



# The Importance of Mineral Resources in a National-International Context

- 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.

# Iron

- Iron-ore production (millions of tonnes)
- World population (millions)
- Per capita consumption (10X kg/person)

~4X more population than 100 years ago

~4X more per capita consumption than 100 years ago

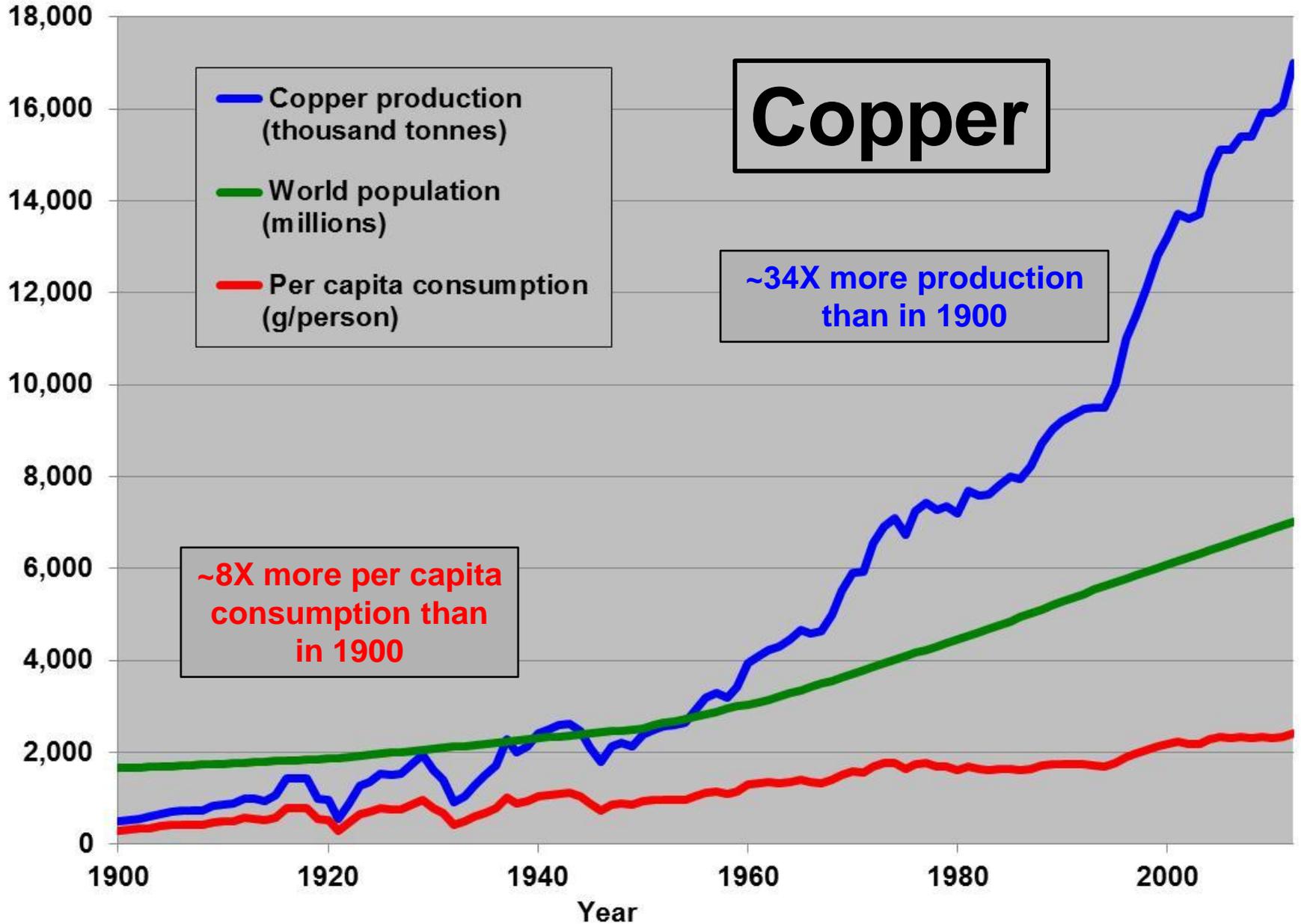
~18X more production than 100 years ago

1900 1920 1940 1960 1980 2000

Year

Source: USGS, CIA

Demand is high for nearly every mineral resource, due to rising population and average standard of living.



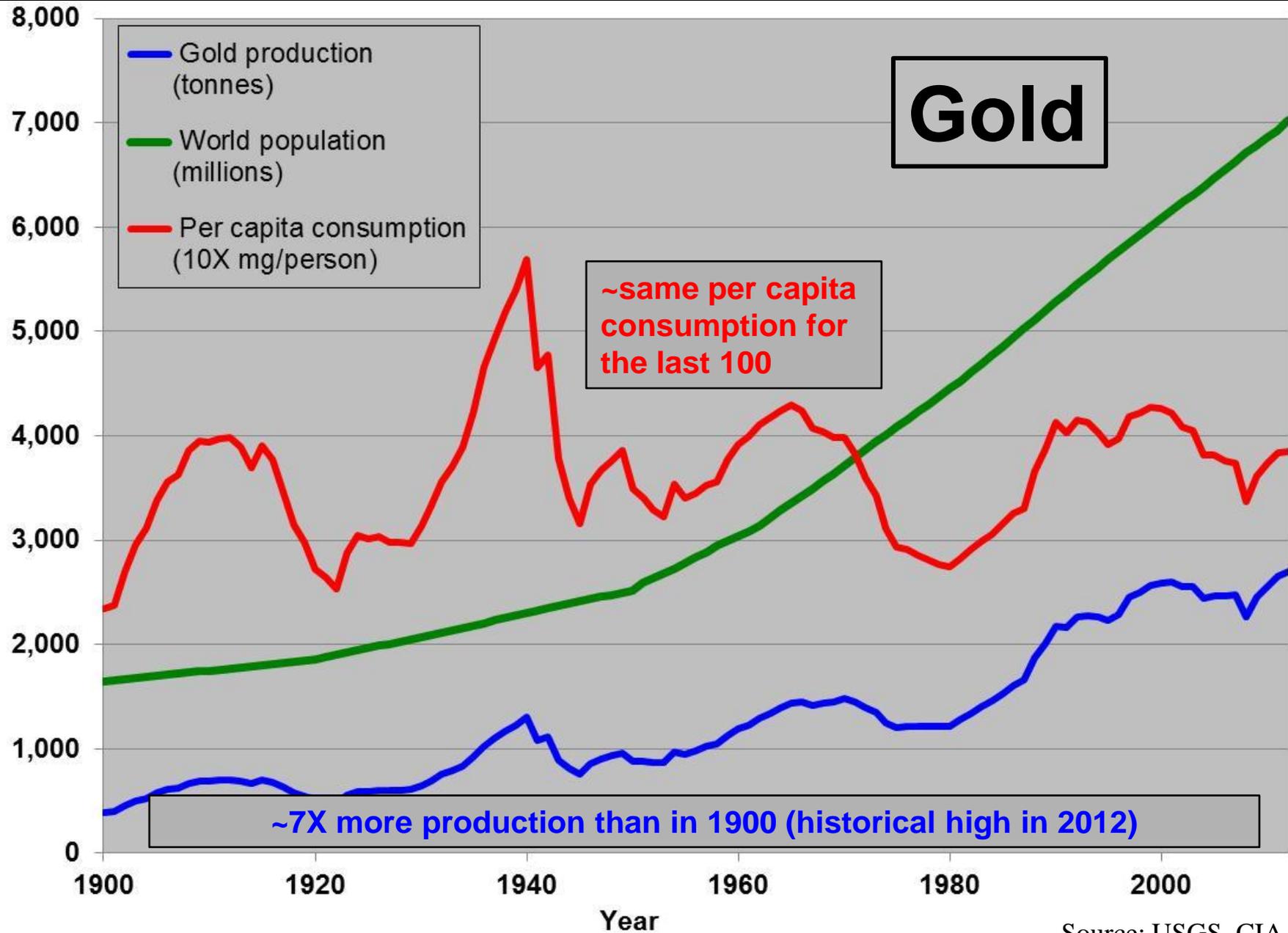
Source: USGS, CIA

**Demand is high for nearly every mineral resource.**

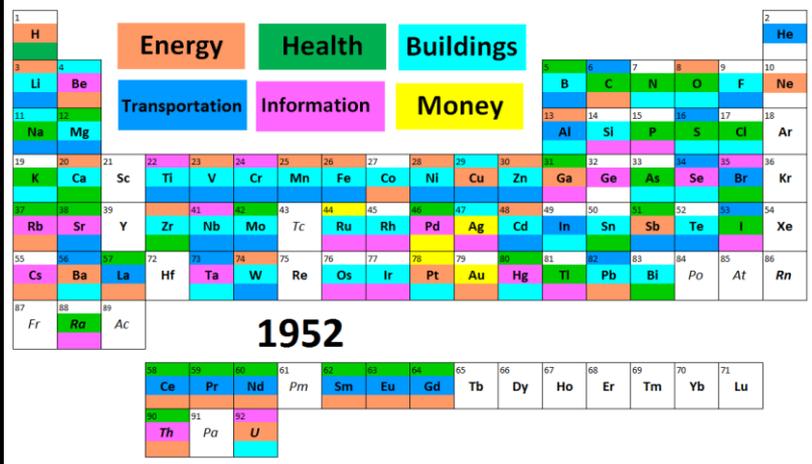
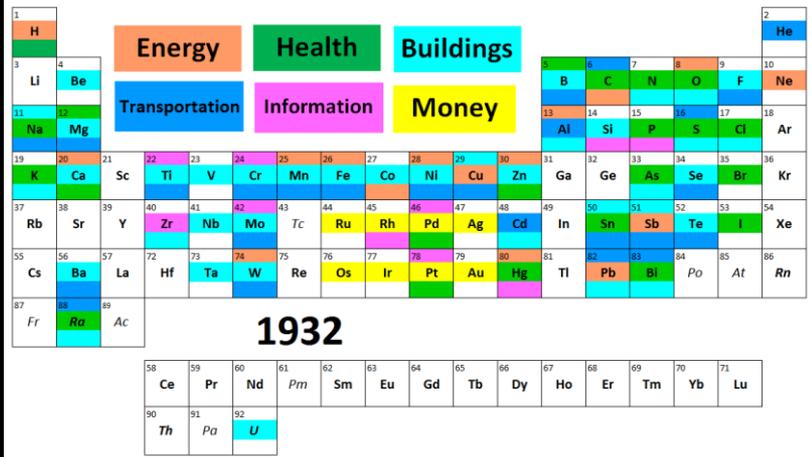


