The Importance of Mineral Resources in a National-International Context

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Statewide • Worldwide

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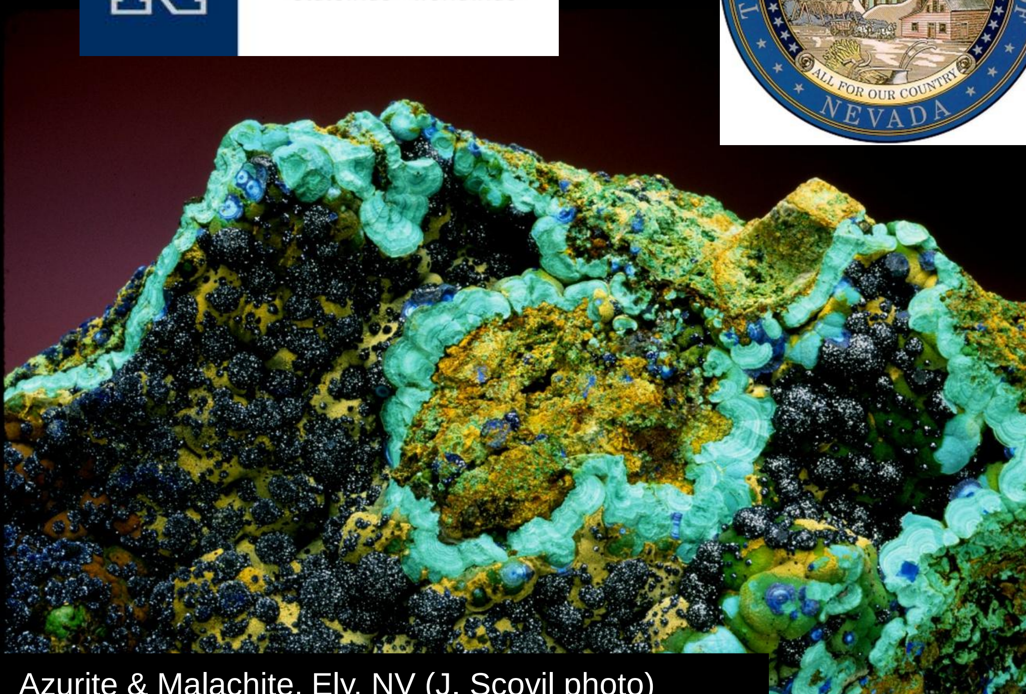


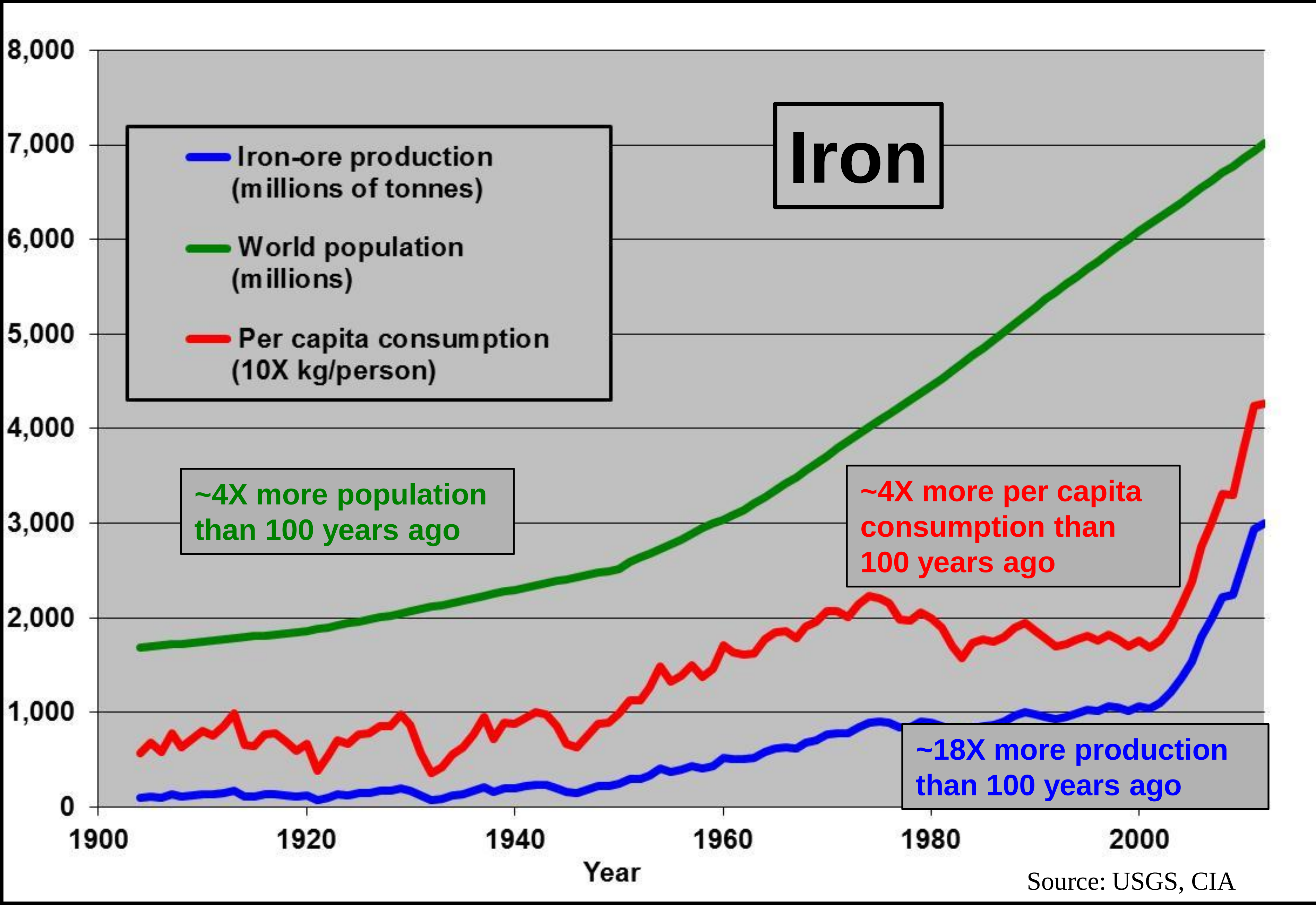
Azurite & Malachite, Ely, NV (J. Scovil photo)

The Importance of Mineral Resources in a National-International Context

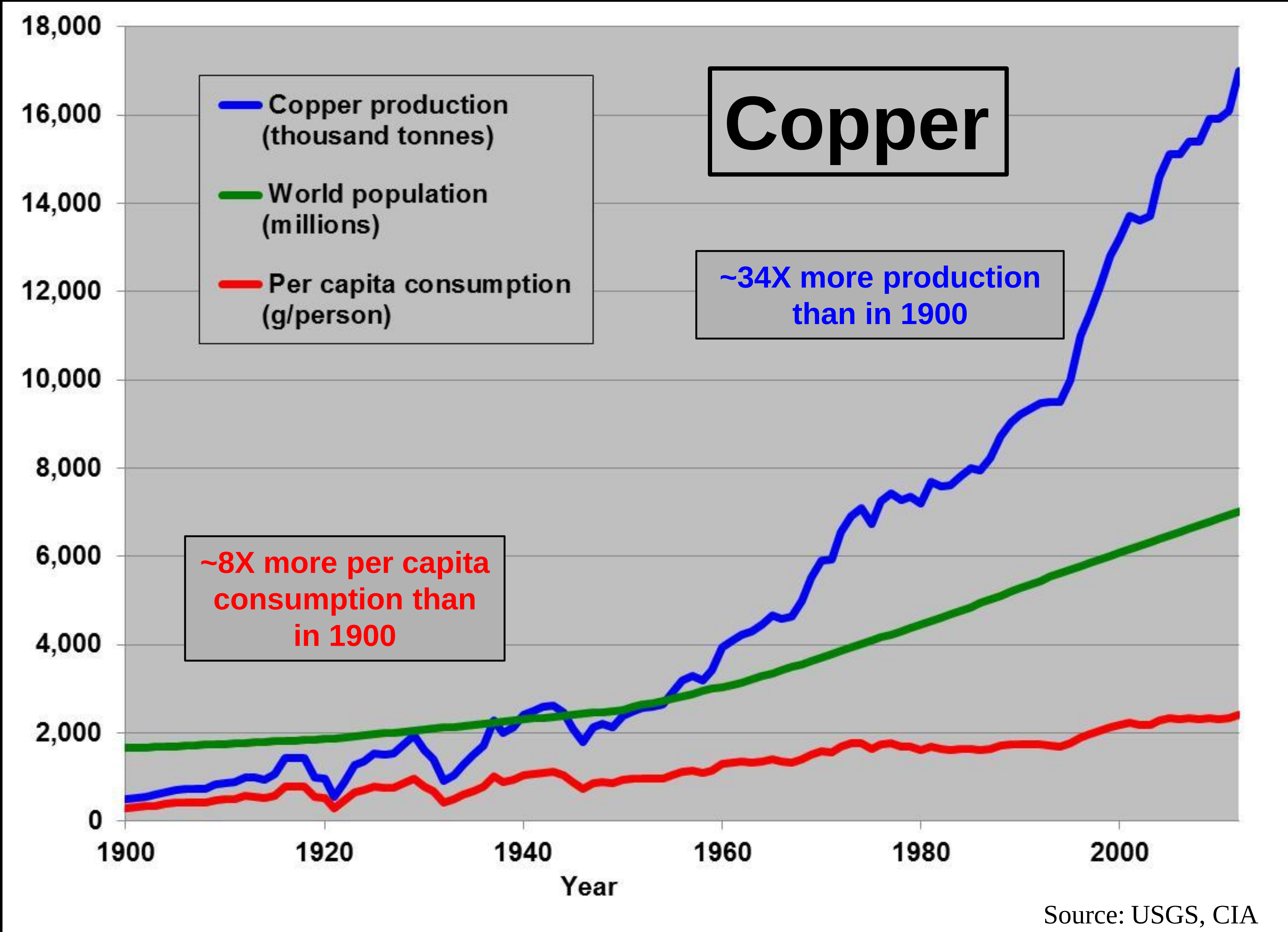
- Demand for mineral resources will continue to grow.

- We are unlikely to run out of mineral resources (globally).

- Nonetheless, there are challenges for the United States.



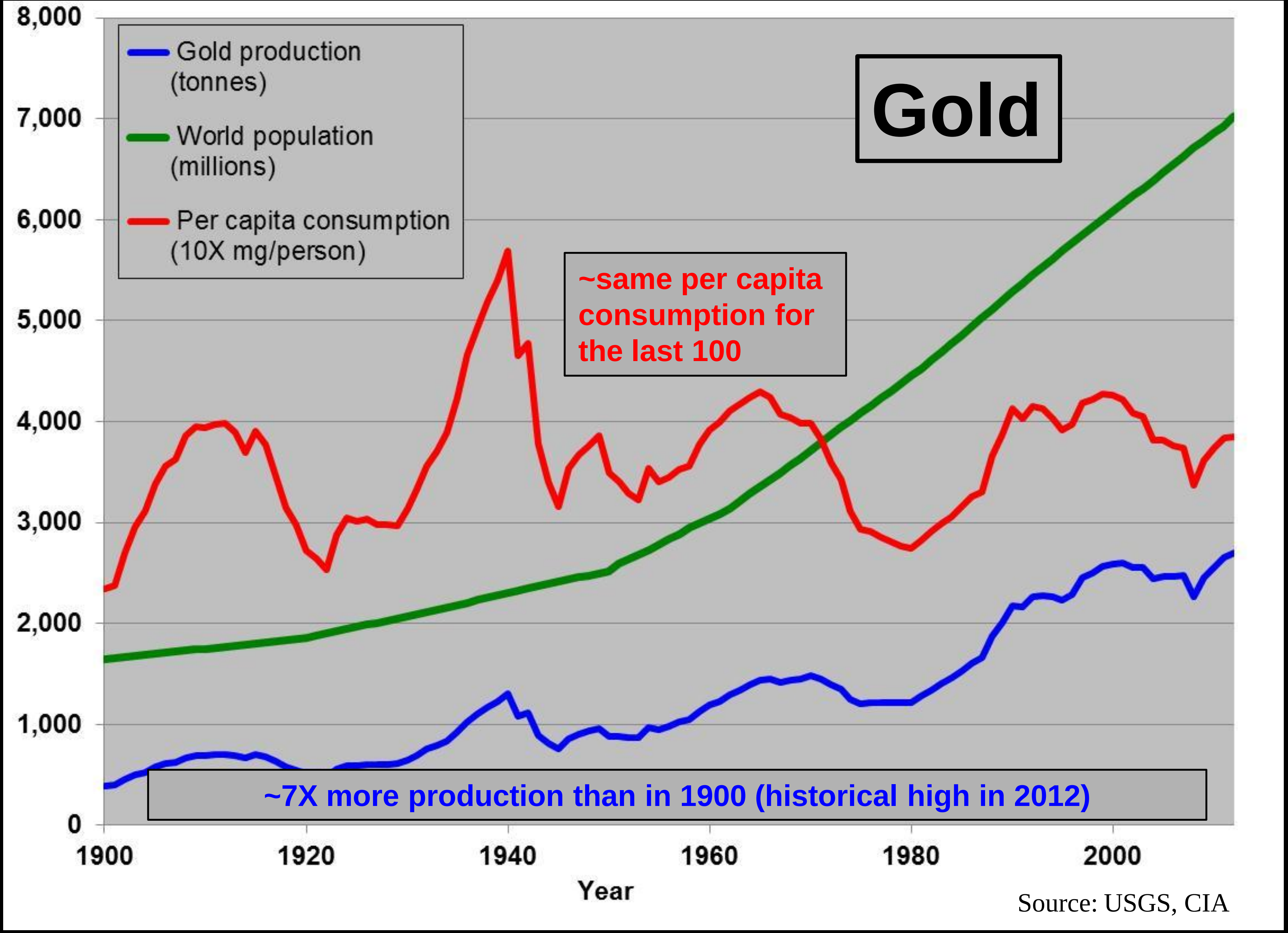
Demand is high for nearly every mineral resource, due to rising population and average standard of living.



