ME589/Geol571/GEOC 589-04D/GEOL 589-04/GEOL 589-04D Advanced Topics

Mineral Deposits in New Mexico

Introduction

Virginia T. McLemore

Safety

- Start each class with a safety moment
  - Each student will be responsible for the day’s safety moment
- Note where the restrooms are, emergency exits
- Call 911 in case of an emergency

Safety—cont

- **Always make sure that you have full instructions for the job to be done.**
  - Always know your objectives before starting your job.
  - Make sure you have read the SOPs relating to your job ahead of time.
    - **WHAT ARE SOPs?**
  - Make sure that you have copies of the SOPs with you.

Virginia T. McLemore

- Principal Senior Economic Geologist with the New Mexico Bureau of Mines and Mineral Resources (NMBGMR) since 1980
- Adjunct Professor with the Departments of Earth and Environmental Sciences, and Mineral Engineering at New Mexico Tech
- worked on mineral-resource assessments and research projects on mineral resources in NM since 1980, including REE, uranium, and beryllium and other critical minerals deposits in NM
- published more than 400 journal articles, books, and other reports
- New Mexico Tech, B.S. 1977, M.S. 1980; University of Texas at El Paso, Ph.D. 1993; Certified Professional Geologist CPG #7438

Class introductions

Name, where from, graduated, degree here

What do you expect to learn from this course?

CLASS REQUIREMENTS

Goals in this class

- Types of mineral deposits in NM
  - Relate the mineral deposits in NM to world-class deposits and critical minerals
  - Why isn’t there more mining in NM
  - Future of mining in NM
- What is involved from exploration thru production thru marketing
  - Reports, field notes, presentations
  - Where to look for information
  - Research needed
- Sustainable development
  - We can mine within public concerns
  - Social license to operate

What are world-class mineral deposits?

Class

- The class will meet one day per week for 120 minutes
- Remaining time spent on field trips or in occasional extra discussion sessions (other presentations, guest speakers)
- May require extra time for the project presentations

March

- March 8, 15 no class
- Part or all of March may be all distance learning
  - Depends upon if I have to do a 2 week quarantine after being in Phoenix

Field Trips

- Depend upon the size of a group allowed by COVID restrictions and how we get everyone there
- We will use some Bureau vehicles, and if you want to travel in your own that is fine
- I am hoping someone will video the trips, then share with those who do not go
- Sometimes we may have small groups on two separate trips to the same site, other times field trips will be limited to a number of students
- We will adjust as necessary
- I would like to go out on the spring break day (Feb 19) and one weekend (camping)
- If you can't go on field trips, then your field trip reports will be on virtual field trips—we will work it out

Lectures found on my web site

http://geoinfo.nmt.edu/staff/mclemore/home.html

or

https://geoinfo.nmt.edu/staff/mclemore/MineraldepositsofNewMexico.html

Textbooks

- McLemore, V.T., 2017, Mining districts and prospect areas of New Mexico: New Mexico Bureau of Geology and Mineral Resources, Resource Map 24, 65 p., scale 1:1,000,000.
- McLemore, V.T. and Lueth, V., 2017, Metallic Mineral Deposits; *in* McLemore, V.T., Timmons, S., and Wilks, M., eds., Energy and Mineral deposits in New Mexico: New Mexico Bureau of Geology and Mineral Resources Memoir 50 and New Mexico Geological Society Special Publication 13, 92 p.
- McLemore, V.T. and Austin, G.S., 2017, Industrial minerals and rocks; *in* McLemore, V.T., Timmons, S., and Wilks, M., eds., Energy and Mineral deposits in New Mexico: New Mexico Bureau of Geology and Mineral Resources Memoir 50 and New Mexico Geological Society Special Publication 13, 128 p.
- Committee on Critical Mineral Impacts of the U.S. Economy, 2008, Minerals, Critical Minerals, and the U.S. Economy: Committee on Earth Resources, National Research Council, ISBN: 0-309-11283-4, 264 p., download from http://www.nap.edu/catalog.php?record_id=12034#toc
- Papers as assigned

https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

Class Details

- Exams: Midterm and Final—both are take home exams that will emphasize short answer and essay questions.
- Term project—you are required to do a term/research project that will involve some original work. If you in the chemistry section, your project should be related to geochemistry.
- Field trips—there will be 2 or more field trips and a trip report on each trip will be required.
- Team work and group projects/reports are encouraged, but midterm and final will be on your own.

Grades

• Midterm	25%
• Final (comprehensive)	30%
• Lab exercises	10%
• Term project	20%
• Field trip reports	10%
• Class Participation	5%

Sources of data

- Internet
- http://minerals.usgs.gov/minerals/pubs/commodity/myb/
- http://www.minerals.com/
- Societies (SME, others)
- My web site
- Library
- Bureau GIC records
- Other reports not in electronic form

Wikipedia

- Use sparingly
- Some of the information on Wikipedia is incorrect
- Some of your best data and sources of information are in the library and not in electronic form

- Be aware of using copyrighted material—get permission

Term Project—examples

- Portion of your thesis (if not in NM, then compare your area to types of deposits in NM)
- Lesson plan, poster, and web site on deposit or commodity in NM
- Mineral resource potential of specific mineral in NM
- Flow/life cycle of a commodity in our society
- Sampling and analytical procedures for a commodity/element
- Detailed analysis of a commodity and relate to NM deposit

Dig A Little Deeper

How Many Minerals and Metals Does It Take to

Make A Light Bulb?

Science: *What makes the bulb work?* **Predict:** *Design light bulbs for the future.*

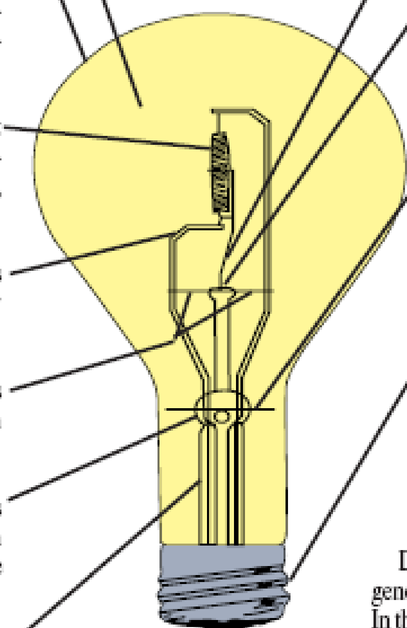
Bulb
Soft glass is generally used, made from *silica, trona (soda ash), lime, coal, and salt.* Hard glass, made from the same minerals, is used for some lamps to withstand higher temperatures and for protection against breakage.

Gas
Usually a mixture of *nitrogen* and *argon* to retard evaporation of the filament.

Support wires
Molybdenum wires support the filament.

Button & Button Rod
Glass, made from the same materials listed for the bulb (plus *lead*), is used to support and to hold the tie wires placed in it.

Filament
Usually is made of *tungsten*. The filament may be a straight wire, a coil, or a coiled-coil.



Heat Deflector
Used in higher wattage bulbs to reduce the circulation of hot gases into the neck of the bulb. It's made of *aluminum.*

Lead-in-wires
Made of *copper* and *nickel* to carry the current to and from the filament.

Base
Made of *brass (copper and zinc)* or *aluminum.* One lead-in wire is soldered to the center contact and the other soldered to the base.

Tie Wires
Molybdenum wires support lead-in wires.

Stem Press
The wires in the glass are made of a combination of *nickel-iron* alloy core and a *copper* sleeve.

Fuse
Protects the lamp and circuit if the filament arcs. Made of *nickel, manganese, copper* and/or *silicon* alloys.

Don't forget the mineral fuels needed to generate the electricity to light up the bulb. In the U.S., these are the sources of our fuels

Coal	Nuclear	Hydro	Natural Gas	Oil	Other
54 %	22 %	10 %	9%	4 %	1 %

For information about minerals in society, go to:
Mineral Information Institute, www.mii.org

Math/Art: *Explore shapes & sizes. Light bulb picture collage.*

Geography: *Research & ID the states and countries producing these minerals.*

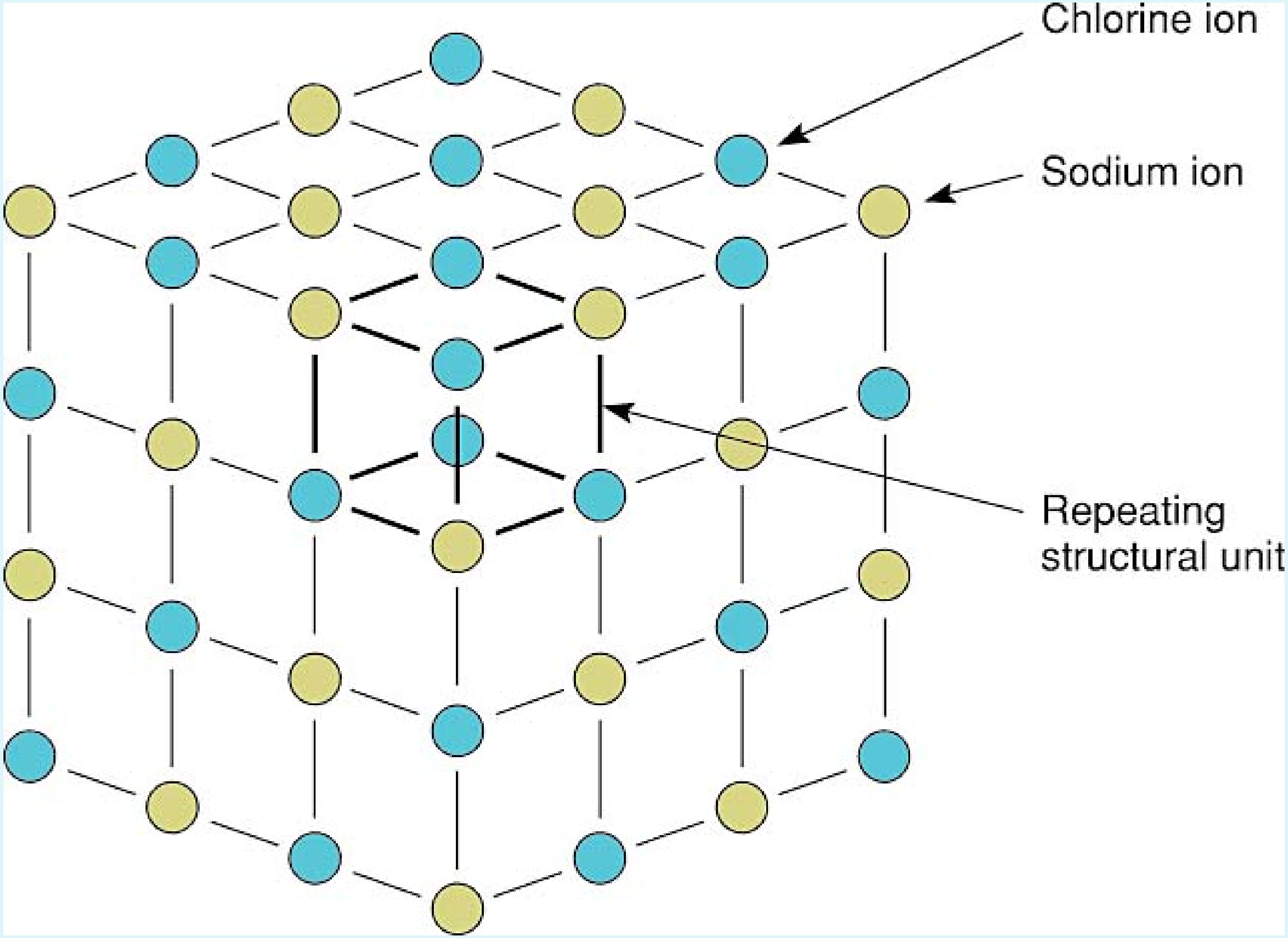
Definitions

- Some of the largest incorrect misperceptions are because of lack of understanding of definitions of terms
- Most reports need a glossary of terms
- Do not assume everyone understands the terms you use

What is a mineral?

What is a mineral?

- Naturally occurring
- Inorganic
- Solid
- Homogeneous
- Crystalline material
- With a unique chemical element or compound with a set chemical formula
- Usually obtained from the ground



A crystal is composed of a structural unit that is repeated in three dimensions. This is the basic structural unit of a crystal of sodium chloride, the mineral halite.

Another definition

Definition of Minerals

In industry, *minerals* refer to any rock, mineral, or other naturally occurring material of economic value, including metals, industrial minerals, energy minerals, gemstones, aggregates, and synthetic materials sold as commodities.

1. Metals - rare, difficult to find, expensive
2. Energy minerals – coal, oil and natural gas
3. Industrial minerals - non-metallic, such as salt, china clay, fluorspar
    - occur in large quantities in a few places
    - require specialised processing and are expensive
4. Construction minerals - sand and gravel, crushed rock, brick clay
    - deposits are extensive and common
    - transportation is economical over short distances only

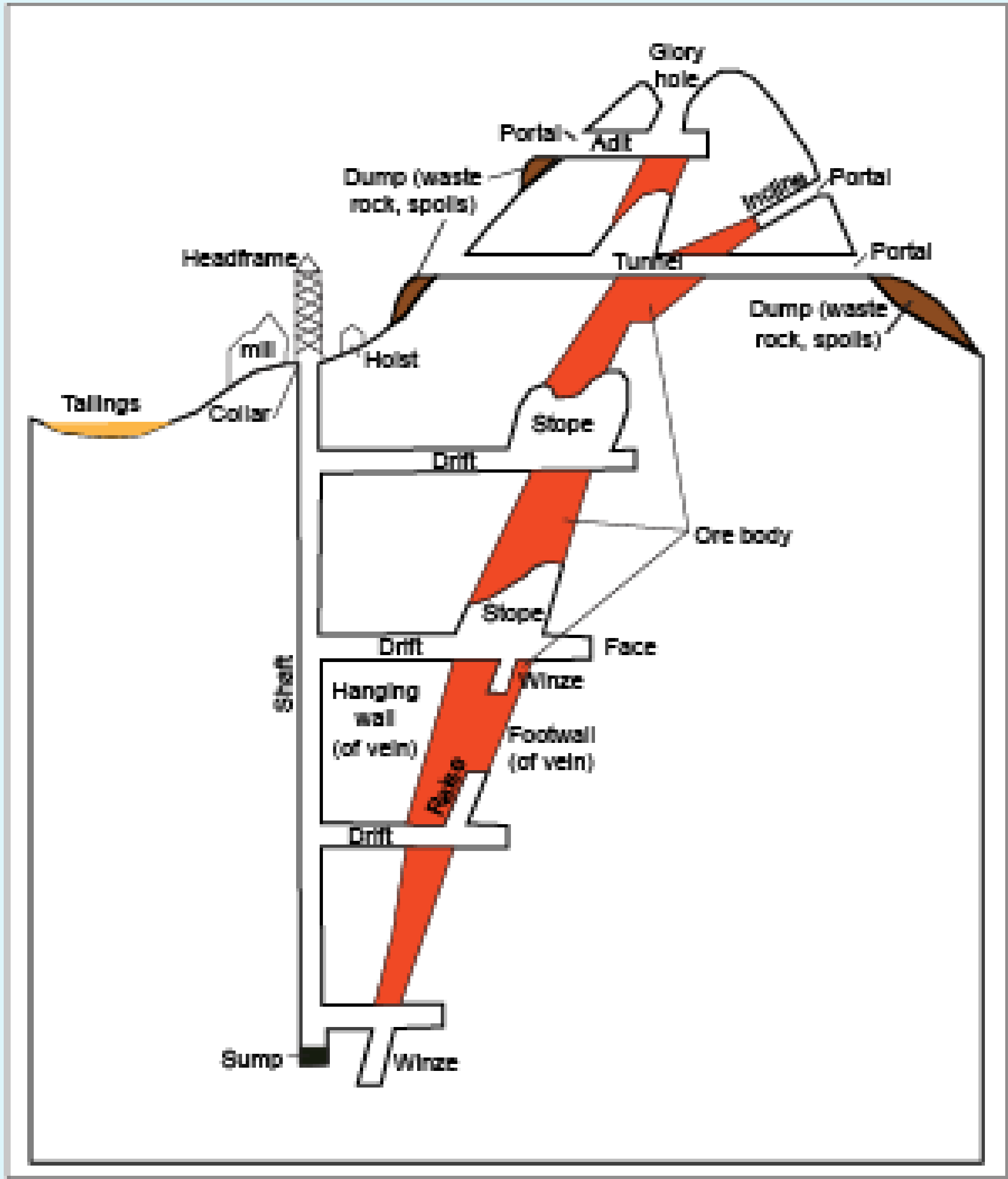
A **mineral occurrence** is any locality where a useful mineral or material is found.

A **mineral prospect** is any occurrence that has been developed by underground or by above ground techniques, or by subsurface drilling to determine the extent of mineralization.

The terms **mineral occurrence** and **mineral prospect** do not have any resource or economic implications.

Definition of mine

any opening or excavation in the ground for extracting minerals, even if no actual production occurred, mine feature



A **mineral deposit** is any occurrence of a valuable commodity or mineral that is of sufficient size and grade (concentration) that has potential for economic development under past, present, or future favorable conditions.

An **ore deposit** is a well-defined mineral deposit that has been tested and found to be of sufficient size, grade, and accessibility to be extracted (i.e. mined) and processed at a profit at a specific time. Thus, the size and grade of an ore deposit changes as the economic conditions change. **Ore refers to industrial minerals as well as metals.**

Mineral Deposits versus *Ore Bodies*

mineral deposit	≠	ore body
ore body	=	reserves
mineral deposit	=	± reserves + unmineable + uneconomic + mined

What is a rock?

What is a rock?

- Naturally occurring
- Solid
- Homogeneous or heterogeneous
- Usually obtained from the ground
- Usually made up of one or more minerals
- Any naturally formed material composed of one or more minerals having some degree of chemical and mineralogic constancy

What are industrial minerals?

What are industrial minerals?

