

SUSTAINABLE DEVELOPMENT IN AGRICULTURE, ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT



Pan Pacific Hotel – No. 1 Thanh Nien Street, Ba Dinh District, Hanoi



Tuesday, 4 November 2025 | 08:00 – 16:00

EVENT AGENDA

- 08:00 - 08:30** Participant Registration
- 08:30 - 08:50** Opening Session
- **Dr. Tran Cong Thang - Director of Institute of Strategy and Policy on Agriculture and Environment**
- Welcome Speech
- **Mr. Tran Thanh Nam - Vice Minister of Agriculture and Environment**
- Welcome Speech
- **Prof. Nguyen Thu Anh - Institute Director of University of Sydney Vietnam Institute**
- Opening Remarks
- **Monica Finlayson - Agriculture Counsellor - Australian Embassy**
- 08:50 - 09:00** Group Photo

Session 1: Circular Economy Development in Agriculture

- 09:00 - 09:15** Orientation for Circular Economy Development in Vietnam
- **Dr. Lai Van Manh - Head of the Department of Natural Resources and Environment Economics - ISPAE**
- 09:15 - 09:30** Advancing Circular Economy Solutions in Key Sectors to Promote Environmental Protection and Climate Change Adaptation
- **Msc. Hoang Thi Dieu Linh - UNDP Vietnam**
- 09:30 - 10:00** Research & Innovation from Australia: Circular Plastic Economy
- **Prof. Ali Abbas - University of Sydney**
- 10:00 - 10:15** Land subsidence in Mekong Delta and Ho Chi Minh City. Risks, Challenges and Adaptation Solutions for the sustainable development of Mekong Delta & Ho Chi Minh City
- **Assoc. Prof. Dr. Le Trung Chon - HCMNRE**
- 10:15 - 10:30** Biocircular economy model applied to rice production in An Giang Province
- **Assoc. Prof. Dr. Nguyen Thi Van Ha - HCMNRE**
- 10:30 - 10:45** Coffee Break

- 10:45 - 11:00** Sustainable Mineral Resources Management in Australia
- **Prof. Ali Abbas - University of Sydney**
- 11:00 - 11:30** Discussion
- **ISPAE**
 - **University of Sydney Vietnam Institute**
- 11:30 - 11:45** End of Session 1 Closing Speech
- **Mr. Tran Thanh Nam - Vice Minister of Agriculture and Environment**
- 11:45 - 12:00** Response Remarks
- **University of Sydney Vietnam Institute**
- 12:00 - 13:45** Lunch Break

Session 2: Sustainable Natural Resources Management and Development in Agriculture

- 13:45 - 14:00** Strategic Mineral Resources in Vietnam
- **Dr. To Xuan Ban - Hanoi University of Mining and Geology**
- 14:00 - 14:15** Exploring Vietnam-Australia collaboration in applied genomic research in agriculture
- **Dr. Duong Ngoc Cuong - VinUni Bigdata Research Institute, Vin University**
- 14:15 - 14:30** AMR on the Menu: Tracking Transmission in Vietnam's Food Chains - Evidence-Based Strategies for Sustainable Agriculture and Food Safety
- **Dr. Duong Nu Tra My - University of Sydney Vietnam Institute**
- 14:30 - 14:45** Coffee Break
- 14:45 - 15:00** AI Forecasting for Water Quality in Vietnam's Sustainable Aquaculture
- **Dr. Thai Mai Thanh - VinUniversity**
- 15:00 - 15:15** Advanced Biochar Materials for Arsenic Treatment in Groundwater in the Mekong Delta
- **Dr. Nguyen Tan Thong - HCMUNRE**
- 15:15 - 15:45** Discussion
- **ISPAE**
 - **University of Sydney Vietnam Institute**
- 15:45 - 16:00** Closing Remarks
- **HCMUNRE**



Strategic Minerals in Vietnam

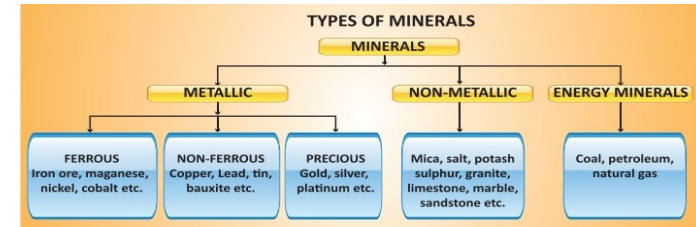


Courtesy of
NETL REE-CM Website

Outline

- **Introduction**
- **Strategic Minerals in Vietnam**
- **Rare Earth Elements (REEs) in Vietnam**

Introduction



Minerals: natural concentrations of solid, liquid, or gaseous substances in the Earth's crust, with sufficient concentration, grade, or quality to be economically extracted and utilized for human benefit

Critical minerals: essential in use and subject to supply risks (National Research Council, 2008).

U.S. Geological Survey (USGS): *critical minerals* as materials vital to a nation's economy and security, characterized by vulnerable supply chains and essential roles in manufacturing

European Commission: raw critical raw materials hold significant economic value and face a substantial risk of supply interruption

Strategic materials generally emphasize defense-related uses more strongly. (e.g. the Colorado Geological Survey differentiates them from critical minerals based on their supply risk during wartime)

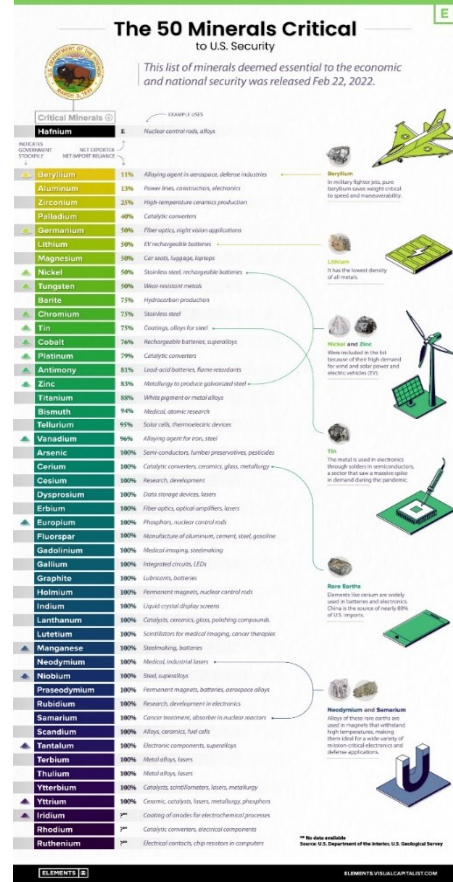
In practice, the industry defines strategic metals essential for defense and heavy industries, while critical metals refer to constrained domestic availability.

Regardless of how the terms are defined, both strategic and critical minerals play essential roles in economic stability and national security.

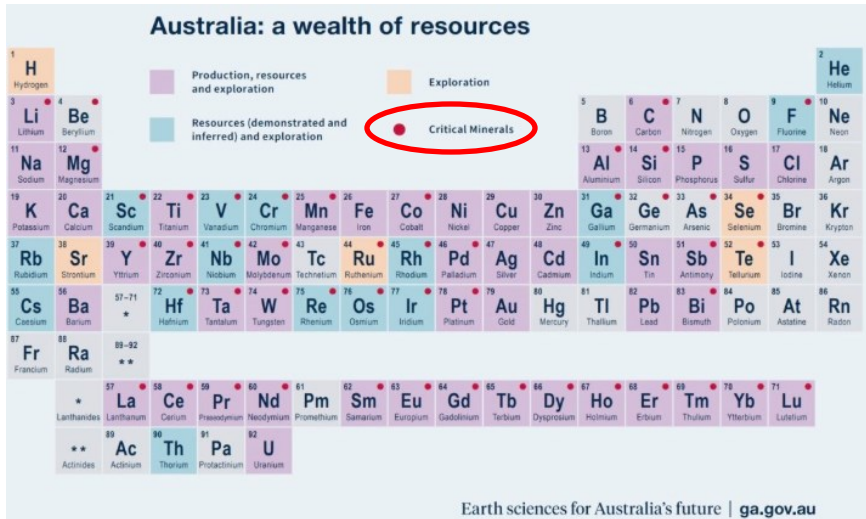
Introduction

Critical mineral lists of selected countries

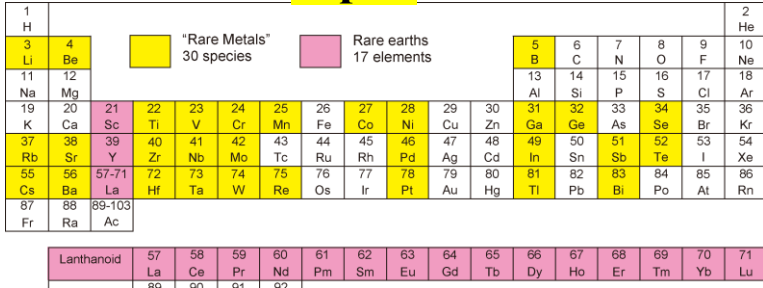
United States



Australia

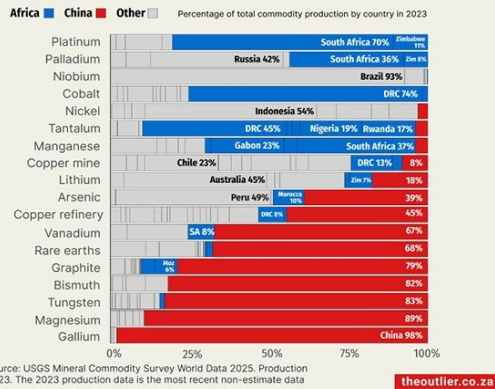


Japan



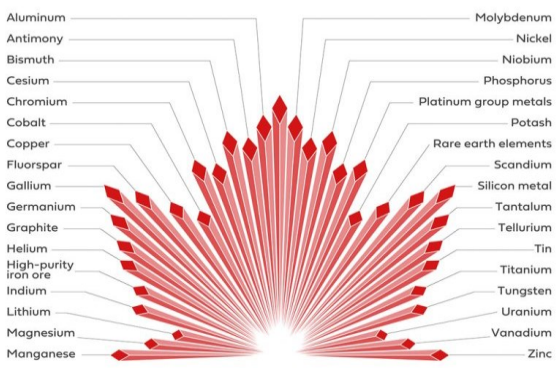
China

China dominates global critical mineral production



Canada

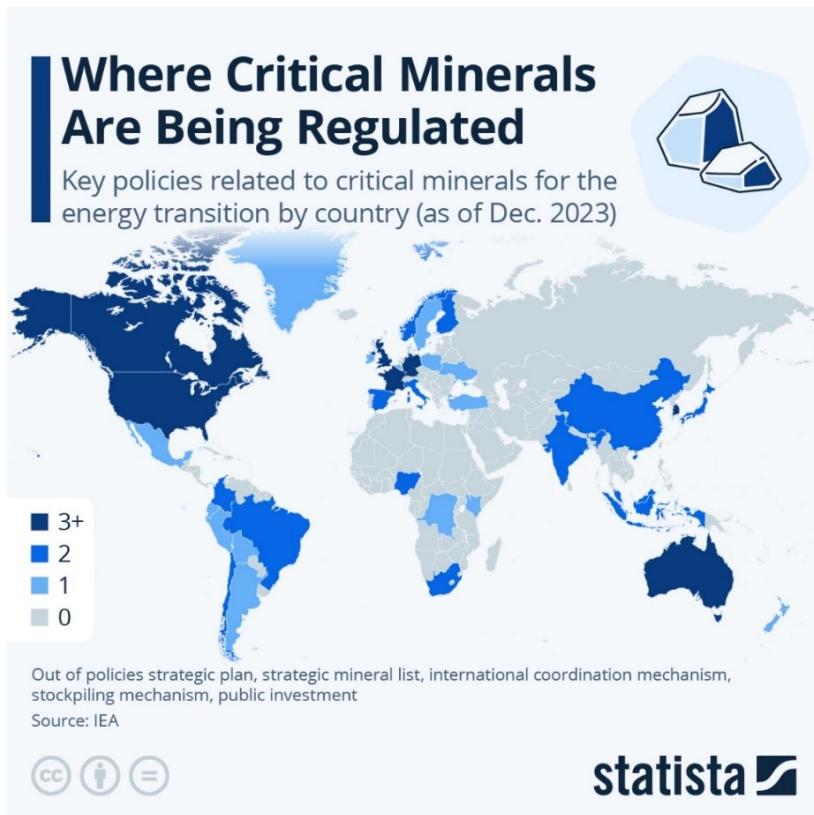
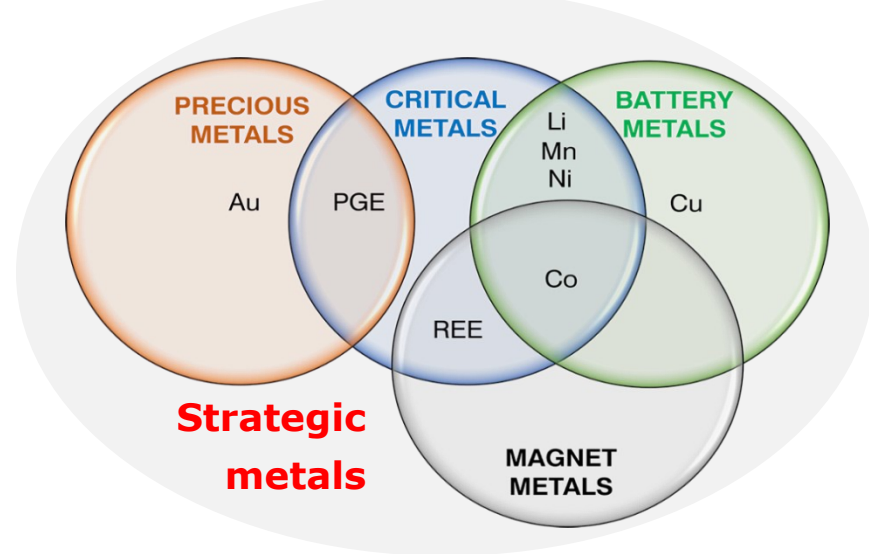
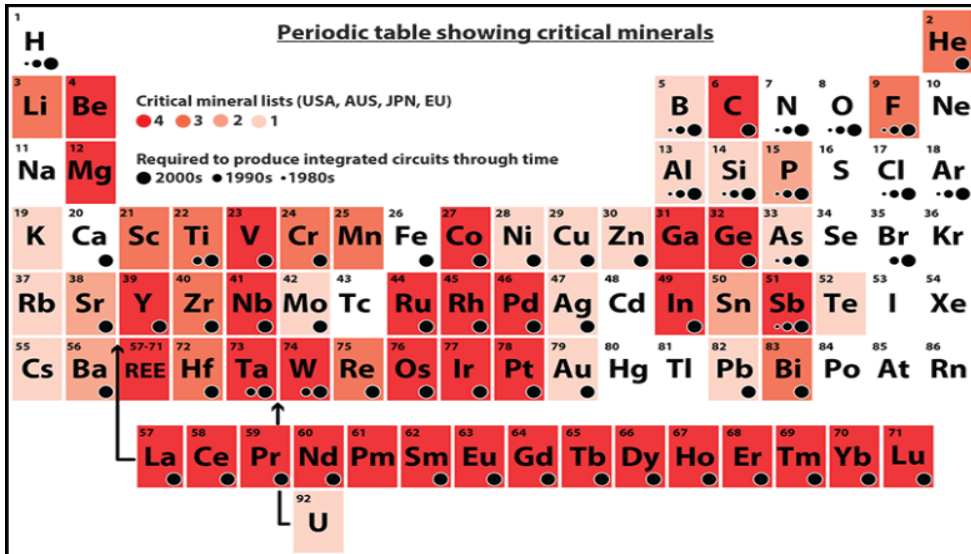
Canada's 34 critical minerals



India

Government has released a list of Hafnium, Indium, Lithium, Molybdenum, Vanadium, Zirconium, Selenum and Ministry of Mines has increased exploration projects taken up by GS





