GEOLOGY, MINING, AND PROCESSING OF THE INDUSTRIAL MINERALS

SPRING 2018

Virginia McLemore

CLASS REQUIREMENTS

Goals in this class

- Importance, geology, mining, processing of industrial minerals, including critical minerals
- 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

Goals in this class

- Understand where your world comes from
- Take pride in being part of the mining community
- Know where to find information
- Provide additional skills that will help you in your future career

Class

- The class will meet Mondays for 90-180 minutes
- Remaining time spent on field trips or in occasional extra discussion sessions (SME meetings, other presentations)
- Gives time for the presentations and project

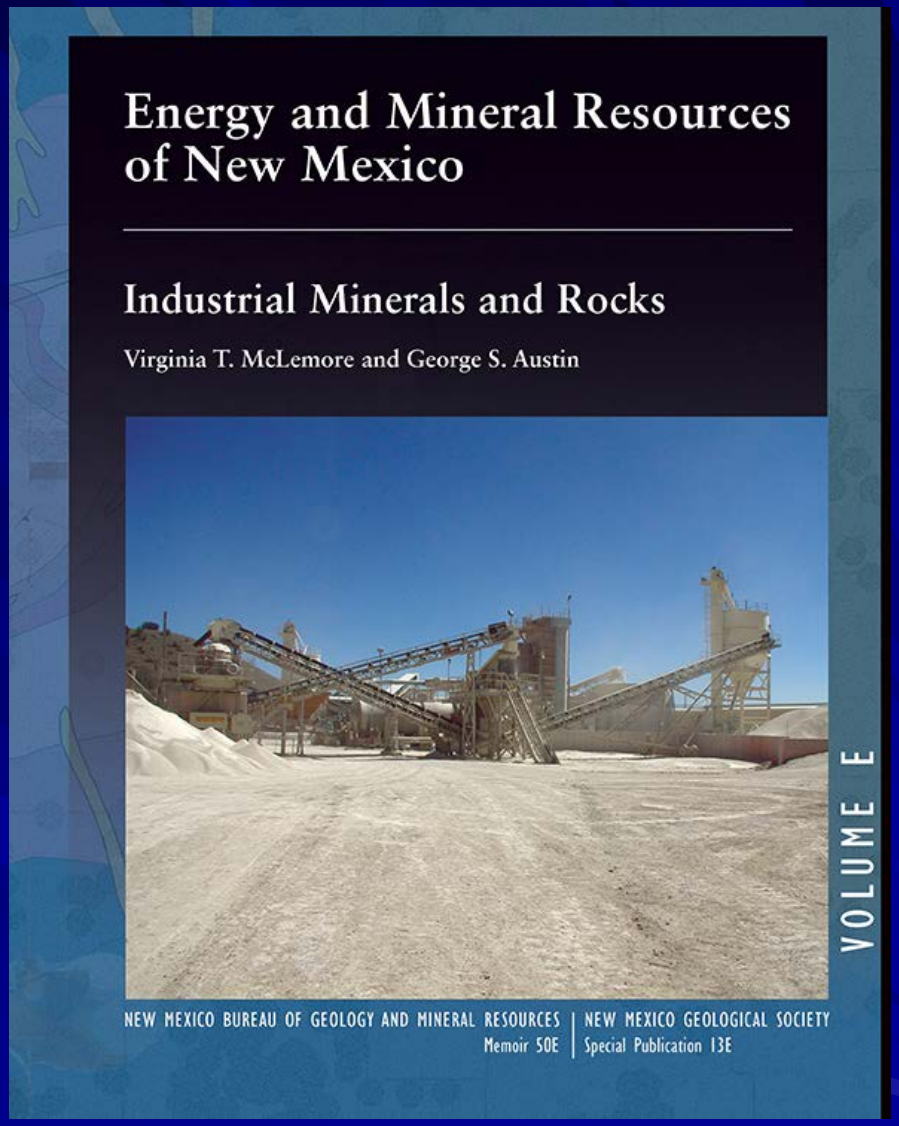
- January 22—Introduction: IM definition and overview
- 29—Basic concepts: Geology, mining, and processing
- February 5—Basic concepts: Geology, mining, and processing
- 12—More IM basic concepts; IM industry flow sheet, Transportation
- 19— Sustainable development
- 26— **Midterm exam** (Take Home) Annual SME meeting in Denver, no class
- March 5— Commodities: Introduction
- 12— spring break NO CLASS
- 19— Commodities
- 26—Marketing, QA/QC, IM Trends
- April 02—Commodities
- 9— New Mexico Geological Society Spring meeting, Socorro
- 16—Commodities
- 23—Commodities
- 30— Present research results in class
- May 07— Present research results in class (15 mins); **Final exam given out** (Take Home)
- 11—**Final Exam** due by noon on May 11th

Lectures found on my web site
http://geoinfo.nmt.edu/staff/mclemore/teaching/imclass/home.html

Textbook

- Kogel, J.E, Trivedi, N.C., Barker, J.M., and Krukowski, S.T., 2006 , ed., Industrial Minerals and Rocks, 7th edition: Society for Mining, Metallurgy, and Exploration, Littleton, Colorado (use McLemore member #0154600) to get this price (save more $ than membership costs plus you should all be members of SME anyway)
- 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

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.



http://geoinfo.nmt.edu/publications/monographs/memoirs/50/E/

https://minerals.usgs.gov/minerals/pubs/mcs/2017/mcs2017.pdf

Specifics

- 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 (thesis, web page, other).
- Field trips—there will be 1 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.
- I will assign papers thru/out the term and each of you will get to lead the discussion each class.

Grades

Midterm	25%
Final (comprehensive)	30%
field trip	5%
Term project	25%
Class Participation/papers	15%

Sources of data

- Internet
- http://minerals.usgs.gov/minerals/pubs/commodity/myb/
- Aggregates http://geopubs.wr.usgs.gov/open-file/of00-011/
- http://www.minerals.com/
- Societies SME, Aggregate Association

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

- Lesson plan, poster, and web site on importance of a specific commodity
- Take a common product and examine what minerals/rocks go into that product
- Mineral resource potential of specific mineral in a geographic area
- Flow of a commodity in our society
- Related to your thesis work
- Analytical procedures for a commodity/element
- Thesis topic

Dig A Little Deeper

How Many Minerals and Metals Does It Take to

Make A Light Bulb?

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.

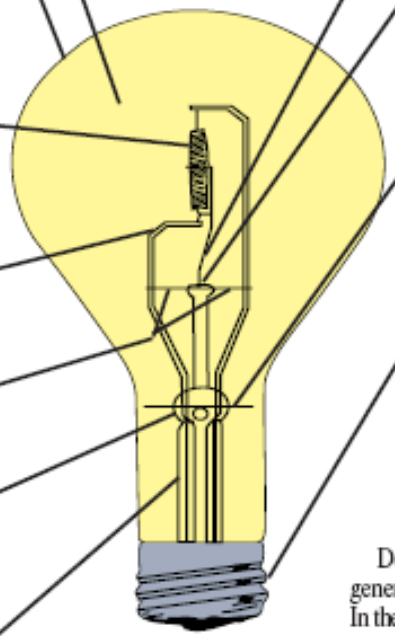
Filament
Usually is made of *tungsten.* The filament may be a straight wire, a coil, or a coiled-coil.

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

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.



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.

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.*

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.

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

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

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

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

Web pages

New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
Earth Science for the 21st Century

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Natural Resources 〉 Minerals 〉 Industrial

Industrial Mineral Resources in New Mexico

Industrial minerals are defined as a naturally occurring rock or mineral, exclusive of metal ores, mineral fuels, and gemstones. Industrial minerals are diverse materials and are used in virtually every aspect of modern life, providing raw materials for many industries, including building, manufacturing, and agriculture. The

http://geoinfo.nmt.edu/publications/index.cfm

OUTLINE

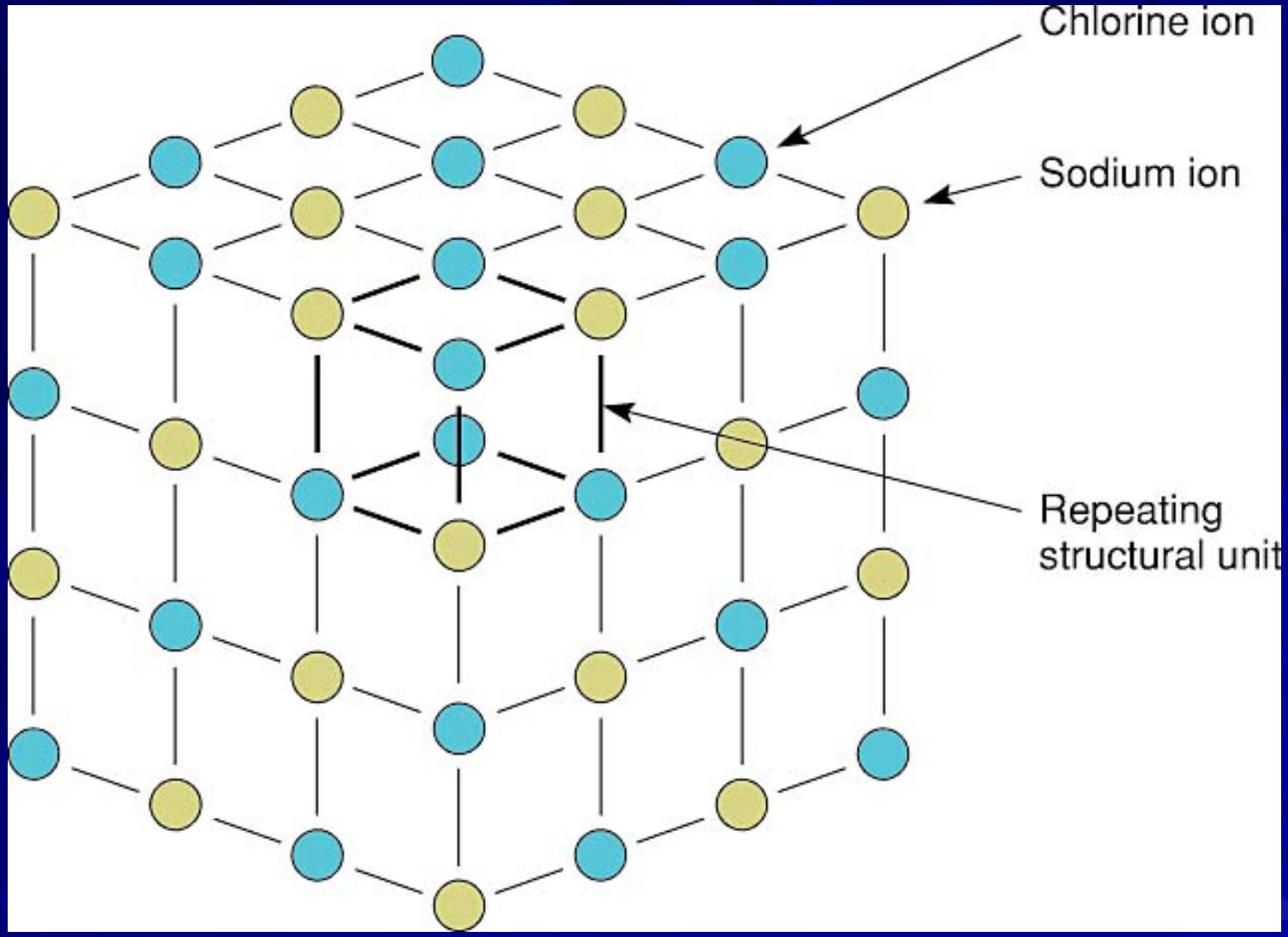
- What are industrial minerals?
- Why are industrial minerals important?
- Strategic and critical minerals
- Classification of Industrial Minerals
- History of mining industrial minerals

WHAT ARE INDUSTRIAL MINERALS?

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.

Minerals refer to any rock, mineral, or other naturally occurring material of economic value, including metals, industrial minerals, energy minerals, gemstones, and aggregates

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
- Includes aggregates and many critical minerals

What are industrial minerals?

