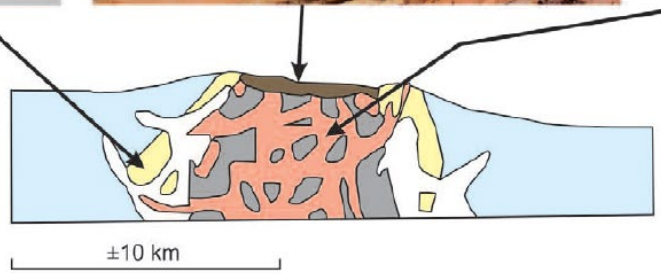


- Tend to be strongly LREE-enriched (value in Pr and Nd)
- Upgrading due to post-formational processes important for economics

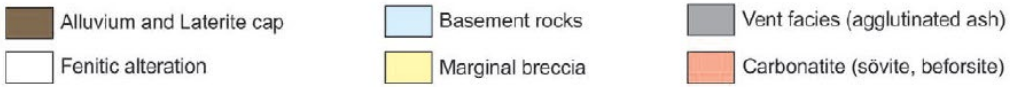
Mount Weld (Eastern Goldfields Superterrane, WA)





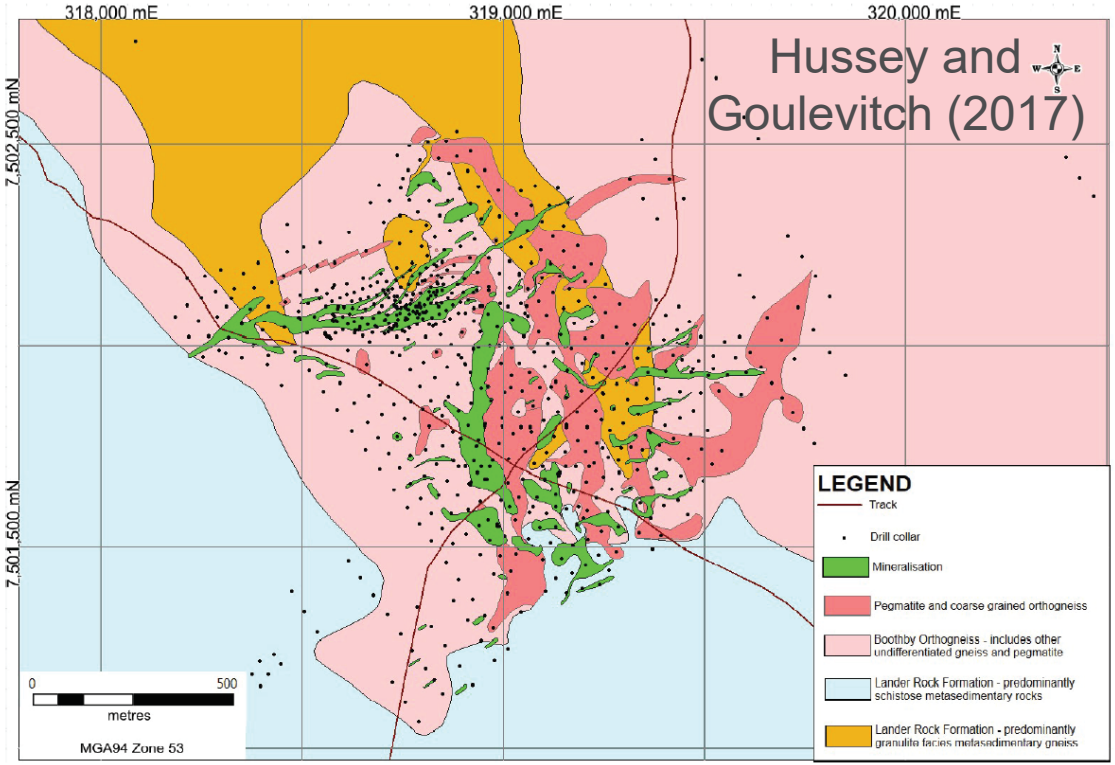


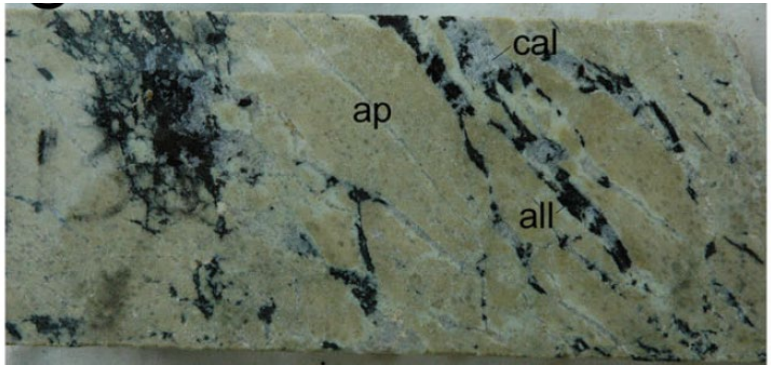
Pirajno et al. (2017)



- Endowment: 3.4 Mt LnO + 27 kt Y
- Hosted by weathered carbonatite
- Formed ca 2025 Ma