COUNTRY	RESERVES	CRITICAL MINERALS
CHINA	44	Rare earth elements, cobalt, lithium
BRAZIL	22	Nickel, bauxite, iron ore
VIETNAM	22	Rare earth elements, tungsten
RUSSIA	12	Nickel, copper, platinum
INDIA	6.9	Rare earth elements
AUSTRALIA	3.2	Lithium, cobalt, rare earth elements
UNITED STATES	1.8	Lithium, cobalt, rare earth elements
SOUTH AFRICA	1.5	Platinum, chromium, vanadium
CANADA	1.2	Nickel, cobalt, lithium
KAZAKHSTAN	1	Uranium, copper, rare earth elements
UK	-	Rare earth elements, lithium, graphite (none currently produced)

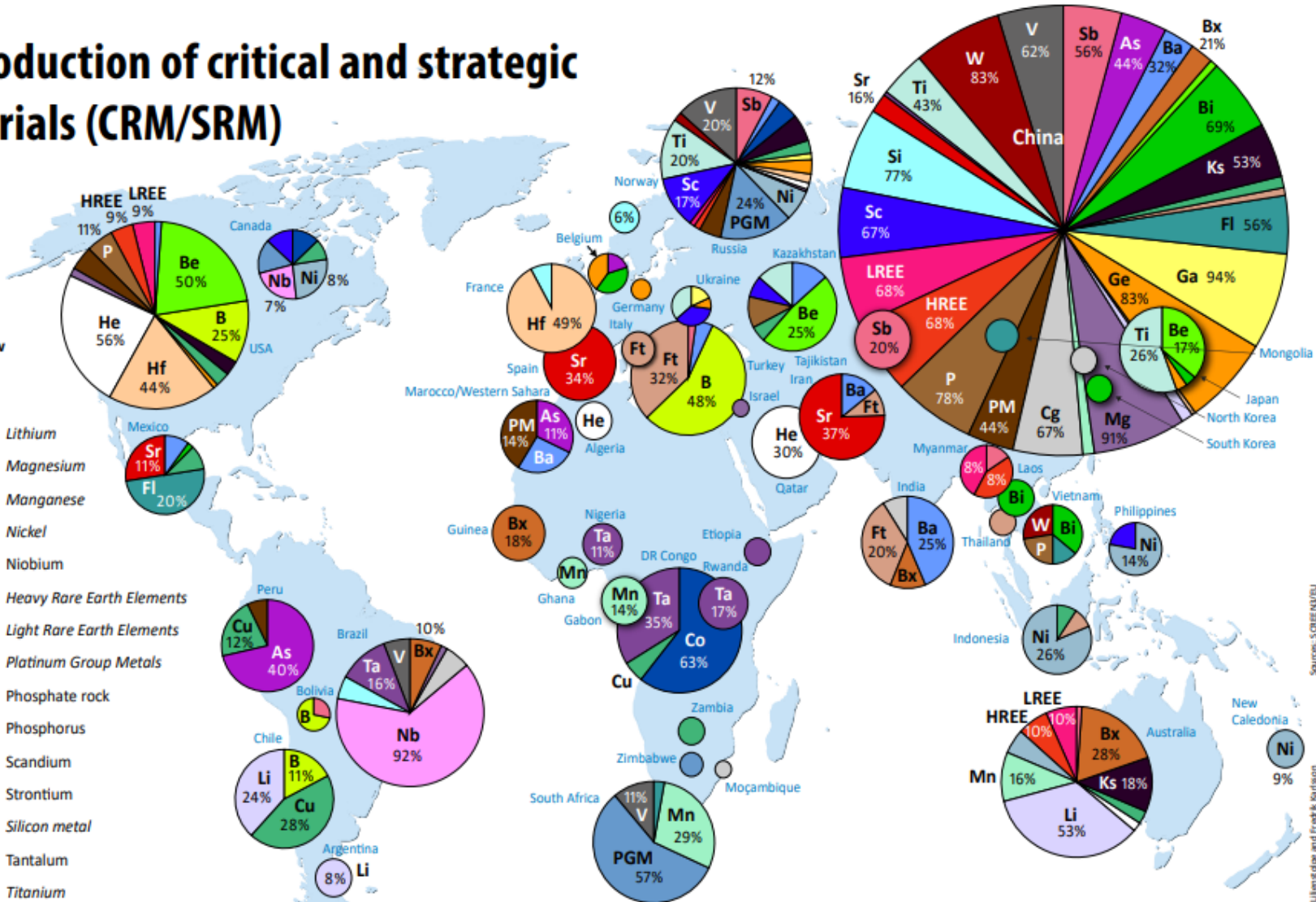
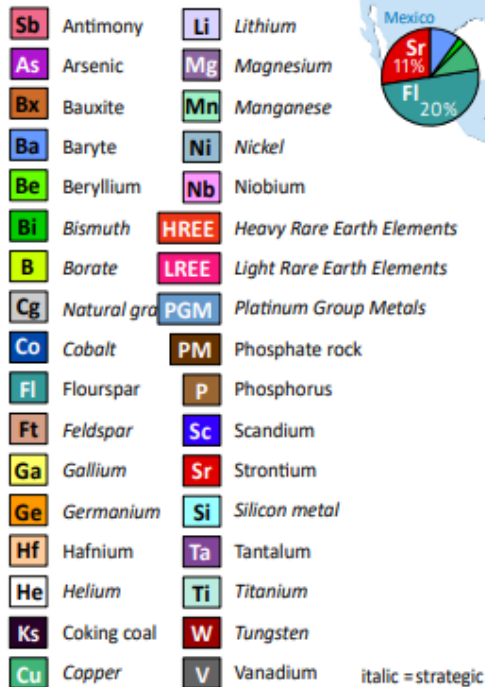
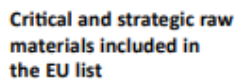
<https://pubs.usgs.gov/periodicals>

Examples of some strategic minerals and their uses

- **Cobalt:** batteries for electric vehicles (EVs) and other technologies.
- **Lithium:** batteries for EVs and other energy storage devices.
- **Rare Earth Elements (REEs):** magnets, electronics, and other advanced technologies.
- **Tin:** industrial and military applications
- **Tungsten (Wolfram):** high-temperature alloys and cutting tools.
- **Beryllium:** aerospace and nuclear technologies.
- **Gallium:** used in semiconductor technology and LEDs.
- **Germanium:** fiber optics and semiconductors.
- **Uranium:** used as fuel for nuclear reactors.
- **Other examples:** iron ore, coal, lead, zinc, barite, gold, antimony, silver, graphite, etc.

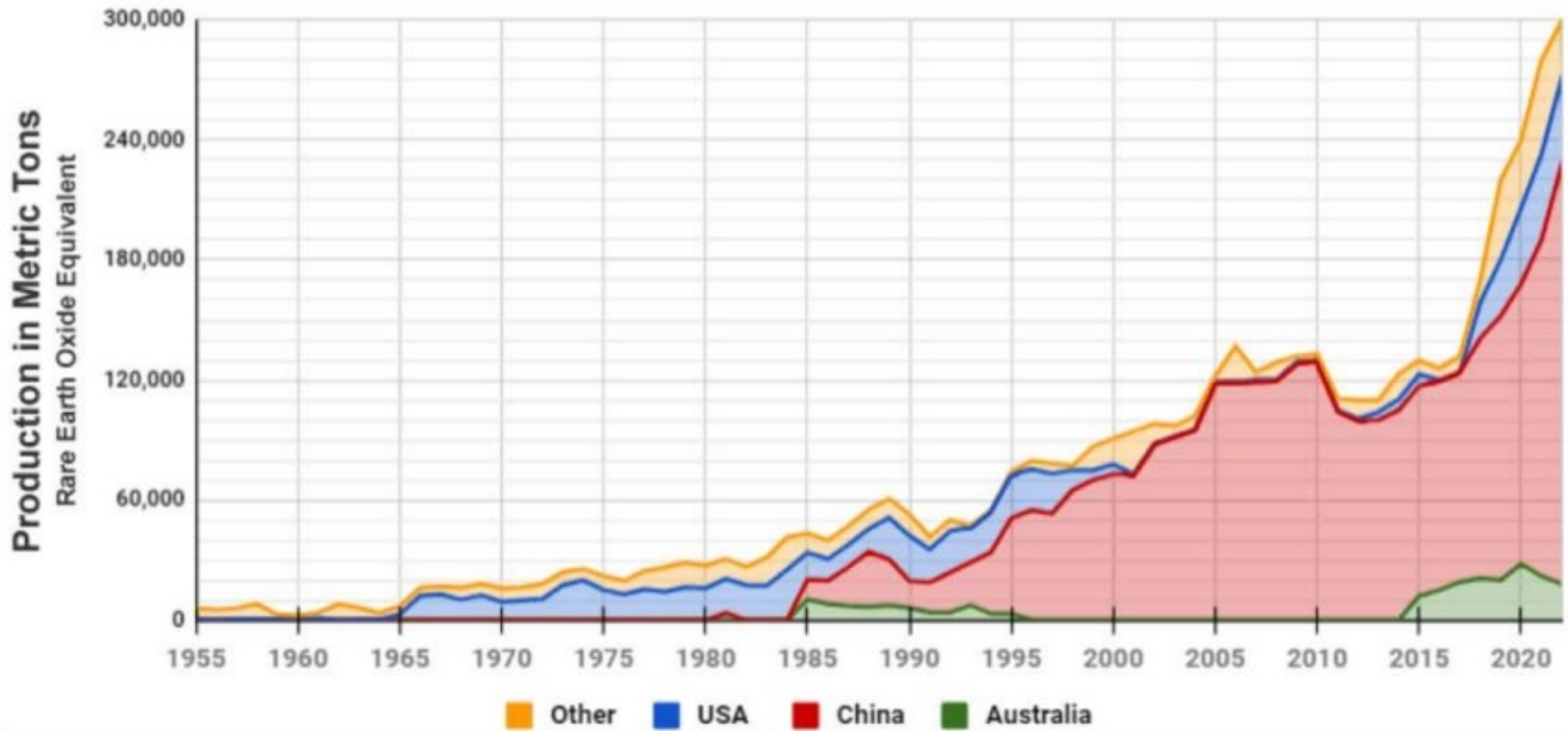


Global production of critical and strategic raw materials (CRM/SRM)



SGU Geological Survey of Sweden

Global Production of Rare Earth Elements (1995 – 2022)



Source: Geology.com, "REE: Rare Earth Elements and their Uses," <https://geology.com/articles/rare-earthelements/>.
The data for this graph are from the U. S. Geological Survey (USGS).

The identification of strategic minerals depends on resource potential and national development strategy.

Each country defines its own list of strategic and critical minerals based on its resource potential, supply capacity and stability, industrial development stability, development goals, and national security considerations.

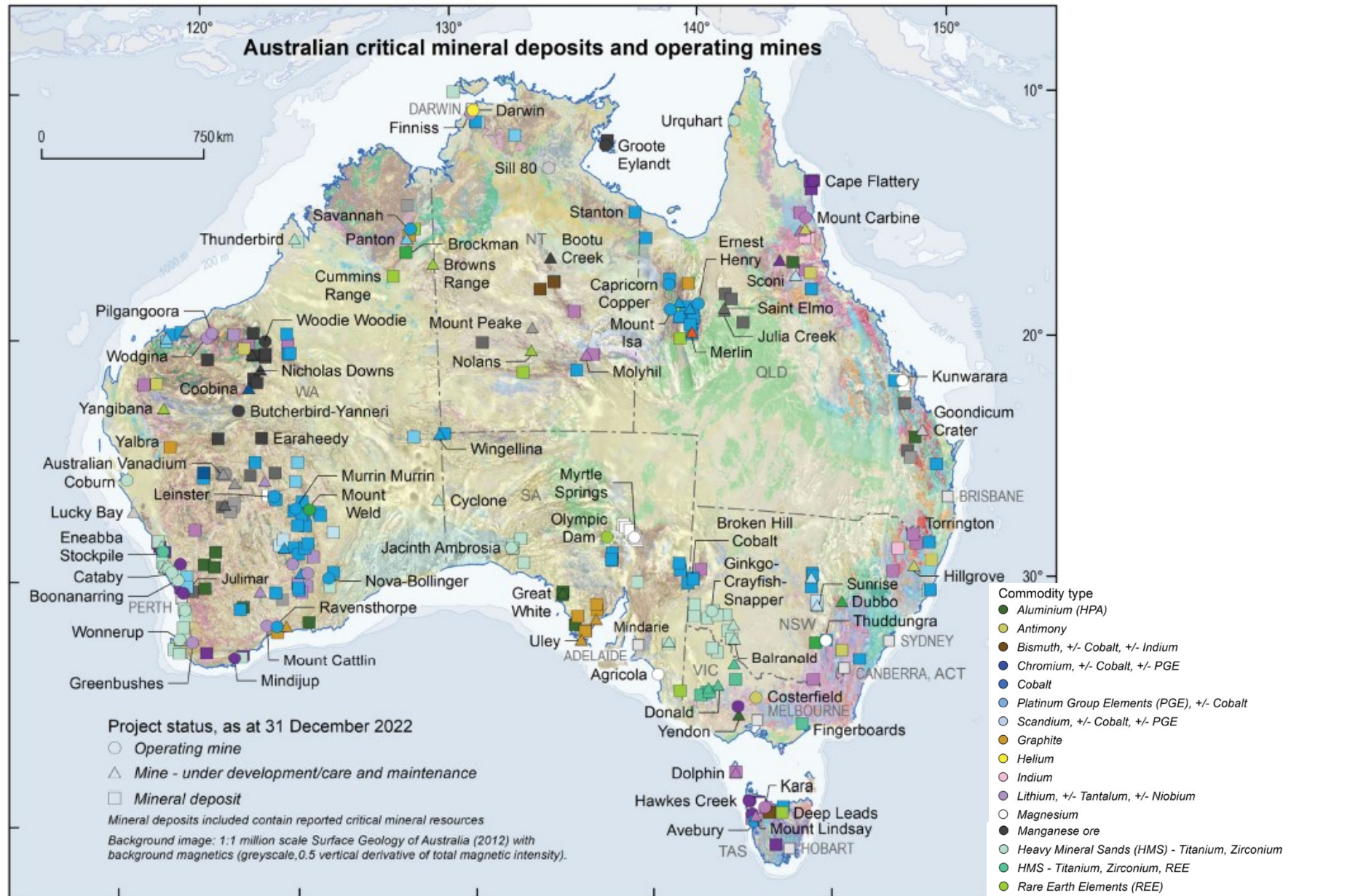
Recently, policymakers have broadened the definition of “critical” minerals to encompass those essential for the transition to clean energy.

The *U.S., Europe, and Japan* remain heavily reliant on imports and are consequently vulnerable to supply chain disruptions.