- Mined and processed from naturally occurring minerals
- Processed directly from minerals/waste=synthetic industrial minerals
- Exploited for their non-metallic value
- Wide range of industrial and domestic applications

Typical examples of synthetic IM:

	made from:
• **mullite**	***bauxite, kaolin***
• **aluminas**	***bauxite***
• **silicon carbide**	***quartz + coke***
• **ppt calcium carbonate**	***lime & CO_2***
• **spinel**	***magnesite + alumina***
• **soda ash**	***salt + limestone + coal + ammonia***
• **fused minerals**	***alumina, magnesia, spinel***

http://www.indmin.com/pdfs/697/53_ima-europe.pdf

Examples of IM that also have a *metallurgical* value:

	non-met. value	*metal value*
• bauxite	*cement, abrasives*	*aluminium*
• chromite	*foundry sand, chemicals*	*chrome, Fe-Cr*
• rutile	*white pigment*	*titanium*
• zircon	*ceramics, glass*	*zirconium*
• manganese	*batteries, pigments*	*manganese*
• quartz	*glass, ceramics*	*silicon*
• stibnite	*flame retardants*	*antimony*

http://www.indmin.com/pdfs/697/53_ima-europe.pdf

What are aggregates?

What are aggregates?

- materials used in construction, including sand, gravel, crushed stone, slag, or recycled crushed concrete
- Fillers and extenders to a certain degree

What are some examples of industrial minerals?

Includes

- Bauxite—Al ore, but also ore for alumina compounds
- Titanium—Ti ore, but also ore of TiO2, white pigments
- Sulfur—from pyrite and by-product of Cu-Pb-Zn mining
- Diamonds—gemstone, but also industrial applications
- Garnet—gemstones, but also abrasive

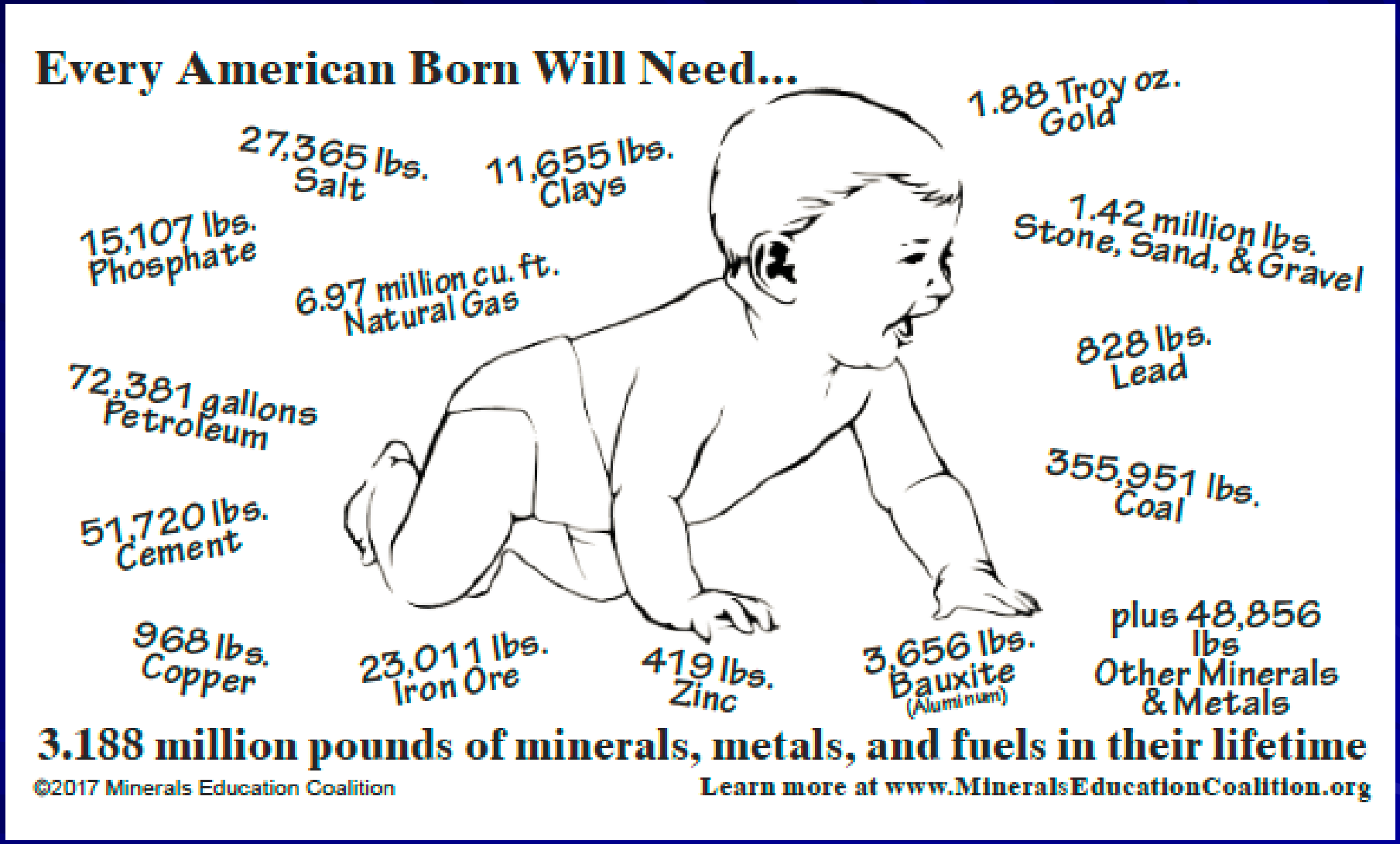
WHY ARE INDUSTRIAL MINERALS SO IMPORTANT?

Why are industrial minerals so important?

- Because your world is made of them
- Building blocks of our way of life

Why are industrial minerals so important?

the average American uses about 3 million pounds of industrial minerals, such as limestone, clay, and aggregate, over the period of a lifetime.



https://mineralseducationcoalition.org/wp-content/uploads/2017-Mineral-Baby-Image.pdf

EVERY YEAR } 40,641 pounds of new minerals must be provided for every person in the United States to make the things we use daily

10,524 lbs. **Stone** used to make roads, buildings, bridges, landscaping, numerous chemical and construction uses

7,501 lbs. **Sand & Gravel** used to make concrete, asphalt, roads, blocks & bricks

656 lbs. **Cement** used to make roads, sidewalks, bridges, buildings, schools, houses

292 lbs. **Iron Ore** used to make steel—buildings, cars, trucks, planes, trains, other construction, containers

347 lbs. **Salt** used in various chemicals, highway deicing, food & agriculture

192 lbs. **Phosphate Rock** used to make fertilizers to grow food, animal feed supplements

160 lbs. **Clays** used to make floor & wall tile, dinnerware, kitty litter, bricks & cement, paper

46 lbs. **Aluminum (Bauxite)** used to make buildings, beverage containers, autos, airplanes

12 lbs. **Copper** used in buildings, electrical & electronic parts, plumbing, transportation

11 lbs. **Lead** 75% used for transportation—batteries, electrical, communications

5 lbs. **Zinc** used to make metals rust resistant, various metals & alloys, paint, rubber, skin creams, health care, and nutrition

35 lbs. **Soda Ash** used to make all kinds of glass, in powdered detergents, medicines, as a food additive, photography, water treatment

4 lbs. **Manganese** used to make almost all steel for construction, machinery, transportation

523 lbs. **Other Nonmetals** used in glass, chemicals, soaps, paper, computers, cell phones, etc.

22 lbs. **Other Metals** used in electronics, TV & video equipment, recreation equipment, etc.

Including These Energy Fuels

- 918 gallons of Petroleum
- 88,503 cu. ft. of Natural Gas
- 4,517 lbs. of Coal
- 0.2 lb. of Uranium

To generate the energy each person uses in one year—

MEC Minerals Education Coalition

www.MineralsEducationCoalition.org

Society for Mining, Metallurgy & Exploration Foundation

https://mineralseducationcoalition.org/wp-content/uploads/2017percapita.pdf

U.S. flow of raw materials by weight 1900-2015. The use of raw materials in the U.S. increased dramatically during the last 100 years (updated from Wagner, 2002).

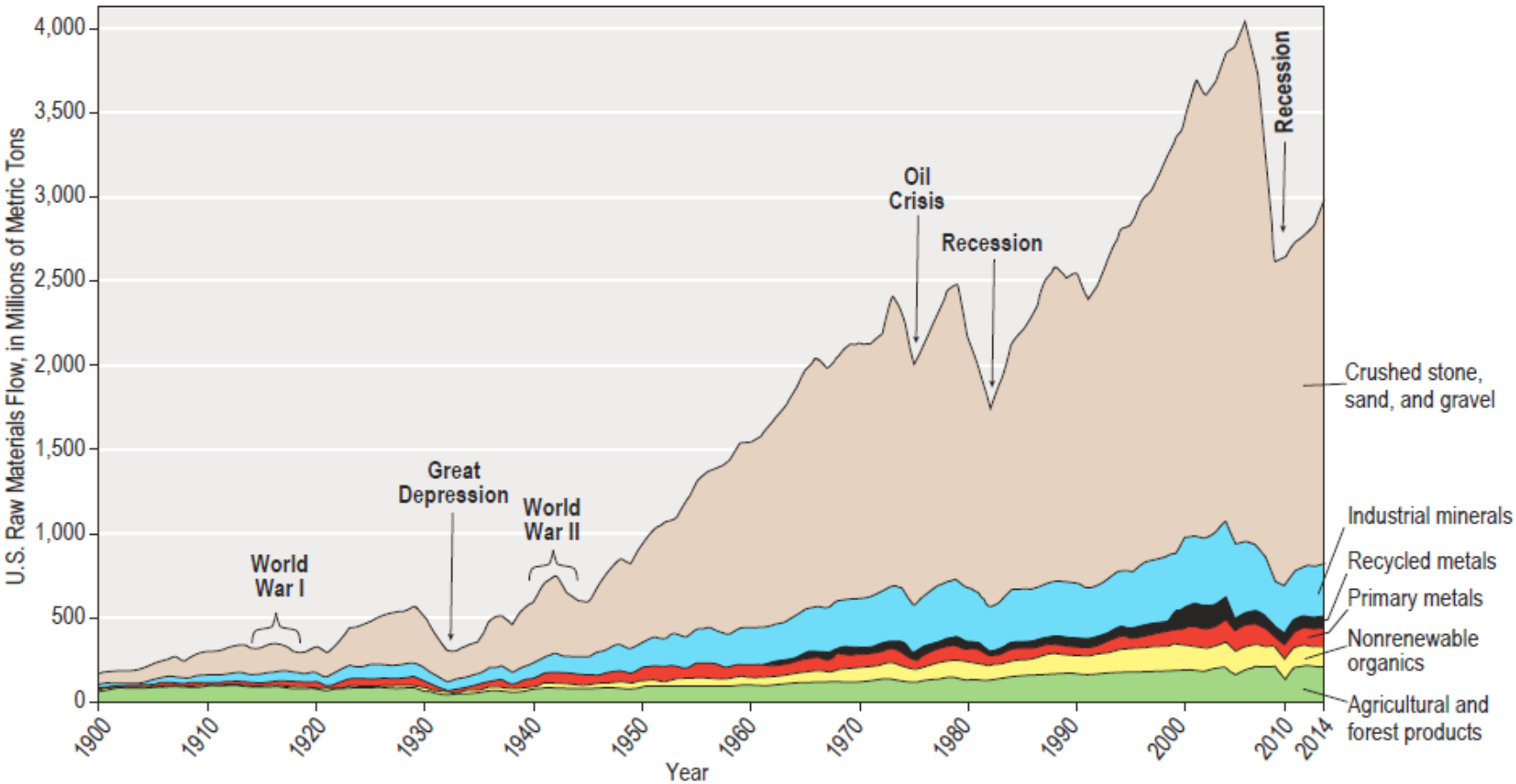


Figure 5. United States flow of raw materials by weight from 1900–2014. The use of raw materials increased dramatically during the last 100 years (modified from Wagner, 2002).