- Any rock, mineral, or other naturally occurring material of economic value, excluding metals, energy minerals, and gemstones
- One of the nonmetallics
- It can include aggregates
- It can include by-product materials from mineral processing

CLASSIFICATION OF MINERAL RESOURCES ON U.S. FEDERAL LAND

Locatable Minerals are whatever is recognized as a valuable mineral by standard authorities, whether metallic or other substance, when found on public land open to mineral entry in quality and quantity sufficient to render a claim valuable on account of the mineral content, under the United States Mining Law of 1872. Specifically excluded from location are the leasable minerals, common varieties, and salable minerals.

Leasable Minerals The passage of the Mineral Leasing Act of 1920, as amended from time to time, places the following minerals under the leasing law: oil, gas, coal, oil shale, sodium, potassium, phosphate, native asphalt, solid or semisolid bitumen, bituminous rock, oil-impregnated rock or sand, and sulfur in Louisiana and New Mexico.

Salable Minerals The Materials Act of 1947, as amended, removes petrified wood, common varieties of sand, stone, gravel, pumice, pumicite, cinders, and some clay from location and leasing. These materials may be acquired by purchase only.

It is important to recognize that mineral deposits are controlled by geological processes, not land ownership or classification, and that mineral resources are found in areas where the geology is favorable for the occurrence of mineral deposits, and not just anywhere on earth. Mineral deposits cannot be moved and can only be developed where they are discovered.

Other terms

Canadian Instrument 43-101

- Set of rules and guidelines for reporting information relating to a mineral property in order to present these results to the Canadian stock exchange
  - created after the Bre-X scandal to protect investors from unsubstantiated mineral project disclosures
  - gold reserves at (Bre-X's) Busang were alleged to be 200 million ounces (6,200 t), or up to 8% of the entire world's gold reserves FRAUD
- Similar to JORC (joint ore reserves committee code, Australia)
- South African Code for the Reporting of Mineral Resources and Mineral Reserves (SAMREC)

Other terms

- Adjacent property
  - Company has no interest
  - Boundary close to project
  - Geologic characteristics similar to project
- Advanced property
  - Mineral reserves
  - Minerals resources with a PEA or feasibilty study
- Early stage exploration property

Qualified person (43-101)

- engineer/geoscientist with a university degree, or equivalent accreditation, in an area of geoscience, or engineering, relating to mineral exploration or mining
- has at least five years of experience
- has experience relevant to the subject matter of the mineral project and the technical report
- is in good standing with a professional association

What are strategic and critical minerals?

Strategic and critical minerals

- Minerals needed for military, industrial or commercial purposes that are essential to renewable energy, national defense equipment, medical devices, electronics, agricultural production and common household items
- Minerals that are essential for use but subject to potential supply disruptions
- Minerals that perform an essential function for which few or no satisfactory substitutes exist
- The absence of which would cause economic or social consequences
- 33-50% minerals are classified as such

Presidential Executive Order No. 13817

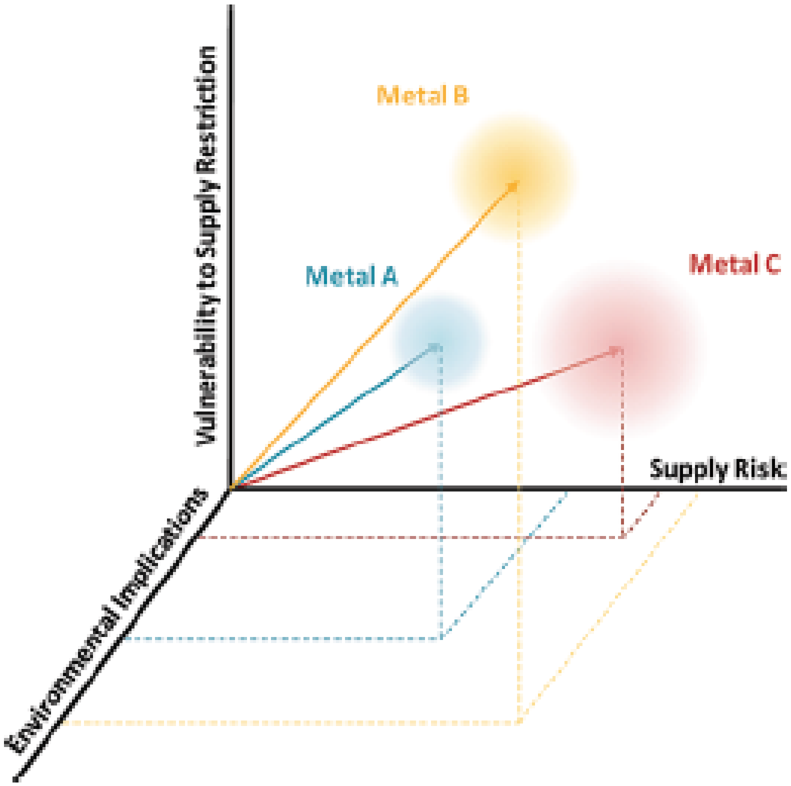
"*a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security*"

- Demand
  - Material composition increasingly complex
  - Potential rapid growth in demand for some minerals
- Supply
  - Seemingly increasingly fragile
  - More fragmented supply chains, US import dependence, export restrictions on primary raw materials, resource nationalism, increased industry concentration

Criticality is context specific:

- What is critical for a given manufacturer or product may not be critical for another, what is critical for a state may not be critical for a country, and what is critical for national defense may be different than what is necessary to make a television brighter or less expensive.

- Recent studies have expanded the scope of criticality to include environmental and technological factors.



Graedel, T. E.; Barr, R.; Chandler, C.; Chase, T.; Choi, J.; Christoffersen, L.; Friedlander, E.; Henly, C.; Nassar, N. T.;Schechner, D.; Warren, S.; Yang, M.; Zhu, C., 2012, Methodology of metal criticality determination: Environ. Sci. Technol., 46, 1063• 1070.

USGS

2019 U.S. NET IMPORT RELIANCE[1]

Commodity	Percent	Major import sources (2015–18)[2]
ARSENIC (all forms)	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, South Africa, China
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, Taiwan
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA, sheet (natural)	100	China, Brazil, Belgium, Austria
NEPHELINE SYENITE	100	Canada
NIOBIUM (columbium)	100	Brazil, Canada, Russia, Germany
RARE EARTHS[3] (compounds and metal)	100	China, Estonia, Japan, Malaysia
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	Rwanda, Brazil, Australia, Congo (Kinshasa)
YTTRIUM	100	China, Estonia, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Belgium, Mexico, Republic of Korea
TELLURIUM	>95	Canada, China, Germany
VANADIUM	94	Austria, Canada, Russia, Republic of Korea
TITANIUM MINERAL CONCENTRATES	93	South Africa, Australia, Canada, Mozambique
POTASH	91	Canada, Russia, Belarus, Israel
DIAMOND (industrial stones)	88	India, South Africa, Botswana, Australia
BARITE	87	China, India, Morocco, Mexico
ZINC (refined)	87	Canada, Mexico, Australia, Peru
TITANIUM (sponge)	86	Japan, Kazakhstan, Ukraine, China, Russia
ANTIMONY (metal and oxide)	84	China, Thailand, Belgium, India
RHENIUM	82	Chile, Germany, Kazakhstan, Canada
STONE (dimension)	81	China, Brazil, Italy, Turkey
COBALT	78	Norway, Japan, China, Canada
TIN (refined)	77	Indonesia, Malaysia, Peru, Bolivia
ABRASIVES, fused Al oxide (crude)	>75	China, Hong Kong, France, Canada
BAUXITE	>75	Jamaica, Brazil, Guinea, Guyana
CHROMIUM	72	South Africa, Kazakhstan, Russia
PEAT	70	Canada
SILVER	68	Mexico, Canada, Peru, Poland

https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

What are the differences between critical and strategic minerals?

Differences between critical and strategic minerals

- Minerals for military uses are strategic
- Minerals for which a threat to supply could involve harm to the economy are critical
- A critical mineral may or may not be strategic, while a strategic mineral will always be critical

History of strategic and critical minerals

- 1918: end of WW1 Harbord List developed
- 1938: Naval Appropriations Act
- 1939: Strategic Minerals Act
- 1940 Reconstruction Finance Corp formed to acquire and transport materials
- 1944: Surplus Property Act authorized strategic materials stockpile
- Became the Defense National Stockpile Center (DNSC)
- 1992: Congress ordered DNSC to sell the bulk of the stockpiles

What are green technologies?

What are green technologies?

- Environmental technologies or clean technologies
- Future and existing technologies that conserve energy and natural resources and curb the negative impacts of human involvement, i.e. environmental friendly (modified from Wikipedia)
  - Alternative power (wind turbines, solar energy)
  - Hybrid and electric cars
  - Batteries
  - Magnets
- Other technologies
  - Water purification
  - Desalination
  - Carbon capture and storage

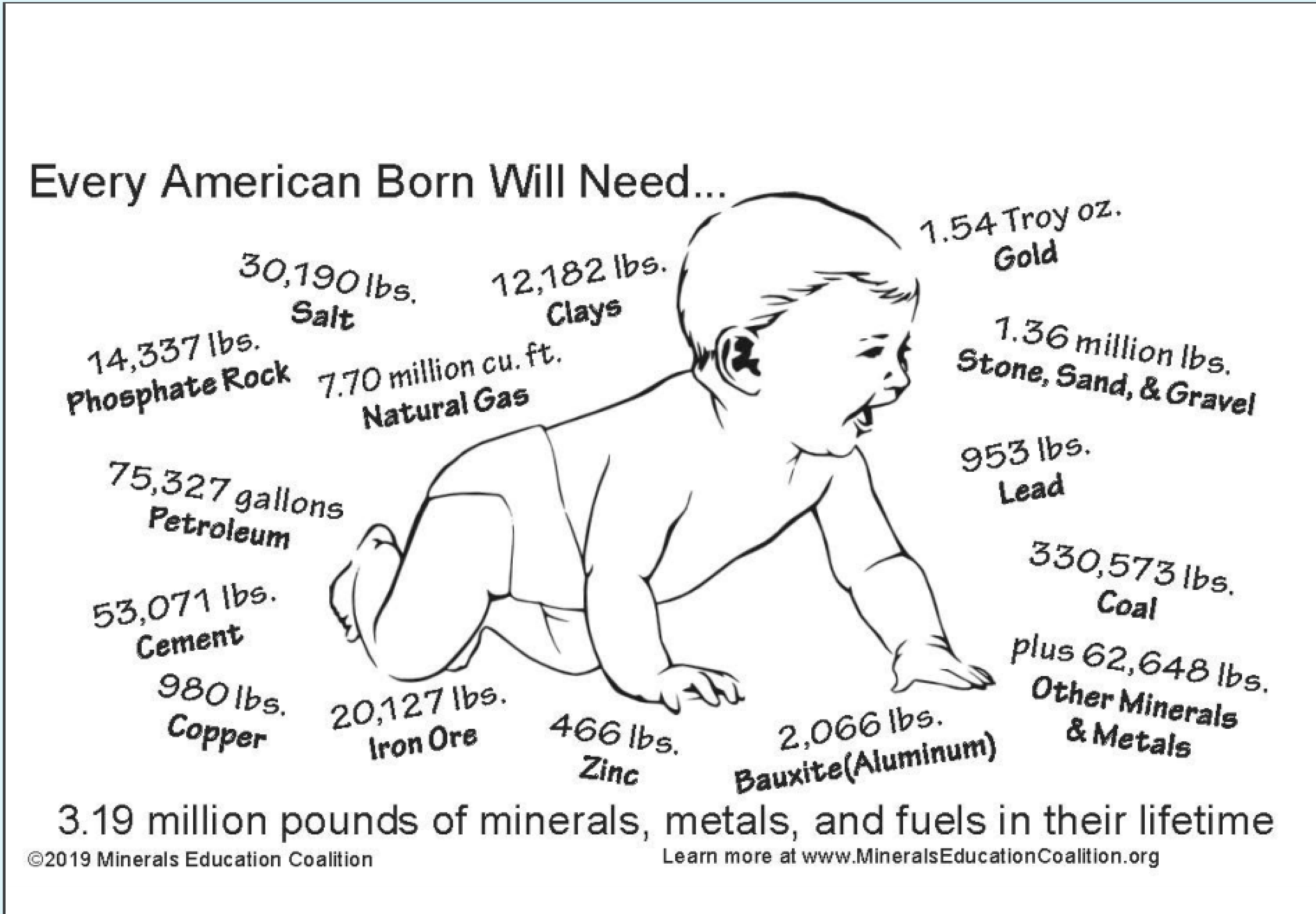
Why are minerals so important?

Why are minerals so important?

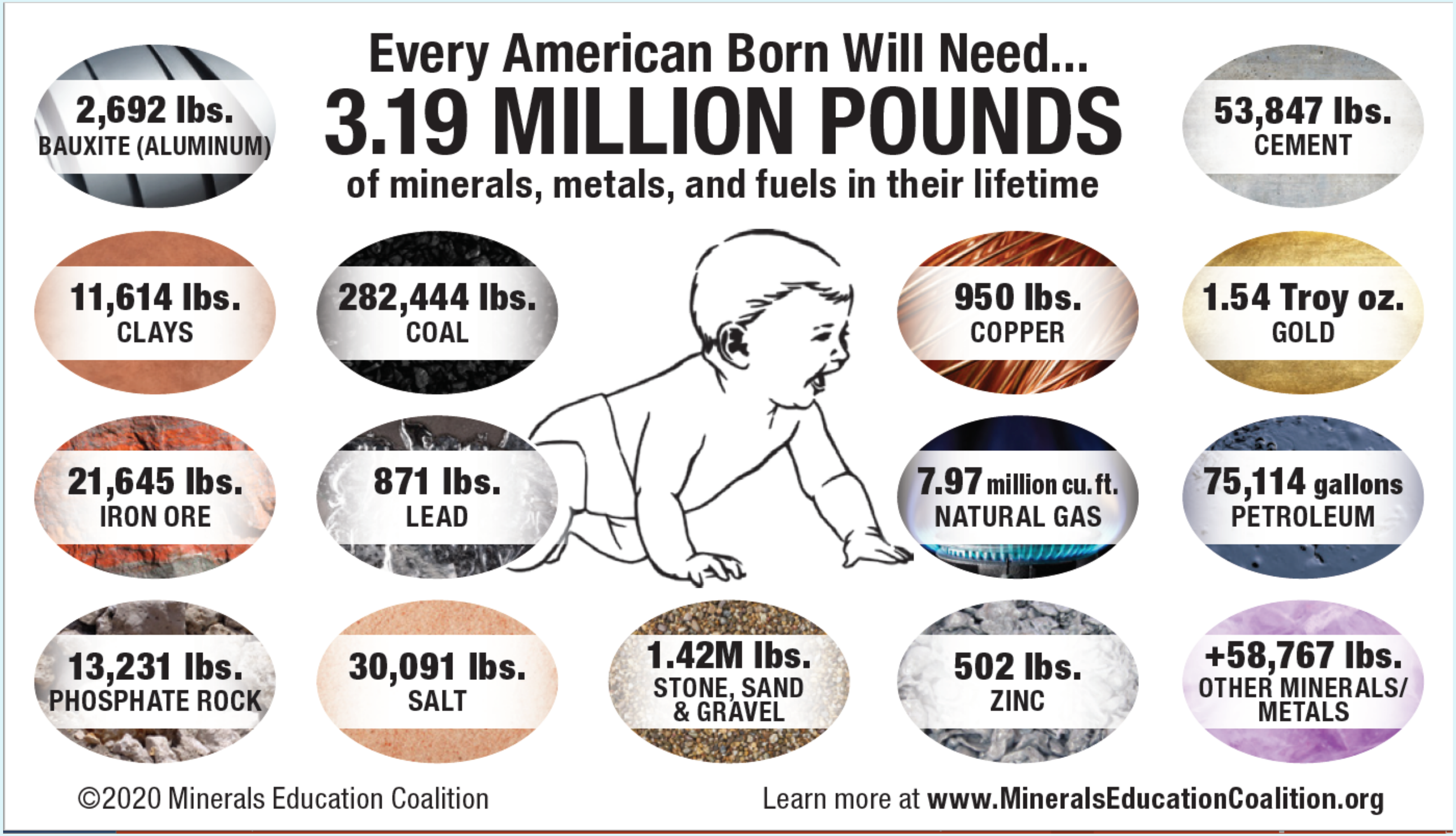
Your world is made of them!

The average American uses about two million pounds of industrial minerals, such as limestone, clay, and aggregate, over the period of a lifetime.