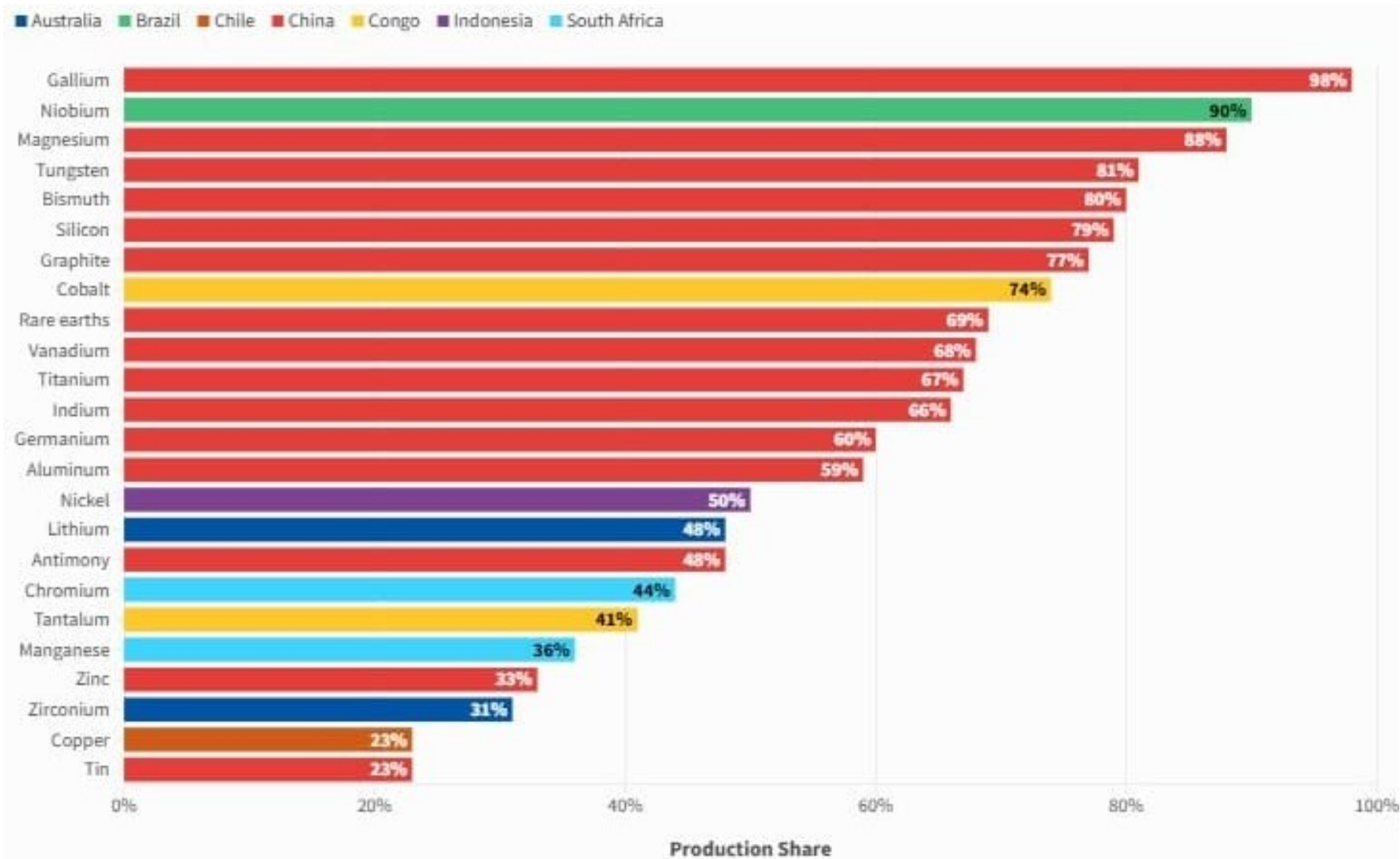
China dominates both production and refining of rare earths, Li, and Co.

Political stability is a crucial factor in the supply of critical minerals, as many regions around the world face trade tensions, along with conflicts and armed disputes between nations and territories.

Strategic and critical minerals lie at the intersection of national security, technological advancement, and the global transition to clean energy

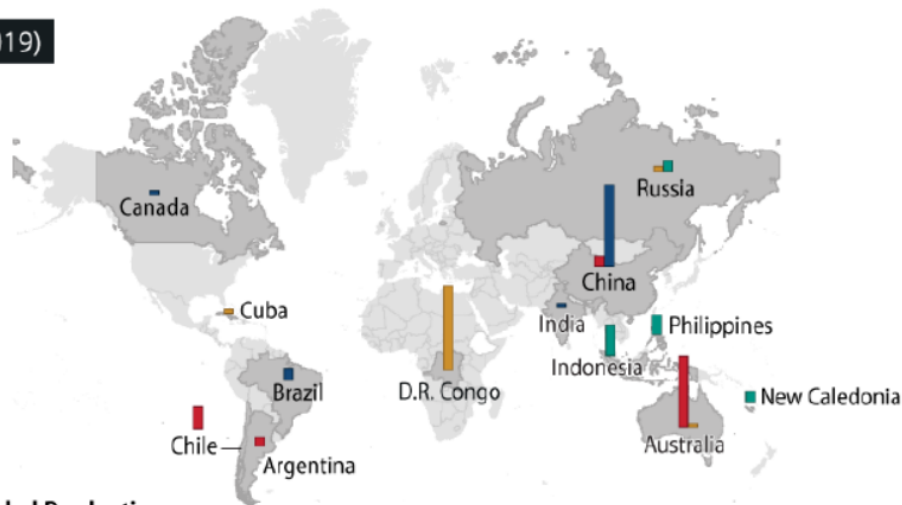


Top Producers of Select Critical Minerals, 2023



(www.investmentmagazine.com.au)

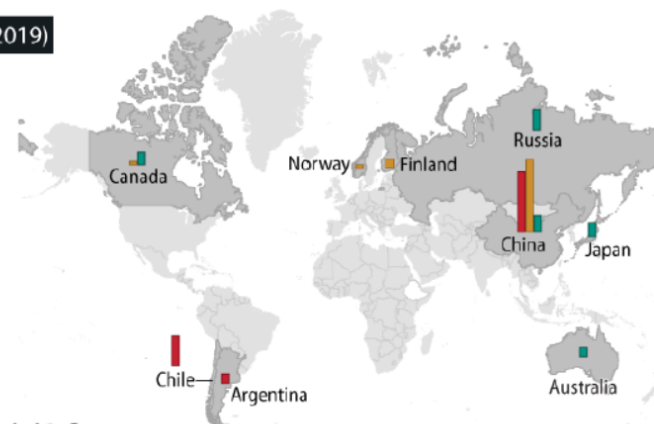
Mining (2019)



Percent of Global Production

	Lithium	Cobalt	Nickel	Graphite
	60% - Australia	70% - D.R. Congo	26% - Indonesia	68% - China
	19% - Chile	5% - Russia	16% - Philippines	10% - Brazil
	9% - China	4% - Cuba	10% - New Caledonia	4% - Canada
	7% - Argentina	4% - Australia	10% - Russia	4% - India
Total metric tons	84,700	128,700	2,133,000	500,000

Refining (2019)

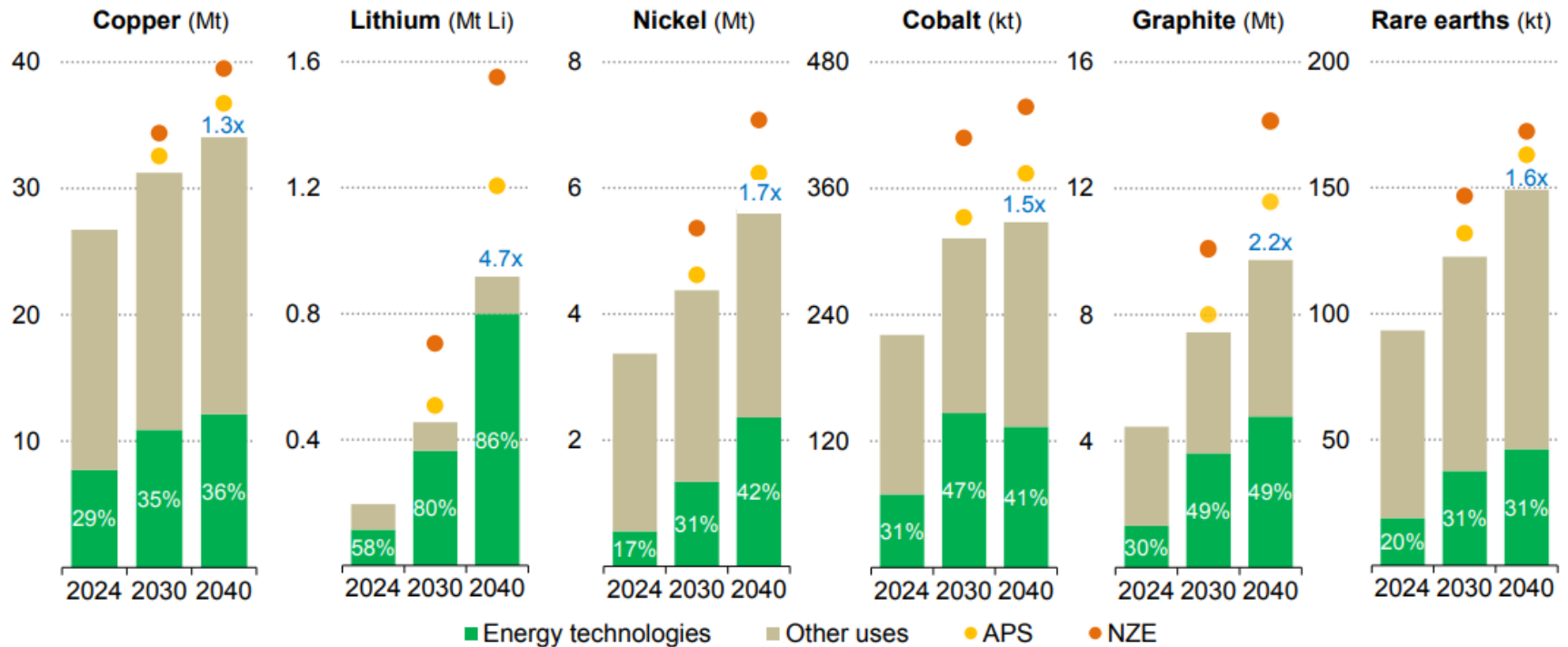


Percent of Global Refinement

	Lithium	Cobalt	Class 1 Nickel
	60% - China	72% - China	21% - Russia
	30% - Chile	9% - Finland	16% - China
	10% - Argentina	4% - Canada	15% - Japan
	—	4% - Norway	13% - Canada
Total metric tons	66,100	162,900	1,171,300

(www.investmentmagazine.com.au)

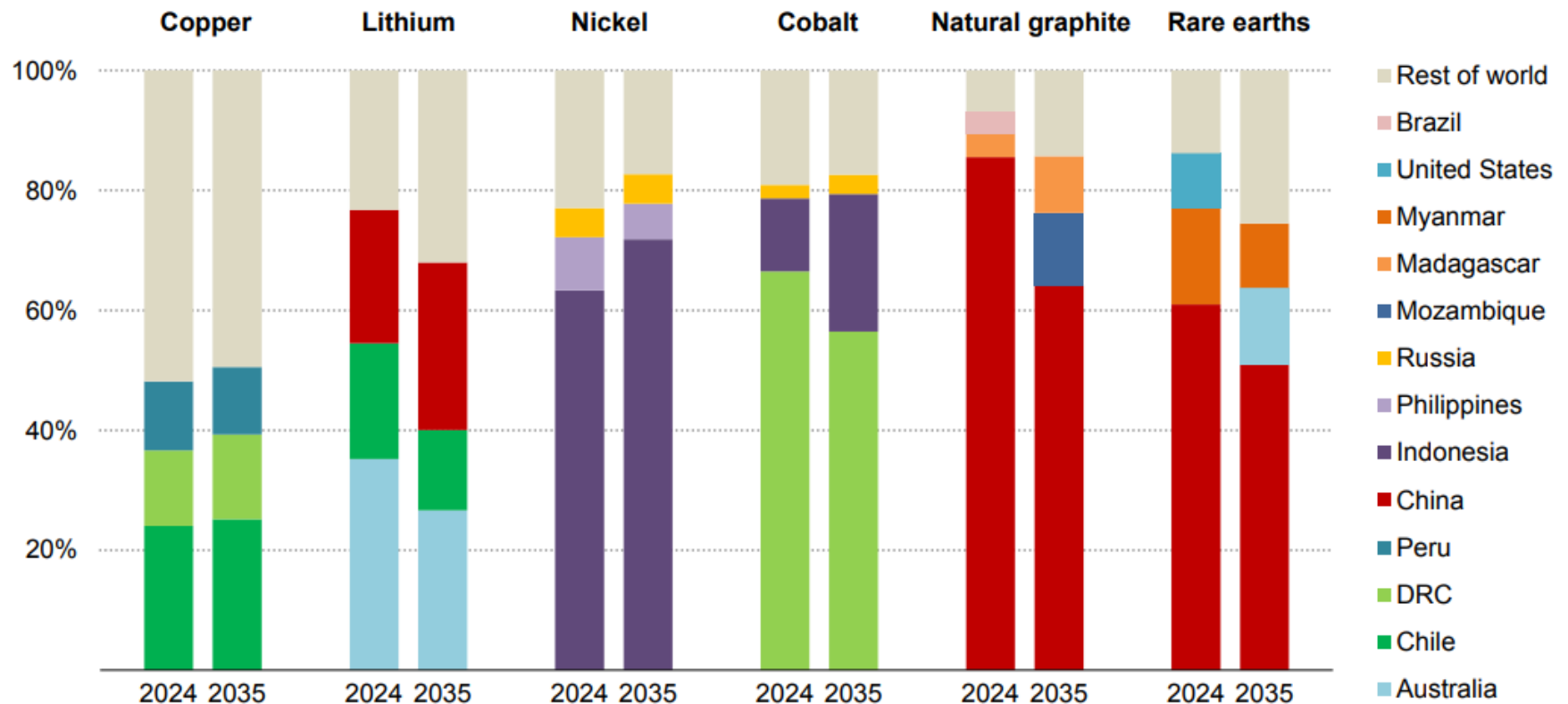
Global critical minerals demand in the STEPS



IEA. CC BY 4.0.

Notes: STEPS = Stated Policies Scenario; Mt = million tonnes; kt = kilotonnes; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario. The figures for copper are based on refined copper (excluding direct-use scrap). Those for rare earth elements are for magnet rare earth elements only. Growth rates (in blue) are between 2024 and 2040.

Geographical distribution of mined or raw material production for key energy minerals in the base case



IEA. CC BY 4.0.

Notes: DRC = Democratic Republic of the Congo. Graphite extraction is for natural flake graphite. The figures for rare earth elements are for magnet rare earth elements only. The figure depicts the value of the top three producing countries in a given year.

Global Critical Minerals Outlook 2025 (<https://iea.blob.core.windows.net>)

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U.S. and Ukraine Reopen Talks on Contentious Minerals Deal

Kyiv and Washington have been haggling over a deal for resource rights that President Trump sees as a way to "recoup" past U.S. aid to Ukraine.

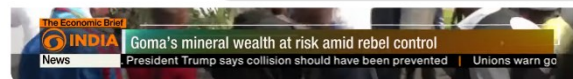


President Volodymyr Zelenskyy of Ukraine during a contentious White House meeting with President Trump and Vice President JD Vance in the Oval Office. Source: White House/White House/White House



YouTube

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War for minerals | Why Rwanda-backed M23 rebels captured DR Congo's Goma, hit Africa supply chains



<https://bigrockexploration.com/2019/04/what-makes-minerals-strategic-critical/>

FT

Financial Times



Western companies warn of China rare-earth supply chain chaos



Strategic minerals in Vietnam

Mineral resources are naturally accumulated useful minerals or substances that exist in solid, liquid, or gaseous form within the Earth's crust or on its surface, including minerals and useful substances found in mine tailings

Strategic/critical minerals are essential minerals that serve the sustainable socio-economic development and the strengthening of national defense and security (Law No. 54/2024/QH15 – Law on Geology and Minerals)

Strategic minerals: essential minerals used in clean energy technologies such as wind turbines, solar panels, electric vehicles, and energy storage systems. They are also key raw materials for high-tech industries such as electronics, aerospace, defense and security, and advanced materials

Strategic minerals: not only a driving force for development but may also become a focal point of geopolitical competition and conflict in the future.

This necessitates sustainable strategies for exploration, extraction, and management to support global green development goals.



