



Critical & Strategic Mineral Supply Chains

3rd Workshop on Isotope Federal Supply and Demand

**Dr. Steven M. Fortier, Director
National Minerals Information Center
United States Geological Survey**

**Rockville, Maryland
November 2014**

National Minerals Information Center

■ Mission

- To collect, analyze, and disseminate information on the domestic and international supply of and demand for minerals and materials essential to the U.S. economy and national security.

■ Goal

- Provide decision makers with the information required to ensure that the U.S. has an adequate supply of minerals and materials to meet it's needs, at an acceptable cost with regard to environmental, energy, and economic factors.



Mineral Commodities Coverage: Broad Scope

hydrogen 1 H 1.00794																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]			ununquadium 114 Uuq [289]			

* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
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** Actinide series

actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]
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Global Coverage: >100 Countries



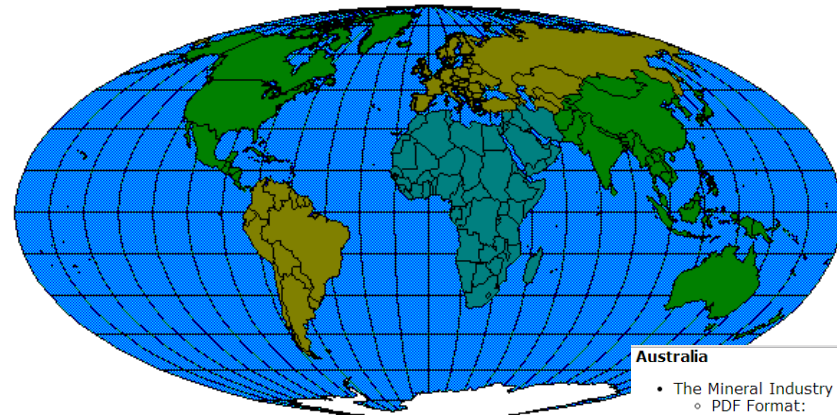
USGS
science for a changing world

Minerals Information

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International Minerals Statistics and Information

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- [Maps](#)
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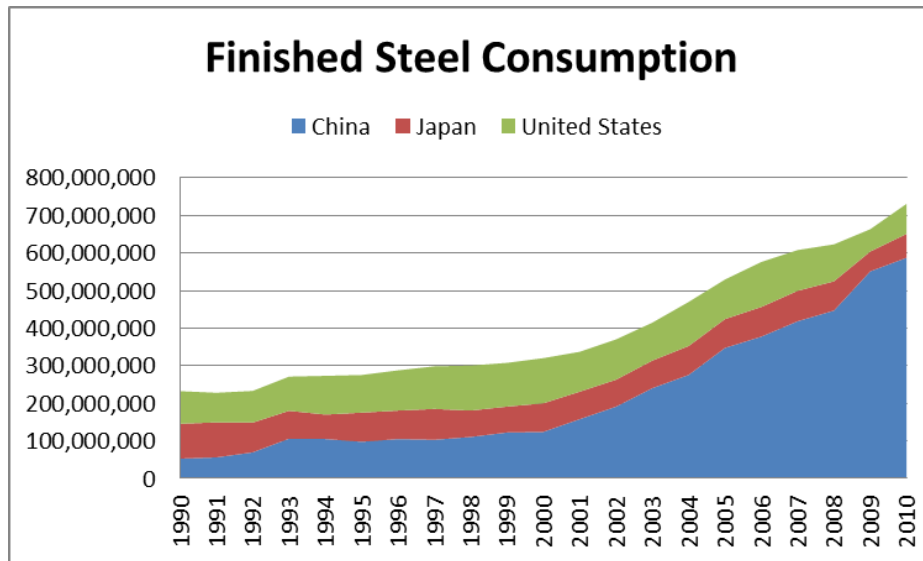
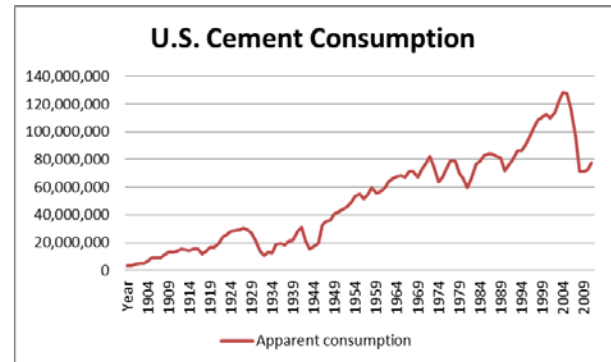
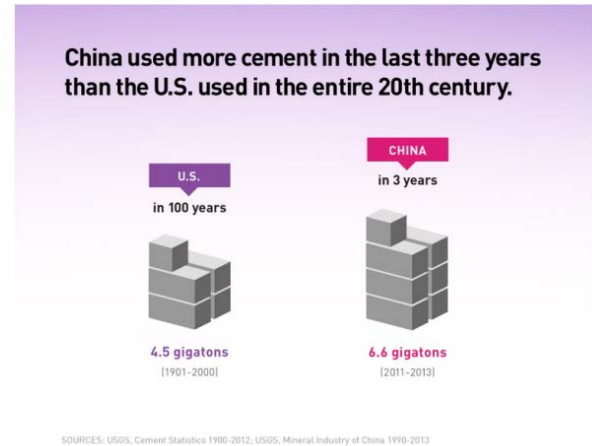
Australia

- The Mineral Industry of Australia
 - PDF Format:
[1994](#) | [1995](#) | [1996](#) | [1997](#) | [1998](#) | [1999](#) | [2000](#) | [2001](#) | [2002](#) | [2003](#) | [2004](#) | [2005](#) | [2006](#) | [2007](#) | [2008](#) | [2009](#) | [2010](#) | [2011](#) | [2012](#)
 - XLS Format:
[2002](#) | [2003](#) | [2004](#) | [2005](#) | [2006](#) | [2007](#) | [2008](#) | [2009](#) | [2010](#) | [2011](#) | [2012](#)
- [Links](#)

Contact: [USGS Country Specialist](#)

Global Demand for Mineral Commodities

- Historically Unprecedented
- Growing Rapidly
- Dominated by Development in China
- Continued Demand Growth Anticipated for ROW
- 2.5 – 3B Increase in Global “Middle Class” Population by 2030



Source: USGS Historical Data Series

“Critical Minerals”: Depends on your definition!