Building blocks of our way of life



https://mineralseducationcoalition.org/mining-mineral-statistics/



https://mineralseducationcoalition.org/mining-mineral-statistics/

Every Year— 38,052 pounds of new minerals must be provided for every person in the United States to make the things we use every day

- 8,509 lbs. **Stone** used to make roads, buildings, bridges, landscaping, and for numerous chemical and construction uses
- 5,599 lbs. **Sand & Gravel** used to make concrete, asphalt, roads, blocks and bricks
- 496 lbs. **Cement** used to make roads, sidewalks, bridges, buildings, schools and houses
- 357 lbs. **Iron Ore** used to make steel— buildings; cars, trucks, planes, trains; other construction; containers
- 421 lbs. **Salt** used in various chemicals; highway deicing; food & agriculture
- 217 lbs. **Phosphate Rock** used to make fertilizers to grow food; and as animal feed supplements
- 164 lbs. **Clays** used to make floor & wall tile; dinnerware; kitty litter; bricks and cement; paper
- 65 lbs. **Aluminum (Bauxite)** used to make buildings, beverage containers, autos, and airplanes
- 12 lbs. **Copper** used in buildings; electrical and electronic parts; plumbing; transportation
- 11 lbs. **Lead** 87% used for batteries for transportation; also used in electrical, communications and TV screens
- 6 lbs. **Zinc** used to make metals rust resistant, various metals and alloys, paint, rubber, skin creams, health care and nutrition
- 36 lbs. **Soda Ash** used to make all kinds of glass; in powdered detergents; medicines; as a food additive; photography; water treatment
- 5 lbs. **Manganese** used to make almost all steels for construction, machinery and transportation
- 332 lbs. **Other Nonmetals** have numerous uses: glass, chemicals, soaps, paper, computers, cell phones
- 24 lbs. **Other Metals** have the same uses as nonmetals but also electronics, TV and video equipment, recreation equipment, and more

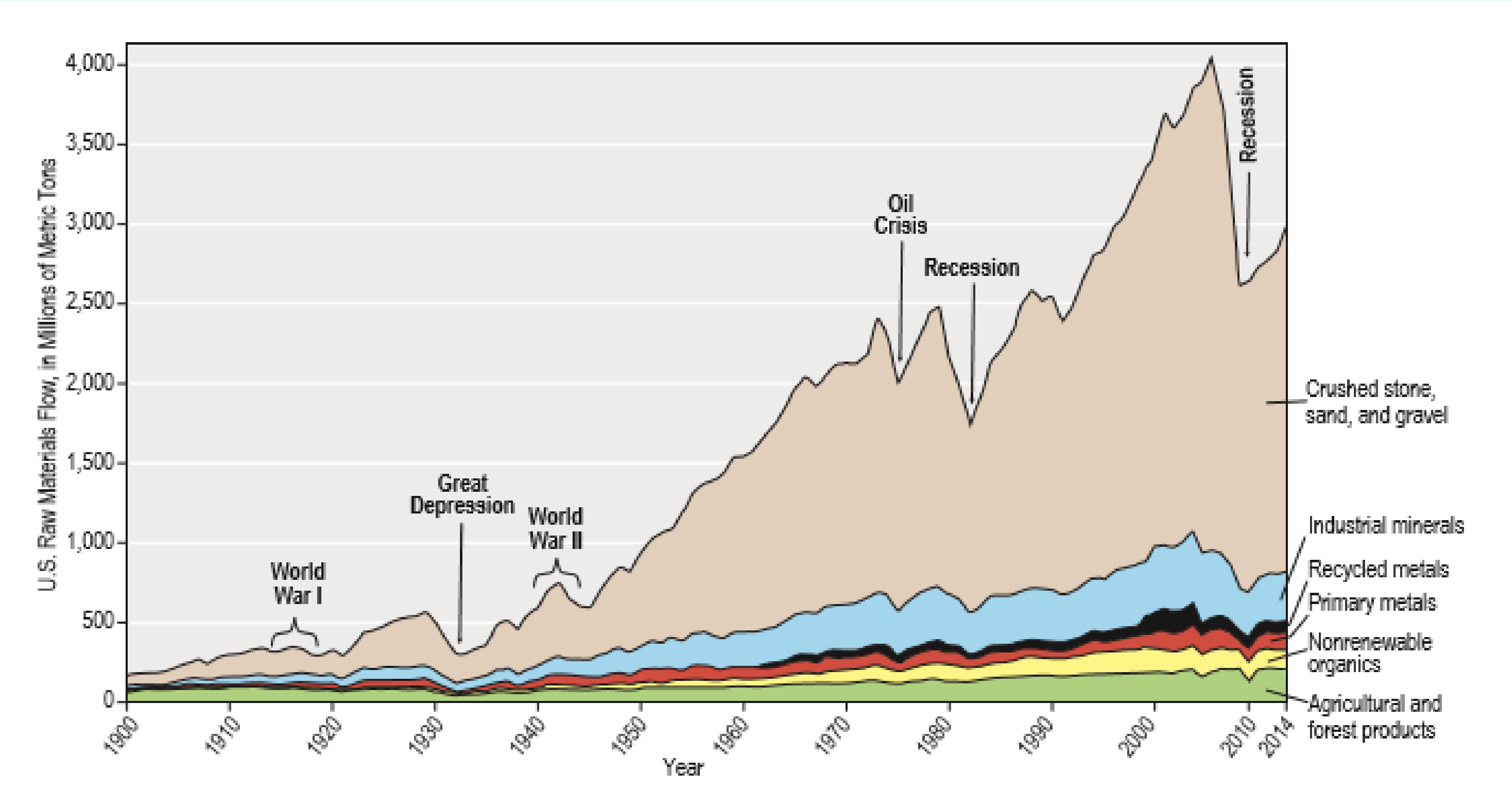
Including These Energy Fuels

• 951 gallons of **Petroleum** • 6,792 lbs. of **Coal** • 80,905 cu. ft. of **Natural Gas** • 1/4 lb. of **Uranium**

To generate the energy each person uses in one year—

http://www.mii.org/pdfs/2011PerCapita.pdf

U.S. flow of raw materials by weight 1900-2014. The use of raw materials in the U.S. increased dramatically during the last 100 years (modified from Wagner, 2002).



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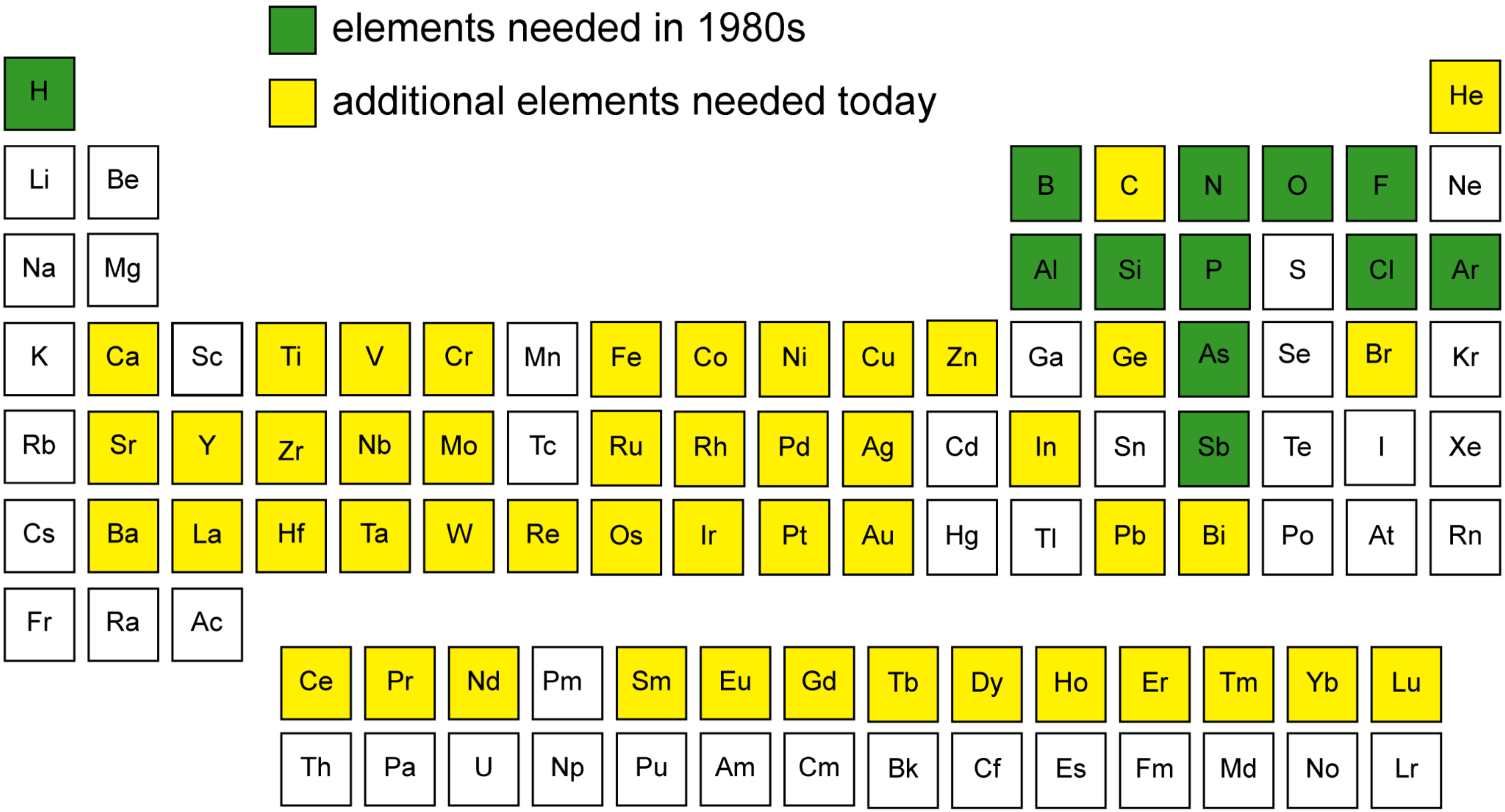
Will we see on increase or decrease in mineral production in 2021?

Elements in Computer Chips
(National Research Council, 2007)



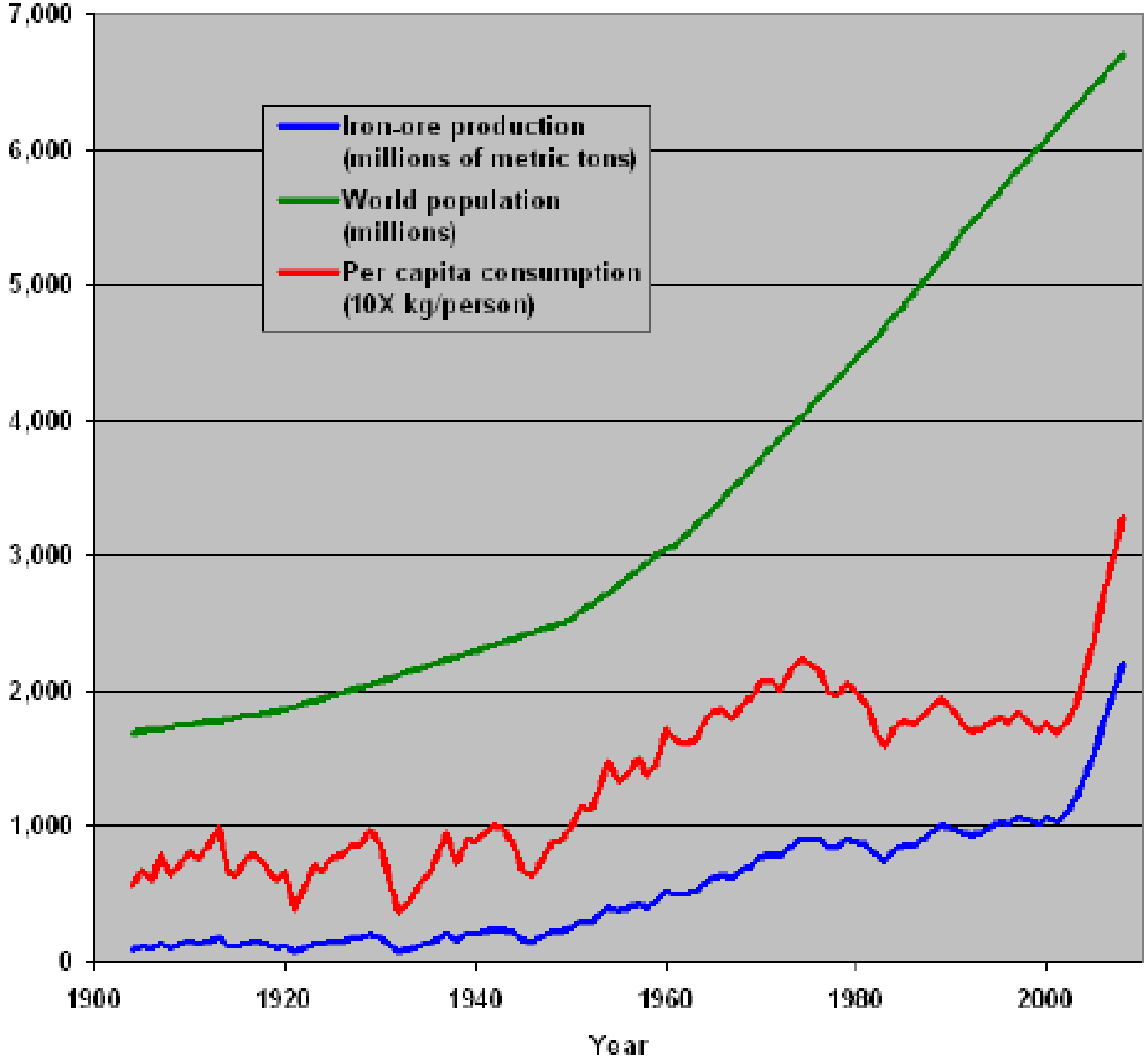
Geologically, most minerals

- are widespread
- have enormous reserves
- are easy accessible

The main challenge is provide society with its needs, protect future resources, limit alteration of the landscape, and affect local communities as little as possible (i.e. sustainable development).

DEMAND

Demand is growing partly because world population is increasing, and partly because standards of living (measured by per capita consumption) are increasing.