LUẬT

ĐỊA CHẤT
VÀ KHOÁNG SẢN

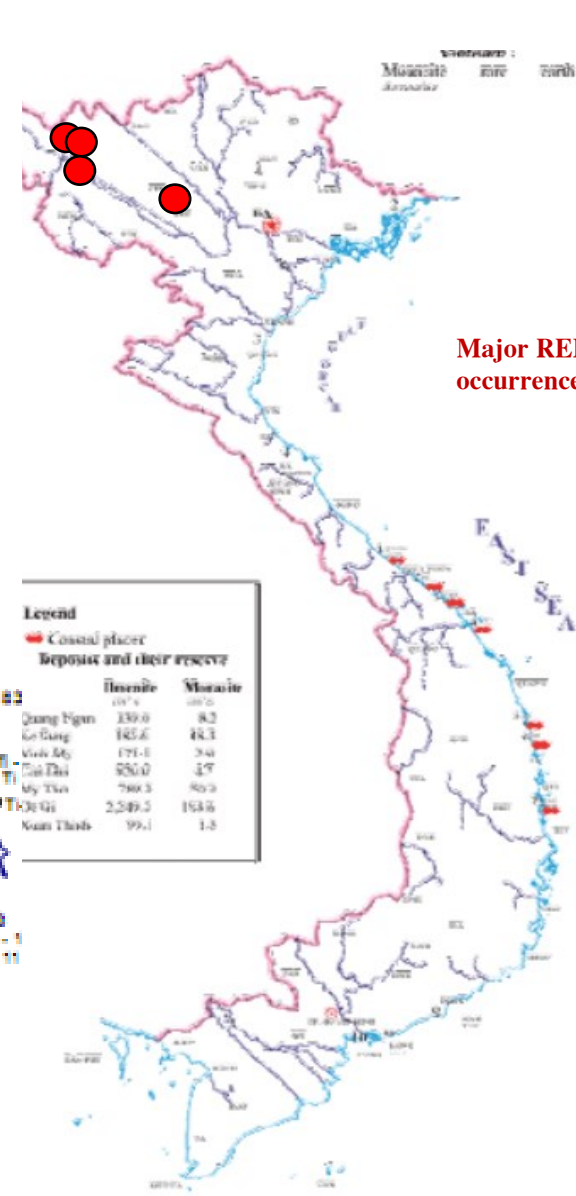
(HIỆN HÀNH)

Vietnam rich in mineral resources/strategic minerals: REEs, bauxite, nickel, copper, cobalt, antimony, bismuth, manganese, tin, tungsten, phosphate, fluorite, lithium, and graphite.

But, yet to have a clear list of strategic minerals and complete supply chain from *upstream* (exploration, mining, beneficiation) to *downstream* (extraction, refining, and advanced material production). Focusing solely on upstream technologies while neglecting midstream and downstream technologies reduces added value and limits the country's ability to attract investment and facilitate technology transfer from international corporations.

Vietnam aims to develop technologies for the mining, processing, and refining of several important minerals such as bauxite and REEs (According to Decision No. 866/QĐ-TTg on the “*Approval of the Planning for Exploration, Mining, Processing, and Use of Various Minerals for the Period 2021–2030, with a Vision to 2050,*”)

The application of modern technologies in management and processing not only enhances resource value and reduces dependence on raw material exports but also promotes the production of advanced materials, recycling, resource conservation, and the development of a circular economy.



(Tran Van Tri et al, 2009)

Potential Strategic Minerals in Vietnam: location, type, reserve, status

#	Mineral	Major Distribution Areas	Deposit Type	Proven Reserves	Reserve type	Mining Status
1	REEs	Bac Nam Xe, Dong Pao, Nam Nam Xe (Lai Chau); Muong Hum (Lao Cai); Yen Phu (Yen Bai); coastal placer deposits	Carbonatite-type primary deposits, titanium–zircon placer, ion-adsorption type	~24.96 million tons TRE ₂ O ₃	121, 333	Not yet mined on an industrial scale; under exploration and auction procedures
2	Lithium (Li)	Ba To (Quang Ngai); pegmatite zones in Binh Thuan – Ninh Thuan; Central Highlands	Pegmatite, adsorption-type	~4,400 tons Li ₂ O (Ba To)	333	Not yet exploited; under research and investigation
3	Nickel (Ni)	Son La (Ban Phuc), Cao Bang, Central Highlands	Sulfide (Ban Phuc), laterite (Central Highlands)	~360,000 tons Ni	121, 333	Industrial mining at Ban Phuc; laterite resources remain untapped
4	Cobalt (Co)	Cao Bang, Son La, Ha Giang, Lao Cai, Thanh Hoa, Central Highlands	Associated with Ni, Cu ores and chromite tailings	Not fully quantified	—	Not mined independently; recovered as by-product
5	Uranium (U)	Viet Bac, Northwest region, Central Vietnam	Sandstone-hosted, vein, volcanic rocks	Pa Lua: 0.031–0.095% U ₃ O ₈	333	Not yet mined; only exploration and survey work conducted
6	Tungsten (W)	Nui Phao (Thai Nguyen), Lao Cai	Scheelite, wolframite veins	~230,000 tons WO ₃ (Nui Phao)	121	Industrial-scale mining in operation (Masan High-Tech Materials)
7	Molybdenum (Mo)	O Quy Ho, Kin Chang Ho (Lao Cai)	Molybdenite veins	~15,000 tons Mo	333	Not yet mined
8	Antimony (Sb)	Quang Ninh, Tuyen Quang, Thanh Hoa	Sb–Au, Sb–quartz veins	~60,000 tons Sb	121, 333	Small-scale, intermittent mining
9	Graphite (C)	Lao Cai, Quang Ngai, Tuyen Quang	Metamorphosed sedimentary deposits	~22.39 million tons	333	Not yet mined on a large scale
10	Zircon (Zr)	Coastal placer deposits (Binh Thuan, Ninh Thuan, Quang Tri, etc.)	Titanium–zircon placer	~87 million tons	121, 333	Mined jointly with titanium placers

(Ministry of Education and Training of Vietnam, unpublished 2025)

Resources & Reserves of some Strategic Minerals in Vietnam

#	Type of Mineral	Unit	Reserves	Resources and Forecasted Resources	Total
1	REEs	Tons TRE ₂ O ₃	3,472,347	16,349,207	19,821,554
2	Bauxite	10 ³ tons (ore)	3,084,674	6,465,328	9,550,002
3	Titanium – Ilmenite	10 ³ tons (ore)	109,053	502,301	611,354
	Zircon	10 ³ tons	—	—	82,426
4	Lead, Zinc	Tons	865,190	4,943,816	5,809,006
5	Chromite	10 ³ tons Cr ₂ O ₃	14,484	7,288	21,772
6	Manganese	10 ³ tons metal	3,989	6,779	10,768
7	Tin	Tons metal	23,251	125,198	148,449
8	Tungsten (Wolfram)	Tons metal	172,908	136,499	309,407
9	Antimony	Tons metal	54,375	90,501	144,876
10	Copper	Tons metal	432,106	1,098,520	1,530,626
11	Nickel	10 ³ tons metal	612	3,454.5	4,066
12	Molybdenum	Tons	7,400	21,000	28,400
13	Gold	Kilograms	75,012.7	124,631	199,644
14	Apatite	10 ³ tons (ore)	126,247	1,854,257	1,980,504
15	Graphite	10 ³ tons	9,715	21,670	31,385

(Ministry of Education and Training of Vietnam, unpublished 2025)

Production of Mineral Raw Materials

Vietnam

		2019	2020	2021	2022	2023	Change 19/23	Change 22/23
Iron	(t)	3 663 400	2 136 200	1 850 300	1 084 400	876 700	-76.07	-19.15
Manganese	(t)	106 000	121 100	147 000	155 000	150 000	41.51	-3.23
Nickel	(t)				0	2 100	.	.
Titanium	(t)	112 680	139 760	156 000	156 210	114 500	1.62	-26.70
Tungsten	(t)	4 816	5 970	11 735	10 817	7 900	64.04	-26.97
Antimony	(t)	396	312	268	517	394	-0.51	-23.79
Bauxite	(t)	3 700 000	3 610 000	4 100 000	3 900 000	3 800 000	2.70	-2.56
Bismuth	(t)	917	993	2 067	1 938	1 148	25.19	-40.76
Copper	(t)	29 240	30 780	33 930	34 560	29 040	-0.68	-15.97
Lead	(t)	12 500	14 100	16 350	20 560	15 870	26.96	-22.81
Rare Earths	(t)	300	700	1 000	1 300	1 100	266.67	-15.38
Tin	(t)	6 071	7 229	7 804	8 016	9 079	49.55	13.26
Zinc	(t)	13 000	11 150	10 700	14 420	20 970	61.31	45.42
Gold	(kg)	540	559	664	1 114	962	78.15	-13.64
Silver	(kg)	500	555	670	1 451	1 744	248.80	20.19
Baryte	(t)	43 000	51 500	39 600	42 000	48 500	12.79	15.48
Fluorspar	(t)	238 003	219 920	215 027	217 975	146 007	-38.65	-33.02
Graphite	(t)	3 500	3 700	1 200	500	1 100	-68.57	120.00
Kaolin	(t)	100 000	100 000	100 000	50 000	50 000	-50.00	0.00
Phosphates	(t)	1 346 880	606 650	813 960	711 780	895 020	-33.55	25.74
Salt	(t)	945 000	1 134 600	1 208 100	569 900	648 700	-31.35	13.83
Zircon	(t)	6 600	10 700	30 400	16 500	16 750	153.79	1.52
Steam Coal	(t)	47 158 000	44 598 400	48 315 600	49 688 100	47 258 700	0.21	-4.89
Nat. Gas (Mio m ³)		10 200	9 160	7 460	8 080	7 468	-26.78	-7.57
Petroleum	(t)	11 043 000	9 650 000	9 100 000	8 980 000	8 628 000	-21.87	-3.92
Total	(t)	76 693 305	69 781 766	72 129 043	72 128 495	68 695 981		

(World Mining Data 2025)

Rare Earth Elements in Vietnam

What are Rare Earth Elements?

- Rare Earth Elements (REEs) include the lanthanides (57-71) plus Scandium (Sc) (21) and Yttrium (Y) (21)
- Yttrium (Y) occurs together with the lanthanides, Sc mostly does not
- Sc is very important, due to its high value among the REEs.

1 H hydrogen 1.0080 ± 0.0002	2 He helium 4.0026 ± 0.0001																	18
3 Li lithium 6.94 ± 0.06	4 Be beryllium 9.0122 ± 0.0001																	10
11 Na sodium 22.990 ± 0.001	12 Mg magnesium 24.305 ± 0.002																	18
19 K potassium 39.098 ± 0.001	20 Ca calcium 40.078 ± 0.004	21 Sc scandium 44.956 ± 0.001	22 Ti titanium 47.867 ± 0.001	23 V vanadium 50.942 ± 0.001	24 Cr chromium 51.996 ± 0.001	25 Mn manganese 54.938 ± 0.001	26 Fe iron 55.845 ± 0.002	27 Co cobalt 58.933 ± 0.001	28 Ni nickel 58.693 ± 0.001	29 Cu copper 63.546 ± 0.003	30 Zn zinc 65.38 ± 0.02	31 Ga gallium 69.723 ± 0.001	32 Ge germanium 72.630 ± 0.008	33 As arsenic 74.922 ± 0.001	34 Se selenium 78.971 ± 0.008	35 Br bromine 79.904 ± 0.003	36 Kr krypton 83.798 ± 0.002	18
37 Rb rubidium 85.468 ± 0.001	38 Sr strontium 87.62 ± 0.01	39 Y yttrium 88.906 ± 0.001	40 Zr zirconium 91.224 ± 0.002	41 Nb niobium 92.906 ± 0.001	42 Mo molybdenum 95.95 ± 0.01	43 Tc technetium [97]	44 Ru ruthenium 101.07 ± 0.02	45 Rh rhodium 102.91 ± 0.01	46 Pd palladium 106.42 ± 0.01	47 Ag silver 107.87 ± 0.01	48 Cd cadmium 112.41 ± 0.01	49 In indium 114.82 ± 0.01	50 Sn tin 118.71 ± 0.01	51 Sb antimony 121.76 ± 0.01	52 Te tellurium 127.60 ± 0.03	53 I iodine 126.90 ± 0.01	54 Xe xenon 131.29 ± 0.01	18
55 Cs caesium 132.91 ± 0.01	56 Ba barium 137.33 ± 0.01	57-71 lanthanoids	72 Hf hafnium 178.49 ± 0.01	73 Ta tantalum 180.95 ± 0.01	74 W tungsten 183.84 ± 0.01	75 Re rhenium 186.21 ± 0.01	76 Os osmium 190.23 ± 0.03	77 Ir iridium 192.22 ± 0.01	78 Pt platinum 195.08 ± 0.02	79 Au gold 196.97 ± 0.01	80 Hg mercury 200.59 ± 0.01	81 Tl thallium 204.38 ± 0.01	82 Pb lead 207.2 ± 1.1	83 Bi bismuth 208.98 ± 0.01	84 Po polonium [209]	85 At astatine [210]	86 Rn radon [222]	18
87 Fr francium [223]	88 Ra radium [226]	89-103 actinoids	104 Rf rutherfordium [261]	105 Db dubnium [268]	106 Sg seaborgium [266]	107 Bh bohrium [270]	108 Hs hassium [269]	109 Mt meitnerium [277]	110 Ds darmstadtium [281]	111 Rg roentgenium [282]	112 Cn copernicium [285]	113 Nh nihonium [286]	114 Fl flerovium [290]	115 Mc moscovium [290]	116 Lv livermorium [293]	117 Ts tennessine [294]	118 Og oganeson [294]	18



INTERNATIONAL UNION OF
PURE AND APPLIED CHEMISTRY

57 La lanthanum 138.91 ± 0.01	58 Ce cerium 140.12 ± 0.01	59 Pr praseodymium 140.91 ± 0.01	60 Nd neodymium 144.24 ± 0.01	61 Pm promethium [145]	62 Sm samarium 150.36 ± 0.02	63 Eu europium 151.96 ± 0.01	64 Gd gadolinium 157.25 ± 0.03	65 Tb terbium 158.93 ± 0.01	66 Dy dysprosium 162.50 ± 0.01	67 Ho holmium 164.93 ± 0.01	68 Er erbium 167.26 ± 0.01	69 Tm thulium 168.93 ± 0.01	70 Yb ytterbium 173.05 ± 0.02	71 Lu lutetium 174.97 ± 0.01
89 Ac actinium [227]	90 Th thorium 232.04 ± 0.01	91 Pa protactinium 231.04 ± 0.01	92 U uranium 238.03 ± 0.01	93 Np neptunium [237]	94 Pu plutonium [244]	95 Am americium [243]	96 Cm curium [247]	97 Bk berkelium [247]	98 Cf californium [251]	99 Es einsteinium [252]	100 Fm fermium [257]	101 Md mendelevium [258]	102 No nobelium [259]	103 Lr lawrencium [262]

(International Union of Pure and Applied Chemistry (IUPAC), 2022)

Grouping of REEs

- Light Rare Earths (**LREEs**) - La, Ce, Pr, Nd, Sm, Eu
- Heavy Rare Earths (**HREEs**) – Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu
- Sc (21) and Y (39) are sometimes included as HREEs. But Y is commonly more abundant than the lanthanide HREEs combined

or

- Light Rare Earths (**LREEs**) - La, Ce, Pr, **Nd**
- Middle Rare Earths (**MREEs**) - Sm, **Eu**, Gd, **Tb**, **Dy**
- Heavy Rare Earths (**HREEs**) - Ho, **Er**, Tm, Yb, Lu

