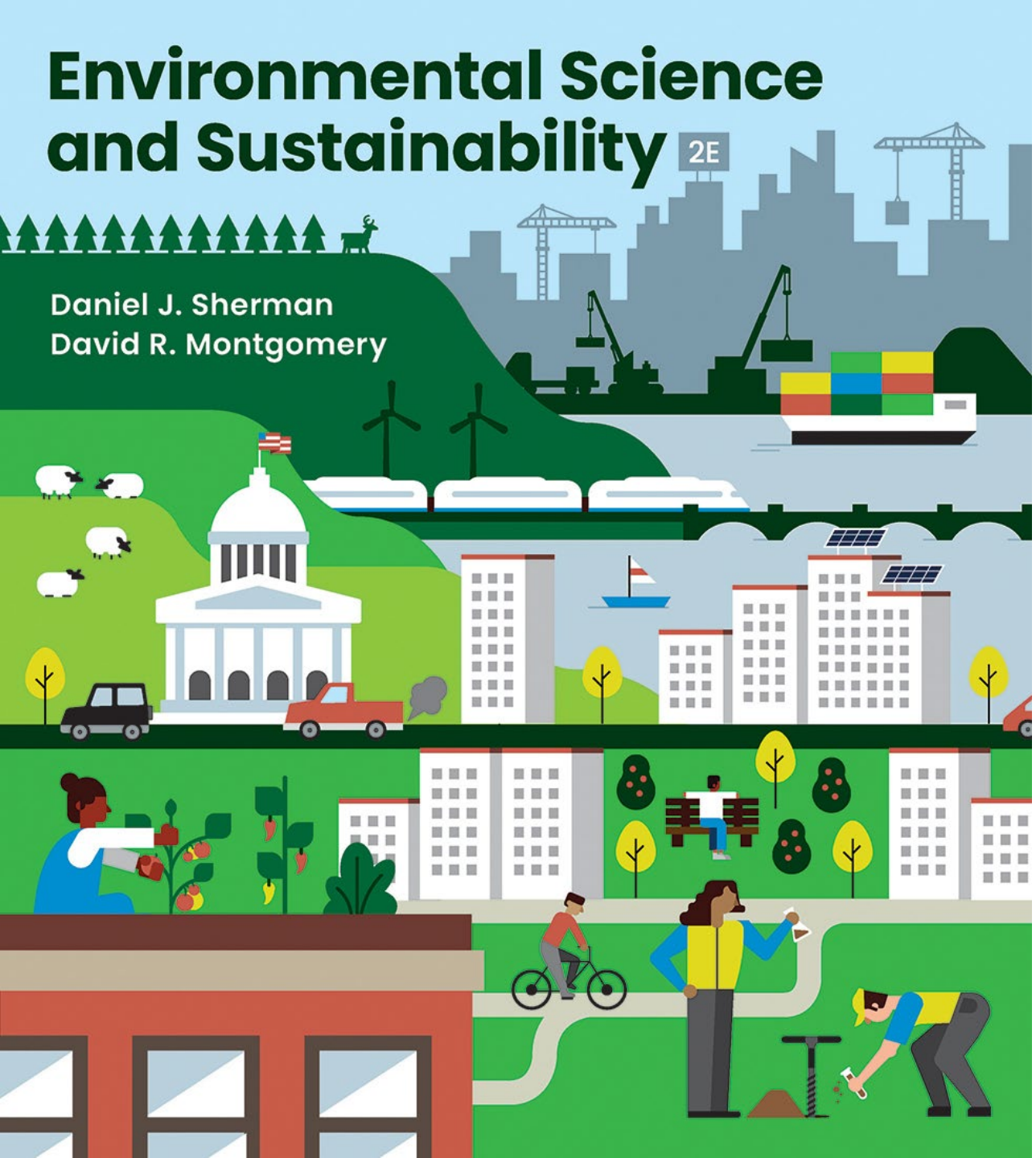