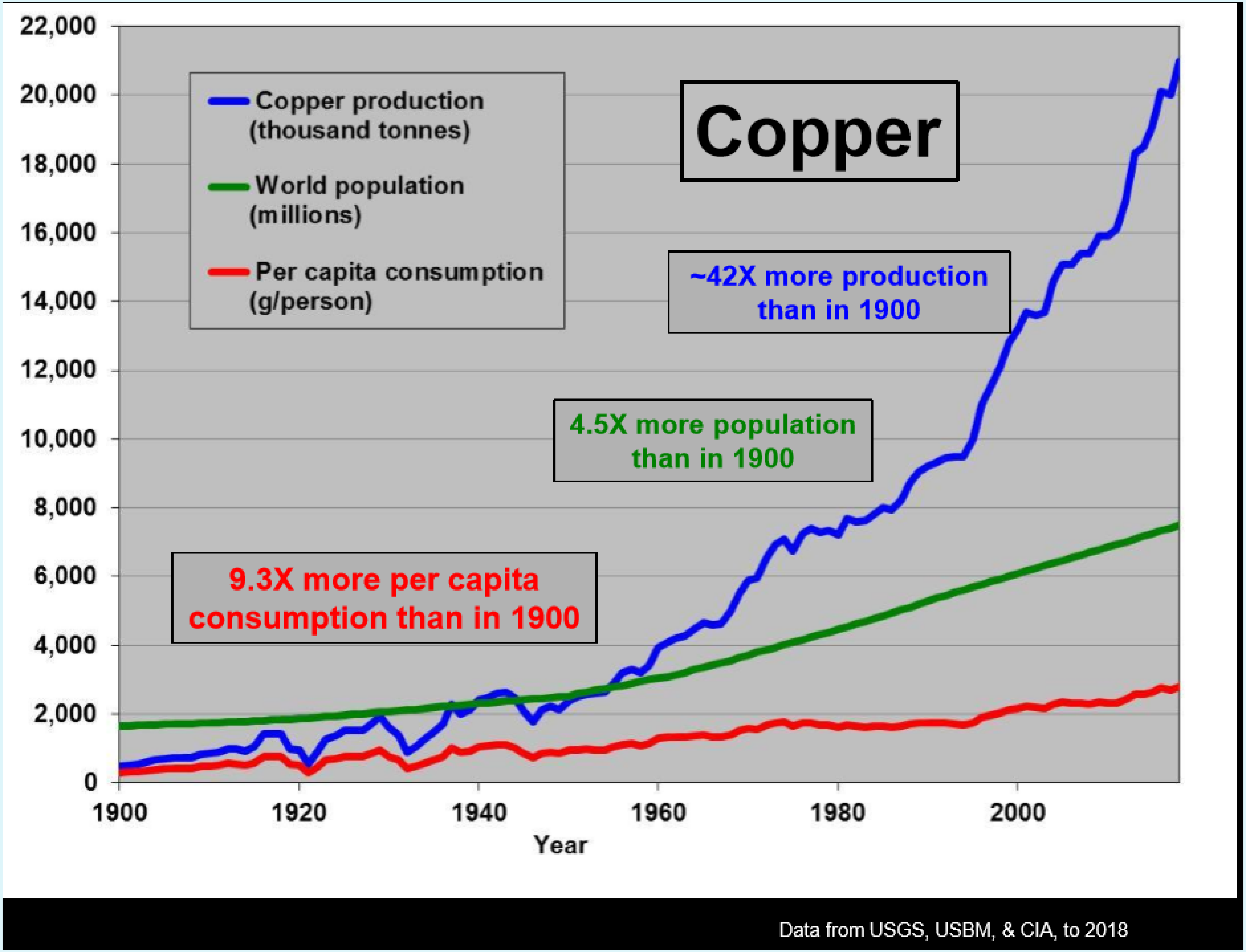
Iron

~4X more population than 100 years ago

~14X more production than 100 years ago

~4X more per capita consumption than 100 years ago

Production statistics mostly from USGS/USBM

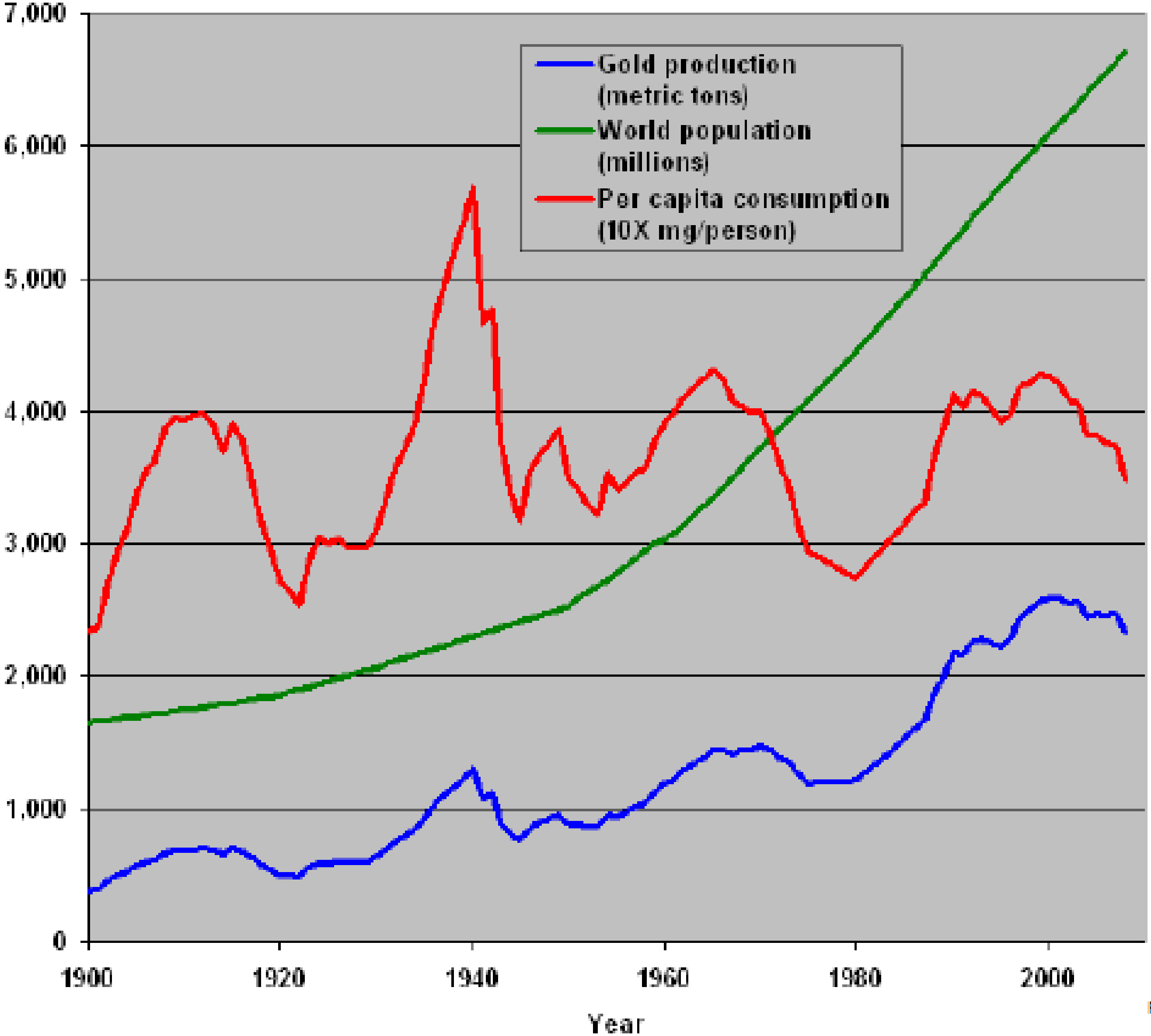


Copper
Copper production (thousand tonnes)
World population (millions)
Per capita consumption (g/person)
~42X more production than in 1900
4.5X more population than in 1900
9.3X more per capita consumption than in 1900
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1900
1920
1940
1960
1980
2000
Year
Data from USGS, USBM, & CIA, to 2018

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 2018 (21 million metric tons) exceeded over 100 years of production from the Bingham Canyon mine (~17 million metric tons).

Demand for nearly every mineral (and energy) commodity is high.



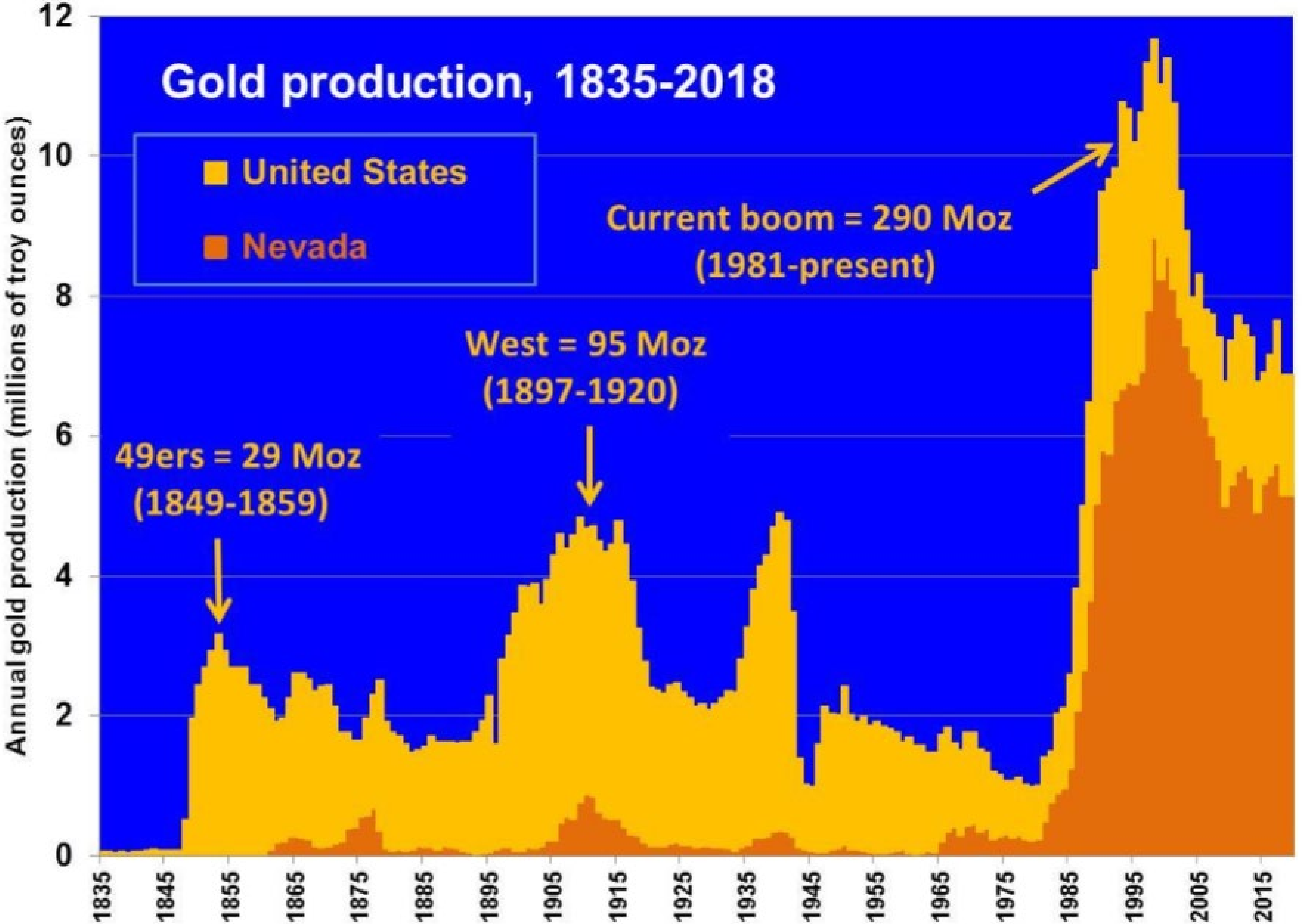
Gold

~same per capita consumption as 100 years ago

~4X more production than 100 years ago

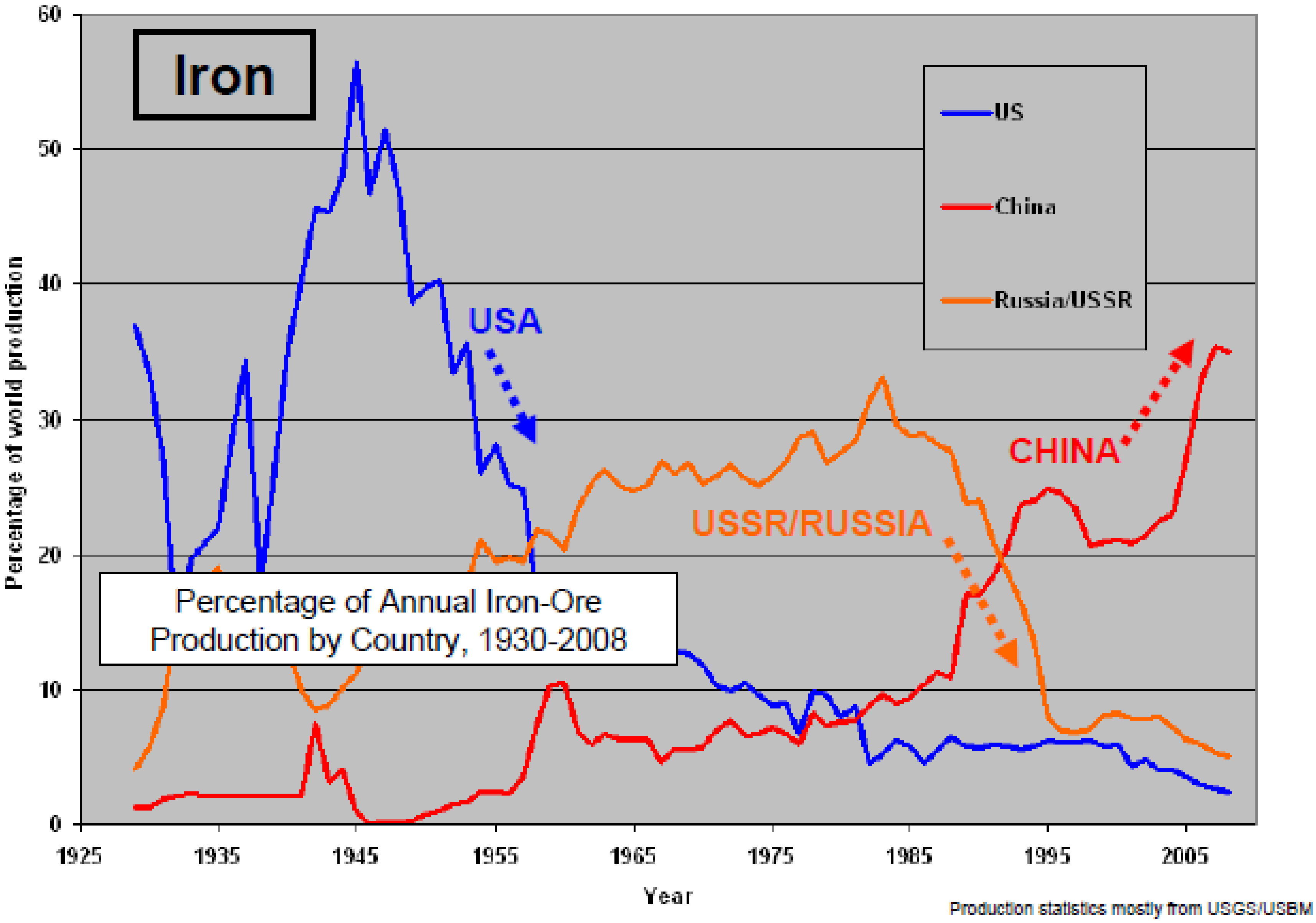
Production statistics mostly from USGS/USBM

Global gold production in 2018 (3,260 metric tons) exceeded the cumulative production from the Carlin trend in Nevada (~3,000 tons), one of world's top regions.

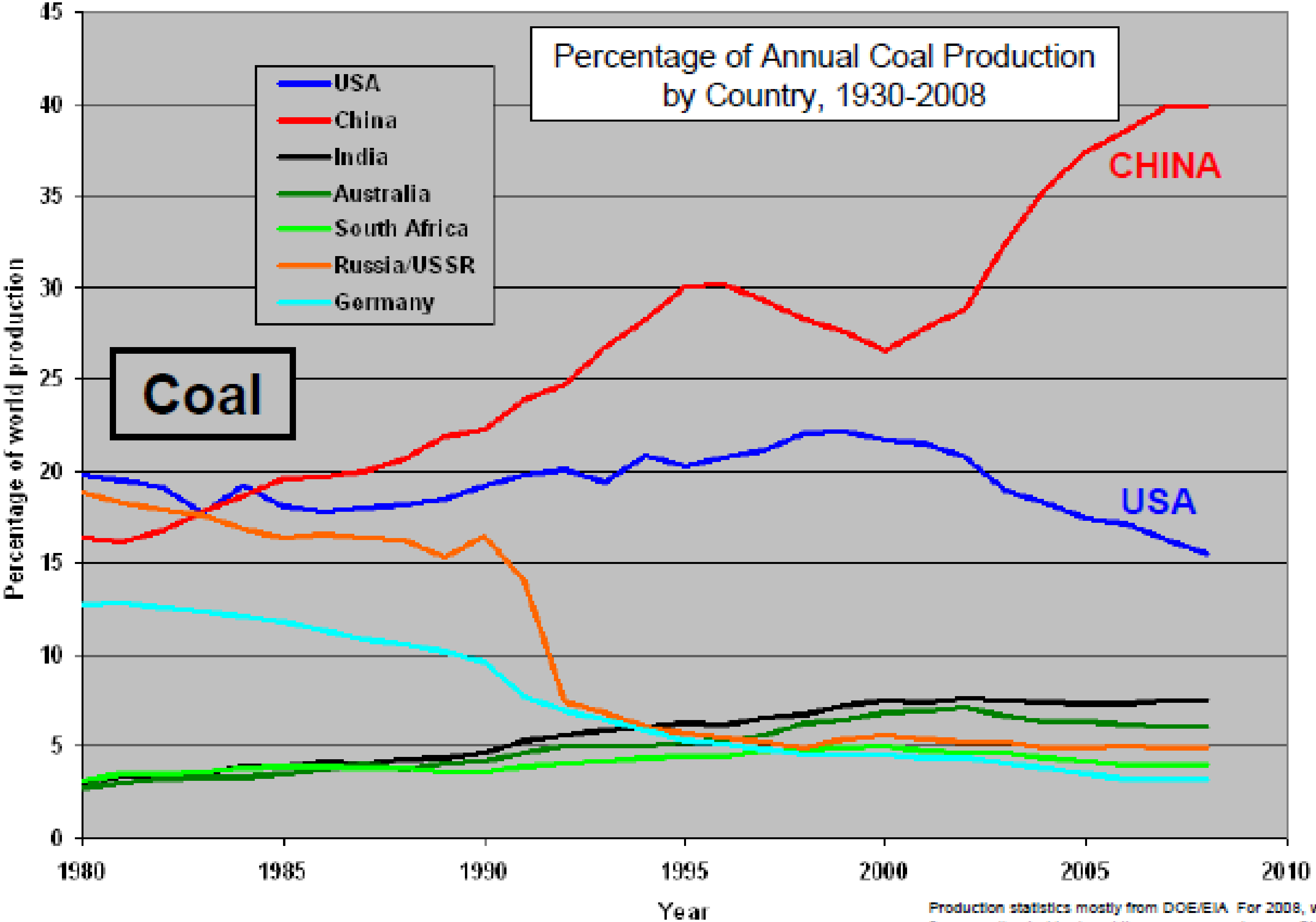


We are in the midst of the biggest gold-mining boom in history.

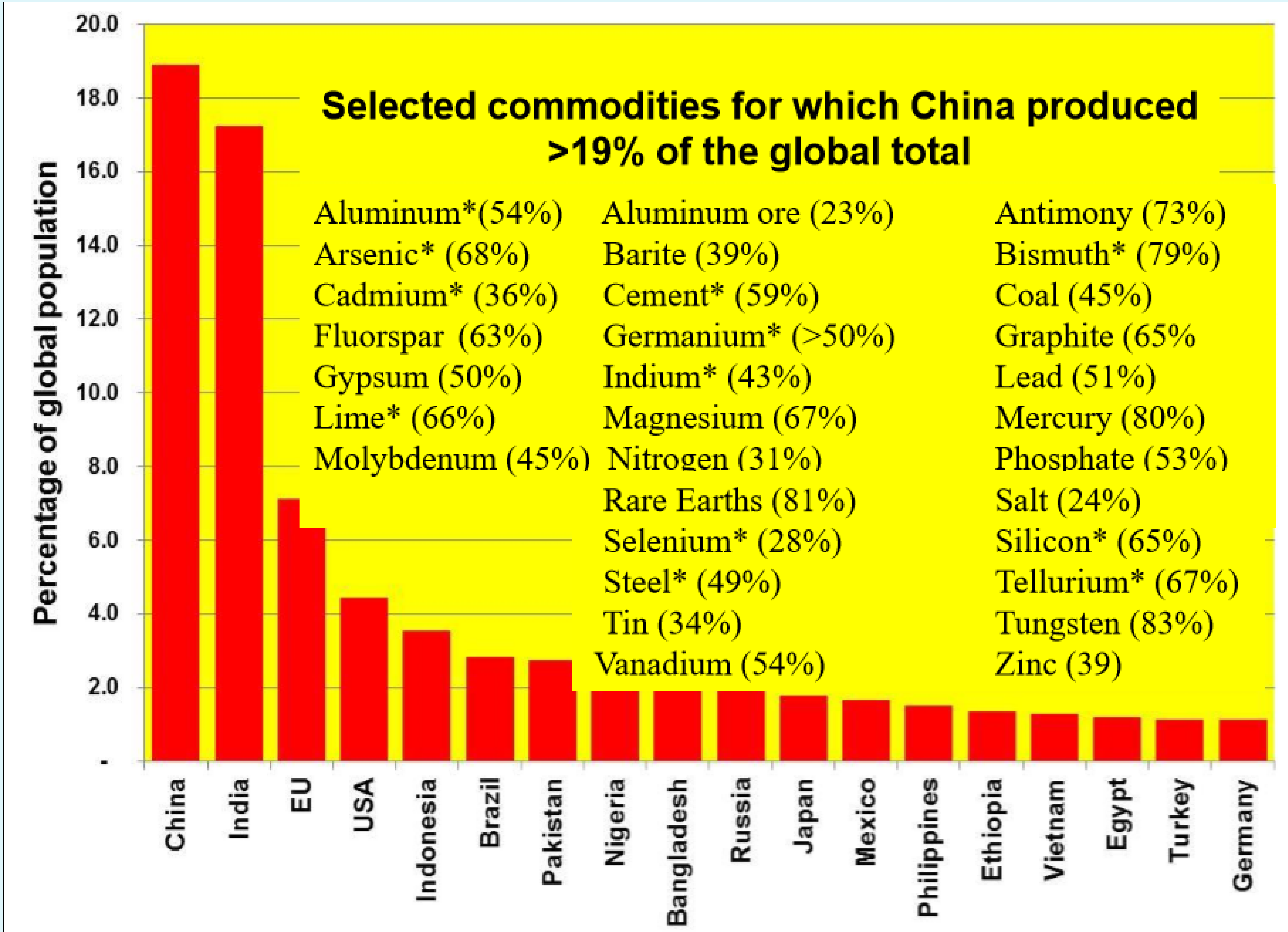
China has been #1 in iron-ore production since 1992.



