Testimony on Mineral Resources Mining in Oregon

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House Agriculture and Natural Resources Committee,

Oregon Legislature

By John H Dilles

Professor of Geology with Research Expertise on Mineral Resources at Oregon State University

John.Dilles@oregonstate.edu; phone 541-737-1245

BS, MS Caltech; PhD, Stanford University

~5 years work with minerals industry

Professor at OSU since 1986, graduated 32 MS/PhD students

60 research publications, 2017 Silver Medal of Society of Economic Geologists

We want cars and clean energy. What is our mineral (and energy) footprint?

A geologic & resource perspective

BASIC & CRITICAL Minerals are used in many high technology applications, for hydrid & electric cars, to wind turbines to solar cells, to cell phones:
Lithium, rare earth elements, tellurium, cobalt, copper, gold, titanium

Toyota Prius……"a green image"
(Li, REEs)

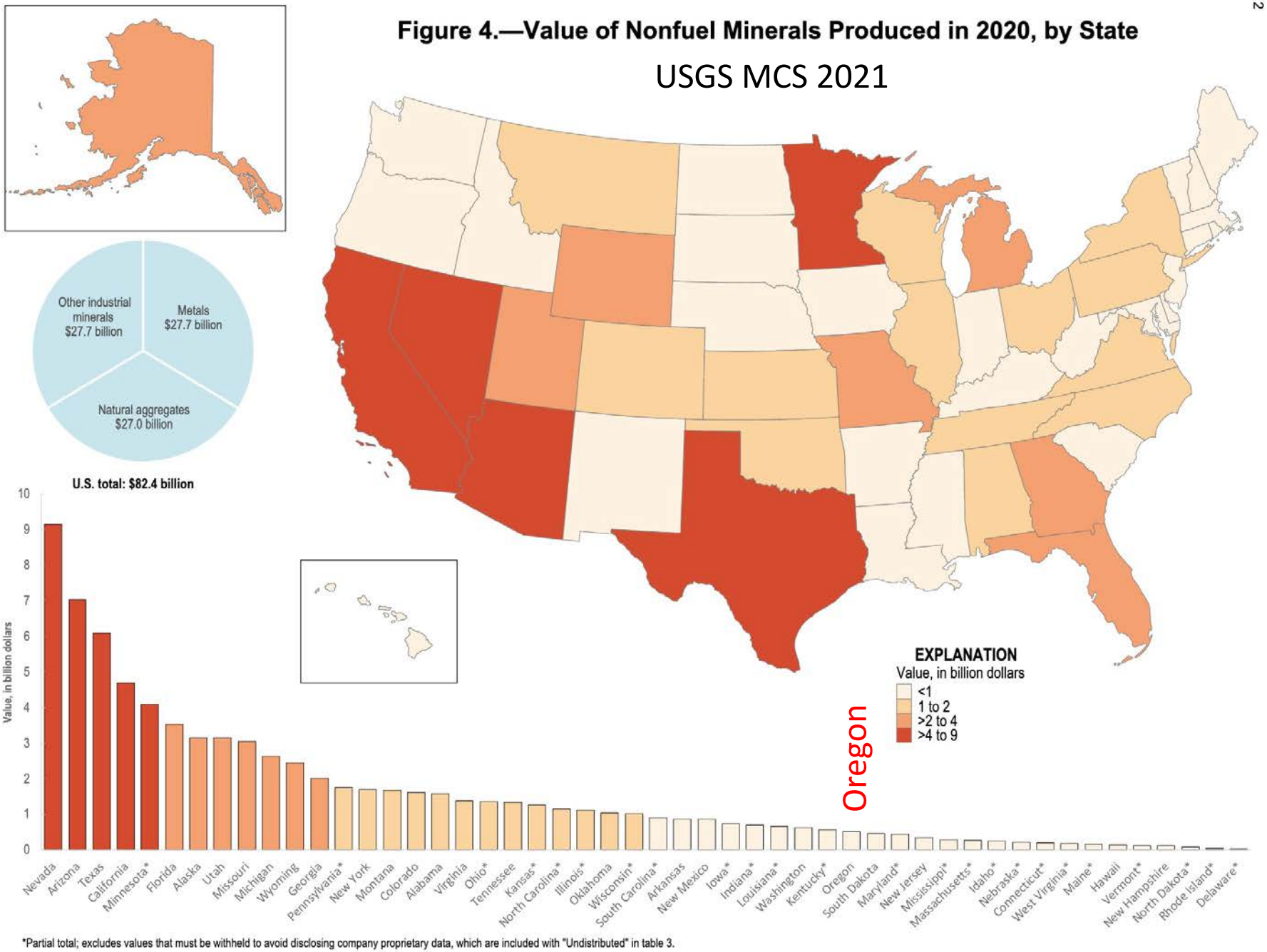
Tesla electric car S……. 160 lbs copper; 410 lb Aluminum, 1200 lb battery of nickel, lithium, cobalt, graphite; ~100 lb titanium

Oregon Mineral Production (USGS MCS 2021)

- 0.62% of US mineral production in 2020
- Rank of states, #36 is USA, at $513 million
- #2 producer of gemstones (total is $53 M in USA)
- Cement (portland), diatomite, perlite (crude), sand and gravel (construction, ~$170 M), stone (crushed, ~$250 M).
- Metal mining (insignificant)

