USGS
science for a changing world

SPEAKERS

Jon Price
Nevada Bureau of Mines and Geology (Emeritus)

Larry Meinert
U.S. Geological Survey

Joe Gambogi
U.S. Geological Survey

U.S. Department of the Interior
U.S. Geological Survey

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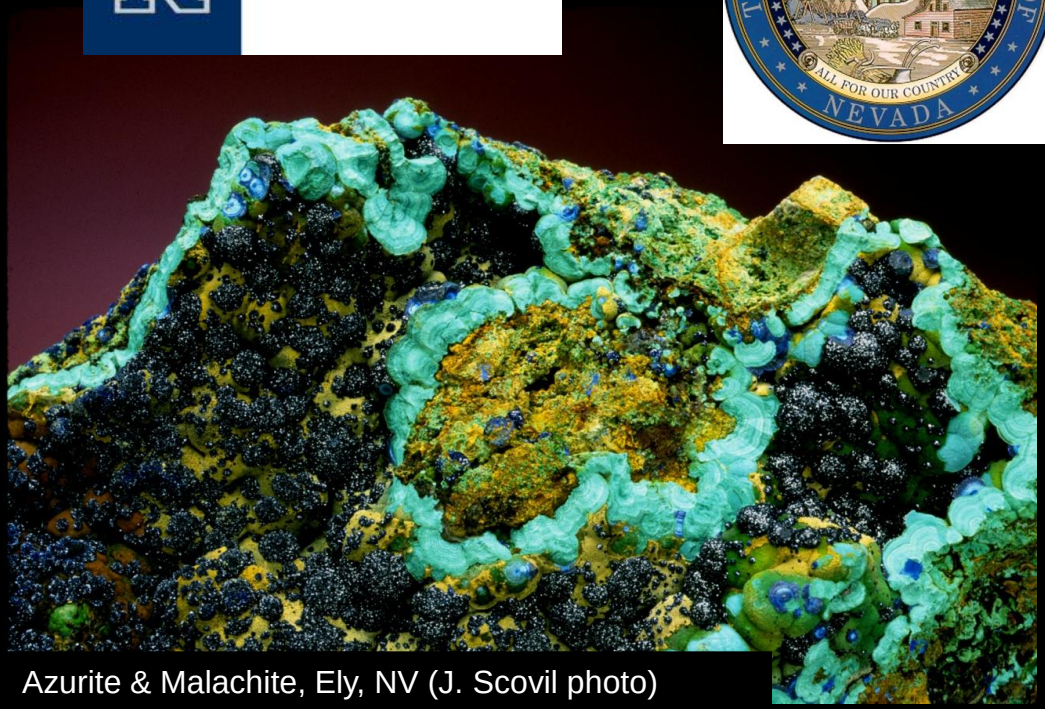
The Importance of Mineral Resources in a National-International Context

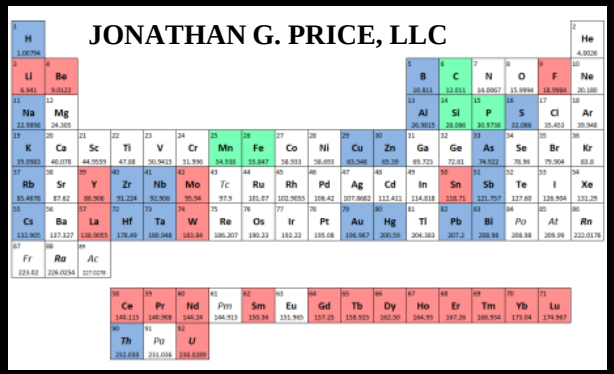
Jonathan G. Price

State Geologist Emeritus
Nevada Bureau of Mines and Geology

University of Nevada, Reno
Statewide • Worldwide



Azurite & Malachite, Ely, NV (J. Scovil photo)

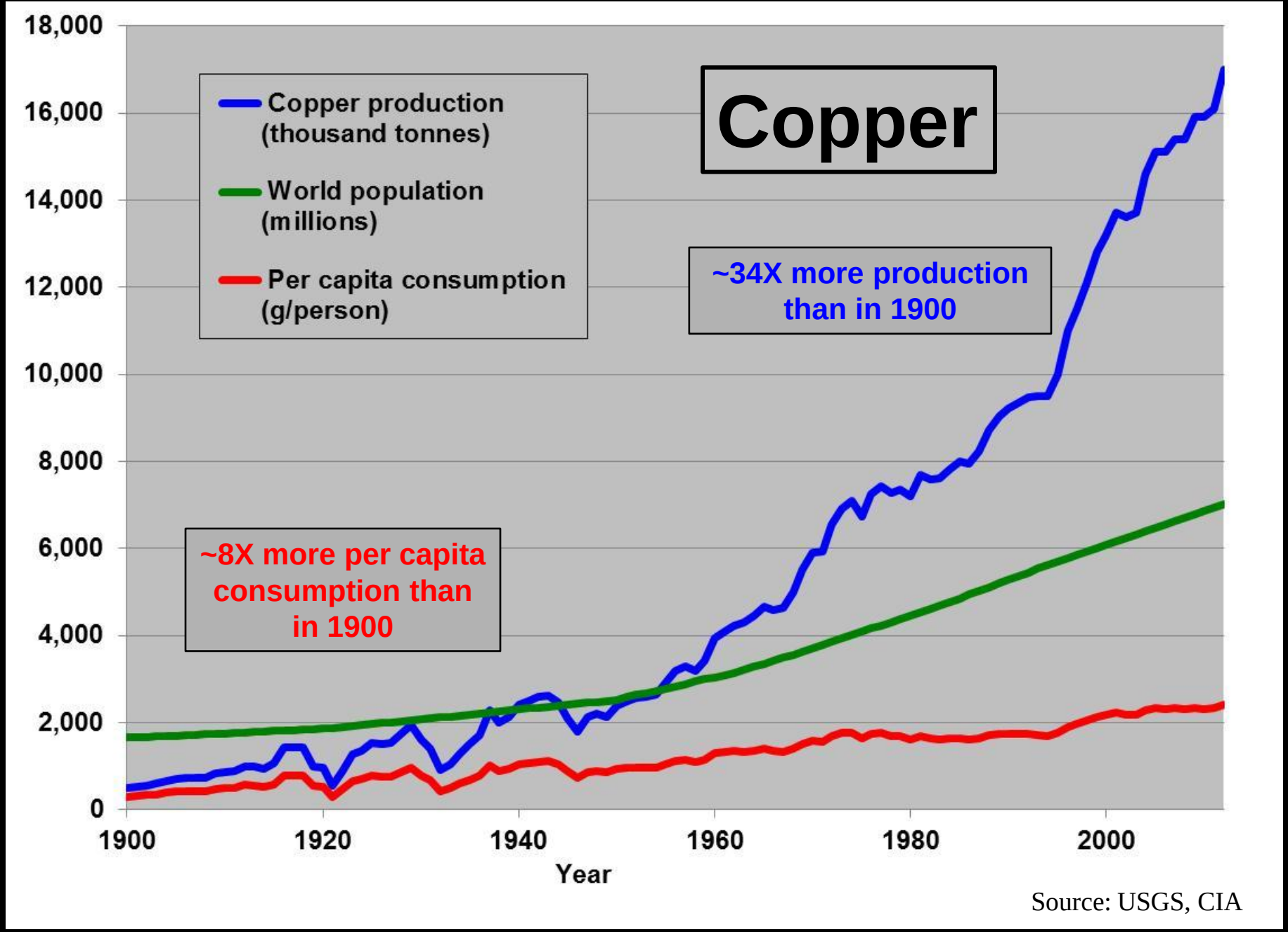


jprice@unr.edu

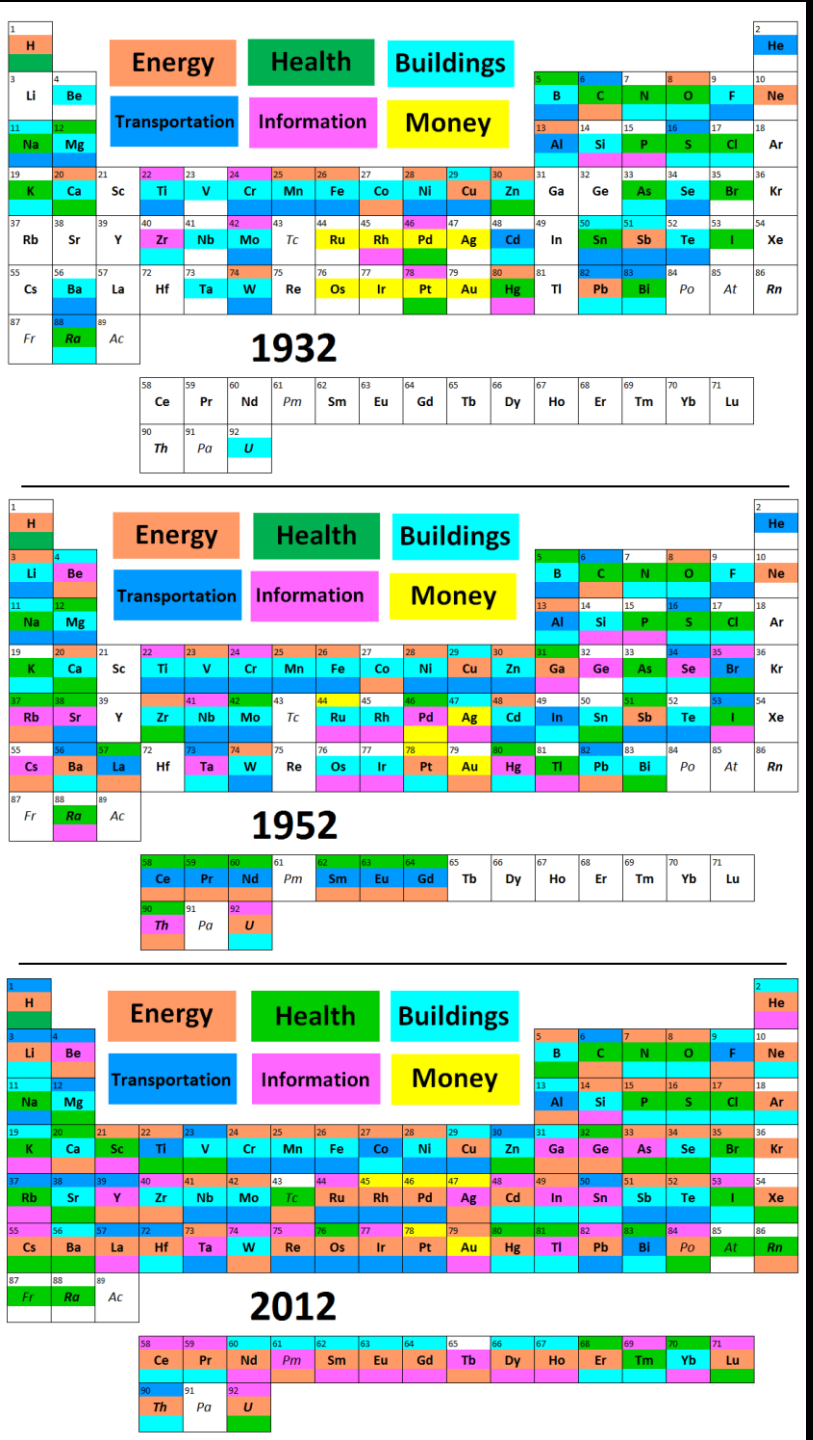
775-329-8011

The Future of Mineral Resources

- Demand for mineral resources will continue to grow.
- We are unlikely to run out of mineral resources (globally).
- Nonetheless, there are challenges for the United States.

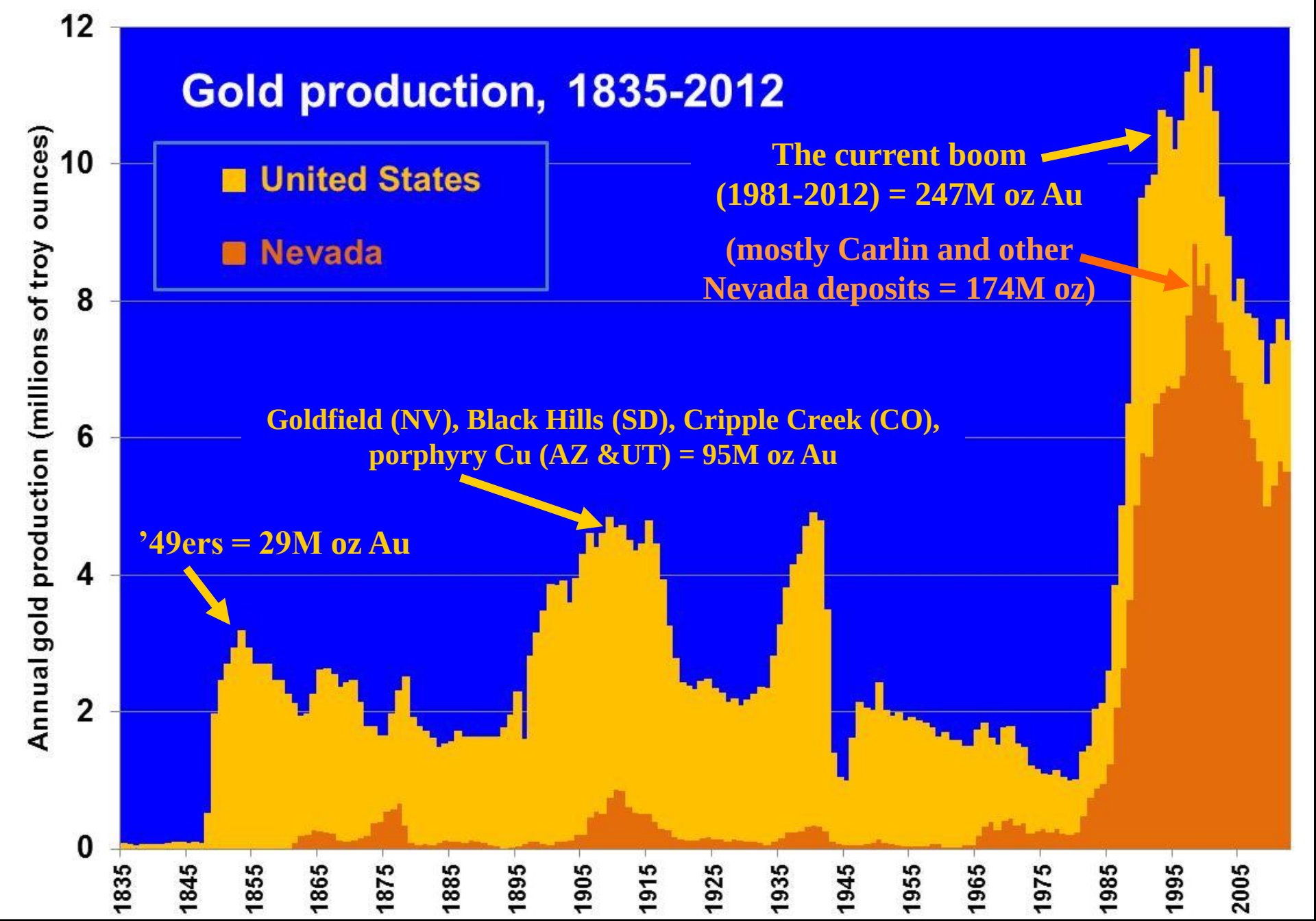


Demand is high for nearly every mineral resource.



The number of mineral commodities in demand for products in society has increased markedly in the last 80 years.

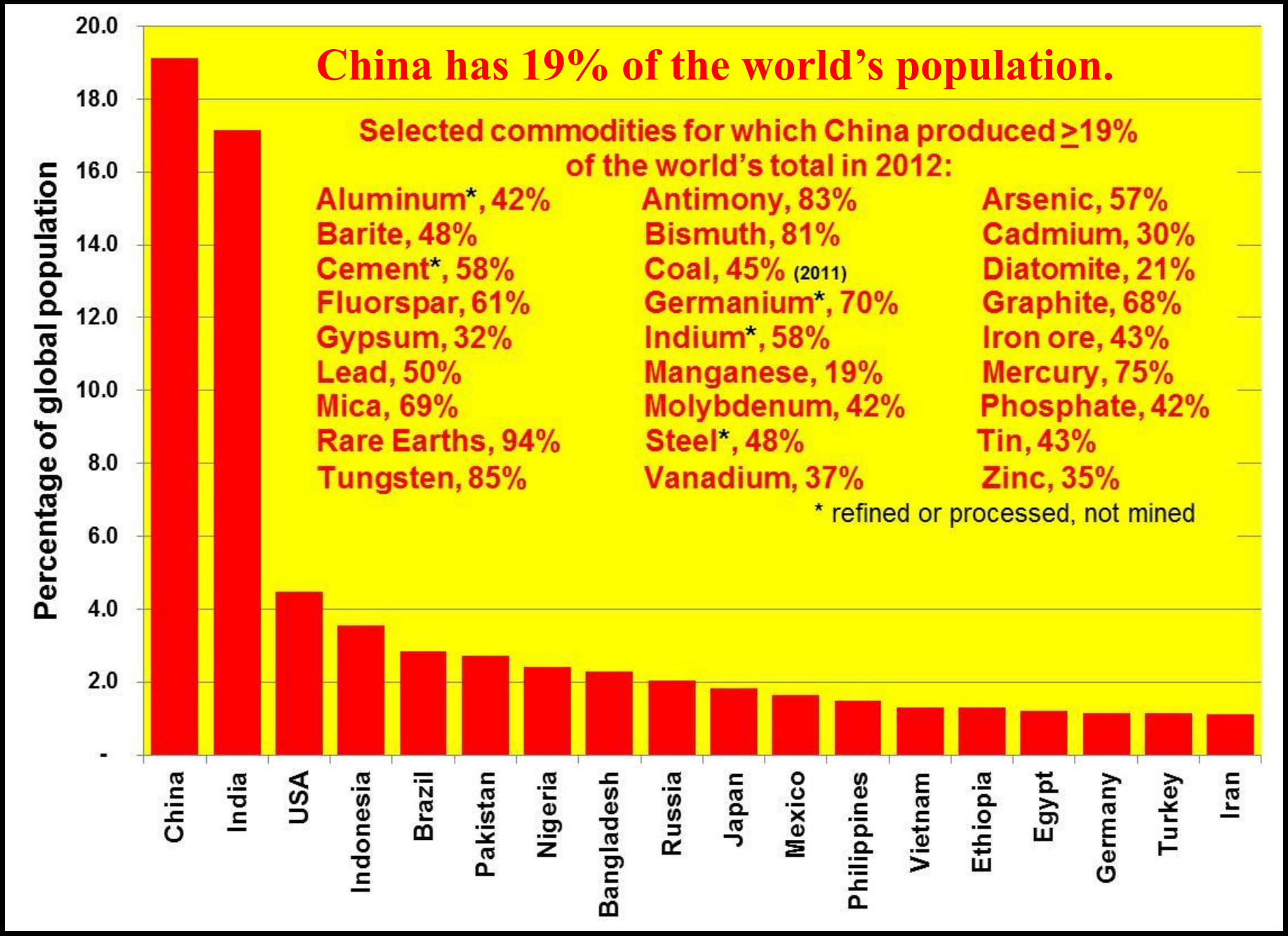
Source: USGS data



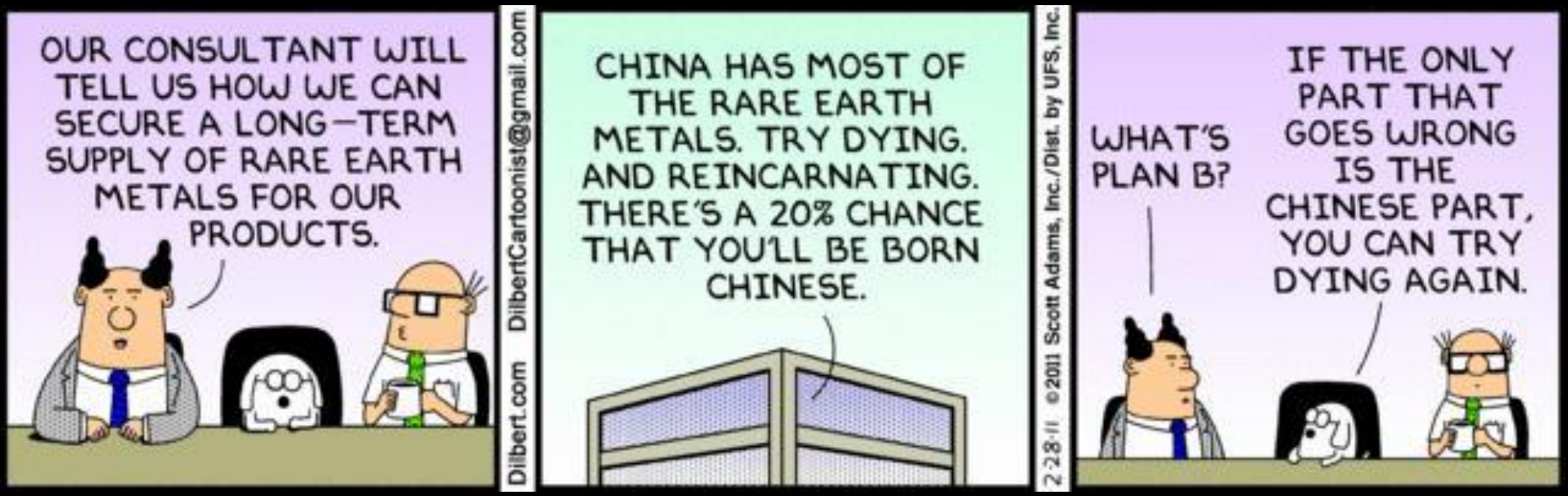
Discoveries continue to feed the biggest gold boom in US and world history.