China has been #1 in coal production since 1985.



Production statistics mostly from DOE/EIA. For 2008, world coal figures estimated to rise at the same percentage as China.



Data from USGS in 2017, except coal from IEA in 2016.

In production of 44 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	21	28
USA	4	11
South Africa	4	6
Australia	3	11
Chile	2	4
Congo	2	3
Russia	1	15
Canada	1	5
Kazakhstan	1	4
Brazil, Mexico, & Indonesia	1	2

Data for 2017, except coal, oil, and gas (2016)

The World Has Changed

For industry, the changes in the world are creating opportunities for:

exploration (domestically and worldwide, particularly in areas with potential for large deposits),

development and production (including new technologies for extracting metals from known deposits), and

sustainability (including the future of the environment, local and national economies, social and governmental stability, recycling, and substitutions of other minerals and products).

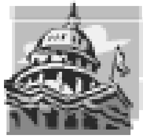
New deposit types are still being found – e.g., Carlin gold (1961), Olympic Dam copper-iron-gold, South Australia (1975), HREE in kaolinite-rich laterite developed on granites in China (2000s) – and will be found in the future.

We need to be thinking about ore-forming systems and future resources – USGS Professional Paper 820 (1973).

What are some of the challenges in producing minerals?

5 Dimensions of Mineral Availability

WHAT Questions Must We Ask?

1	**Geologic** Availability		✓Does the mineral resource exist?
2	**Technical** Availability		✓Can we extract and process it?
3	**Environmental & Social** Availability		✓Can we produce it in environmentally and socially responsible and acceptable ways?
4	**Political** Availability		✓How do governments influence availability through their policy and actions?
5	**Economic** Availability		✓Can we produce it at a cost users are willing and able to pay?

Can you get financing for your new project?

Limits on mineral resource availability

Are more about

- Costs
- Distribution
- Time frame

Than about tons

Some of the challenges in producing minerals

- How much of the minerals do we need?
- Are there enough materials in the pipeline to meet the demand for these technologies and other uses?
- Can any of these be recycled?
- Are there substitutions that can be used?
- Are these minerals environmental friendly—what are the reclamation challenges?
  - REE and Be are nearly always associated with U and Th and the wastes from mining REE and Be will have to accommodate radioactivity and radon

Additional challenges in producing these technologies

Are any of these minerals “conflict minerals”, i.e. minerals that fall under the Conflict Minerals Trade Act (H.R. 4128)

- Minerals that provide major revenue to armed fractions for violence, such as that occurring in the Democratic Republic of Congo (GSA, Nov. 2010)

Critical minerals

- Many critical elements are produced entirely as by-products of the refining of major metals
  - Tellurium (copper)
  - Indium & germanium (zinc)
  - Gallium (aluminum)
  - Rhenium (molybdenum)
  - Cobalt (copper, nickel)
- Prices are artificially low (economy of scope) until the co-production saturates
- By-product does not drive production of main product, even at high prices
- Price demand inelasticity

Coproduction Issues - Rhenium

- Rhenium is produced as a by-product of molybdenum – there are no primary rhenium producers.
- It is used in producing specialty steels.

Rhenium

- Atomic number 75
- 0.05-1 ppb in crust
- combustion chambers, turbine blades, and exhaust nozzles of jet engines
- US $4,575 per kg (2011)
- By-product of molybdenum and copper production
- Found in molybdenite

Salient Statistics—United States:

	2015	2016	2017	2018	2019[e]
Production[1]	7,900	8,440	8,200	8,220	8,400
Imports for consumption[2]	31,800	31,900	34,500	39,400	39,000
Exports	NA	NA	NA	NA	NA
Consumption, apparent[3]	39,700	40,300	42,700	47,600	47,000
Price, average value, dollars per kilogram, gross weight:[4]					
Metal pellets, 99.99% pure	2,670	2,030	1,550	1,470	1,300
Ammonium perrhenate	2,820	2,510	1,530	1,410	1,300
Employment, number	Small	Small	Small	Small	Small
Net import reliance[5] as a percentage of apparent consumption	80	79	81	83	82

World Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2018	2019[e]	
United States	8,220	8,400	400,000
Armenia	281	280	95,000
Canada	—	—	32,000
Chile[8]	27,000	27,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	1,000	1,000	190,000
Peru	—	—	45,000
Poland	9,090	9,300	NA
Russia	NA	NA	310,000
Uzbekistan	460	400	NA
World total (rounded)	48,600	49,000	2,400,000

https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

- Rhenium changes the phase structure in complex alloys, allowing turbine blades to operate longer at higher temperatures (>1600°C) and pressures without deformation

- General Electric discovered that sufficient Re (by-product of molybdenum production) for mass produced turbines might not be available (or extremely expensive).

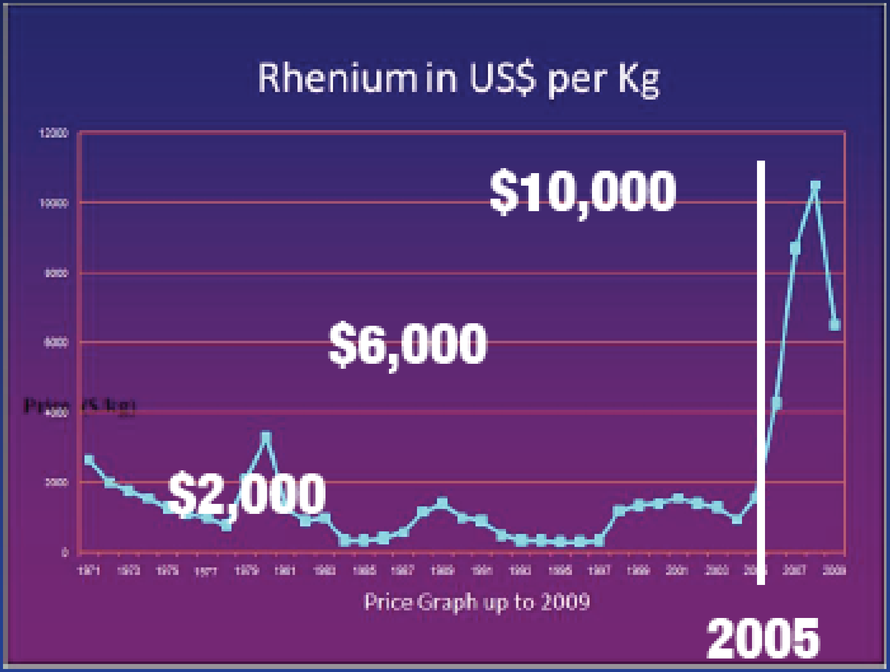
~25 kg Re per gas turbine

General Electric's Rhenium Story

GE launched a two pronged approach in 2005:

- Recycle pre-consumer scrap to forestall shortage (new supply)
- Develop new alloys with low (zero?) Re (substitution)
- Had success over 5 years*

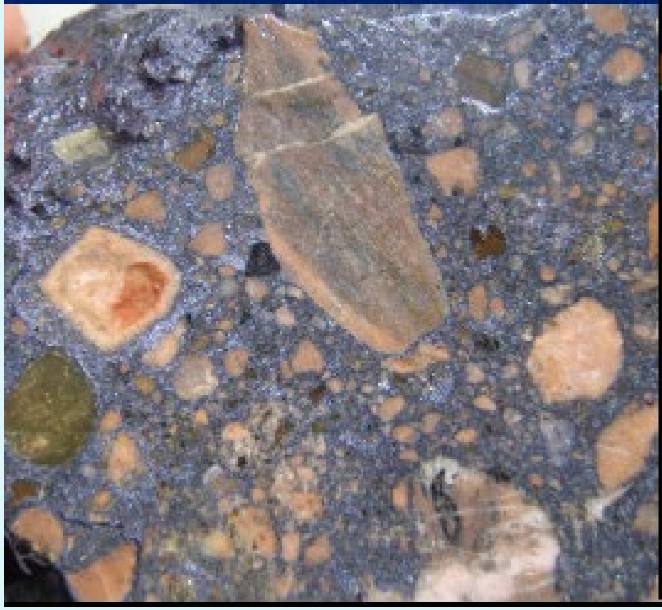
* Fink, P.J., Miller, J.L., and Konitzer, D.G., 2010, J. Minerals Metals Mater. Soc. 62, 57.

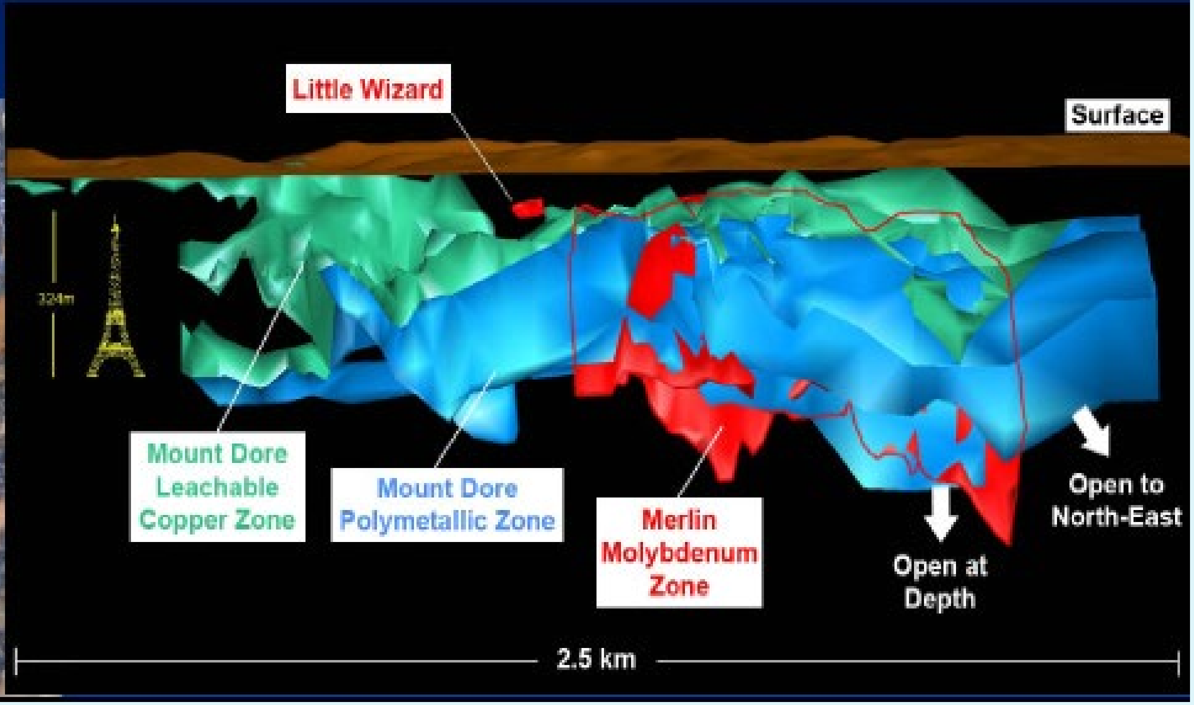


Rhenium 10 Years On ©Anthony Lipmann (2009)

Is there really a shortage of Rhenium?

- Serendipity recently resulted in the discovery of a new type of super high grade moly deposit with a high Re content.
- Merlin, Australia (6.7 Mt @1.34% Mo, 23.2 g/t Re)
- Discovery of additional deposits (if we can develop a geological model for the deposits) should ease fears of Re supply.





Where in New Mexico do we have rhenium potential?

MINING’S INFLUENCE IN HISTORIC CULTURES

Arrowhead clipart from www.firstpeople.us

Critical and strategic minerals will change with time.

Avatar

Importance of minerals

- Mining began with prehistoric man who wanted to improve their way of life
- Ancient cultures often settled time after time around areas that provided raw materials
- 300,000-100,000 years ago mining of flint in N France and S England
- Throughout history, wars were fought over natural resources

Important Cultural Eras

- Stone Age (prior to 4000 B.C.)
- Bronze Age (4000 to 5000 B.C.)
- Iron Age (1500 B.C. to 1780 C.E.)
- Steel Age (1780 to 1945)
- Nuclear Age (1945 to the present)

- **Early civilisations**: fundamental importance of nonfuel minerals, metals, and materials technology and applications.
  - Stone Age, Copper Age, Bronze Age, Iron Age
  - Discovery of metals: **innovations and applications**
    - Gold (6000 BC), copper (4200 BC), silver (4000 BC), lead (3500 BC), tin (1750 BC), iron (1500 BC), mercury (750 BC)
- **Information Age**: developments in materials science and engineering, mineral exploration, and processing continue to enable and support the development of new technologies

Table 1.1.1. Chronology of Events Related to Mining				
Period—Stage	**Near East—Mediterranean—Africa**	**Central and Northern Europe and Great Britain**	**North and South America**	**Australasia**
BC				c.500,000 Use of fire (China)
Paleolithic		300,000–100,000 Surface mining of flint (N. France, S. England)		
c.20,000	c.40,000 Hematite mined for ritual painting (Africa)	c.30,000 Use of fire, lamps, cave art, hunting with projectiles End of Ice Age		
Late Paleolithic	c.9500 Copper pendant. (Iraq)	c.10,000 Gold ornaments		

Mining Engineering Handbook

When was the first mine?

Certainly after agriculture????

How would you find the answer to this question?

When was the first mine?

- Prehistoric man used chert and flint as tools 450,000 years ago
- Nazlet Khater 4 site, Nile Valley, Upper Egypt 33,000 yr
- British flint quarries
- Krzemionki Opatowskie,Southern Poland
  - Upper Palaeolithic
  - Middle and Neolithic (4500 B.C.)
  - Early Bronze Age

When was the first underground mine?

- Bomvu Ridge, Swaziland
- Hematite
- 40,000 years old
- crude methods of ground control, ventilation, haulage, hoisting, lighting, and rock breakage

http://media.wiley.com/product_data/excerpt/11/04713485/0471348511.pdf

Krzemionki Opatowskie,Southern Poland

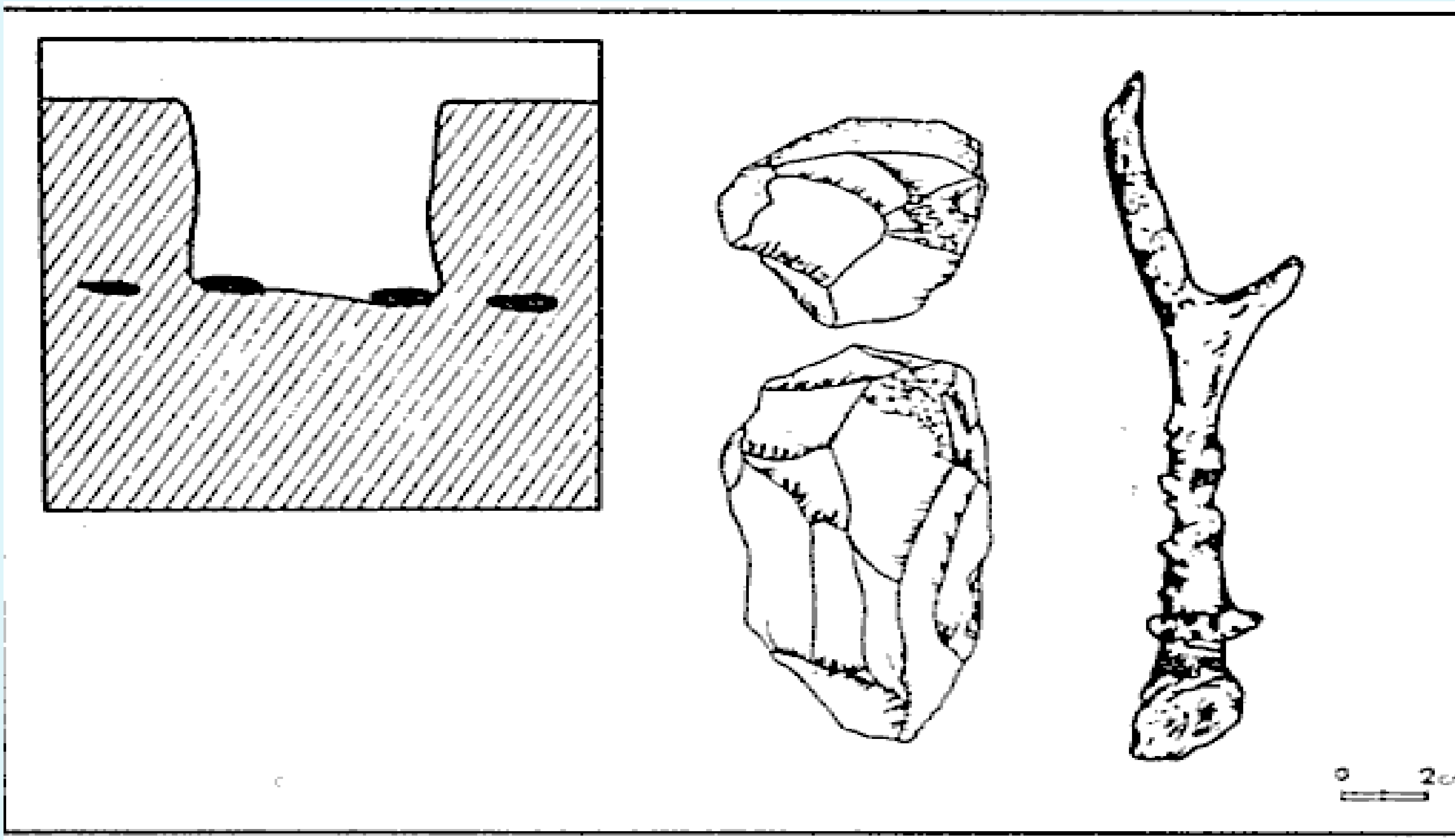


Fig. 1. From the left: scheme of a pit-mine, miner tools.