Figure 4.—Value of Nonfuel Minerals Produced in 2020, by State

USGS MCS 2021

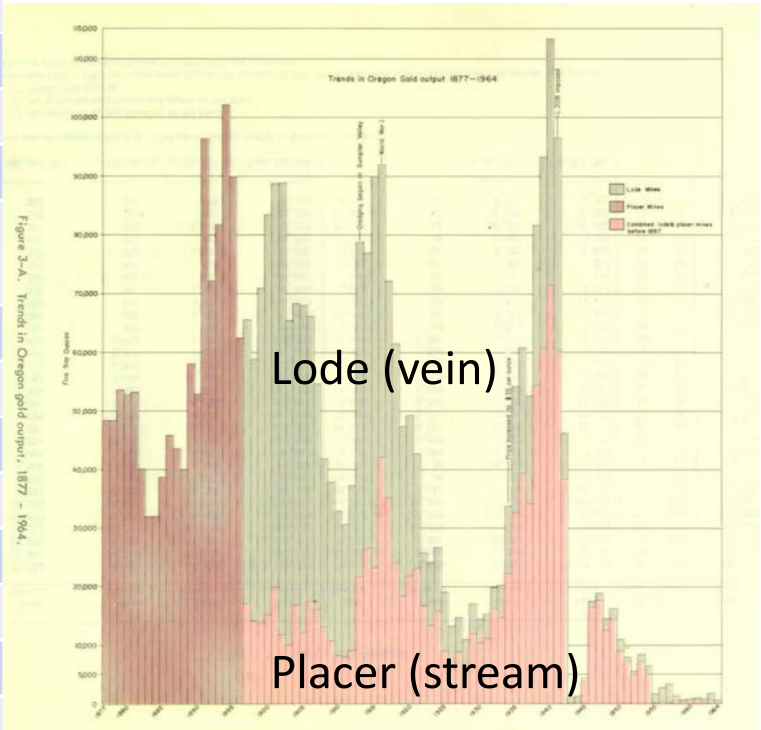


*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

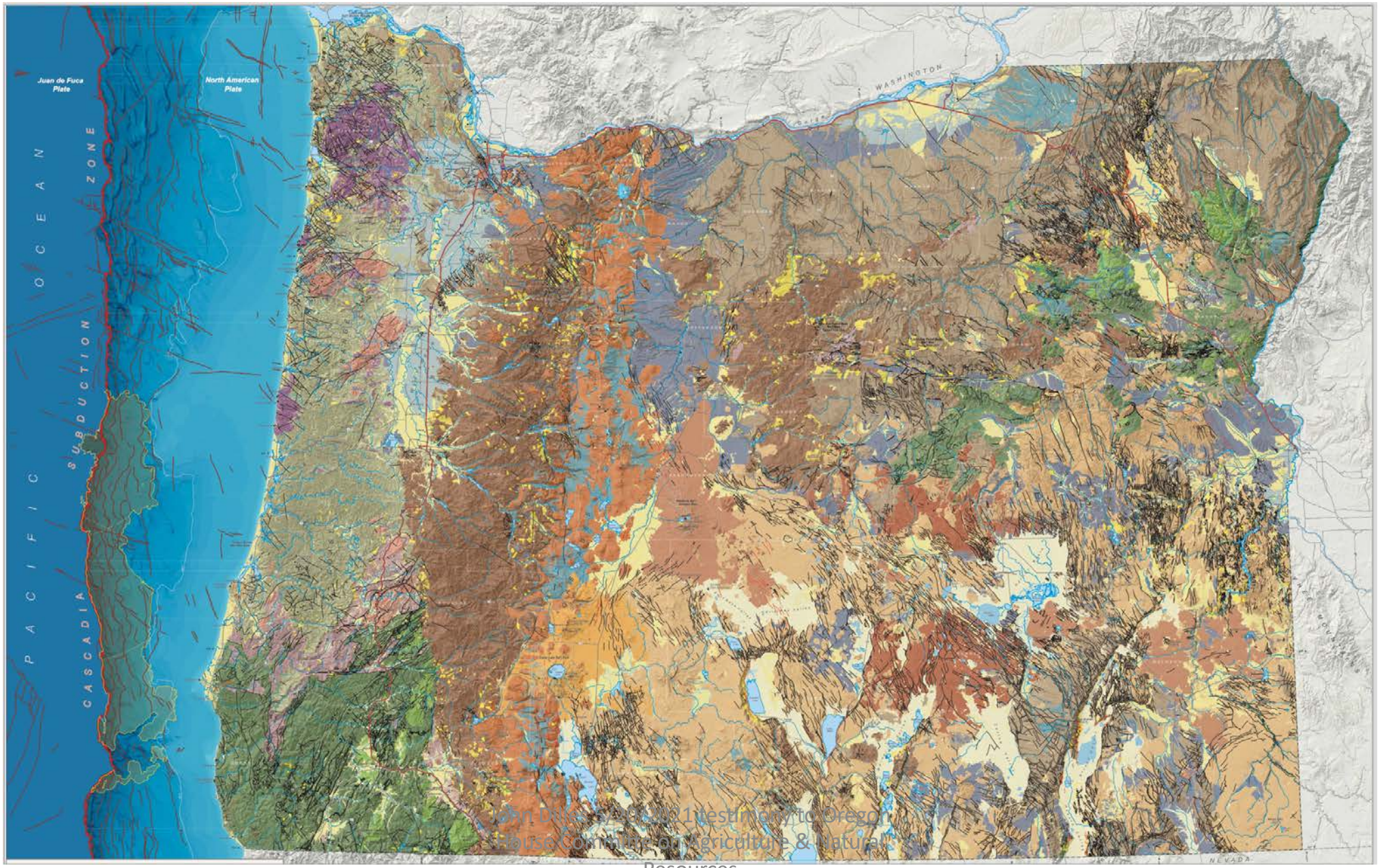
Table 1, Total Oregon production of metals and industrial minerals (2015, DOGAMI)

Commodity	Total Recorded/Estimated Production
Cement/Lime	2,451,000 tons
Chromite	127,531 tons (worth ~ $500,000)
Clay	11,210,000 tons (brick and specialty)
Copper	17,640 tons (worth ~ $120 million)
Diatomite	75,000 tons
Emery	1,150 tons
Gemstones	$57,873,000
Gold	6,362,228 troy oz (worth ~ $8 billion today)
Lead	1,150 tons
Manganese	317 tons
Mercury	95,319 flasks
Nickel	435,816 tons (worth ~ $3-4 billion)
Perlite	16 tons (likely very low estimate)
Pumice	15,518,000 tons
Silver	6,270,491 troy oz (worth $100 million)
Talc	1,554 tons
Uranium	6,672 tons
Zinc	1,277 tons