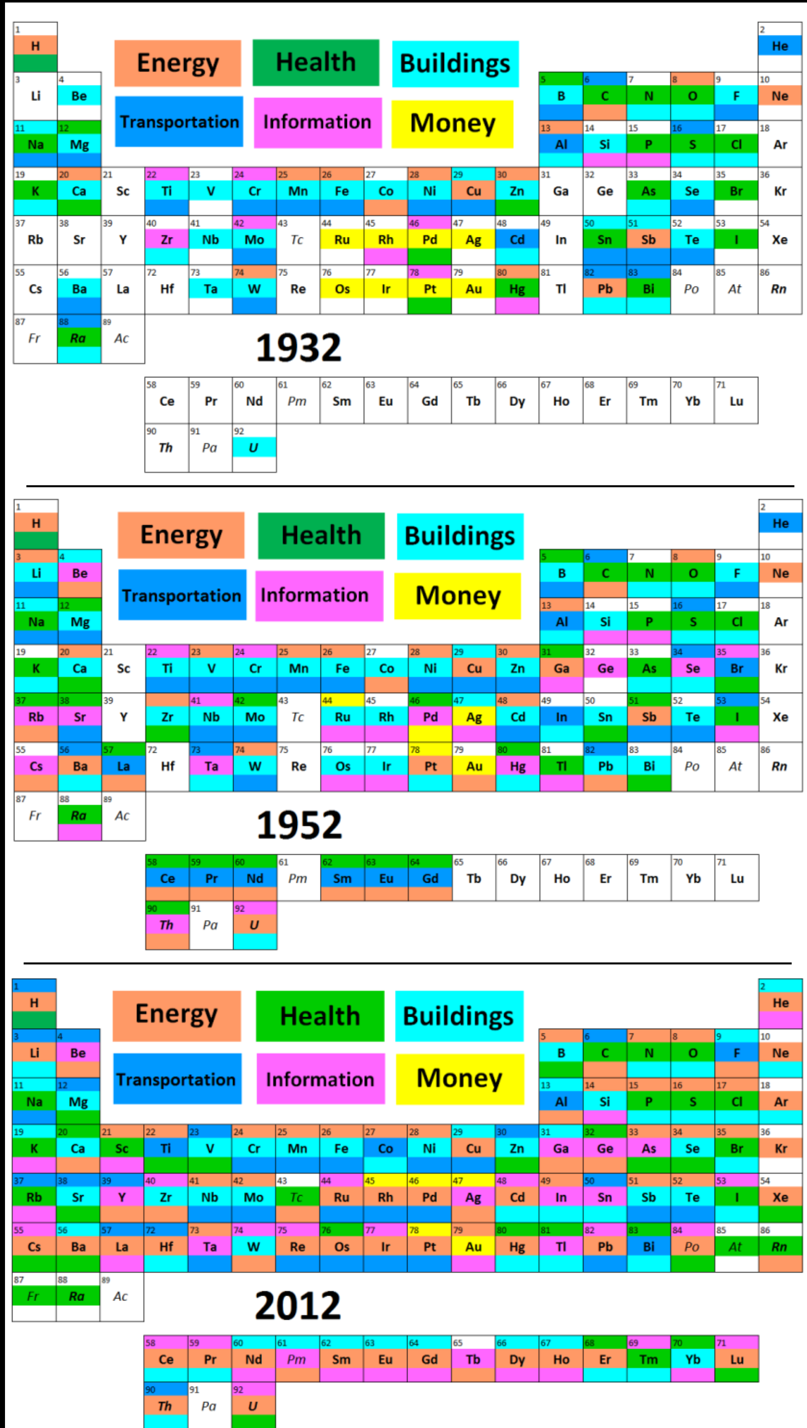
Demand is high for nearly every mineral resource.

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).



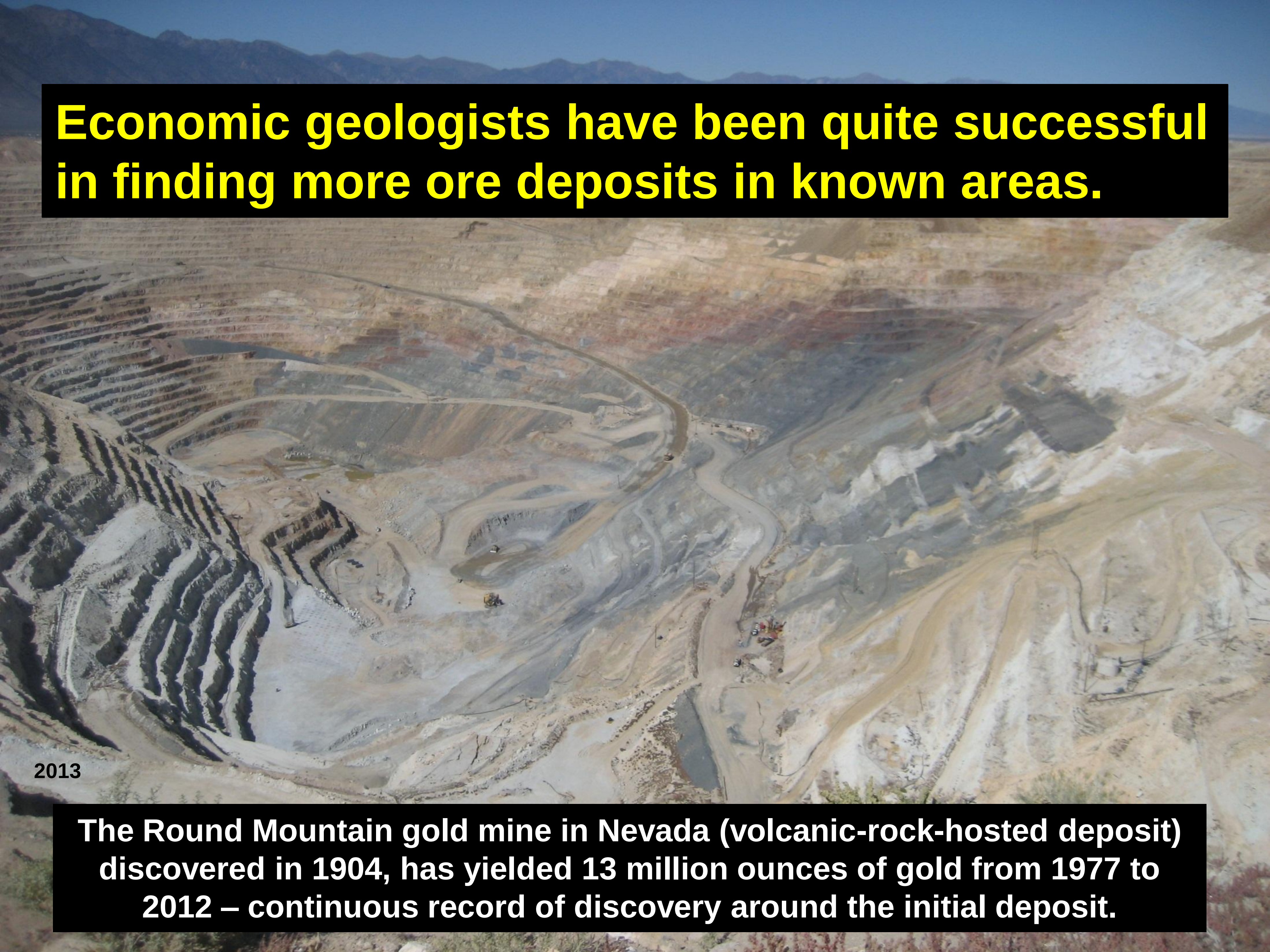
Demand is high for nearly every mineral resource.



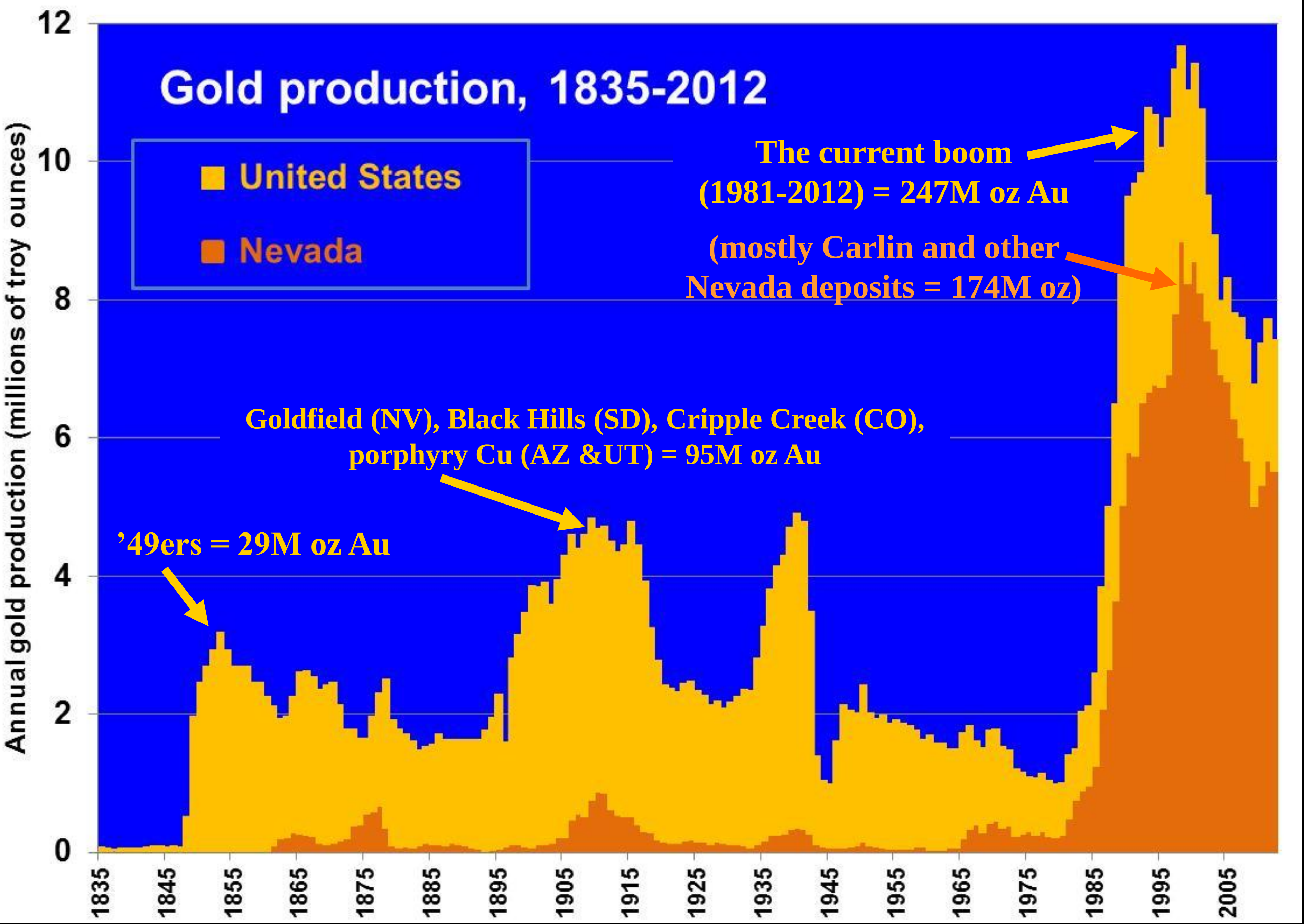
The number of mineral commodities in demand for products in society has increased markedly in the last 80 years.

Source: USGS data

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



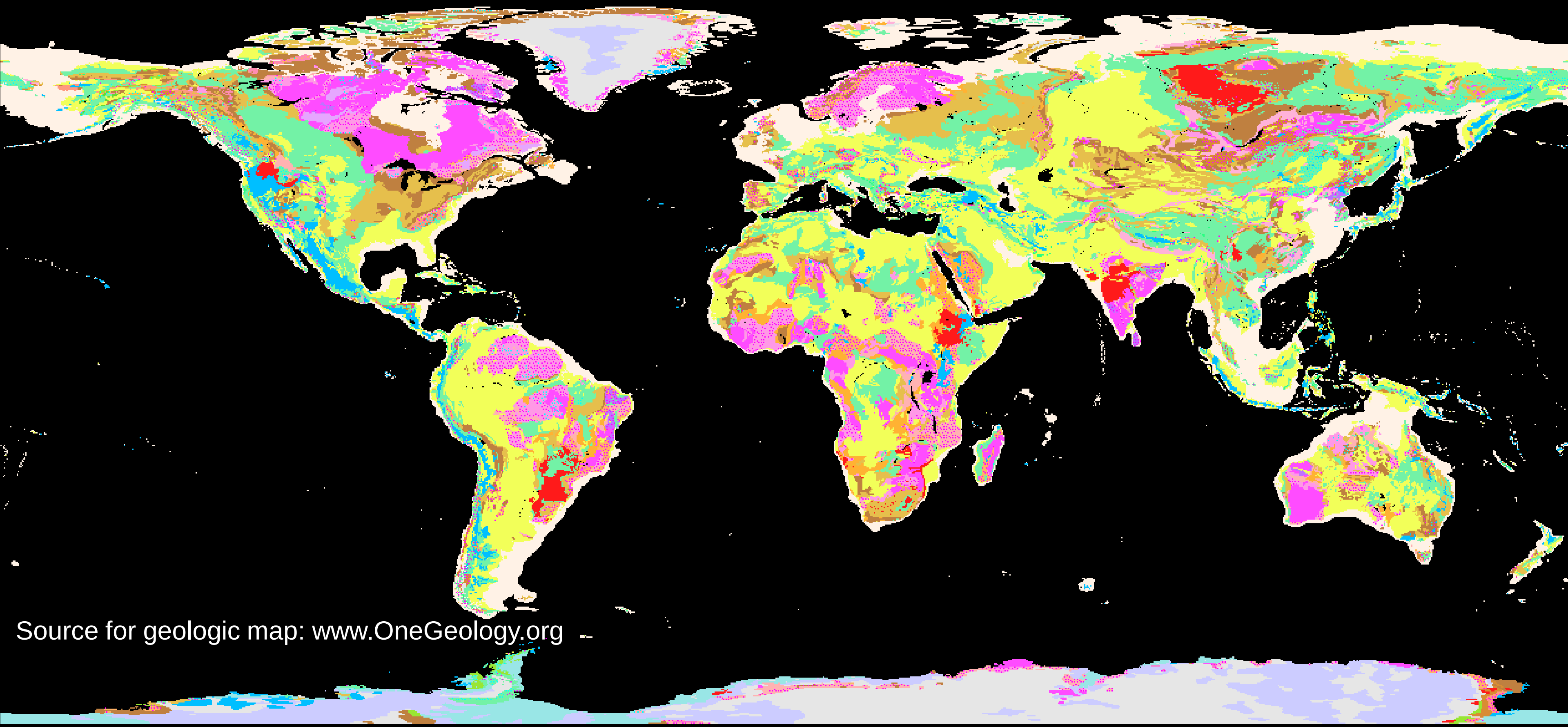
The Round Mountain gold mine in Nevada (volcanic-rock-hosted deposit) discovered in 1904, has yielded 13 million ounces of gold from 1977 to 2012 – continuous record of discovery around the initial deposit.