Challenges for the United States

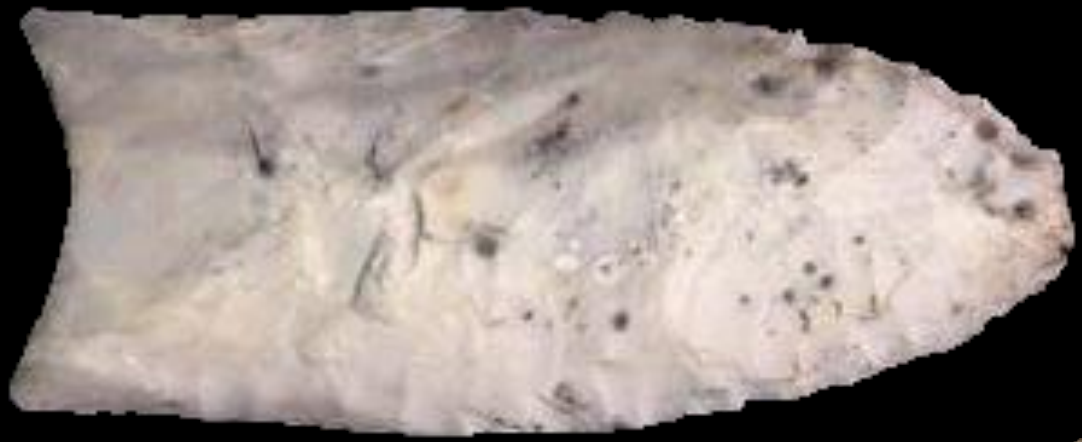
China is #1
in terms of mineral-resource production.


China has 19% of the world's population.
Selected commodities for which China produced ≥19% of the world's total in 2012:
Aluminum*, 42%
Antimony, 83%
Arsenic, 57%
Barite, 48%
Bismuth, 81%
Cadmium, 30%
Cement*, 58%
Coal, 45% (2011)
Diatomite, 21%
Fluorspar, 61%
Germanium*, 70%
Graphite, 68%
Gypsum, 32%
Indium*, 58%
Iron ore, 43%
Lead, 50%
Manganese, 19%
Mercury, 75%
Mica, 69%
Molybdenum, 42%
Phosphate, 42%
Rare Earths, 94%
Steel*, 48%
Tin, 43%
Tungsten, 85%
Vanadium, 37%
Zinc, 35%
* refined or processed, not mined
Percentage of global population
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
-
China
India
USA
Indonesia
Brazil
Pakistan
Nigeria
Bangladesh
Russia
Japan
Mexico
Philippines
Vietnam
Ethiopia
Egypt
Germany
Turkey
Iran

Rare Earth Elements (REEs)

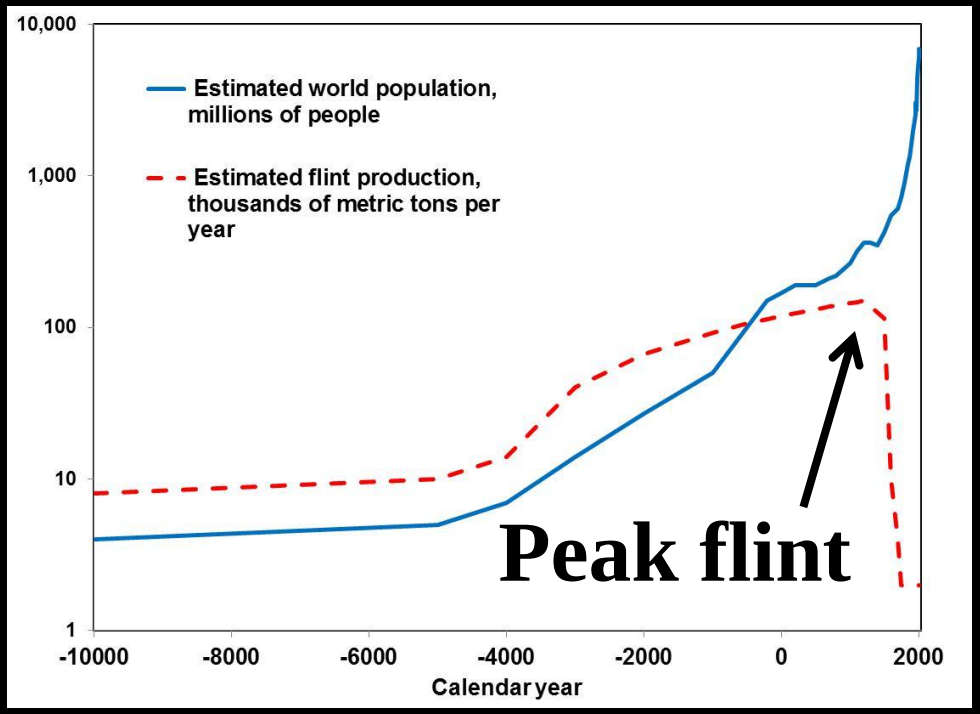


Solar panels	**$CuIn_xGa_{(1-x)}Se_2$, CdTe, GaAs, Ag, and $Si_{1-x}Ge_x$**
Wind turbines	**$Fe_{14}(Nd,Dy)_2B$, $SmCo_5$, and Sm_2Co_{17}**
Batteries	**Li, La, Ni, and V**
Fuel cells	**Pt, Pd**
Fluorescent lights	**Tb, Eu**



Arrowhead clipart from www.firstpeople.us

Critical and strategic minerals do change with time.



What minerals will be critical for the country?

Energy Critical Elements:

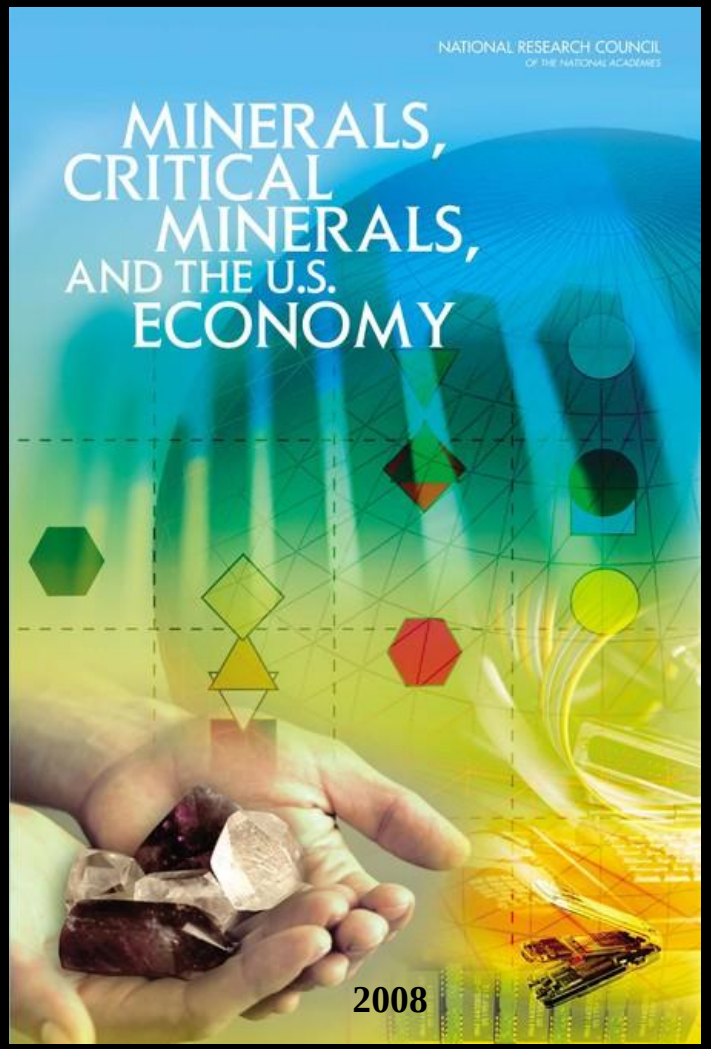
								2 He Helium 4.003
			5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
			13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066		
28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 As Arsenic 74.92160	34 **Se** Selenium 78.96		
46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 Cd Cadmium 112.411	49 **In** Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 **Te** Tellurium 127.60		
78 **Pt** Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967		

Securing Materials for Emerging Technologies

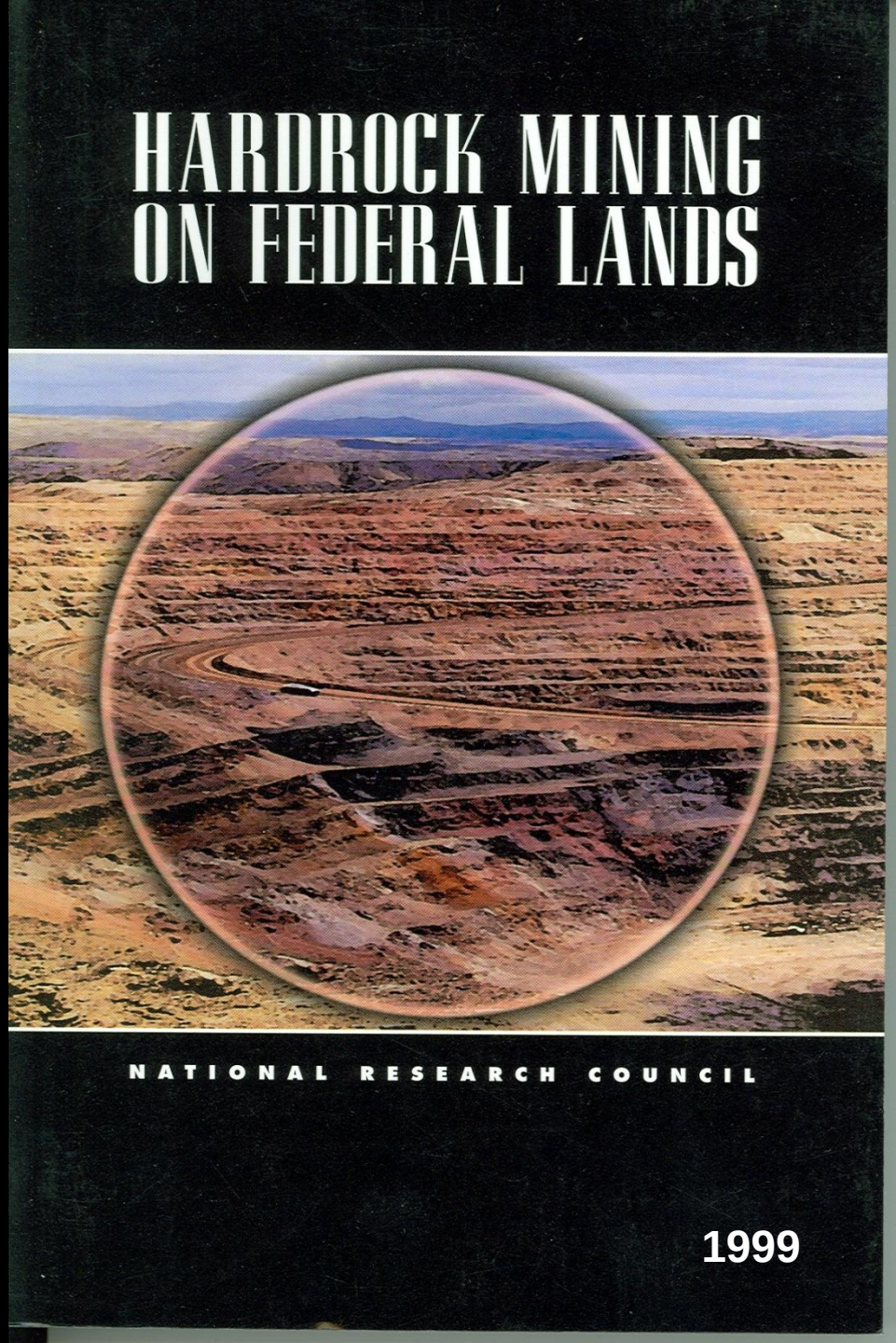
A REPORT BY THE APS PANEL ON PUBLIC AFFAIRS & THE MATERIALS RESEARCH SOCIETY

MRS APS physics

2011



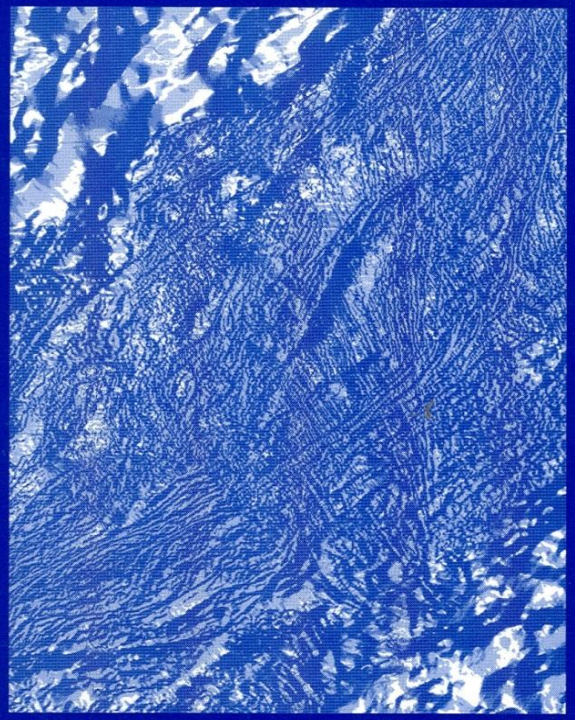
2008



Will the USA be a major producer of mineral resources in the future?

Mineral Resources and Society

A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan



NATIONAL RESEARCH COUNCIL 1996

FUTURE ROLES AND OPPORTUNITIES FOR THE U.S. GEOLOGICAL SURVEY

2001

NATIONAL RESEARCH COUNCIL

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SPEAKERS

Larry Meinert
U.S. Geological Survey

U.S. Department of the Interior
U.S. Geological Survey

USGS
science for a changing world

2013 USGS Congressional Briefing Series

Critical Minerals – Ensuring America's Future

Larry Meinert
Mineral Resources Program

U.S. Department of the Interior
U.S. Geological Survey

The New York Times

Chinese Civilian Boats Roil Disputed Waters

By EDWARD WONG
October 5, 2010

BEIJING — The diplomatic discord set off by Japan's recent detention of a Chinese fishing trawler captain points to what foreign military officials say is a growing source of friction along China's borders: civilian vessels plying disputed waters — and sometimes acting as proxies for the Chinese

The New York Times

China Is Said to Halt Trade in Rare-Earth Minerals With Japan

By KEITH BRADSHER
and HIROKO TABUCHI
September 24, 2010

HONG KONG — Akihiro Ohata, the Japanese trade minister, said Friday that his ministry
that Japanes
were compla
from China
category of
that the gov
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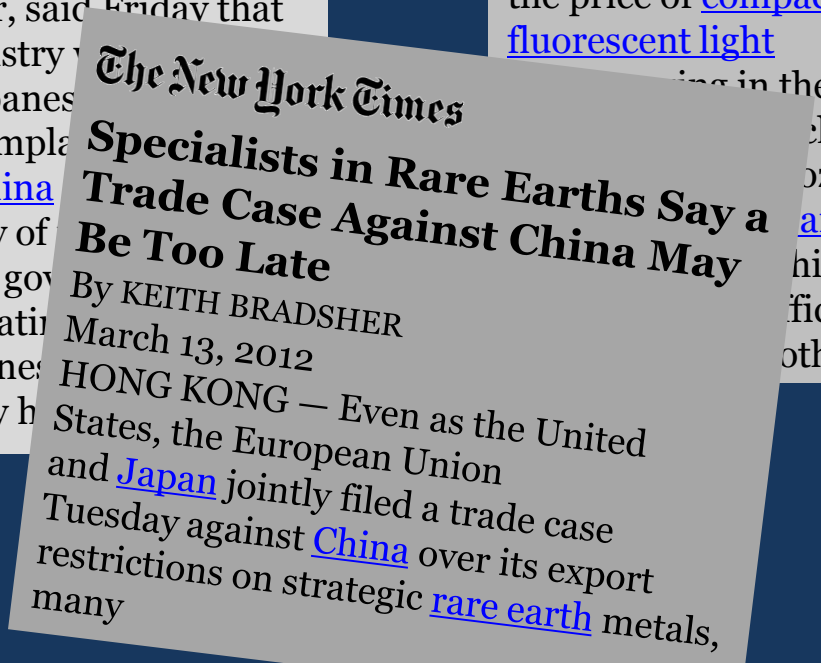
The Chines
Ministry h

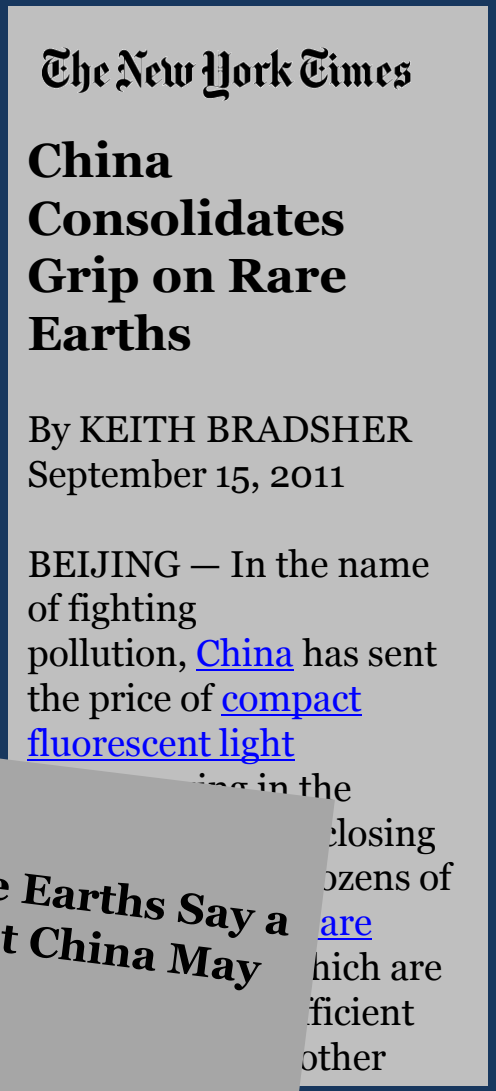


The New York Times

Specialists in Rare Earths Say a Trade Case Against China May Be Too Late

By KEITH BRADSHER
March 13, 2012

HONG KONG — Even as the United States, the European Union and Japan jointly filed a trade case Tuesday against China over its export restrictions on strategic rare earth metals, many