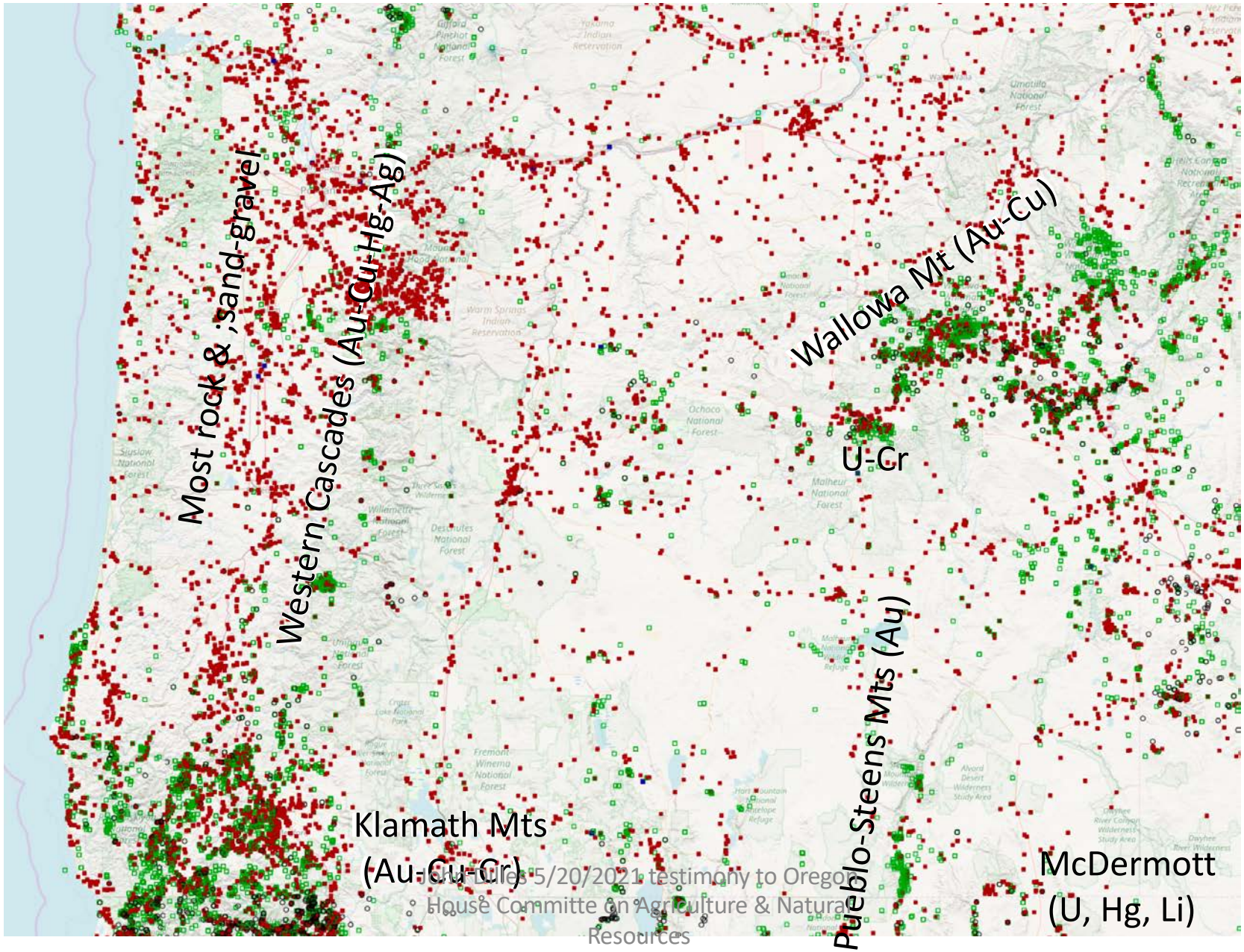
Gold Production to 1964 (DOGAMI)



Geological Map of Oregon, 2009 (Ian Madin, DOGAMI)



USGS –MRDS data compilation: Oregon metal mines & quarries: Red=past producers; Green = Prospects