- Strongly LREE-enriched
- Post-formational weathering essential to economic viability

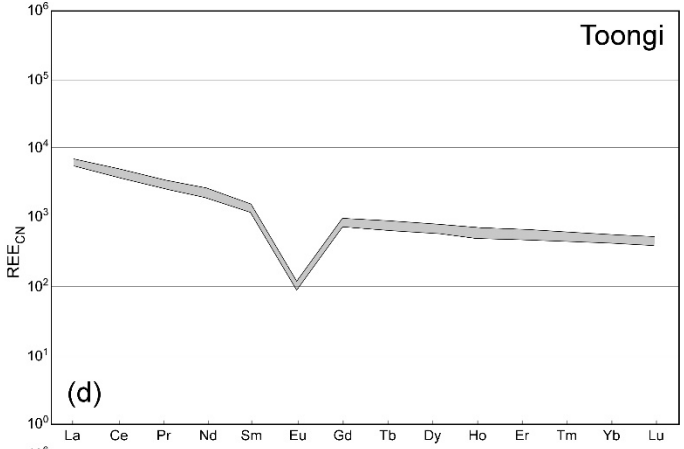
Nolans Bore (Aileron Province, NT)

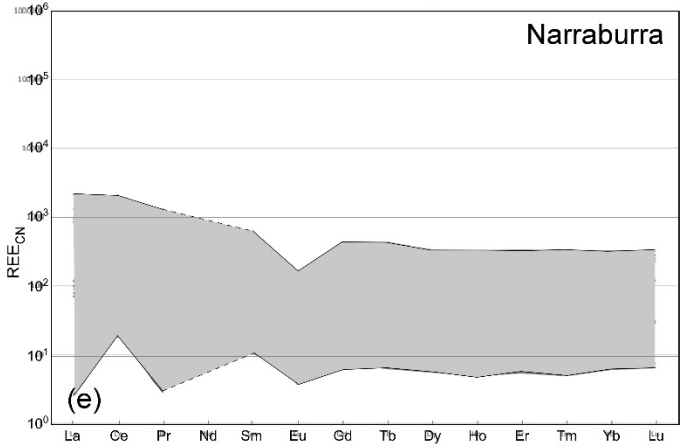


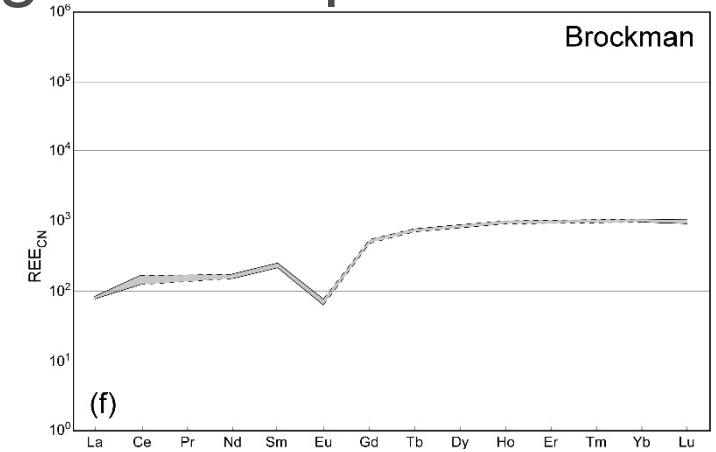


- Endowment: 1.4 Mt LnO + 15 kt Y + 11 kt U_3O_8 + 6.7 Mt P_2O_5
- Hosted by apatite veins (carbonatite-related)
- Formed ca 1532 Ma
- Strongly LREE-enriched
- Post-formational remobilisation and supergene enrichment