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

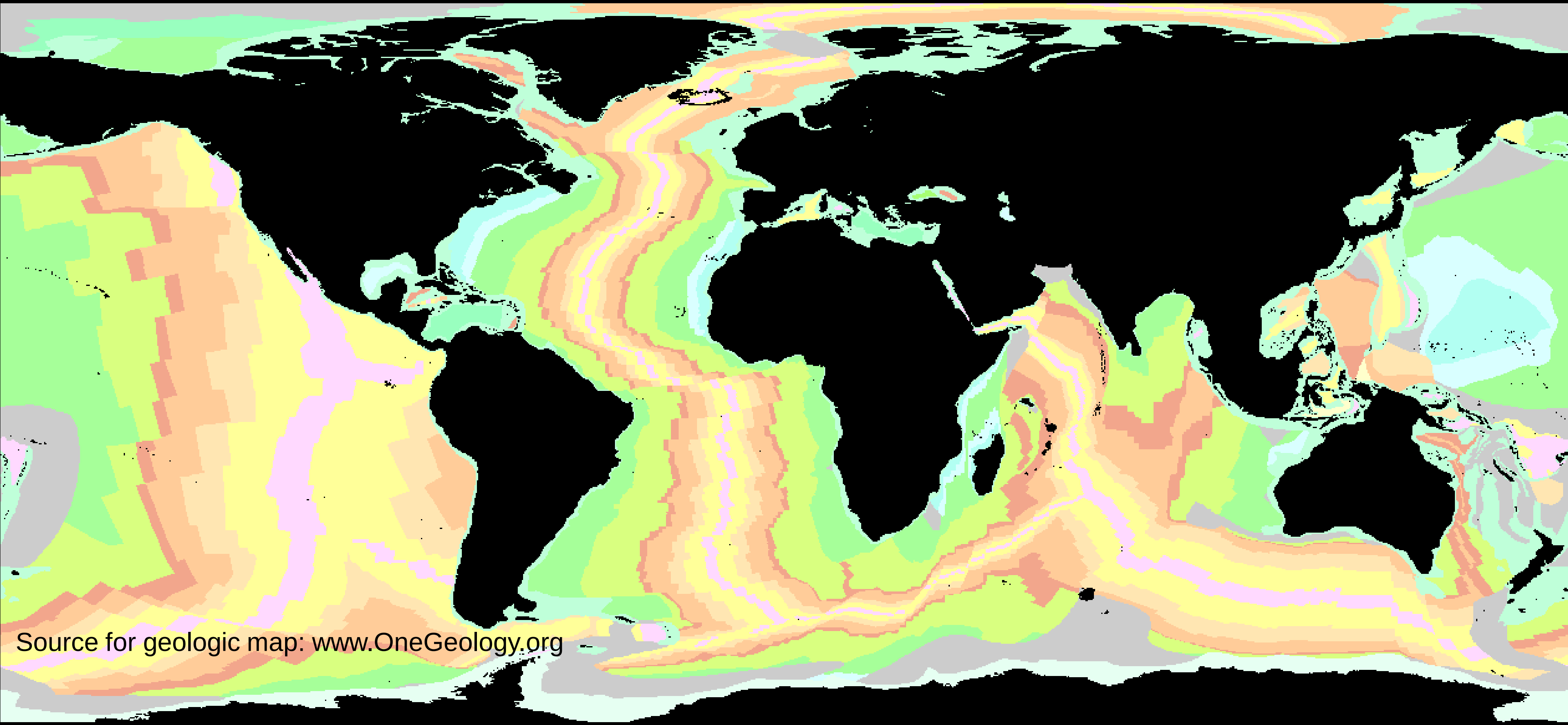
Archean (2.5 to 4.0 Ga) –**Au, Ni, U**

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



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.

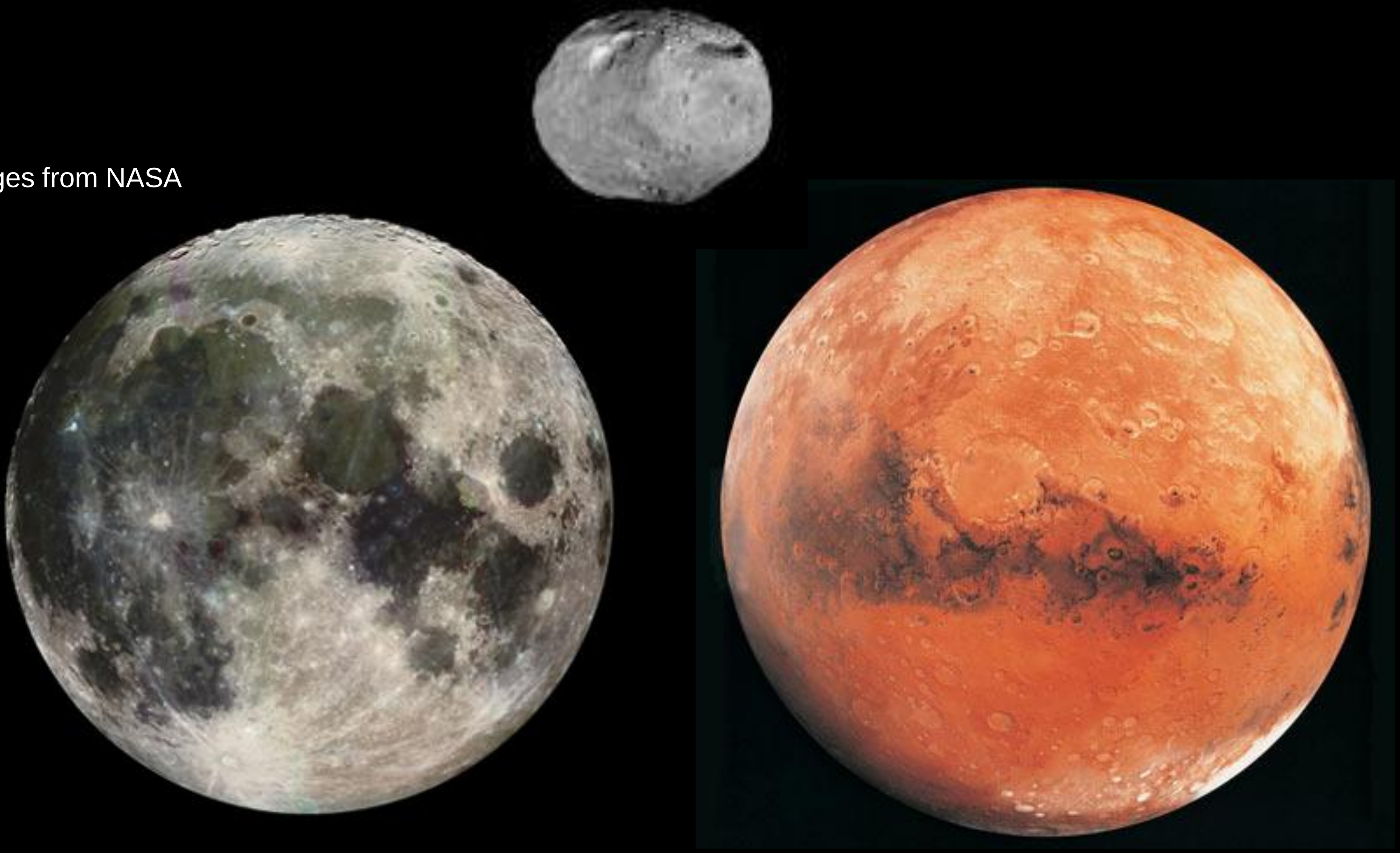
Examples of some new types of ore deposits recognized and brought into production in the last 55 years.

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

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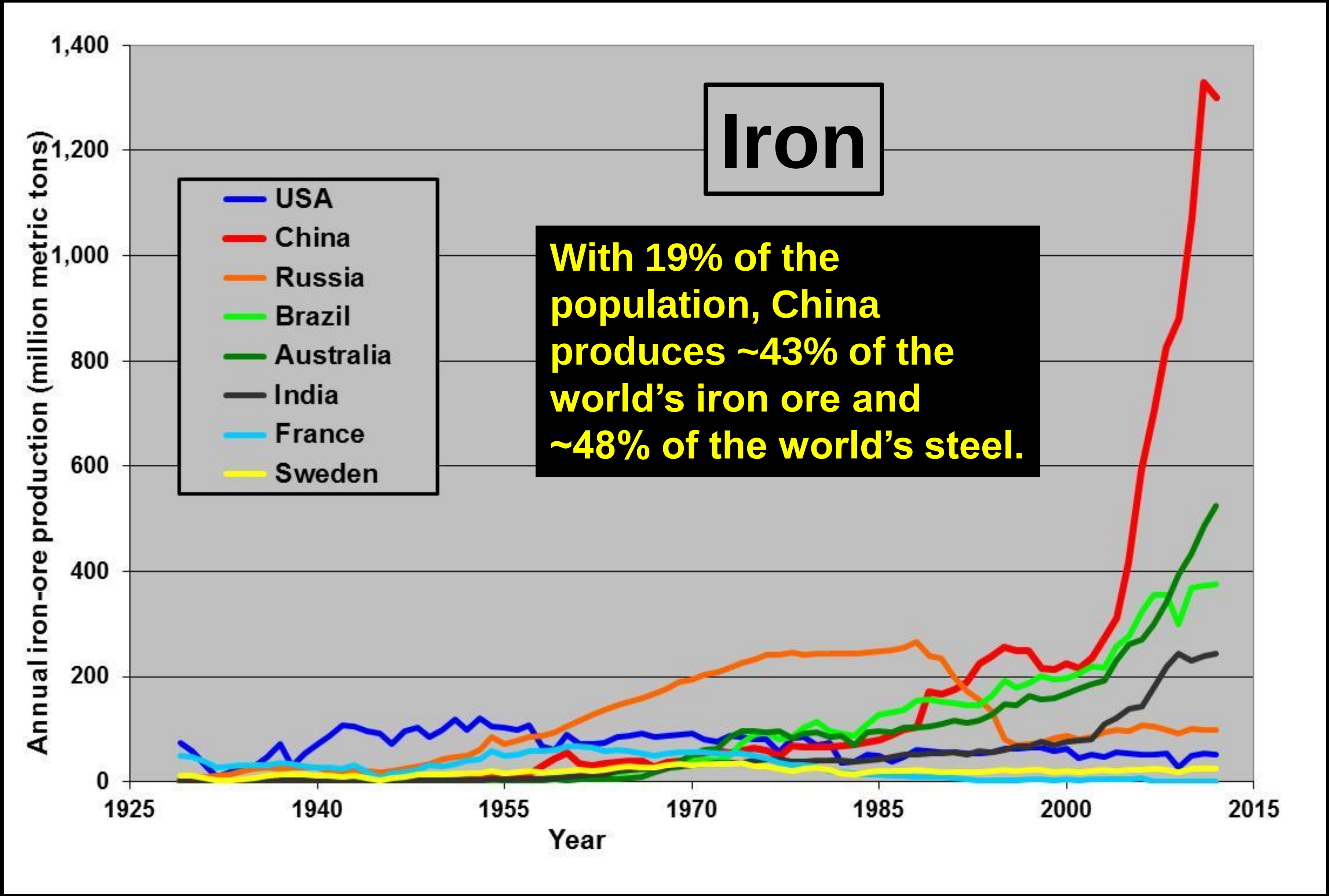
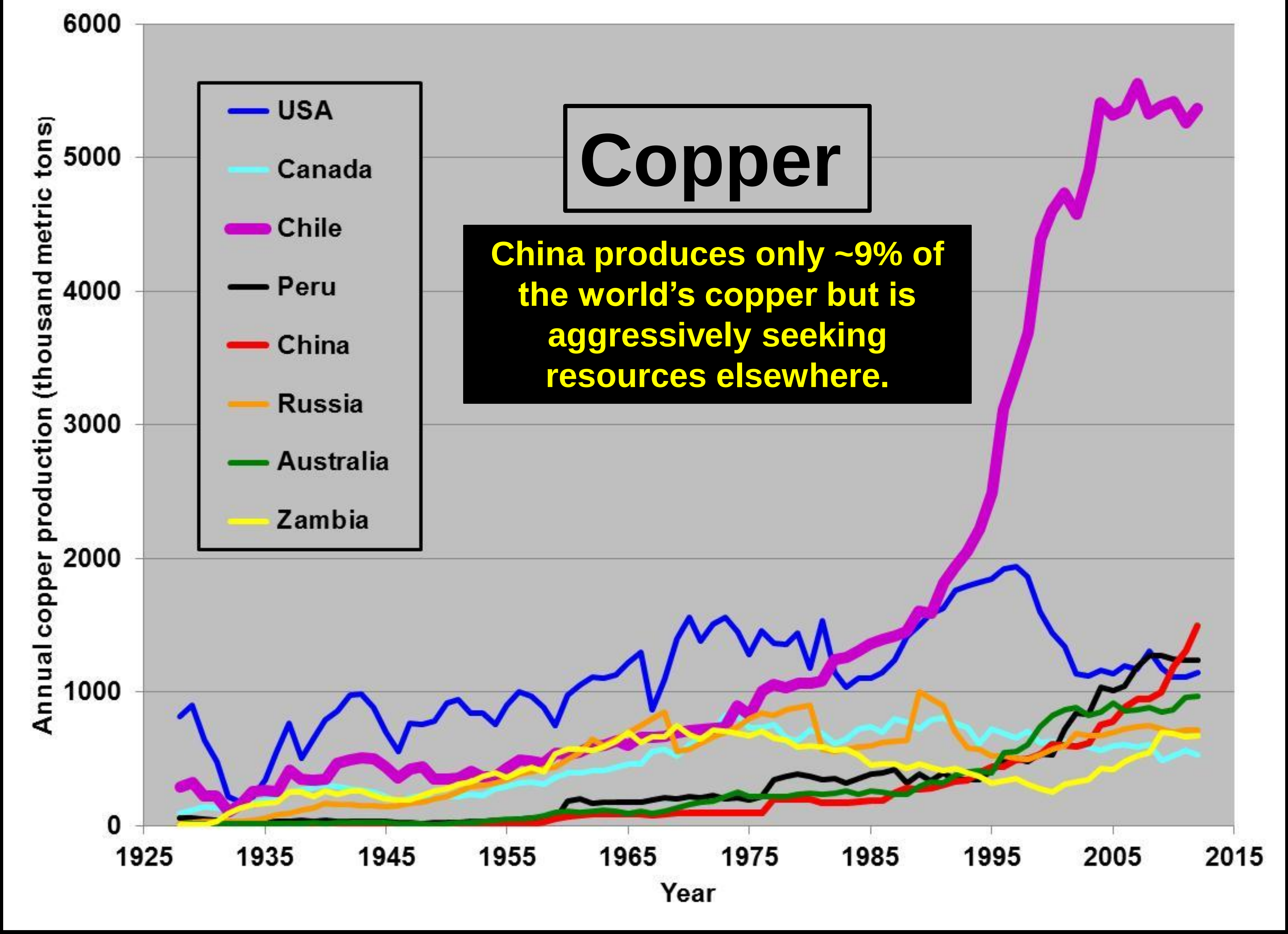
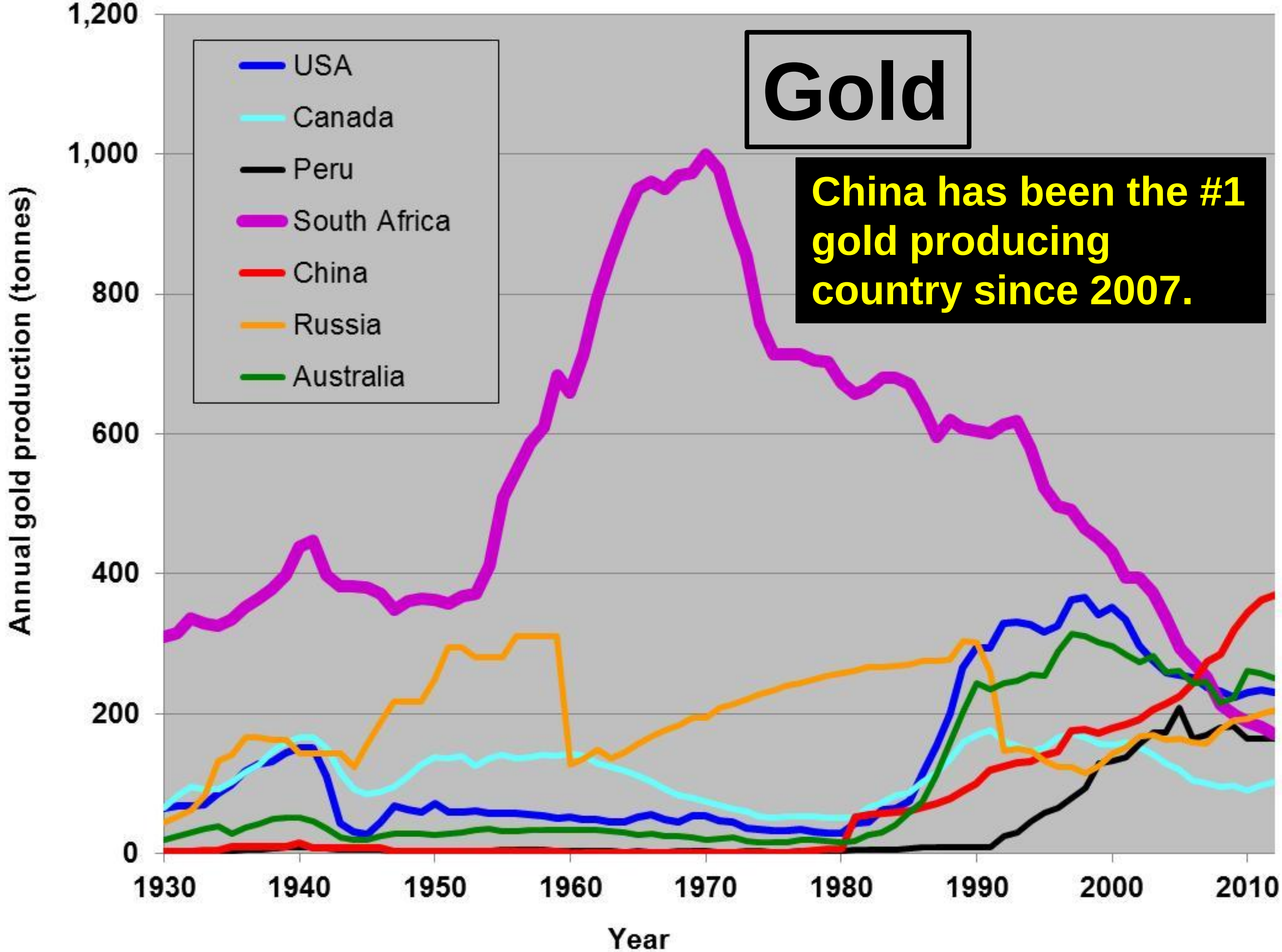
Challenges for the United States