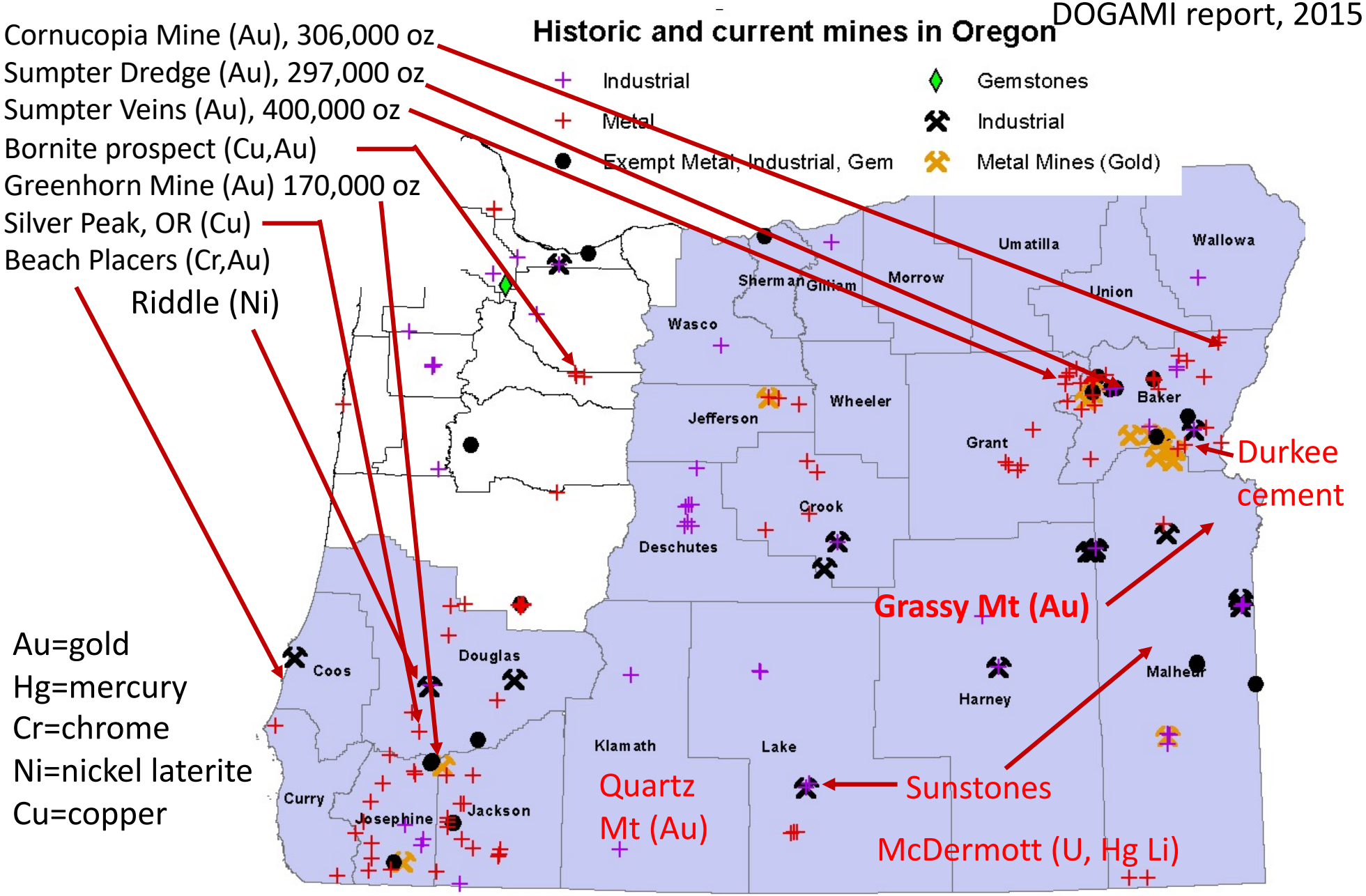


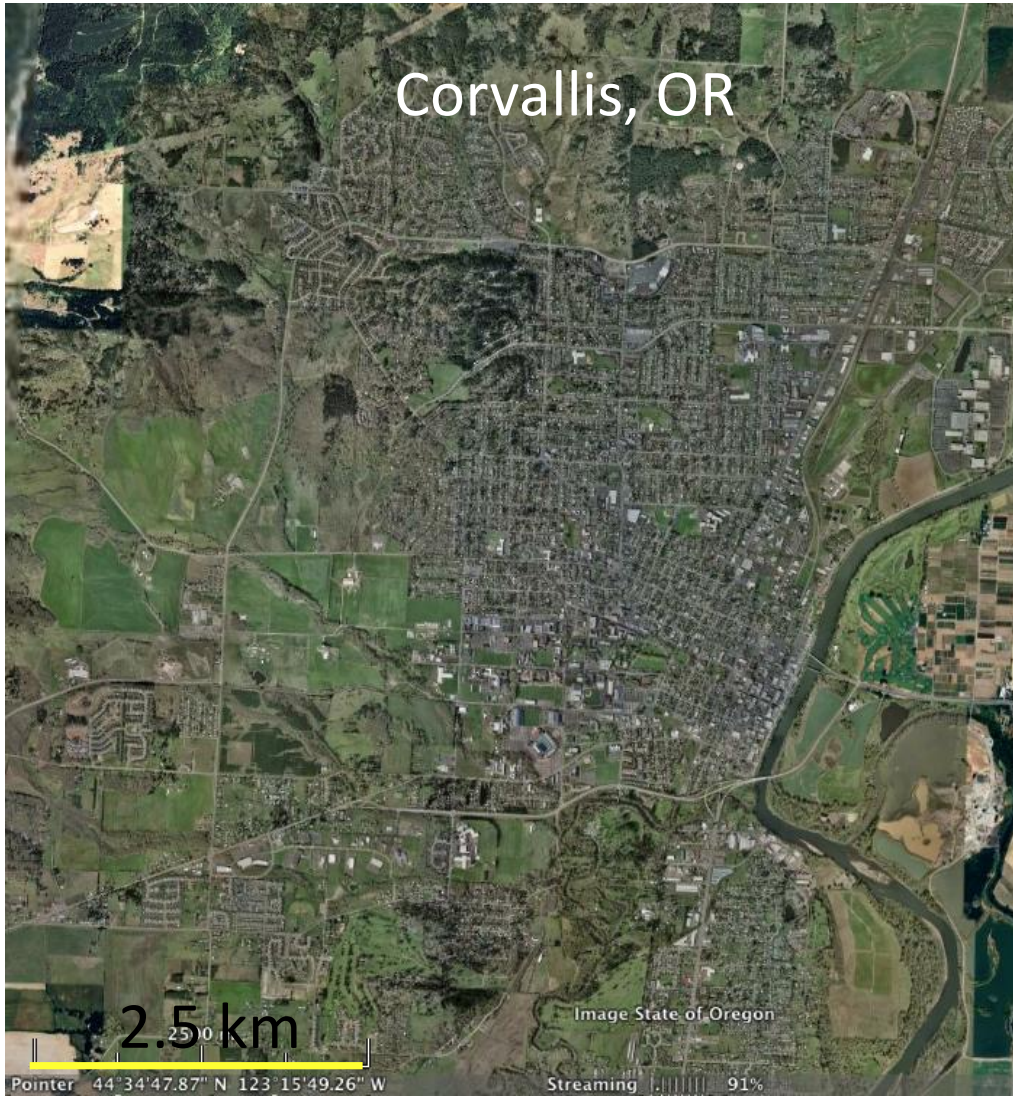
Figure 1. Map of Oregon showing 32 currently permitted and active metal and industrial mineral mines, and the 139 most productive historical mines. An additional 23 mines are exempt from permitting because of the small size of their operations. Shading indicates the counties evaluated in this study.

Mineral Resource Environmental Impacts

- 1) Modification of land surface
  - Cultural and historical features are removed
  - Reclamation can partly restore the surface (but is difficult with large open pit mines)
- 2) Disturbance of and local pollution of groundwater and surface waters
  - Turbidity or sediment discharge
  - Acid mine drainage (with dissolved metals)
- 3) Heavy metal pollution (5 most toxic metals: lead, cadmium, arsenic, mercury, and chromium)
  - Present in impounded tailing ponds (Silver Peak, OR)
  - Present in “stripped” waste rock or pit walls
  - Dispersed via sediment transport in water/air or dissolved in water

Bingham, UT (largest Copper mine in world): 1902-2016 production 20 M tonnes Cu (44 B lb), ~21 M oz Au, 0.6 M tonnes Mo (>$100 B) underpins global economy.

Porphyry deposits produce >65% of global Cu, nearly all Mo, & ~35% of Au



Bingham, UT (±largest Copper mine in world): 1902-2016 production 20 M tonnes Cu (44 B lb), ~21M oz Au, 0.6 M tonnes Mo (>$100 B)

>100 years Bingham production is same as world ***annual*** copper use

i.e., Equivalent of One Huge Deposit is Mined Out Each Year

Total mined 3 km^3 of rock
3 billion tonnes ore mined,
~6-8 billion tonnes waste rock

Environmental Legacy of Metal Pollution
Berkeley Pit (Cu, As, acid pH=2.1 in 2005, today neutral pH=4.8)

Butte & Anaconda USA's biggest superfund site
ARCO holds ~1-2 B$ liability (~2% current value of $100 B ore mined to date)
Acid mine drainage caused by oxidation of pyrite via Ferric/ferrous reduction in water

Above, Cu sulfate in water, Native Cu precipitates on mine rails of Missoula tunnel

Almeda Mine, Klamath Mts, Oregon

Discharge of acidic waters (containing metals Cu, Zn, and traces of Pb and Cd) into Rogue River

Partly from mine discharge, partly natural, partly related to road constructions

Pyrite weathering produces ***sulfuric acid***: $FeS_2 + 4O_2 = 2 \bullet H_2SO_4 + FeOOH$; acid transfers metals

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Formosa Mine (1989-93)

Silver Peak Mine, 10 miles SW of Canyonville, OR

Post-closure failure of waste rock and tailings facility allowed discharge of acid water and metal-bearing rock into 9 miles of trout stream.