Photo copyrighted by Michael Collier, from the AGI website, Rio Tinto/Kennecott Utah Copper mine; the remaining resource as of 16 May 2008 = 3.06 million metric tons of Cu

**Global copper production in 2012 (17.0 million metric tons) equaled over 100 years of production from the Bingham Canyon mine in Utah (17.0 million metric tons).**



**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

**Economic geologists have been quite successful in finding more ore deposits in known areas.**



2013

**The Round Mountain gold mine in Nevada (volcanic-rock-hosted deposit) discovered in 1904, has yielded 13 million ounces of gold from 1977 to 2012 – continuous record of discovery around the initial deposit.**

# Gold production, 1835-2012

Annual gold production (millions of troy ounces)

■ United States  
■ Nevada

The current boom (1981-2012) = 247M oz Au

(mostly Carlin and other Nevada deposits = 174M oz)

Goldfield (NV), Black Hills (SD), Cripple Creek (CO), porphyry Cu (AZ & UT) = 95M oz Au

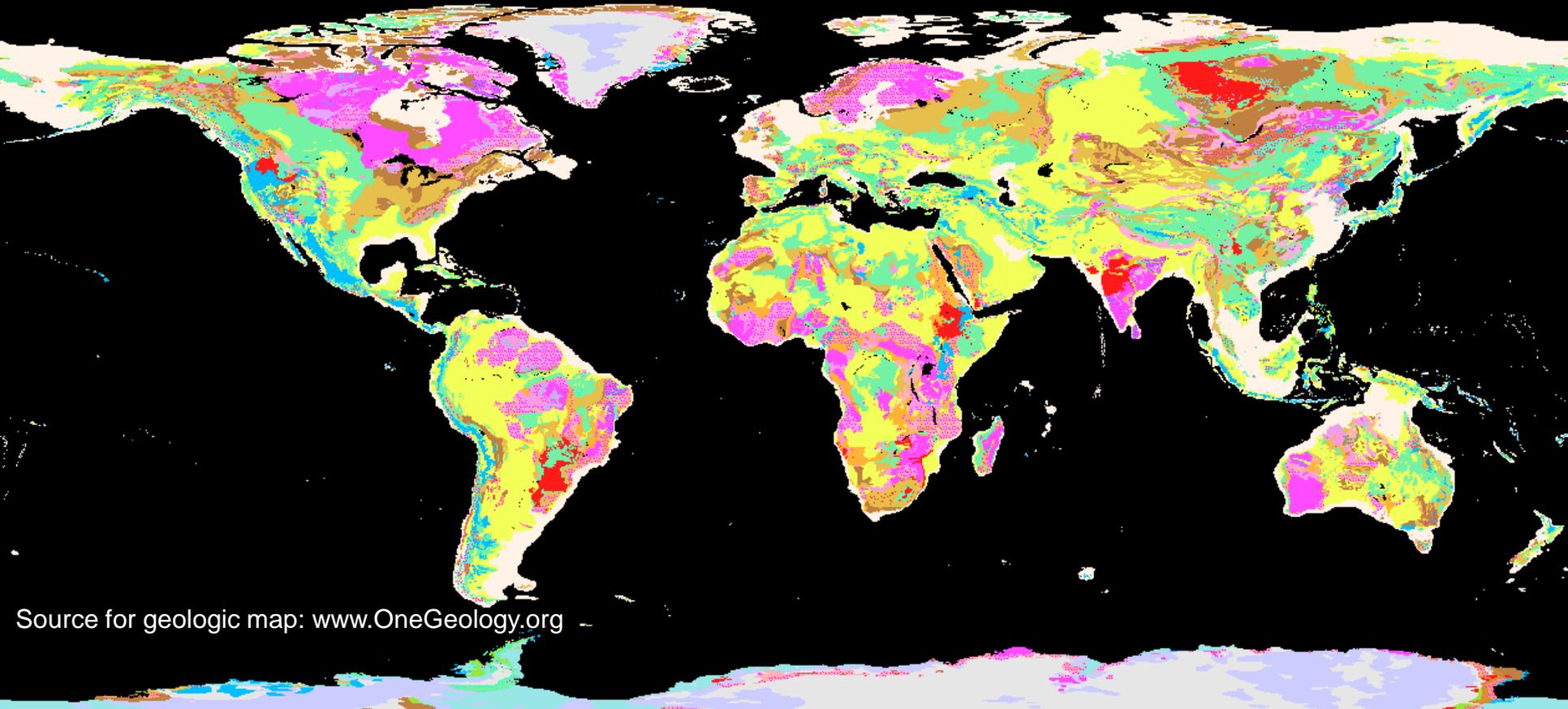
'49ers = 29M oz Au

1835 1845 1855 1865 1875 1885 1895 1905 1915 1925 1935 1945 1955 1965 1975 1985 1995 2005

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

**Archean** (2.5 to 4.0 Ga) – **Au, Ni, U**

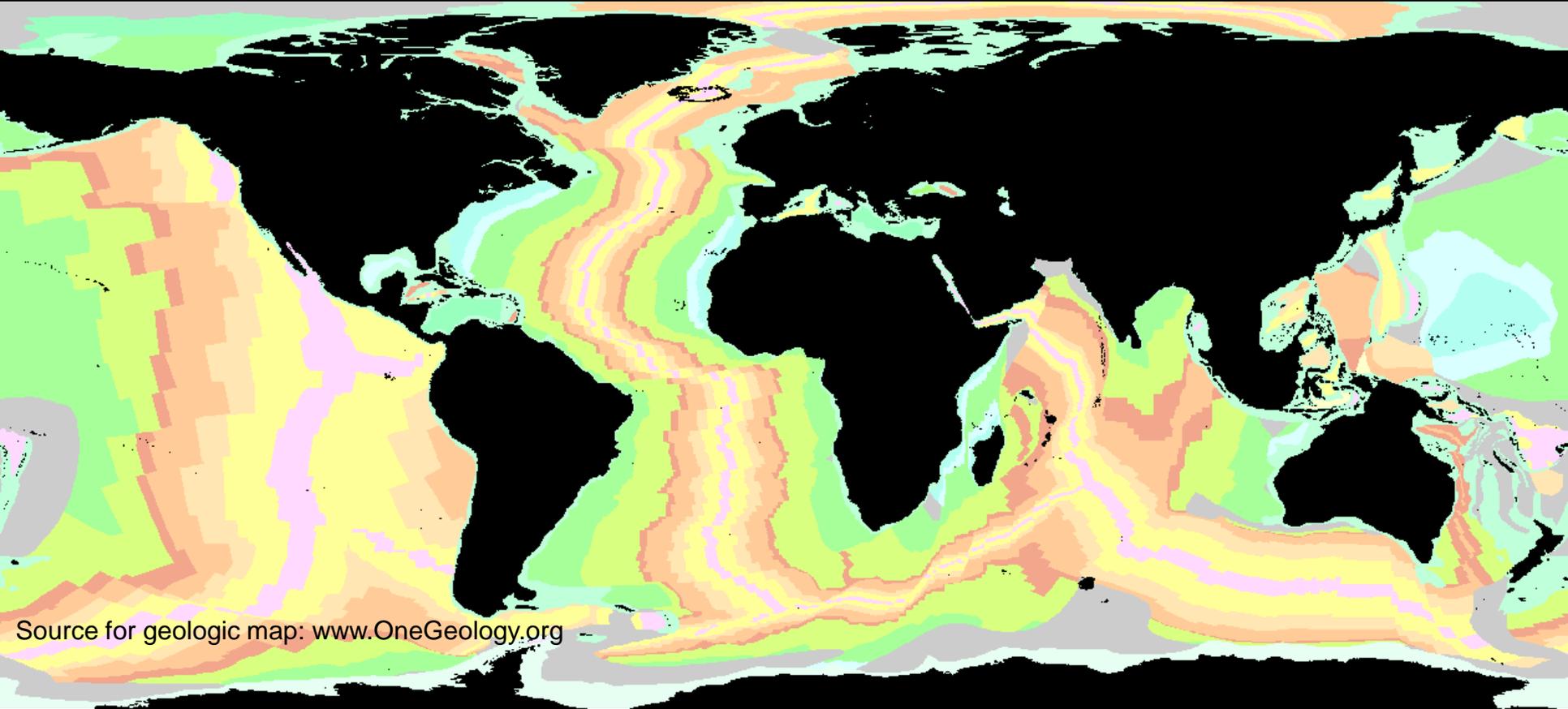
**Proterozoic** (542 Ma to 2.5 Ga) – **Fe, Mn, V, Pt, Pd, Cr, Ni, Au, Cu, Co, U, Ti, diamonds**



Source for geologic map: [www.OneGeology.org](http://www.OneGeology.org)

**Discoveries continue to be made in traditional terrains, such as Precambrian cratons, throughout the world – limits are political and economic, not technical.**

**Jurassic to Recent oceanic crust – potential for ore deposits of manganese nodules (Mn, Ni, Co, Cu), massive sulfide deposits & seafloor vents (Cu, Zn, Pb, Au, Ag), and phosphate nodule deposits (P)**



**We have barely started to explore the oceans – political and legal challenges are probably more important than technical challenges.**

**Economic geologists have been quite successful in finding more ore deposits in known areas, deposits in new areas, and new types of deposits.**



**Large open-pit nickel operation at the Mount Keith mine, Western Australia.**

# Examples of some **new types** of ore deposits recognized and brought into production in the last 55 years.

## Deposit type

## Type locality (year discovered) and new features

**Carlin Au**

Carlin, Nevada (**1961**): disseminated gold in sedimentary rocks

**Roll-front U**

Wyoming, Kazakhstan (**1960s**): redox boundaries in sandstones

**Granite-hosted U  
Unconformity U**

Rössing, Namibia (**1960s**): U-rich granite

Rabbit Lake, Saskatchewan (**1968**): high-grade U near unconformities

**Disseminated Ni**

Mt. Keith, W. Australia (**1969**): disseminated Ni sulfides in komatiitic lava channels

**Iron oxide Cu-Au**

Olympic Dam, S. Australia (**1975**): iron-oxide-rich ores in huge regional alteration systems