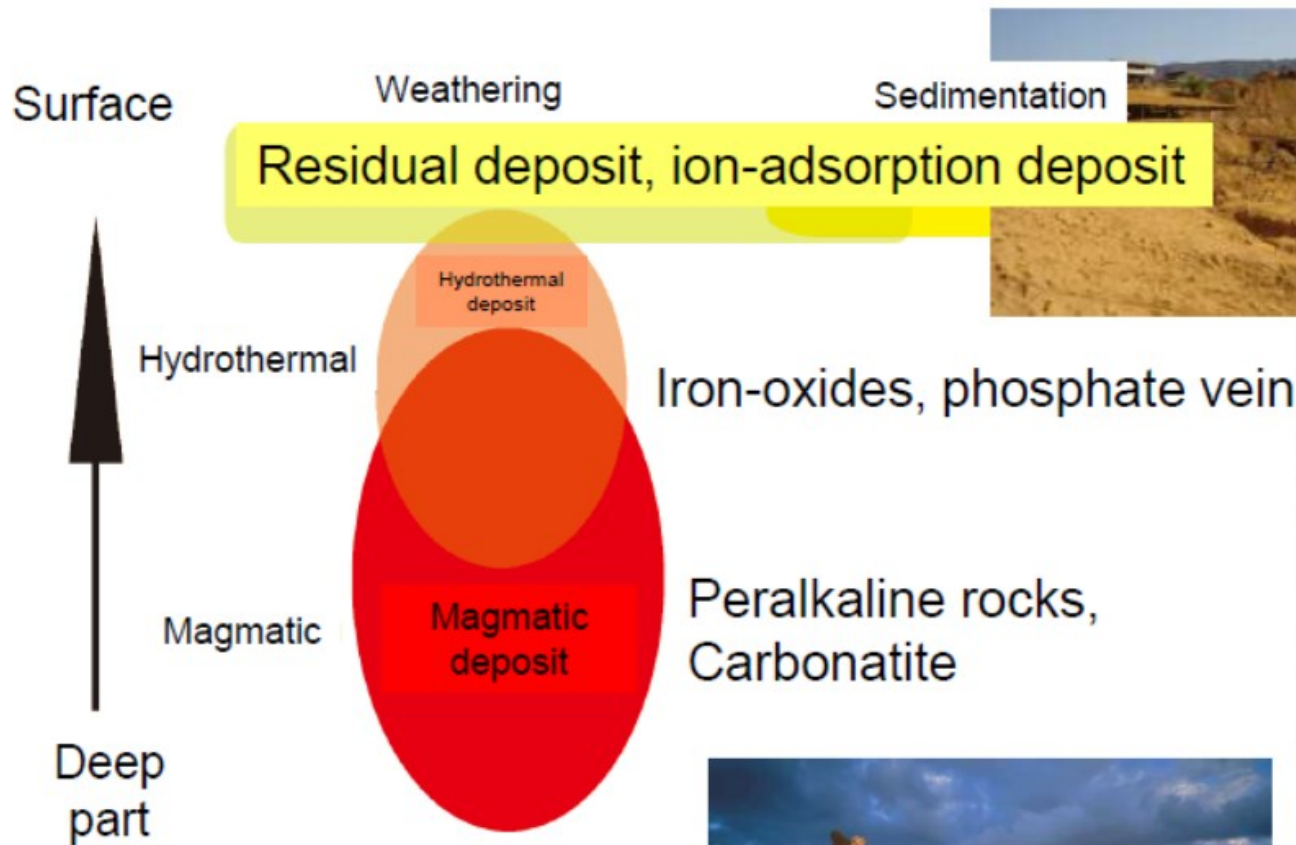
21 Sc scandium 44.956 ± 0.001
39 Y yttrium 88.906 ± 0.001

57 La lanthanum 138.91 ± 0.01	58 Ce cerium 140.12 ± 0.01	59 Pr praseodymium 140.91 ± 0.01	60 Nd neodymium 144.24 ± 0.01	61 Pm * promethium [145]	62 Sm samarium 150.36 ± 0.02	63 Eu europium 151.96 ± 0.01	64 Gd gadolinium 157.25 ± 0.03	65 Tb terbium 158.93 ± 0.01	66 Dy dysprosium 162.50 ± 0.01	67 Ho holmium 164.93 ± 0.01	68 Er erbium 167.26 ± 0.01	69 Tm thulium 168.93 ± 0.01	70 Yb ytterbium 173.05 ± 0.02	71 Lu lutetium 174.97 ± 0.01
LREEs					HREEs									
LREEs				MREEs						HREEs				

*Note, Pm is unstable.

(International Union of Pure and Applied Chemistry (IUPAC), 2022)

REE Deposits

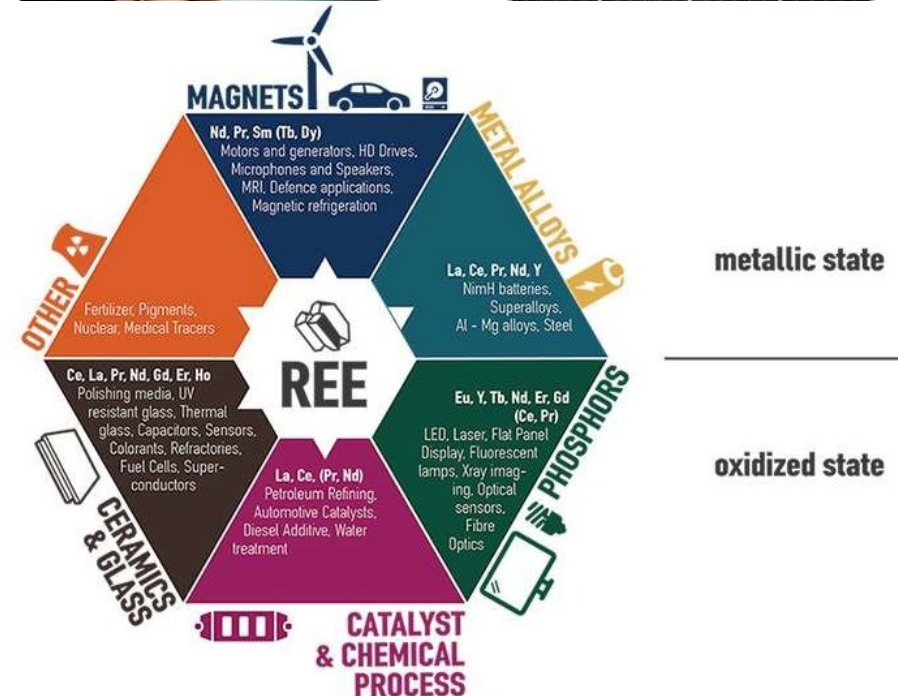


1. Carbonatite Deposits
2. Ion-Adsorption Clay Deposits
3. Pegmatite Deposits
4. Sedimentary Deposits
5. Coal Ash and Byproducts
6. Lateritic (Weathered) Deposits
7. Volcanic and Hydrothermal Deposits

(Wantanabe, 2024)

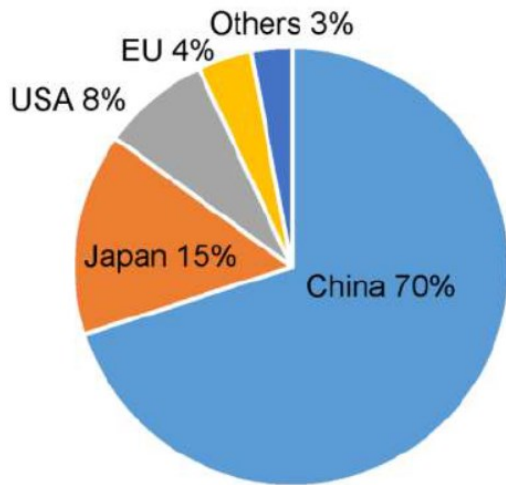
Applications of REEs

- 1. Consumer electronics:** high-performance components for devices: smartphones, laptops, and flat-screen TVs.
- 2. Electric vehicles (EVs):** The production of EVs and their batteries heavily depends on REEs, especially for permanent magnets used in the motors.
- 3. Renewable energy:** Wind turbines use magnets made from neodymium, dysprosium, and other REEs. Solar energy technologies also require certain REEs.
- 4. Military:** high-performance defense technologies like radar systems, missile guidance systems, and jet engines.
- 5. Medical:** imaging technologies and in cancer treatment research
- 7. Other modern applications**



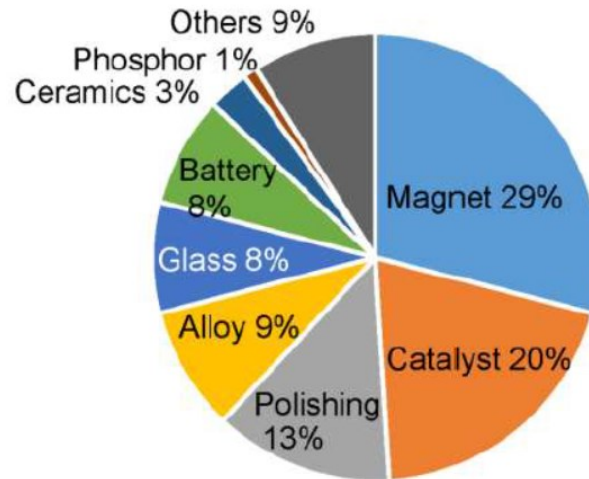
REEs demand & sources

- China dominates current world REE production.
- New sources of REE production are needed for current and projected uses.

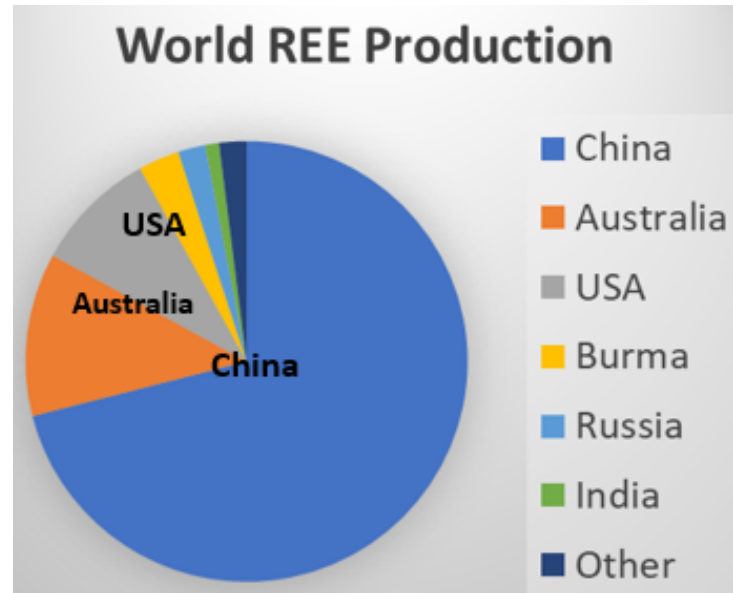


REE demand by country
(2020)

(Industrial Rare Metals 137, (2021))



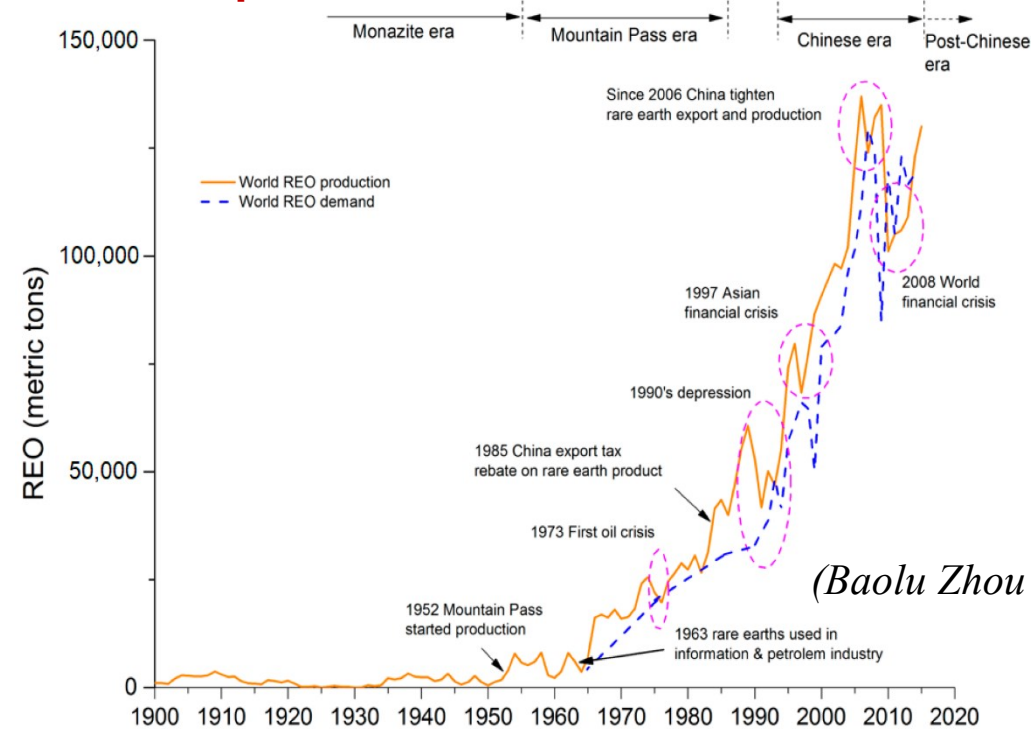
REE demand by application
(2020)



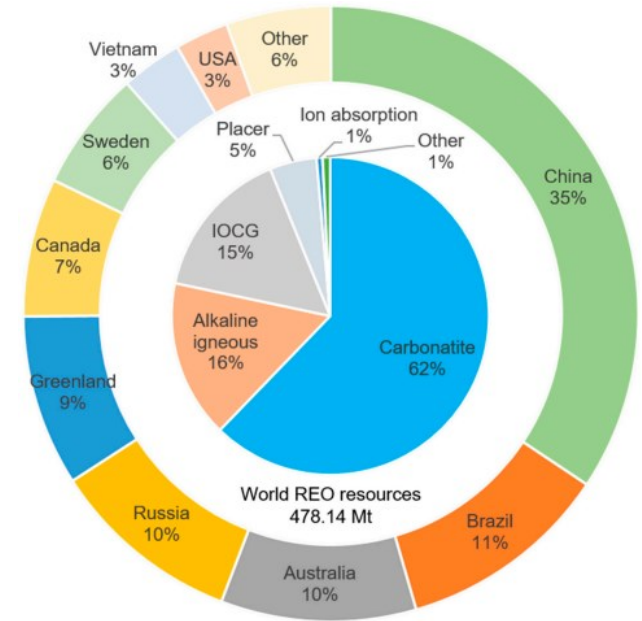
(U.S. Geological Survey, 2019)

REEs production

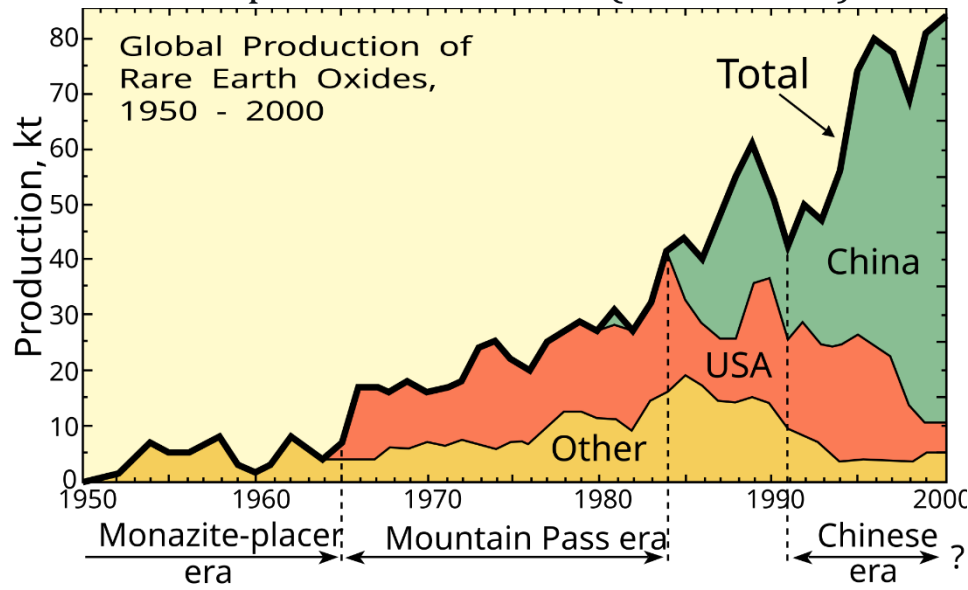
The distribution of global REEs by principle deposit type and country



(Baolu Zhou et al. 2017)