Subsequently, EPA Superfund & DEQ site to reduce acid mine drainage and preserve water quality (2008 report, right)

Local, state and federal officials view acid mine drainage at the Formosa Mine Site

Tailings Ponds

San Fransisco Mine, Mexico, tailings pond

Butte, Montana, tailings in foreground

Esmeralda Mill, Nevada, 100 acres, rubber-lined tailings pond 60 ft high; to be covered with rubber, sealed & designed to manage 100 years floods

Closing Remarks

- We use a lotta minerals stuff in the USA. Conservation (limiting use) has merit, but economic drivers dictate global growth (*everyone on the planet wants to live like we do in USA*)
- Addressing future energy supplies & reducing CO_2 in the atmosphere *will require use of specialized earth materials (mines) for high-tech solutions*.

Citizen Choices (from LWV talk, 2019)

- Citizens have an important role in deciding if and how earth science issues are addressed.
  - Economic realities (jobs, profits) drive most decisions in USA….what you buy has impact
  - Citizen input in the political system (voting, marching, writing letters, etc)…has great impact
- The mineral resource business in the USA (& internationally) has not been very profitable for 20 years…
  - Little political clout
  - Low profit often means riskier operations.
  - Mineral resource decisions have largely been made by 2 generations of Americans who have not seen any resource shortages, and for whom environmental issues are very important.

Thank-you for your attention

- Questions?

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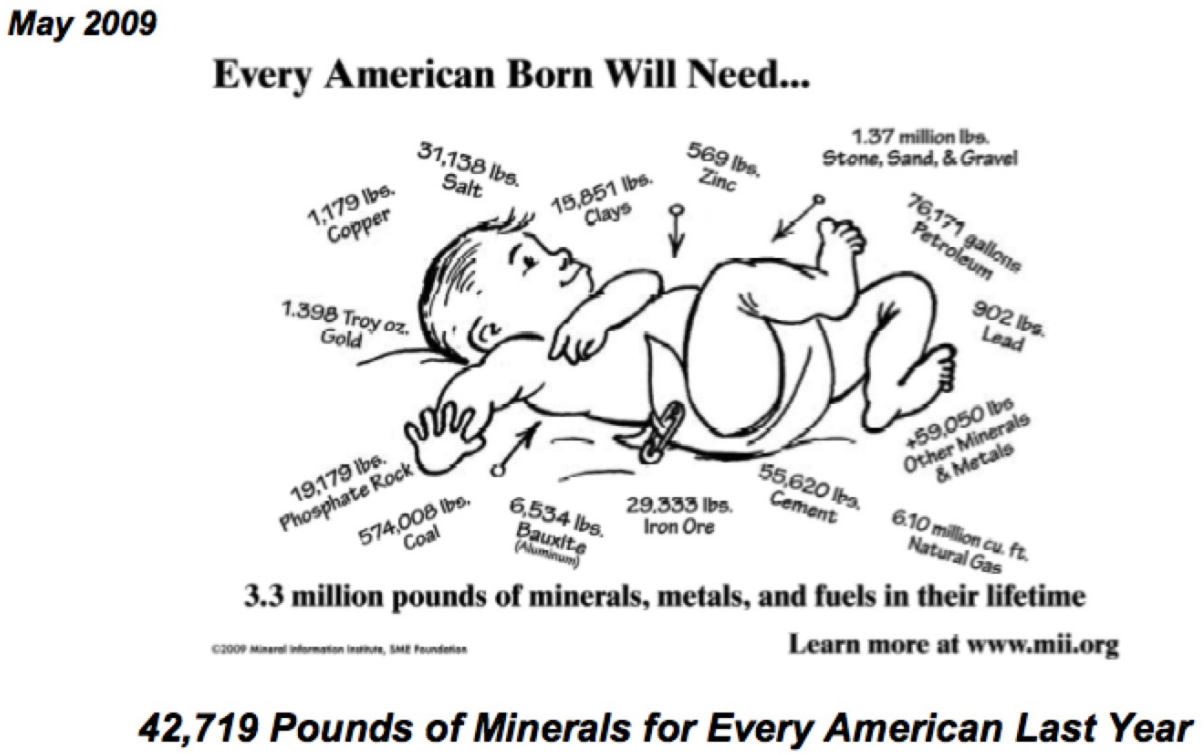

(extra slides follow)

Sustainability versus Resources

- Resources
- Non-renewable
  - Most energy (coal, nuclear, petroleum)
  - All mineral materials
- Renewable
  - Agricultural Products
  - Forestry Products
  - Wind, Solar, & Hydro-power
- Are “renewables” completely renewable???

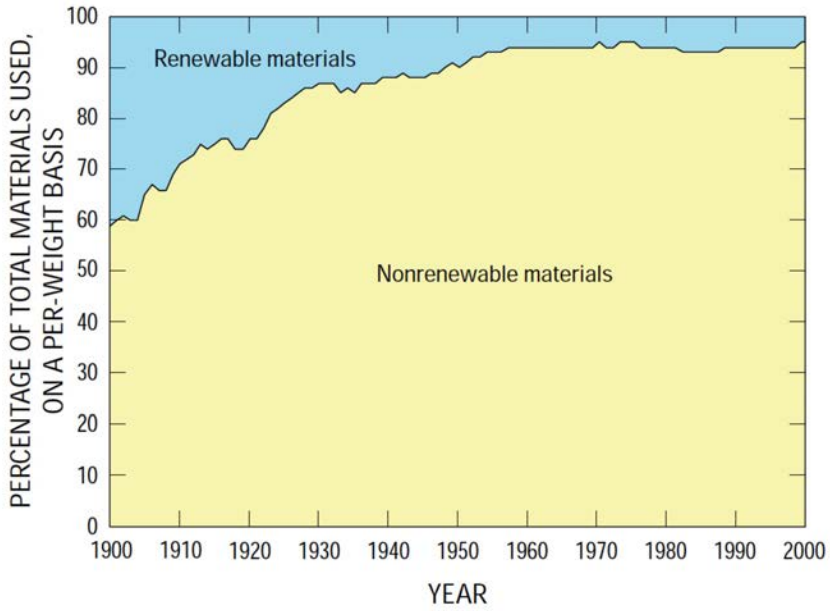

Figure 3. Renewable and nonrenewable materials used in the United States. Use of nonrenewable resources has increased dramatically in the United States during the 20th century (modified from Matos and Wagner, 1998, fig. 2).