**Intrusion-related Au**

Fort Knox, Alaska (**1980s**): Au in granitic rocks, without Cu

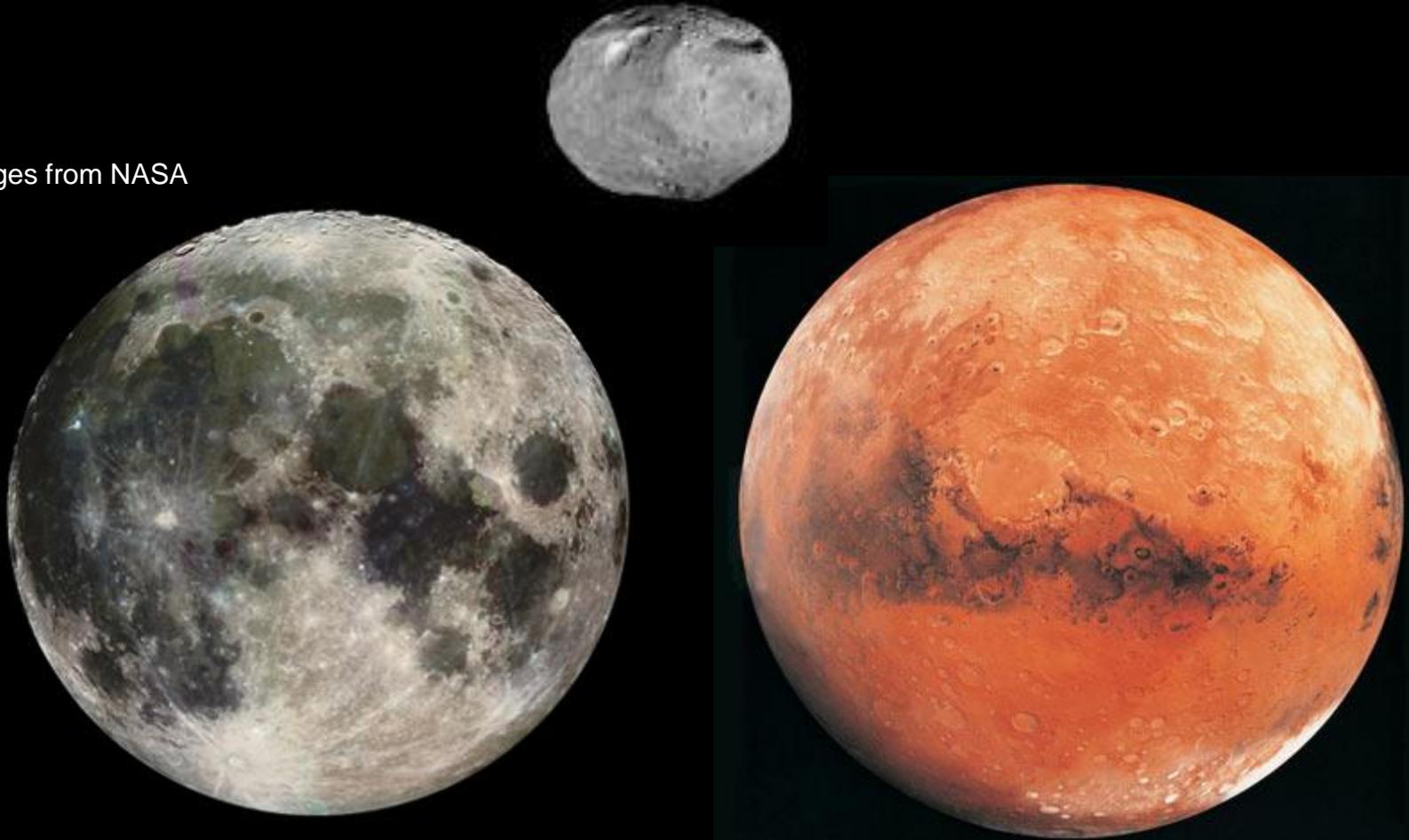
**Ion Absorption REE**

South China (**1980s**): low-grade REEs with kaolinite in weathered granites

**More new types of ore deposits will be discovered in the future...**

**We may not need to worry about mining on the Moon, Mars, or asteroids for some time.**

Images from NASA



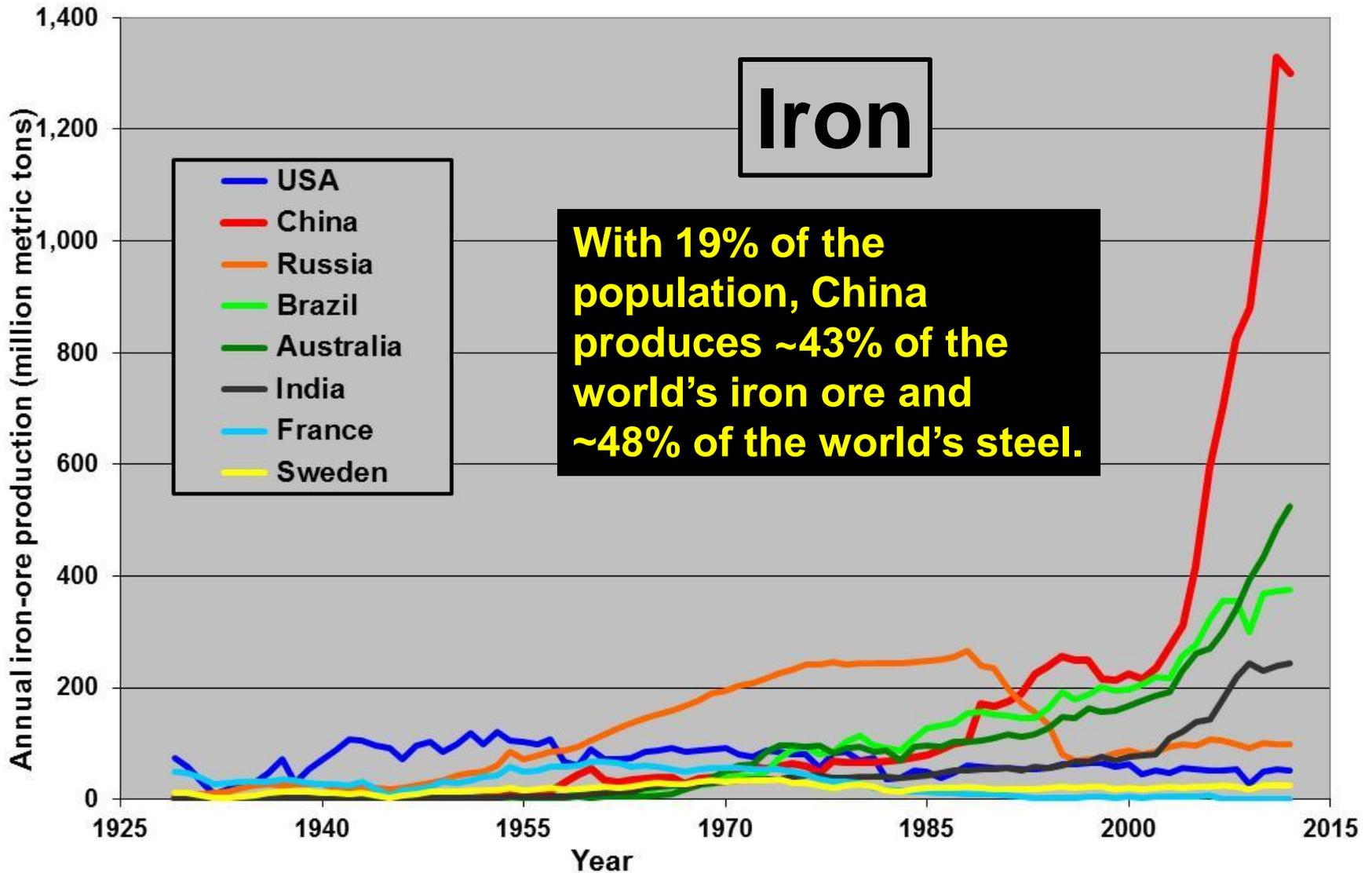
***Though thinking about how ore deposits might form on such bodies could help us be more imaginative on Earth!***

# The Importance of Mineral Resources in a National-International Context

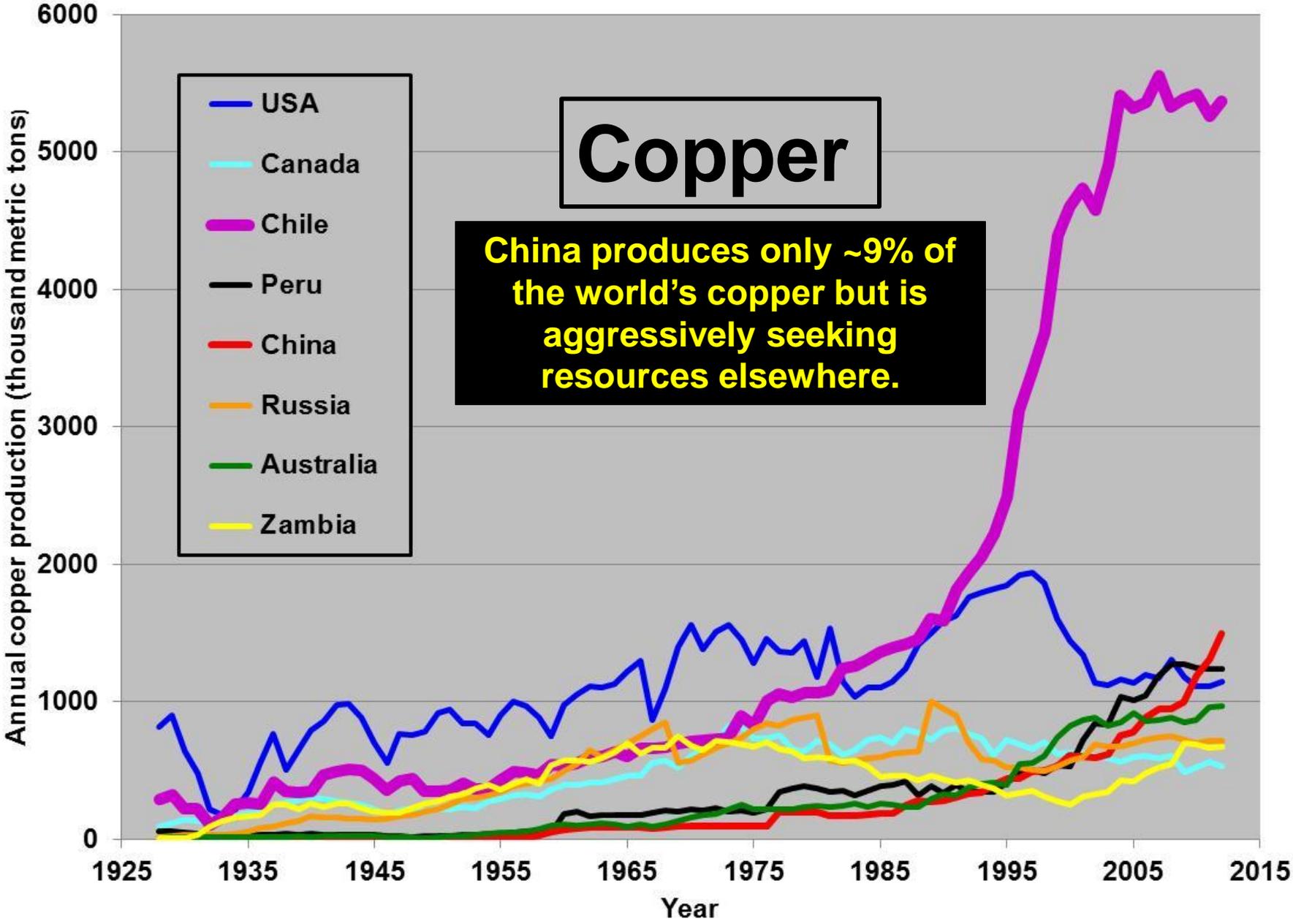
- Demand for mineral resources will continue to grow.
- We are unlikely to run out of mineral resources (globally).
- **Nonetheless, there are challenges for the United States.**