Reference: Erdmann & Graedel (2011), Environ. Sci. Technol. 45, 7620-763

hydrogen 1 H 1.00794																	helium 2 He 4.00260
lithium 3 Li 6.941	beryllium 4 Be 9.01218											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
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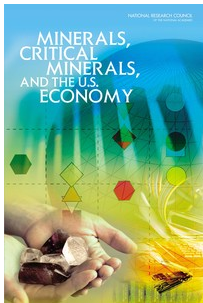
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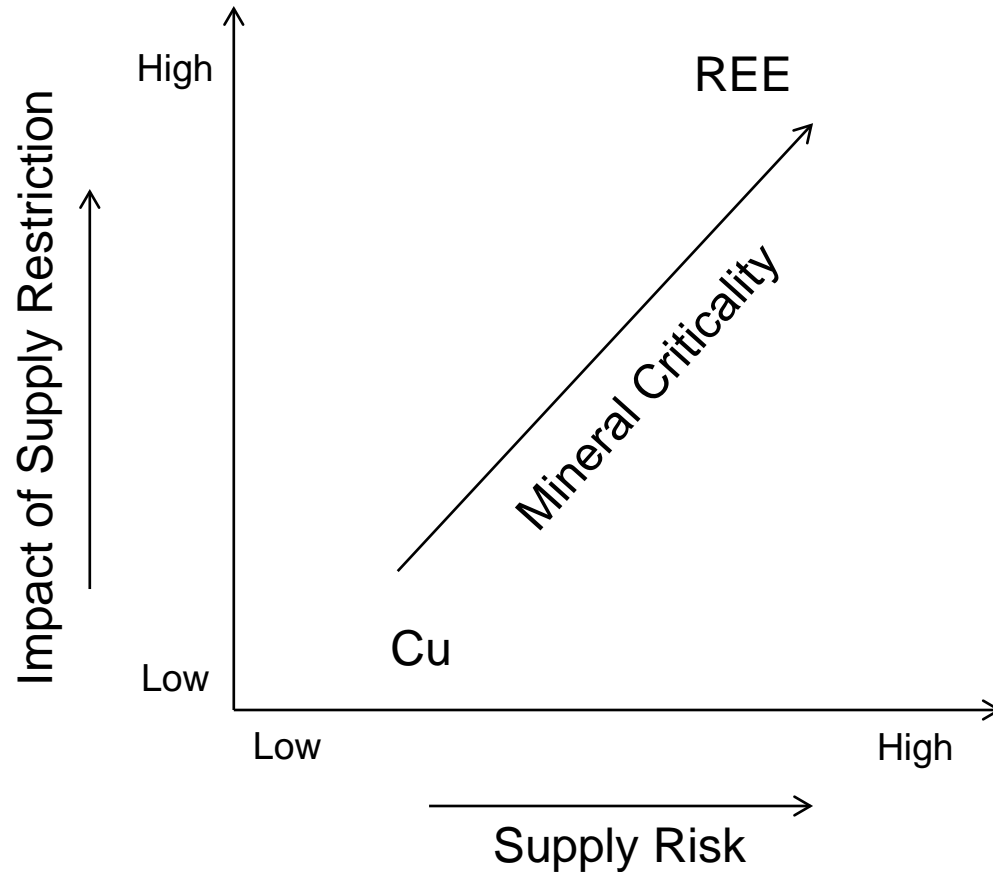
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Criticality Matrix



Reference:
Minerals, Critical Minerals, and
the U.S. Economy
National Academy of Sciences,
2008



Some Factors Impacting Criticality

Vulnerability Dimension

- Market share
- Impact on revenues
- Substitution options
- Pricing power
- Gross Value Added
- National Security

Supply Risk Dimension

- Absolute abundance
- Source country concentration
- Specific country risk factors (political risk, governance)
- Company Concentration
- Physical supply restrictions (wars, natural disasters)

Cross-Cutting Issues

- Emerging technologies
- Recycling
- Environmental issues
- Time Horizons

Time Scale – Market Response to Changes in Availability / Production Shortfalls

Duration	Years	Constraints	Recourse
Short	0-3	Existing production capacity	Inventories / underutilized capacity
Medium	3-10	Existing technology / known resources	Substitution / higher cost resources
Long	>10	Technical development / undiscovered resources	Investment in exploration / mine development / process development

New Mine Development

- Costs
- Permitting
- Environmental
- Social / Political

Stages of Mineral Exploration & Development

Aboriginal Affairs and Northern Development Canada



10 years

Image used by permission <https://www.aadnc-aandc.gc.ca/eng/1100100023711/1100100023713>



New Mine Development: Risks

Mount Polley Mine Tailings Pond Breach Sends Toxic Waste Into Waterways (PHOTOS, VIDEO)

The Huffington Post B.C.

Posted: 08/05/2014 2:06 pm EDT | Updated: 08/06/2014 1:59 am EDT

Mount Polley rated high in mines' ministry safety ranking

Imperial Metals' mine tailings dam subjected to 'dam safety review' only once every 10 years

GORDON HOEKSTRA / VANCOUVER SUN
SEPTEMBER 8, 2014 09:33 AM

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An aerial view shows the damage caused by a tailings pond breach near the town of Likely on Aug. 5. The B.C. government on Monday announced an independent inquiry into the Mount Polley Mine tailings spill. Photograph By JONATHAN HAYWARD, The Canadian Press



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The New Science of Food Additives

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Wal-Mart Weighs Matching Web Prices

BUSINESS

Grupo Mexico to Face Major Cleanup Fees After Spill

Copper Mine's Acid Spill Contaminated T... World Cost Company Millions in Fees

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REUTERS EDITION: U.S.