- American manufacturers currently rely on foreign suppliers for more than half of the minerals they use in finished products.
- The United States is 100% dependent on imports for 19 minerals and more than 50% import- dependent for an additional 24 minerals – many of which are industrial minerals.
- As the U.S. economy continues to expand, manufacturing, construction and agriculture will drive demand for increased use of industrial minerals that will fuel the domestic engine of growth.

2016 U.S. NET IMPORT RELIANCE[1]

Commodity	Percent	Major import sources (2012–15)[2]
ARSENIC	100	China, Japan
ASBESTOS	100	Brazil
CESIUM	100	Canada
FLUORSPAR	100	Mexico, China, South Africa, Mongolia
GALLIUM	100	China, Germany, United Kingdom, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	Canada, China, France, Belgium
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA, sheet (natural)	100	China, Brazil, Belgium, Austria
NIOBIUM (columbium)	100	Brazil, Canada
QUARTZ CRYSTAL (industrial)	100	China, Japan, Romania, United Kingdom
RARE EARTHS[3]	100	China, Estonia, France, Japan
RUBIDIUM	100	Canada
SCANDIUM	100	China
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Kazakhstan, Germany, Thailand
THALLIUM	100	Germany, Russia
THORIUM	100	India, France, United Kingdom
VANADIUM	100	Czech Republic, Canada, Republic of Korea, Austria
YTTRIUM	100	China, Estonia, Japan, Germany
GEMSTONES	99	Israel, India, Belgium, South Africa
BISMUTH	95	China, Belgium, Peru, United Kingdom
TITANIUM MINERAL CONCENTRATES	91	South Africa, Australia, Canada, Mozambique
POTASH	90	Canada, Russia, Chile, Israel
GERMANIUM	85	China, Belgium, Russia, Canada
STONE (dimension)	84	China, Brazil, Italy, Turkey
ANTIMONY	83	China, Thailand, Bolivia, Belgium
ZINC	82	Canada, Mexico, Peru, Australia
RHENIUM	81	Chile, Poland, Germany
GARNET (industrial)	79	Australia, India, South Africa, China
BARITE	78	China, India, Morocco, Mexico
FUSED ALUMINUM OXIDE (crude)	>75	China, Canada, Venezuela
BAUXITE	>75	Jamaica, Brazil, Guinea, Guyana

https://minerals.usgs.gov/minerals/pubs/mcs/2017/mcs2017.pdf

How do industrial minerals differ from other commodities?

Mine to market supply chain

- supply sector

- logistics sector

- consuming market sector

Mine to market supply chain

SUPPLY

SUPPLY
- exploration
- mineral finance
- plant engineering
- mining
- processing

LOGISTICS
- trading
- port handling
- mineral inspection
- freight
- warehousing/distribution

MARKET
- direct market mineral consumer
- intermediate market mineral consumer
- end market mineral consumer

DEMAND

Price comparison of metals & IM

US$/tonne unless indicated

Metals		*Industrial minerals*	
Gold	392/oz	Salt	15-18
Silver	6.23/oz	Silica sand	14-25
Aluminium HG	1,645	Olivine	50-110
Copper A	2,760	Dead burned magnesia	140-210
Zinc	1,014	Zircon	400-490

Source: LME; *Mineral PriceWatch*

US metals & IM production 2003

tonnes; US$/tonne

Metals			*Industrial minerals*		
	Volume	Value		Volume	Value
Aluminium	2.7m.	4,000m.	Crushed stone	1,490m.	8,600m.
Gold	266	2,900m.	Sand & gravel	1,158m.	6,366m.
Copper	1.1m.	2,000m.	Lime	18.2m.	1,017m.
Zinc	770,000	664m.	Soda ash	10.6m.	800m.

Source: USGS

WHAT ARE STRATEGIC AND CRITICAL MINERALS?

What are strategic and critical minerals?

- Minerals required for national defense
- Minerals that we export more than 75%
  - Beryllium
  - Aluminum

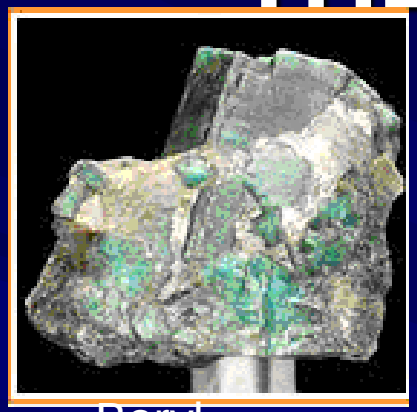
Differences between critical and strategic

- 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

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

WHAT MINERALS ARE USED IN THESE TECHNOLOGIES?



Beryl

beryllium tuff (USGS OF 98-524)

Monazite
http://mineral.galleries.com

Kernite http://www.borax.com

Elements in Computer Chips
(National Research Council, 2007)

elements needed in 1980s

additional elements needed today

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Toyota Prius

2.2 lbs Nd in magnets

22-33 lbs La in batteries

http://www.molycorp.com/hybrid_ev.asp

CLASSIFICATION OF INDUSTRIAL MINERALS

Classification of Industrial Minerals

- Alphabetical
  - Obscures links between commodities
- Geologic processes
  - Igneous, sedimentary, metamorphic
  - Misses waste and processes materials
- Tectonic models
  - Important properties
  - Chemical
- Important properties
- End uses

Construction

- limestone
- dimension stone (granite, marble, flagstone, etc.)
- clay
- diatomite
- perlite
- gypsum
- lime

Metallurgical

- Bauxite
- Silica
- Quartz
- Dolomite
- Magnesite
- Garnet
- Iron oxide
- Barite
- Pumice
- Graphite
- Asbestos

Chemicals

- Barite
- Dolomite
- Lithium
- Magnesite
- Phosphates
- Bauxite
- Limestone
- Pumice
- Borates
- Zeolite

Agricultural

- Phosphates
- Borates
- Clays
- Perlite
- Dolomite
- Talc
- Vermiculite
- Peat

Glass and ceramics

- Borates
- Silica
- Quartz
- Soda ash
- Kaolin
- Pyrophyllite
- Talc
- Bauxite
- Alumina

Fillers and extenders

- Barite
- Clays
- Soda ash
- Diatomite
- Titanium minerals
- Gypsum
- Limestone

Energy

- Clays
- Magnesite
- Graphite
- Lithium
- Drilling mud
- Refining additives
- Batteries

Environmental

- Bauxite
- Alumina
- Dolomite
- Limestone
- Zeolite
- Asbestos
- Perlite
- Magnesia
- Gypsum
- Pyrophyllite

Other uses

- Clays
- Dolomite
- Talc
- Magnesite
- Limestone magnesia
- Zeolites
- Nitrates
- Potash
- Salt
- Pharmaceuticals
- Drugs
- Cosmetics
- Food additives

- *“Without a market, an industrial mineral deposit is merely a geological curiosity”*

- Demand feeds back from the end-use market, to the end product, to the intermediate end product, and finally back to the mineral supplier.

Geologically, most industrial minerals

- Are widespread
- Have enormous reserves
- Are easy accessible
- Can be mined by small operations
- High volume, low value but VITAL
- Prerequisite raw materials for a wide range of products

Economics

- development needs less investments
- are cheaper to obtain
  - must be closer to the market
  - some specialty minerals demand a higher market price than metals
- are more effective
- Market demand drives IM supply

Technological

- needs less processing
- needs less energy
- less effect on the environment
- possess exceptionally attractive properties for the industry

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).

Some of the challenges in producing industrial minerals

- How much of industrial 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

- 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)

MINING’S INFLUENCE IN HISTORIC CULTURES

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)
		300,000–100,000 Surface mining of flint (N. France, S. England)		
Paleolithic				
	c.40,000 Hematite mined for ritual painting (Africa)	c.30,000 Use of fire, lamps, cave art, hunting with projectiles		
c.20,000				
		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

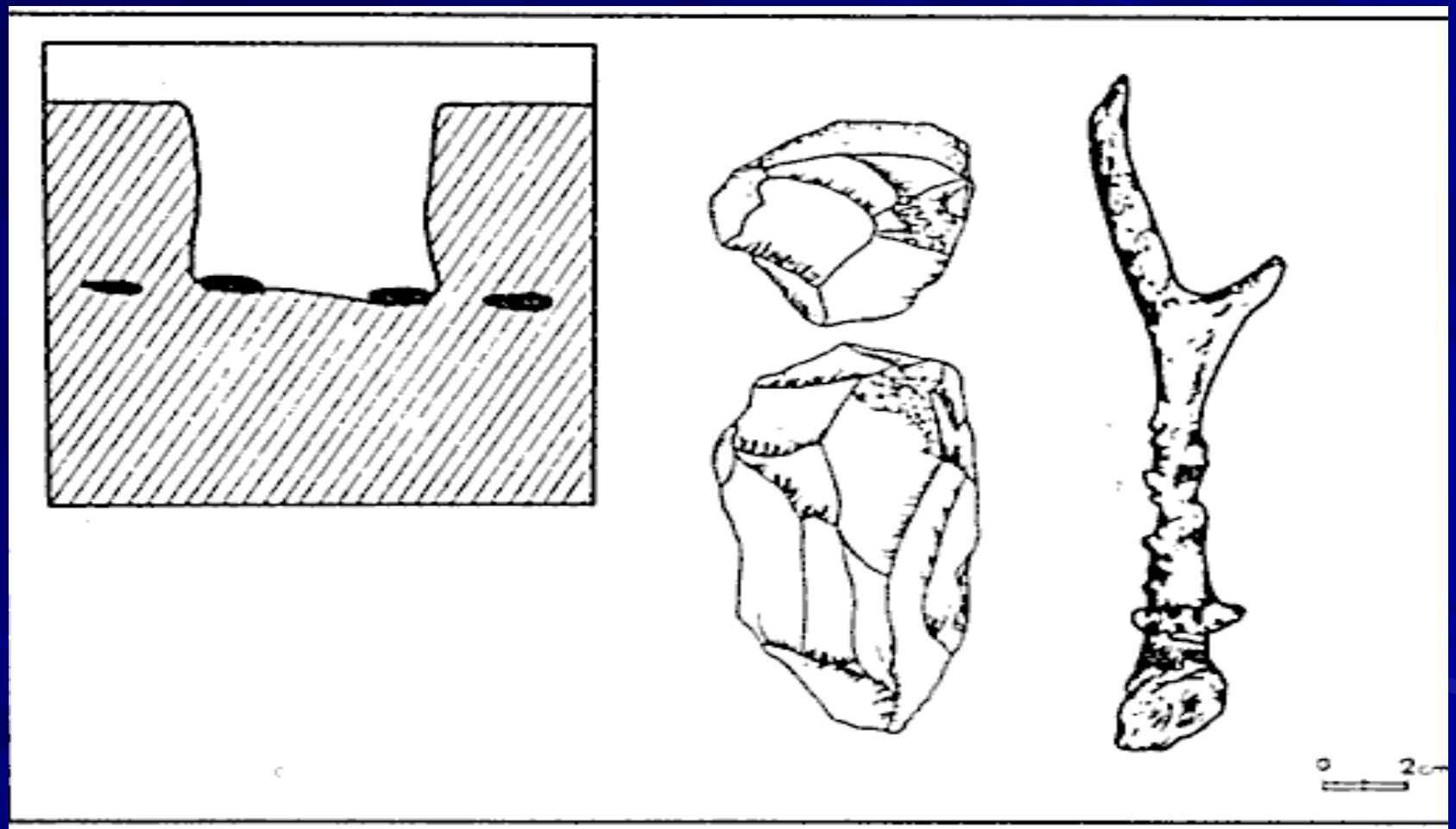


Fig. 1. From the left: scheme of a pit-mine, miner tools.