The New York Times

China Consolidates Grip on Rare Earths

By KEITH BRADSHER
September 15, 2011

BEIJING — In the name of fighting pollution, China has sent the price of compact fluorescent light
ing in the
closing
ozens of
are
hich are
fficient
other

Historical Perspective

- **WWI & WWII**
  - War Dept., 1922: antimony, chromium, graphite, iodine, manganese, mercury, mica, nickel, platinum, potash, tin, tungsten, vanadium
  - 1939: plus aluminum, asbestos, cadmium, cryolite, fluorspar, titanium
  - *Strategic and Critical Materials Stock Piling Acts of 1939,1946*

- **Oil Embargo of 1970s**
  - Rising commodity prices
  - *Strategic and Critical Materials Stock Piling Revision Act of 1979*
  - *National Materials and Minerals Policy, Research and Development Act of 1980*

- **Resource War of 1980s**
  - Concern that USSR was denying access to strategic resources needed for U.S. economy and defense
  - Concern about increasing import dependence
  - Research by government and academia on Chromite, Cobalt, Manganese, …
  - International Strategic Mineral Inventory (ISMI)
  - *The National Critical Materials Act of 1984*

- **Rise of Developing Economies in the 21st Century**
  - Concerns about reliable supply
  - National critical mineral strategy development – multiple OSTP working groups
  - *Currently several bills pending in 113th Congress*

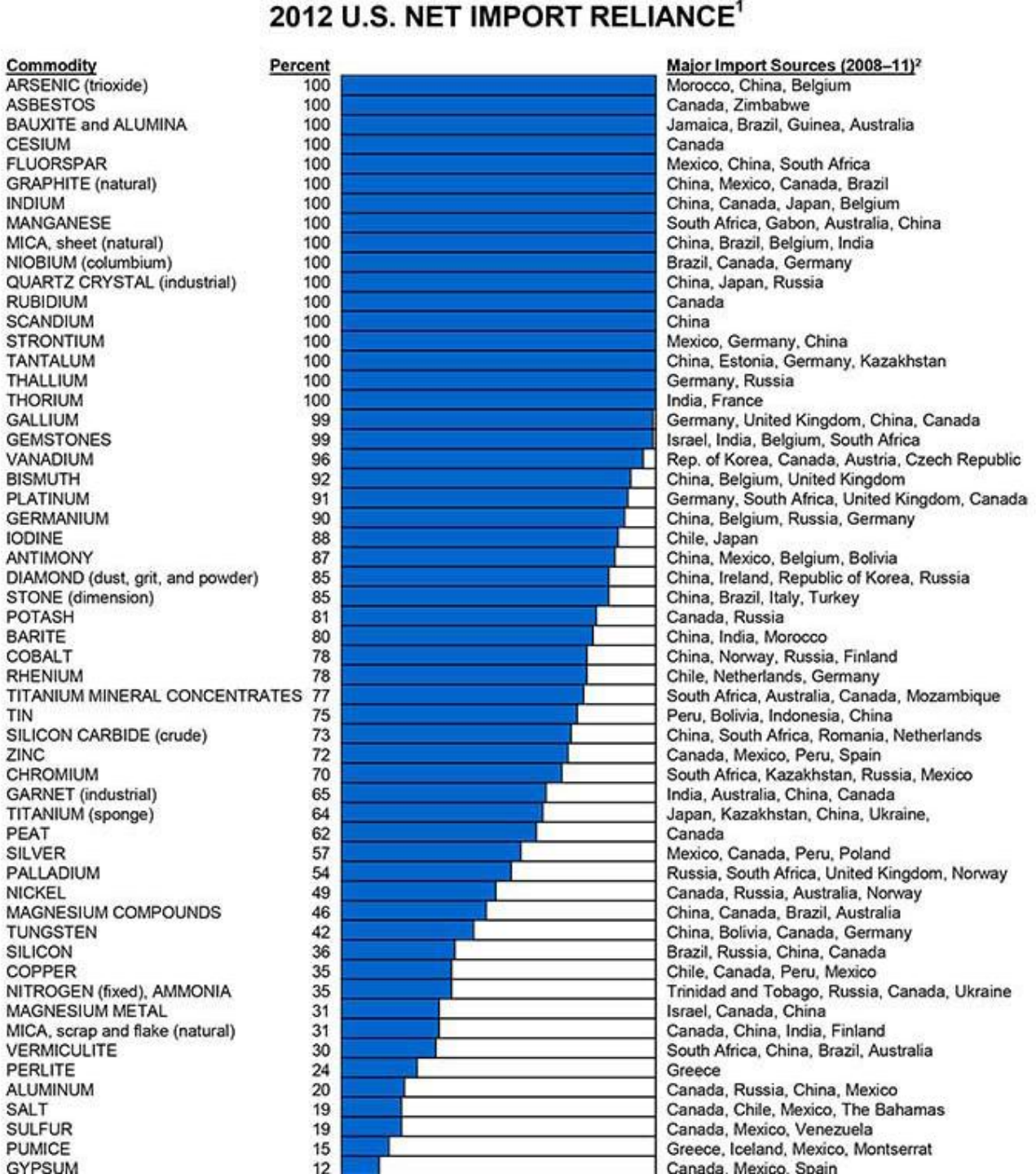
USGS

World Trade

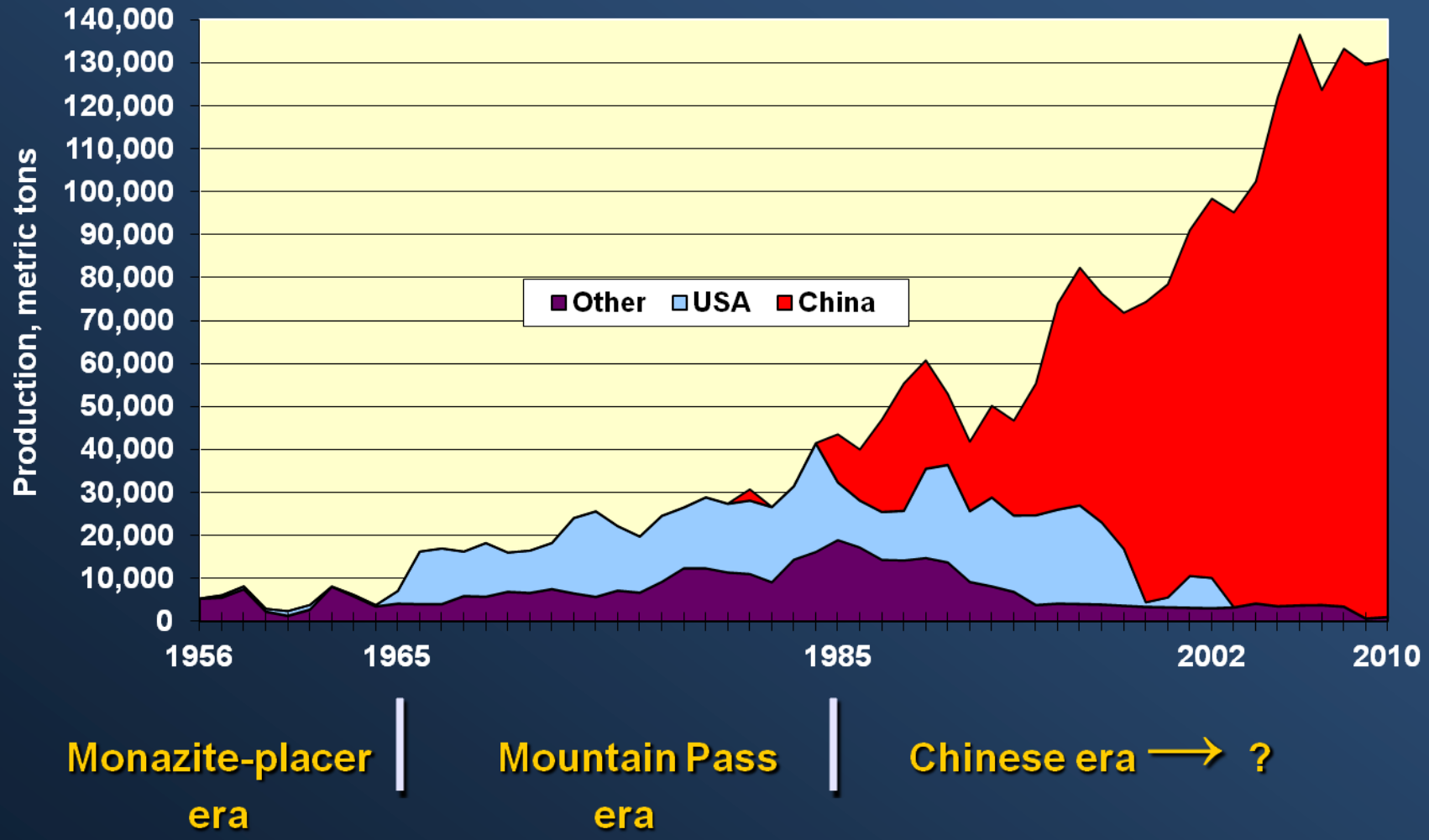
Although the US is a major producer and exporter of many commodities such as molybdenum and beryllium, it relies on world trade for most mineral resources and is >90% reliant on imports for 24 commodities, including REE

Source: USGS Mineral Commodity Summaries (2013)

USGS



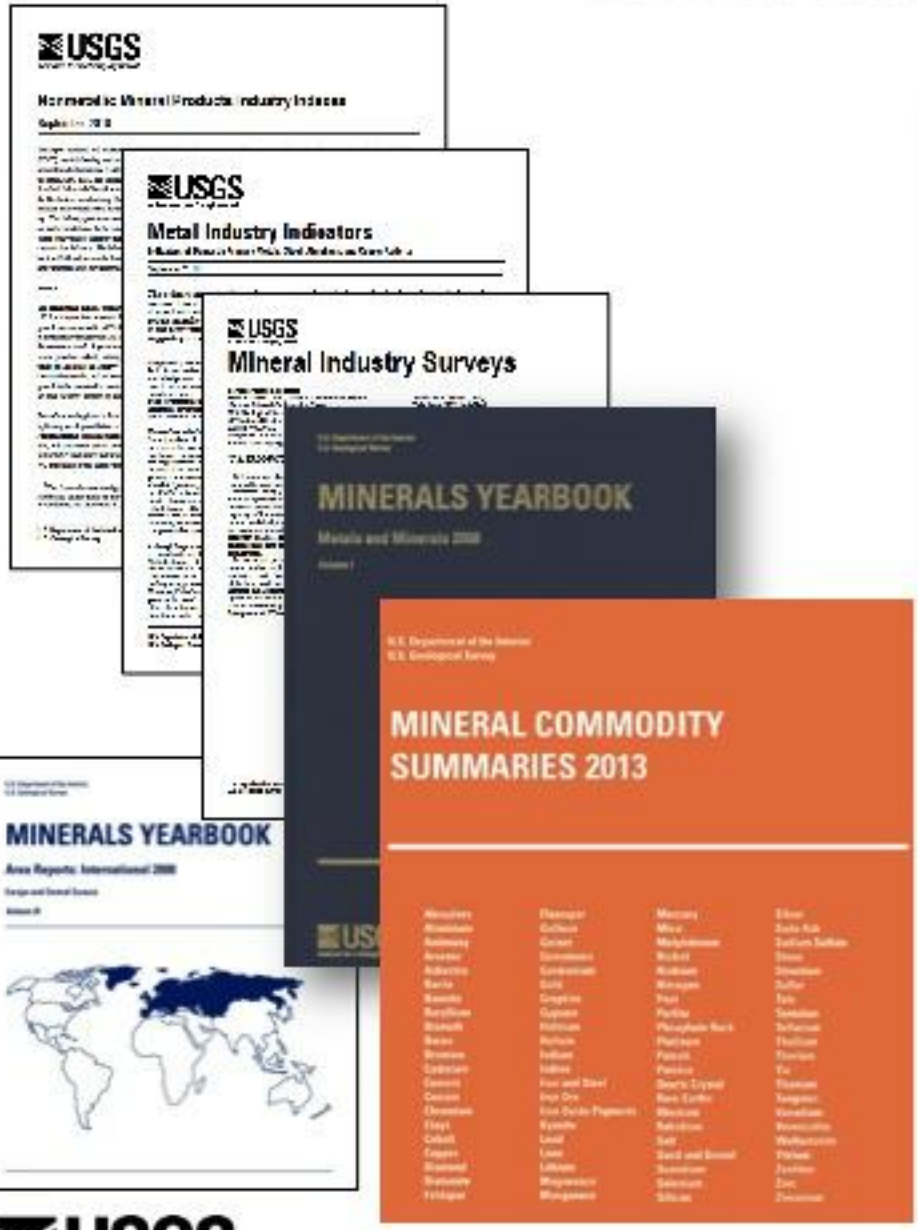
REE Production Trends – 1956 to 2010

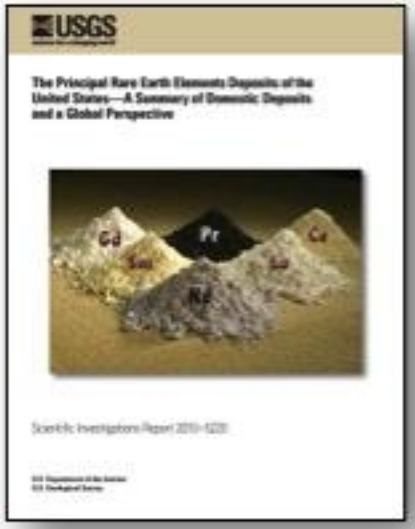


Sources: USGS Fact Sheet 087-02 updated with recent USGS Minerals Yearbook data

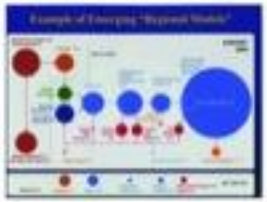
USGS

Information is Critical





The Global Flow of Aluminum From 2006 Through 2025: *USGS Open-file Report 2010-1256*

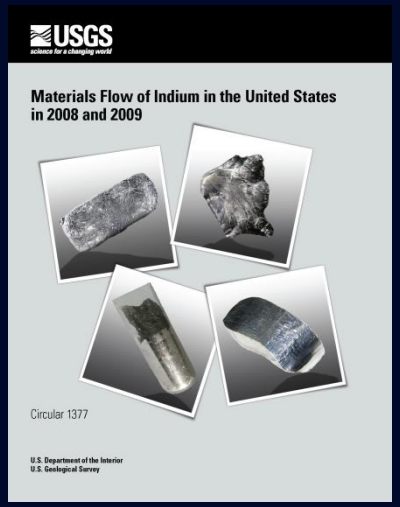


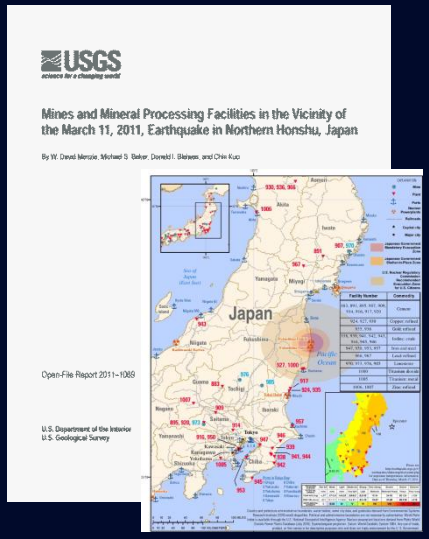
Mines and Mineral Processing Facilities in the Vicinity of the March 11, 2011, Earthquake in Northern Honshu: *USGS Open-file Report 2011-1069*

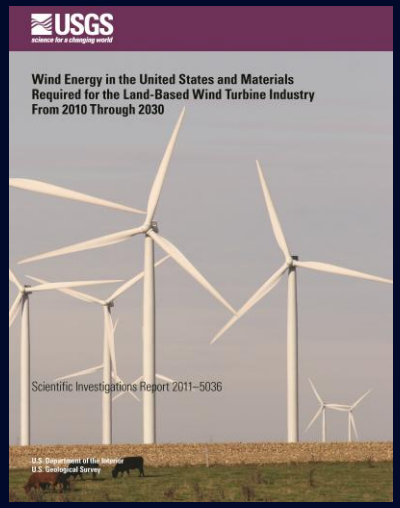
USGS

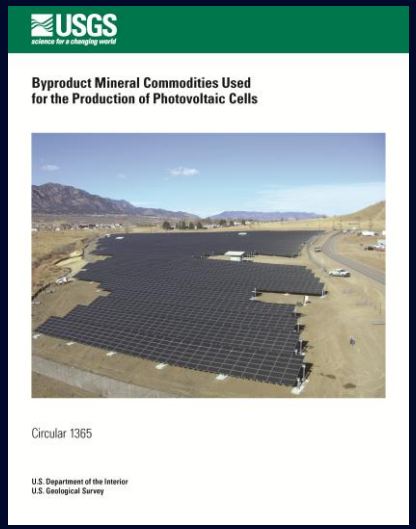
Minerals Information

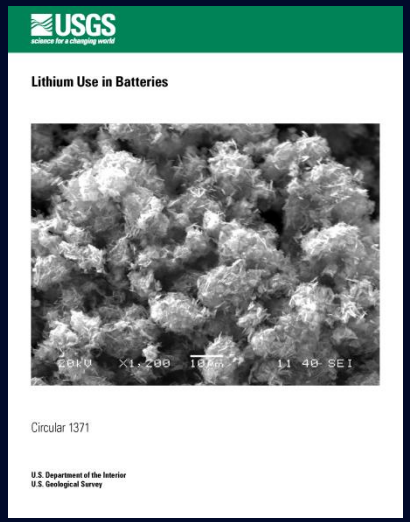
Materials Flow Studies











USGS

Supply Disruption

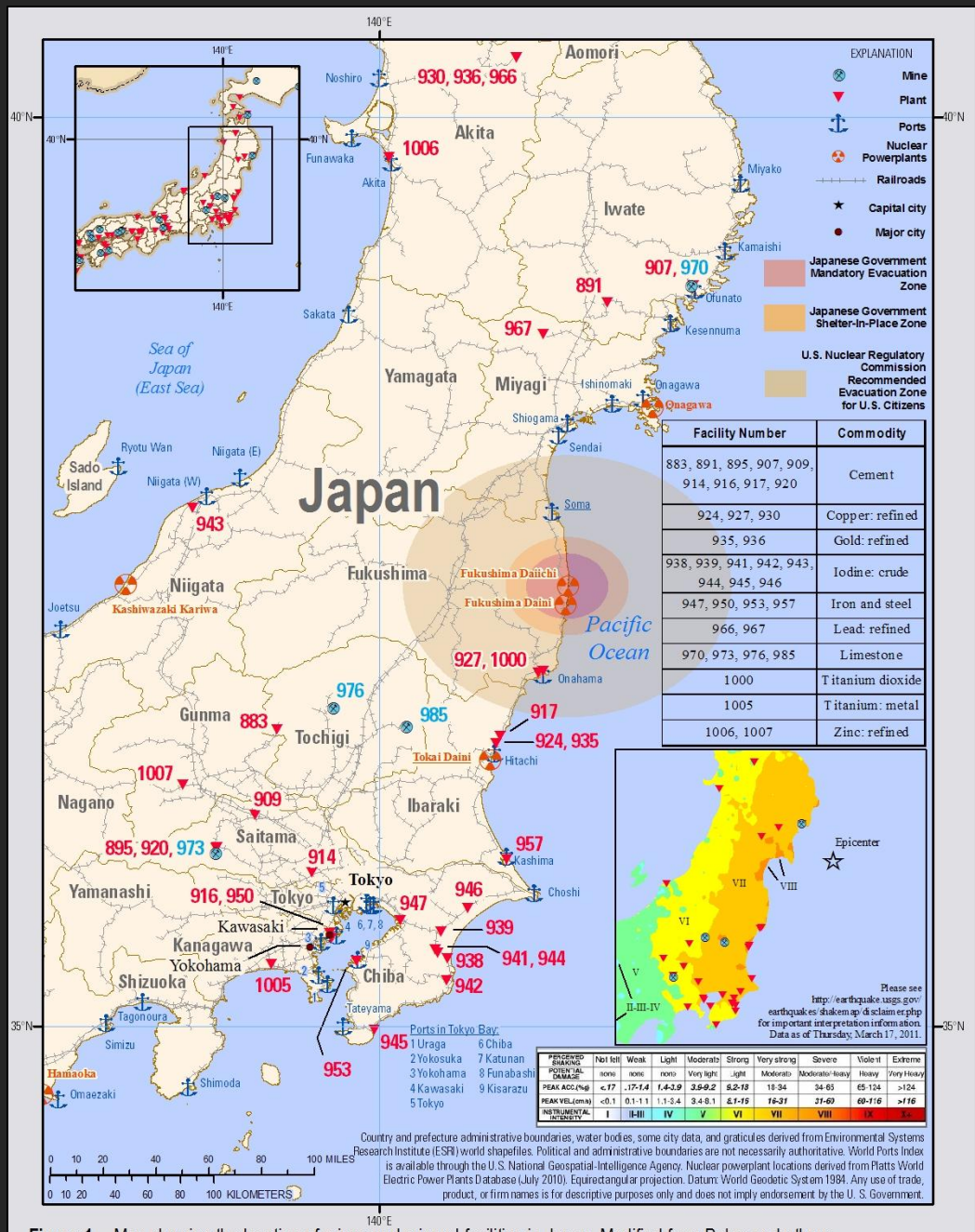
Facilities in impact zone of March 11, 2011, magnitude 9.0 earthquake and associated tsunami :

9 cement plants
4 iron and steel plants
3 copper refineries
2 lead refineries
1 titanium dioxide plant
1 titanium sponge processing facility.
8 iodine plants
4 limestone mines
2 gold refineries
2 zinc refineries

These facilities have the capacity to produce the following percentages of the world's nonfuel mineral production:

25 % of iodine (Japan is world's second leading producer (after Chile))
10 % of titanium sponge (metal)
3 % of refined zinc
2.5 % of refined copper
1.4 % of steel

The 9 cement plants produce 30% of Japan's annual cement production



Facility Number	Commodity
883, 891, 895, 907, 909, 914, 916, 917, 920	Cement
924, 927, 930	Copper: refined
935, 936	Gold: refined
938, 939, 941, 942, 943, 944, 945, 946	Iodine: crude
947, 950, 953, 957	Iron and steel
966, 967	Lead: refined
970, 973, 976, 985	Limestone
1000	Titanium dioxide
1005	Titanium: metal
1006, 1007	Zinc: refined

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 1.—Map showing the location of mines and mineral facilities in Japan. Modified from Baker and others (2010).