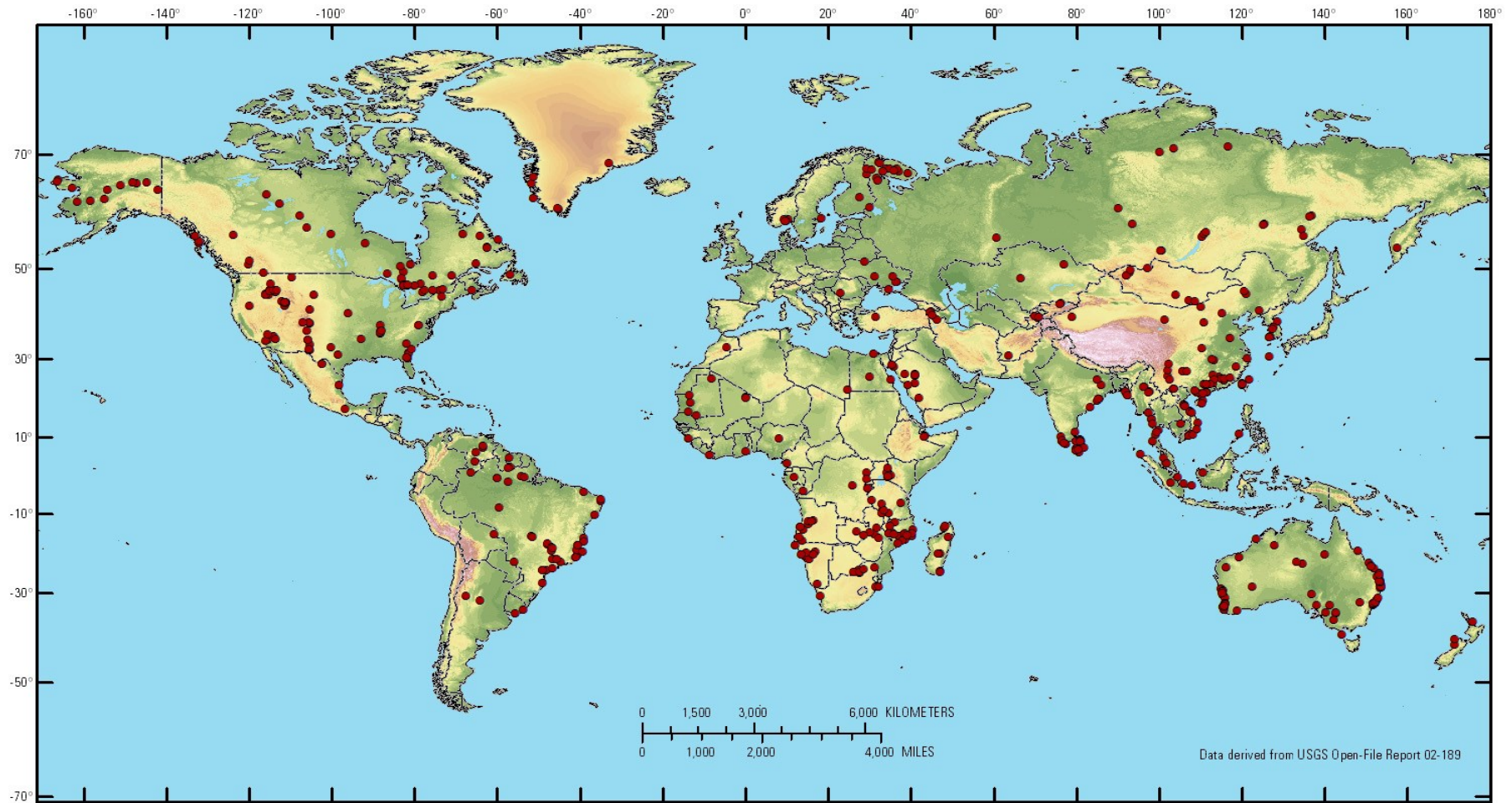


Global production of REEs (1950 -2000)

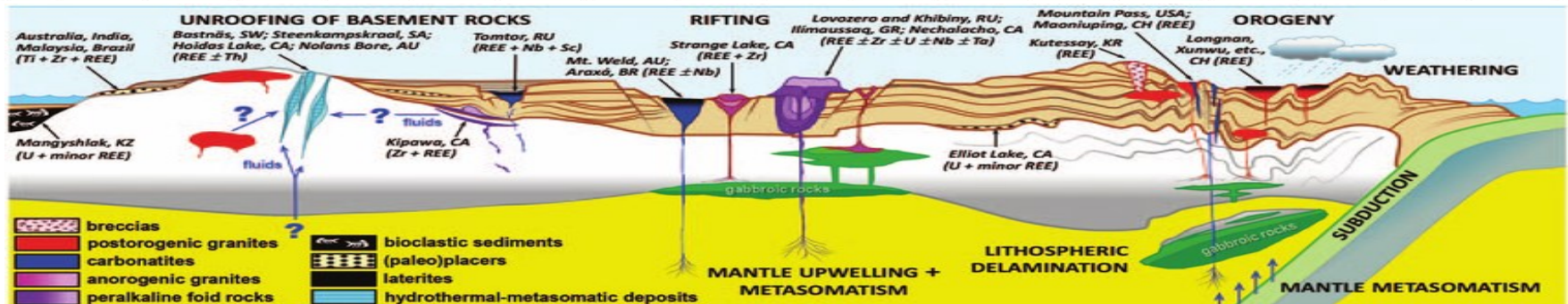


(www.en.wikipedia.org)

REE deposits and occurrences around the world



Data derived from USGS Open-File Report 02-189



Production and reserves of REEs in the World

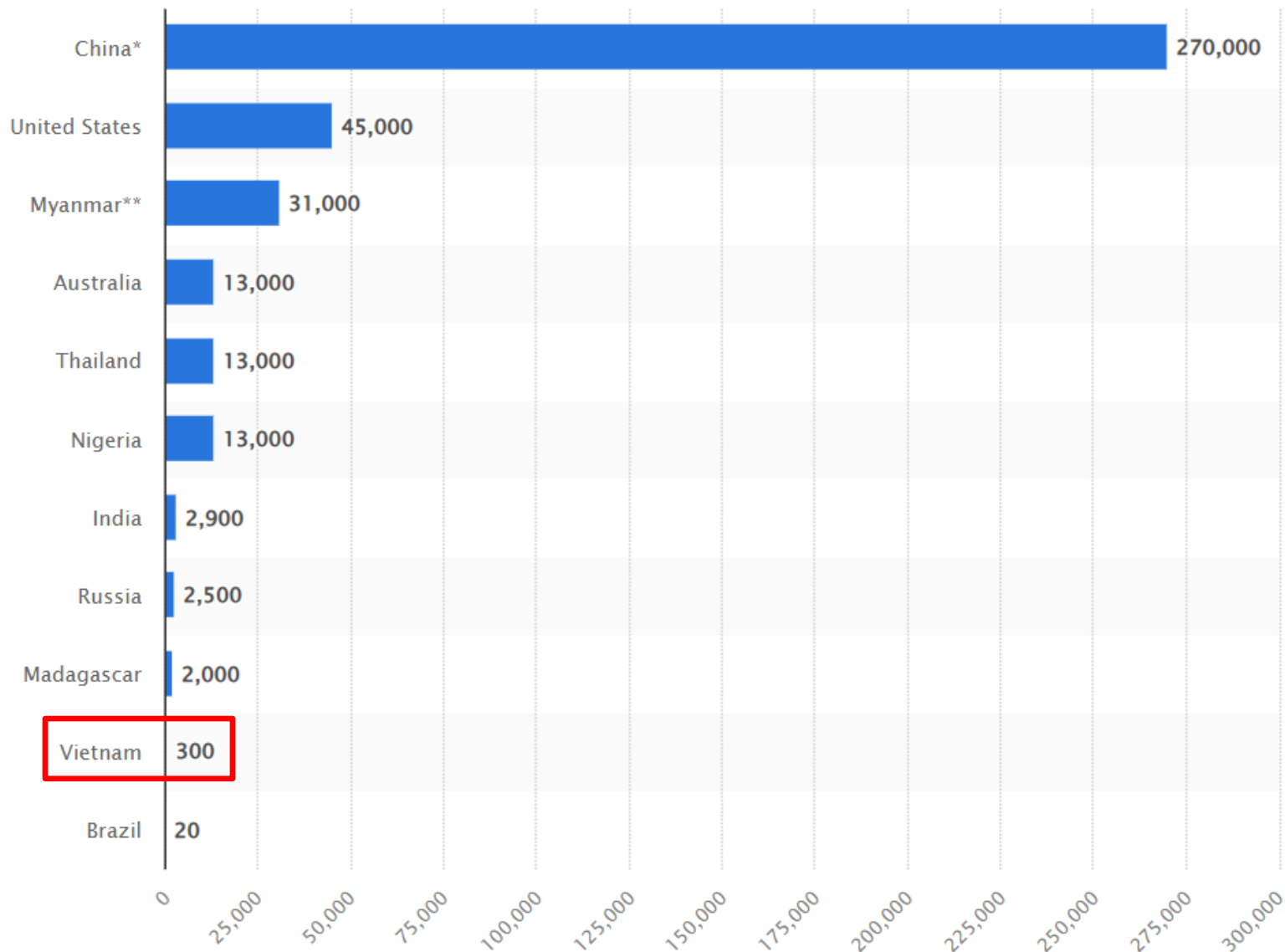
World Mine Production and Reserves: Reserves for Russia, South Africa, the United States, and Vietnam were revised based on company and Government reports.

	Mine production ^o		2024 Reserves ¹¹	2023 Reserves ⁹
	2023	2024		
United States	41,600	45,000	1,900,000 ↘	2,300,000
Australia	¹² 16,000	¹² 13,000	¹³ 5,700,000 ↘	¹⁰ 4,200,000
Brazil	140	20	21,000,000	21,000,000
Burma	¹² 43,000	¹² 31,000	NA	NA
Canada	—	—	830,000	830,000
China	¹⁴ 255,000	¹⁴ 270,000	44,000,000	44,000,000
Greenland	—	—	1,500,000	1,500,000
India	2,900	2,900	6,900,000	6,900,000
Madagascar	¹² 2,100	¹² 2,000	NA	NA
Malaysia	¹² 310	¹² 130	NA	
Nigeria	¹² 7,200	¹² 13,000	NA	
Russia	2,500	2,500	3,800,000 ↘	21,000,000
South Africa	—	—	860,000 ↘	790,000
Tanzania	—	—	890,000	890,000
Thailand	¹² 3,600	¹² 13,000	4,500 ↘	NA
Vietnam	¹² 300	¹² 300	3,500,000 ↘	22,000,000
Other	1,440	1,100	NA	280,000
World total (rounded)	376,000	390,000	>90,000,000	130,000,000

(USGS, 2025)

Country leading in mine production of REEs worldwide in 2024

(in metric tons REO)



Production in metric tons of rare earth oxide

(www.statista.com)

REEs Resources in Vietnam

- Research and exploration since 1950s
- Vietnam is believed to be a country with great potential for REEs
- Hydrothermal origin, and concentrated in the Northwest region of Vietnam.
- As of origin, there are 3 types:
 - Hydrothermal deposits:
 - Ion absorption deposits
 - Placement deposits: mainland and coastal placers
- As of elemental composition, there are 2 groups:
 - Light rare earth group (LREEs)
 - Rare earth heavy group (HREEs)

1) Hydrothermal deposits

- The Northwest area: Nam Xe North, Nam Xe South, Dong Pao (Lai Chau province), Muong Hum (Lao Cai province), Yen Phu (Yen Bai province) and a series of other REE mineralization places in the region.
- Ore bodies: veins, lenticulars, pockets, cutting through into different rocks such as limestone, basic eruption, syenite, shale.
- REE-oxide: 1% - > 36%.

2) Ion absorption deposits

- In Ben Den, Bao Thang district, Lao Cai province.
- REE ores in the weathered crust of alkaline granite
- REE-oxide $0.0443 \div 0.3233\%$, average of 0.1%.
- Low content, but mining conditions are favorable, ore processing technology is simple

3) Placement deposits

- Mainland placer

- + The North of Bu Khang area (Pom Lau, Chau Binh and Ban Gio), Nghe An province.
- + REE minerals: monazite, xenotime along with ilmenite and zircon.
- + Ore located in the riverbed sediments of the I and II levels.
- + Bu Khang granite block is the main supply sources of RE mineral, with monazite of $0.15 \div 4.8\text{kg/m}^3$

- Coastal placer

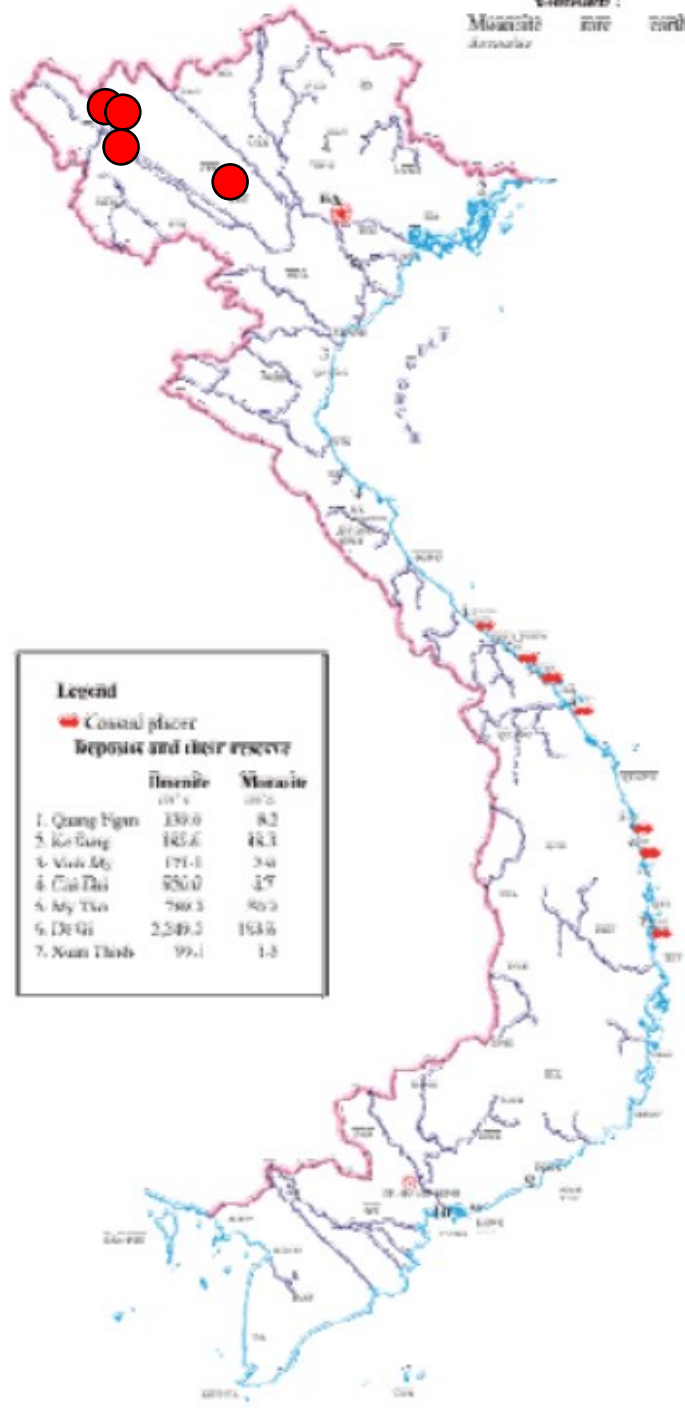
- + At Ky Khang and Ky Ninh, Cam Hoa, Cam Nhung (Ha Tinh province), Ke Sung (Thua Thien Hue province), Cat Khanh (Binh Dinh province), Ham Tan (Binh Thuan province).
- + Many places of ilmenite placer ores containing REE minerals (monazite, xenotime) with contents of $0.45 \div 4.8\text{kg/m}^3$

LREEs

- Nam Xe South, Nam Xe North, Dong Pao mines and placer deposits.
- Mainly bastnaesite (Nam Xe, Dong Pao, Muong Hum) and monazite (Bu Khang Northern, coastal placer).

HREEs

- Yen Phu deposit (Yen Bai province)
HREE-oxide/Total REE-oxide: ~ 30%.
- Muong Hum (Lao Cai province)
HREE-oxide/Total REE-oxide: ~ 22%.