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



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


Copper
China produces only ~9% of the world's copper but is aggressively seeking resources elsewhere.
USA
Canada
Chile
Peru
China
Russia
Australia
Zambia
Annual copper production (thousand metric tons)
0
1000
2000
3000
4000
5000
6000
Year
1925
1935
1945
1955
1965
1975
1985
1995
2005
2015

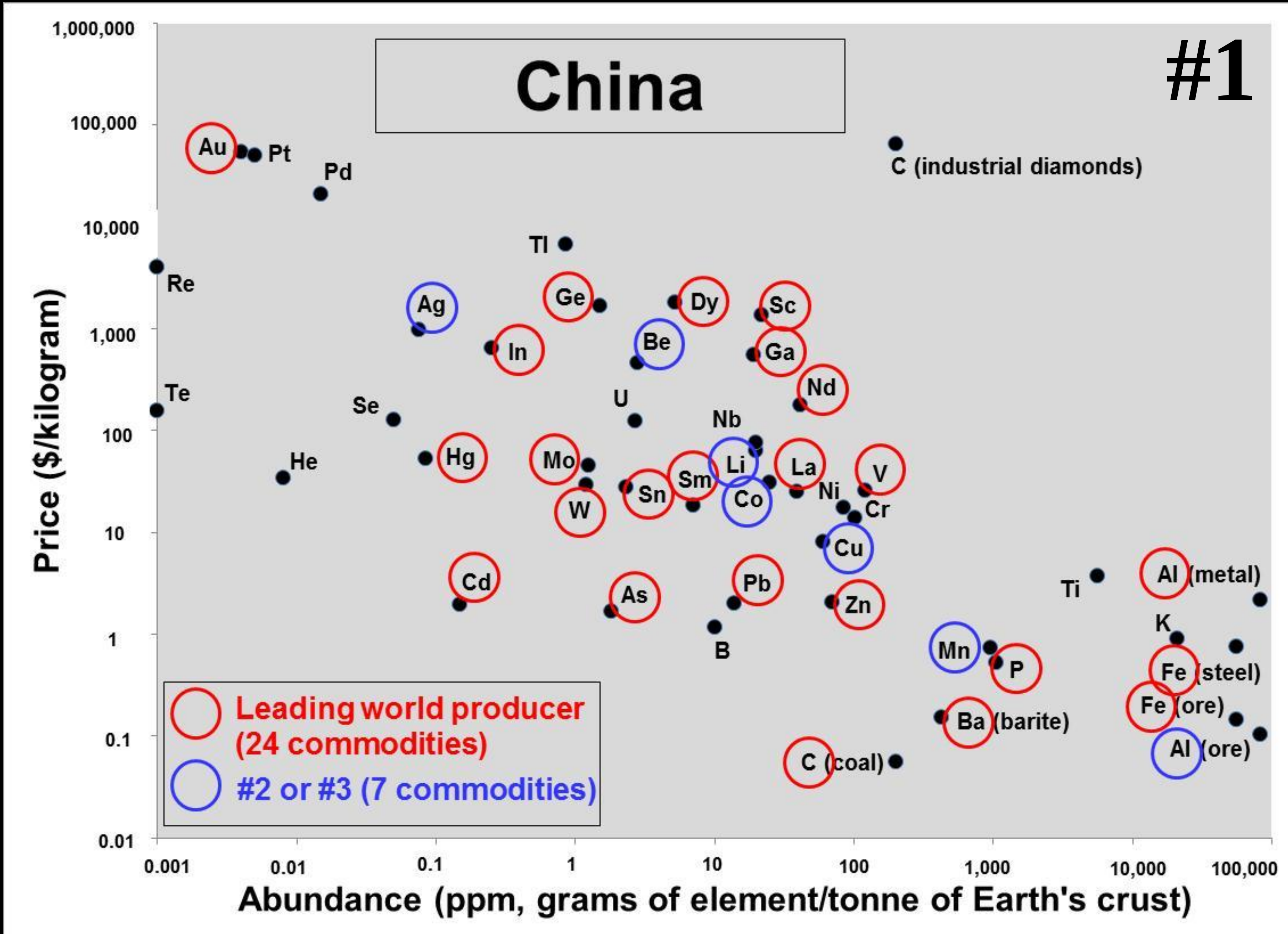


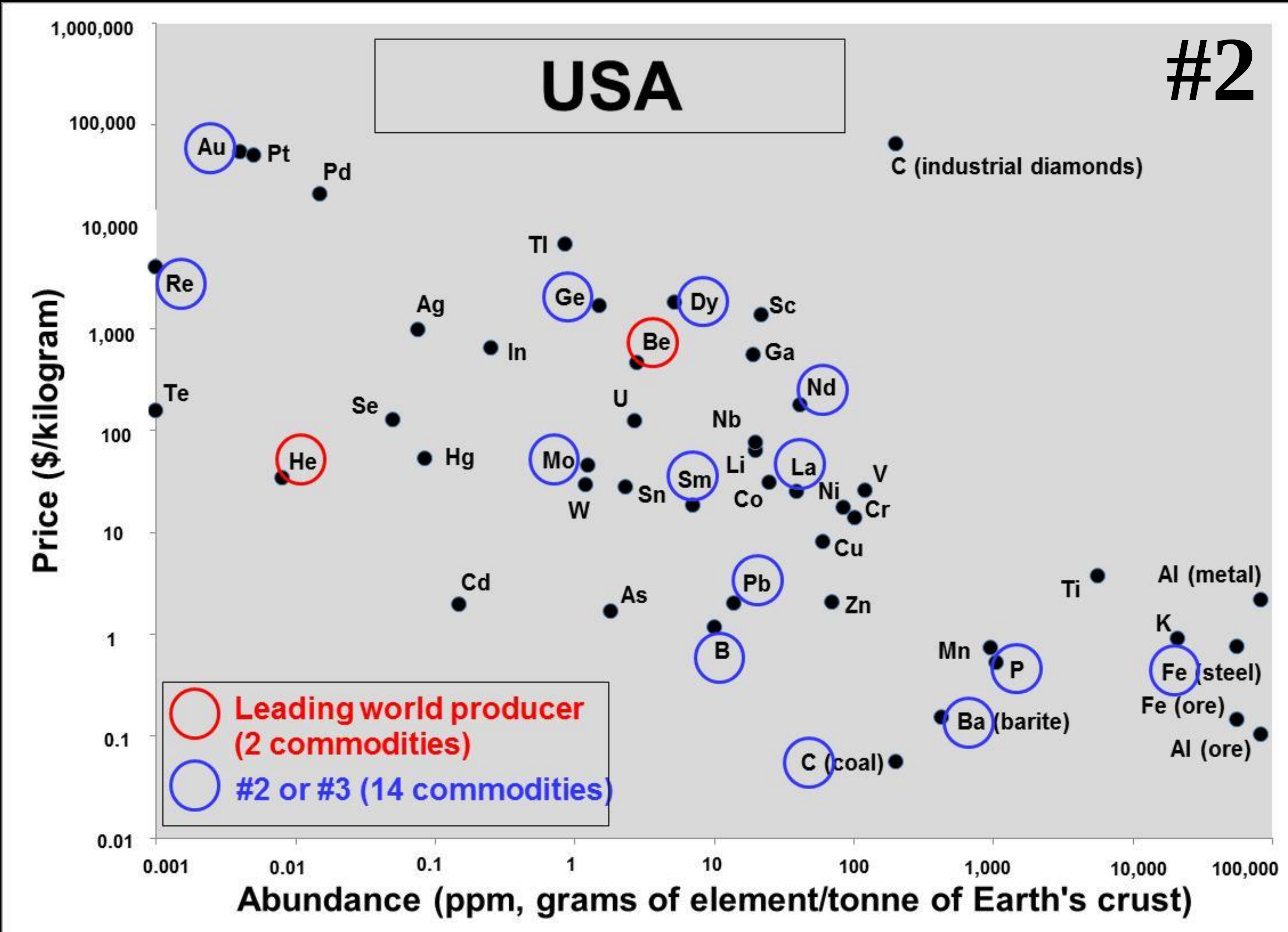
Gold
China has been the #1 gold producing country since 2007.
USA
Canada
Peru
South Africa
China
Russia
Australia
Annual gold production (tonnes)
1,200
1,000
800
600
400
200
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year

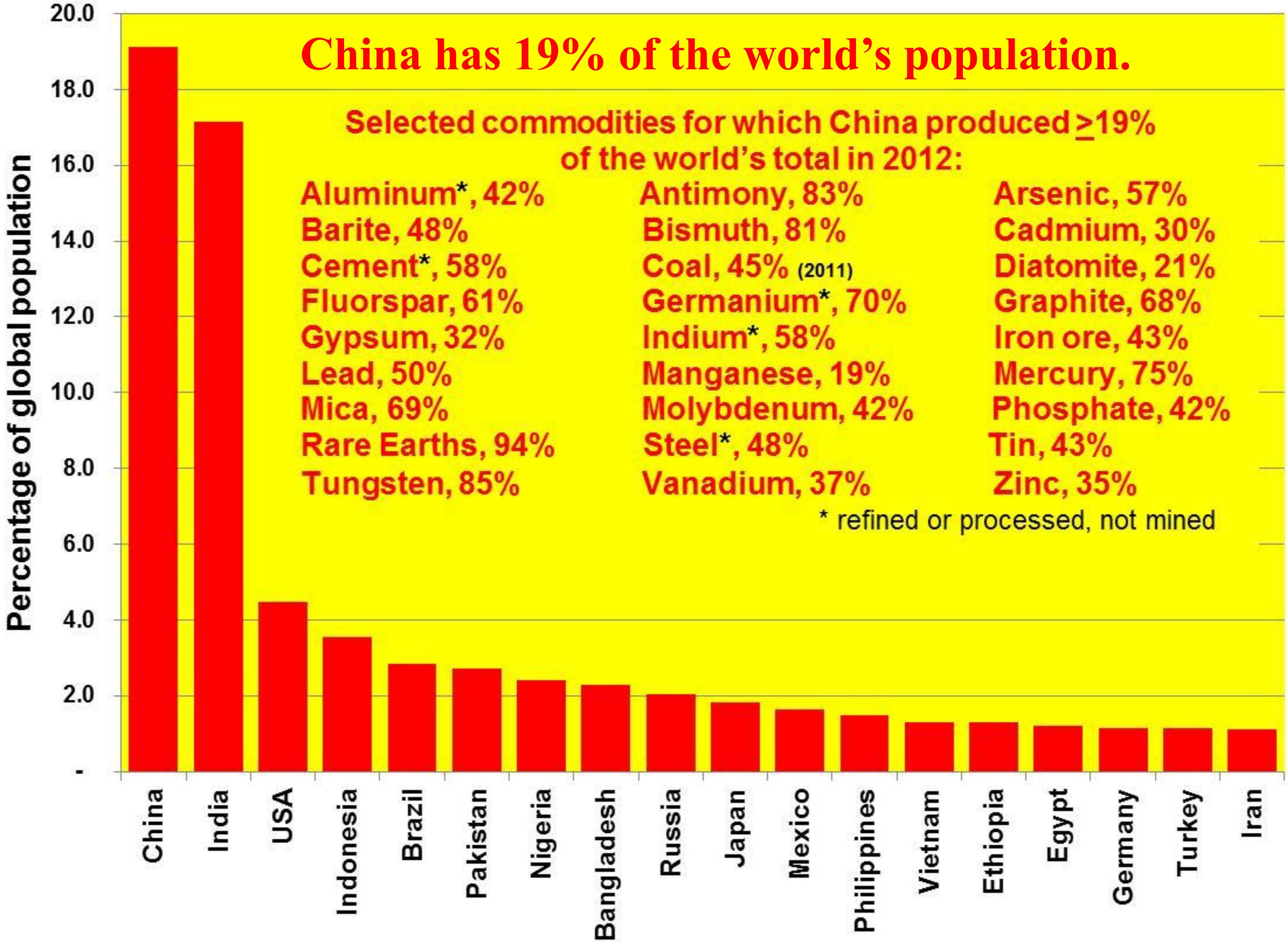
In production of 46 mineral commodities, China ranks well above all others.