Menzie, W.D., Baker, M.S., Bleiwas, D.I., and Kuo, Chin, 2011, Mines and mineral processing facilities in the vicinity of the March 11, 2011, earthquake in northern Honshu, Japan: U.S. Geological Survey Open-File Report 2011–1069, 7 p. (Available only at http://pubs.usgs.gov/of/2011/1069/.)

Inventory vs Assessment

Identified resources

Near- and medium-term supply

Often classified by commodity

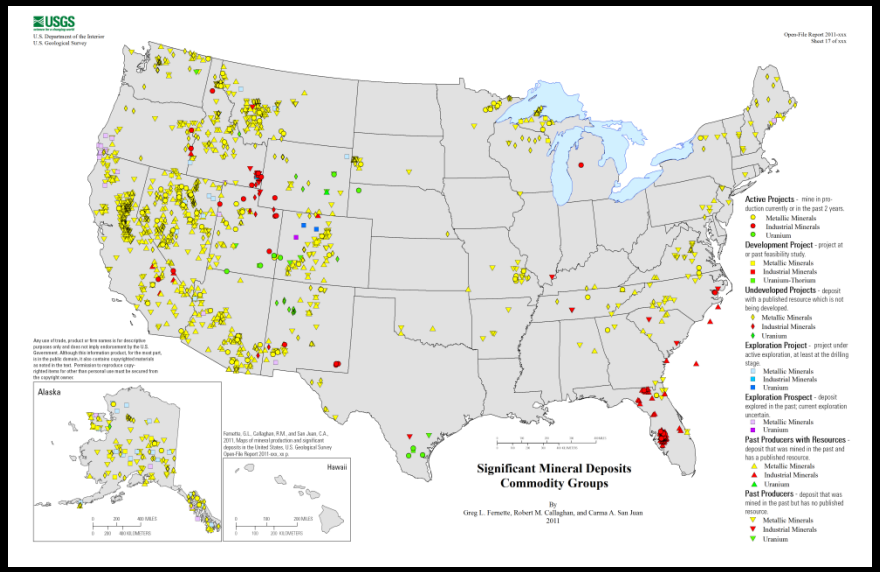
Important first step for assessment

Undiscovered resources

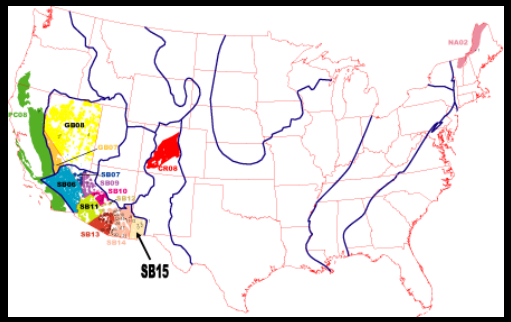
Long-term potential supply

Classified by mineral deposit type

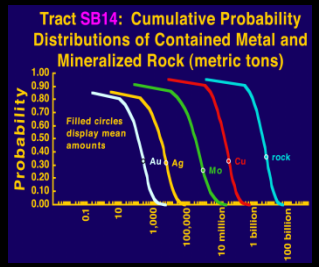
Qualitative and Quantitative



Where



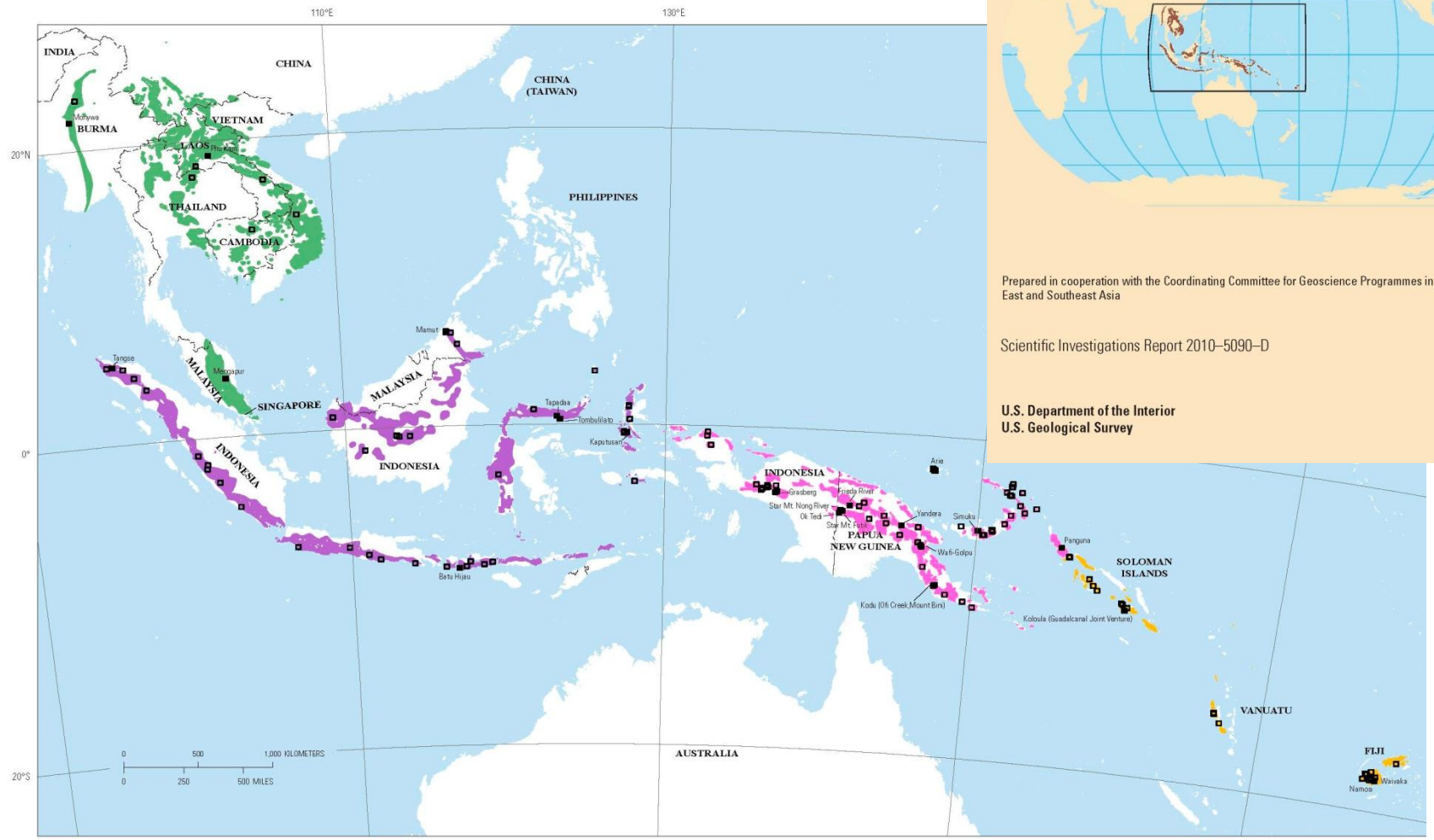
How much



Probabilistic

USGS

Indonesia is included in a report on parts of Southeast Asia and Melanesia



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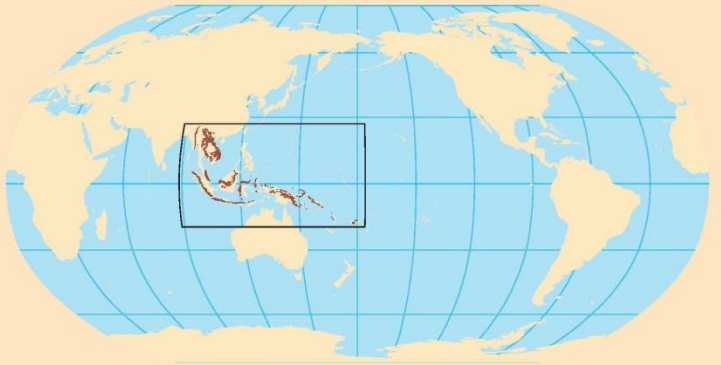
Global Mineral Resource Assessment

Porphyry Copper Assessment of Southeast Asia and Melanesia

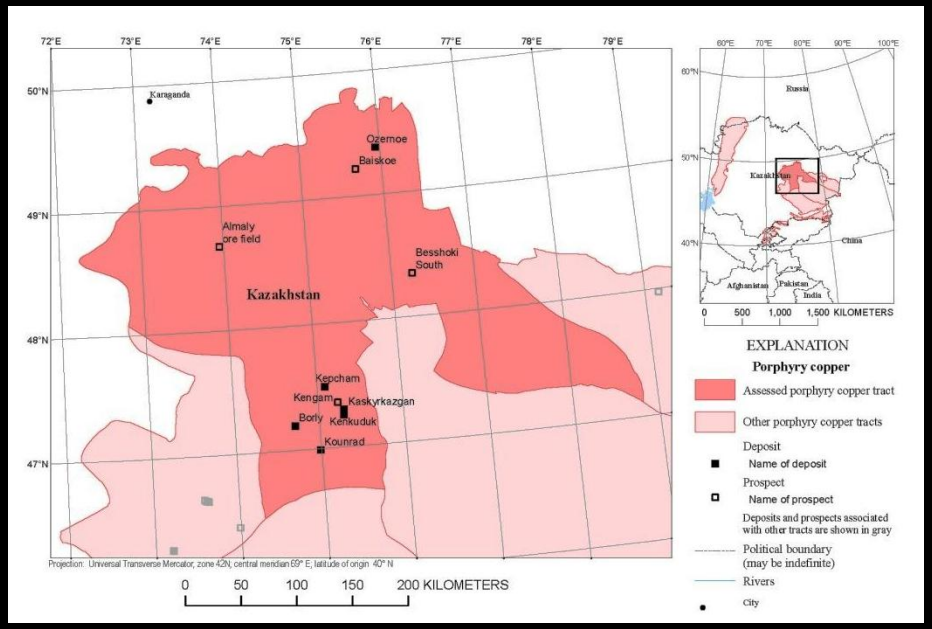


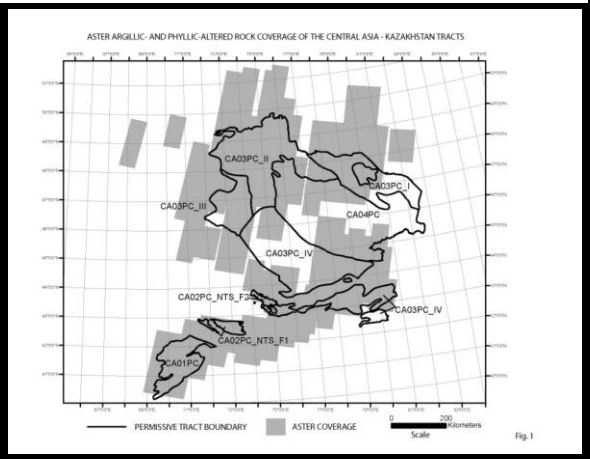
Prepared in cooperation with the Coordinating Committee for Geoscience Programmes in East and Southeast Asia

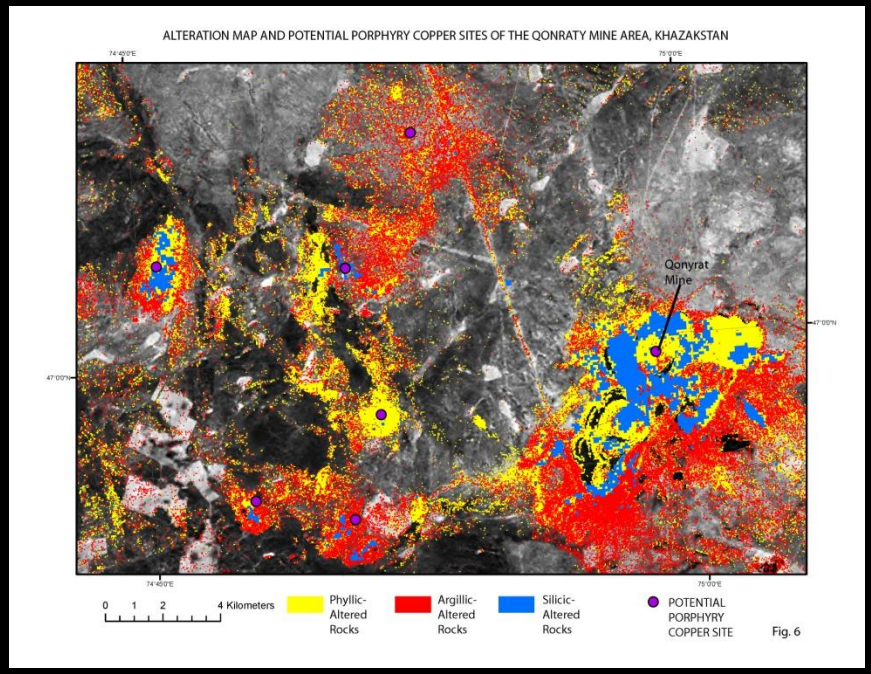
Scientific Investigations Report 2010–5090–D

U.S. Department of the Interior
U.S. Geological Survey

ASTER alteration mapping as a guide for porphyry copper estimates in Central Asia