Peralkaline magmatic deposits

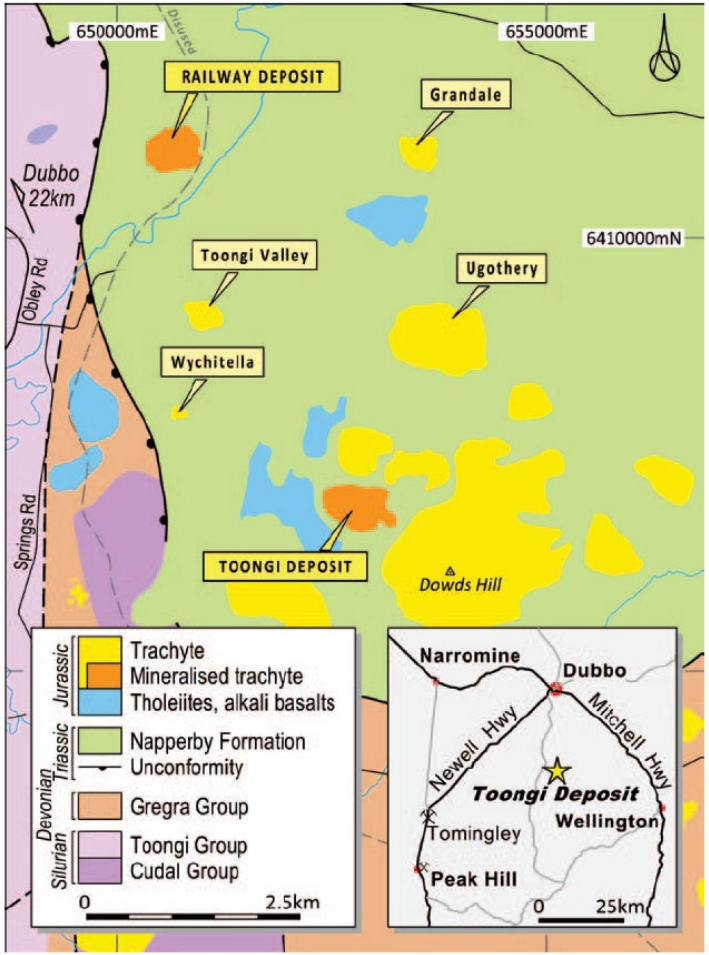


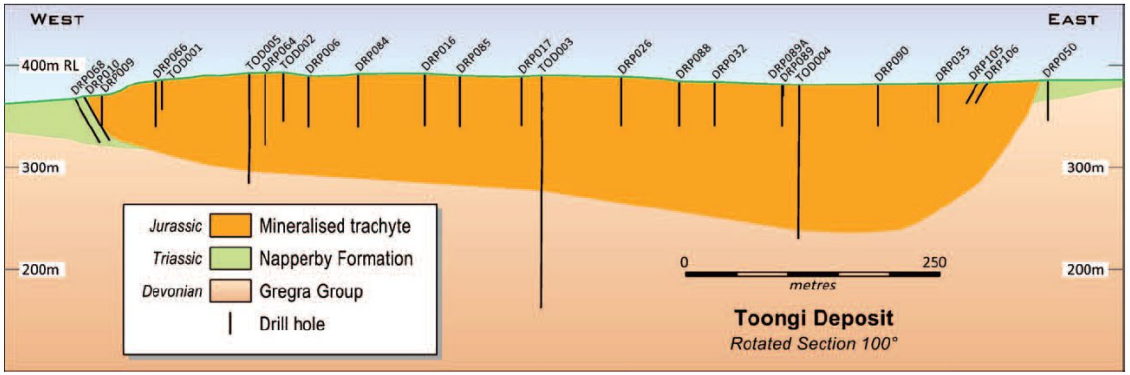




- Tend to be weakly LREE-enriched to moderately HREE-enriched (value in HREEs – Dy and Tb)
- Lower overall REE grade
- Coproducts (Nb, Zr, Y, etc) important