# Challenges for the United States

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

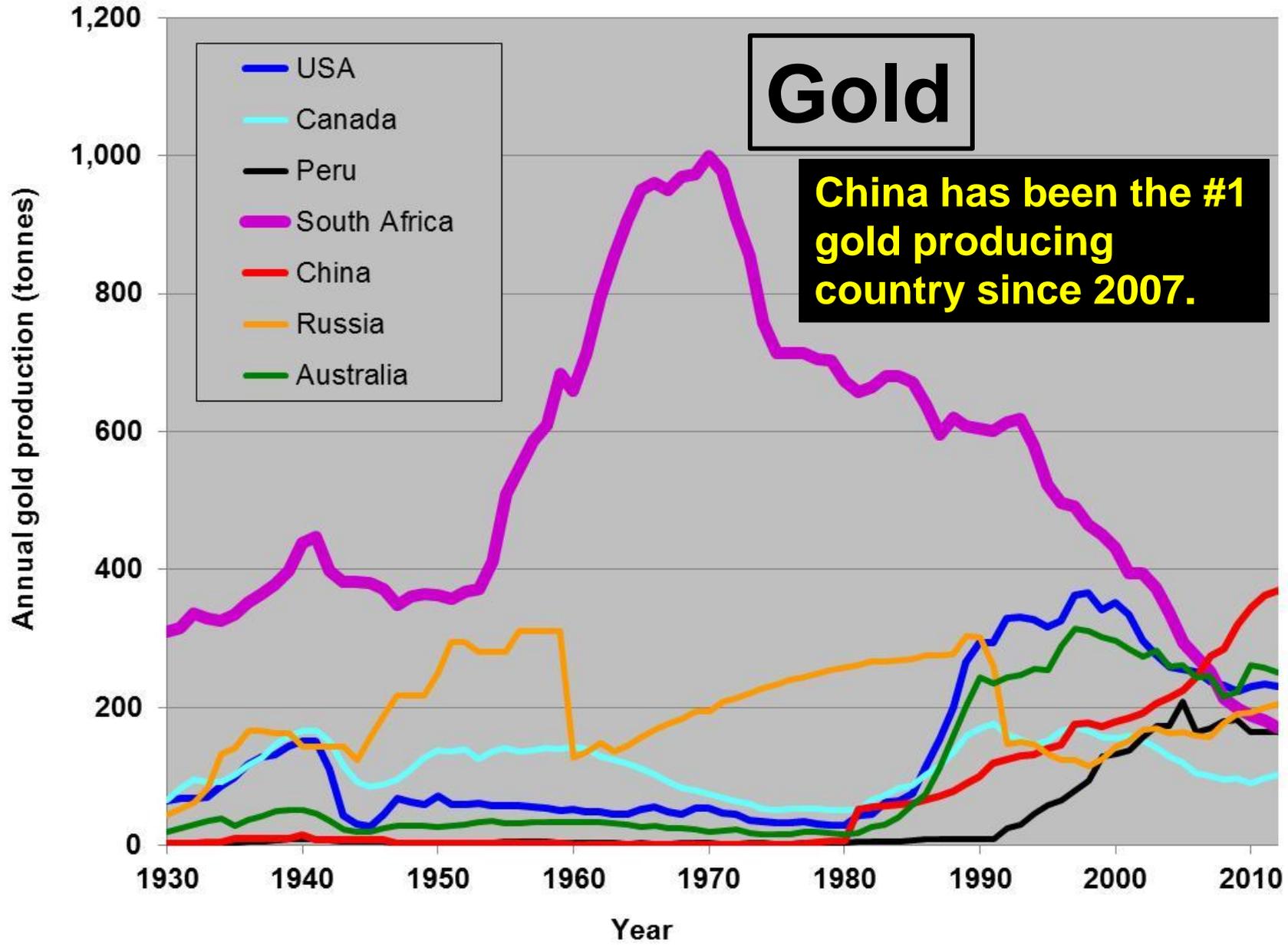


**China's economy continues to boom, although 2012 iron-ore production suggests a slowdown.**



# Gold

**China has been the #1 gold producing country since 2007.**

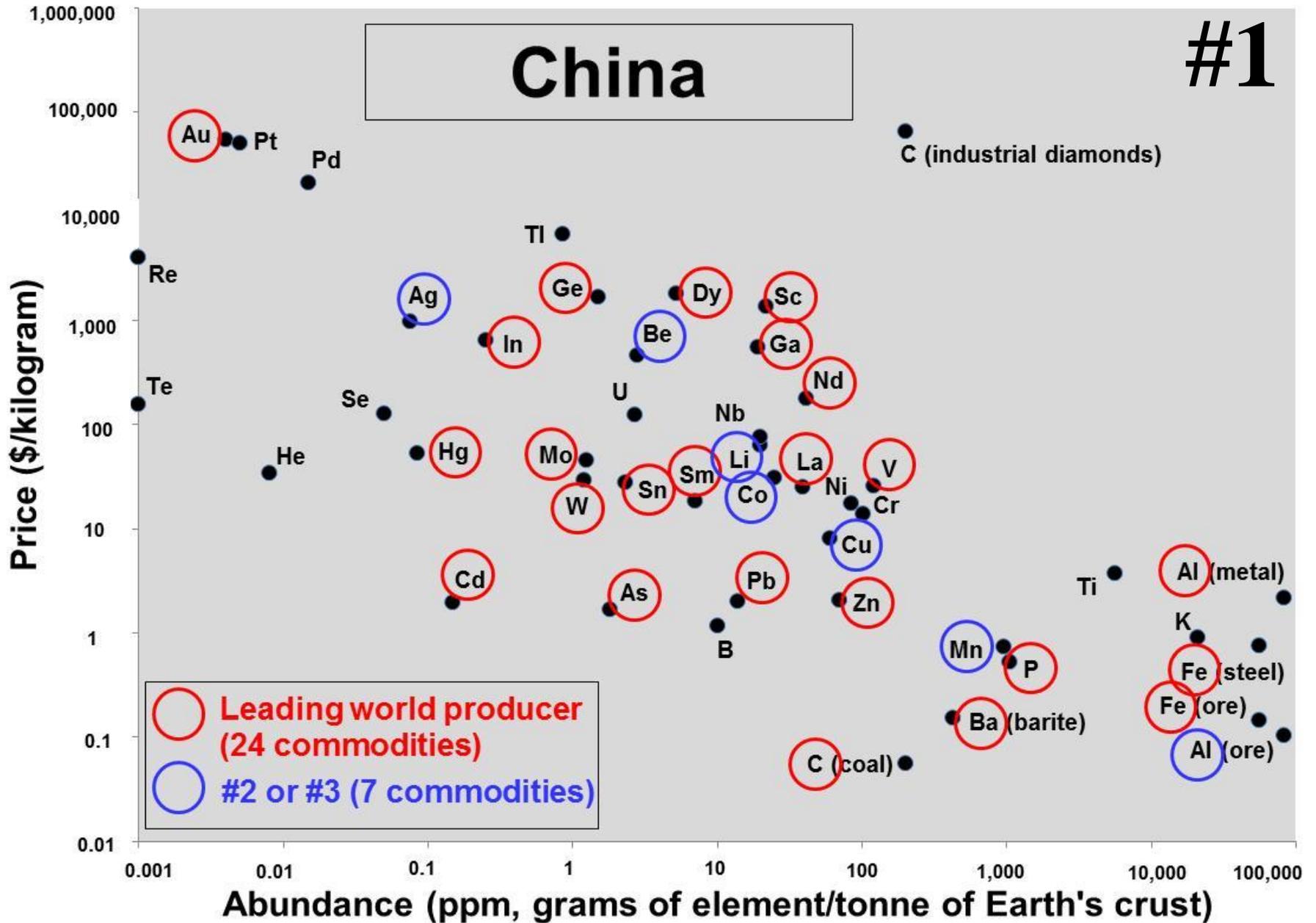


**In production of 46 mineral commodities, China ranks well above all others.**

<b>Country</b>	<b>Number of commodities for which this country is the #1 producer</b>	<b>Number of commodities for which this country is among the top 3 producers</b>
<b>China</b>	<b>24</b>	<b>31</b>
<b>USA</b>	<b>2</b>	<b>16</b>
<b>Australia</b>	<b>2</b>	<b>13</b>
<b>Russia</b>	<b>1</b>	<b>10</b>
<b>Canada</b>	<b>1</b>	<b>9</b>
<b>Chile</b>	<b>3</b>	<b>6</b>
<b>South Africa</b>	<b>3</b>	<b>6</b>
<b>Kazakhstan</b>	<b>1</b>	<b>4</b>
<b>Brazil</b>	<b>1</b>	<b>3</b>
<b>Congo</b>	<b>1</b>	<b>2</b>