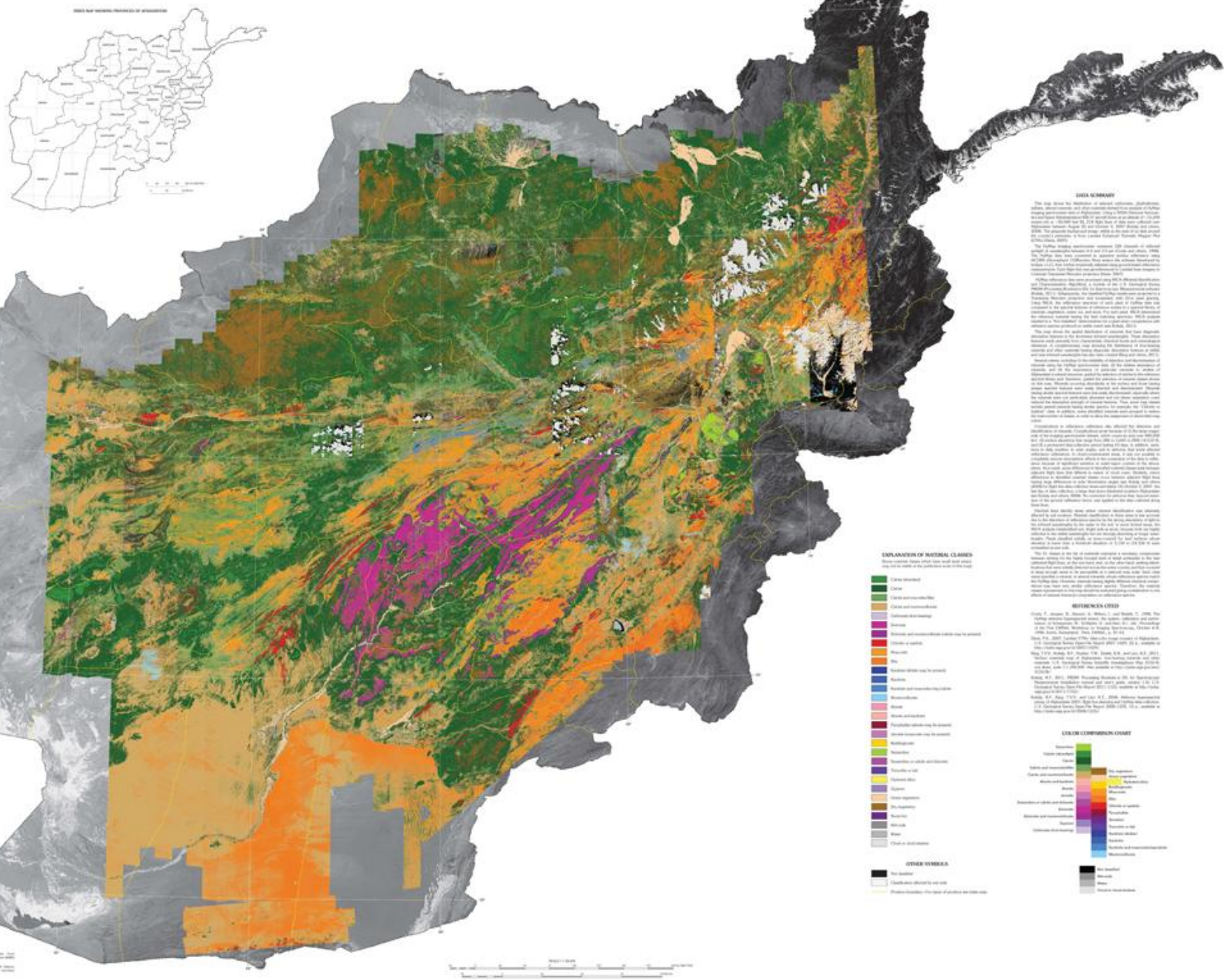
Tract area: 79,500 km^2

5 known deposits

90-50-10 Estimate: 1-5-12

5.8 expected undiscovered

USGS

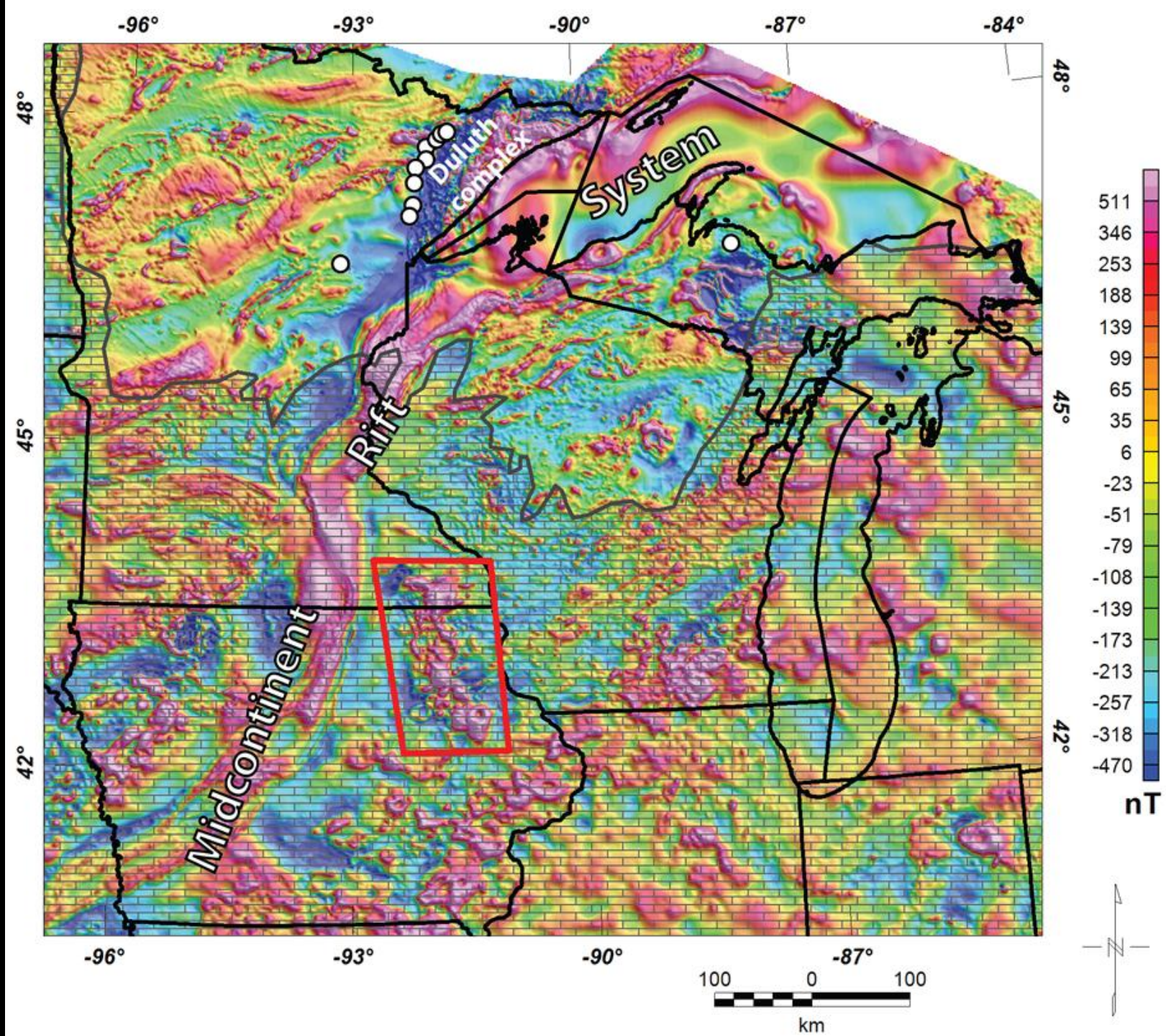


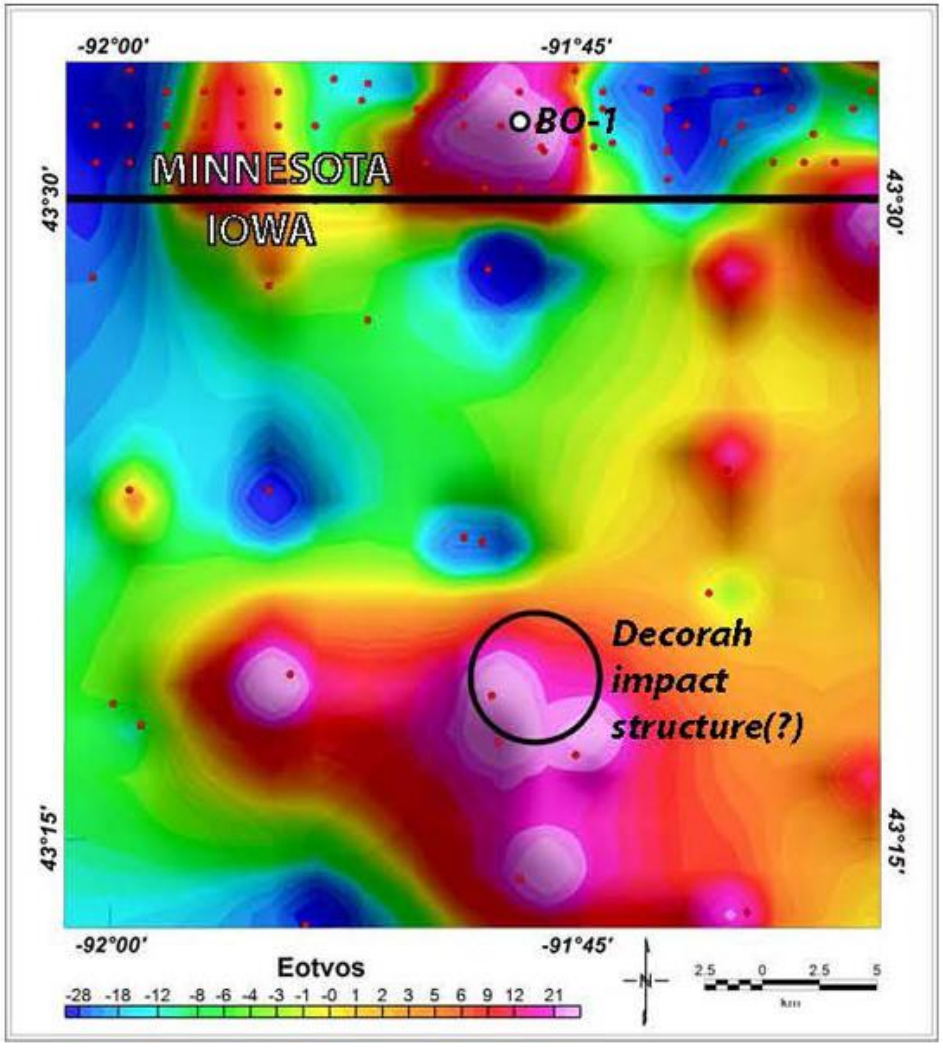
SURFACE MATERIALS MAP OF AFGHANISTAN: CARBONATES, PHYLLOSILICATES, SULFATES, ALTERED MINERALS, AND OTHER MATERIALS

By

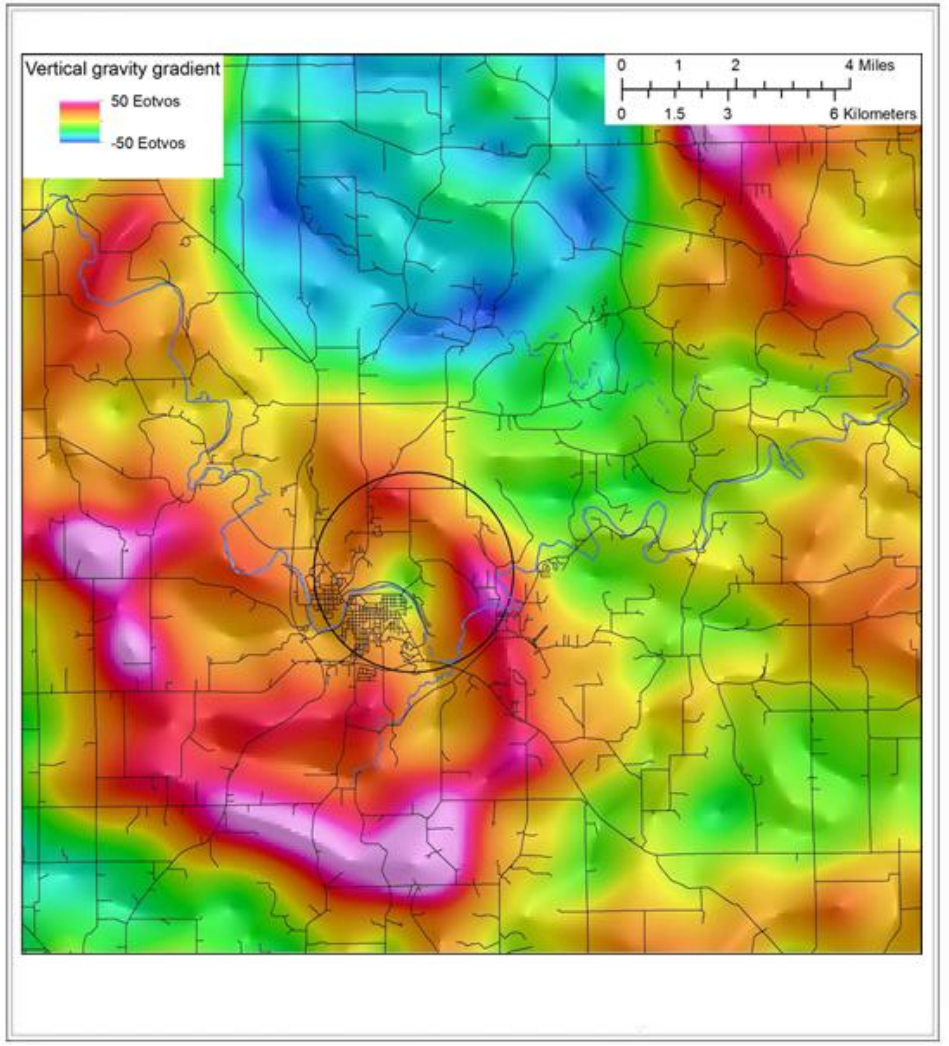
Raymond F. Kokaly, Trude V.V. King, Todd M. Hoefen, Kathleen B. Dudek, and Keith E. Livo

2011


-96°
-93°
-90°
-87°
-84°
48°
45°
42°
Duluth complex
System
Rift
Midcontinent
511
346
253
188
139
99
65
35
6
-23
-51
-79
-108
-139
-173
-213
-257
-318
-470
nT
100
0
100
km
N



Old ground vertical gradient, calculated

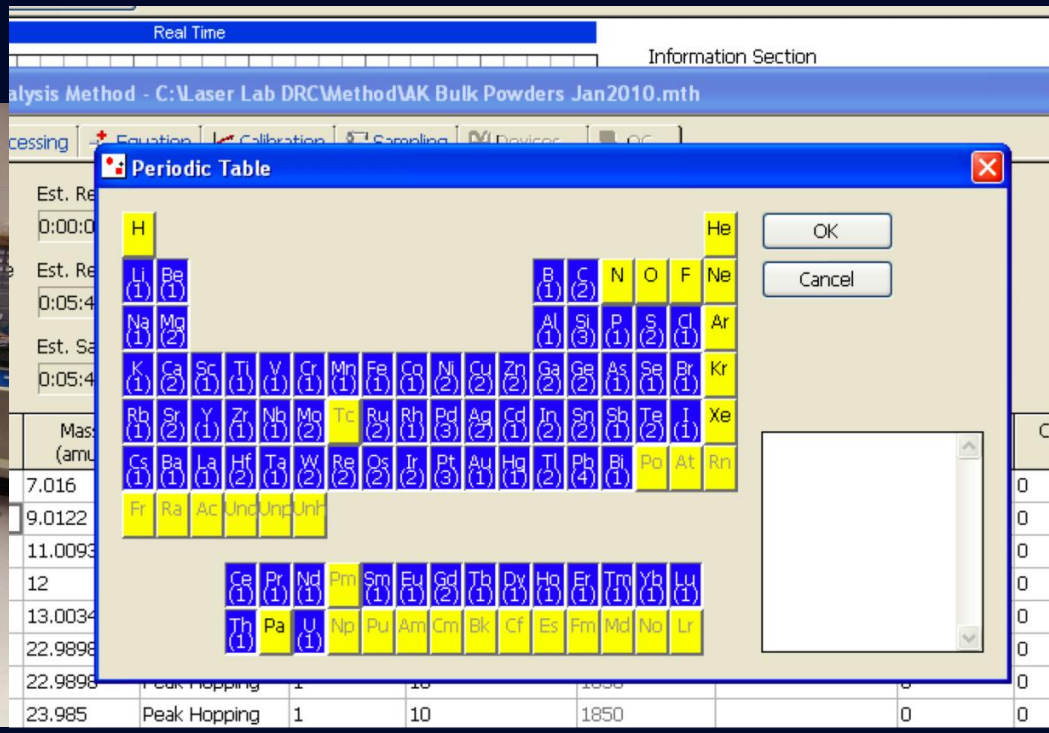


New airborne vertical gradient, measured

Inventory and Characterization of Byproduct Critical Mineral Resources

Critical Metal Content of Domestic Mineral Deposits

New USGS Laser Ablation Bulk ICP-MS Method



- Low cost, efficient, and accurate analytical method
- Entire periodic table (minus H, He, N, O and F) in a single rapid analysis
- Trace and ultra trace detection (ultra trace to less than 10 ppb in some cases)
- 100+ analyses per day

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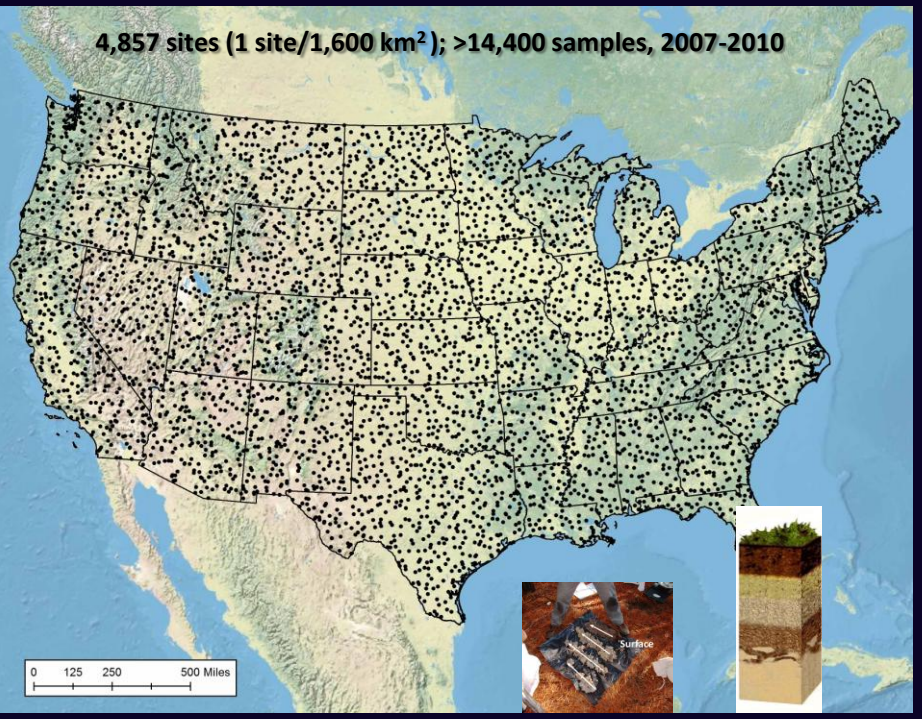
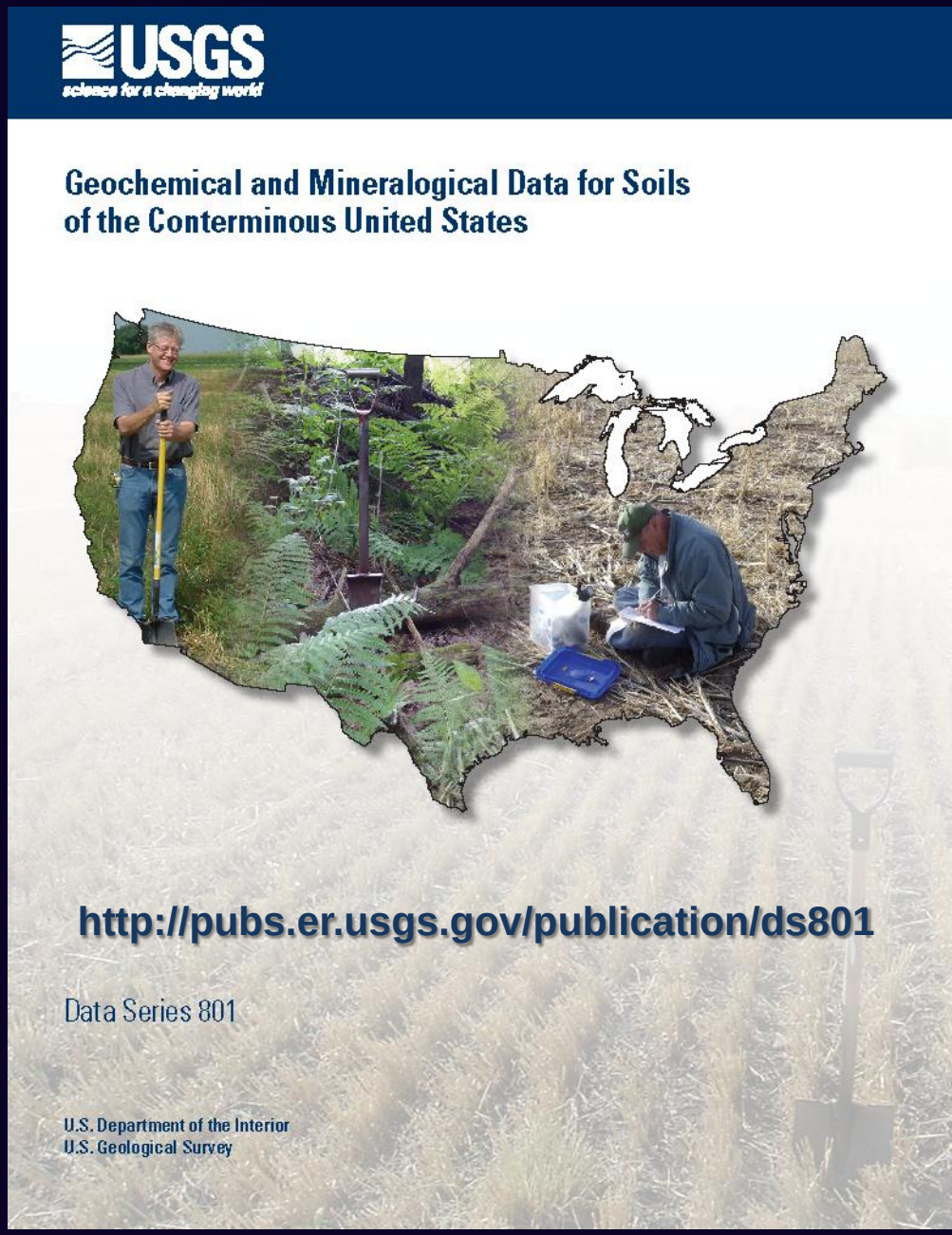
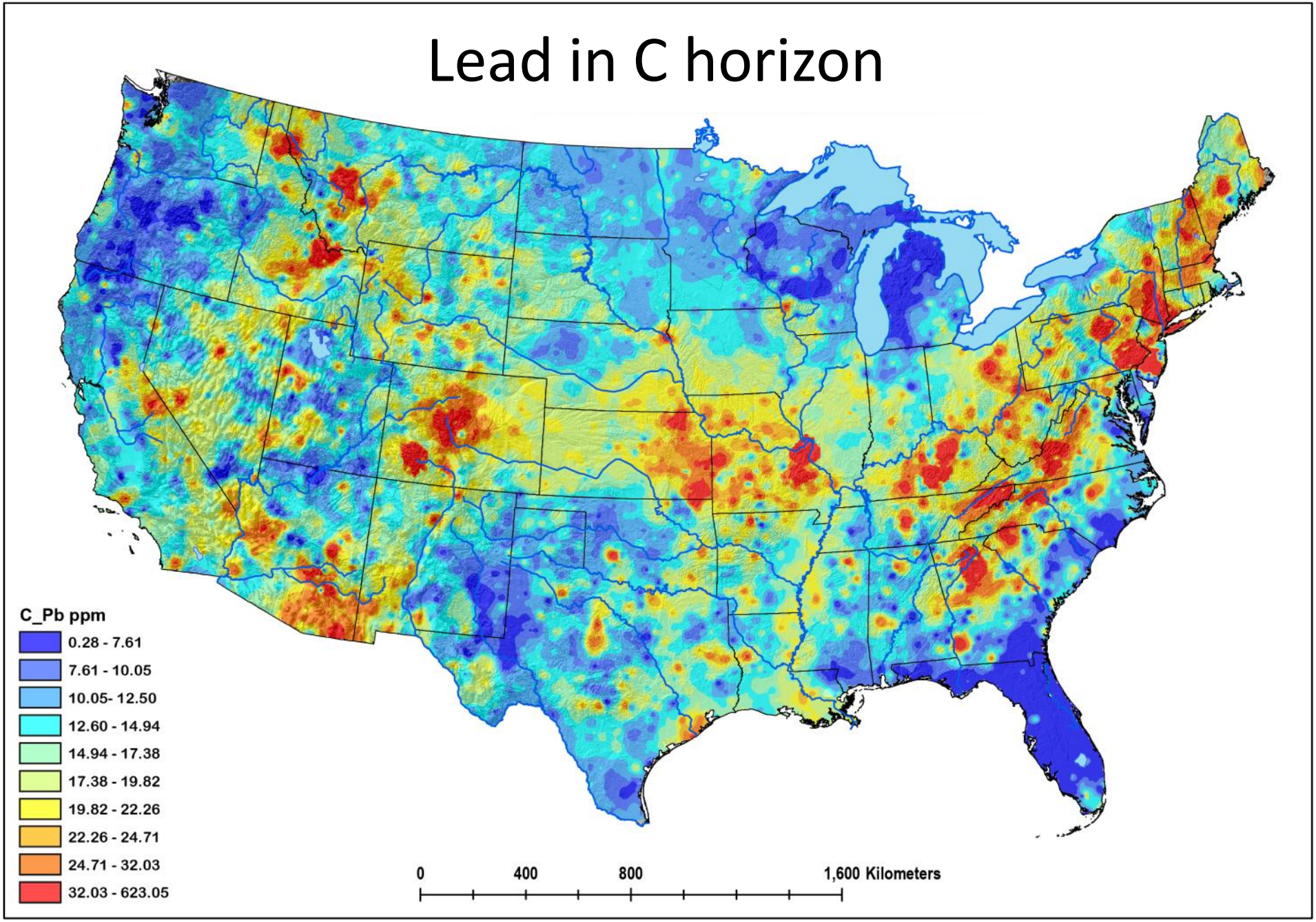
New National-scale Soil Geochemical and Mineralogical Data for the Conterminous United States