Toongi (Lachlan Orogen, NSW)

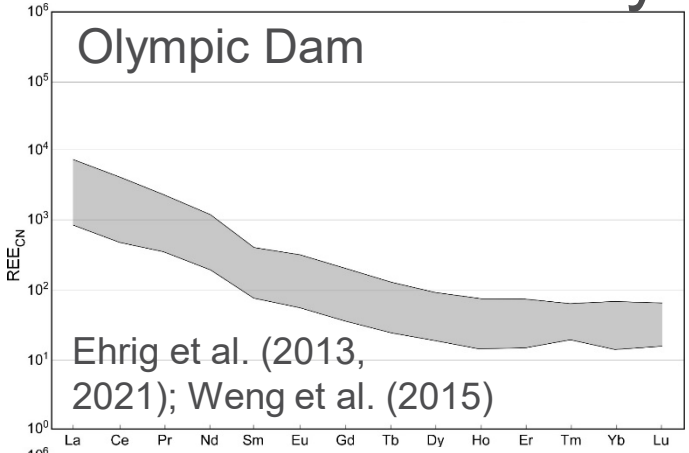


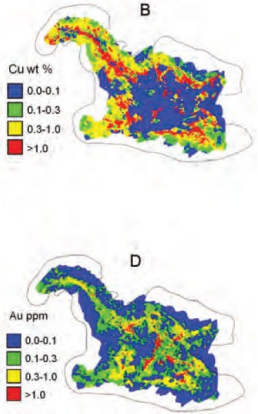


- Endowment: 0.55 Mt LnO + 81 kt Y + 25 kt Hf + 19 kt Ta + 268 kt Nb + 1.22 Mt Zr
- Hosted by Toongi Trachyte
- Formed ca 184 Ma
- Weakly LREE-enriched
- Some post-formational remobilisation and supergene enrichment

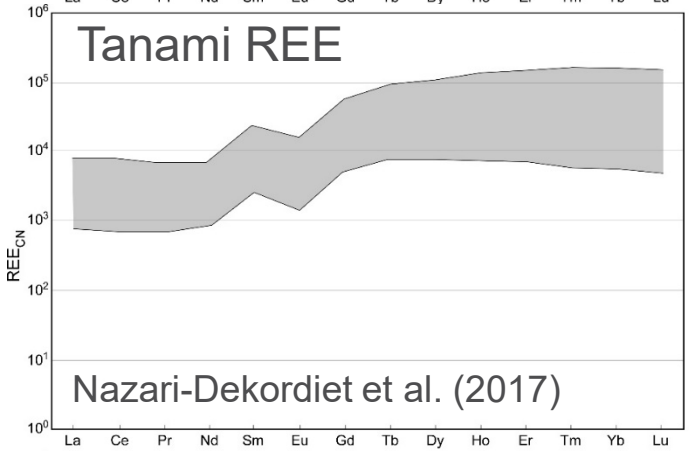
Chalmers et al. (2017)