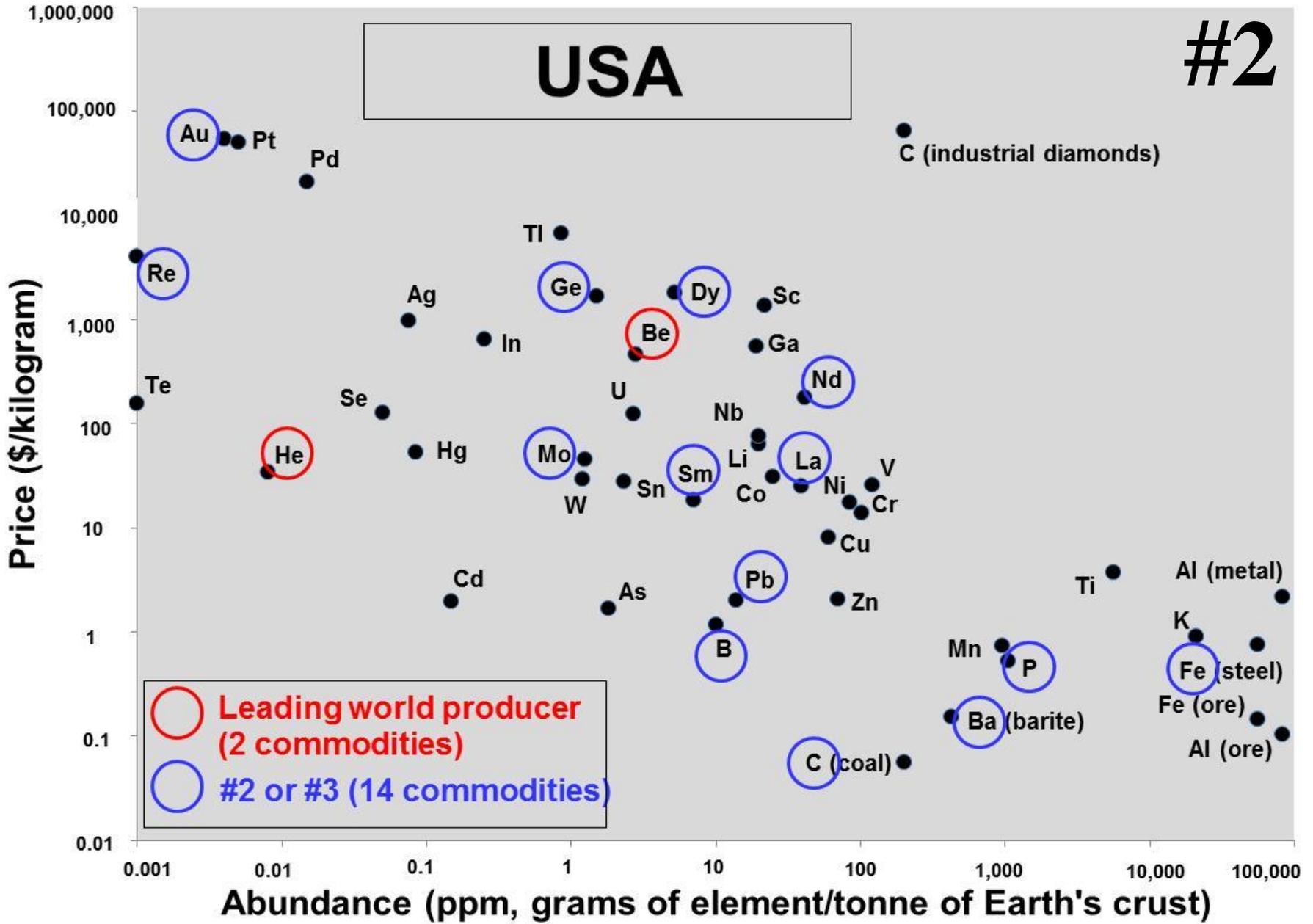
# China

# #1



# USA

# #2

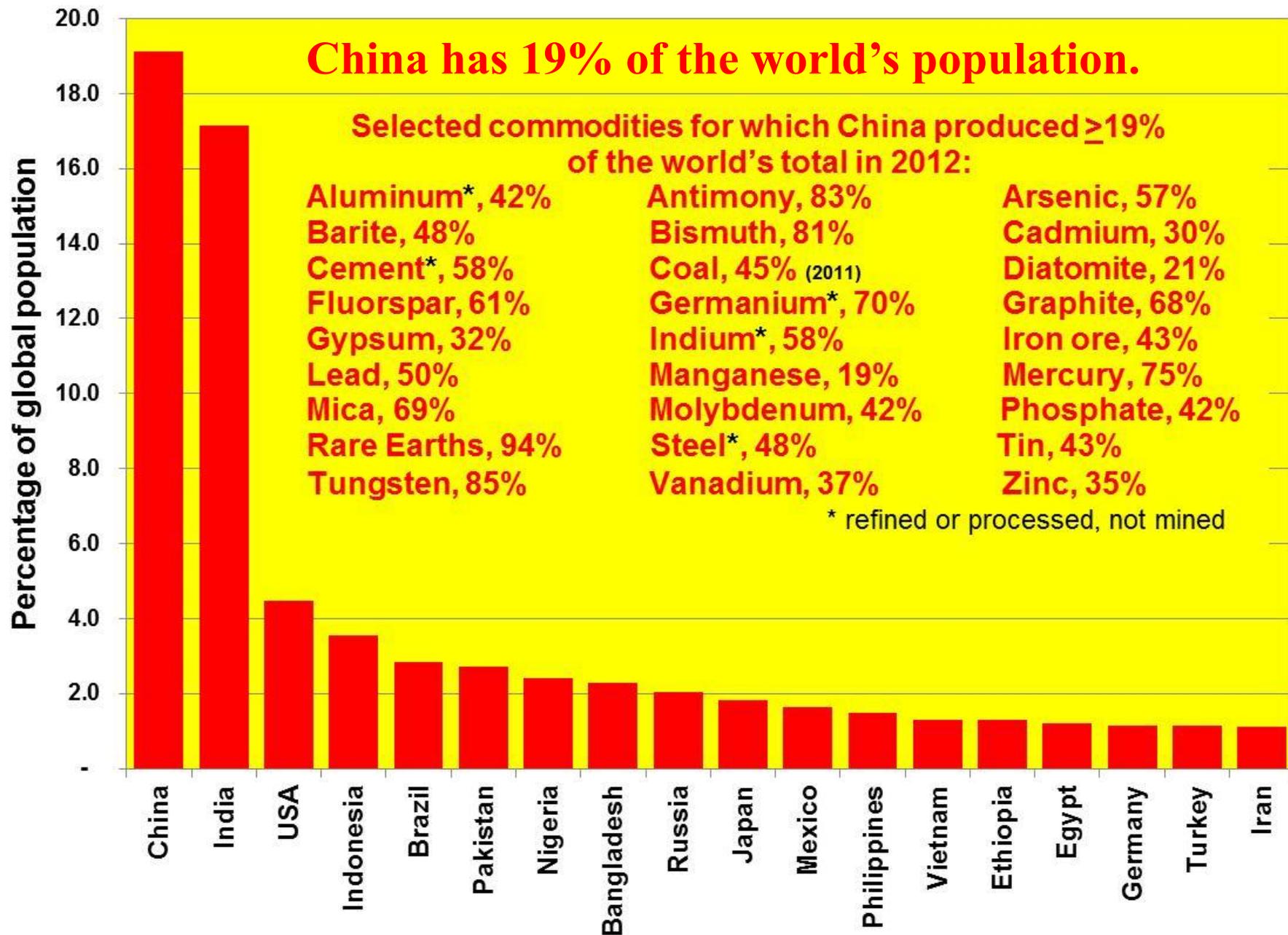


## China has 19% of the world's population.

Selected commodities for which China produced  $\geq 19\%$  of the world's total in 2012:

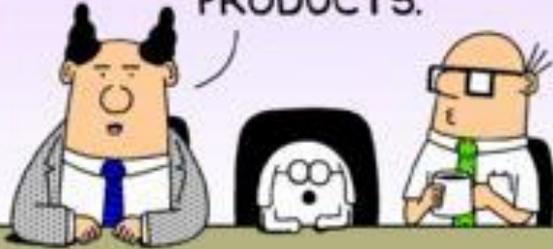
Aluminum*, 42%	Antimony, 83%	Arsenic, 57%
Barite, 48%	Bismuth, 81%	Cadmium, 30%
Cement*, 58%	Coal, 45% (2011)	Diatomite, 21%
Fluorspar, 61%	Germanium*, 70%	Graphite, 68%
Gypsum, 32%	Indium*, 58%	Iron ore, 43%
Lead, 50%	Manganese, 19%	Mercury, 75%
Mica, 69%	Molybdenum, 42%	Phosphate, 42%
Rare Earths, 94%	Steel*, 48%	Tin, 43%
Tungsten, 85%	Vanadium, 37%	Zinc, 35%

\* refined or processed, not mined



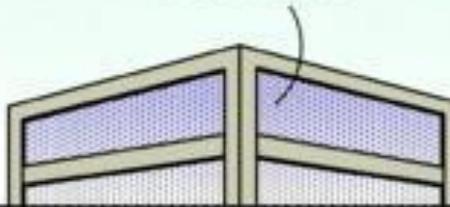
# Rare Earth Elements (REEs)

OUR CONSULTANT WILL TELL US HOW WE CAN SECURE A LONG-TERM SUPPLY OF RARE EARTH METALS FOR OUR PRODUCTS.



Dilbert.com DilbertCartoonist@gmail.com

CHINA HAS MOST OF THE RARE EARTH METALS. TRY DYING. AND REINCARNATING. THERE'S A 20% CHANCE THAT YOU'LL BE BORN CHINESE.



2.28.11 © 2011 Scott Adams, Inc./Dist. by UFS, Inc.

WHAT'S PLAN B?



IF THE ONLY PART THAT GOES WRONG IS THE CHINESE PART, YOU CAN TRY DYING AGAIN.