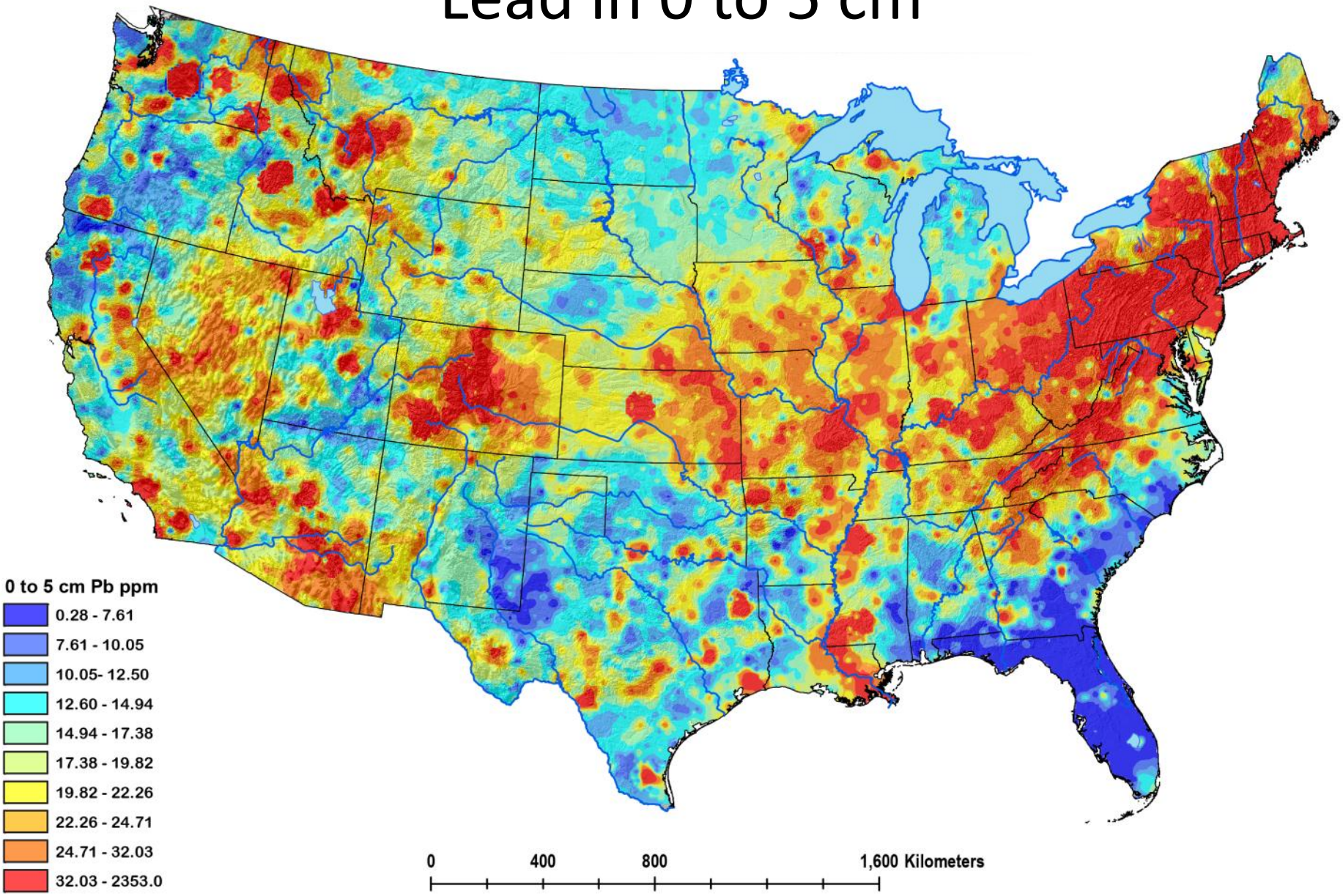
U.S. Department of the Interior
U.S. Geological Survey



Lead in C horizon



Lead in 0 to 5 cm



General information:

minerals.usgs.gov/

Products available online at:

minerals.usgs.gov/global/
minerals.usgs.gov/minerals

Contact information:

Larry Meinert
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SPEAKERS

Joe Gambogi
U.S. Geological Survey

U.S. Department of the Interior
U.S. Geological Survey

Market Update for Rare Earths

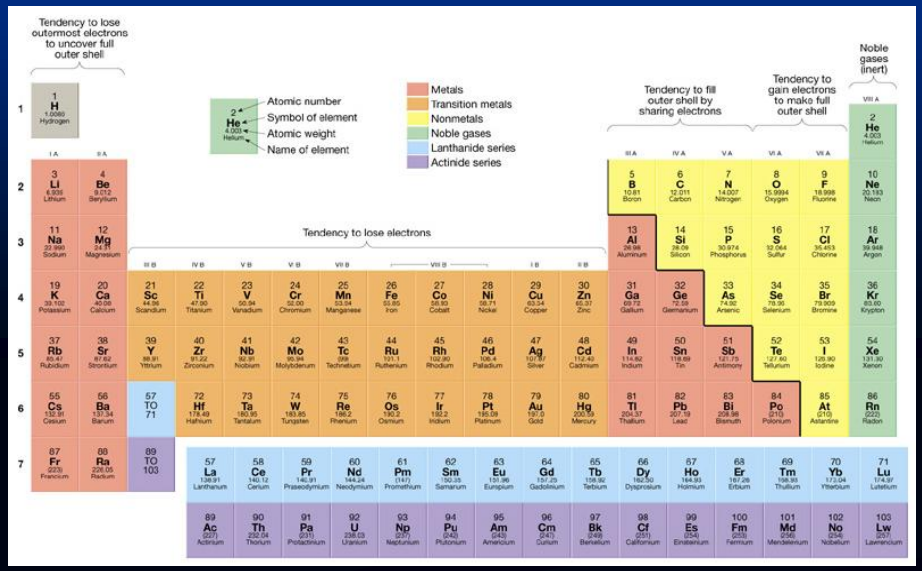
2013 USGS Congressional Briefing Series
December 13, 2013

Joseph Gambogi
Rare Earth Commodity Specialist
USGS National Minerals Information Center

U.S. Department of the Interior
U.S. Geological Survey

Rare Earths — the Lanthanide Series, Scandium, and Yttrium

	Atomic #	Symbol	Name
	21	Sc	Scandium
Light Rare Earth Elements	57	La	Lanthanum
	58	Ce	Cerium
	59	Pr	Praseodymium
	60	Nd	Neodymium
	61	Pm	Promethium
	62	Sm	Samarium
	63	Eu	Europium
	64	Gd	Gadolinium
Heavy Rare Earth Elements	65	Tb	Terbium
	66	Dy	Dysprosium
	67	Ho	Holmium
	68	Er	Erbium
	69	Tm	Thulium
	70	Yb	Ytterbium
	71	Lu	Lutetium
	39	Y	Yttrium



USGS

Uses

- Catalysts: Ce, La, Nd
- Metallurgical
  - Alloys
  - Batteries: La, Ce, Nd, Pr
- Magnets: Nd, Pr, Sm, Dy, Tb
- Polishing: Ce, La, Nd
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  - Ceramics: Y
  - Phosphors: Eu, Y, Tb
  - Electronics
  - Fiber optics and lasers: Er, Y, Nd, Yb, Tm, Pr, Ho
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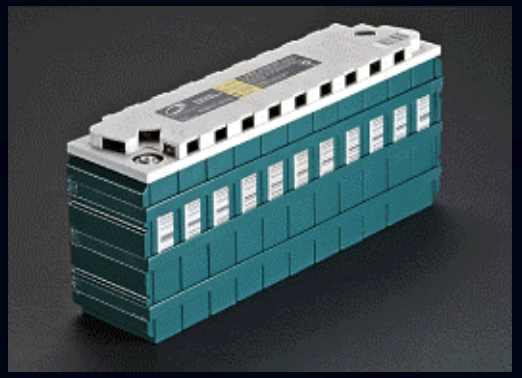
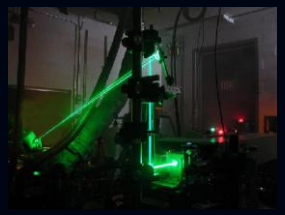
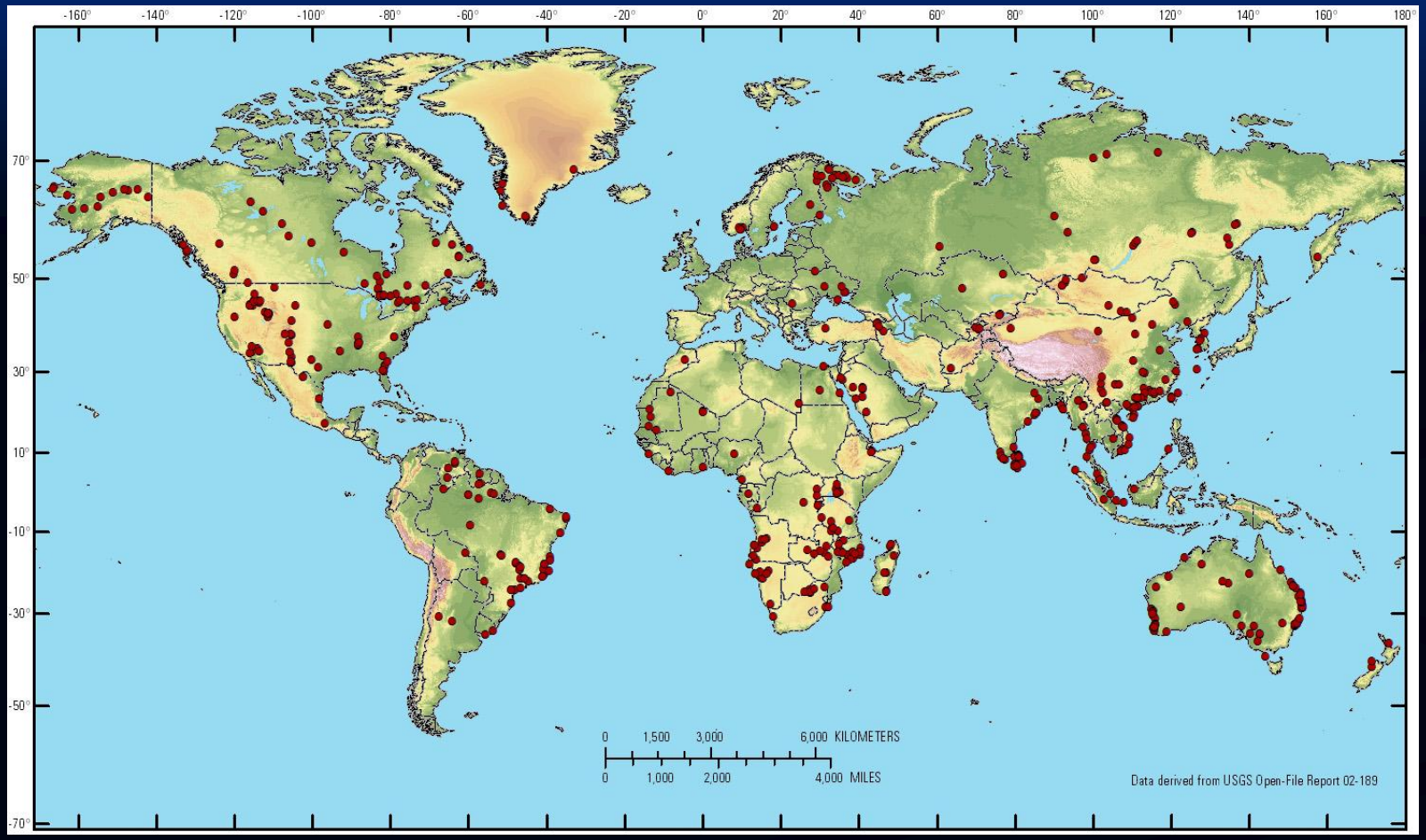
  - Neutron absorption: Nd





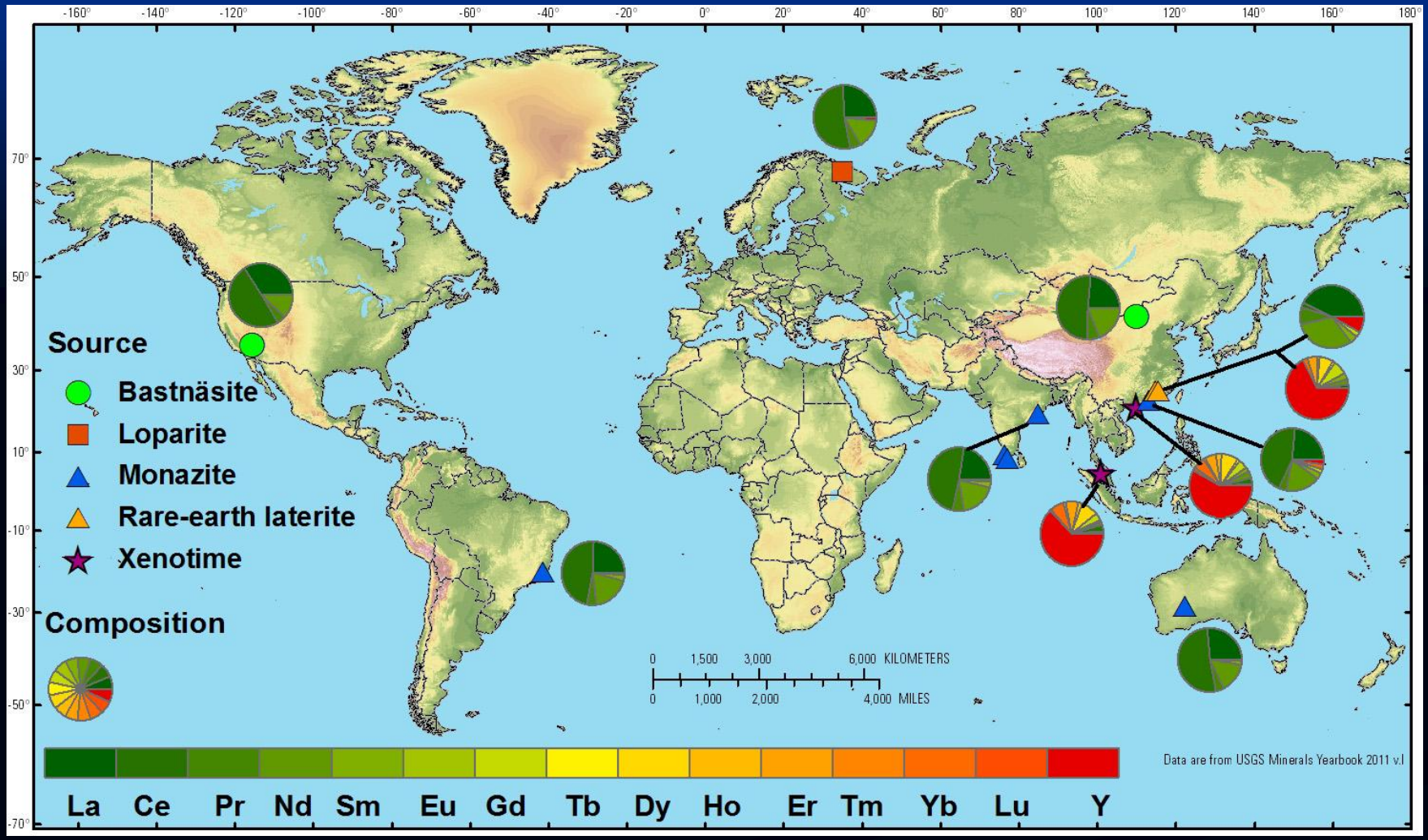
USGS

Global Rare–Earth Deposits and Occurrences



USGS

Rare–Earth Mining Locations



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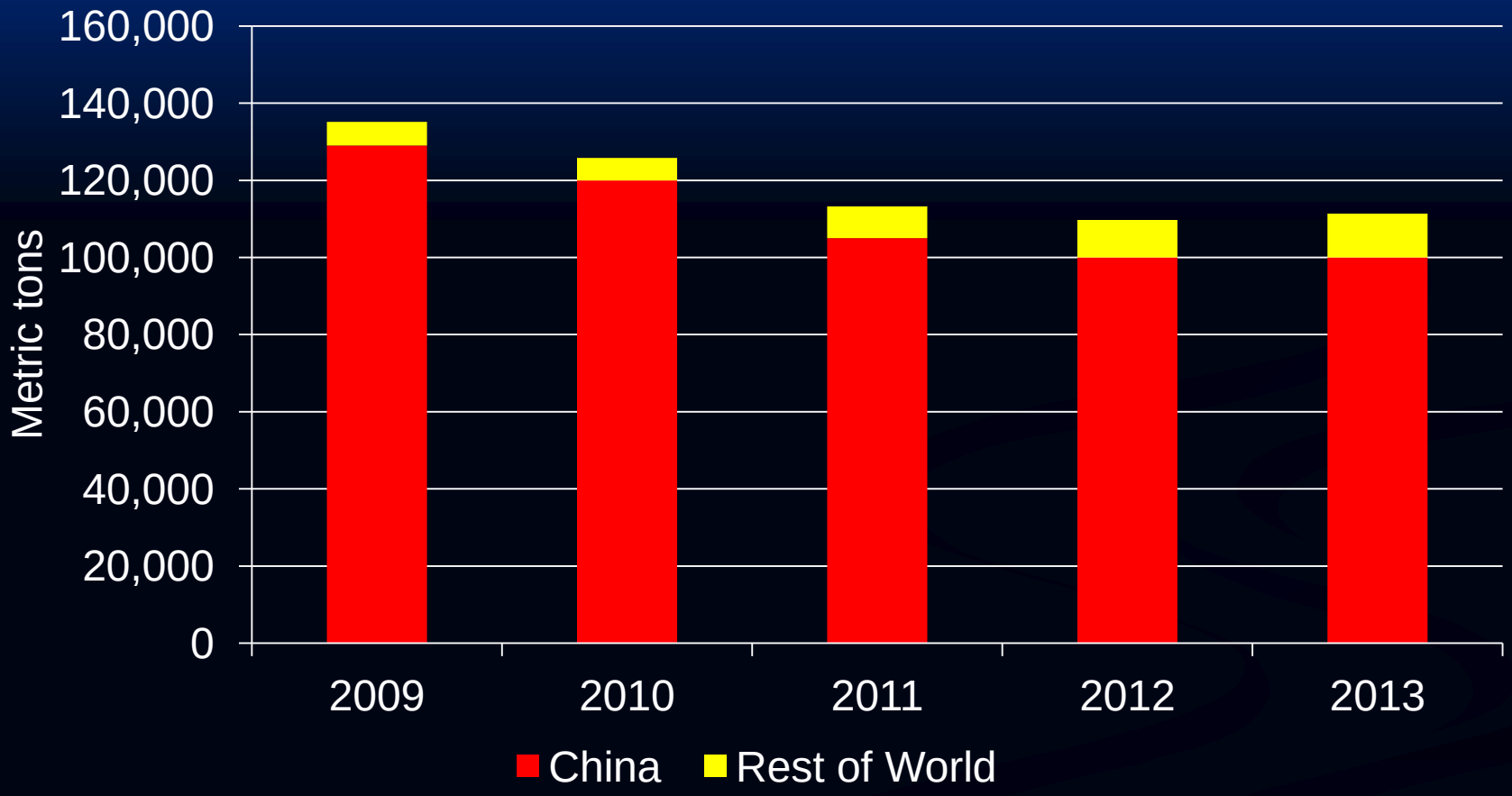
Supply—Rare–Earth Oxide World Mineral Production Trends 2009–2013