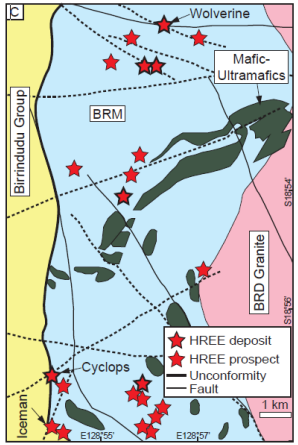
Hydrothermal deposits





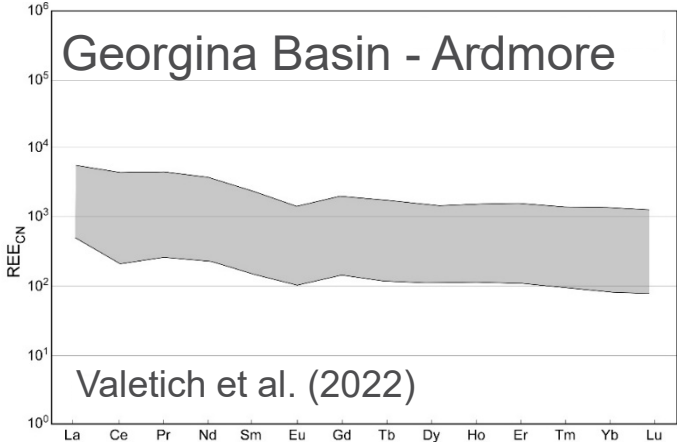
- Iron oxide copper-gold deposit
- Endowment: ~50 Mt LnO + Y
- Hosted by Olympic Dam Breccia Complex in Roxby Downs Granite
- Formed ca 1590 Ma with ca 700-500 Ma upgrading/remobilisation
- Strongly LREE-enriched

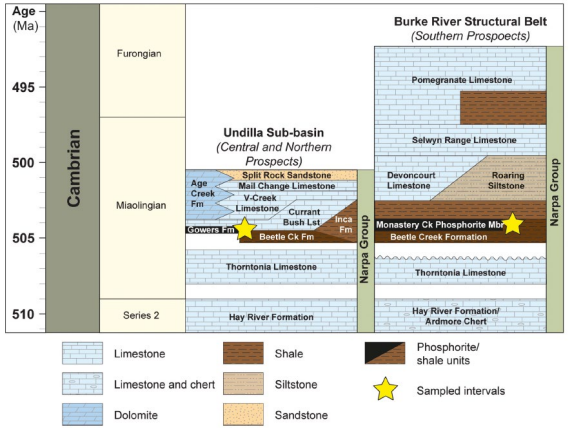




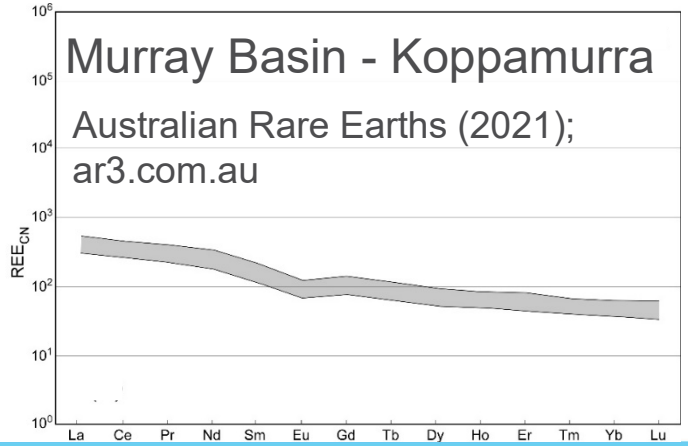
- Unconformity-related REE deposits
- Endowment: 0.040 Mt LnO + 27 kt Y
- Hosted by basement below unconformity
- Formed ca 1650-1610 Ma
- Xenotime main ore mineral
- Strongly HREE-enriched