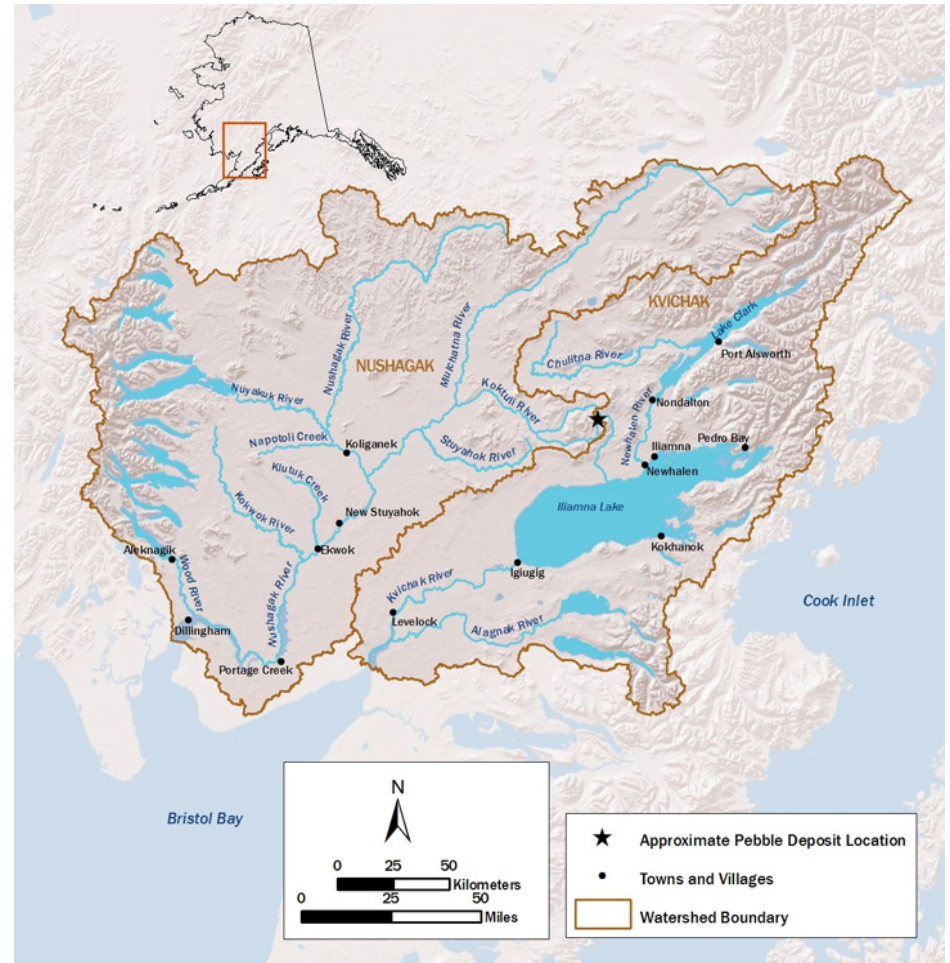
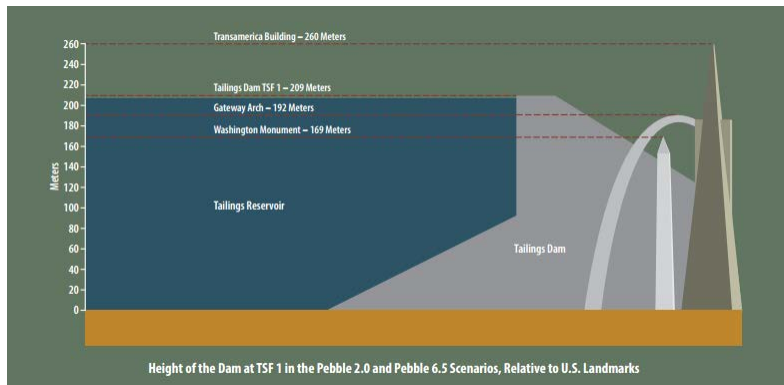
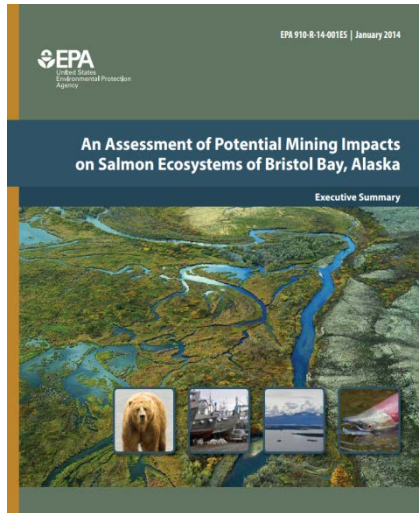
HOME BUSINESS MARKETS WORLD POLITICS TECH OPINION BREAK

UPDATE 1-Mexico's Grupo Mexico says third-quarter profit up 12 pct

Tue Oct 28, 2014 12:26pm EDT

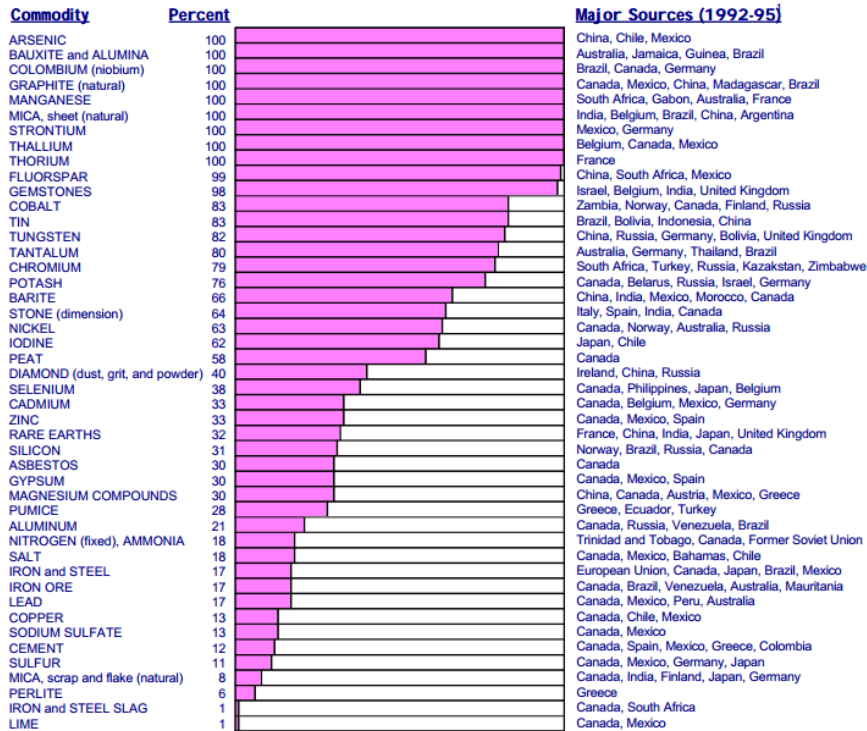
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New Mine Development: Environmental Constraints