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

Krzemionki Opatowskie,Southern Poland

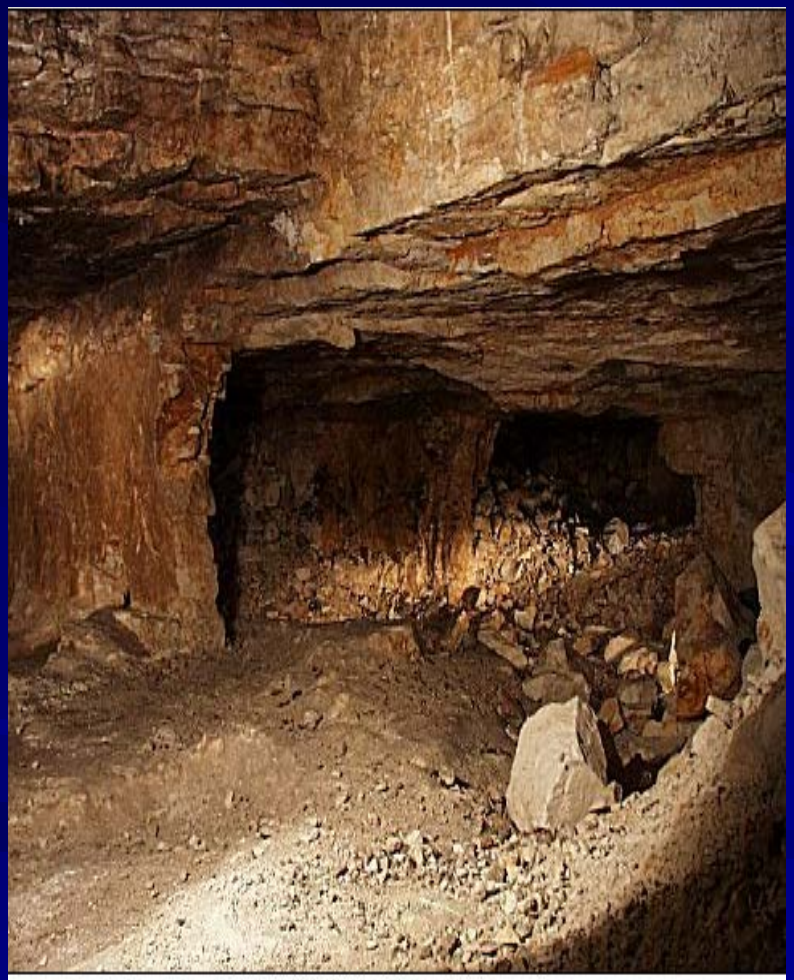


Photo 22. Widok kopalni filarowej.

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

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 industrial 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

Ancient Egypt

- Nile River provided means of transport
- Quarried rocks for buildings
  - Limestone from Memphis
  - Quartzite from Gebel el-Ahmar
  - Alabaster
  - Granite near Aswan
  - Drilled holes, then filled with wood and wetted
- Used smelting to refine copper
- Flint used for farming tools (sickles)

Cosmetics in Egypt

- Black from galena, manganese, magnetite, cuprite, tenorite, stibnite
- Green from malachite, chrysocolla
- White cerussite
  - laurionite(a lead chlor-hydroxide)
  - phosgenite (a lead chlorocarbonate)

http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&sqi=2&ved=0CEoQFjAF&url=http%3A%2F%2Fminds.wisconsin.edu%2Fbitstream%2Fhandle%2F1793%2F11541%2FCosmetic.pdf%3Fsequence%3D1&ei=XznMUsLGNM_aoATZ8ILQDw&usg=AFQjCNFt8WhNQKdH6zq2CUnYo0oglC6pOg&sig2=ZyZhC5mMN-8lZ9k9H0WLjg&bvm=bv.58187178,d.cGU

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

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

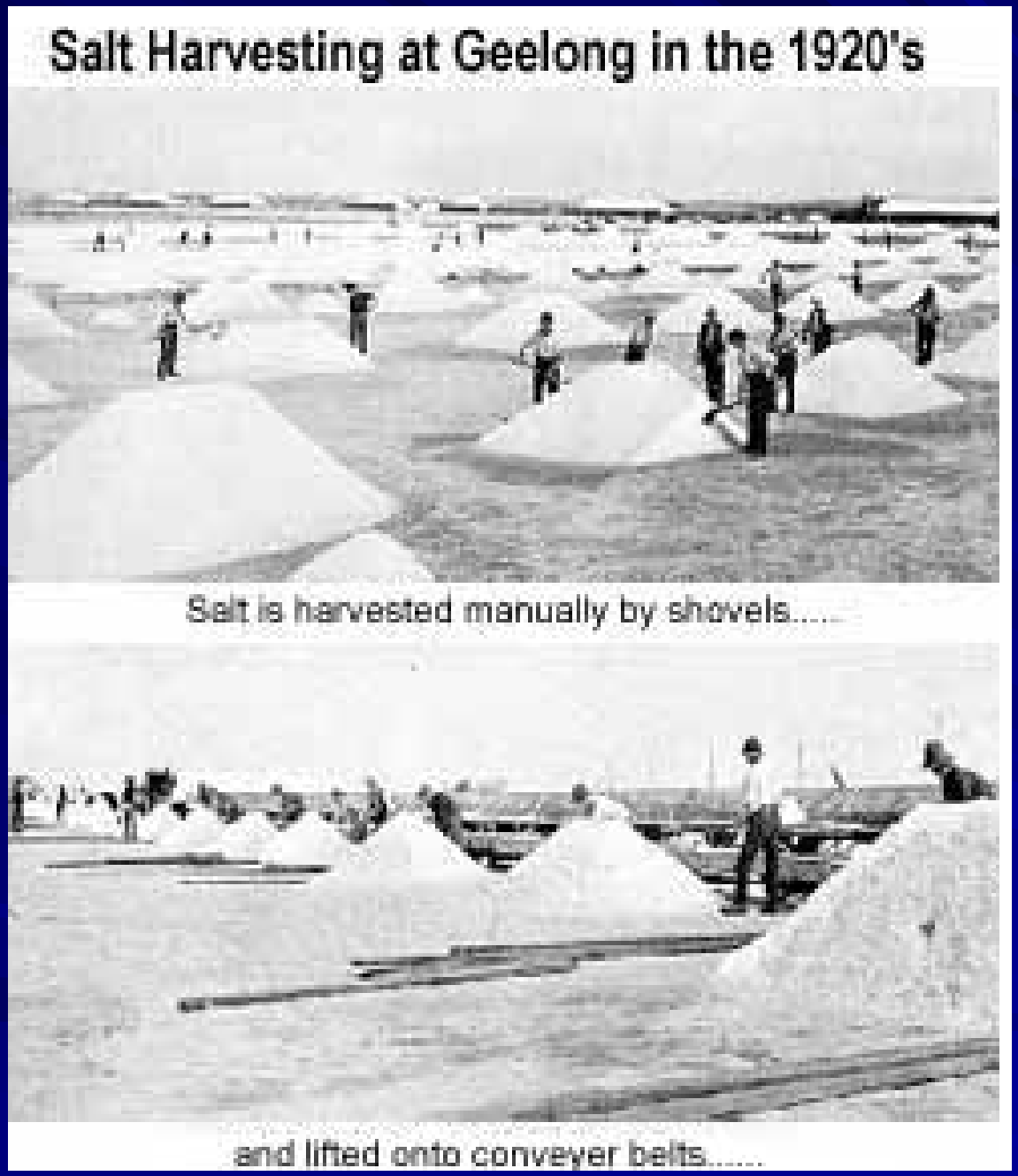
- Greek worshippers consecrated salt in their rituals
- in the Old and New Testaments, covenants were sealed with salt
- Jewish "KASHRUT" [hygiene] tradition and law, involves the dehydration of meat for its preservation
- Catholic Church used salt in purifying rituals
- Buddhist believed salt repeals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

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.cheetham salt.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.

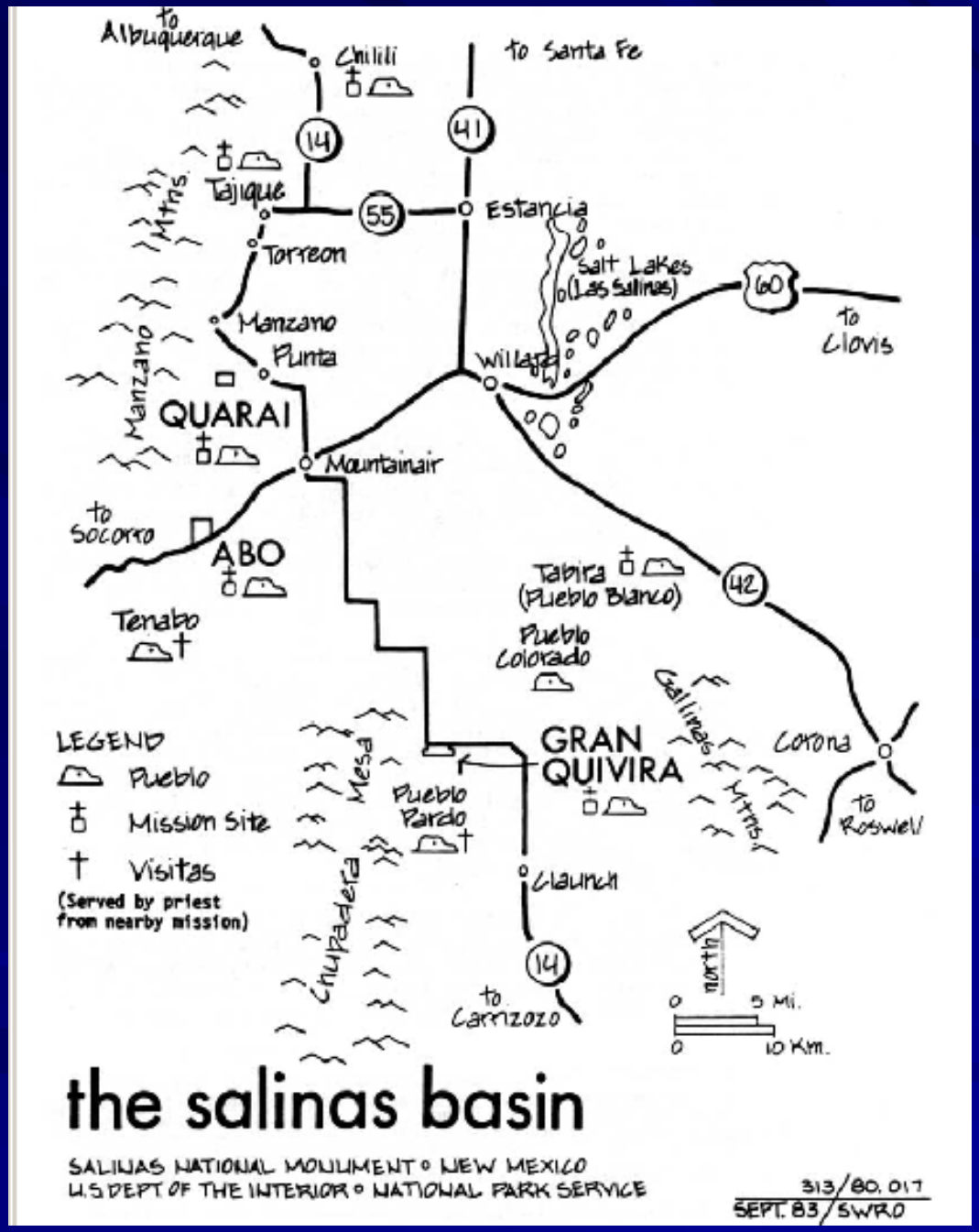
http://salt.org.il/frame_rel.html

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, built churches, and demanded more salt
- Spanish shipped salt to Mexico for use in processing silver



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

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
  - Apache raids increased
  - Famine
  - Poor harvests
  - Pueblo revolt in 1680

Is salt a critical/strategic mineral?

Is salt an industrial mineral?

What has changed from prehistorical times to today?

What minerals are considered critical and strategic minerals?