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

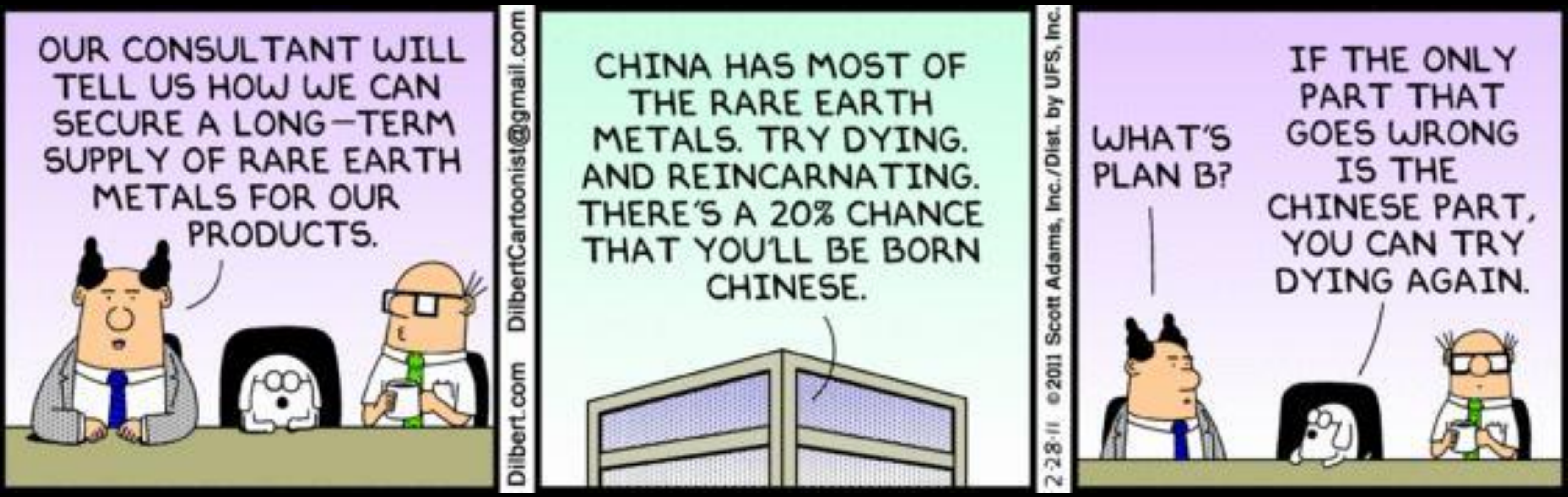
2012 production statistics from USGS, EIA for coal and uranium in 2011


China
#1
Price ($/kilogram)
Abundance (ppm, grams of element/tonne of Earth's crust)
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1,000
10,000
100,000
Au
Pt
Pd
C (industrial diamonds)
Tl
Re
Ag
Ge
Dy
Sc
In
Be
Ga
Nd
Te
Se
U
Nb
He
Hg
Mo
Li
La
V
Sm
Sn
Ni
W
Co
Cr
Cu
Cd
As
Pb
Zn
Ti
Al (metal)
B
K
Mn
P
Fe (steel)
Fe (ore)
Ba (barite)
Al (ore)
C (coal)
Leading world producer
(24 commodities)
#2 or #3 (7 commodities)


USA
#2
Price ($/kilogram)
1,000,000
100,000
10,000
1,000
100
10
1
0.1
0.01
Abundance (ppm, grams of element/tonne of Earth's crust)
0.001
0.01
0.1
1
10
100
1,000
10,000
100,000
Au
Pt
Pd
C (industrial diamonds)
Tl
Re
Ge
Dy
Sc
Ag
Be
Ga
In
Nd
Te
Se
U
Nb
He
Hg
Mo
Li
La
V
Sm
Co
Ni
Sn
W
Cr
Cu
Cd
As
Pb
Ti
Al (metal)
Zn
K
B
Mn
P
Fe (steel)
Fe (ore)
Ba (barite)
Al (ore)
C (coal)
Leading world producer (2 commodities)
#2 or #3 (14 commodities)


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)



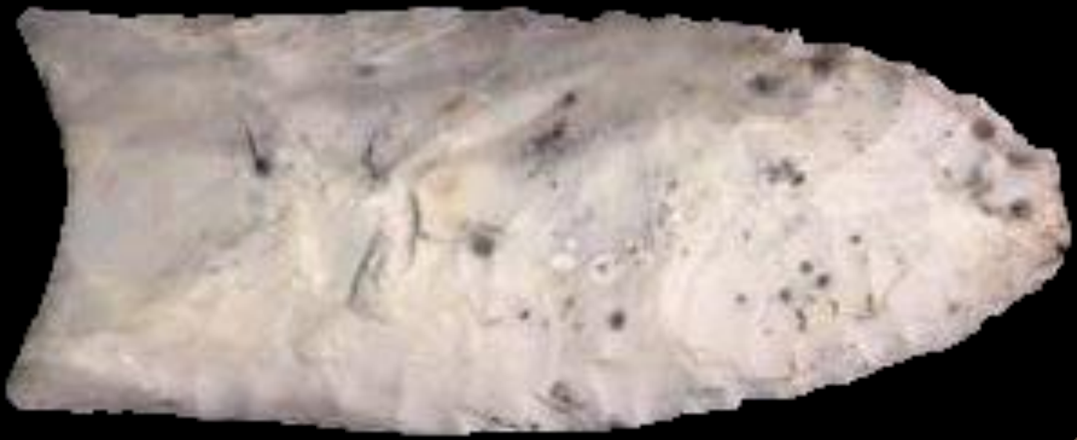
$CuIn_xGa_{(1-x)}Se_2$, CdTe, GaAs, Ag, and $Si_{1-x}Ge_x$ for solar panels

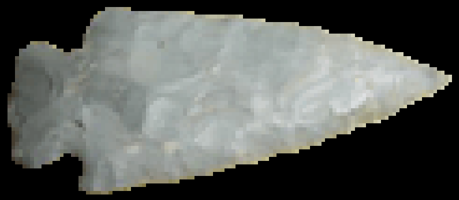
$Fe_{14}(Nd,Dy)_2B$, $SmCo_5$, and Sm_2Co_{17} for magnets, e.g., in wind turbines

Li, La, Ni, and V for batteries

Pt, Pd for catalysts in fuel cells

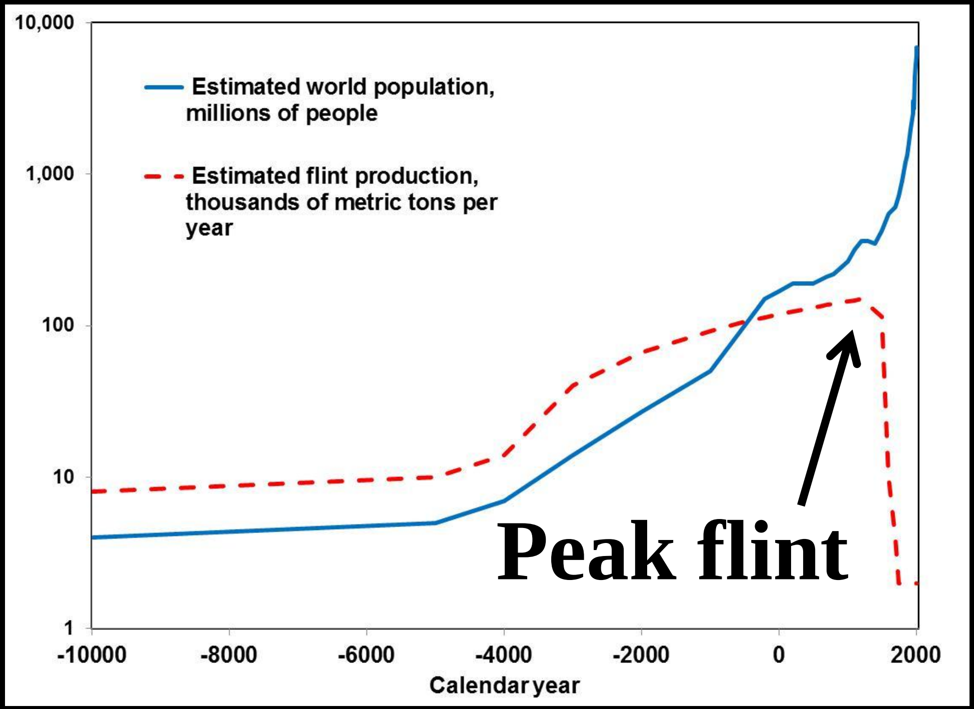
Tb, Eu in fluorescent lights



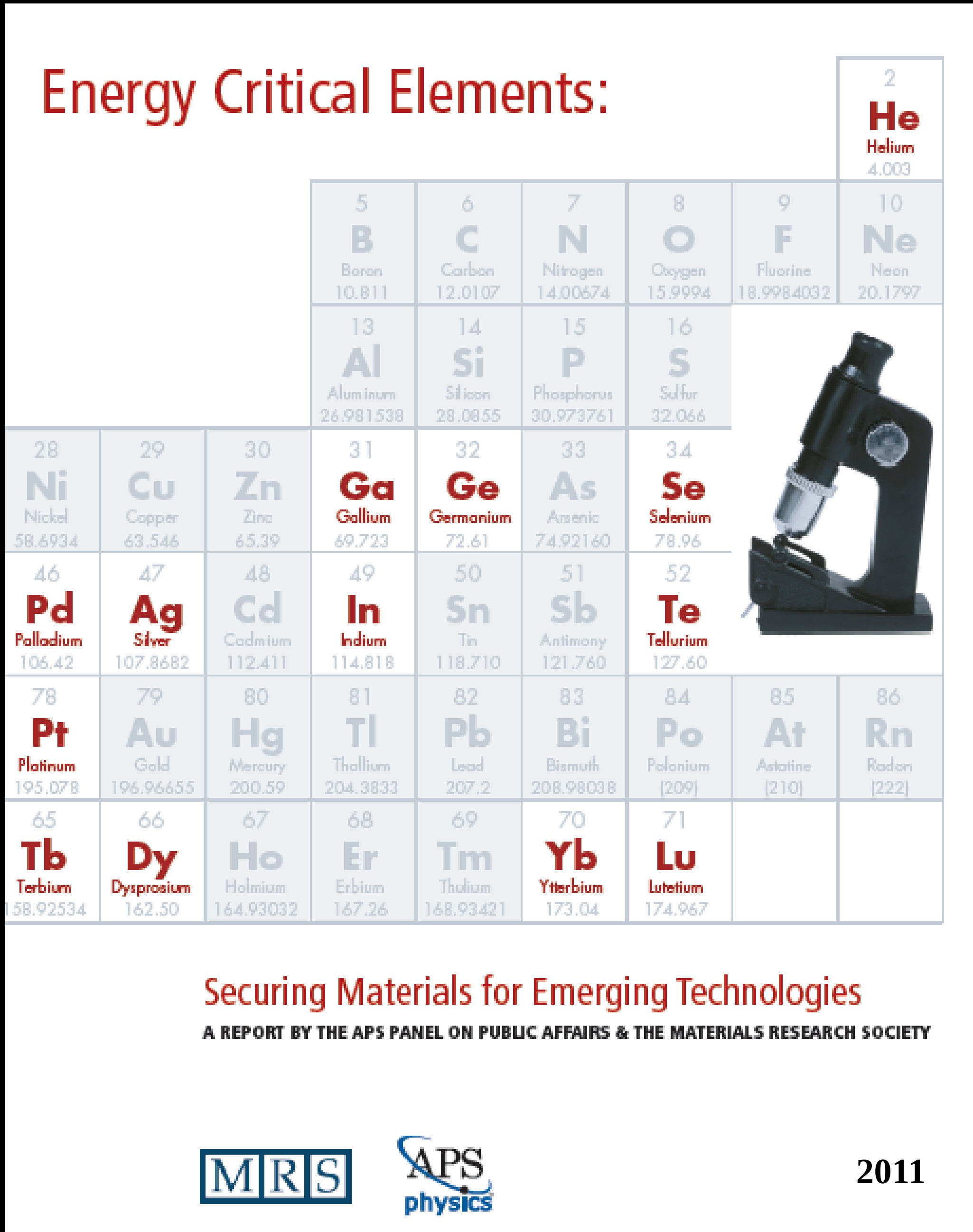


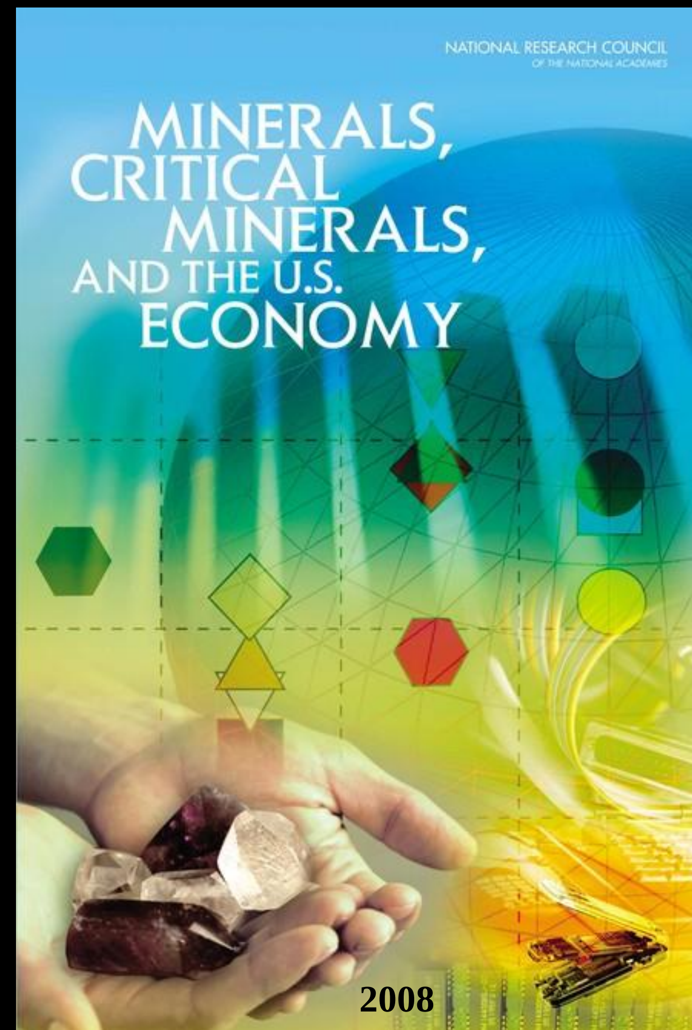
Arrowhead clipart from www.firstpeople.us