Major REEs deposits in Vietnam

HOANG SA ISLANDS

EAST SEA

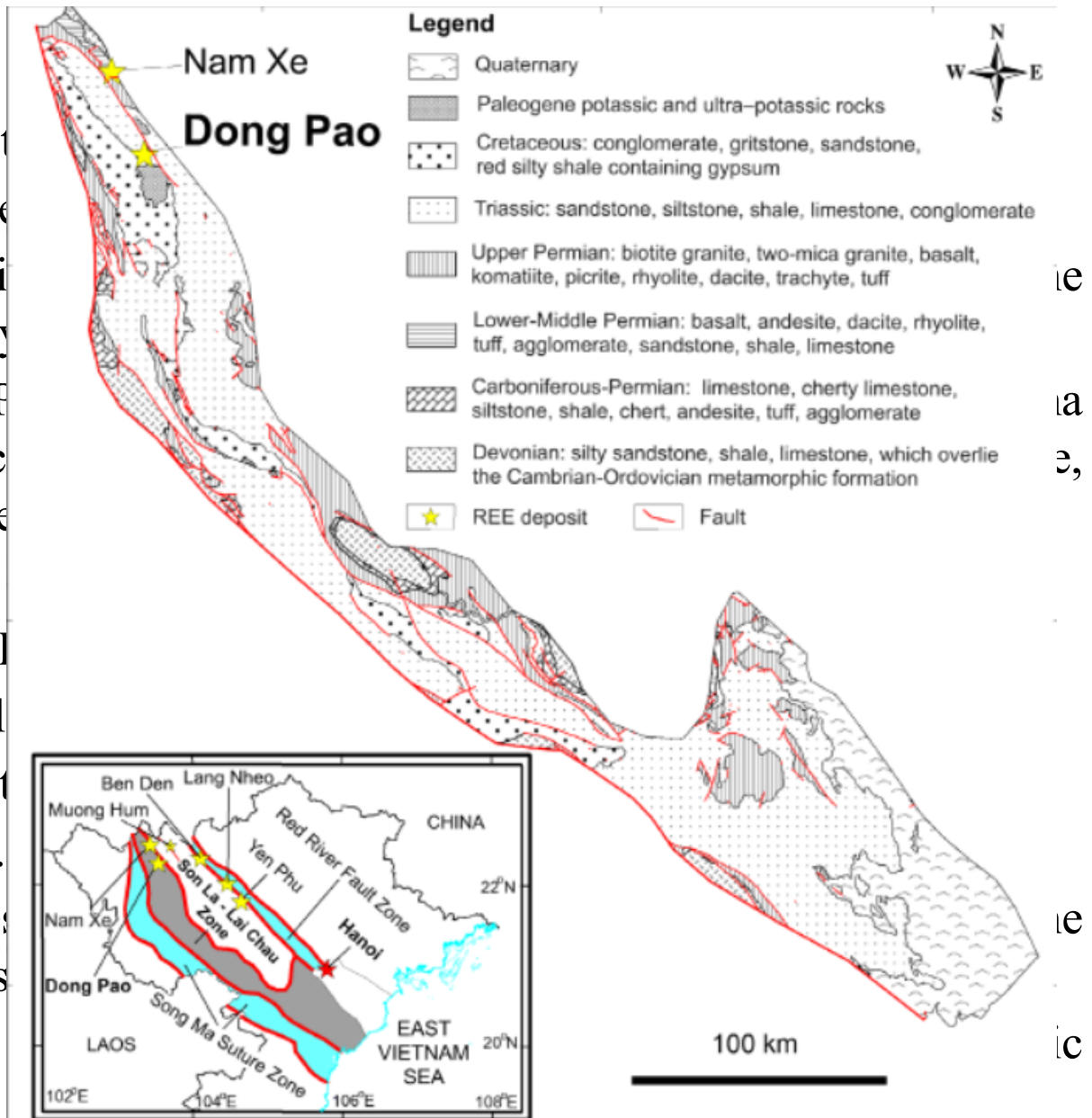
TRUONG SA ISLANDS

(Hop & Huan 2016; Tran Kim Phuong, 2014)

Main REE mines in Vietnam

Dong Pao mine

- In the northwest of Vietnam
- Conducted in 1986 (Vietnam)
- Area of $\sim 12 \text{ km}^2$ within the margins of Dong Pao syncline
- REE-bearing rocks: Felsic gneiss, which varies mainly from acidic to alkaline granite, syenite
- Carbonatite type
- REE minerals; mainly monazite
- A type of "multi-metallic" deposit
- Many minerals associated with REE
- REE-oxide (TR_2O_3): 0.1%
- Reserves and resources: 1.5% of country's total reserves
- Methods for extraction: separation - flotation



Geological map of Song Da structure and locations of Dong Pao and Nam Xe mines (Tinh et al. 2025)

Main REE mines in Vietnam

Nam Xe North mine

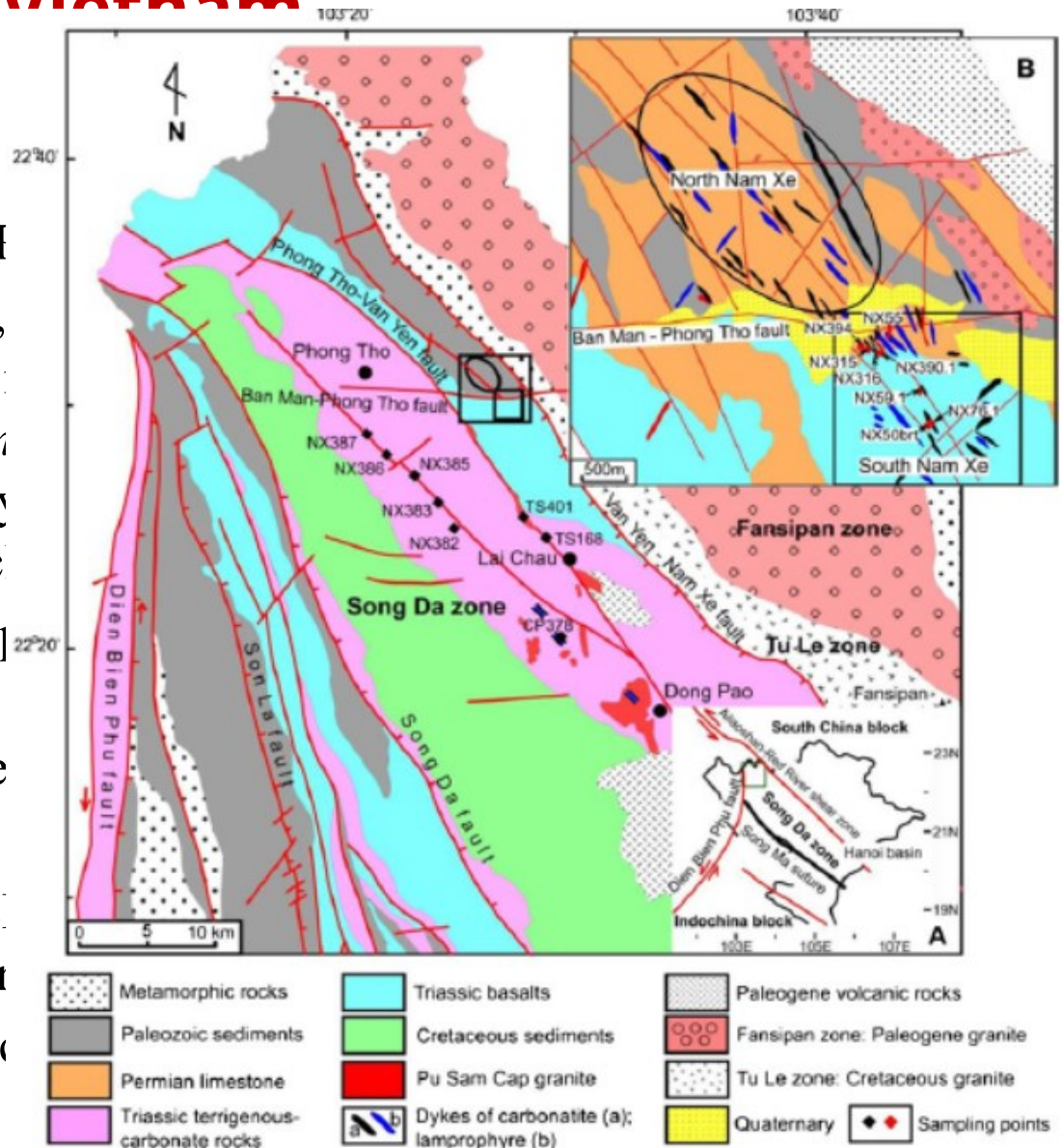
- In the northwest of Vietnam (Phong Tho district, Lai Chau province)
- REEs accumulates in marble sets interlaced with shale rocks and late Paleozoic mafic eruptions.
- The ore is related to alkaline syenite, granosyenite and alkaline granite of the Pusamcap - Putra Complex- Carbonatite type
- REES formed in 2 ways: hydrothermal filling and exchange metamorphism; in forms: veins, lenses, pockets, and dispersion
- Ore formed by filling and injecting into the fracture systems, and metamorphosing the surrounding rocks to create the ore zones.
- Strongly weathered at the upper part of the deposit. The weathering process has relatively enriched the content of useful components, especially the content of TR_2O_3 , Nb_2O_5 , creating a remnant weathering deposit
- REE-oxide (TR_2O_3): weathered: $2.0 \div 16.8\%$; primary $0.6 \div 31.35\%$
- Reserves and resources of REE of $\sim 7,7\text{m}$ tones, accounted for 45% of the country's total reserves/resources
- Methods for extraction and recovery: mainly flotation



Main REE mines in Vietnam

Nam Xe South mine

- In the northwest of Vietnam (I
- Unlike Nam Xe North deposit, formation surrounding the ore
- Vien Nam Formation (P_2 - T_1) with colored rocks such as dark gray of the Vien Nam formation inc
- 4 main ore bodies that extend with a length of 100s m
- Minerals: bastnaesite, parasite
- REE-oxide (TR_2O_3): 0.5÷36
- Reserves and resources of RE country's total reserves/resour
- Methods for extraction and re

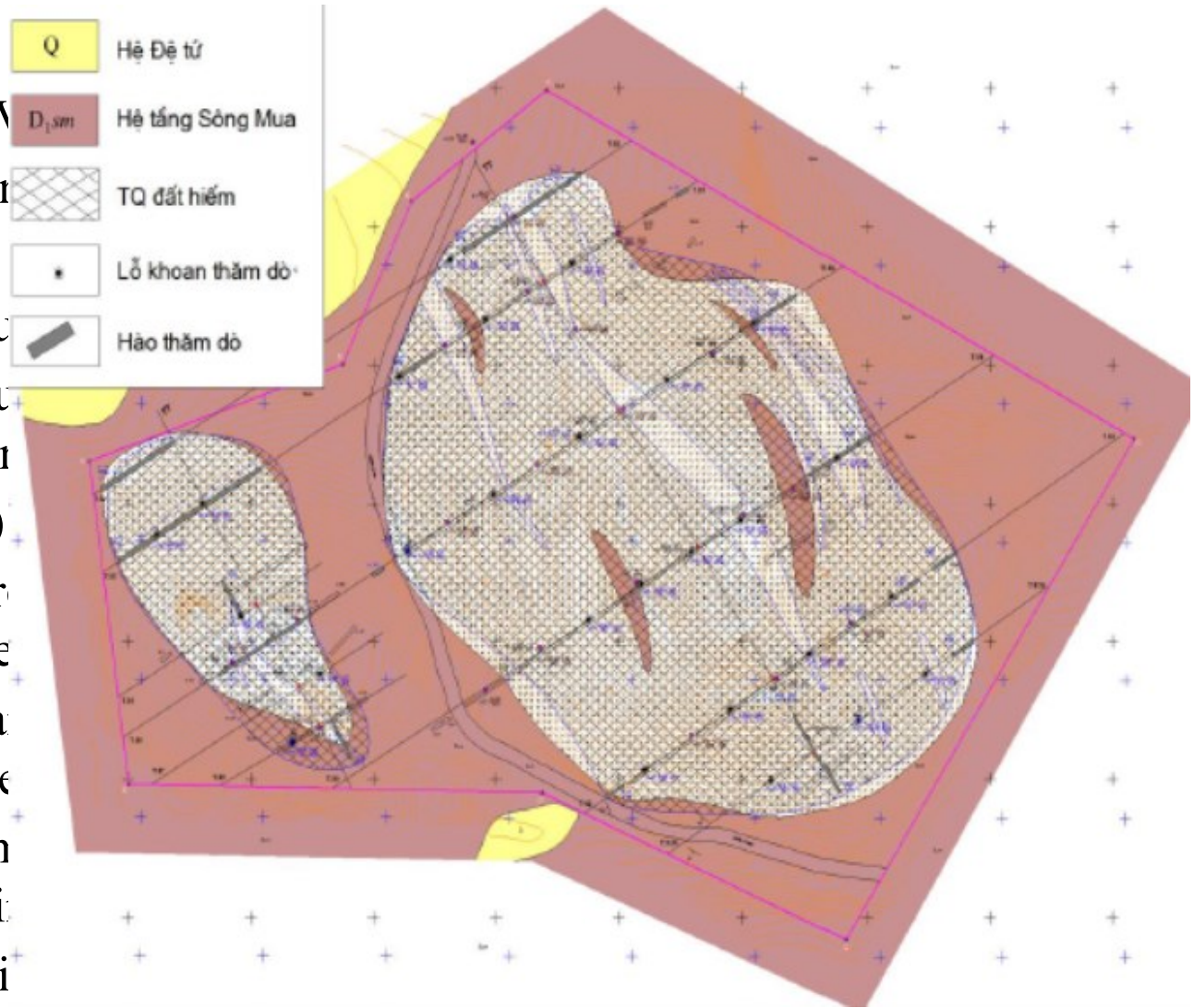


A Sketch map showing location of the Song Da zone in northwest Vietnam (A); Geological map of Nam Xe area, northwest (B) (Thuy Nguyen Thi et al. 2013)

Main REE mines in Vietnam

Yen Phu mine

- In the northwest of Vietnam
- Discovered in the first half of the 20th century
- Presence of HREEs
- A small area of about 10 km²
- Deposits are distributed in the area of intrusive magmatic rocks
- REE-oxide (TR_2O_3)
- Reserves and resources account for 10% of the country's total reserves
- The Yen Phu rare earth elements are concentrated in the area of intrusive magmatic rocks
- Yen Phu rare earth mining and processing
- Methods for extraction and separation - flotation



A Sketch geological map of Yen Phu mine with exploration network
(Luong Quang Khang, 2012)

Main REE mines in Vietnam

Muong Hum mine

- In the northwest of Vietnam (Bat Xat district, Lao Cai province)
- Accumulate in Neogene sedimentary formations. The ore is distributed in 2 lines extending along the valley from Muong Hum to Nam Pung.
- Mainland placer deposit (eluvial- deluvial placer)
- Minearls: monazite, bastnaesite, rhabdophane, coccilit, okenite, thorium silicate
- There are 9 main ore bodies
- Presence of HREEs.
- REE-oxide (TR_2O_3): as small as 1.0 – 3.18%
- Reserves and resources of REE of ~ 129,207 tones, accounted for only 0.8% of the country's total reserves/resources



Main REE mines in Vietnam

Coastal placers

- REEs in coastal placer: mainly in minerals (monazite, xenotime, silicate (orthite)).
- Monazite and xenotime accumulated and located together with ilmenite, zircon, rutile, and other heavy minerals in different proportions, forming large, small deposits or ore occurrences (calculated in ilmenite). These ore occurrences and mines are in the coastal sand including modern beaches and coastal sand dunes.
- The reserves of monazite - xenotime in some mines: $\sim 303,000$ tons
- During the production of ilmenite, zircon from coastal placers, monazite - xenotime was recovered, with a content of 60 - 65 % TR_2O_3 . C
- No complete assessment of the REE placer potential in coastal Vietnam
- Yearly, only exploited a few thousand tons of monazite ore with content of 35-45% TR_2O_3 in the central coastal placer
- Note: Vietnam has **3,260km of coastline**, along which the main sand deposits containing ilmenite, rutile, zircon and monazite