http://archterra.cilea.it/exhibits/archweb/pocz_gor.htm

Krzemionki Opatowskie,Southern Poland

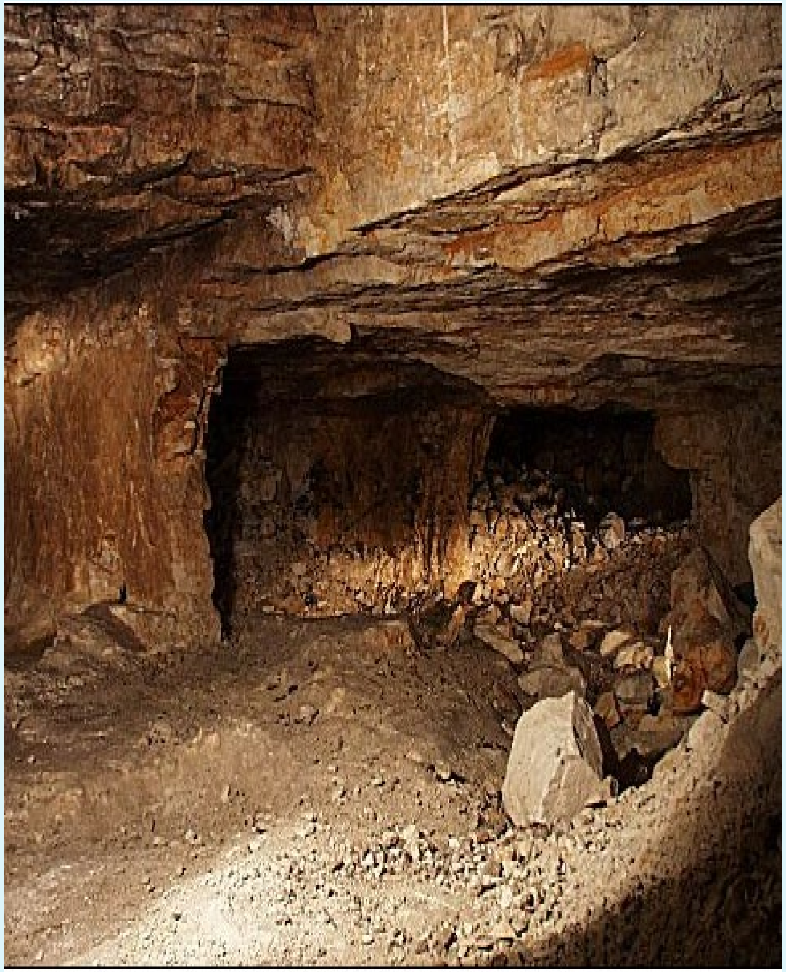


Photo 22. Widok kopalni filarowej.

Photo 26. Widok kopalni filarowej.

http://archterra.cilea.it/exhibits/archweb/pocz_gor.htm

When was the first mine?

- Prehistoric man used soapstone
- Fleur de Lys quarry, Newfoundland
- Maritime Archaic peoples used it approximately 4,000 years ago

Back to Article   Home   Search   Site Map   Table of Contents

Small Soapstone Vessels from Fleur de Lys.
Soapstone vessels were used as lamps and cooking pots. Lamps were generally used for lighting purposes or for heating suspended cooking pots. Cooking pots were used for cooking meals and were either suspended over an open fire or soapstone lamp or placed directly into an open fire.

Reproduced by permission of Brent Murphy. Photo ©1997.

http://www.heritage.nf.ca/environment/soapstone.html

Old Testament recognized the land of Ophir (Zimbabwe), which was somewhere in Africa, as a source of gold

African mining sites

- Zimbabwe 20,000 to 26,000 BC
- Swaziland 50,000 BC

http://www.anvilfire.com/21centbs/stories/rsmith/biblical_1.htm

Other uses of minerals in ancient societies

- Egyptians replaced water clocks with sand hour glasses
- Greek and Romans made concrete-like structures that are still standing today
- Building stones used in many ancient cultures

Lets look at a commodity in more detail

SALT

- NaCl
- table salt
- essential to life (man 2-5 gr/day)
- salt was used as a preservative, tanning leather, stock, mining
- salt was used to preserve Egyptian mummies

Why is salt important?

SALT

- Trade in salt was very important; salt was valuable enough to be used as currency in some areas.
  - Salt cakes
- The Latin phrase "salarium argentum," "salt money," referred to part of the payment made to Roman soldiers.

- http://www-geology.ucdavis.edu/~gel115/salt.html

- Greek worshippers consecrated salt in their rituals
- in the Old and New Testaments, covenants were sealed with salt
- Jewish "KASHRUT" [hygiene] tradition and law, involves the dehydration of meat for its preservation
- Catholic Church used salt in purifying rituals
- Buddhist believed salt repeals evil spirits
- Pueblo people worship the Salt Mother

Blocks of pure salt cut from the earth sit stacked in rows awaiting carriers in Taoudenni, as a miner removes earth from his pit mine.

http://www.ask.com/main/metaAnswer.asp?t=ai&s=a&MetaEngine=directhit&en=te&eo=1&o=7039&frames=True&url=http%3A%2F%2Fwww%2Esaltinstitute%2Eorg%2F3%2Ehtml&ac=24&adcat=jeev&pt=The+Salt+Industry&dm=http%3A%2F%2Fwww%2Esaltinstitute%2Eorg%2F3%2Ehtml&io=0&qid=F258E627CA006B41B7CDB7AF2837895D&back=origin%3D7039%26ask%3Dsalt%2Bmining%26search%3Dsalt%2Bmining&ask=salt+mining&dt=030107155051&amt=&pg=1&qsrc=0

Caravans across the Sahara basin carrying salt across the desert to the trading centers of Karta, Bambara, Cairo and Timbuktu.

http://www.cheethamsalt.com.au/

Mining salt in 1920s at The Cheetham Salt mine, Australia

http://www.cheethamsalt.com.au/

The star of David used to crystallise salt in salt pans in Mexico, La Concordia - from "Maya Salt Production and Trade - Antony P. Andrews " courtesy Gertrude Blom.

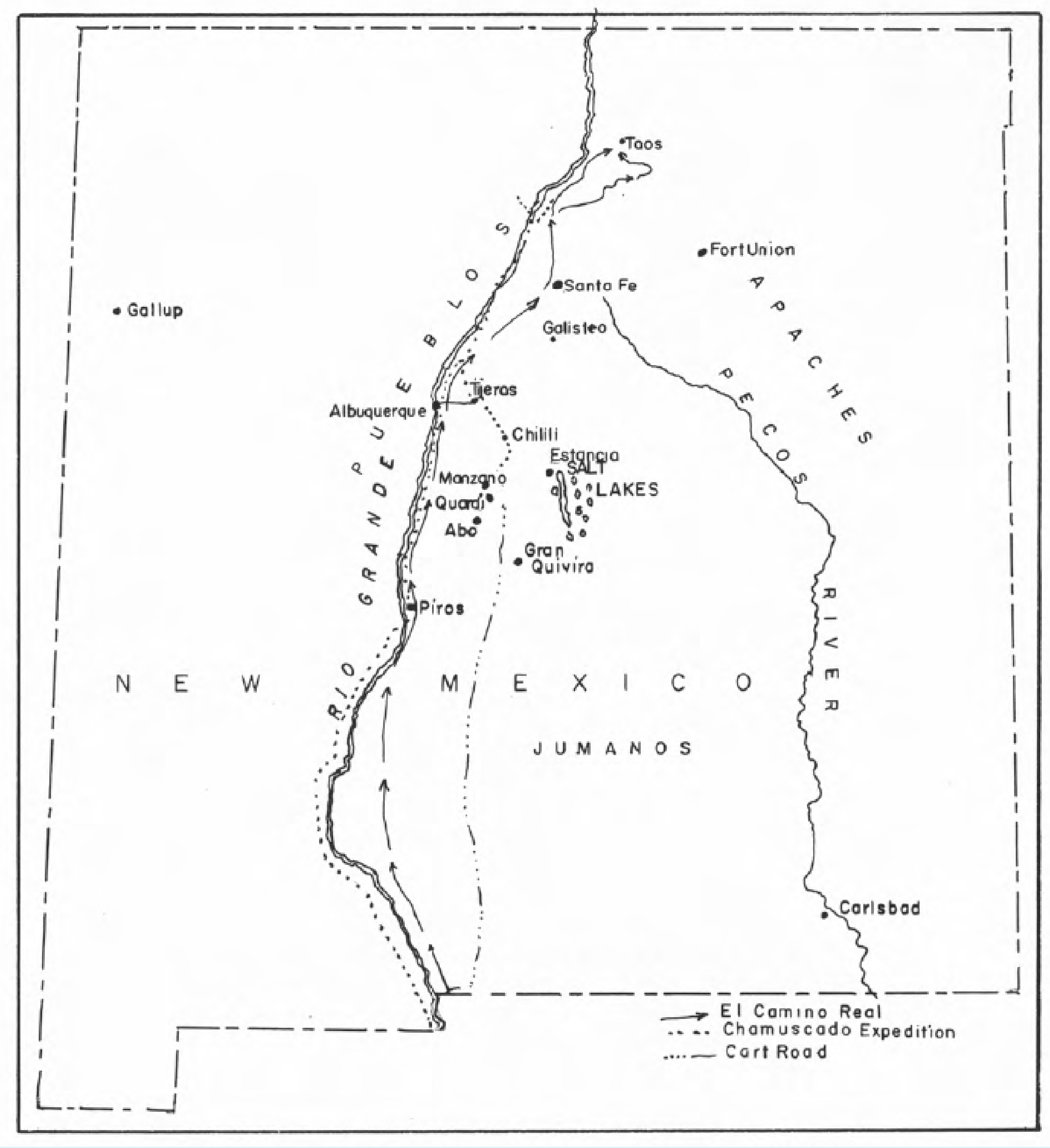
http://salt.org.il/frame_rel.html

Salt in Austria

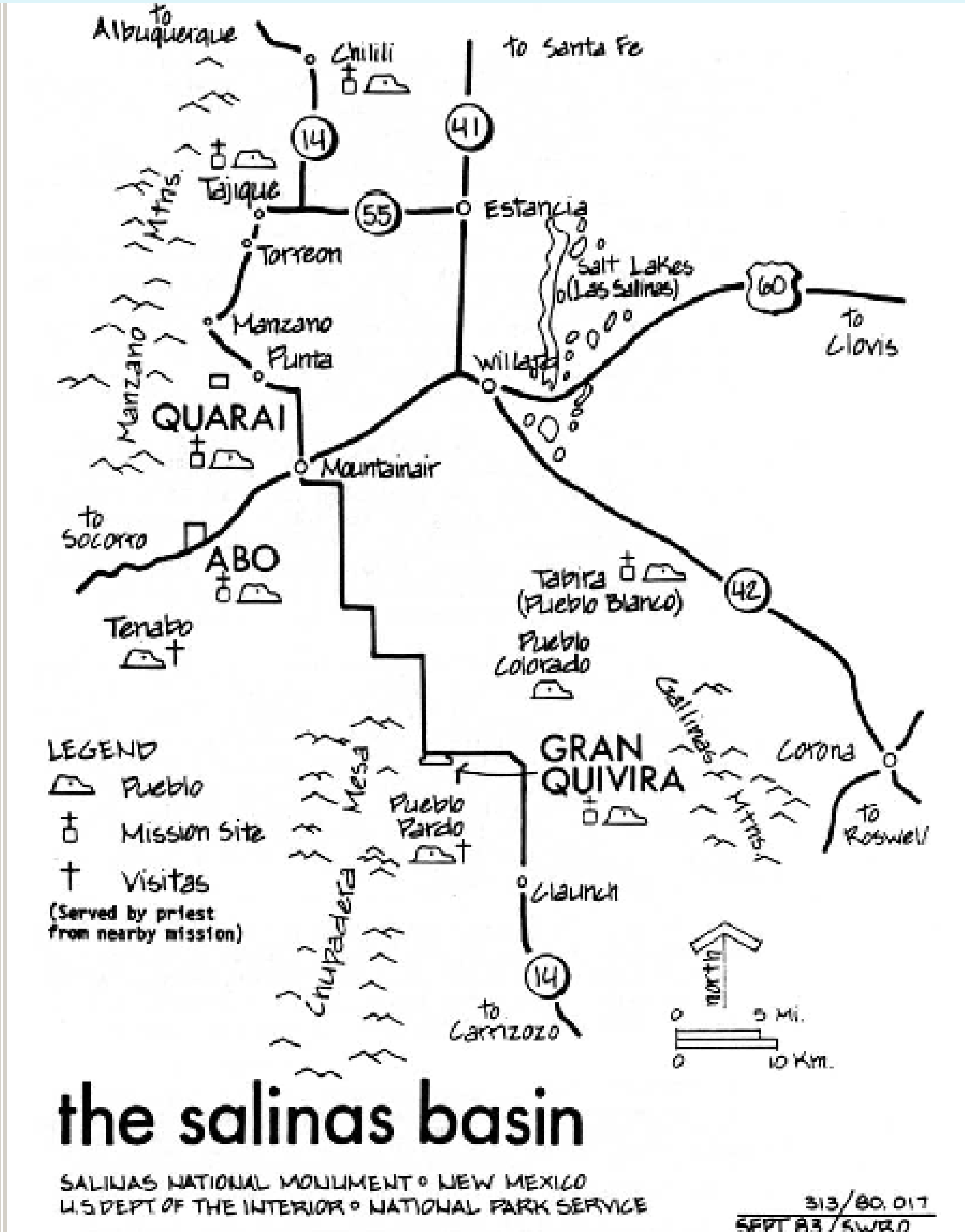
- Heilbad Durrnberg
- 750-150 BC
- 200 people worked the deposits
- wealth of this small settlement is clearly evidenced by the clusters of graves which surrounded the various rectangular houses

Estancia Basin in central New Mexico

- Salt basin, few areas with edible salt
- Central to Indian Pueblos—Abo, Gran Quivira, Salinas, a total of 10 Piro pueblos
- Important in trade by 13th century
- Spanish conquest in 1581, built churches, and demanded more salt
- By 1660 Spanish shipped salt 700 mi to Mexico for use in processing silver


Taos
Fort Union
Santa Fe
Galisteo
Gallup
PUEBLOS
APACHES
PECOS
Tijeras
Albuquerque
Chilili
Estancia
SALT
LAKES
Manzano
Quarai
Abo
Gran
Quivira
RIO GRANDE
Piros
NEW MEXICO
RIVER
JUMANOS
Carlsbad
El Camino Real
Chamuscado Expedition
Cart Road

Kraemer, 19)



http://www.nps.gov/sapu/hsr/fig1.jpg

Gran Quivira

Estancia playa, looking northwest

Salt and Silver Processing

- Patio process developed in 1557 in Pachuca, Hidalgo, Mexico
- silver ores crushed in arrastras to a fine slime
- mixed with salt, water, copper sulfate, mercury
- spread onto a patio and allowed to dry in the sun
- silver could then amalgamate with mercury and thus be recovered

End of an Era

- By the late 1670s the entire Salinas district, as the Spanish had named it, was depopulated
  - 1672 Apache raids increased
  - 1671 Famine hit the area
  - Poor harvests
  - By the Pueblo revolt in 1680, the pueblos were abandoned
- Salt was still needed and when the Spanish resettled New Mexico, armed escorts frequently traveled to the lakes and mined salt for the rest of the state
- 1821, area near Mountainair in the Manzano Mountains was resettled
  - Some of the orchards from past settlement remained
- Even soldiers from Ft. Craig mined salt from the playas in 1860s
- The coming of the railroad in 1879, ended the salt trade

Modern Era

- Julius Meyer produced salt in 1915
- Between 1915-1933, several operators
- In 1932 New Mexico Salt Co. mined and marketed 350 short tons of salt and 700 short tons in 1933
  - Sold in 3 grades 85, 92, and 98% pure
  - Vats formed by low dike controlled deposition
  - Used a well to pump water into the vats and allow to evaporate
- In 1931, Carlsbad salt deposits were exploited
- In the 1950s, the Southwestern Chemical Co. attempted to process salt for fertilizer
- Thicker salt beds in Laguna Salina
- Today exploration for Li, Sr, B, Br
- Uranium also is found in the playas (as much as 334 ppb U in waters)

Salt, Societies, and Spirituality: A Tale of Two Cultures.

Tucked away in the middle of New Mexico you'll find Salinas Pueblo Missions National Monument. Its three distinct sites offer a glimpse into a unique time in history—a time entrenched with cultural borrowing, conflict and struggles. These sites continue to stand as reminders of the Spanish and Pueblo peoples' early encounters and prompt exploration of today's interactions among different people.

Virtual Tour of Abó ›

Take a tour of Abó from your home! Abó features a short trail to the picturesque mission ruins.

Gran Quivira ›

Gran Quivira is the most remote of the three sites. If you're interested in visiting excavated Puebloan ruins, you won't want to miss it!