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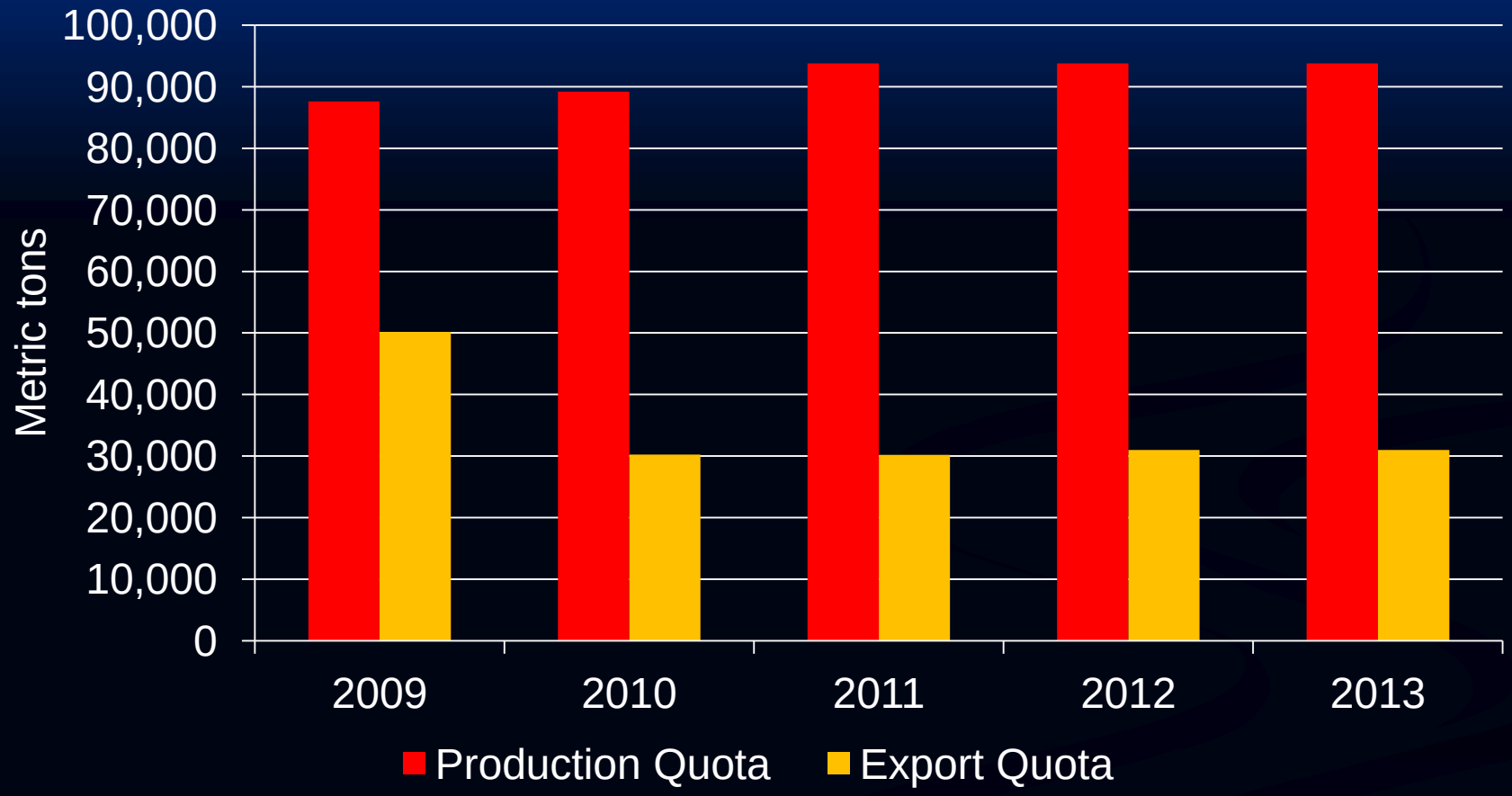
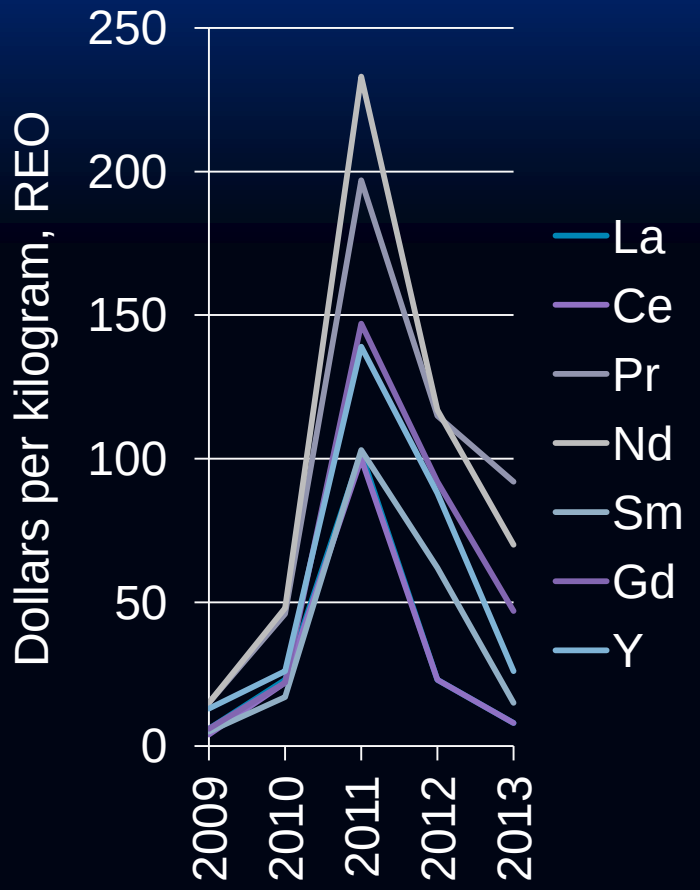
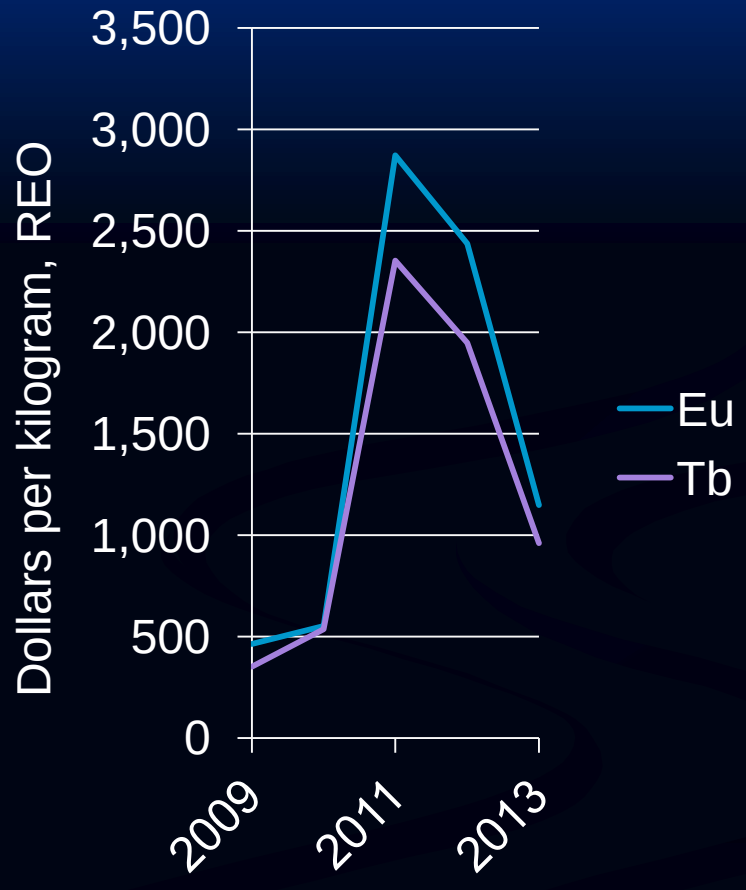
China's Rare-Earth Production and Export Quotas



USGS

Average Prices of Selected Rare-Earth Oxides (REO)

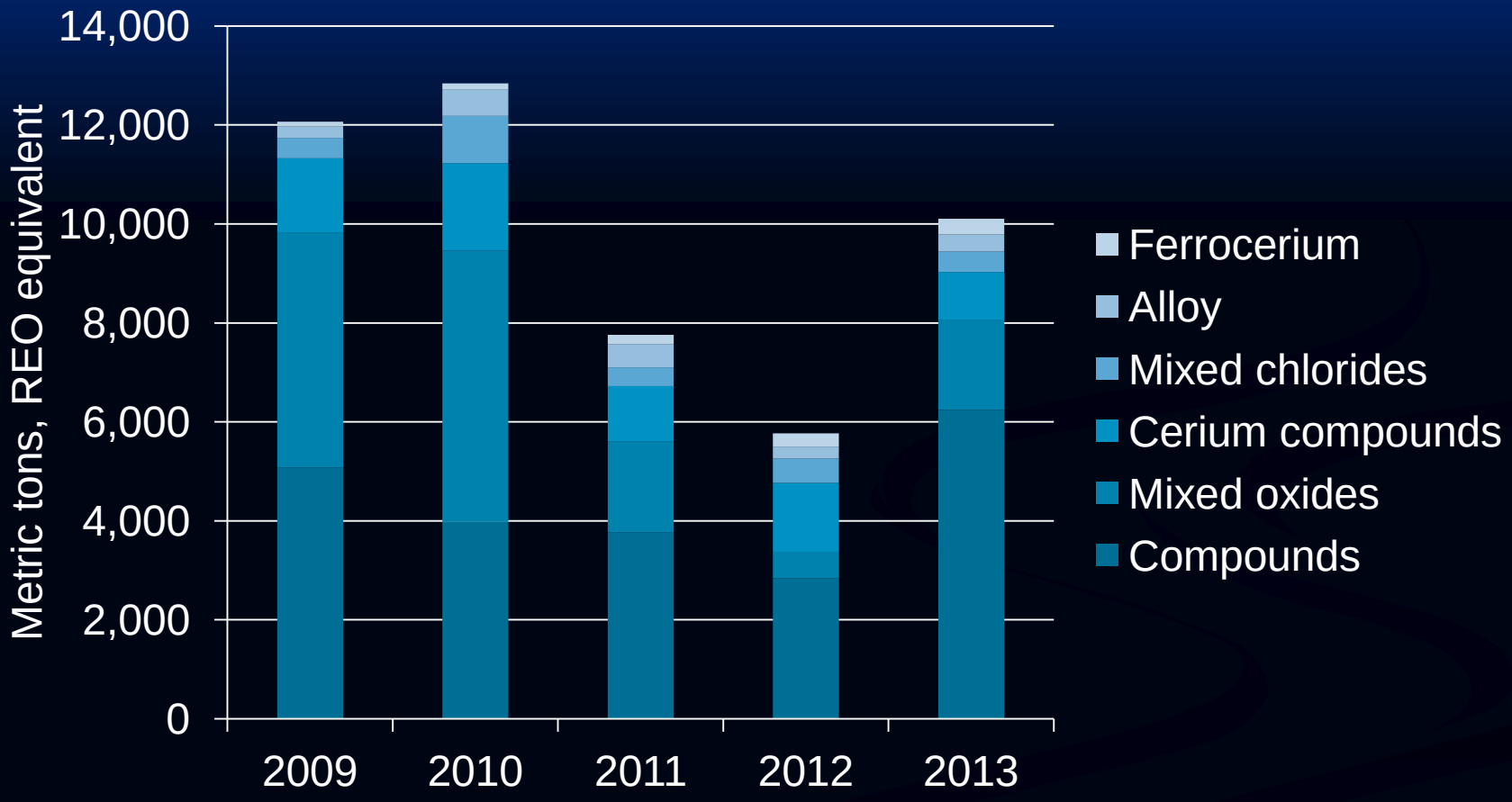




USGS

Source: Metal-Pages Ltd

U.S. Imports for Consumption of Rare–Earth Materials



USGS

Closing Thoughts

- China continues to dominate rare-earth supply
- Numerous projects for mining and separation underway
- Prices of rare-earths have decreased significantly
- U.S. imports of rare-earths increased in 2013
- Consumers pursuing conservation and recycle programs

USGS

Contact Information

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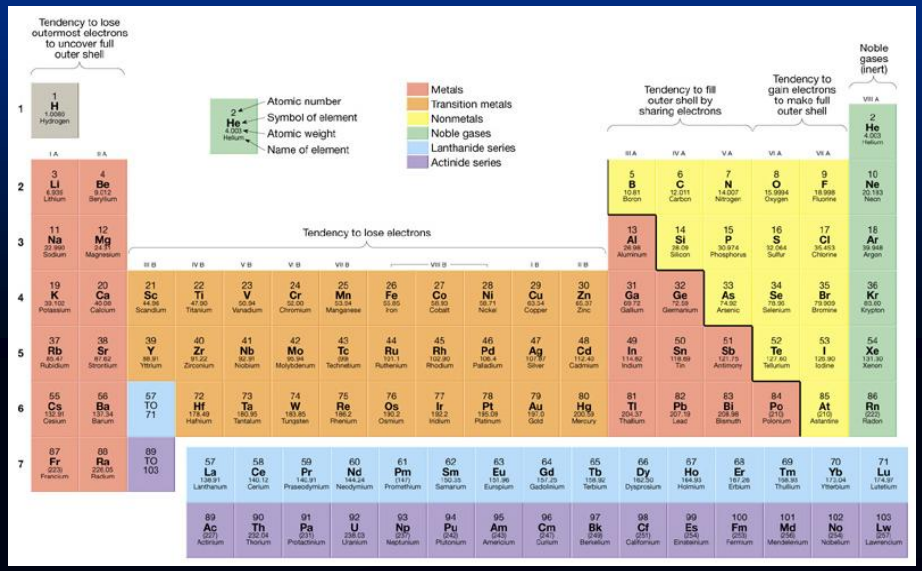

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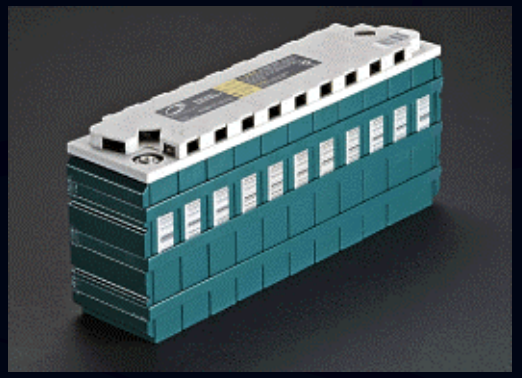

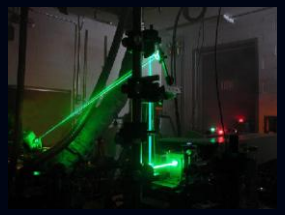

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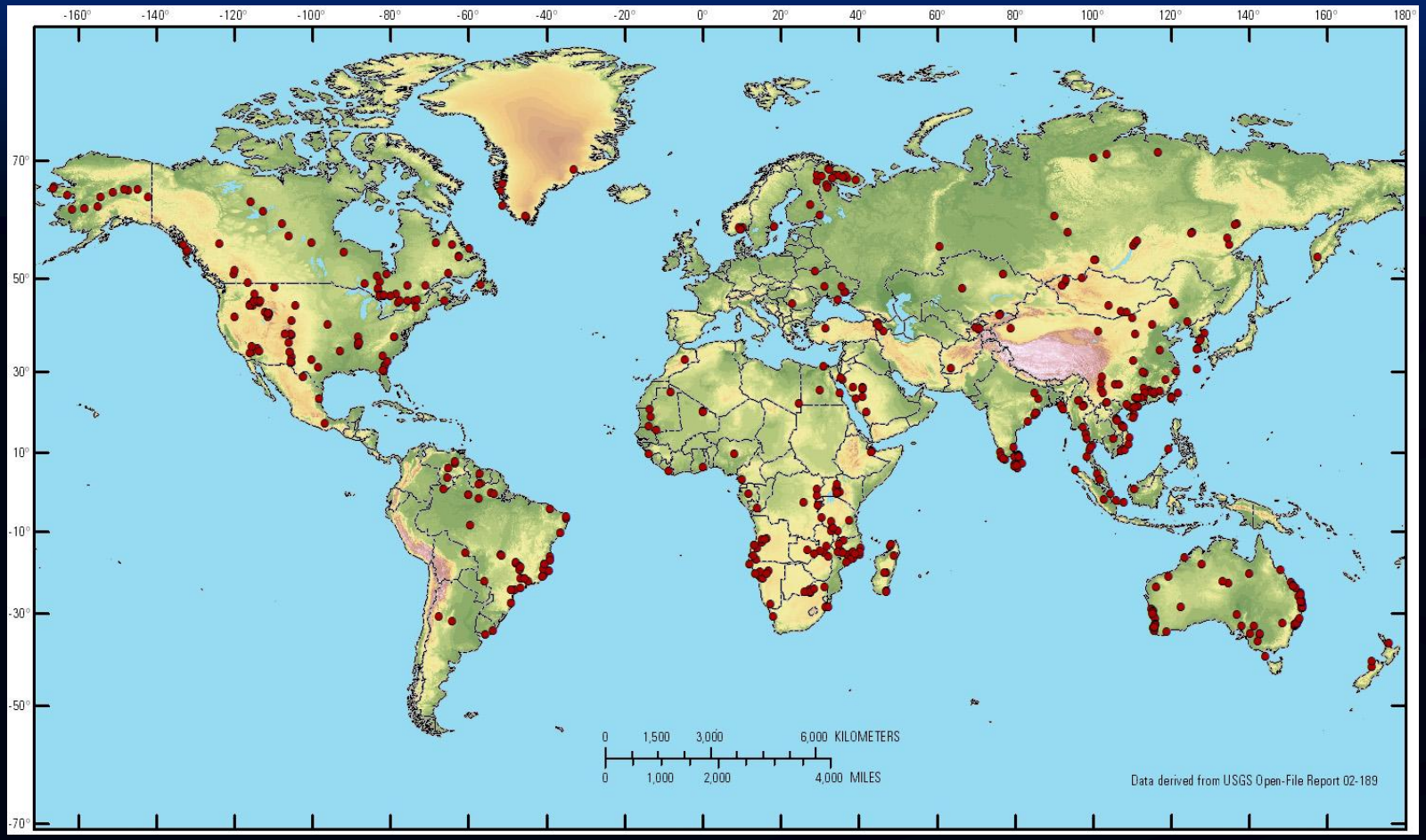