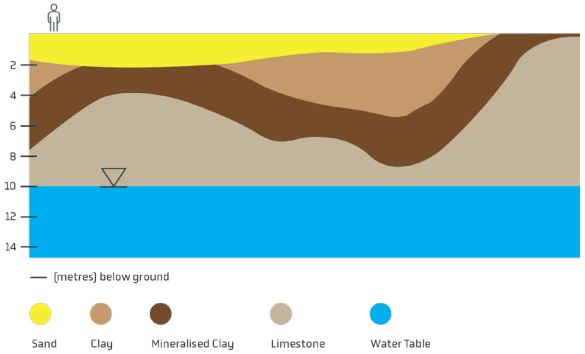
Basinal and weathering-related deposits





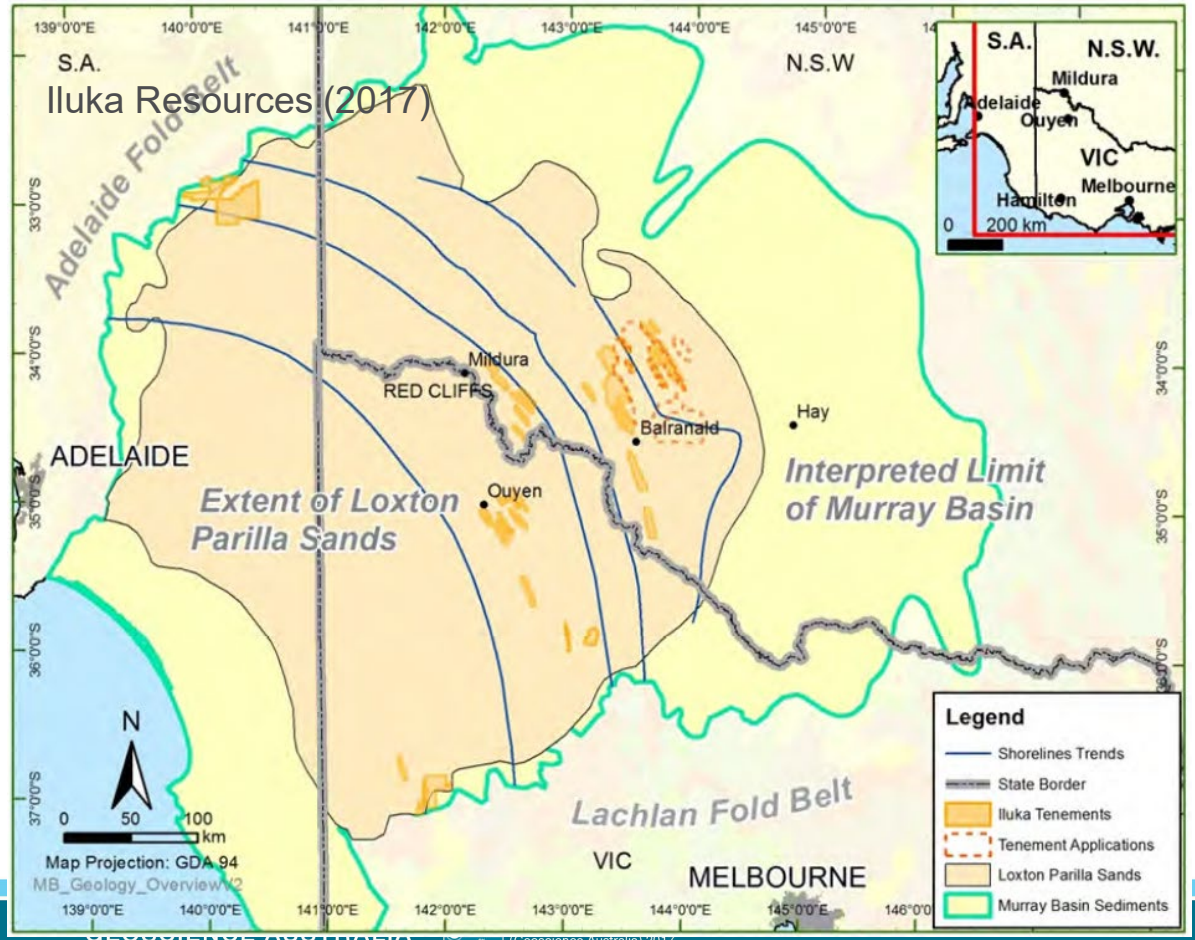
- Phosphorite REE
- “Grade”: ~1700 ppm LnO
- Hosted by phosphorite
- Formed ca 505 Ma
- Very weakly LREE-enriched





- Ion adsorption clay REE
- Endowment: 0.029 Mt LnO
- Hosted by clay unit overlying limestone
- Active (?)
- Weakly LREE-enriched

Placer (heavy mineral sand) deposits



- Endowment: 33.0 Mt heavy minerals (2017 mineral resources, Iluka Resource)
- Hosted by Loxton and Parilla Sands
- Formed ca 6.1 Ma (technically paleo-placers)
- Contains both monazite (LREE-rich) and xenotime (M-HREE-rich)
- Monazite production prior to mid-1990s
- Some companies now reporting and extracting monazite and xenotime