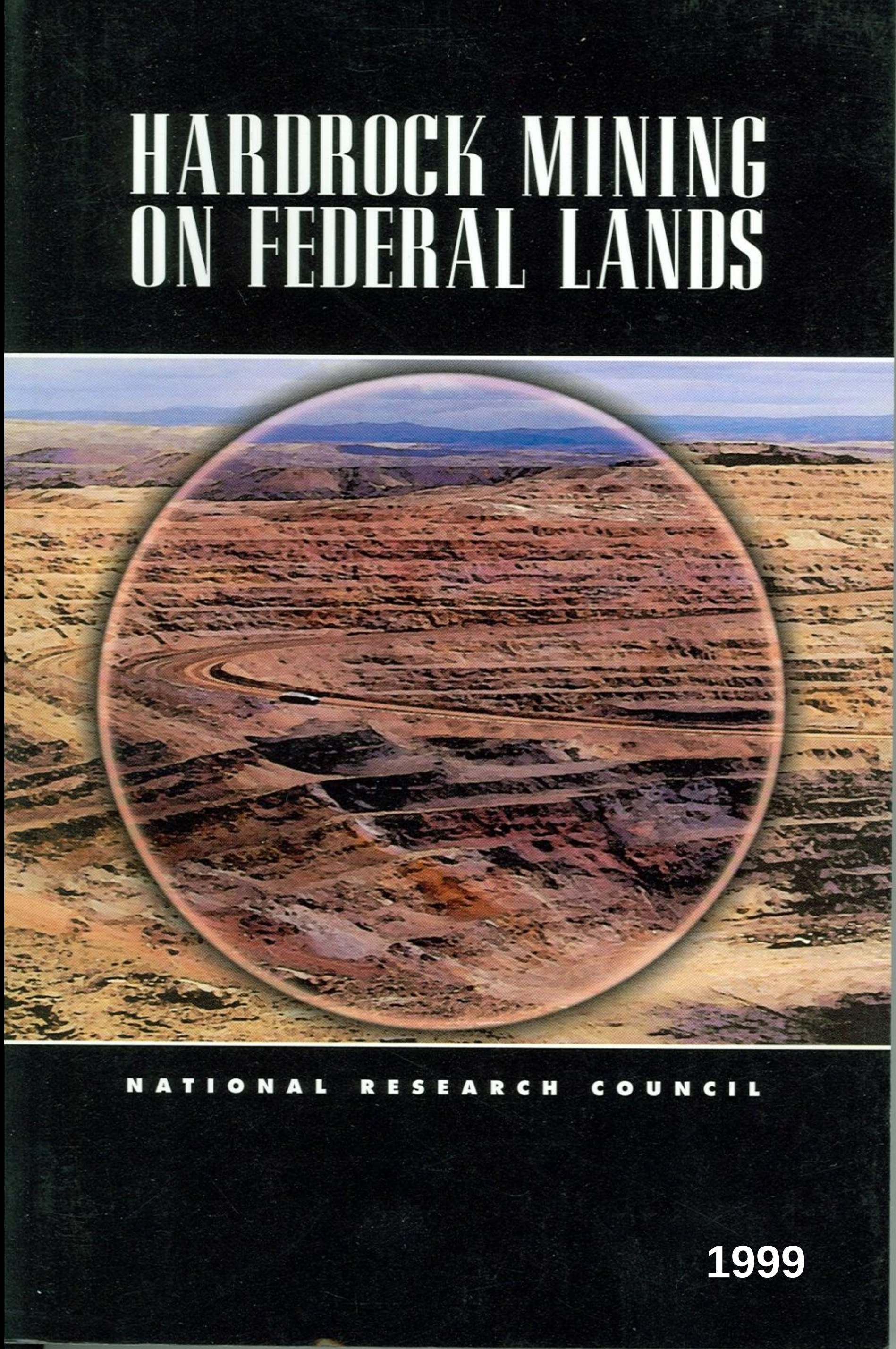
Critical and strategic minerals do change with time.



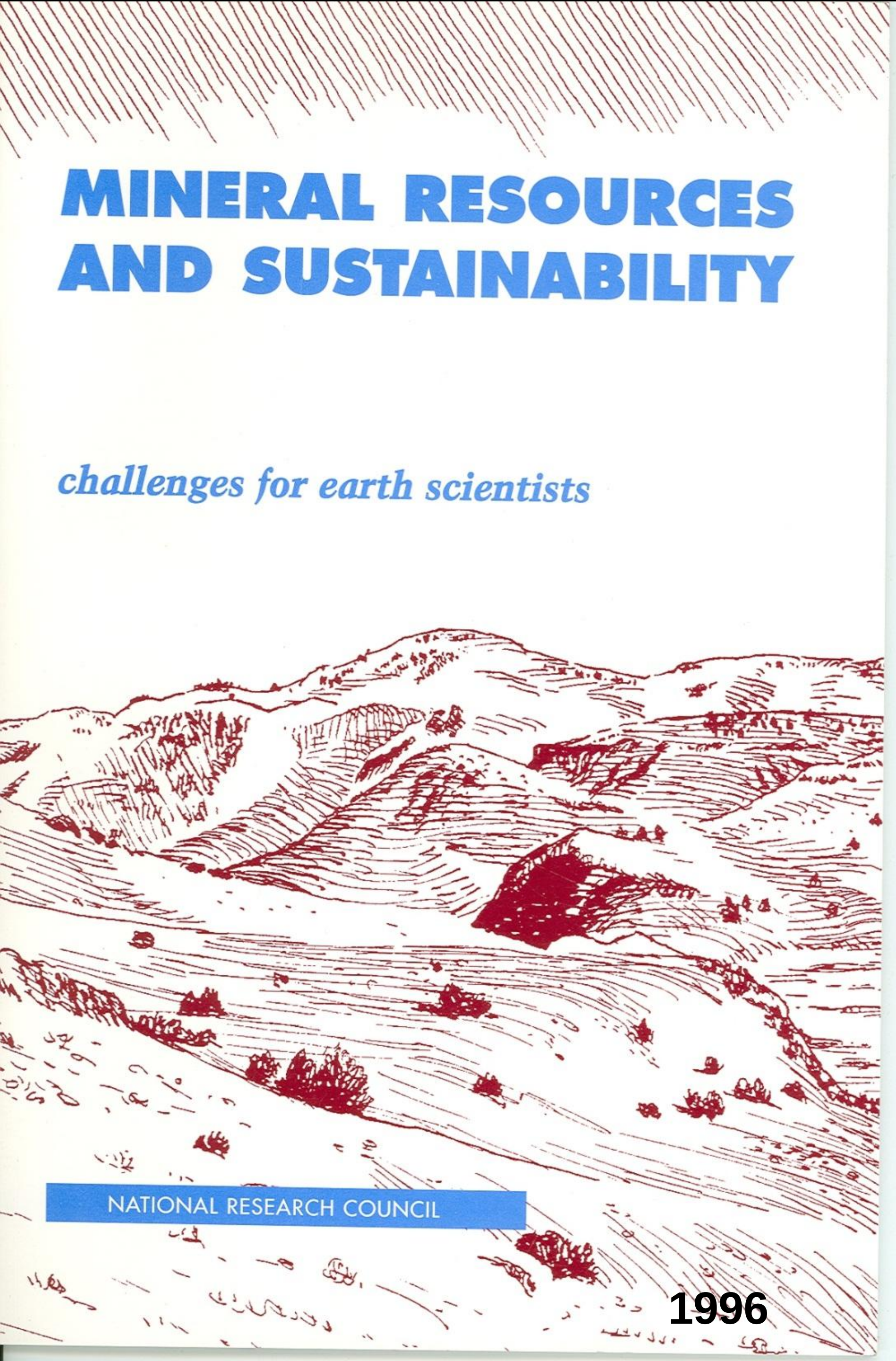
What minerals will be critical for the country?







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



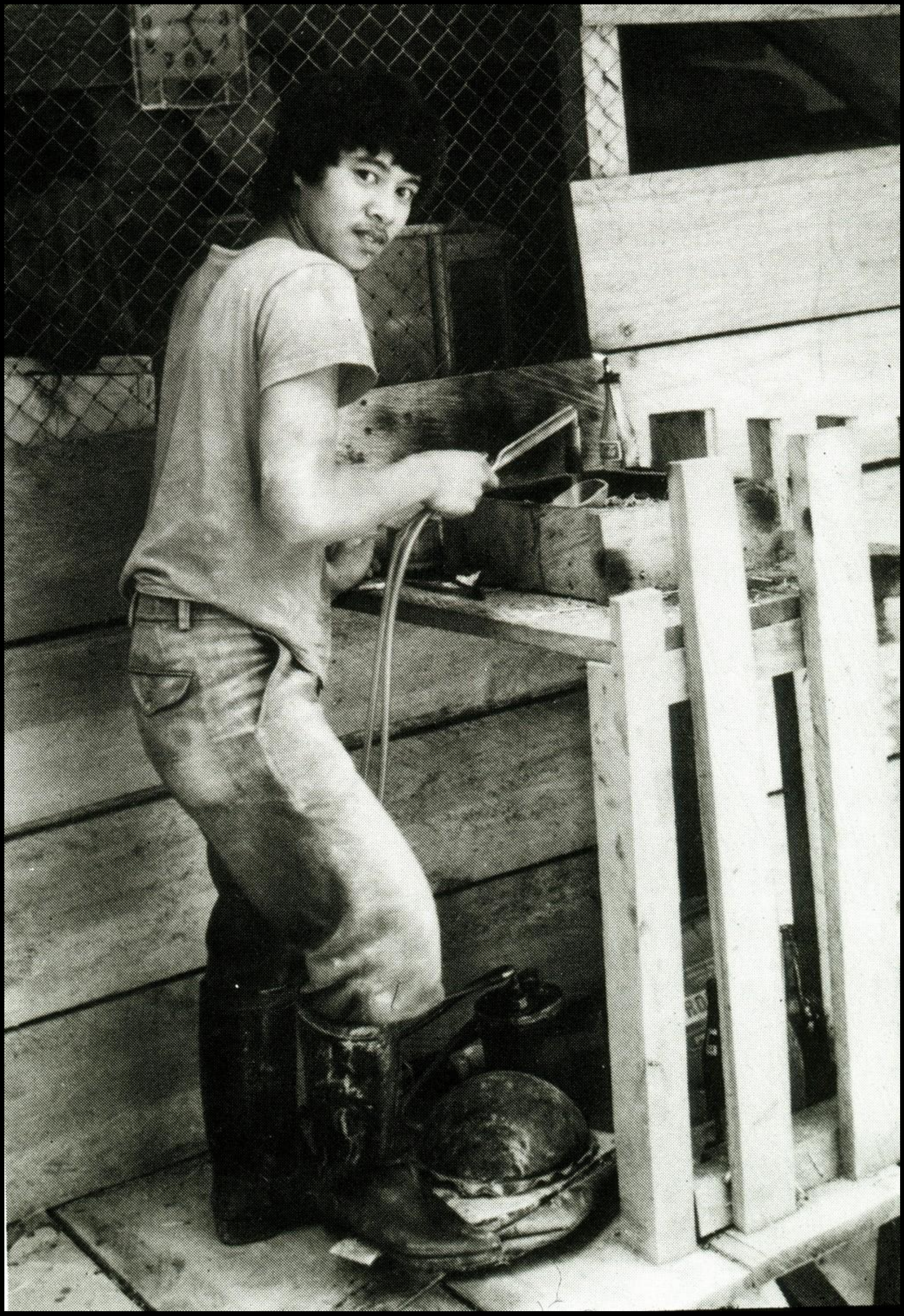
Will the USA be a major producer of mineral resources in the future?

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.

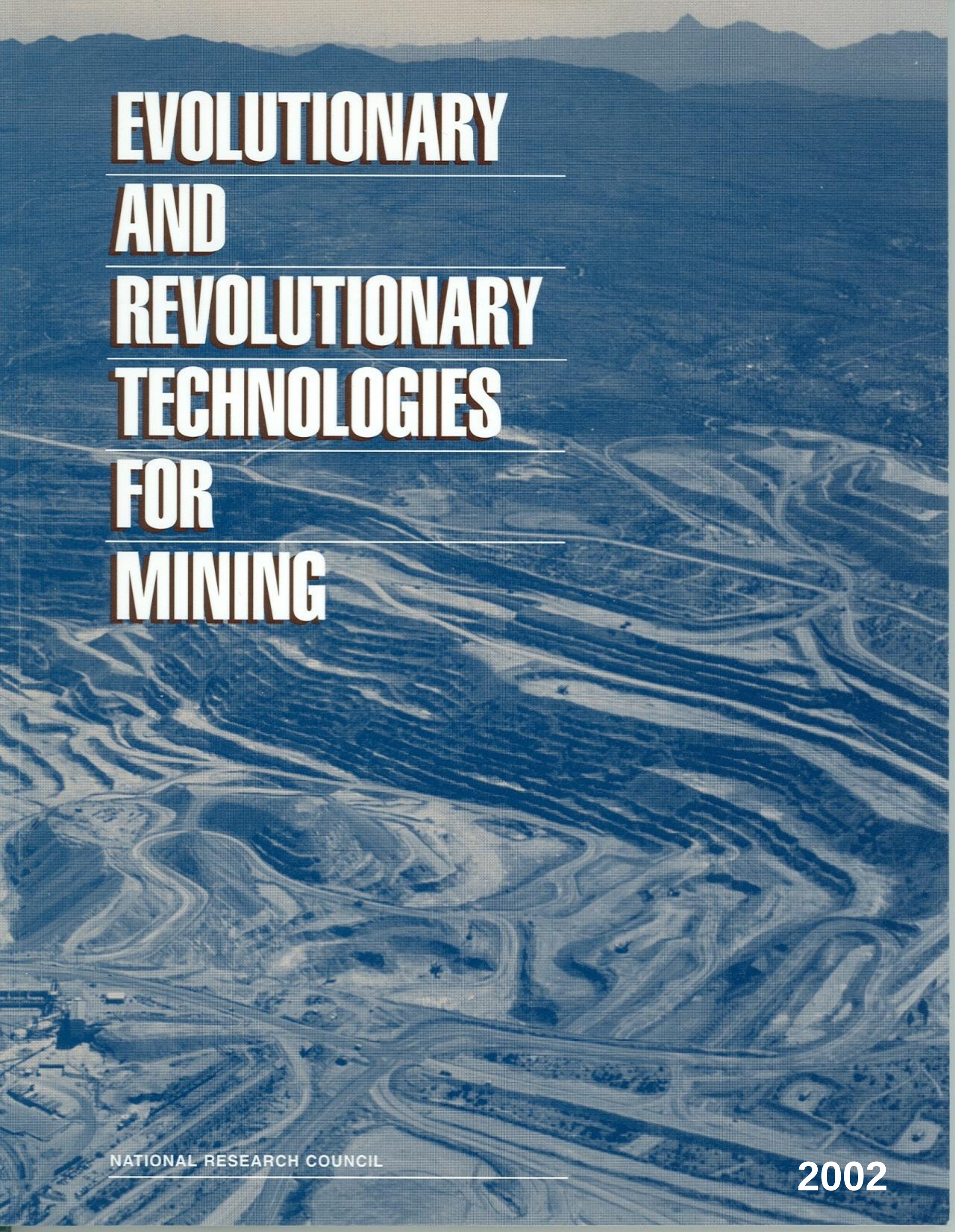
Four artisanal miners (galamsey) work unsafely, without personal protective equipment or ground support, near Kyereboso in Ghana in 2008.