Minerals Used in USA

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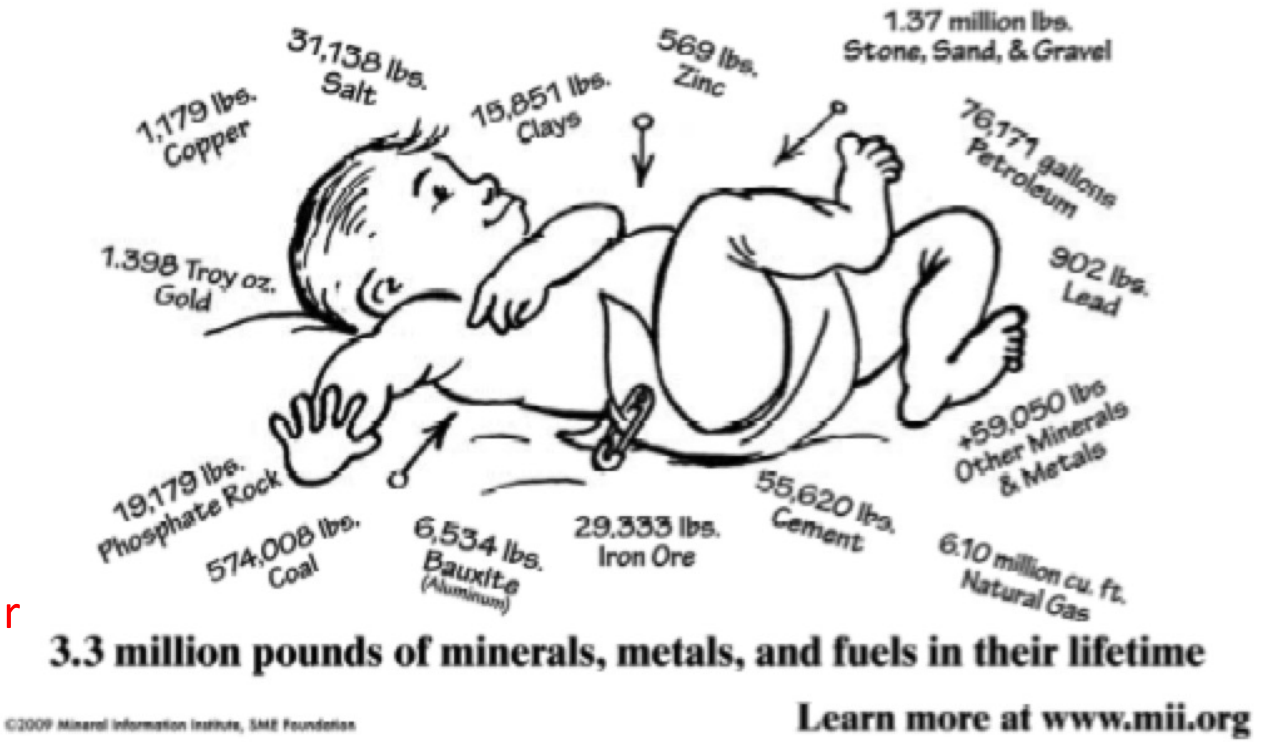
Nevada bumper Sticker "If it can't be grown, it has got to be mined"

Average per capita USA use 20 tonnes (mostly sand, gravel,rock & cement) Earth Materials Includes 15 lbs of copper (Cu) per year



42,719 Pounds of Minerals for Every American Last Year

The Cost of Minerals—Is Very Low

- Mineral production costs have decreased enormously in last century, like all global manufactured products
- Industry has enormously increased energy use to reduce labor costs.

Copper prices, for example,have risen slower than wages or inflation

90% of value of mined metals are Copper, Gold, Iron, Aluminum

Increased minerals use means higher energy use

Where do you find gold?

- A gold wedding ring contains 5-10 grams of gold (~about 1/6 to 1/3 of a troy ounce).
- It is worth about $200 to $400 at today's price of gold ($1200-1300 per oz)
- In the biggest gold mining area of the USA (Carlin, Nevada), the ore contains <1 gm/tonne.
- So, 5-10 tonnes of ore, and >10 tonnes of non-ore rock are moved for each gold ring.
- **20 t is 4x6x10 ft = 240 cu ft**