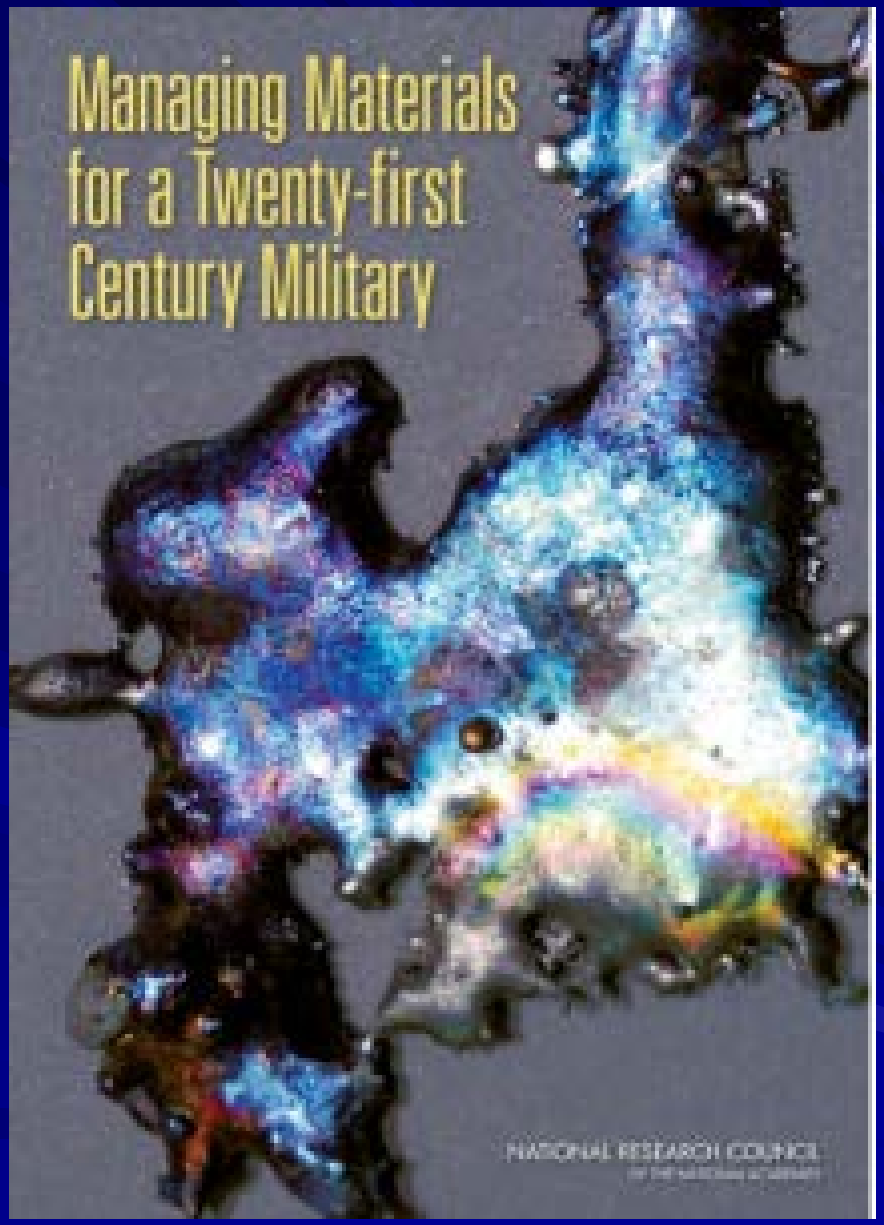
Certainly petroleum!

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

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

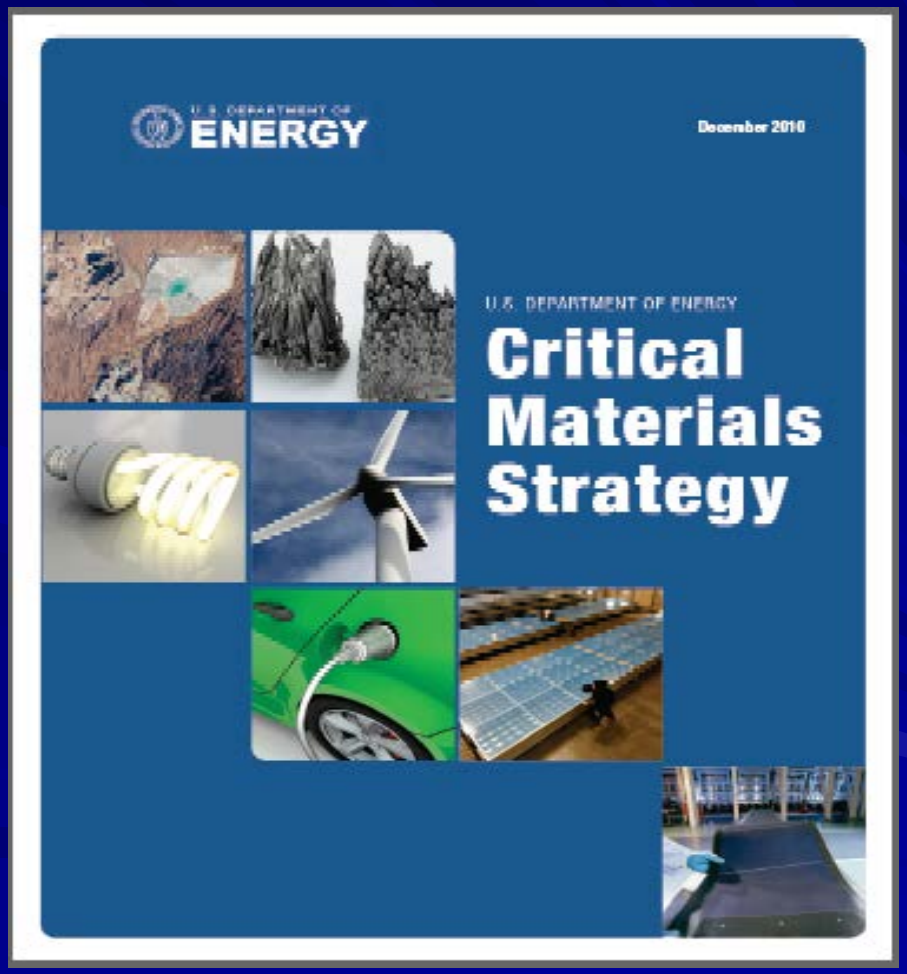
Green minor metals—basis for cleaner technology innovation

- 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

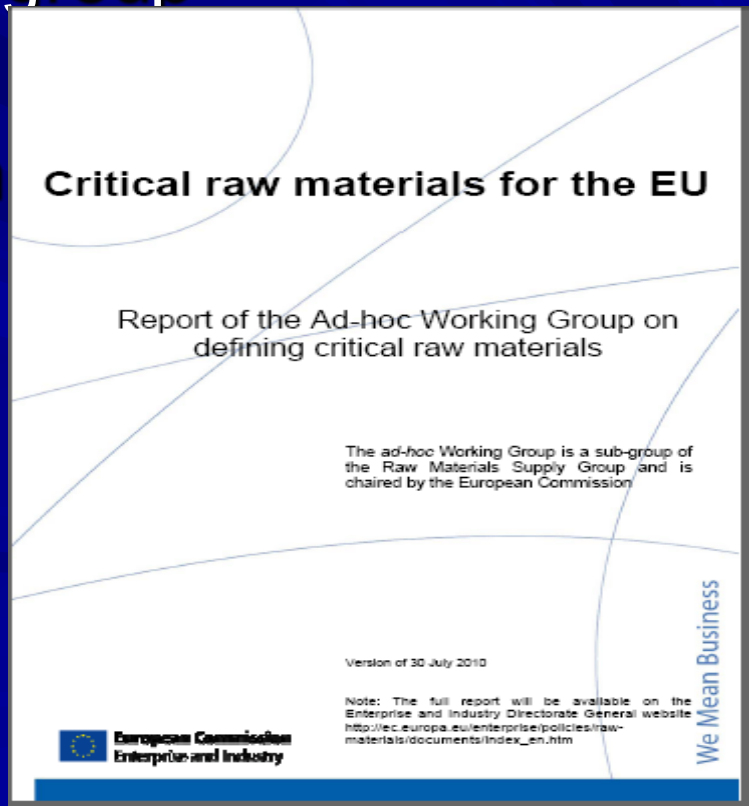
- Lithium
- Cobalt
- Gallium
- REE, Y
- Indium
- Tellurium