Critical minerals recovered from major commodity concentrates

Copper concentrates – Se, Te, Co, Bi, PGEs

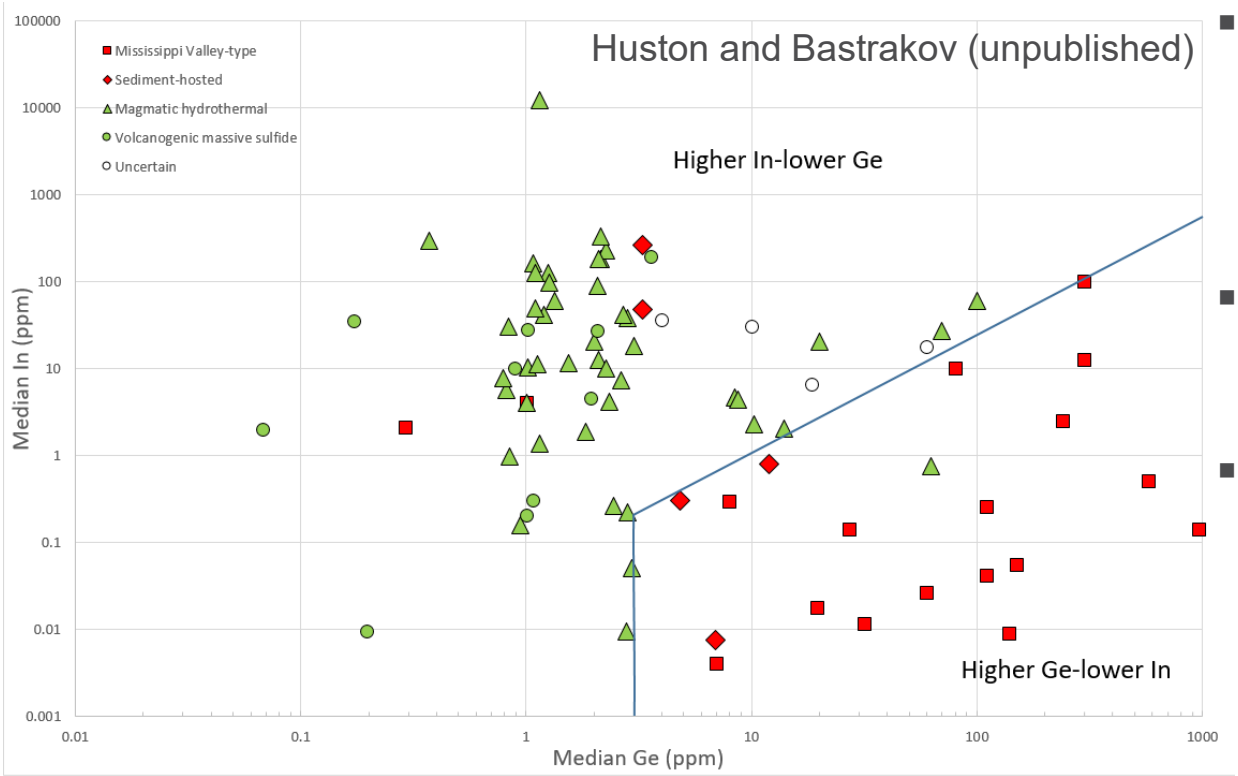
Nickel concentrates – Co, PGEs

Molybdenum concentrates – Re

Lead concentrates – Bi

Zinc concentrates – Cd, In, Ge, Ga

Critical minerals in zinc concentrates



- Sphalerite trace elements reflect deposition temperature (e.g. Stoiber, 1940)
  - Ge – enriched at lower T
  - In – enriched at higher T
- Fresnell et al. (2016) – geo-thermometer using Ge-In-Ga contents of sphalerite
- Can be used to predict CM potential of sphalerite concentrates
  - Ge-rich – MVT and some shale-hosted Zn deposits
  - In-rich – VHMS and intrusion-related deposits

Conclusions

Australia has established resources and significant potential to be a significant global supplier of many critical mineral, including:
(1) Ni, Co, and PGEs associated with (ultra)mafic magmatism;
(2) Sn, W, Mo, Re and In associated with intermediate/felsic magmatism;
(3) REEs and associated elements related to carbonatite and peralkaline magmatism, IOCG and unconformity-related deposits, phosphorites, weathering (ion adsorptions deposits) and the formation of placers; and
(4) Bi, Co, Ge, In, Re, Se and Te as by-products from the processing of mineral concentrates