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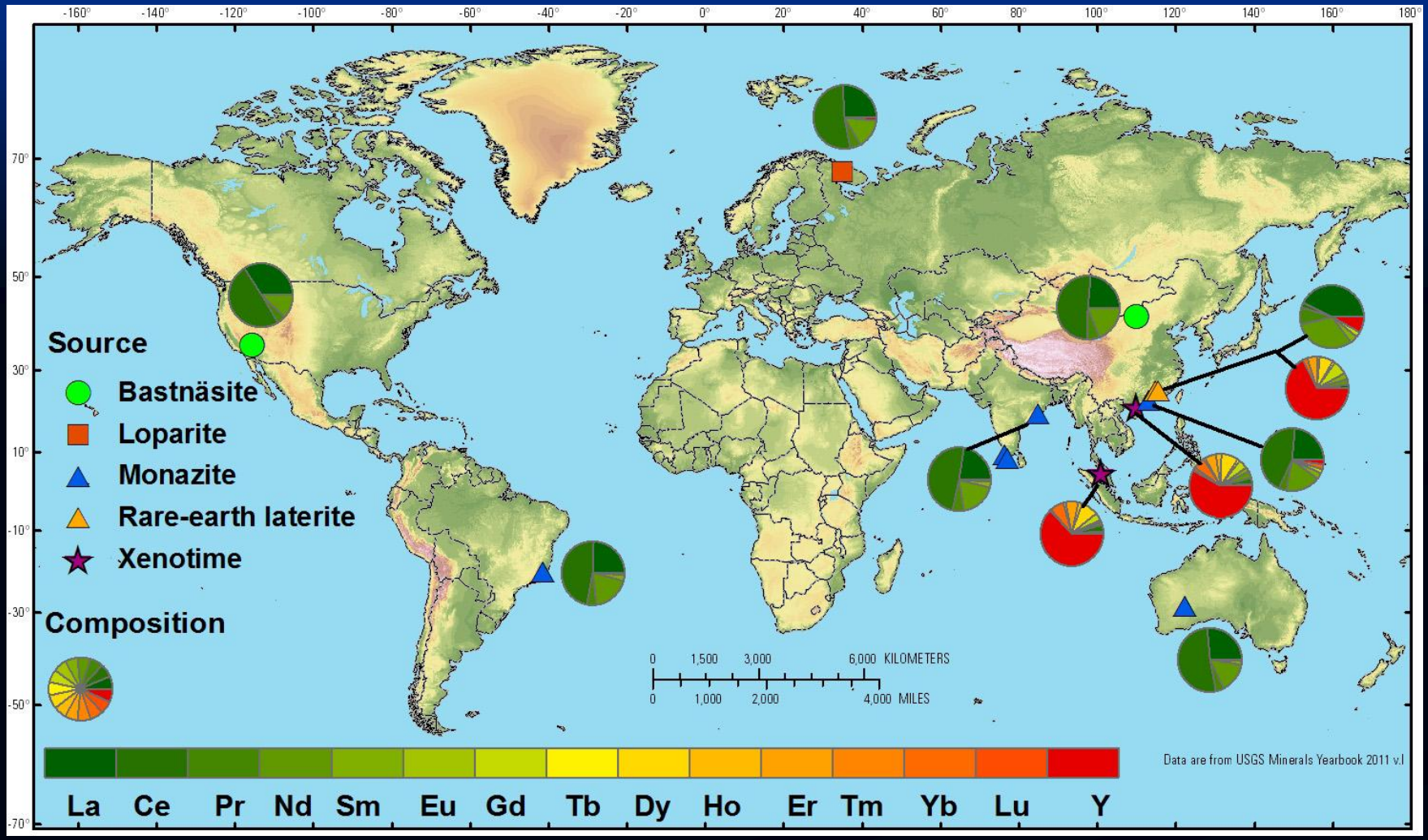

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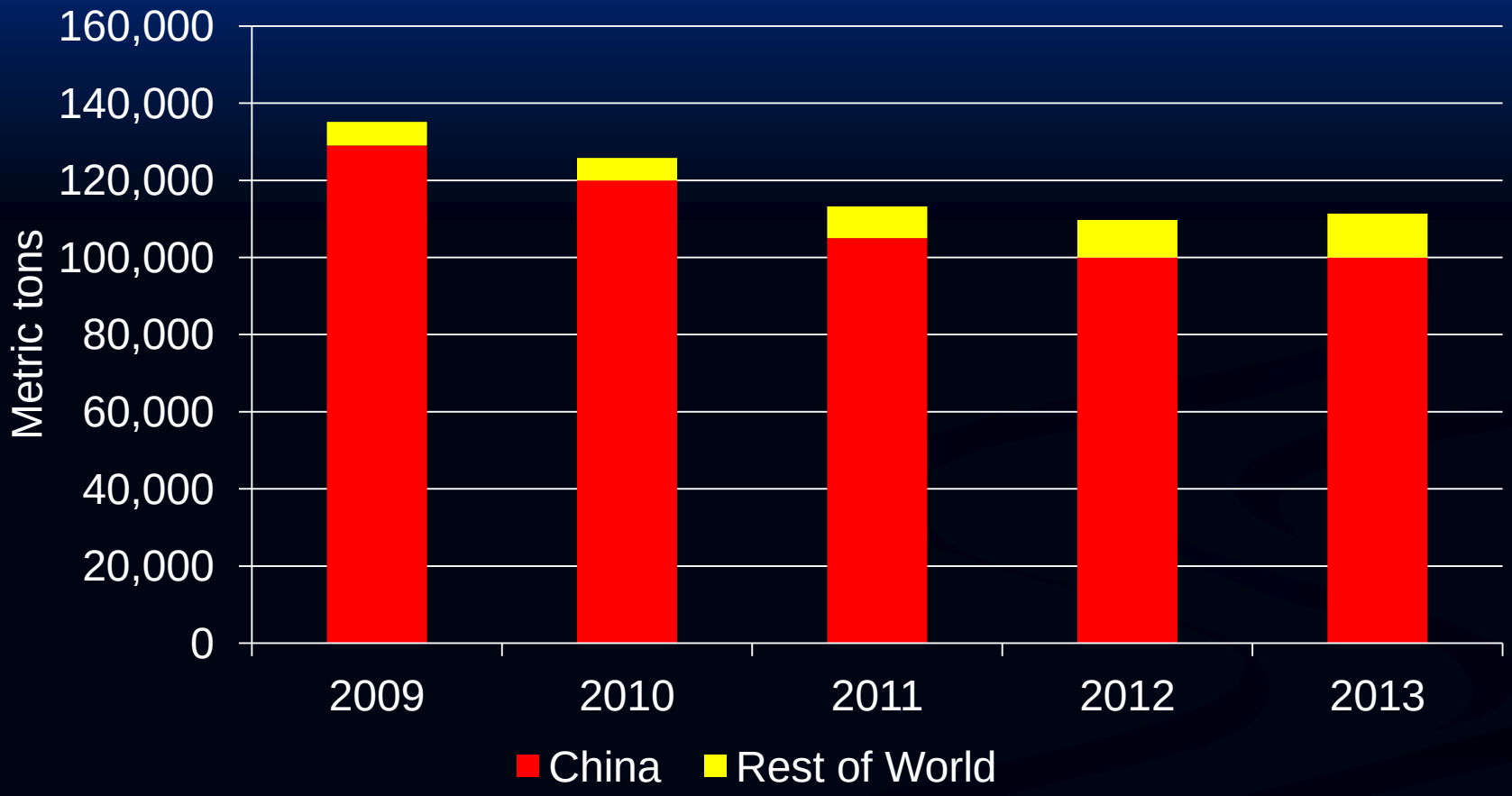

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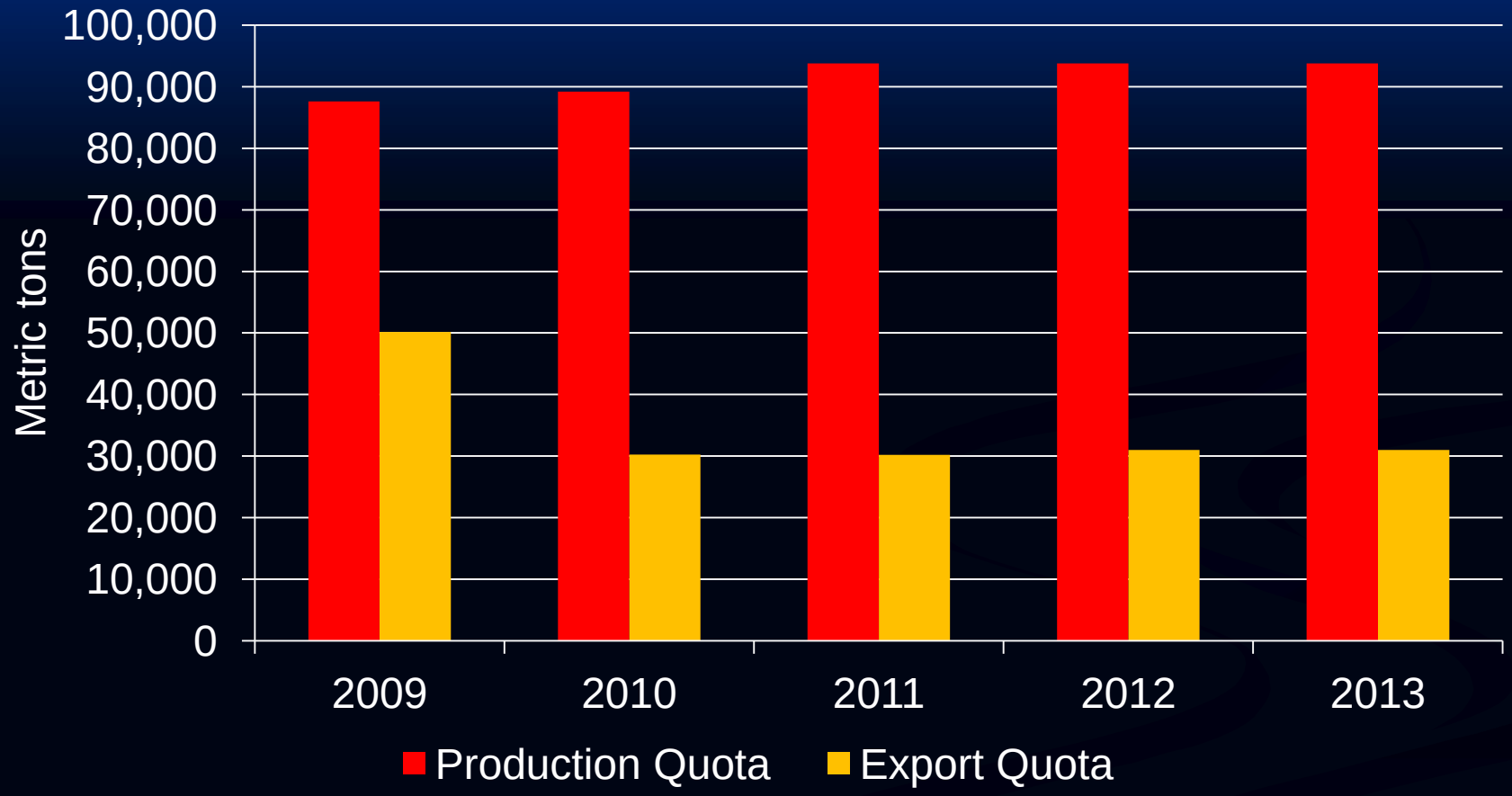

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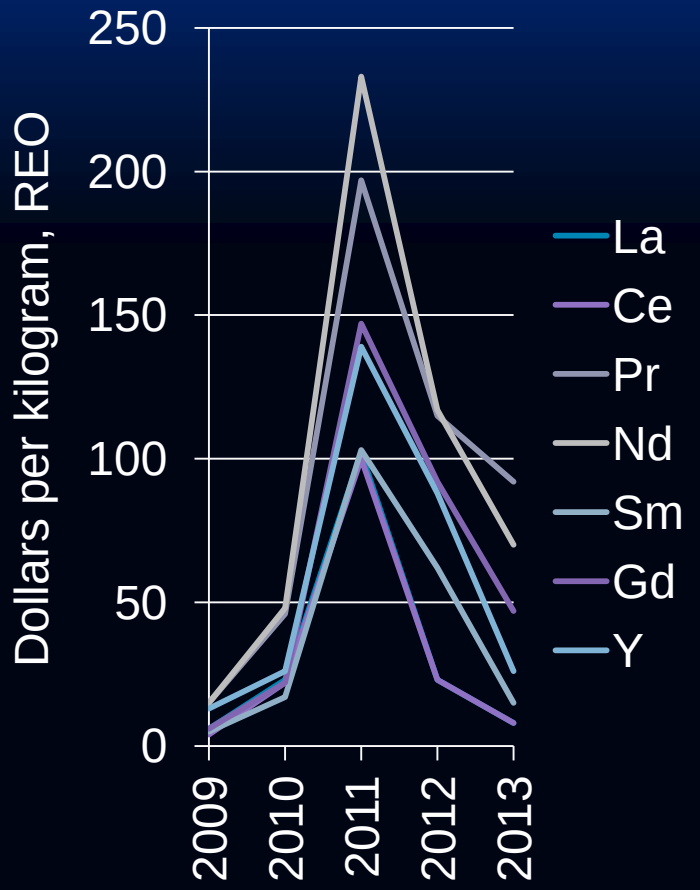

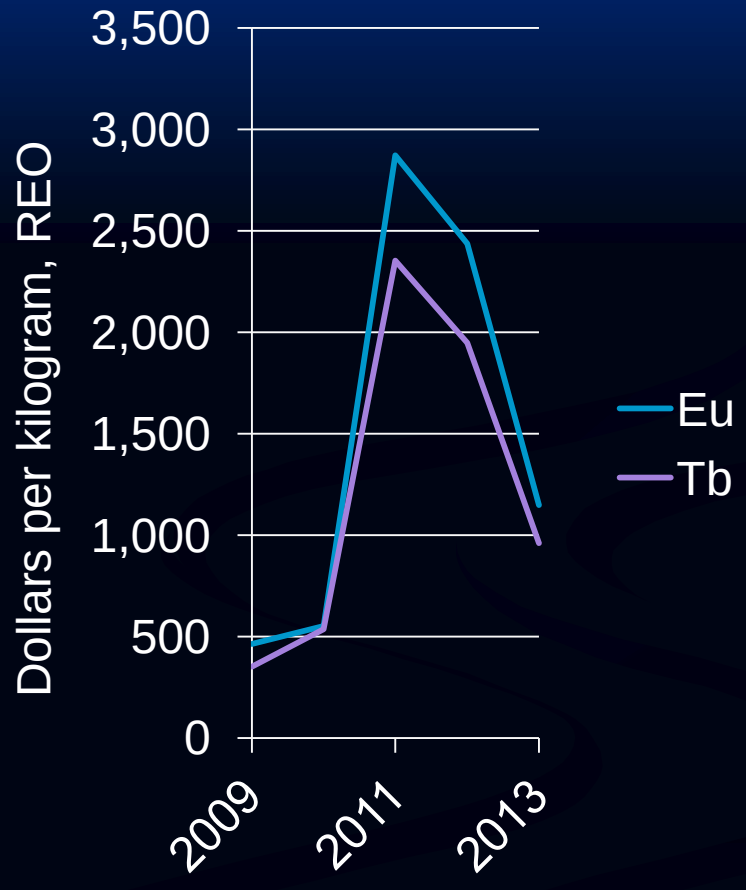

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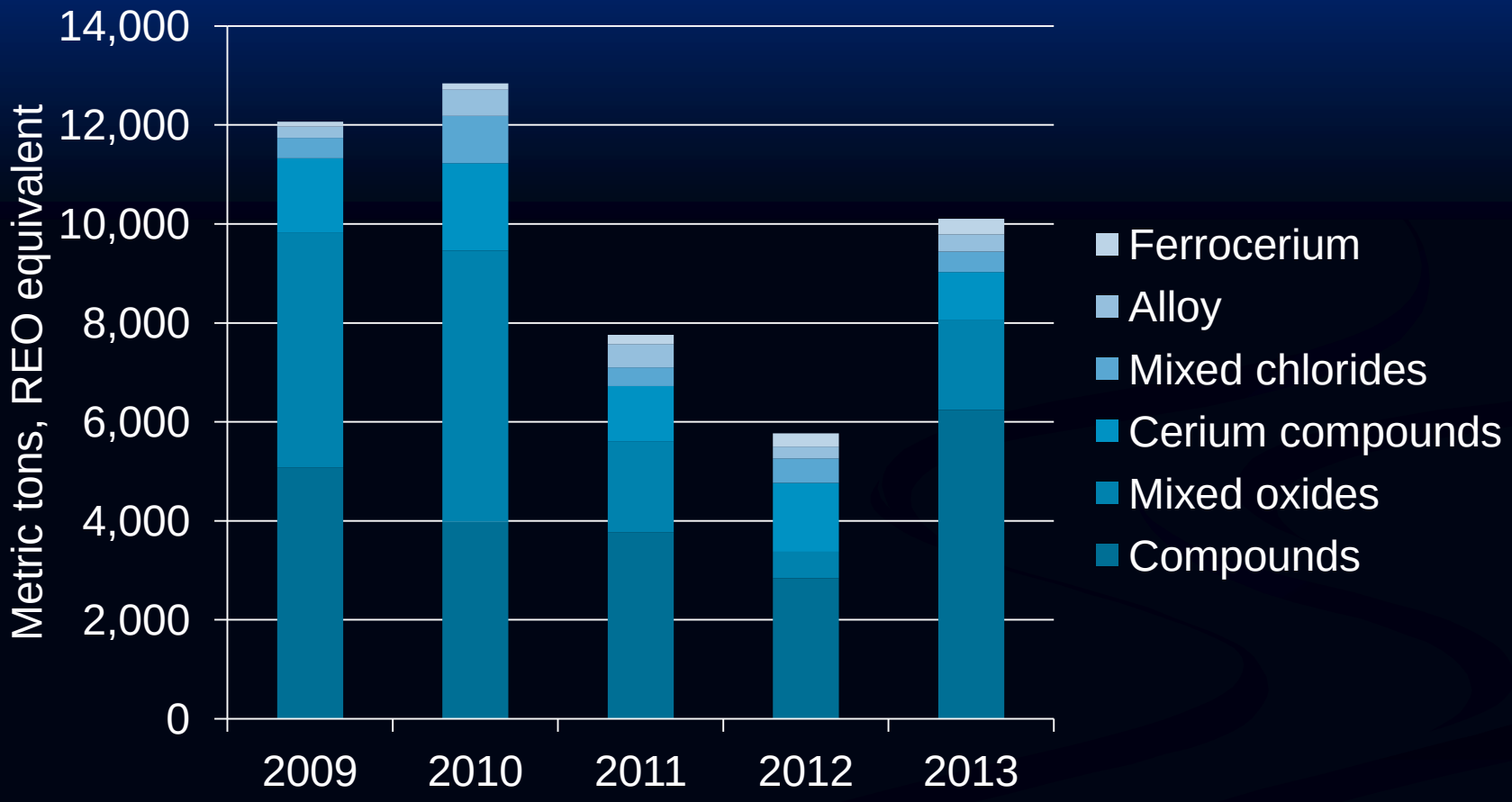

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Nevada Bureau of Mines and Geology (Emeritus)

Larry Meinert
U.S. Geological Survey

Joe Gambogi
U.S. Geological Survey

Please check out the Energy and Minerals Science Strategy at:
http://pubs.usgs.gov/fs/2013/3111

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