Modern Mine, 280 ton trucks

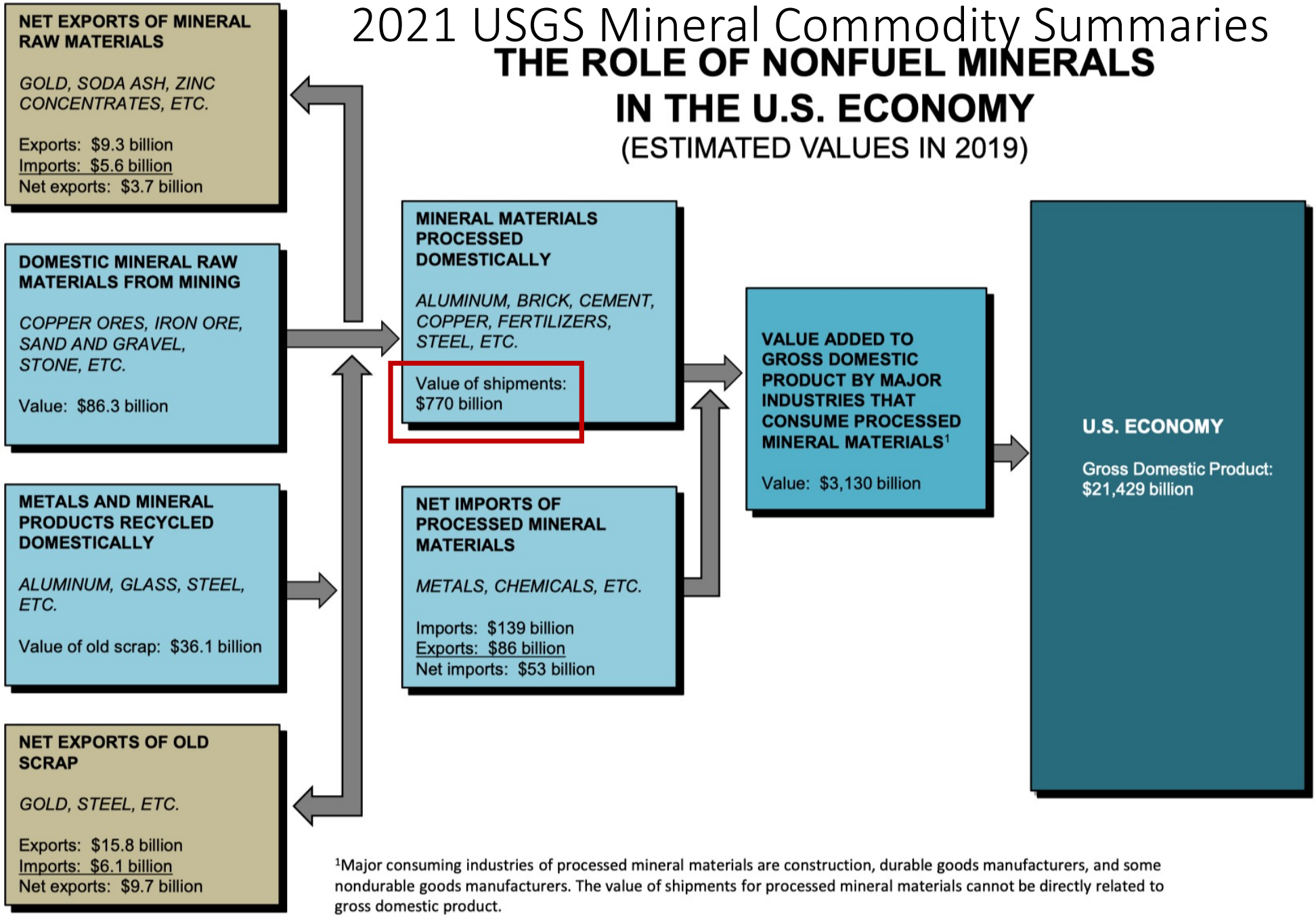
Golden Sunlight Mine, Montana

Carlin District, Nevada

- >60 million ounces of gold produced since 1962
- >$75 Billion

Betze (Post) Pit

2021 USGS Mineral Commodity Summaries



[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

Sources: U.S. Geological Survey and the U.S. Department of Commerce.

2019 US Net Import reliance on nonfuel mineral materials (USGS)

By value (% imports)

Non-metallics

- cement (12%)
- sand & gravel (1%)

Metals

- REE (100%)
- Te (?; $215/kg)
- Copper (35%)
- Lithium >25%, $5.5/kg)
- Aluminum (22%)
- Iron & Steel (21%)
- Gold (0%)

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
GARNET (industrial)	64	Australia, India, South Africa, China
PLATINUM	64	South Africa, Germany, Italy, Russia
ALUMINA	54	Brazil, Australia, Jamaica, Canada
MAGNESIUM COMPOUNDS	52	China, Canada, Australia, Hong Kong
ABRASIVES, silicon carbide (crude)	>50	China, South Africa, Netherlands, Hong Kong
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
IRON OXIDE PIGMENTS (natural and synthetic)	>50	China, Germany, Brazil, Canada
TUNGSTEN	>50	China, Bolivia, Germany, Spain
DIAMOND (industrial dust, grit, and powder)	50	China, Ireland, Republic of Korea, Russia
CADMIUM	<50	China, Australia, Canada, Peru
MAGNESIUM METAL	<50	Israel, Canada, Mexico, United Kingdom
NICKEL	47	Canada, Norway, Australia, Finland
SILICON (metal and ferrosilicon)	41	Russia, Brazil, Canada
MICA, scrap and flake (natural)	37	Canada, China, India, Finland
COPPER (refined)	35	Chile, Canada, Mexico
PALLADIUM	32	South Africa, Russia, Germany, Italy
LEAD (refined)	30	Canada, Mexico, Republic of Korea, India
SALT	29	Chile, Canada, Mexico, Egypt
PERLITE	28	Greece, China, Mexico
LITHIUM	>25	Argentina, Chile, China
BROMINE	<25	Israel, Jordan, China
SELENIUM	<25	China, Philippines, Mexico, Germany
ALUMINUM	22	Canada, Russia, United Arab Emirates, China
IRON and STEEL	21	Canada, Brazil, Republic of Korea

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (abrasives, metallic; boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zirconium mineral concentrates) or less than 21% import reliant (beryllium; cement; feldspar; gypsum; iron and steel slag; lime; nitrogen (fixed)–ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; talc and pyrophyllite; and vermiculite.). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]In descending order of import share.

[3]Data include lanthanides.

Back to Hybrid Cars, our Topic
(with notes on solar energy)

Goal of hybrids…. Reduced CO_2 emissions, increased efficiency of energy use (miles/gal or km/liter).

High-Tech Solutions Require Special Materials--Let's examine 3 of these

Metal	Earth(C1)	Earth Crust	"Ore"	Value
Copper	131 ppm	50 ppm	0.5wt%	$3.00/lb
Rare Earth's	2.2 ppm (all)	230 ppm	5-10wt.%	$10-1000 /lb
Lithium	1.5 ppm	30 ppm	brine	$12/lb