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

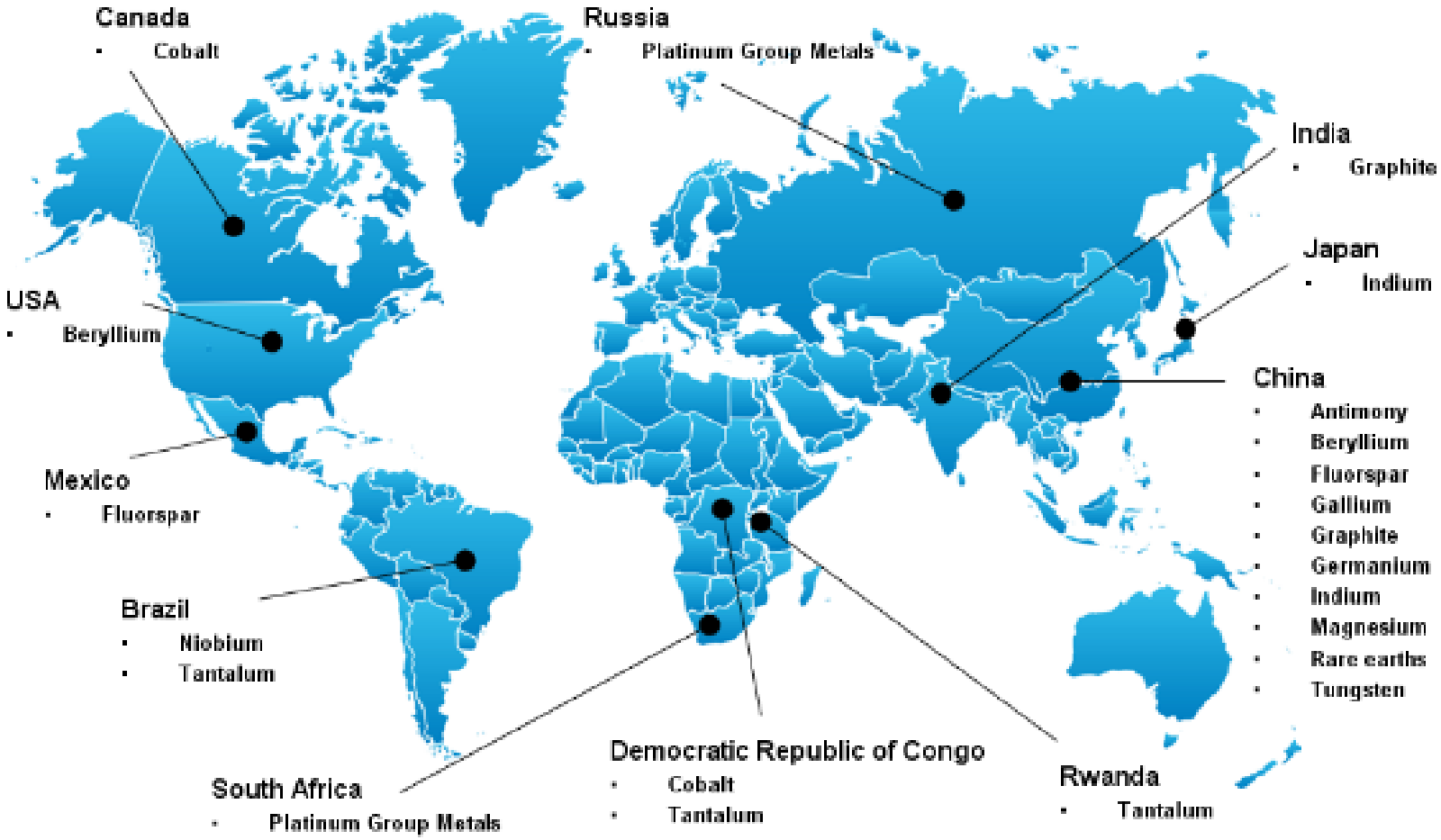
Version of 30 July 2010

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

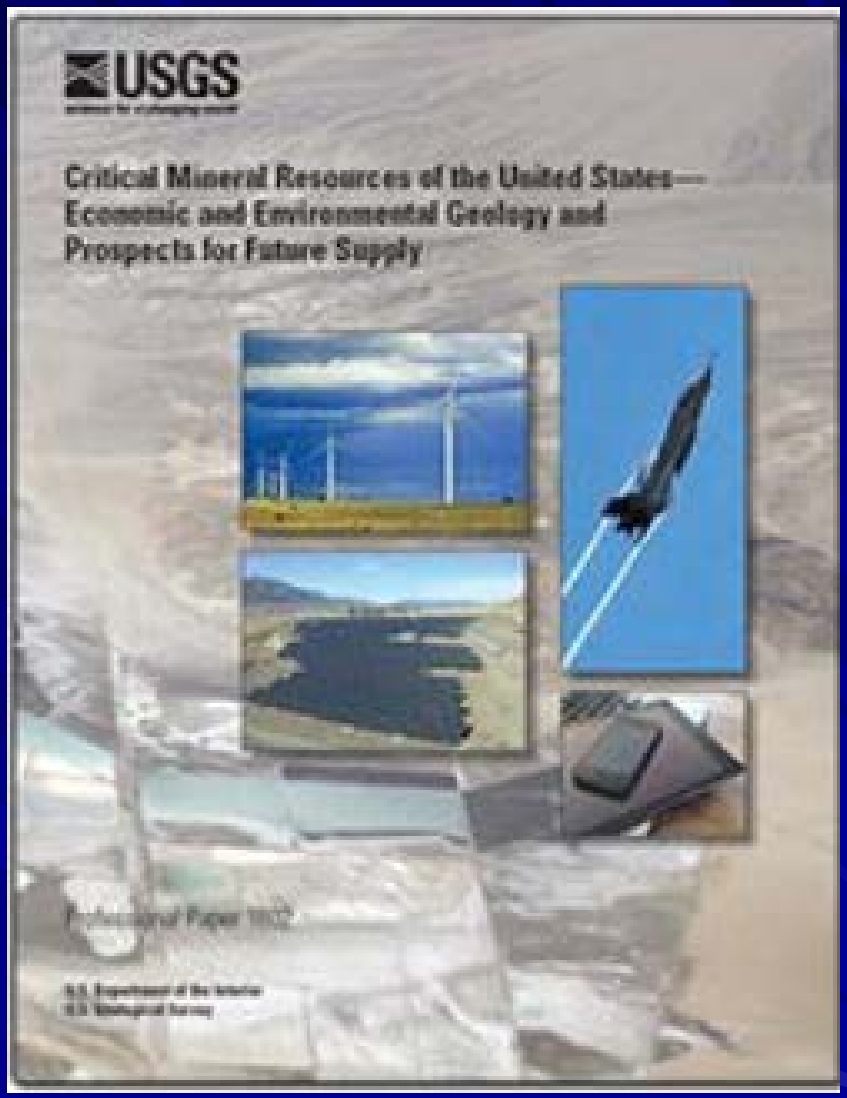
We Mean Business

Production concentration of critical raw mineral materials



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

Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802



https://pubs.er.usgs.gov/publication/pp1802

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

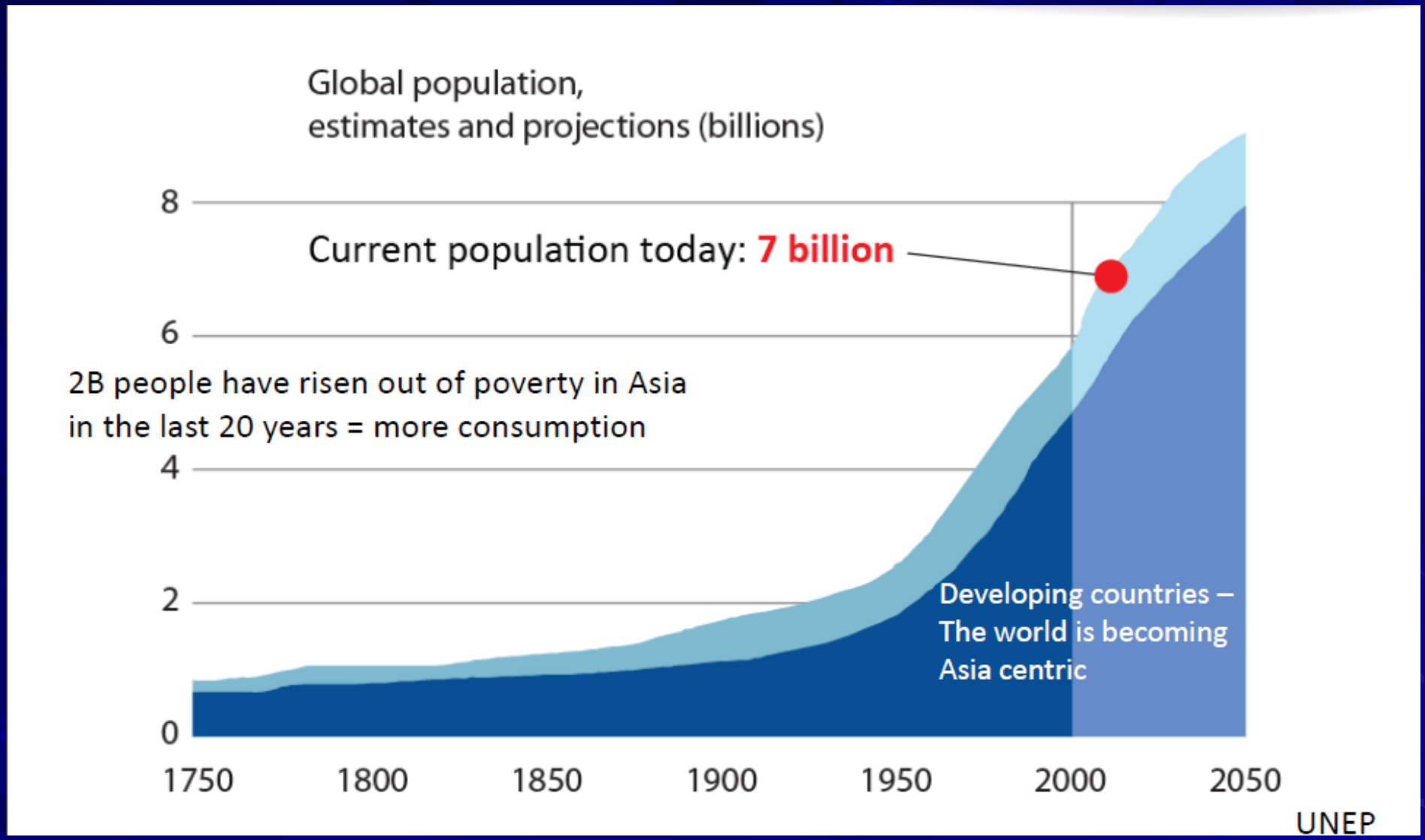
- Significant or unexpected increase in demand
- Small markets
- Production from a small number of mines, companies, or markets
- Minerals whose supply consist significant of byproduct production (i.e. Ga byproduct of bauxite mining)
- Markets for which there is no significant recovery from old scrap