**$\text{CuIn}_x\text{Ga}_{(1-x)}\text{Se}_2$ ,  $\text{CdTe}$ ,  $\text{GaAs}$ ,  $\text{Ag}$ , and  $\text{Si}_{1-x}\text{Ge}_x$**   
for **solar panels**

**$\text{Fe}_{14}(\text{Nd,Dy})_2\text{B}$ ,  $\text{SmCo}_5$ , and  $\text{Sm}_2\text{Co}_{17}$**   
for magnets, e.g., in **wind turbines**

**Li, La, Ni, and V** for **batteries**

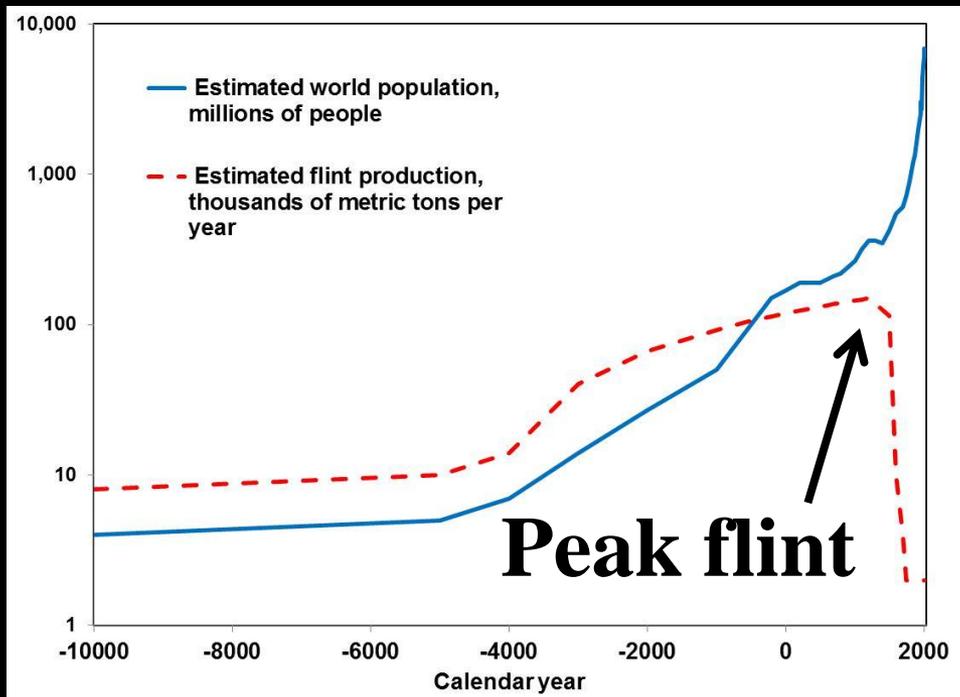
**Pt, Pd** for catalysts in **fuel cells**

**Tb, Eu** in **fluorescent lights**



Arrowhead clipart from [www.firstpeople.us](http://www.firstpeople.us)

**Critical and strategic minerals  
do change with time.**



## Energy Critical Elements:

					2 <b>He</b> Helium 4.003												
5 <b>B</b> Boron 10.811		6 <b>C</b> Carbon 12.0107		7 <b>N</b> Nitrogen 14.00674		8 <b>O</b> Oxygen 15.9994		9 <b>F</b> Fluorine 18.9984032		10 <b>Ne</b> Neon 20.1797							
13 <b>Al</b> Aluminum 26.981538		14 <b>Si</b> Silicon 28.0855		15 <b>P</b> Phosphorus 30.973761		16 <b>S</b> Sulfur 32.066											
28 <b>Ni</b> Nickel 58.6934		29 <b>Cu</b> Copper 63.546		30 <b>Zn</b> Zinc 65.39		31 <b>Ga</b> Gallium 69.723						32 <b>Ge</b> Germanium 72.61		33 <b>As</b> Arsenic 74.92160		34 <b>Se</b> Selenium 78.96	
46 <b>Pd</b> Palladium 106.42		47 <b>Ag</b> Silver 107.8682		48 <b>Cd</b> Cadmium 112.411		49 <b>In</b> Indium 114.818						50 <b>Sn</b> Tin 118.710		51 <b>Sb</b> Antimony 121.760		52 <b>Te</b> Tellurium 127.60	
78 <b>Pt</b> Platinum 195.078		79 <b>Au</b> Gold 196.96655		80 <b>Hg</b> Mercury 200.59		81 <b>Tl</b> Thallium 204.3833						82 <b>Pb</b> Lead 207.2		83 <b>Bi</b> Bismuth 208.98038		84 <b>Po</b> Polonium [209]	
65 <b>Tb</b> Terbium 58.92534		66 <b>Dy</b> Dysprosium 162.50		67 <b>Ho</b> Holmium 164.93032		68 <b>Er</b> Erbium 167.26		69 <b>Tm</b> Thulium 168.93421		70 <b>Yb</b> Ytterbium 173.04		71 <b>Lu</b> Lutetium 174.967					

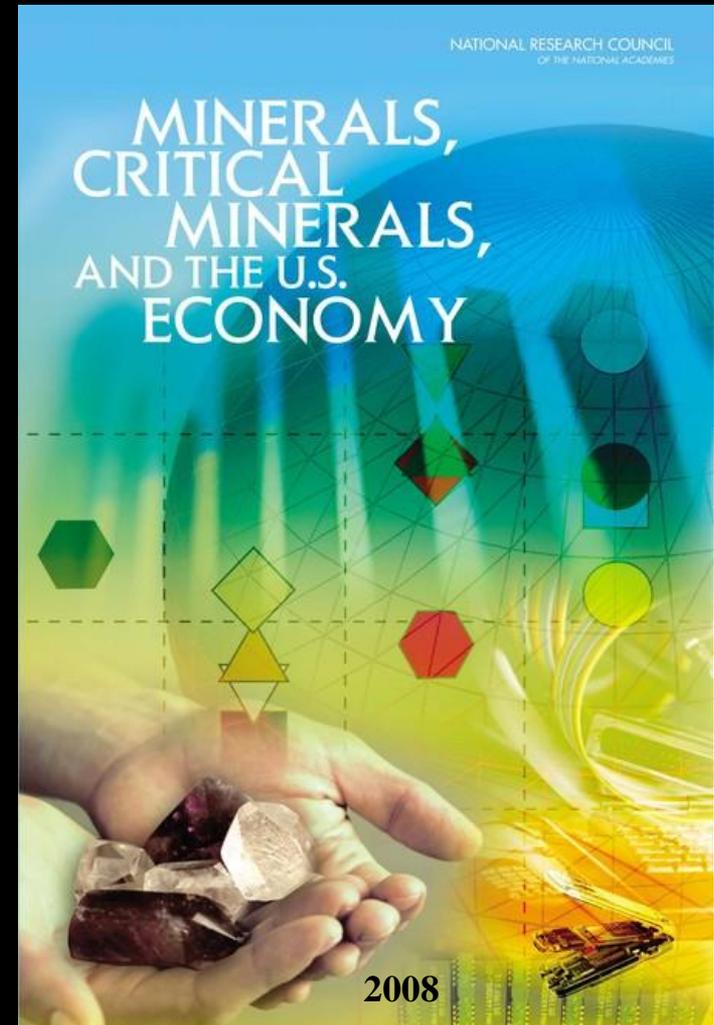
## Securing Materials for Emerging Technologies

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



2011

## What minerals will be critical for the country?



2008

# HARDROCK MINING ON FEDERAL LANDS

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

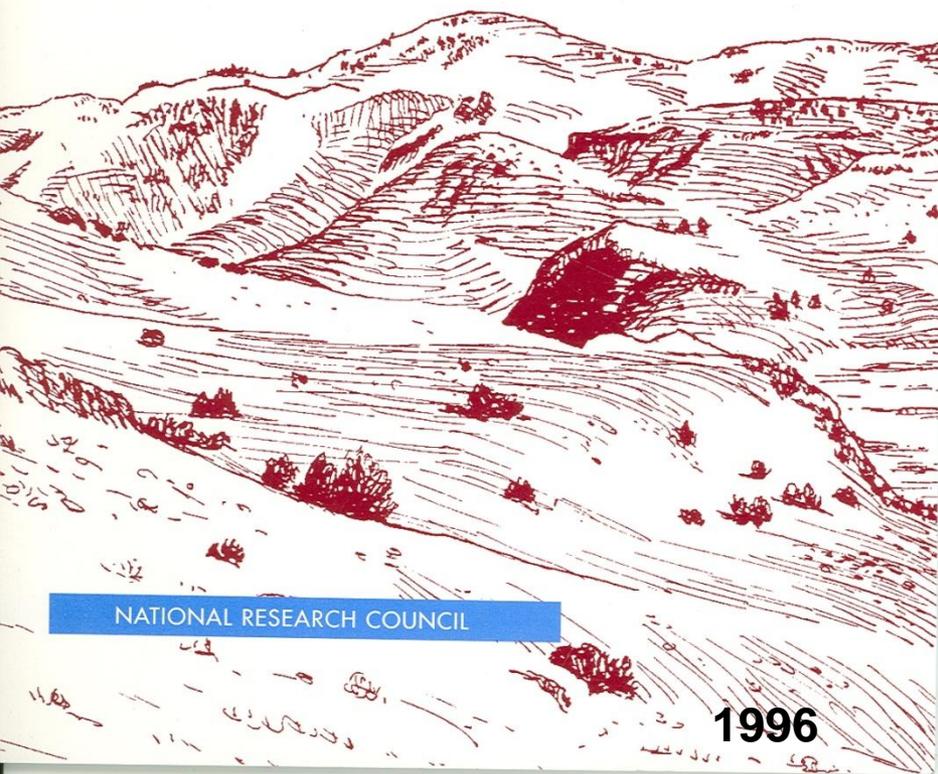


NATIONAL RESEARCH COUNCIL

1999

# MINERAL RESOURCES AND SUSTAINABILITY

*challenges for earth scientists*



NATIONAL RESEARCH COUNCIL

1996

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

Or will we, perhaps by default, practice “environmental imperialism” – export the negative environmental, health, safety, aesthetic, and cultural aspects of mining to other countries?

**Artisanal mining outside the US will likely continue as a health, safety, and environmental challenge for society, governments, and industry worldwide.**



Four artisanal miners (galamsey) work unsafely, without personal protective equipment or ground support, near Kyereboso in Ghana in 2008.