Extraordinary Earth Enrichment Processes Form Ores

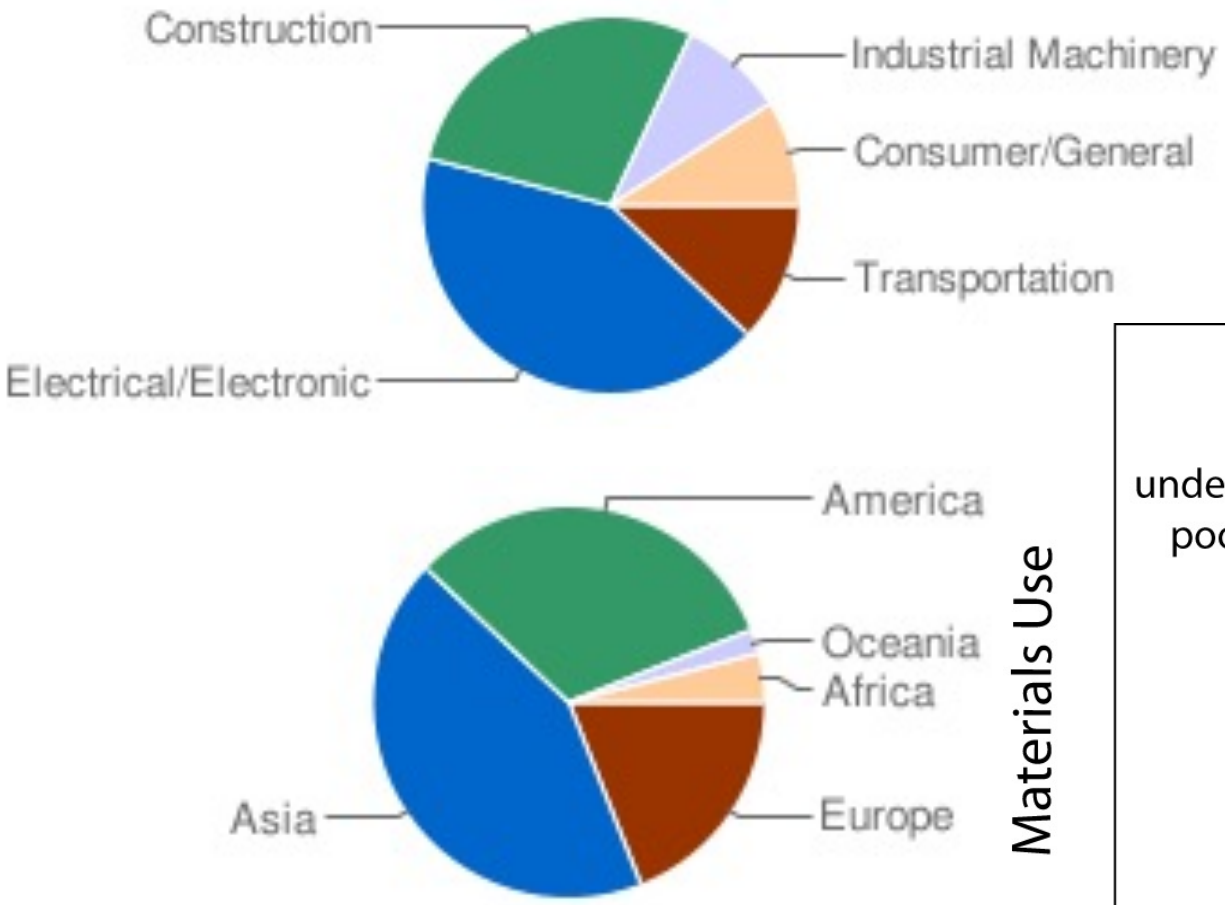
Global Copper Mining, economics

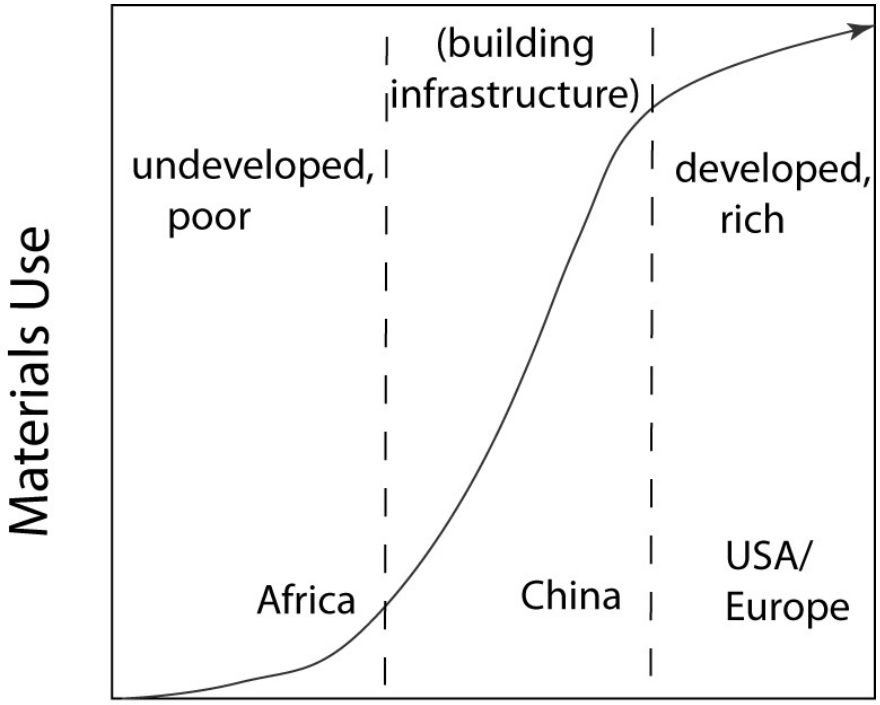
- Current price (~$4.56/pound). Economics are scary cheap 1 ton of rock with 0.4 wt% copper to produce 8.8 pounds of copper so at a cost of
- Global production rose ~5-8% (700,000 tonnes) a year (2005-08) due to east Asian demand.
- World consumes ~20 M tonnes of copper, including 16-18 M tonnes (40 B lb) of newly mined Cu, in total worth ~$200 B.
- Largest mine in world produces 1 Million tonnes Cu/year
- **World reserve base is about 30 years production, at current rate.** ***In order to sustain production, more discoveries need to be made***

- Currently there is ~10 year lag time between exploration and production as a result of low discovery rates, capitalization of mine plants, mine planning, and permitting/environmental planning

Global copper consumption

Growth in east/south Asia, not in Europe/USA





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Why should we care about minerals (Cu as an example)?

- Automobiles:
  - A conventional car needs 45-50 lbs copper and transport accounts for ~5 percent of USA or global copper usage.
  - The Tesla car uses 100 lb (45kg) copper for the motor along

- Wind turbines, solar cells, etc
- USA per capita use ~15 kg/year (33 lbs)
- World consumption is increasing 0.2-0.5 M tonnes Cu per year
- Per capita world use is ~3-4 kg/year