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

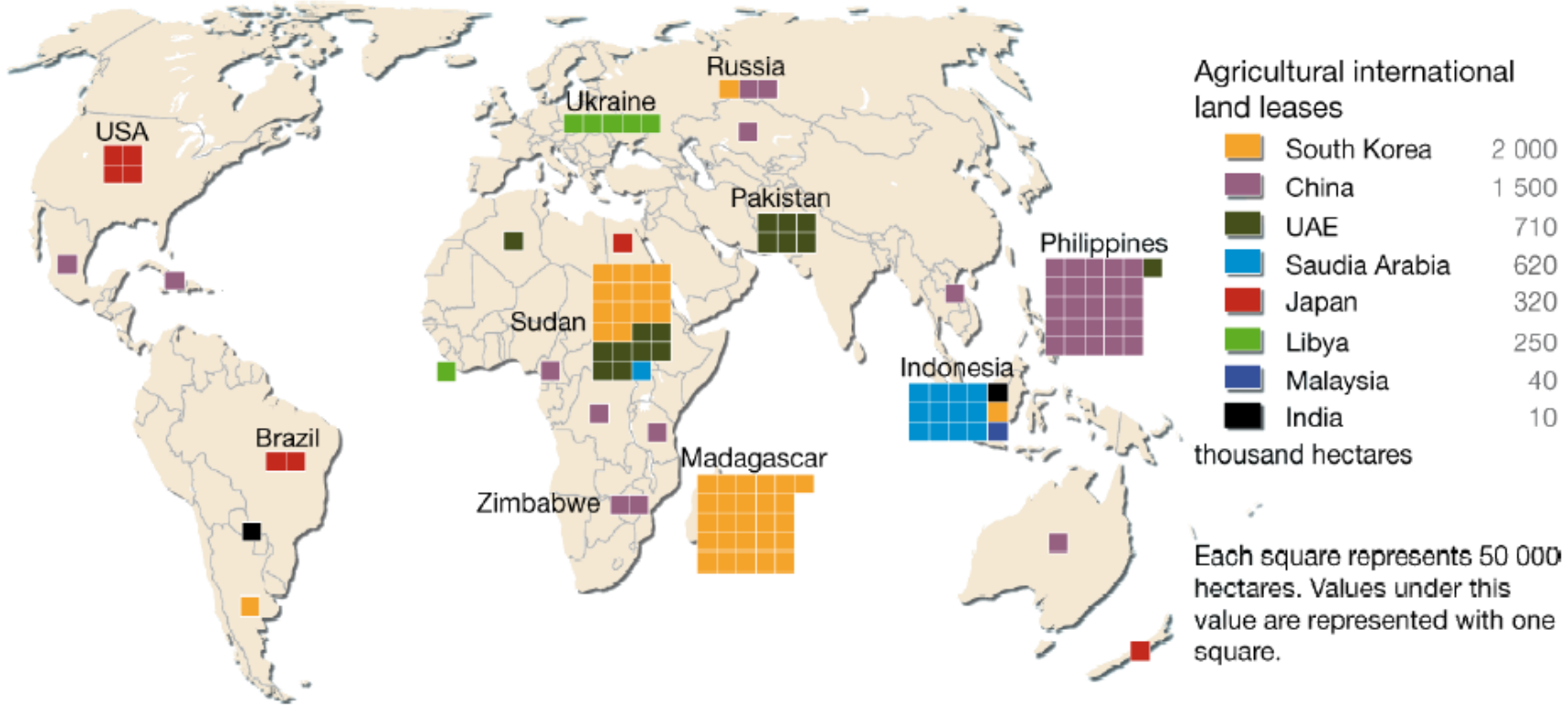
Other factors

- Population
- Food



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

Food Security

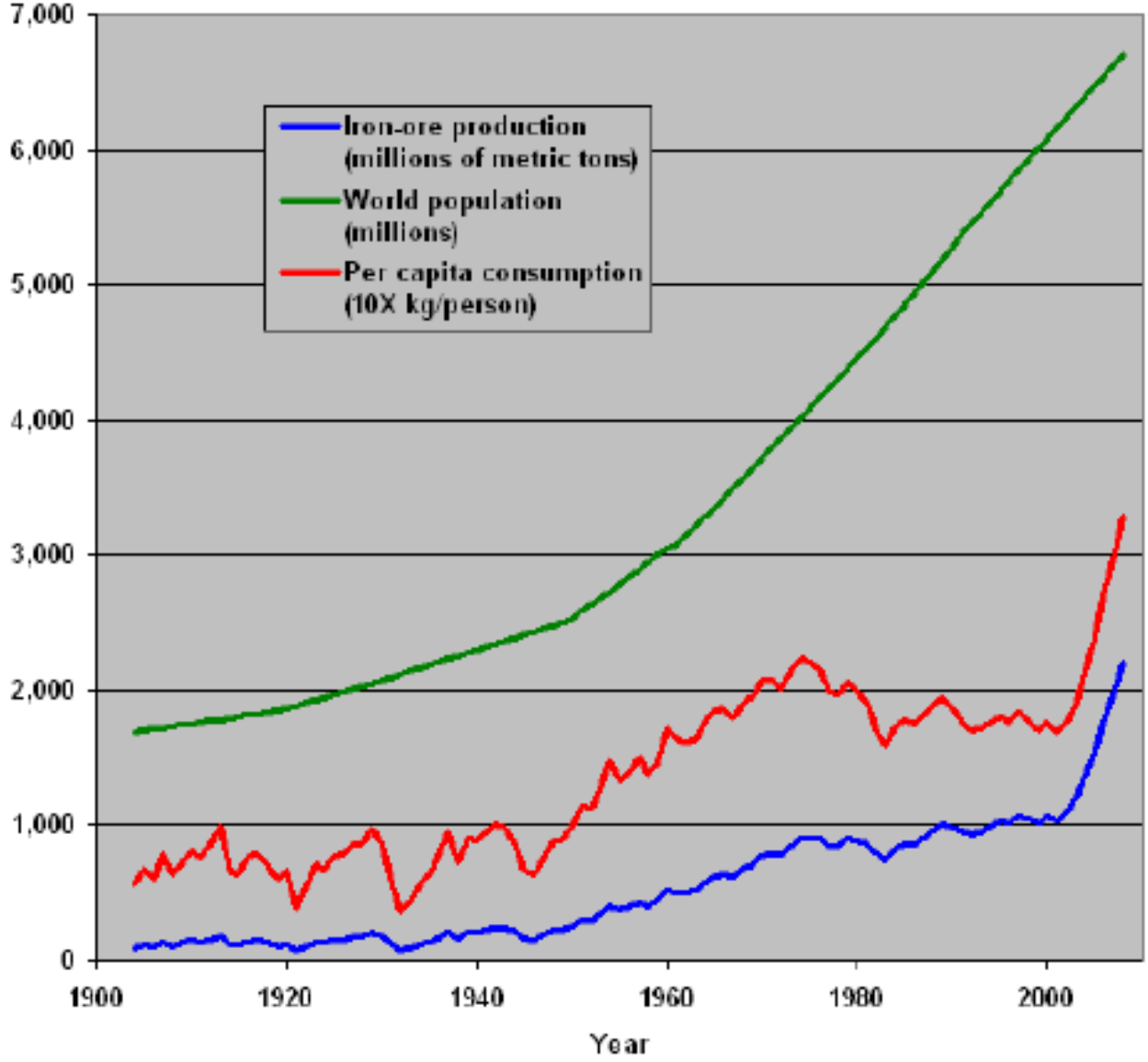


UNEP

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

DEMAND

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



Iron

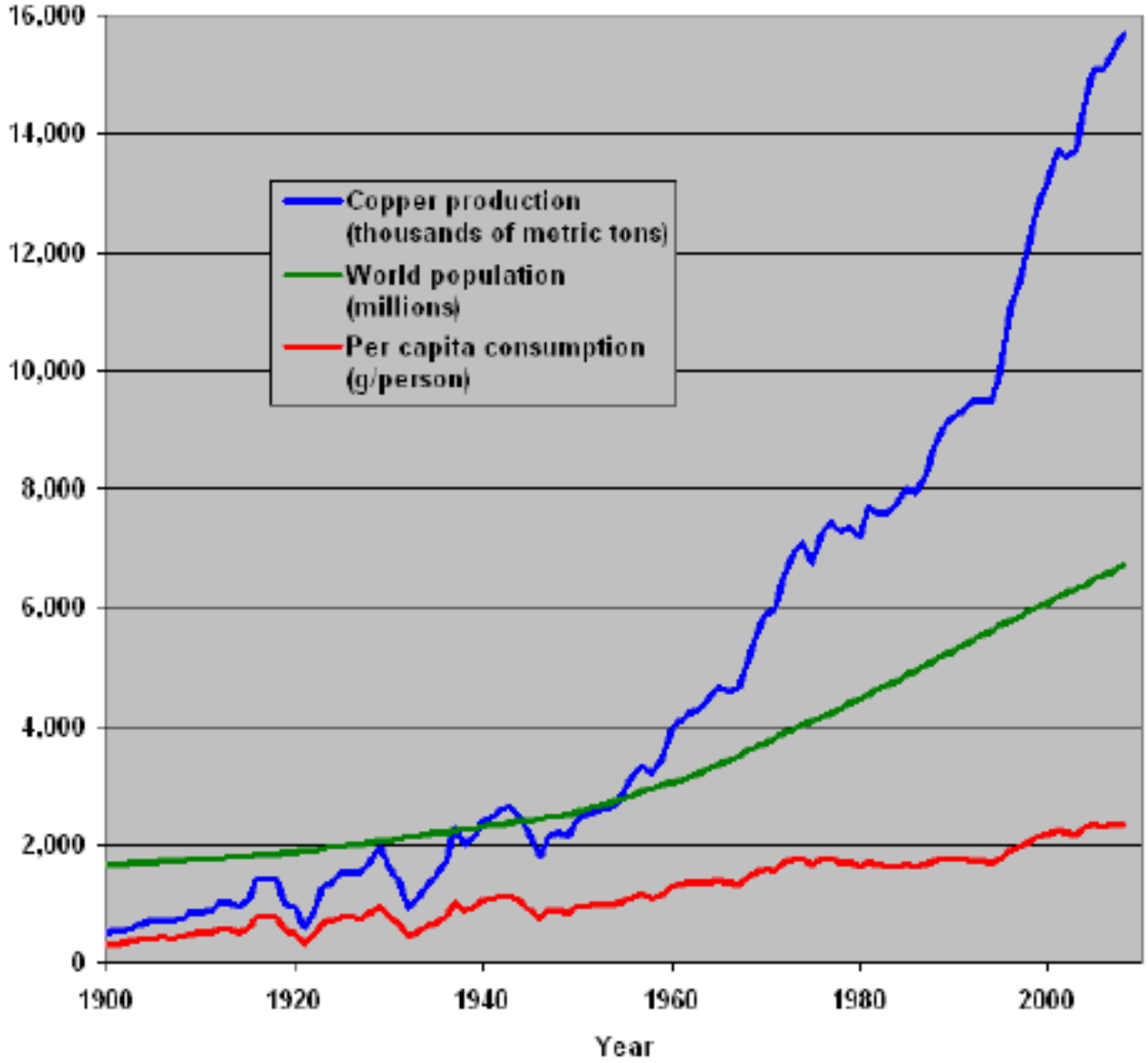
~4X more population than 100 years ago

~14X more production than 100 years ago

~4X more per capita consumption than 100 years ago

Production statistics mostly from USGS/USBM

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



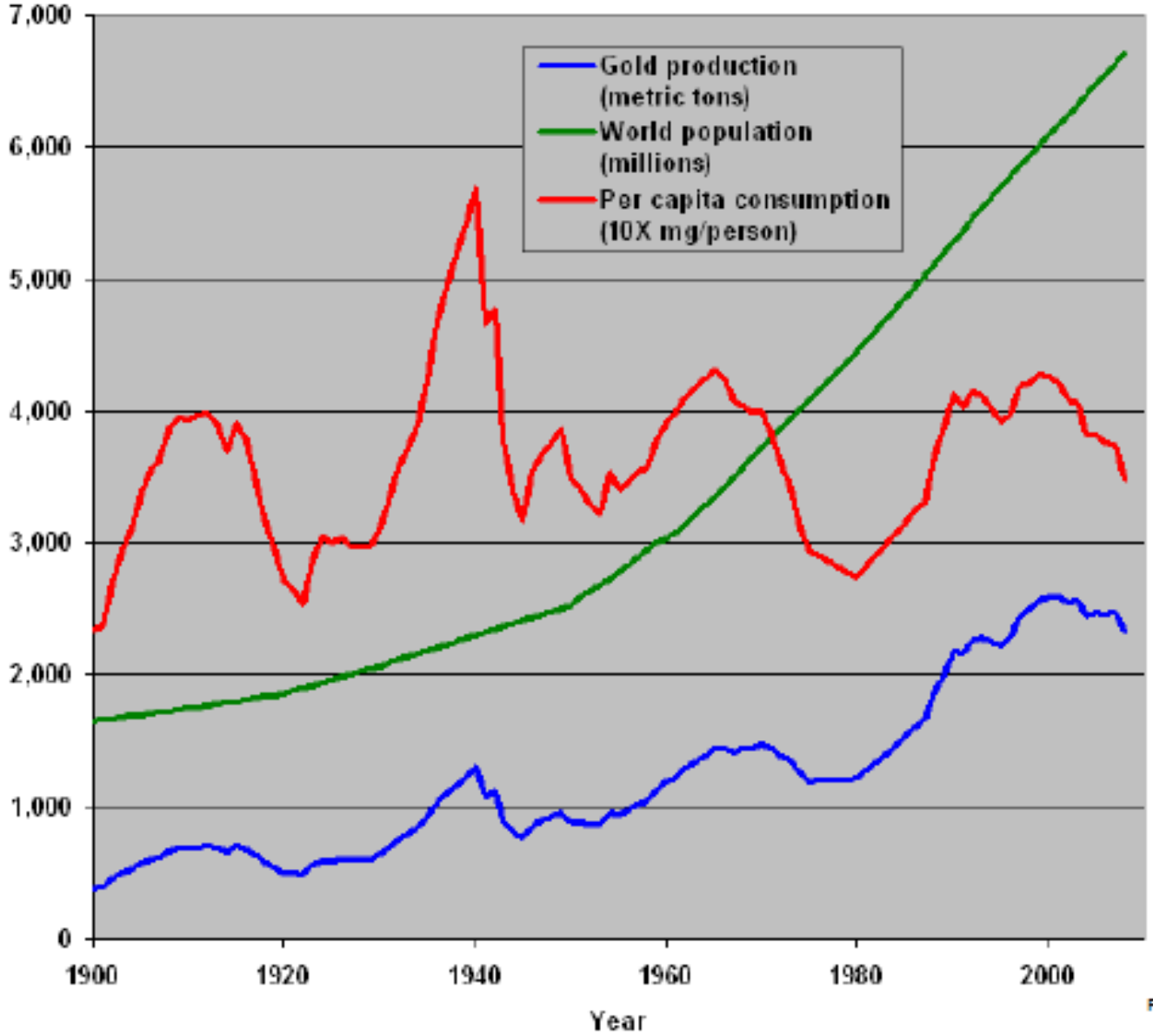
Copper

~22X more production than 100 years ago

~6X more per capita consumption than 100 years ago

Production statistics mostly from USGS/USBM

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



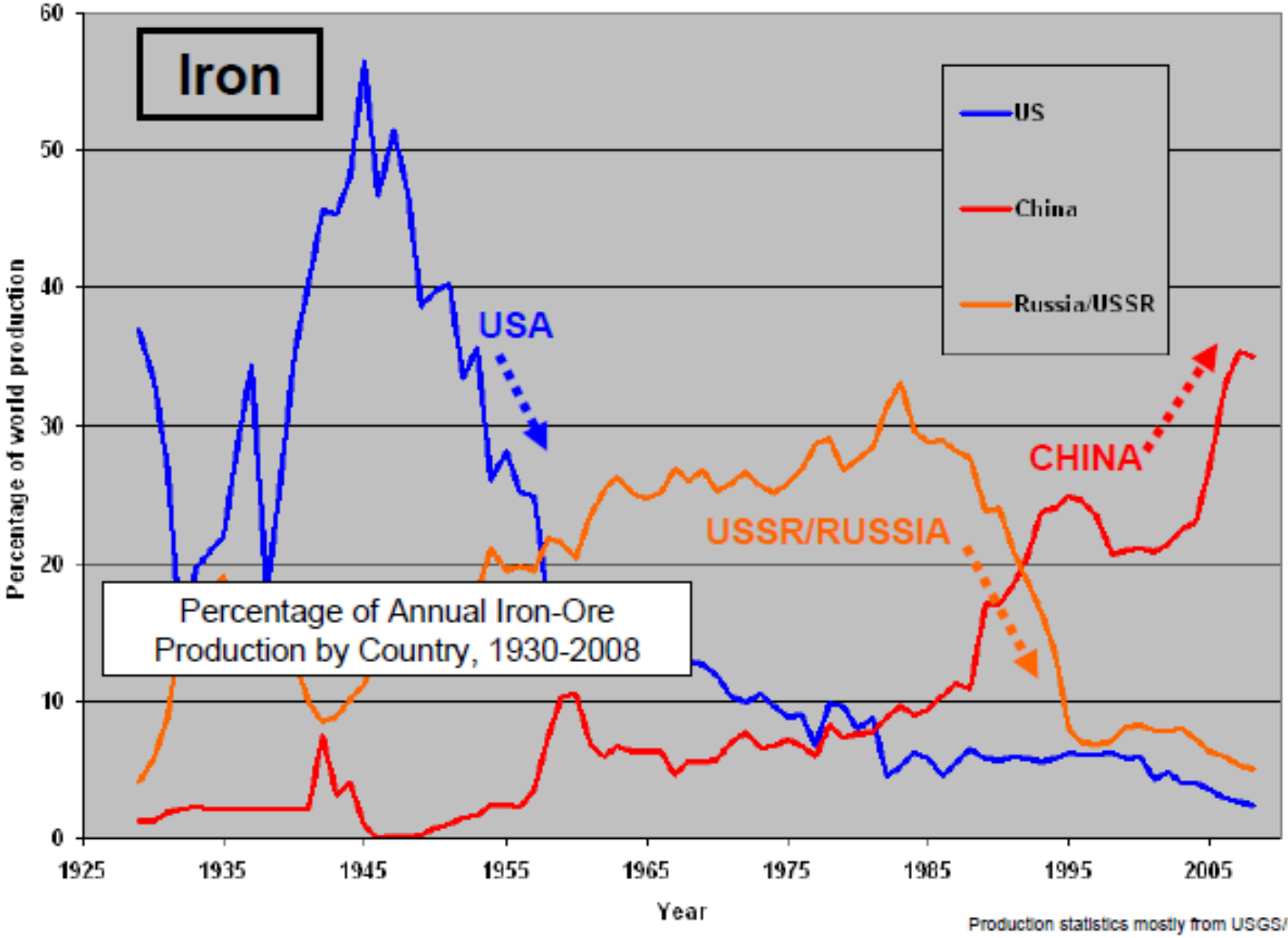
Gold

~same per capita consumption as 100 years ago

~4X more production than 100 years ago

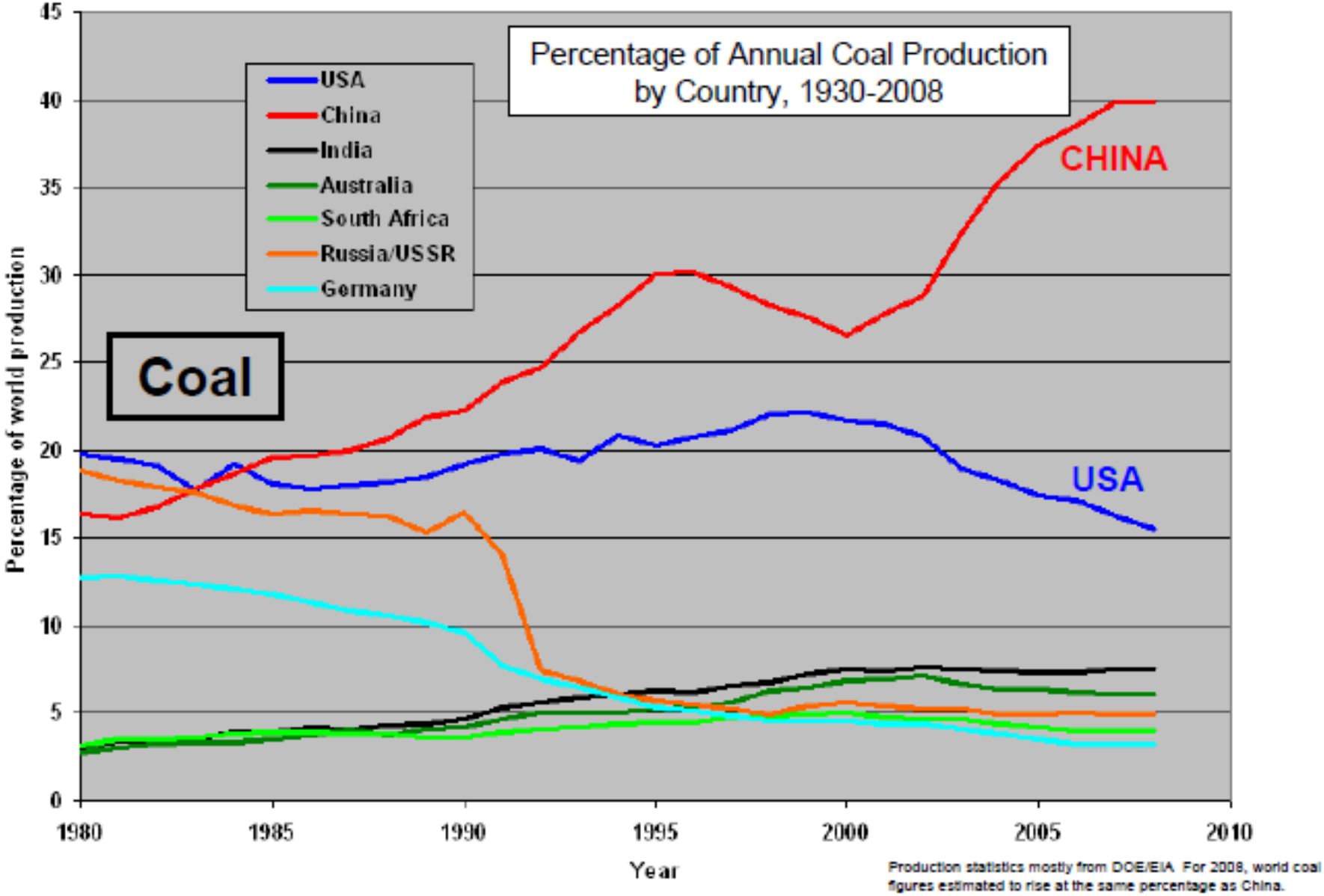
Production statistics mostly from USGS/USBM

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



Production statistics mostly from USGS/USBM

China has been #1 in coal production since 1985.



	Elements	Top three supply countries and share (%)			Top three share (%)	Metal life (years)
China	REE	China 95%	USA 3%	CIS 2%	100%	709