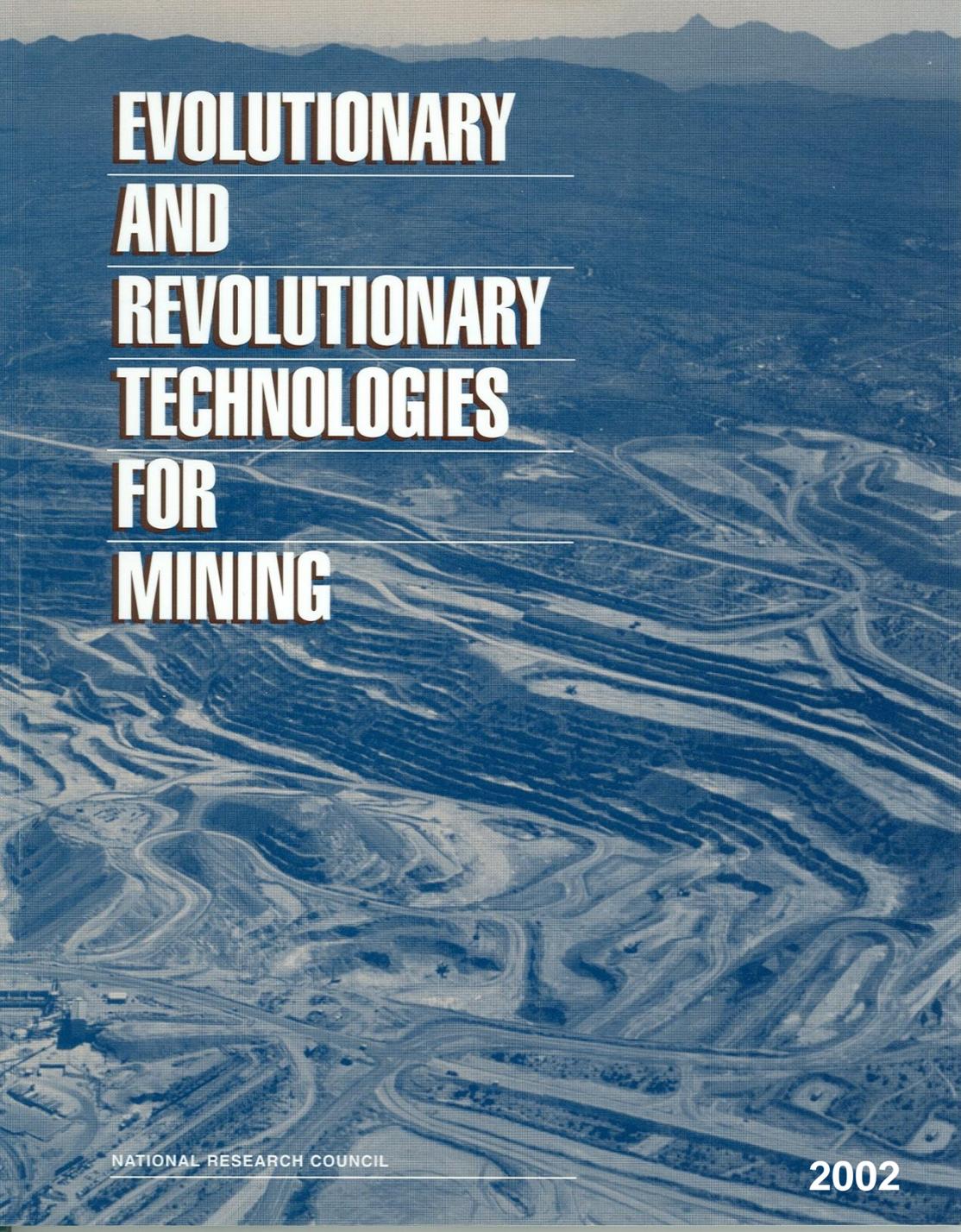


Gold mill in Sulawesi (Larry James photo)



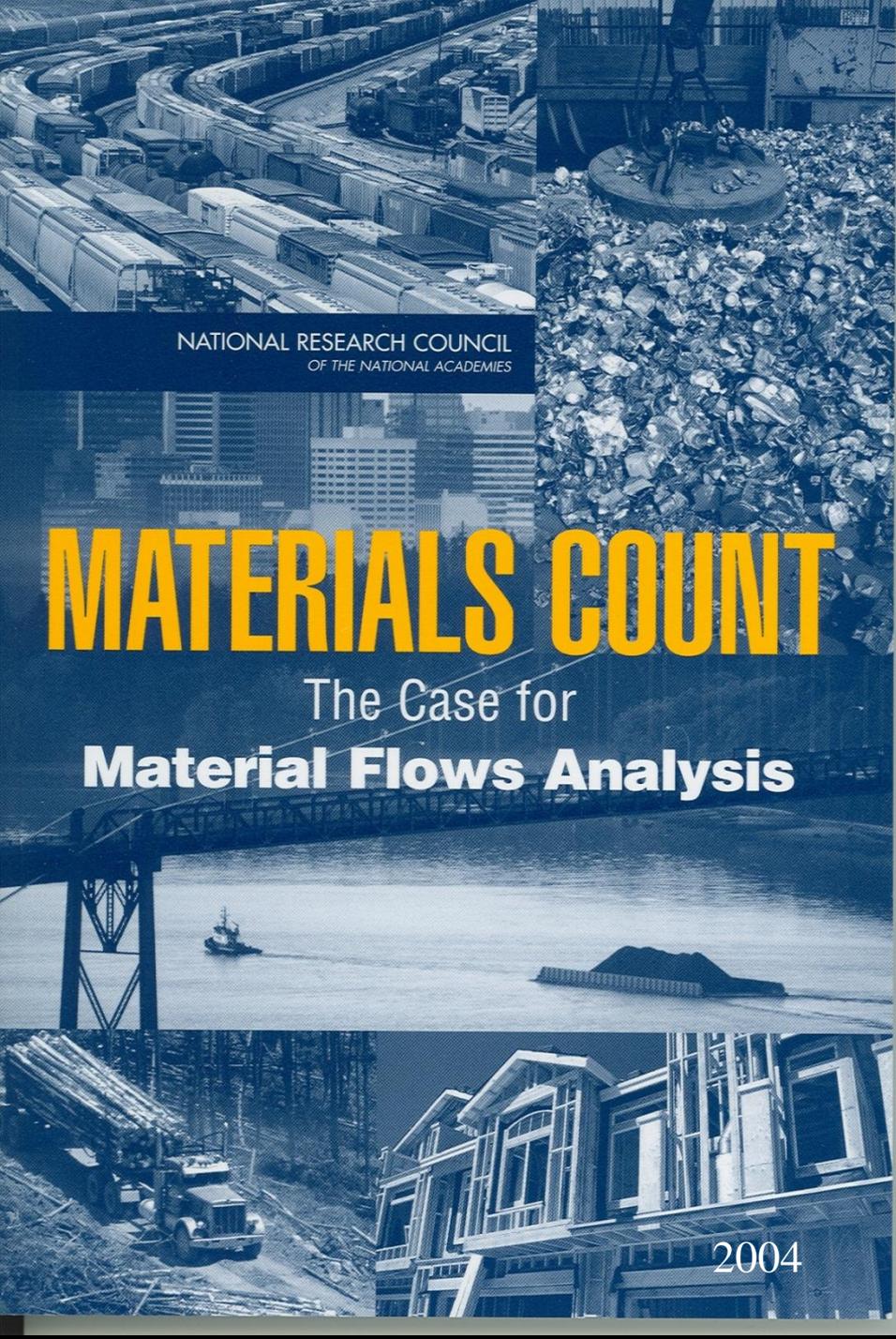
**Recent reports  
(Science Oct. 2013)  
state that 70% of Hg  
pollution worldwide is  
from artisanal mining.**

Using blowtorch to remove  
mercury from amalgam,  
Sulawesi (Larry James photo)



**EVOLUTIONARY  
AND  
REVOLUTIONARY  
TECHNOLOGIES  
FOR  
MINING**

**Will the US  
government invest in  
research needed to  
discover, extract,  
and process mineral  
resources in an  
environmentally  
responsible manner?**



NATIONAL RESEARCH COUNCIL  
OF THE NATIONAL ACADEMIES

# MATERIALS COUNT

The Case for  
**Material Flows Analysis**

**Will the US government invest in research on improving the rate of recycling of mineral resources, and on finding substitutes for mineral resources that become too expensive for commercial or other applications?**

2004

**More recycling can be accomplished by increasing collection rates of various products, better product design with recycling in mind, and improvements in recycling technologies.** - Reck and Graedel (2012).

1 H																	2 He						
3 Li	4 Be																	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg																	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr						
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 <i>Tc</i>	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe						
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 <i>Po</i>	85 <i>At</i>	86 <i>Rn</i>						
87 <i>Fr</i>	88 <i>Ra</i>	89 <i>Ac</i>																					

58 Ce	59 Pr	60 Nd	61 <i>Pm</i>	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 <i>Th</i>	91 <i>Pa</i>	92 <i>U</i>											

Source: Graedel et al. (2011)