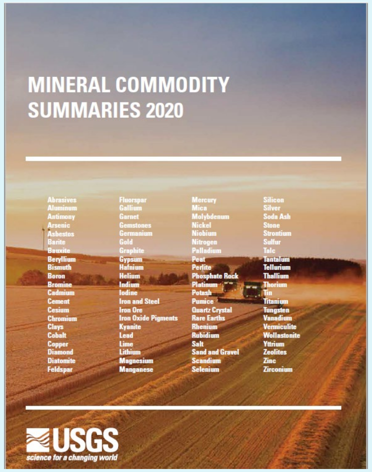
Quarai Virtual Tour ›

Quarai features the most intact church of the three sites and is a wonderful birding location. Learn more about Quarai in this virtual tour.

https://www.nps.gov/sapu/index.htm

Salient Statistics—United States:[1]	2015	2016	2017	2018	2019[e]
Production	45,100	41,700	39,600	[e]41,000	42,000
Sold or used by producers	42,800	39,900	38,200	[e]40,000	41,000
Imports for consumption	21,600	12,100	12,600	17,900	17,000
Exports	830	729	1,120	986	730
Consumption:					
Apparent[2]	63,600	51,300	49,700	[e]57,000	57,000
Reported	52,300	47,800	45,500	[e]48,000	49,000
Price, average value of bulk, pellets and packaged salt, dollars per ton, f.o.b. mine and plant:					
Vacuum and open pan salt	188.87	197.78	211.71	[e]220.00	220.00
Solar salt	102.04	99.69	115.88	[e]120.00	120.00
Rock salt	56.32	56.75	60.41	[e]62.00	62.00
Salt in brine	10.27	8.68	9.49	[e]10.00	10.00
Employment, mine and plant, number[e]	4,200	4,000	4,100	4,100	4,100
Net import reliance[3] as a percentage of apparent consumption	33	22	23	30	29

Recycling: None.



Salt

World Production and Reserves:

	Mine production[e] 2018	Mine production[e] 2019	Reserves[4]
United States[1]	41,000	42,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	12,000	13,000	
Austria	4,900	4,900	
Brazil	7,500	7,600	
Canada	12,000	12,000	
Chile	8,000	9,000	
China	58,000	60,000	
France	5,700	5,700	
Germany	14,000	14,000	
India	29,000	30,000	
Italy	4,100	4,100	
Mexico	9,000	9,000	
Netherlands	7,000	7,000	
Pakistan	4,400	4,500	
Poland	4,400	4,500	
Russia	7,000	7,000	
Spain	4,200	4,300	
Turkey	6,500	6,600	
United Kingdom	4,100	4,100	
Other countries	43,000	44,000	
World total (rounded)	286,000	293,000	

https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

Is salt a critical/strategic mineral?

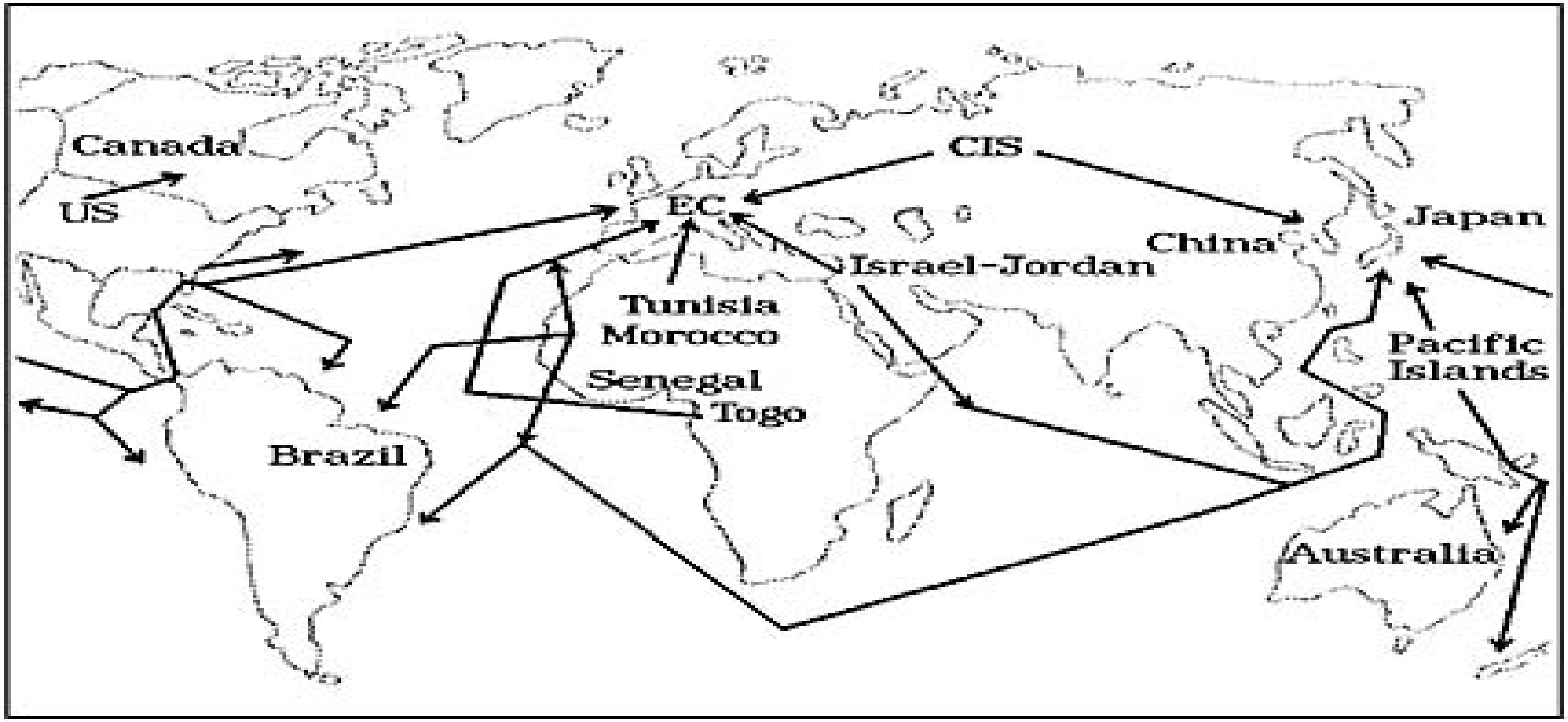
What has changed from Prehistoric times to today?

Need for more commodities

Technology

Global market

Fig. 1. Trade patterns in phosphate rock.



Environmental concerns

Mineral availability

Long term mineral availability (>10 Yr)

- Geologic (does the mineral resource exist)
- Technical (can we extract and process it)
- Environmental and social (can we mine and process it in environmentally and socially acceptable ways)
- Political (how does politics influence)
- Economic (can we mine and produce it at a cost the markets will pay)

Short- and medium-term availability

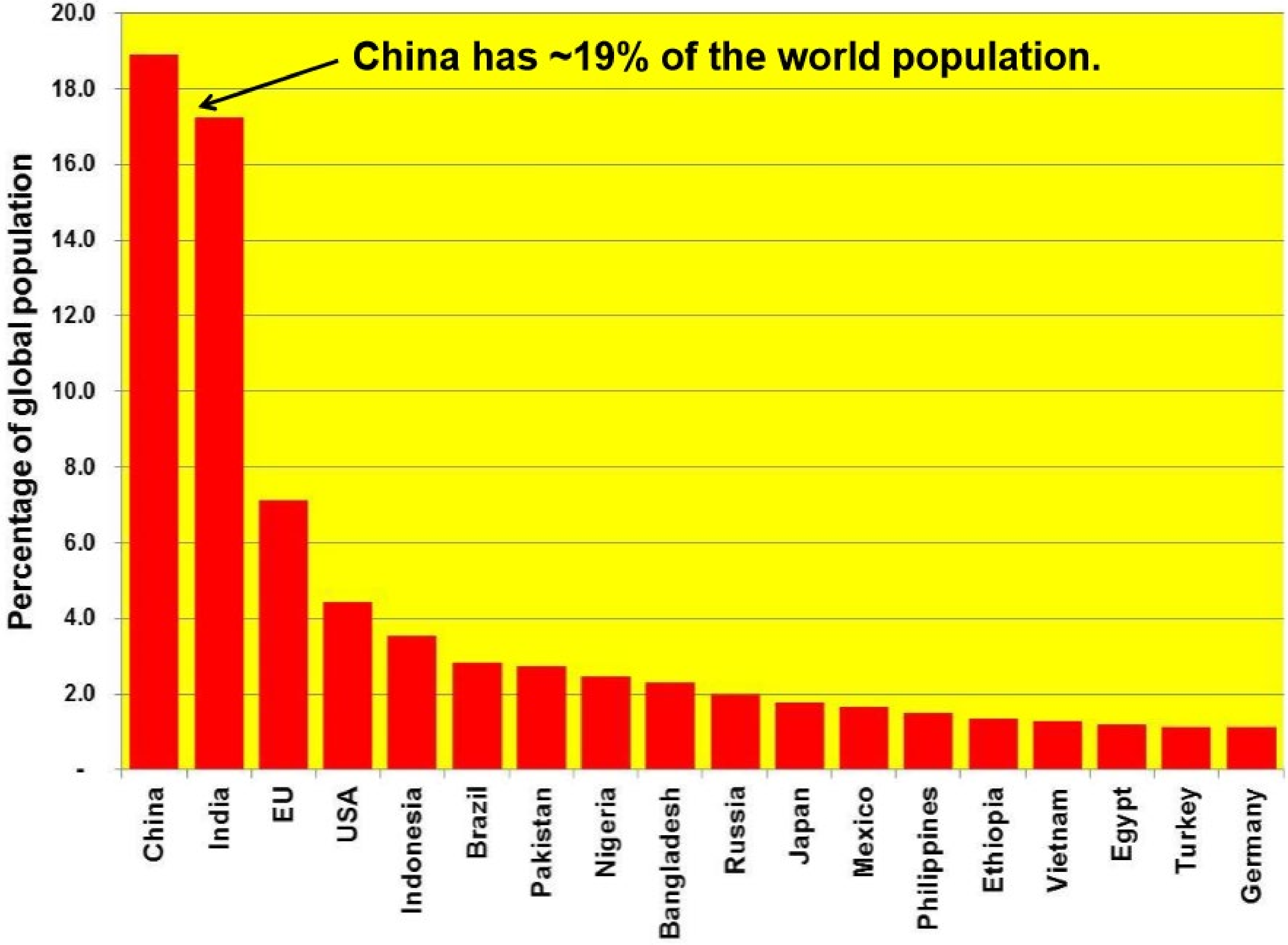
- Significant or unexpected increase in demand
- Small markets
- Production from a small number of mines, companies, or markets
- Minerals whose supply consist significant of byproduct production (i.e. Ga byproduct of bauxite mining)
- Markets for which there is no significant recovery from old scrap

Global challenges

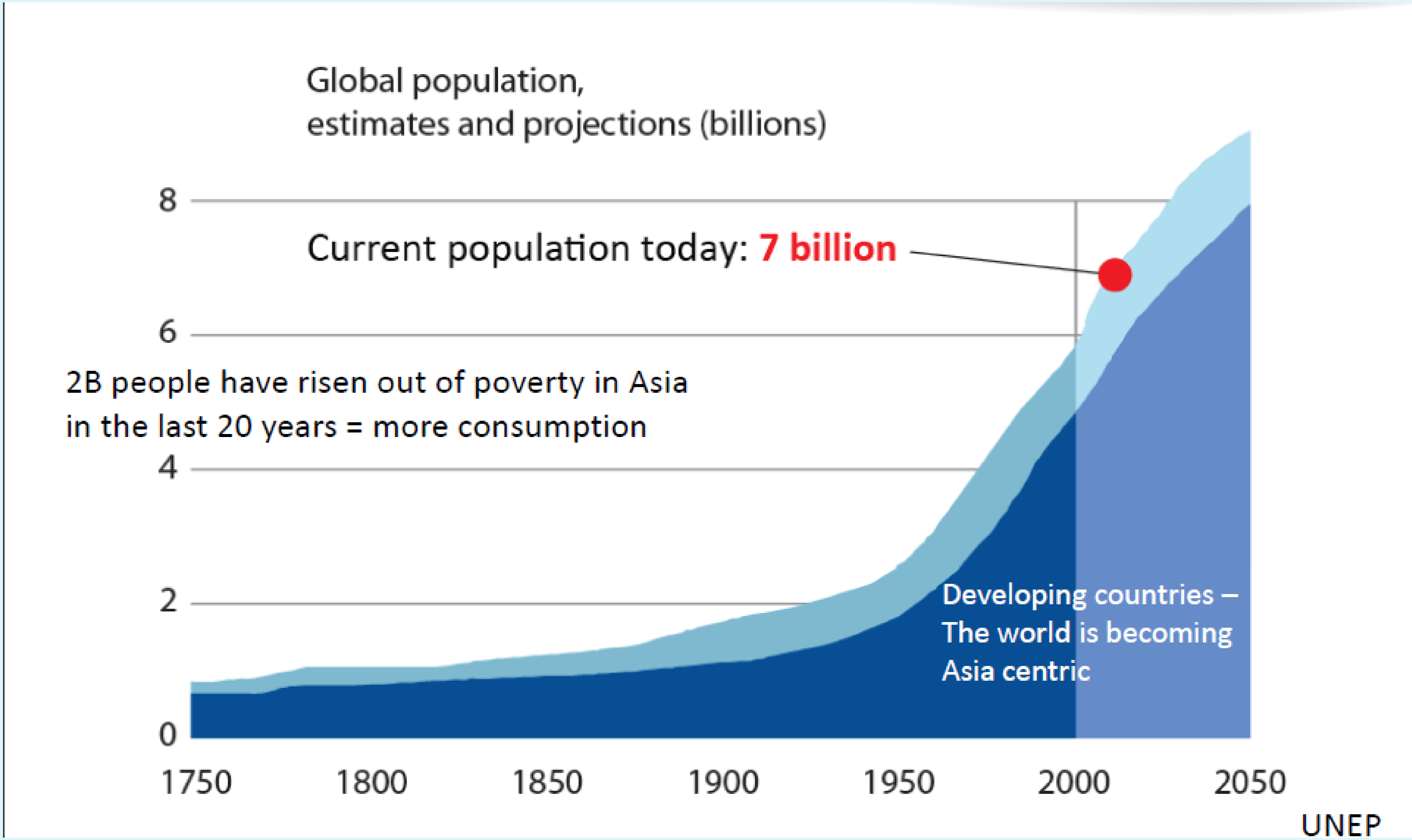
- The small volumes of strategic/critical minerals utilized makes them price sensitive
- New producers need a reliable, long-term buyer
- Long-term buyers require a fixed price, but operating costs are variable
- Monopolies/oligopolies can drive out marginal producers by over-supplying the market until the competition is eliminated

Other factors

- Population
- Food
- Pandemic

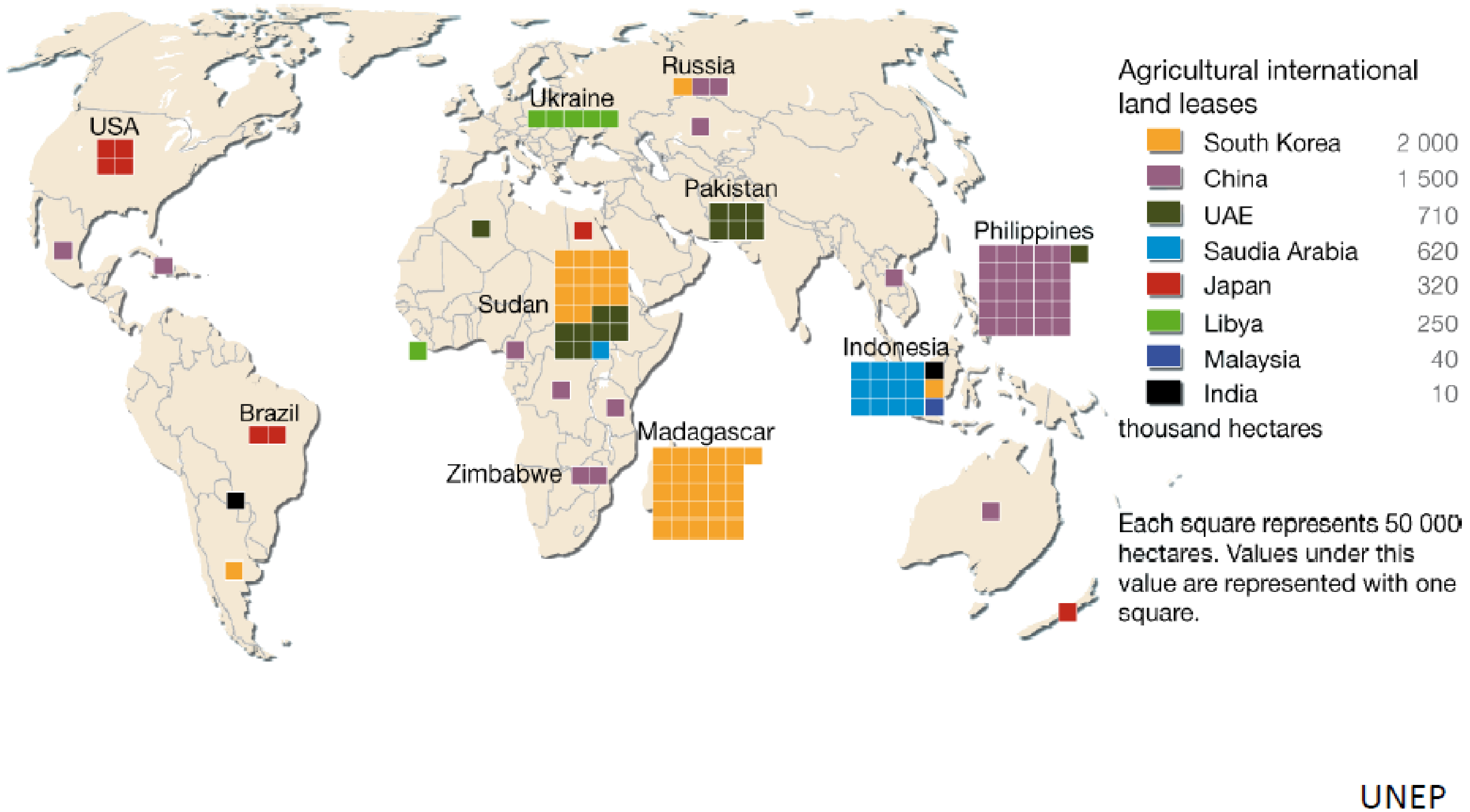


Data from CIA.



http://dnr.alaska.gov/commis/priorities/Slides/Lance_Miller.pdf

Food Security



http://dnr.alaska.gov/commis/priorities/Slides/Lance_Miller.pdf

What minerals are considered critical and strategic minerals?

