

Where critical materials really come from — and how the squeeze tightened

32 critical raw materials, mine → refine → trade, reconciled from public data and tested over two decades. Varcolacus · public data only · 2002–2024

FINDING 1 · THE ORIGIN GAP

The country that exports a critical material usually isn't the one that mines it

In **19 of 32** materials the top exporter is not the top miner — customs records the refiner or shipping hub, not the source, so import-origin statistics overstate how diversified supply really is. Beryllium, unwrought (kzKazakhstan exports, usUnited States mines) · Strontium carbonate (deGermany exports, esSpain mines) · Lithium carbonate (clChile exports, auAustralia mines).

FINDING 2 · TWO DECADES

Concentration is intensifying — and it's testable

With the reconciled series back to 2002, **9 of 32** materials show a rising export-concentration trend that is significant on an FDR-corrected Mann–Kendall *screen* (23 annual points — exploratory, not confirmatory), and **8 of those 9** break in **2012–2016**. The trade-side origin gap also runs wide (~15–18pp), though part of the level steps at the 2017 HS-vintage join — read it as drift, not a clean trend.

FINDING 3 · THE HUB

China became the processing hub, not just an exporter

China's average network throughput — its centrality as importer *and* broker — rose from **10% to 18%** (2002–2024). Its export share of rare-earth magnets climbed 19→64%, of tungsten 9→74%. For bauxite, China's throughput rose 5→44% *while its exports fell* — it became the place the ore flows *into*. China is now the top refiner in 22 of 32 materials.

FINDING 4 · THE CHOKEPOINTS THAT MATTER

The materials with no way out

9 materials are at once hard to substitute, essentially un-recycled (<5% end-of-life) and supply-concentrated — so a disruption bites, has no secondary supply, and one country controls the flow. For **8 of the 9**, that chokepoint is China's refining. They are: Rare-earth

permanent magnets, Germanium, Natural graphite, Gallium, Lithium carbonate, Fluorspar, >97% CaF₂, Silicon, < 99.99%, Beryllium, unwrought, Phosphorus.

How it's built — and why it holds up. Bilateral trade is reconstructed from raw UN Comtrade via a Gaulier–Zignago-style mirror reconciliation and **validated against the official CEPII BACI** dataset: it recovers the top exporter in 25 of 30 materials with a 3.5pp share error. Mine/refine layers are USGS/IEA. The 2025 nowcast is **pre-registered**. Everything is **public data only and reproducible end-to-end with no API key**, and the two-decade trends are **statistically tested** (a reproducible Mann–Kendall / Theil–Sen / Pettitt screen), not just plotted — uncommon in the critical-minerals literature. Full method & citations: [technical note](#).

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