# Emerging Workforce Trends in the U.S. Energy and Mining Industries

**A CALL TO ACTION**



**Do we have, and are we training, the people needed to ensure the US can meet its mineral and energy needs?**

2013

NATIONAL RESEARCH COUNCIL  
OF THE NATIONAL ACADEMIES

# Geologic Mapping

## Future Needs

*Committee on Geologic Mapping*

*Board on Earth Sciences*

*Commission on Physical Sciences, Mathematics, and  
Resources*

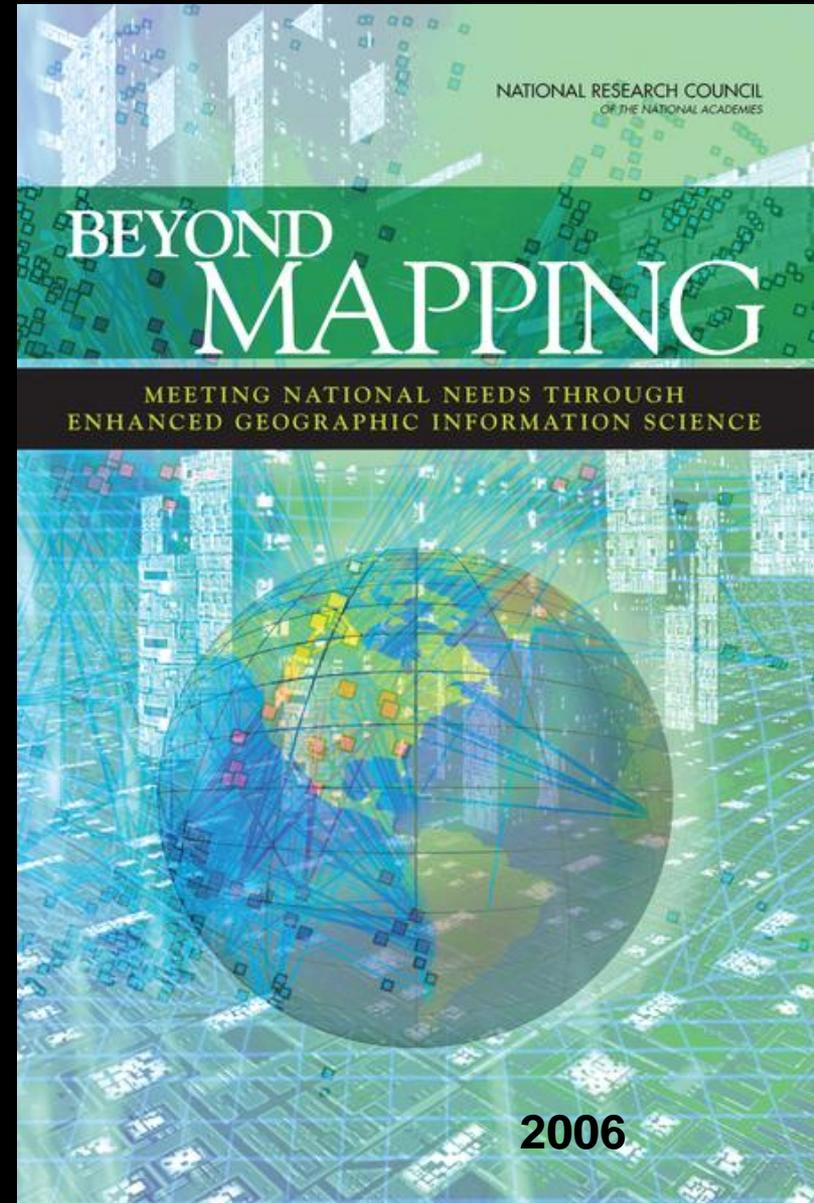
*National Research Council*

NATIONAL ACADEMY PRESS

Washington, D.C.

1988

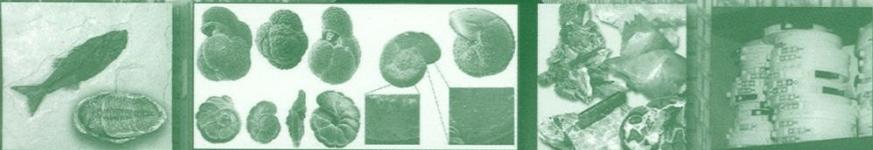
**Will the US and other governments support the basic research, including geologic mapping, needed to understand where resources are likely to be found?**



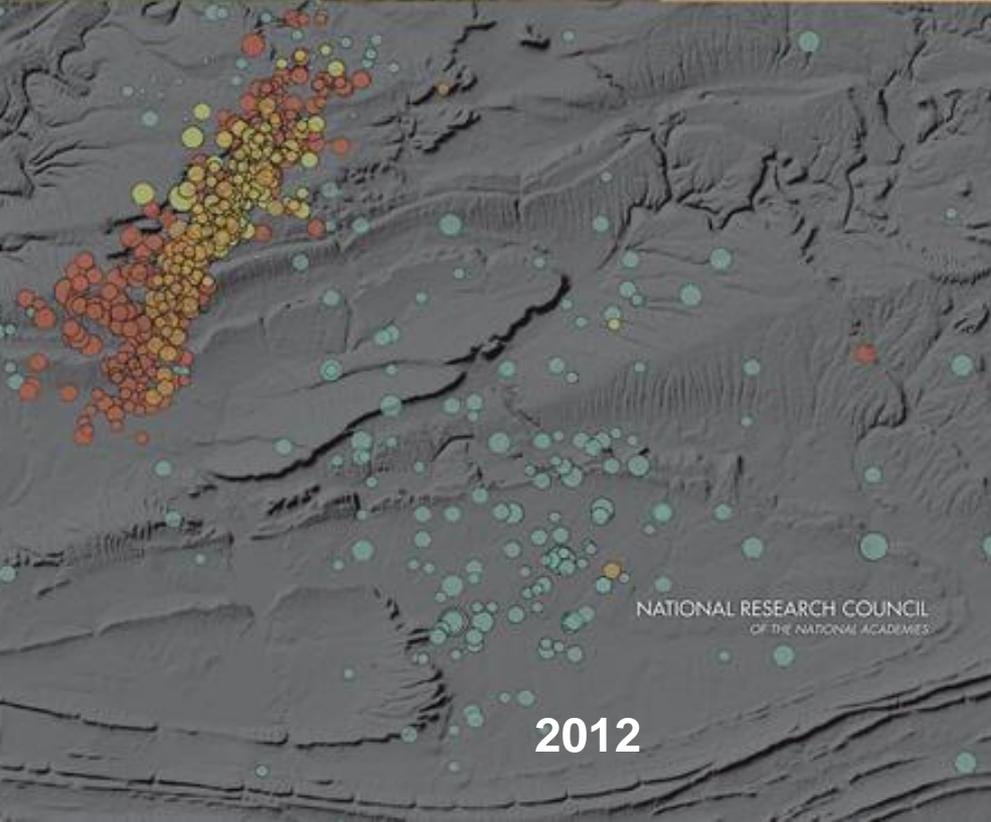
# Geoscience Data and Collections

## NATIONAL RESOURCES IN PERIL

**Will the US and other governments support the preservation of geological data and collections that stimulate discovery?**



# Induced Seismicity Potential in ENERGY TECHNOLOGIES



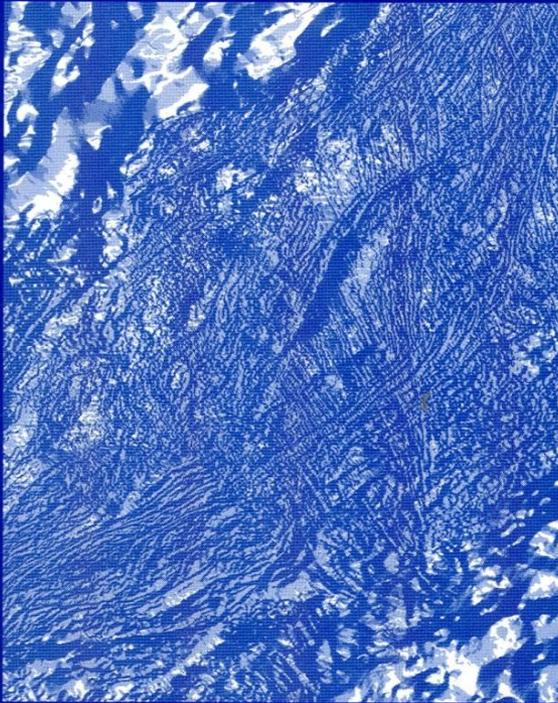
NATIONAL RESEARCH COUNCIL  
OF THE NATIONAL ACADEMIES

2012

**What may be the  
unintended  
consequences of  
new mineral  
resource  
production ?**

# 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

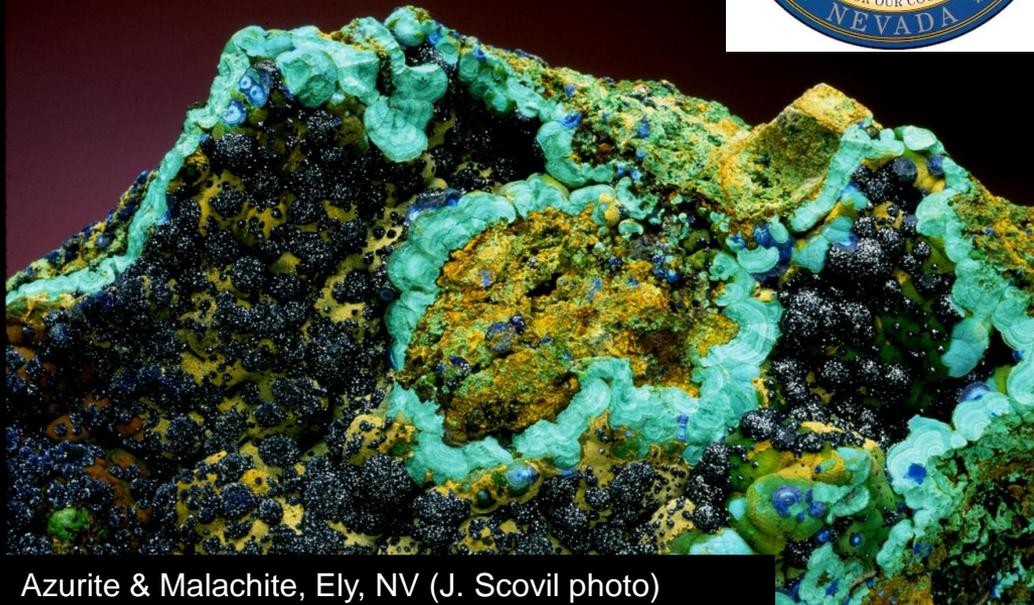
# The Importance of Mineral Resources in a National-International Context

- **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.**

# The Importance of Mineral Resources in a National-International Context

**Jonathan G. Price**

State Geologist Emeritus  
Nevada Bureau of Mines and Geology



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

**JONATHAN G. PRICE, LLC**

H	He																	He																
1.00794																		4.0026																
Li	Be	B	C	N	O	F	Ne																	Ne										
6.941	9.0122	10.811	12.011	14.007	15.9994	18.9984	20.180																	20.180										
Na	Mg	Al	Si	P	S	Cl	Ar																	Ar										
22.990	24.305	26.9815	28.086	30.9738	32.06	35.453	39.948																	39.948										
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																	Kr
39.0983	40.078	44.9559	47.88	50.9415	51.996	54.938	55.847	58.933	58.693	63.546	65.38	69.723	72.61	74.922	78.96	79.904	83.8																	83.8
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																	Xe
85.4678	87.62	88.906	91.224	92.906	95.94	97.9	101.07	101.063	106.42	107.865	112.411	114.818	118.71	121.757	127.6	126.904	131.29																	131.29
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn																	Rn
132.905	137.327	138.905	178.49	180.948	183.84	186.207	190.23	192.22	195.08	196.967	200.59	204.383	207.2	208.98	208.98	208.98	222.0176																	222.0176
Fr	Ra	Ac																																
223.0	226.0254	227.0276																																
																		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
																		140.12	140.908	144.24	144.913	150.36	151.965	157.25	158.925	162.50	164.93	167.26	168.934	173.04	174.967			
																		Th	Pu	U														
																		232.0377	238.0289	238.0289														

[jprice@unr.edu](mailto:jprice@unr.edu)

775-329-8011