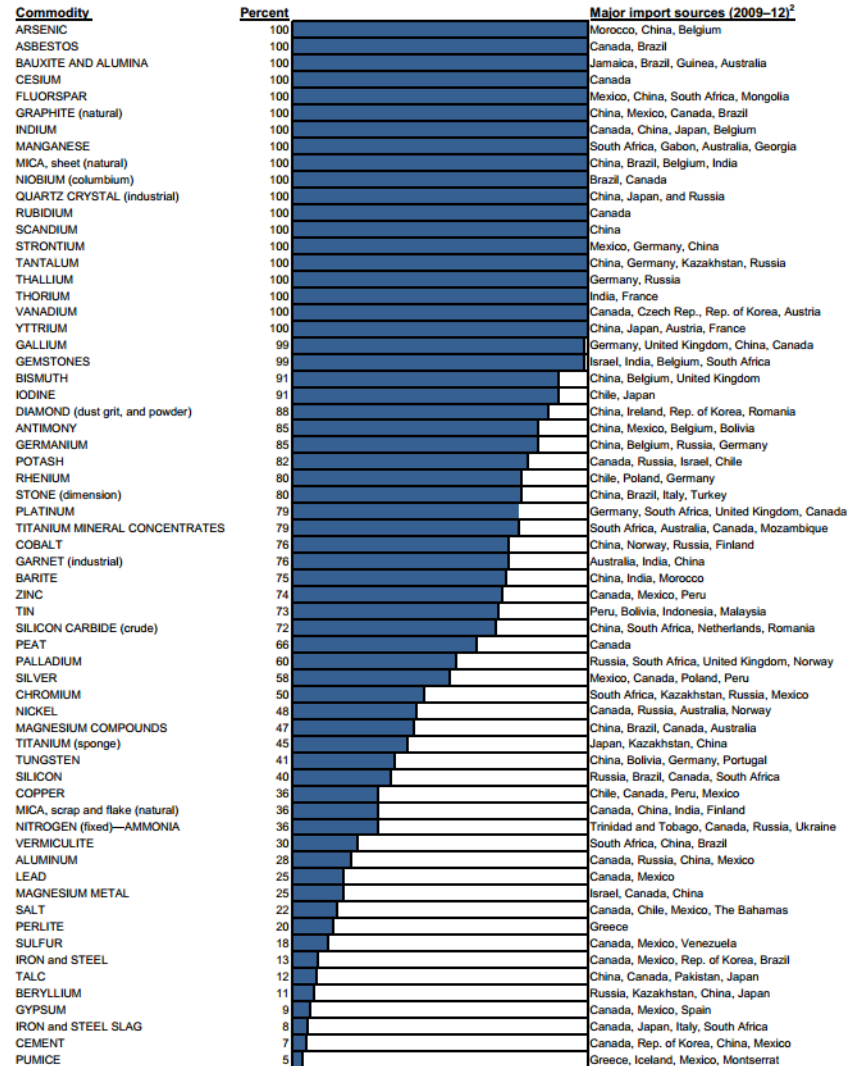
Increasing Mineral Commodity Import Dependence

1996 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS



¹ In descending order of importance

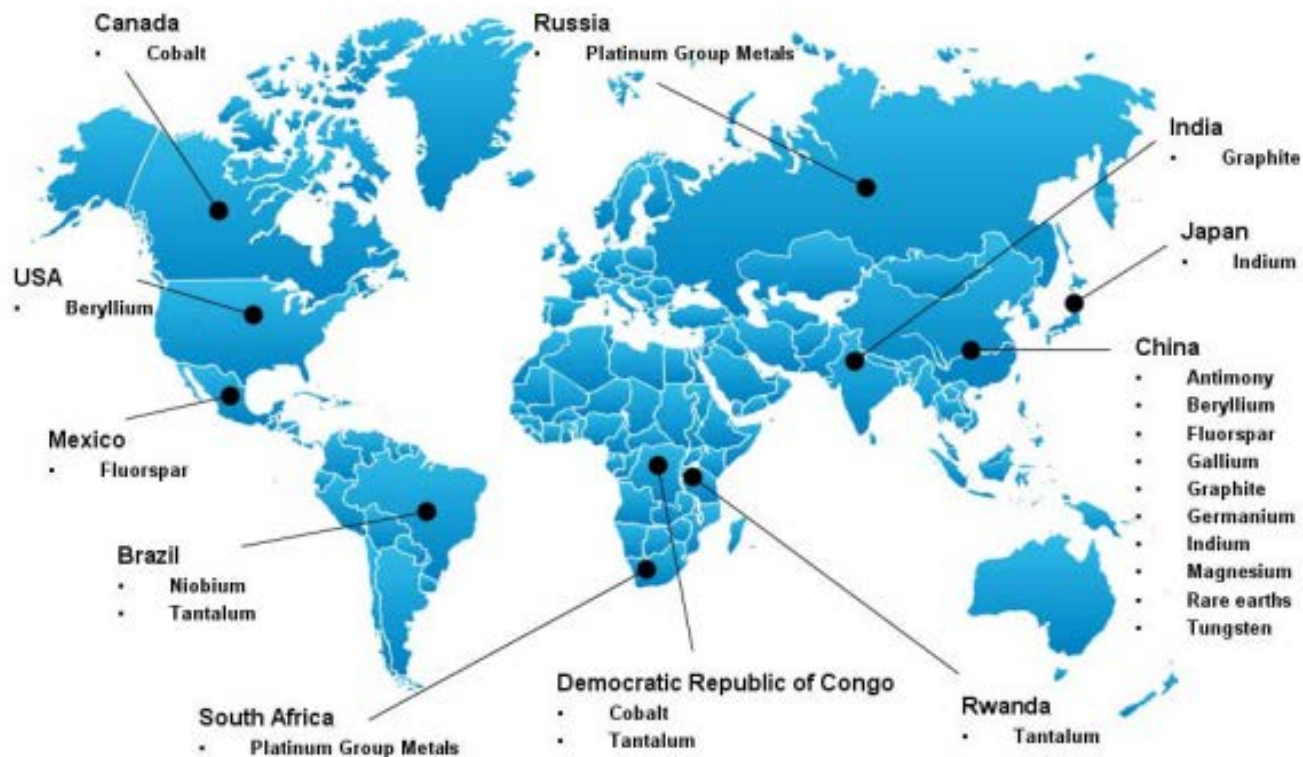
2013 U.S. NET IMPORT RELIANCE¹



Not necessarily indicative of risk!



Production concentration of critical raw mineral materials



© European Union, 1995-2014

Supply Concentration

- Geopolitical risks
- Geographic distribution
- Large increases in domestic demand

An Exploration in Mineral Supply Chain Mapping Using Tantalum as an Example

By Yadira Soto-Viruet, W. David Menzie, John F. Papp, and Thomas R. Yager

 Open-File Report 2013–1239

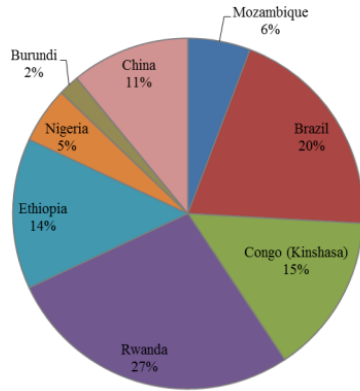


Figure 1. Chart showing percentage of mined tantalum produced in the world in 2011, by country. The amount of contained tantalum in the ore totaled 706 metric tons. Data are from Mobbs (2012), Papp (2013), Tse (2013), and Yager (2013a–c).