	Mo (Re)	USA 32%	China 25%	Chile 22%	78%	46
	Sb	China 88%	Guatemala 3%	Bolivia 2%	95%	13
	Ga	China 43%	Germany 20%	Kazakhstan17%	80%	365
	W	China 75%	CIS 6%	Canada 5%	86%	55
	In	China 58%	Japan11%	Canada, Korea 9%	78%	22
	Bi	China 52%	Mexico 21%	Peru17%	90%	55
South Africa	PGE	South Africa 80%	CIS 12%	Canada 4%	96%	154
	Cr	South Africa 38%	India 18%	Kazakhstan 18%	74%	>24
	V	South Africa 39%	China 32%	CIS 27%	98%	221
	Mn	South Africa 20%	Australia 19%	China 14%	53%	40
Others	Ni	CIS 19%	Canada 16%	Australia 11%	46%	40
	Li	Chile 38%	Australia 22%	Argentina, China 12%	84%	164
	Co	Congo 36%	Canada 13%	Australia 12%	61%	22

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).

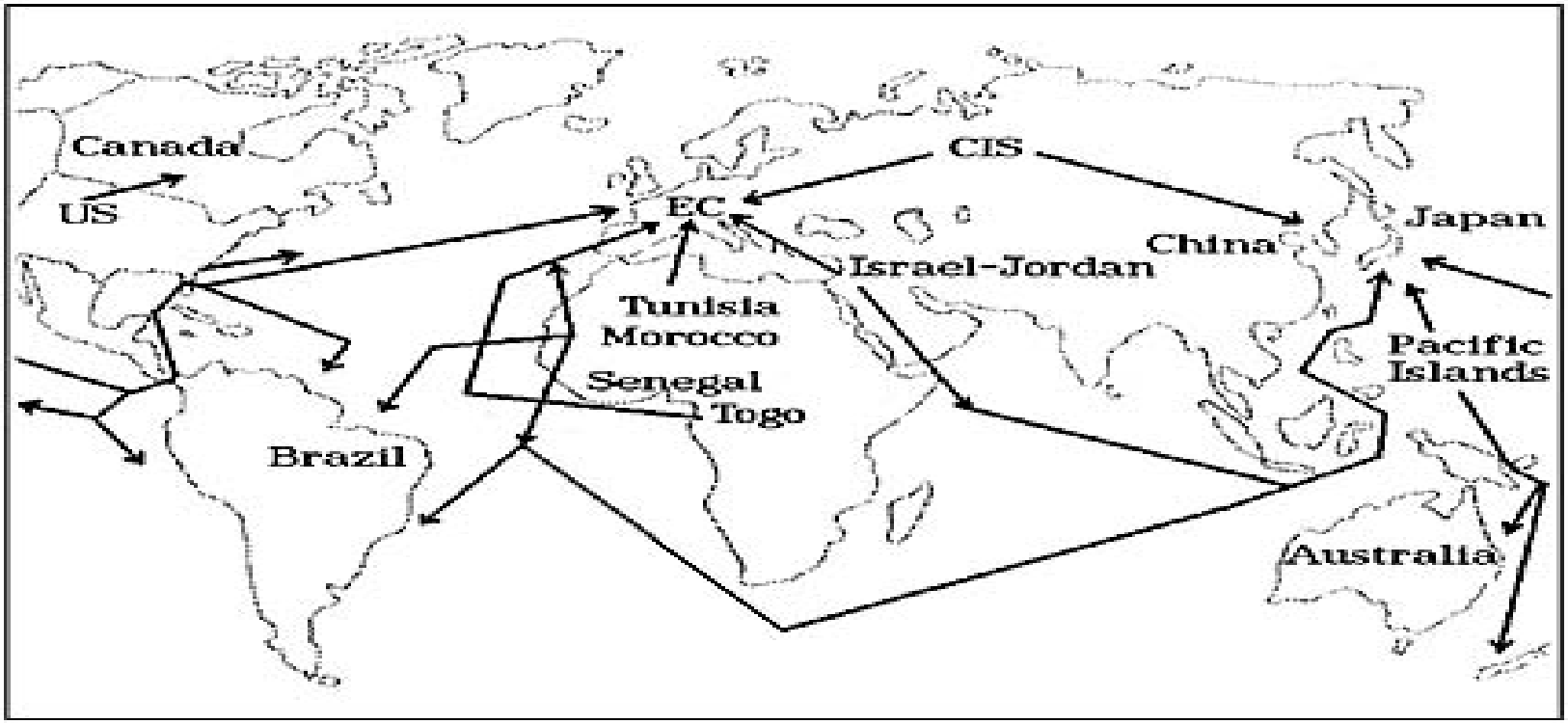

Round Mountain, NV (2007)

Need for more commodities

Technology

Global market

Fig. 1. Trade patterns in phosphate rock.



Environmental concerns

Summary

- Industrial minerals are vital to our everyday life and has been since man wanted to improve his way of life
- Most industrial minerals are high volume, low value
- Industrial minerals are vital to a wide range of industrial and commercial products
- Industrial minerals are important to our economy (jobs, raw materials)

Assignment

- Mineral deposit models (Cox and Singer, 1986, http://pubs.usgs.gov/bul/b1693/Tlbc.pdf)
- 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*)

- **CHOOSE YOUR COMMODITY**