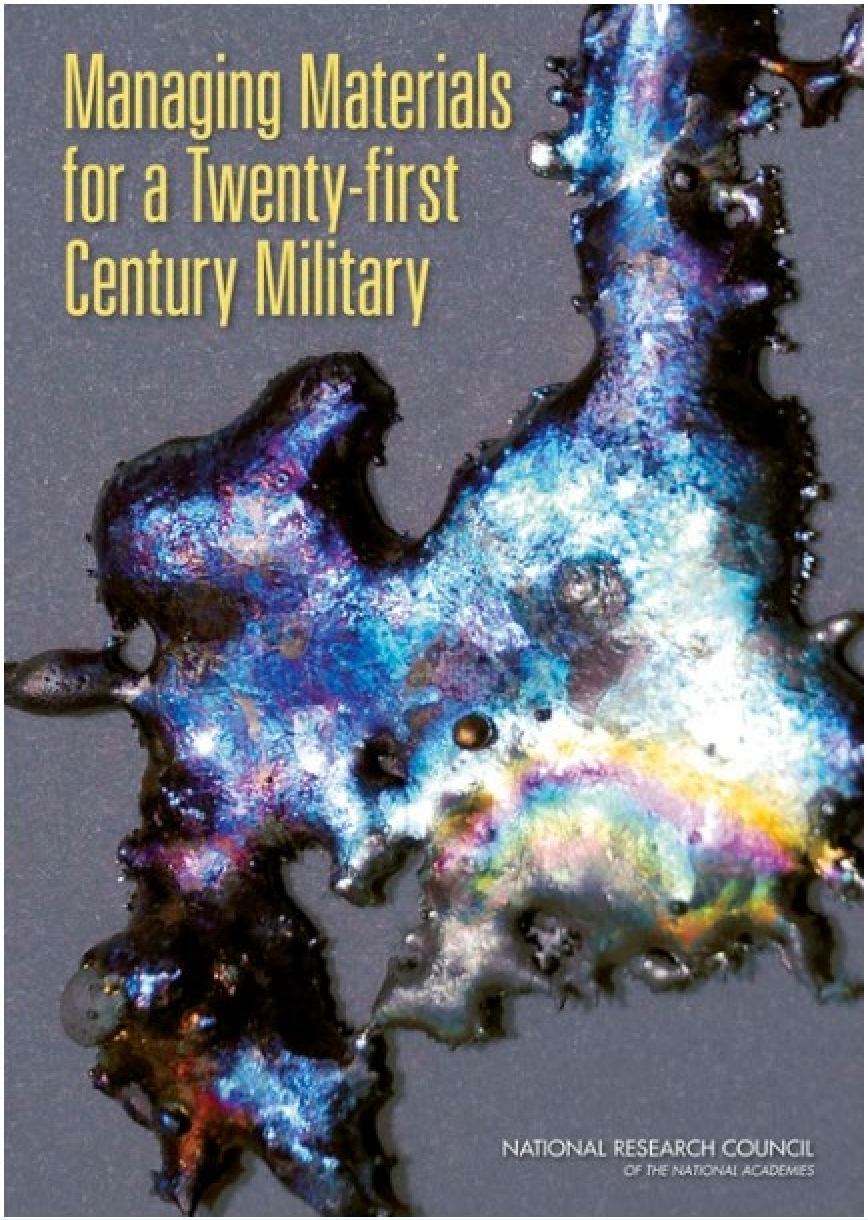
Certainly petroleum!

But it is not on the list

Why?

DOD

- REE
- U
- Be
- Cr
- Co
- Mn
- Ge
- PGM
- Ta
- Sn
- W
- Zn
- Al
- Bi
- B
- Cd
- Cu
- F
- Ga
- Hf
- In
- Pb



http://www.nap.edu/catalog.php?record_id=12028

Strategic and critical minerals for the U.S. (Long, 2009; Long et al., 2010)

- Antimony
- Barite
- Chromite
- Cobalt
- Fluorite
- Gallium
- Graphite
- Indium
- PGE (platinum group elements)
- REE (rare earth elements)
- Rhenium
- Tantalum
- Titanium
- Tungsten
- Yttrium
- Niobium

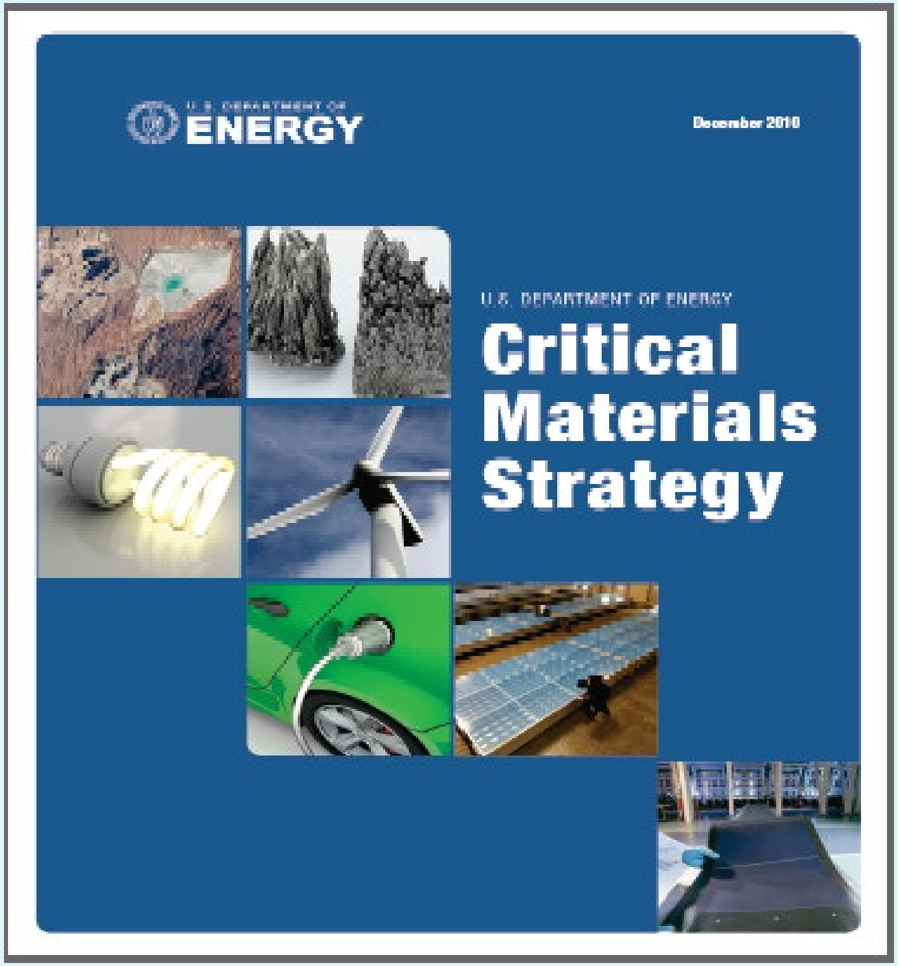
Green minor metals—basis for cleaner technology innovation

- Indium
- Germanium
- Tantalum
- PGM
- Tellurium
- Cobalt
- Lithium
- Gallium
- REE

http://www.unep.fr/shared/publications/pdf/DTIx1202xPA-Critical%20Metals%20and%20their%20Recycling%20Potential.pdf

Minerals required for clean energy technologies

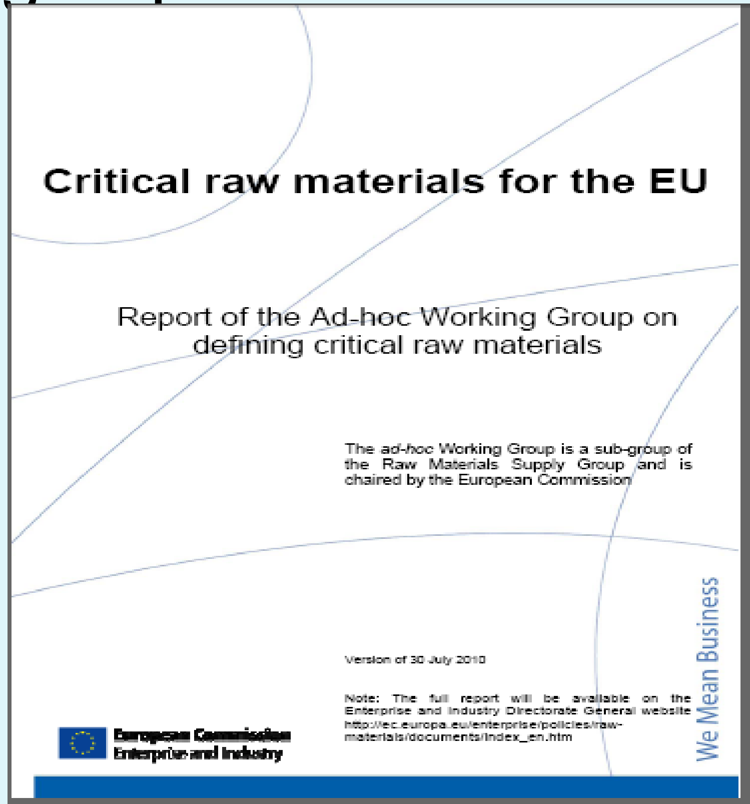
- Lithium
- Cobalt
- Gallium
- REE, Y
- Indium
- Tellurium



http://www.energy.gov/news/documents/criticalmaterialsstrategy.pdf

Strategic minerals for the European Union

- Antimony
- Beryllium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite
- Indium
- Magnesium
- Niobium
- PGM (platinum group metals)
- REE (rare earth elements)
- Tantalum
- Tungsten


Critical raw materials for the EU

Report of the Ad-hoc Working Group on defining critical raw materials

The *ad-hoc* Working Group is a sub-group of the Raw Materials Supply Group and is chaired by the European Commission

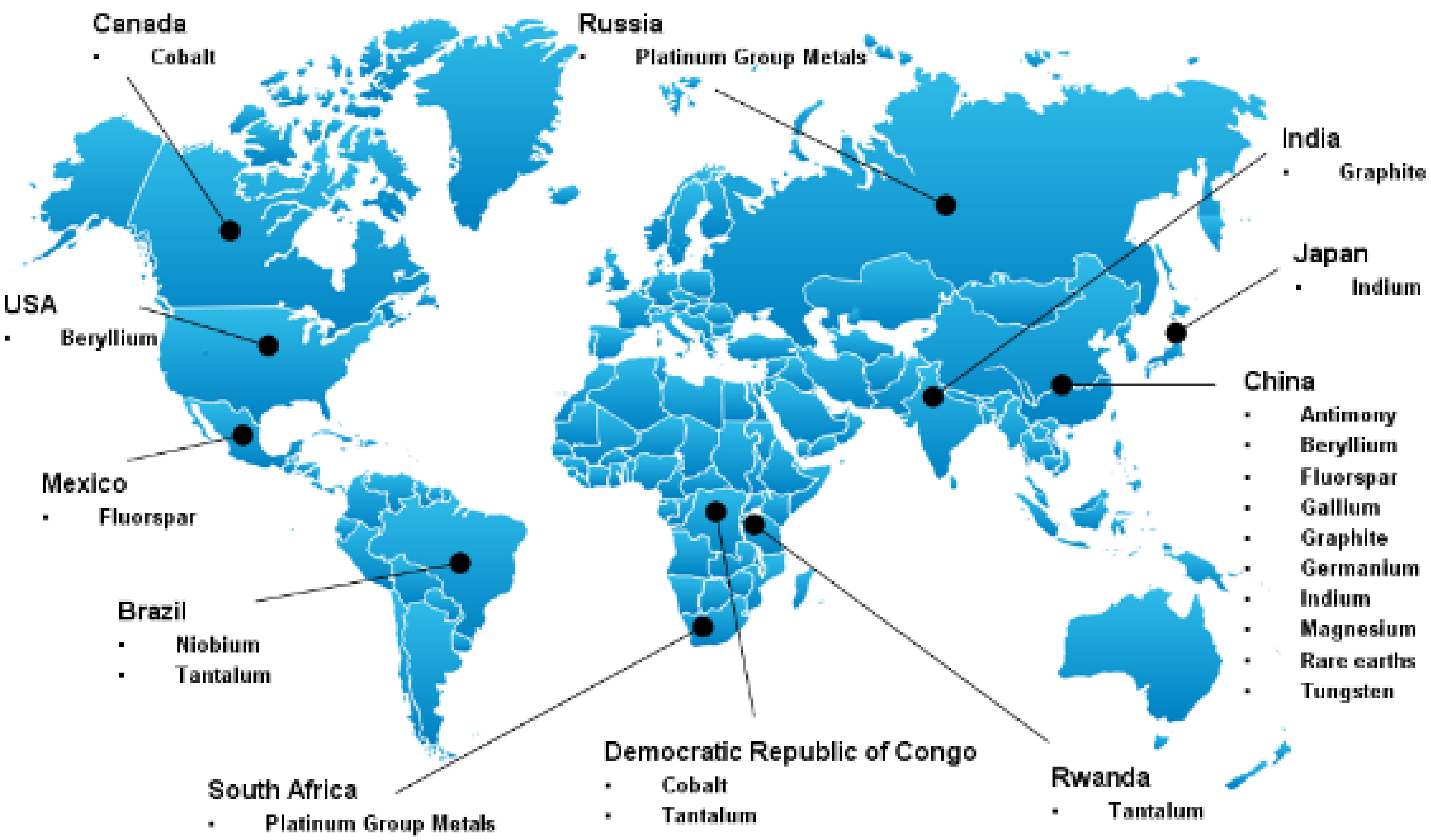
Version of 30 July 2010

Note: The full report will be available on the Enterprise and Industry Directorate General website http://ec.europa.eu/enterprise/policies/raw-materials/documents/index_en.htm

European Commission
Enterprise and Industry

We Mean Business

Production concentration of critical raw mineral materials



http://europa.eu/rapid/press-release_MEMO-10-263_en.htm?locale=en

Raw material	Production 2006 (t)	Demand from emerging technologies 2006 (t)	Demand from emerging technologies 2030 (t)	Indicator1) 2006	Indicator1) 2030
Gallium	152 6)	28	603	0,18	3,97
Indium	581	234	1.911	0,40	3,29
Germanium	100	28	220	0,28	2,20
Neodymium (rare earth)	16.800	4.000	27.900	0,23	1,66
Platinum (PGM)	255	very small	345	0	1,35
Tantalum	1.384	551	1.410	0,40	1,02
Silver	19.051	5.342	15.823	0,28	0,83
Cobalt	62.279	12.820	26.860	0,21	0,43
Palladium (PGM)	267	23	77	0,09	0,29
Titanium	7.211.000 2)	15.397	58.148	0,08	0,29
Copper	15.093.000	1.410.000	3.696.070	0,09	0,24

http://europa.eu/rapid/press-release_MEMO-10-263_en.htm?locale=en

Critical Minerals 2018 in the US

- Aluminum (bauxite), used in almost all sectors of the economy
- Antimony, used in batteries and flame retardants
- Arsenic, used in lumber preservatives, pesticides, and semi-conductors
- Barite, used in cement and petroleum industries
- Beryllium, used as an alloying agent in aerospace and defense industries
- Bismuth, used in medical and atomic research
- Cesium, used in research and development
- Chromium, used primarily in stainless steel and other alloys
- Cobalt, used in rechargeable batteries and superalloys
- Fluorspar, used in the manufacture of aluminum, gasoline, and uranium fuel
- Gallium, used for integrated circuits and optical devices like LEDs
- Germanium, used for fiber optics and night vision applications
- Graphite (natural), used for lubricants, batteries, and fuel cells
- Hafnium, used for nuclear control rods, alloys, and high-temperature ceramics
- Helium, used for MRIs, lifting agent, and research
- Indium, mostly used in LCD screens
- Lithium, used primarily for batteries

Critical Minerals 2018 in the US—cont

- Magnesium, used in furnace linings for manufacturing steel and ceramics
- Manganese, used in steelmaking
- Niobium, used mostly in steel alloys
- Platinum group metals, used for catalytic agents
- Potash, primarily used as a fertilizer
- Rare earth elements group, primarily used in batteries and electronics
- Rhenium, used for lead-free gasoline and superalloys
- Rubidium, used for research and development in electronics
- Scandium, used for alloys and fuel cells
- Strontium, used for pyrotechnics and ceramic magnets
- Tantalum, used in electronic components, mostly capacitors
- Tellurium, used in steelmaking and solar cells
- Tin, used as protective coatings and alloys for steel
- Titanium, overwhelmingly used as a white pigment or metal alloys
- Tungsten, primarily used to make wear-resistant metals
- Uranium, mostly used for nuclear fuel
- Vanadium, primarily used for titanium alloys
- Zirconium, used in the high-temperature ceramics industries

Assignment

- Safety moment
- Mineral deposit models (Cox and Singer, 1986, http://pubs.usgs.gov/bul/b1693/Tlbc.pdf)
- The classification of ore deposits (Noble, 1955)
- Principles of a resource/reserve classification for minerals (http://pubs.usgs.gov/circ/1980/0831/report.pdf)
- NATIONAL INSTRUMENT 43-101, *STANDARDS OF DISCLOSURE FOR MINERAL PROJECTS (http://web.cim.org/standards/documents/Block484_Doc111.pdf)*
- McLemore, V.T. and Lueth, V., 2017, Metallic Mineral Deposits; Energy and Mineral deposits in New Mexico: New Mexico Bureau of Geology and Mineral Resources Memoir 50 and New Mexico Geological Society Special Publication 13, PROTEROZOIC DEPOSITS