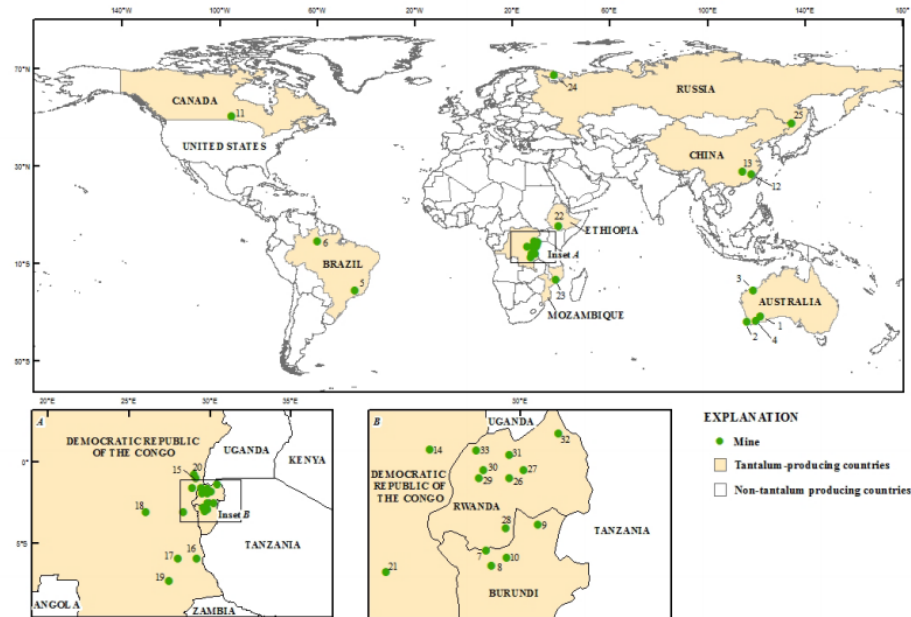


Figure 3. Significant tantalum (Ta) mines in the world. Insets A and B show the location of Ta mines in Burundi, the Democratic Republic of the Congo [Congo (Kinshasa)], and Rwanda in detail. The numbers used to identify locations are keyed to the "ID" in table 1.

Tantalum

- Dense, ductile, highly corrosion resistant
- Refractory, transition metal
- Occurrence: Rare (1-2ppm) associated with Nb (Tantalite, Columbite)
- Main Use: tantalum capacitors
- Substitutes: Nb, others; < effective
- Criticality (E&G 2011): (2)6
- U.S Import Dependence: 100%
- Conflict Mineral per Dodd / Frank

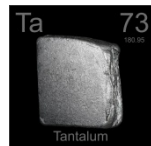
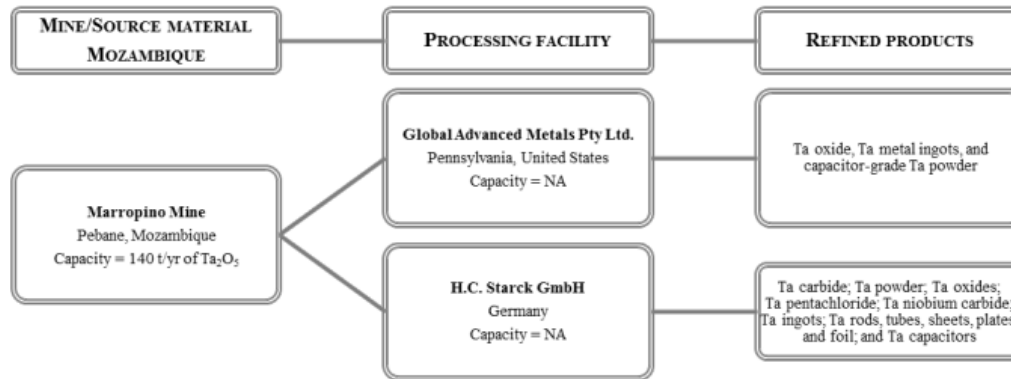


Table 1. Significant tantalum mines.

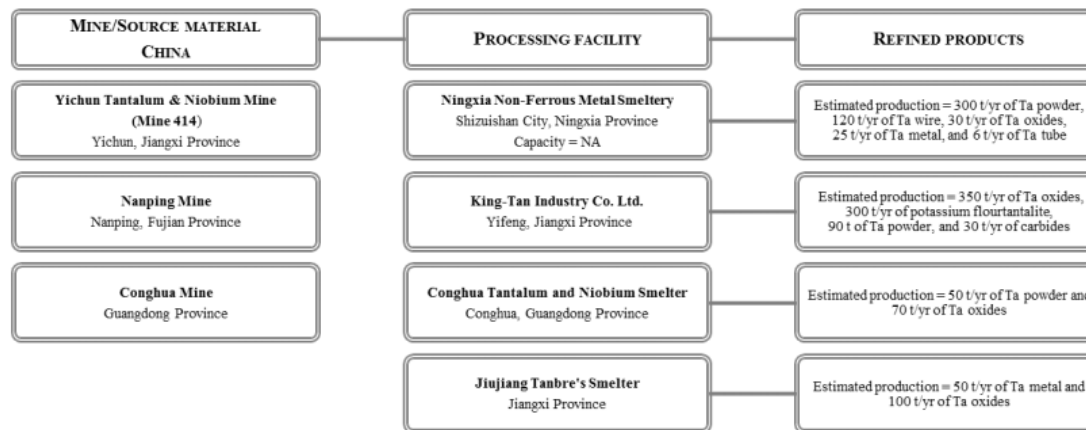
[Mine locations are shown on the map in figure 3. --, not applicable or no data; A, active; CM, care and maintenance; e, estimated; GL, general location; km, kilometer; M, mine; NA, not available; S, surface/open pit; SL, specific location; SU, surface/open pit and underground; Ta₂O₅, tantalum pentoxide; U, underground. Data are from U.S. Geological Survey Minerals Yearbook 2011, vol. III (<http://minerals.usgs.gov/minerals/>)]

ID	Year	Specific mineral commodity and (or) product	Country	Location description	Location name	Facility type	Mining method	Ownership	Annual capacity (metric tons)	Status	Latitude (decimal degrees)	Longitude (decimal degrees)	Locational accuracy
1	2011	Tantalum, tantalite, Ta ₂ O ₅	Australia	60 km southeast of Kambalda, Western Australia	Bald Hill tantalite mine	M	SU	Altura Mining Ltd., 100%	100 Ta ₂ O ₅	CM	-31.672	121.894	SL
2	2011	Tantalum, tantalite, Ta ₂ O ₅	Australia	250 km from Perth	Greenbushes open pit/underground tantalite-spodumene mine	M	SU	Global Advanced Metals Pty Ltd., 80% and Traxys Tantalum LP (Traxys Group), 20%	550 Ta ₂ O ₅	A	-33.857	116.051	SL
3	2012	Tantalum, tantalite, Ta ₂ O ₅	Australia	2 km north of Ravensthorpe	Mt. Cattlin Mine	M	S	Galaxy Resources Ltd.	25 Ta ₂ O ₅	A	-33.582	120.048	GL
4	2011	Tantalum, tantalite, Ta ₂ O ₅	Australia	100 km southeast of Port Hedland	Wodgina open pit tantalite mine	M	SU	Global Advanced Metals Pty Ltd., 80%, and Traxys Tantalum LP (Traxys Group), 20%	250 Ta ₂ O ₅	CM	-21.184	118.671	SL
5	2011	Tantalum, concentrate	Brazil	Fluminense Mine, Minas Gerais State	Fluminense Mine (Volta Grande Mine)	M	S	Companhia Industrial Fluminense (AMG Advanced Metallurgical Group N.V.)	25 concentrate	A	-21.084	-44.583	SL
6	2011	Tantalum, concentrate	Brazil	Pitinga Mine, Amazonas State	The Pitinga Mine	M	S	Mineração Taboca S.A. (private, 100%)	180 concentrate	A	-0.784	-60.079	SL
7	2012	Niobium (columbium) and tantalum, columbite-tantalite, ore and concentrate	Burundi	Kabarore, Kayanza Province	Mine at Kabarore	M	--	Comptoir Minier des Exploitations du Burundi S.A. (COMEBU)	6 ^e	A	-2.824	29.581	GL