Gold mill in Sulawesi (Larry James photo)

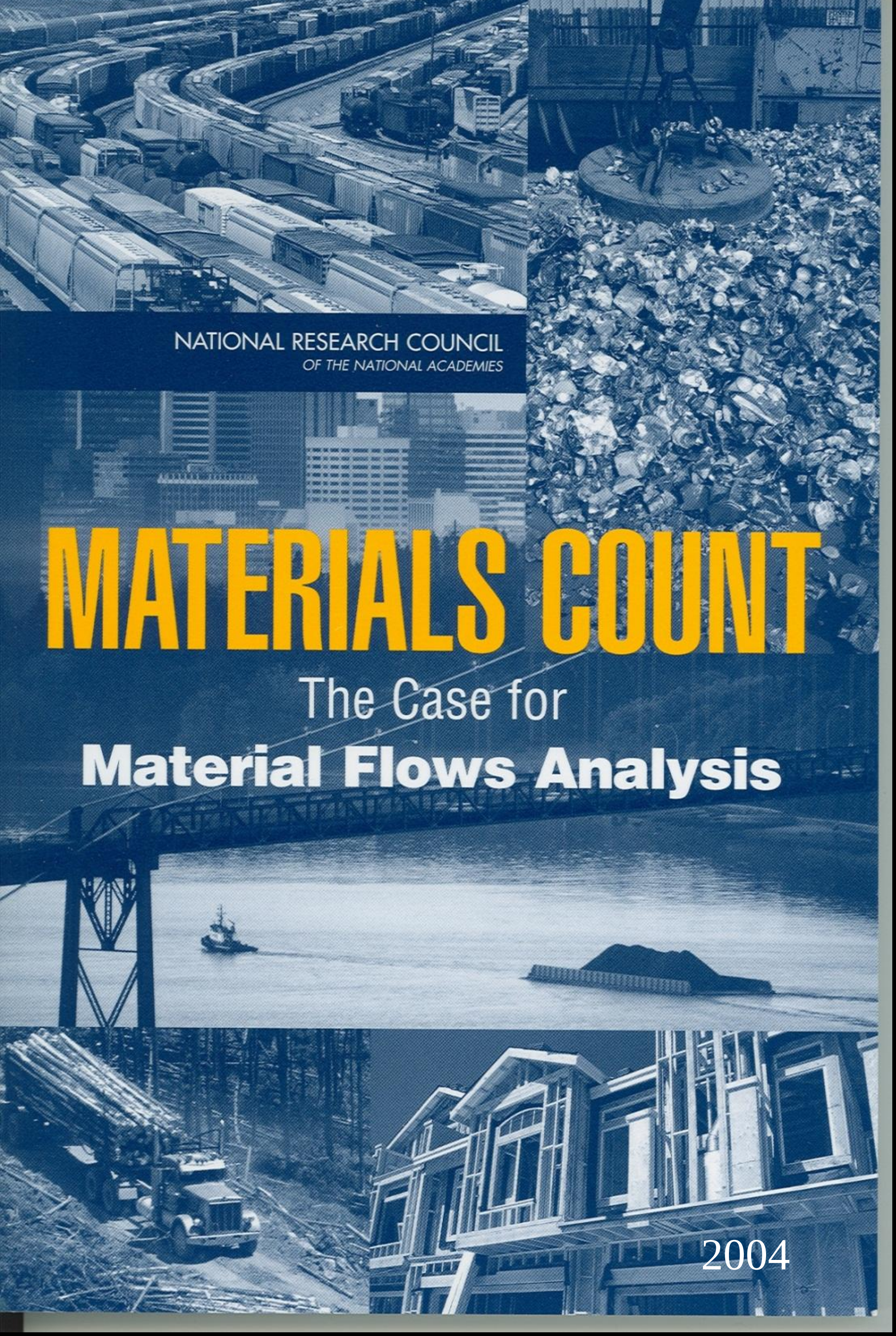


Recent reports (Science Oct. 2013) state that 70% of Hg pollution worldwide is from artisanal mining.

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

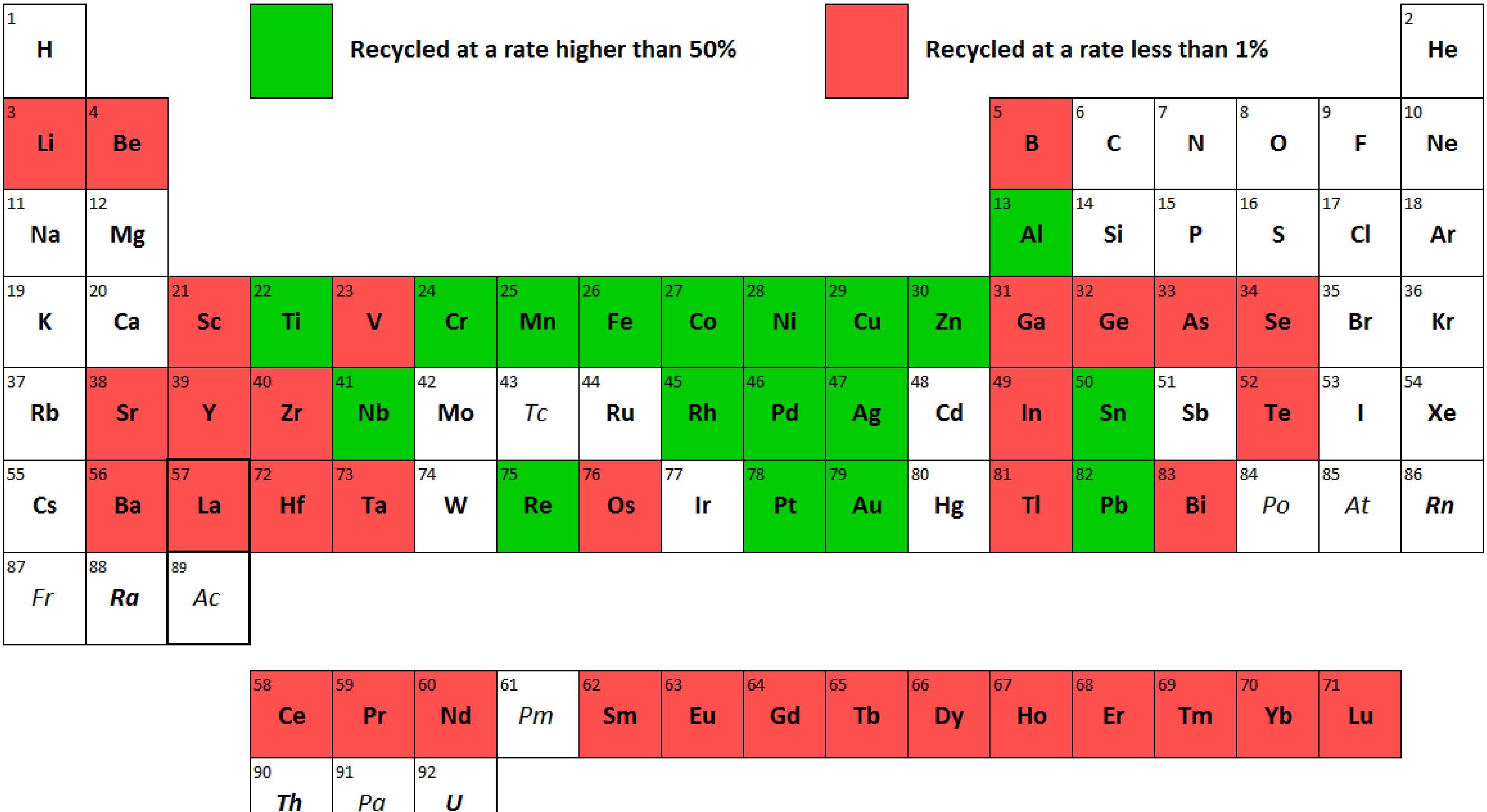


Will the US government invest in research needed to discover, extract, and process mineral resources in an environmentally responsible manner?

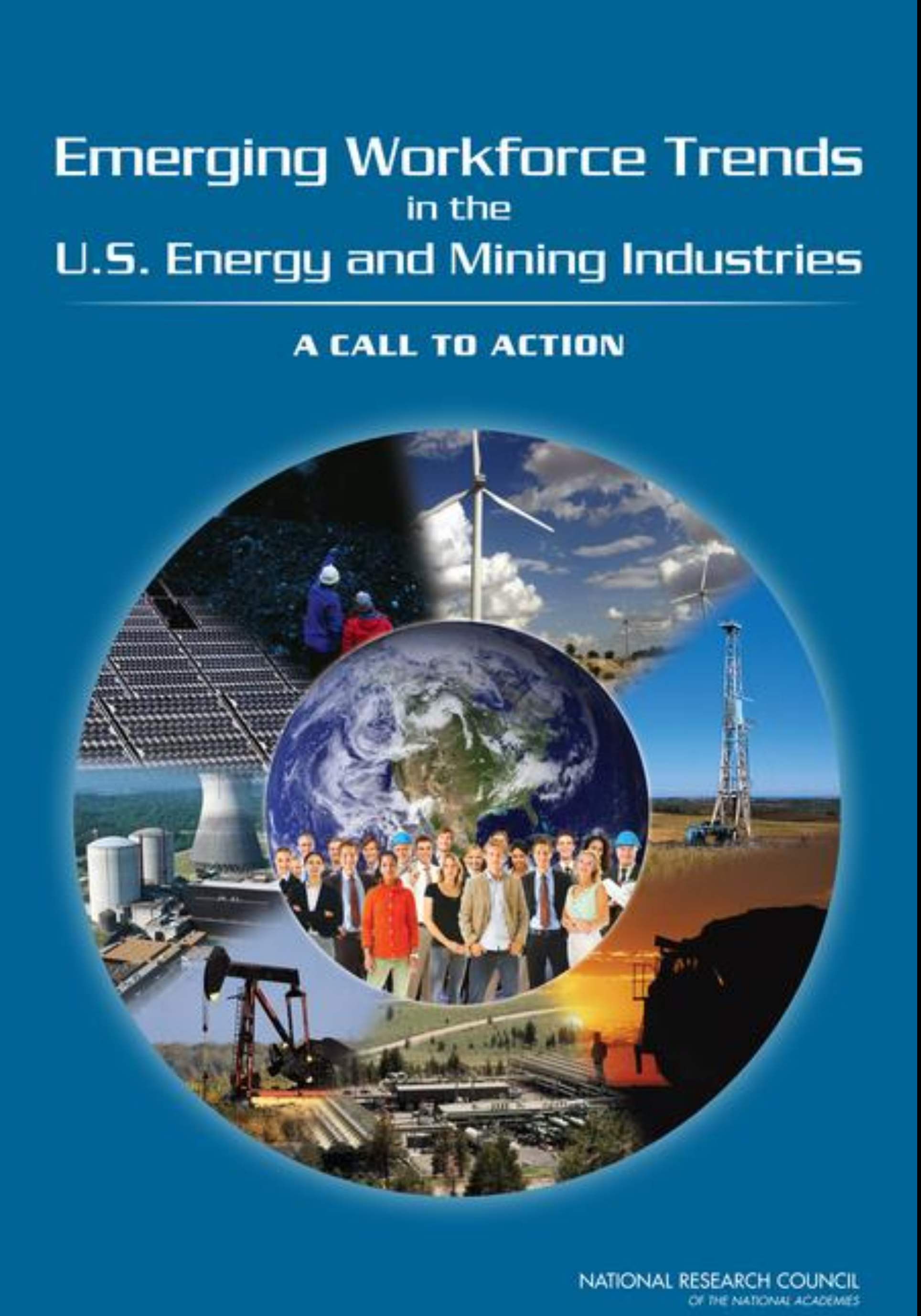


Will the US government invest in research on improving the rate of recycling of mineral resources, and on finding substitutes for mineral resources that become too expensive for commercial or other applications?

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).



Source: Graedel et al. (2011)