Potential REEs in Vietnam

Mine / Occurrence	Location	Main mineral	TREO content (%)	Reserves (tons TREO)	Area (km ²)	Number / characteristics of ore bodies	Remarks
Bac Nam Xe	Lai Chau	Bastnaesite, Parisite (Light REEs)	0.6 – 31.35	7,707,461	12.0	8 main ore bodies	Associated U, Th, Nb
Nam Nam Xe	Lai Chau	Parisite, Bastnaesite (Light REEs)	0.5 – 36.0	4,090,059	8.0	5 main ore bodies	Contains ThO ₂ (0.026–2.3%); U (0.008–0.24%)
Dong Pao	Lai Chau	Bastnaesite, Synchysite, Barite, Fluorite	0.5 – 39.0	4,381,873	60.0	16 large ore bodies	One of the largest REE deposits in Southeast Asia
Muong Hum	Lao Cai	Monazite, Bastnaesite, Samarskite	1.0 – 3.18 (avg. 1.45)	129,207	3.0	3 ore bodies	High heavy REE content: 25.6–36.4%
Yen Phu	Yen Bai	Fergusonite, Xenotime, Monazite, Allanite	0.1 – 7.0 (avg. 1.12)	31,695	1.5	2 ore bodies	Light REEs: 62.97%; Heavy REEs: 29.16%
Coastal placer Deposits (14 monazite deposits)	Various coastal provinces	Monazite, Xenotime, Titan, Zircon, Rutile	–	308,195	200+ total	Distributed as coastal belts	Predicted potential ~2 million tons of placer resources
Ion-adsorption Clay Type (Ben Den)	Quang Nam, Quang Ngai, etc.	Ion-adsorption clays	0.1 – 0.111	31,695	7.9	Scattered distribution	Large potential

(Ministry of Education and Training of Vietnam, unpublished 2025)

REE Resources in Vietnam

#	Deposit	Ore-bearing rock	Ore mineral composition	Content	Reserves/Resources (tones)	%
1	Dong Pao	Syenite of the Pusamcap Complex	Bastnaesite, parisite, lanthanide, orthite	<u>0.5÷39%</u> TR ₂ O ₃	4,381,873	25.88%
2	Nam Xe North	Limestone of the Na Vang Formation	Bastnaesite, parisite, cordilyle, fluocerite, synchysite, lanthanide, mariniakit, orthite, monazite, xenotime, uranokiecxit,	Weathered ores: 2.0÷16.8% TR ₂ O ₃ Primary ore: 0.6÷31.35% TR ₂ O ₃	7,707,461	45.0%
3	Nam Xe Sourh	Eruption rock of the Vien Nam Formation	Parasite, phlogopite, bastnaesite, lanthanide	<u>0.5÷36%</u> TR ₂ O ₃	4,090,059	23.88%
4	Yen Phu	Shale of the Song Mua Formation	Fergusonite, xenotime, monazite, samarskite, orthite, cheralite, churchite, rhabdophane, torbernite	<u>0.1÷7%</u> TR ₂ O ₃	31,695	0.19%
5	Muong Hum	Neogene sediments	Monazite, bastnaesite, samarskite, rhabdophane, cordilyle, thorite, zircon	1.0÷3.18% TR ₂ O ₃	129,207	0.75%
6	Nam Pung	Biotite-sericite-quartz schists of the SaPa formation	Monazite, bastnaesite, rhabdophane, cordilyle, zircon, psilomelane, apatite	<u>0.1÷9%</u> TR ₂ O ₃	30,000	0.18%
7	REE ores are into copper veins	Metamorphic sedimentary rocks of the Lung Po and Sinh Quyen formations	Magnetite, chalcopyrite, pyrite, pyrrhotine, bornite, garnet, hedenbergite, orthite		453,000	2.64%
8	Other monazite mines combined	Quaternary sediments	Monazite, xenotime, orthite	0.15 -4.8 kg/m ³ Monazite	303,446	1.77%
Total					17,126,741	

(Dung et al. 2021)

REE Exploration in Vietnam



REE Resources in Vietnam

- The reserves and resources of REE ores in primary and weathered deposits in Vietnam > 17 million tons of TREO, mainly in Lai Chau province.
- Primary and weathered REE deposits in Vietnam: large scale, the largest one is Bac Nam Xe.
- The reserves and resources of monazite: ~ 7,000 tons. The volume of resources is not large, but the distribution is concentrated in the placers, the exploitation conditions are simple.
- Other potential sources: **Coal ash and byproducts** (VN has potential of coal resources)

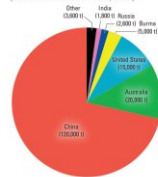


Rare Earth Elements in Coal and Coal Fly Ash

Introduction

The rare earth elements (REEs) are a group of 17 elements sharing similar chemical properties. They include yttrium (Y, atomic number 39), scandium (Sc, atomic number 21), and the 15 elements of the lanthanide series, atomic numbers 57 (lanthanum, La) to 71 (lutetium, Lu). Because promethium (Pm, atomic number 61) does not occur in the Earth's crust and scandium typically has different geological occurrences from other REEs, they are not discussed further herein.

REEs are, on average, more abundant than precious metals (for example, gold, silver, and platinum), but because of their unique geochemical properties, they do not commonly form economically viable ore deposits (Van Gosen and others, 2014). Nevertheless, REEs are increasingly required for a range of modern applications in defense and renewable energy technologies and in commercial products, primarily as magnets, batteries, and catalysts. The United States currently (2018) produces REEs from a single mine in California, accounting for just 9 percent of global production, whereas 70 percent of global REE production comes from China (Gambogi, 2019; fig. 1). For these reasons, REEs are considered a critical resource, and the U.S. Geological Survey (USGS) has an interest in helping to identify new sources of REEs for domestic production (Hansenstrom and Dicken, 2019).



In 2017, coal use accounted for about 30 percent of the electric power generated in the United States (U.S. Energy Information Administration, 2018). Fly ash, produced during the burning of coal, is a fine-grained solid derived from noncombustible constituents of coal, such as clay minerals and quartz. When coal is burned, REEs are retained and enriched in the fly ash and, as a result, fly ash has long been considered a potential resource for REEs (Goldschmidt, 1935; Seredini and Dai, 2012).

The United States has the world's largest coal reserves and, even though gas-fired power generation has increased significantly in the last decade, the United States continues to produce vast quantities of fly ash, about half of which is beneficially reused, primarily in construction materials (American Coal Ash Association, 2017). The remainder is stored, mostly in landfills and impoundments. Thus, annual fly ash production, combined with fly ash already in storage, constitutes a large potential resource (Hower and others, 2017).

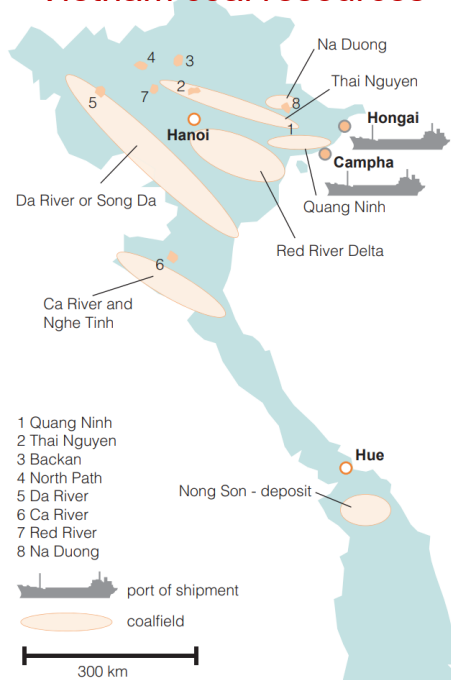
Research into how to utilize coal and coal fly ash as sources of REEs is ongoing (National Energy Technology Laboratory, 2018). Viable recovery of REEs from coal and coal ash requires identification of coals and ashes with the highest REE concentrations and development of workable methods for REE extraction and recovery. Understanding how REEs occur within fly ash, described in this fact sheet, is one of the keys to developing possible methods for their recovery.

U.S. Geological Survey Research on Rare Earth Elements in Fly Ash

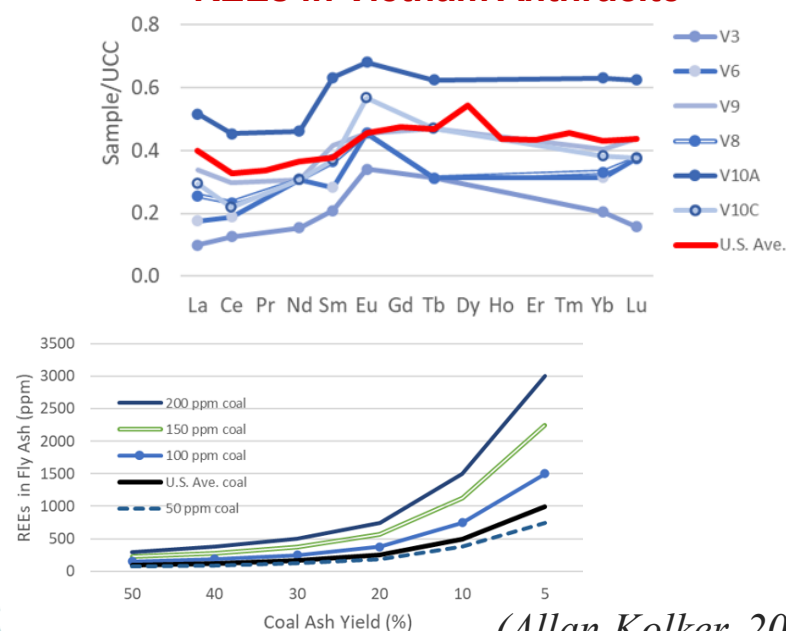
To better understand how REEs are distributed in coal ash, we investigated the distribution of REEs on a fine scale in 19 coal fly ash samples (table 1) having a range of REE contents determined by various workers and compiled by Kolker and others (2017, table 1). The samples include fly ash from U.S. power stations burning bituminous coal from the central Appalachian basin of the eastern United States and from the Illinois basin and sub-bituminous coal from the Powder River basin in the northern Rocky Mountain region. In addition, we studied four U.S. fly ash samples having mixed or unspecified sources and three samples of fly ash obtained from a Chinese powerplant burning bituminous coal. Fly ash samples from the central Appalachian basin include four samples of ash from the Fire Clay coal of Kentucky, which is known for its REE enrichment (table 1).

Fly ash consists of glasses formed by melting at the high temperatures present in powerplant boilers, together with minerals remaining from coal, such as quartz, and new minerals not present in coal. Before our study, it was poorly understood how REEs are distributed in fly ash. In one hypothesis, suggested by Hower and others (2013) and Taggart and others (2016), REEs from coal enter fly ash glasses. These glasses consist mostly of silicon (Si) and aluminum (Al) and so are called aluminosilicate glasses. To test the hypothesis that REEs enter fly ash glasses, we first identified the various glasses and minerals present in fly ash by using a scanning electron microscope and an electron microprobe, and we produced magnified images and maps of major chemical constituents present (fig. 2). Using this approach, we chose areas of interest for later REE analysis and identified four common glass or mineral constituents in the ash samples: (1) Al-Si aluminosilicate glasses; (2) aluminosilicate glasses that are also enriched in calcium (Ca), iron (Fe), or both Ca and Fe; (3) iron oxide minerals; and (4) quartz (SiO₂).

Vietnam coal resources



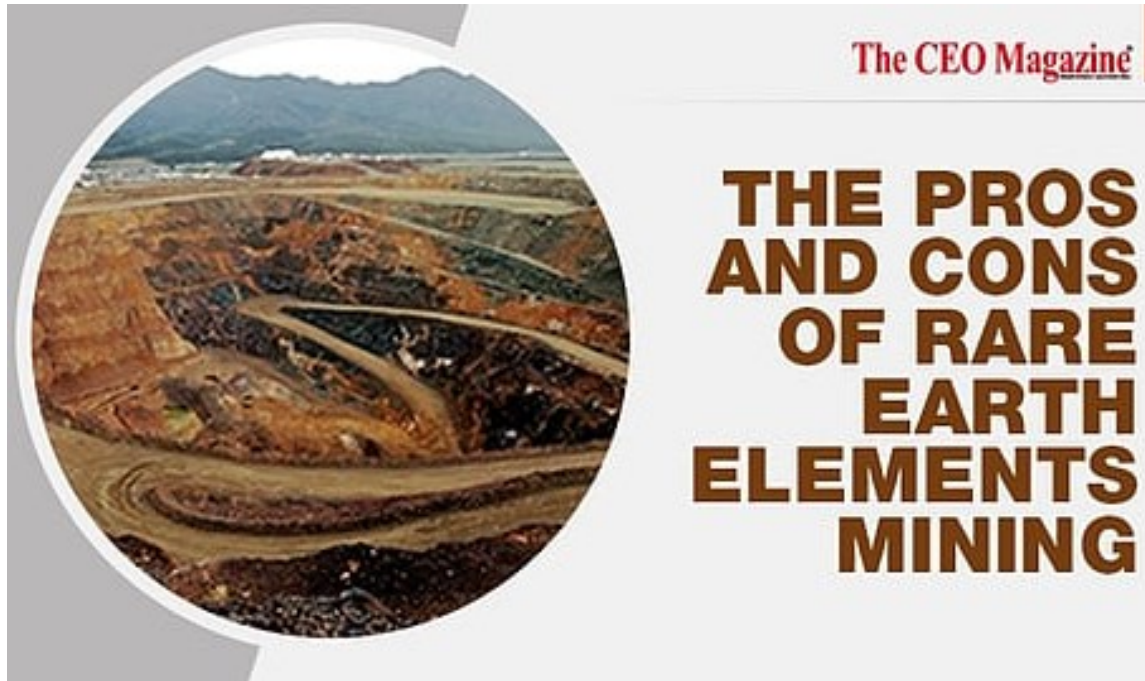
REEs in Vietnam Anthracite



Strategic (REEs) Mineral Resources in Vietnam

Pros

- High potential of REE resources
- Strong global and domestic demand
- Considered a strategic priority



Cons

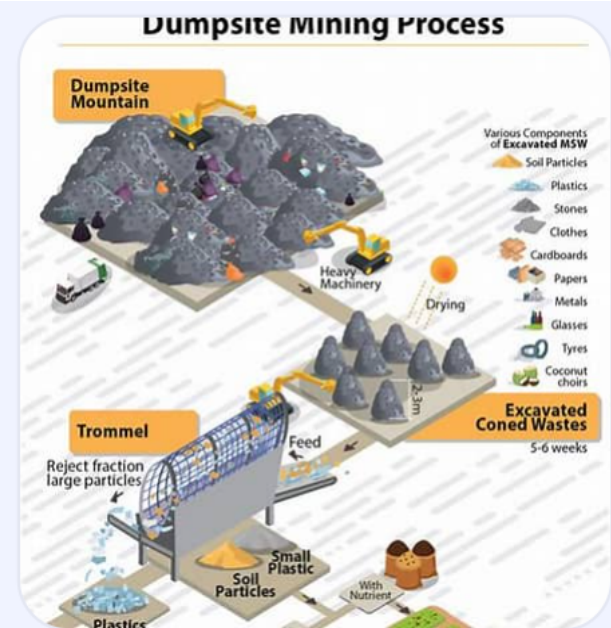
- Outdated policies, technology, and human resources
- Insufficient investment
- Environmental concerns

Development of a Strategic Mineral (REE) Industry in Vietnam

The **rare-earth industry** can be divided into three stages:

1. **Upstream:** Mining of rare-earth elements.
2. **Midstream:** Processing of elements into separate oxides.
3. **Downstream:** Manufacturing of permanent magnets and other components made with rare earths.

End uses of rare earths include production of magnets, batteries, catalysts, displays, and more.



Conclusions so far...

- Strategic and critical minerals are in irreversible and rapidly growing demand worldwide, especially for green technologies driving the clean energy transition.
- Amid rising demand and tightening supply, investment in research, resource assessment, and recovery of critical minerals—particularly rare earth elements (REEs)—is crucial for industrial development, resource security, and national stability.
- Vietnam holds abundant strategic mineral resources, yet their potential remains largely underexplored and undervalued. The country has **not** established a clear **list of strategic minerals** to guide sustainable investment, exploitation, and management. Small-scale REEs mining has led to resource inefficiency and environmental harm.
- Building a strong strategic and REEs mineral industry requires coherent strategies, consistent policies, and dedicated investment in advanced research, specialized training, and international collaboration to drive technological innovation.

Thank You