Examples of Supply Chains: (Front End)

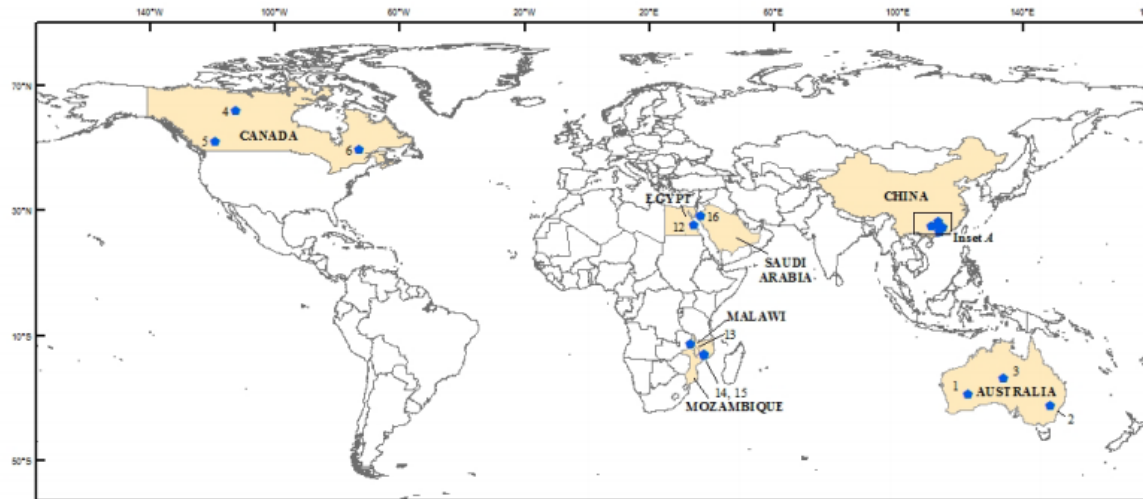


U.S. / Europe



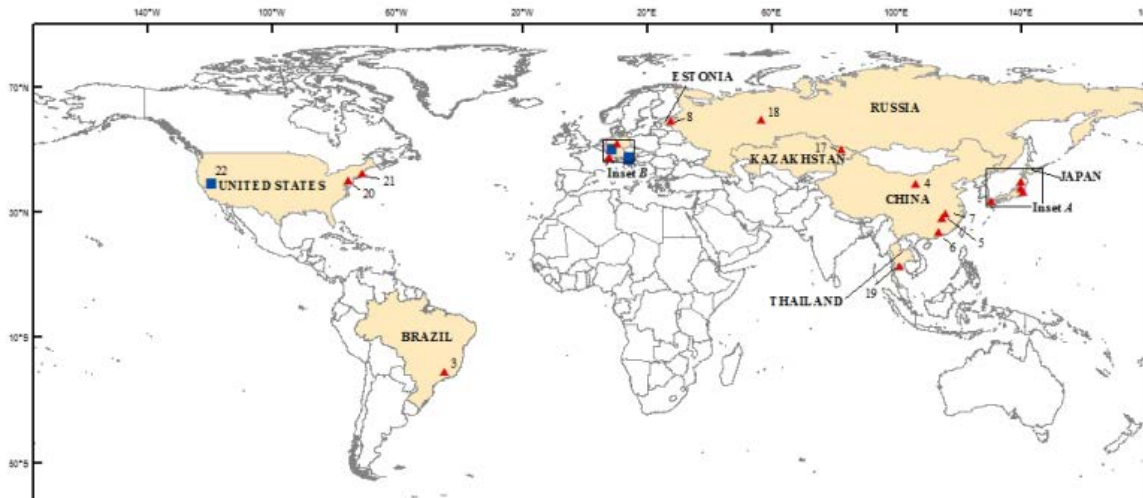
China

Alternative Supply / Downstream Processing



EXPLANATION

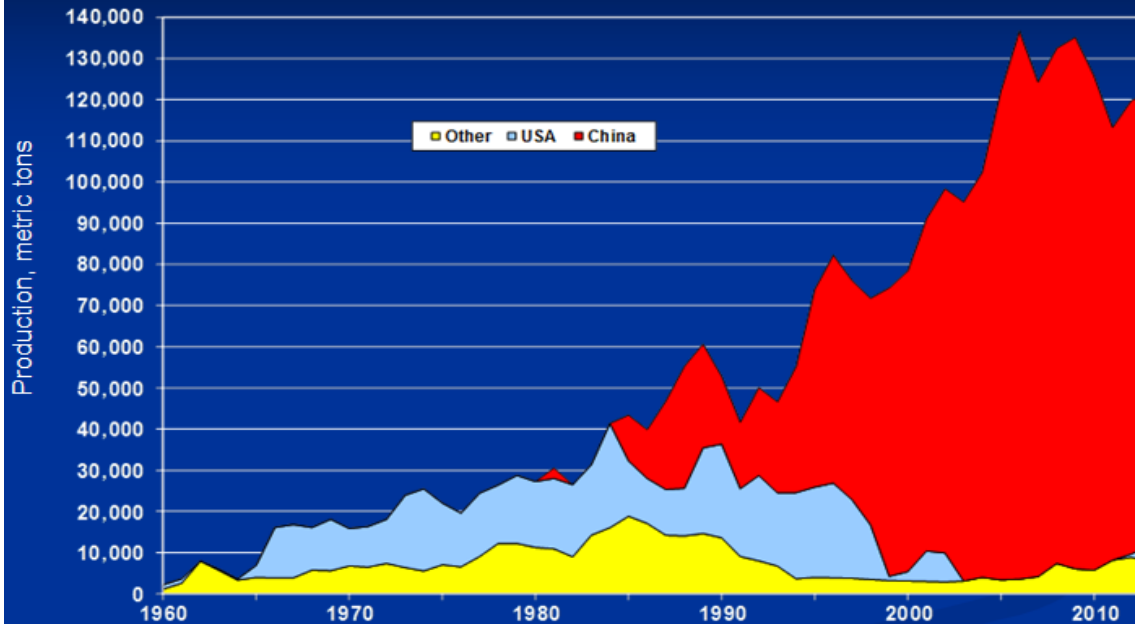
- Prospective tantalum producer
- Prospective tantalum-producing countries
- Countries not prospective for tantalum production