2013

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

Geologic Mapping

Future Needs

Committee on Geologic Mapping

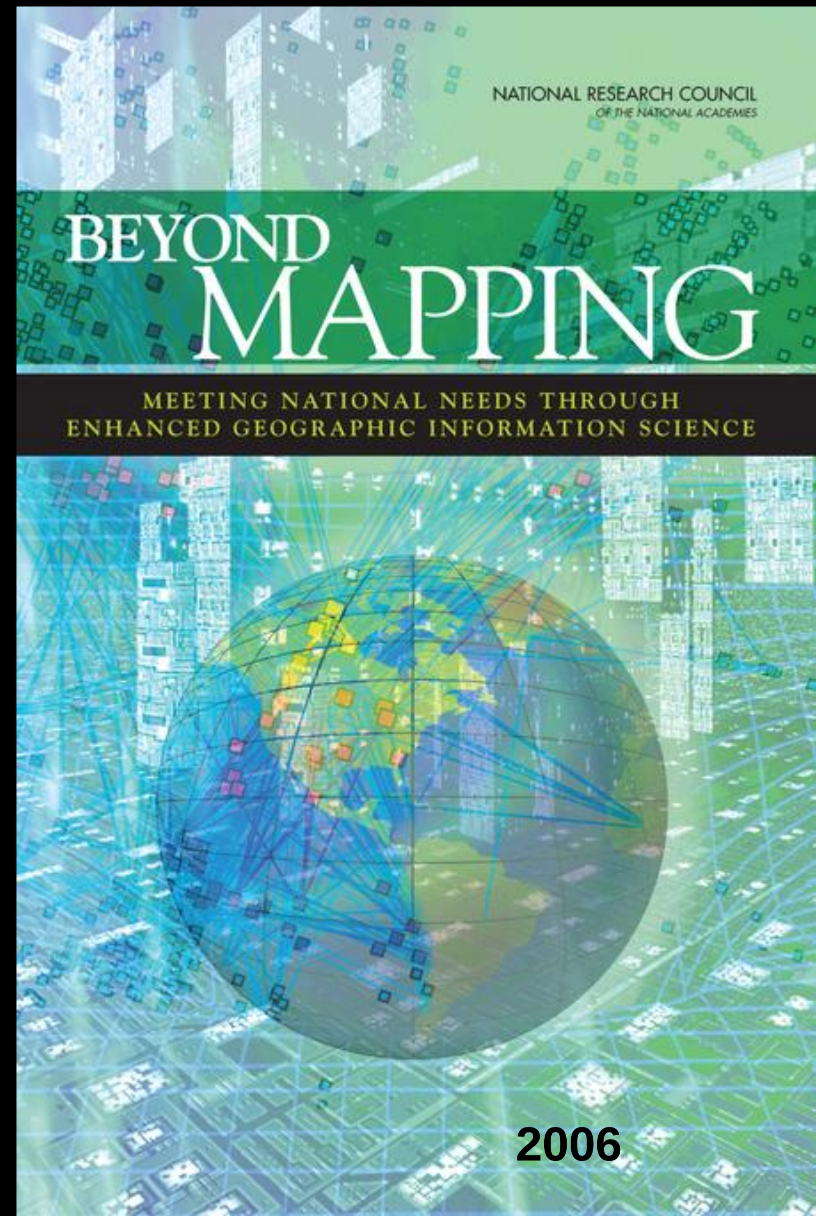
Board on Earth Sciences

Commission on Physical Sciences, Mathematics, and Resources

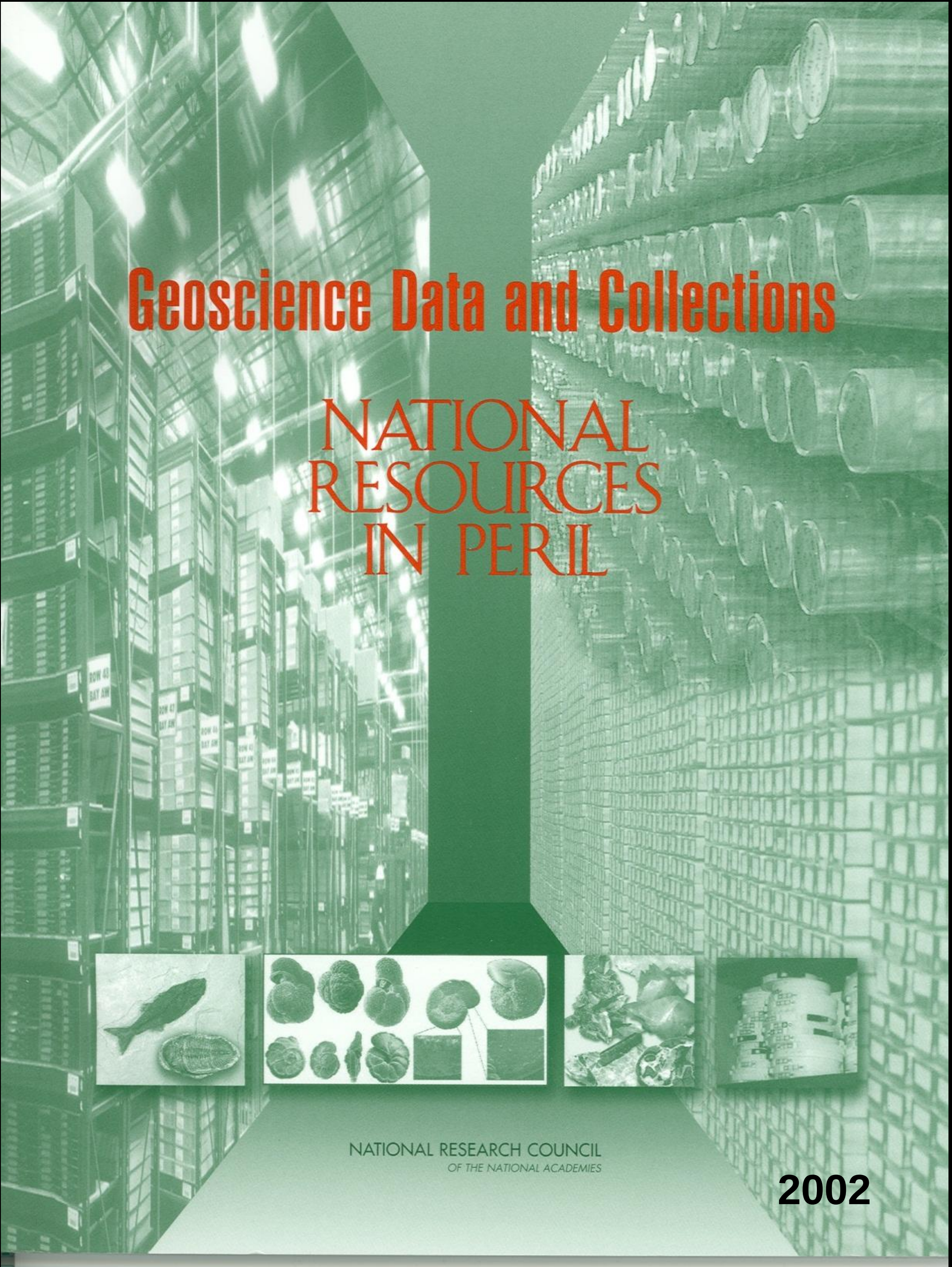
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.
1988

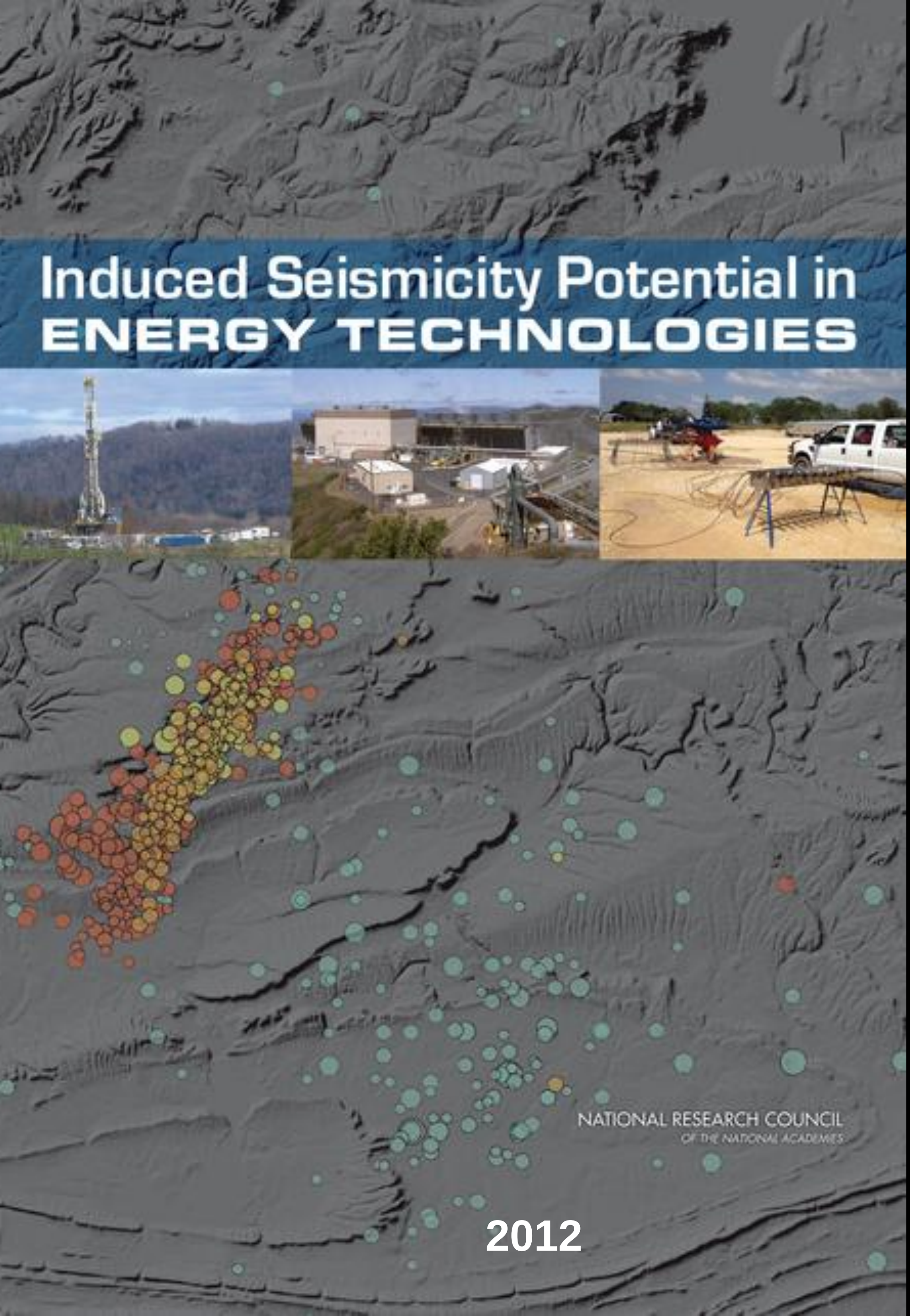
Will the US and other governments support the basic research, including geologic mapping, needed to understand where resources are likely to be found?



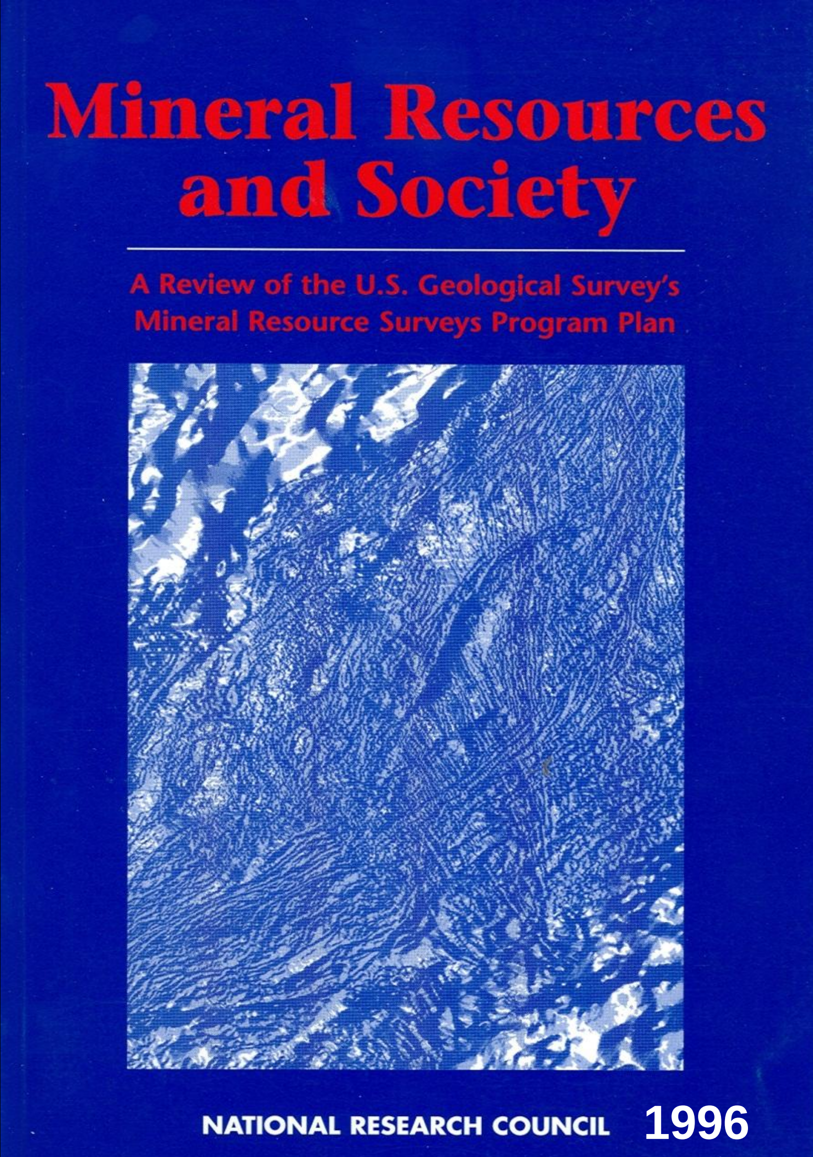
2006



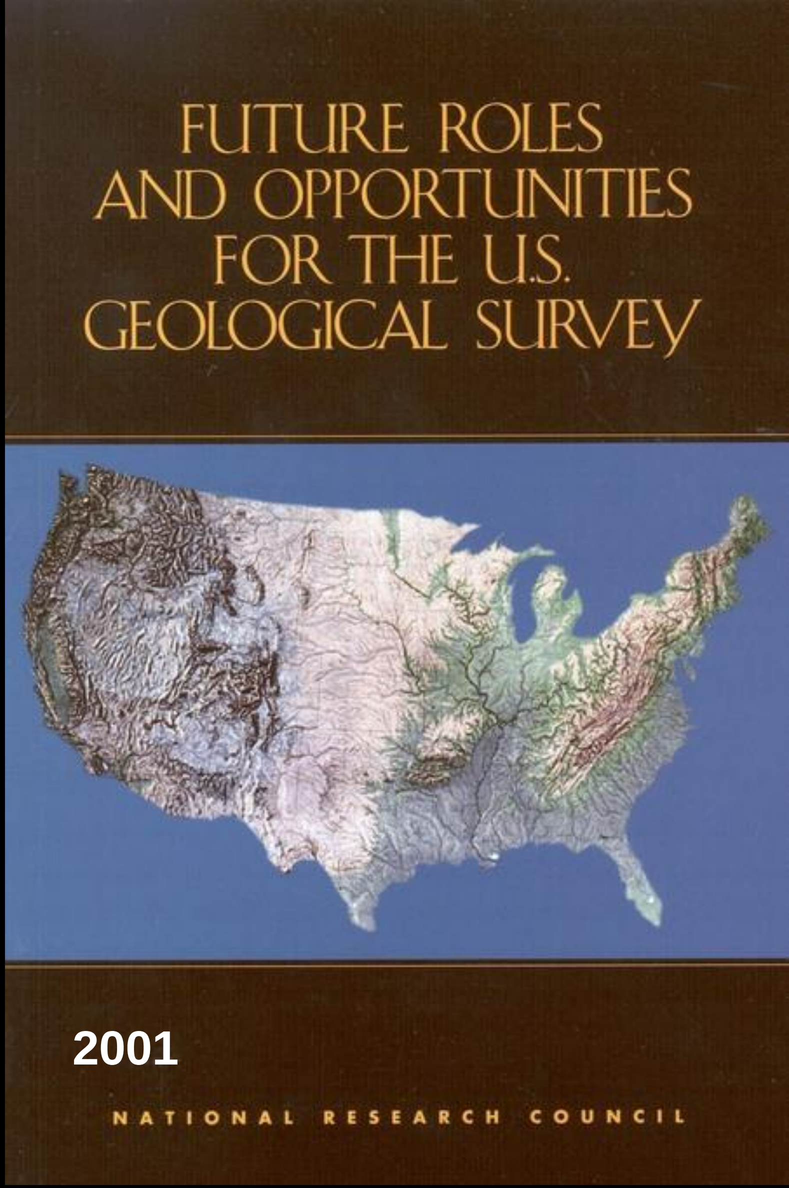
Will the US and other governments support the preservation of geological data and collections that stimulate discovery?



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
NATIONAL RESEARCH COUNCIL

2001

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