EXPLANATION

- ▲ Refinery
- Fabricator
- Tantalum-producing countries
- Non-tantalum producing countries

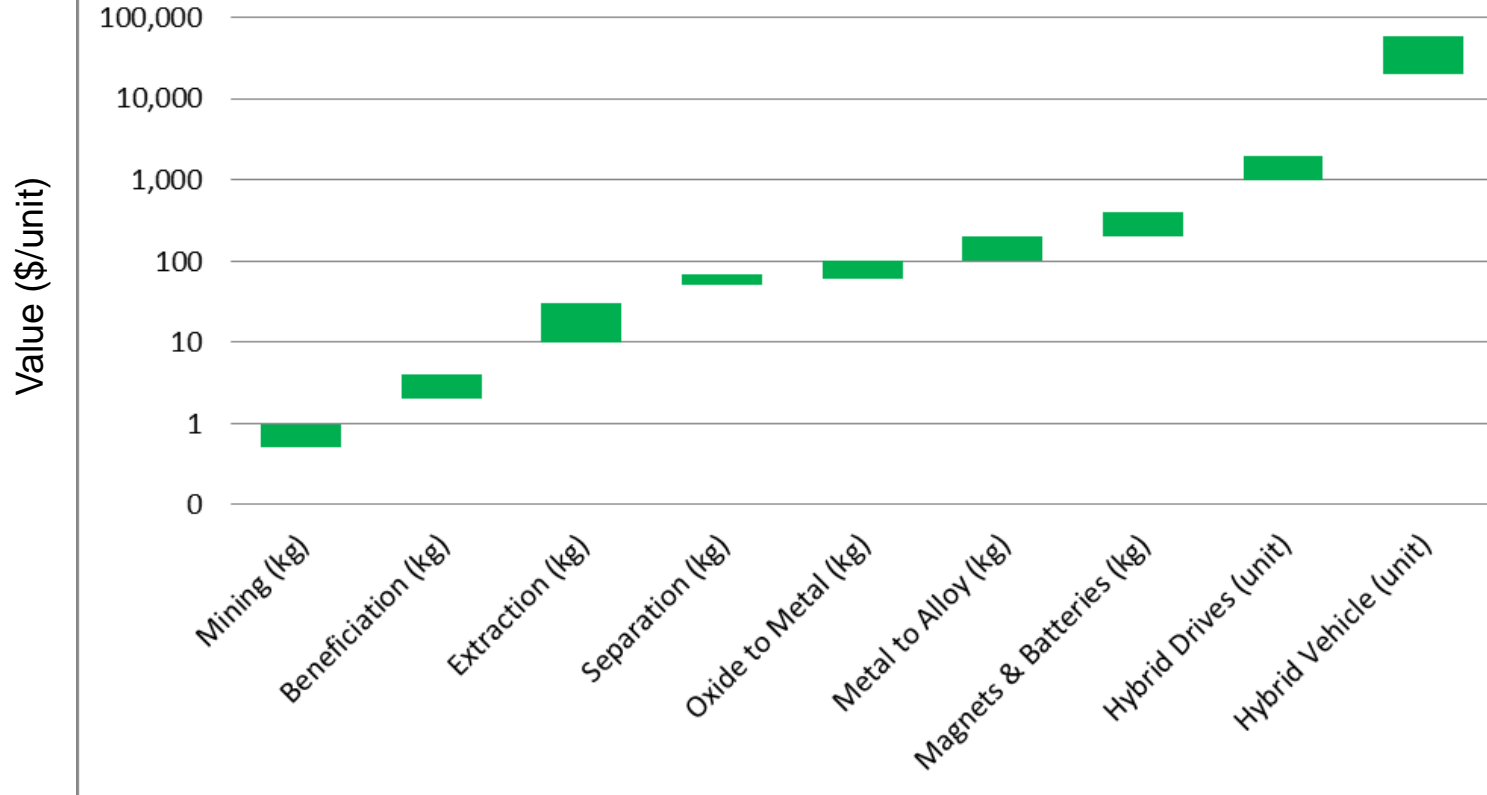
REO World Mineral Production Trends 1956 - 2013



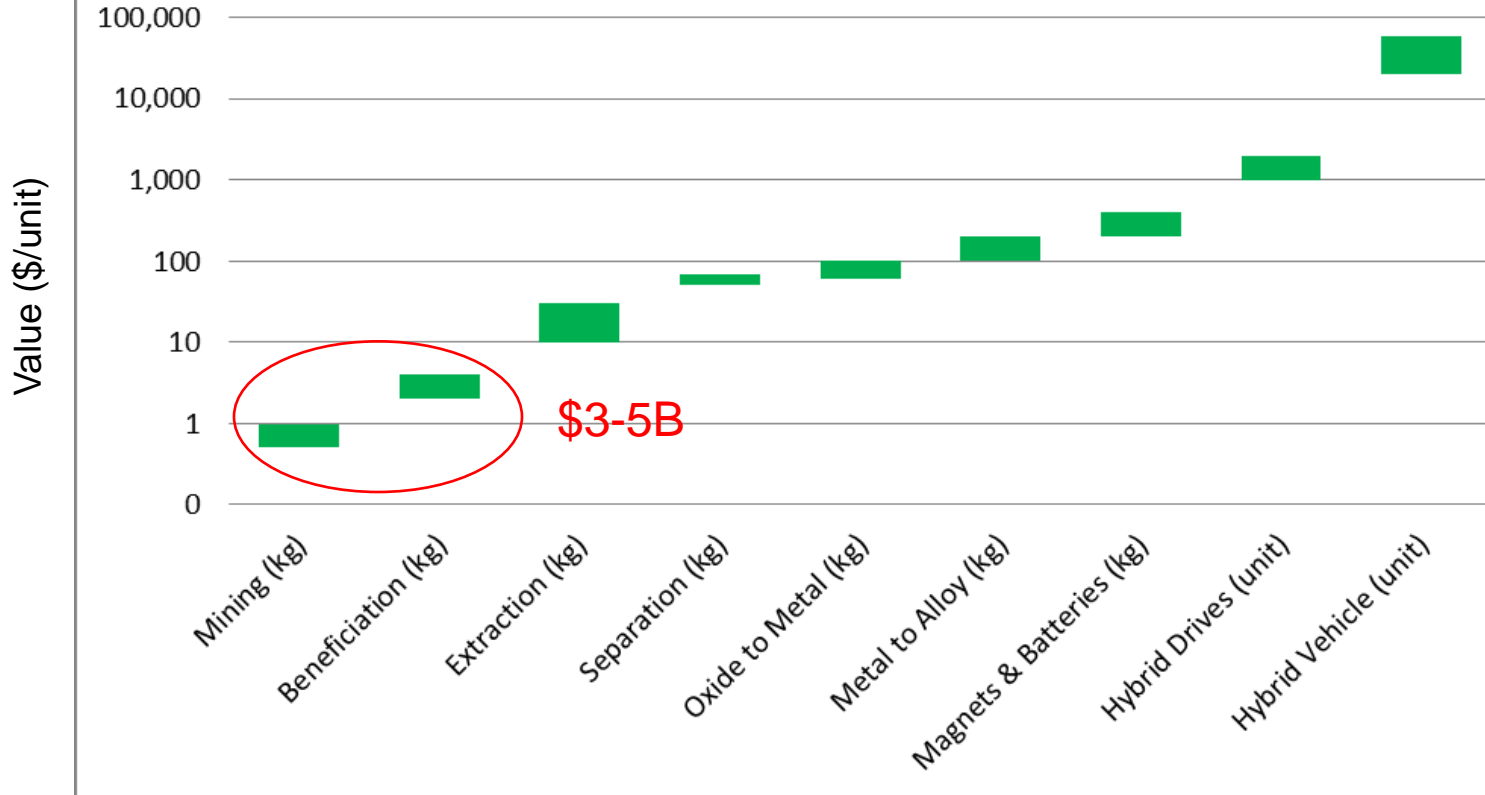
Sources: USGS Fact Sheet 087-02 updated with recent USGS Minerals Yearbook and Mineral Commodity Summaries data

Own the front end of the supply chain + Vertical integration = Own the entire supply chain

REE Value Chain



REE Value Chain

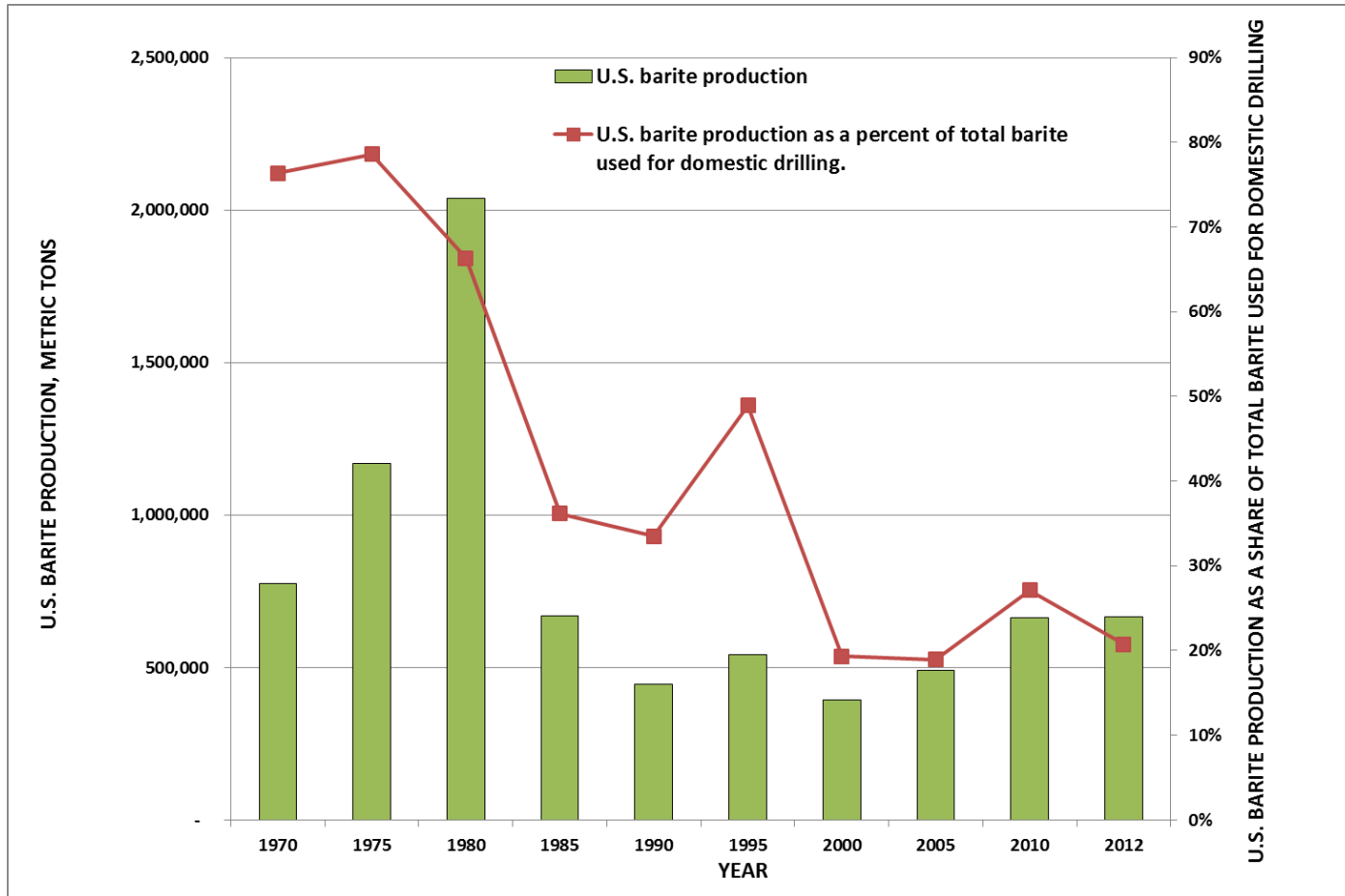


GLOBAL DISTRIBUTION OF RARE EARTH ELEMENT RESOURCES ACTIVE MINES AND ADVANCED PROJECTS



REE DISTRIBUTION AND MOBILITY IN RESIDUAL DEPOSITS FORMED ON ALTERED GRANITES OF THE SOUTHEASTERN UNITED STATES. Foley et al (2014).

Comparison of Domestic Barite Production and Percentage Share of Total Barite Used for Drilling in the United States



Barite – A Case Study of Import Reliance on an Essential Material for Oil and Gas Exploration and Development Drilling (Bleiwas & Miller, USGS SIR, 2014)

China Has Very Large Reserves of Shale Oil & Gas

- What happens when (not if) China develops these resources?
- Are we prepared for possible supply disruptions that result from a rapid increase in demand for barite (and other) minerals used for hydrocarbon production?