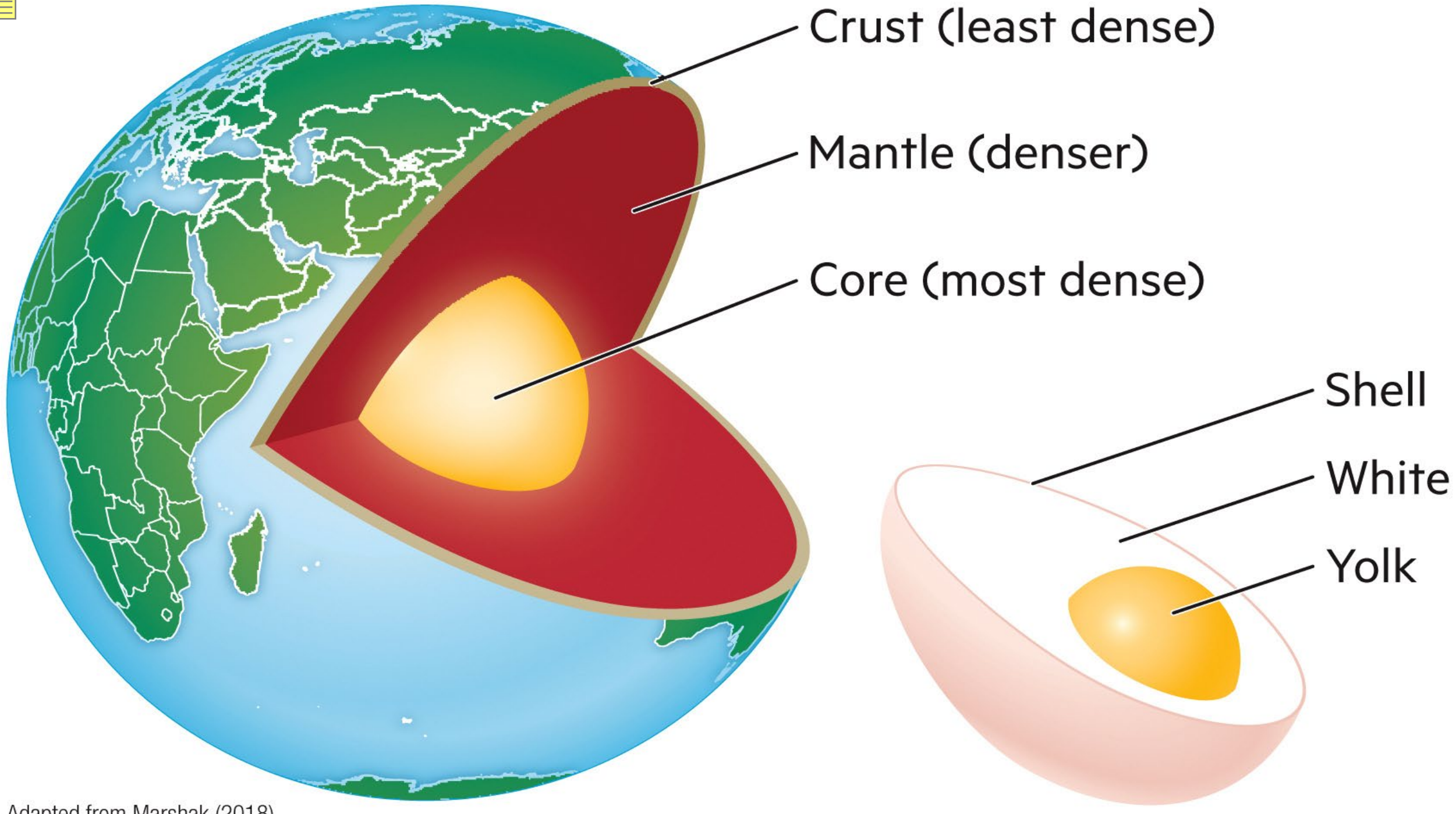


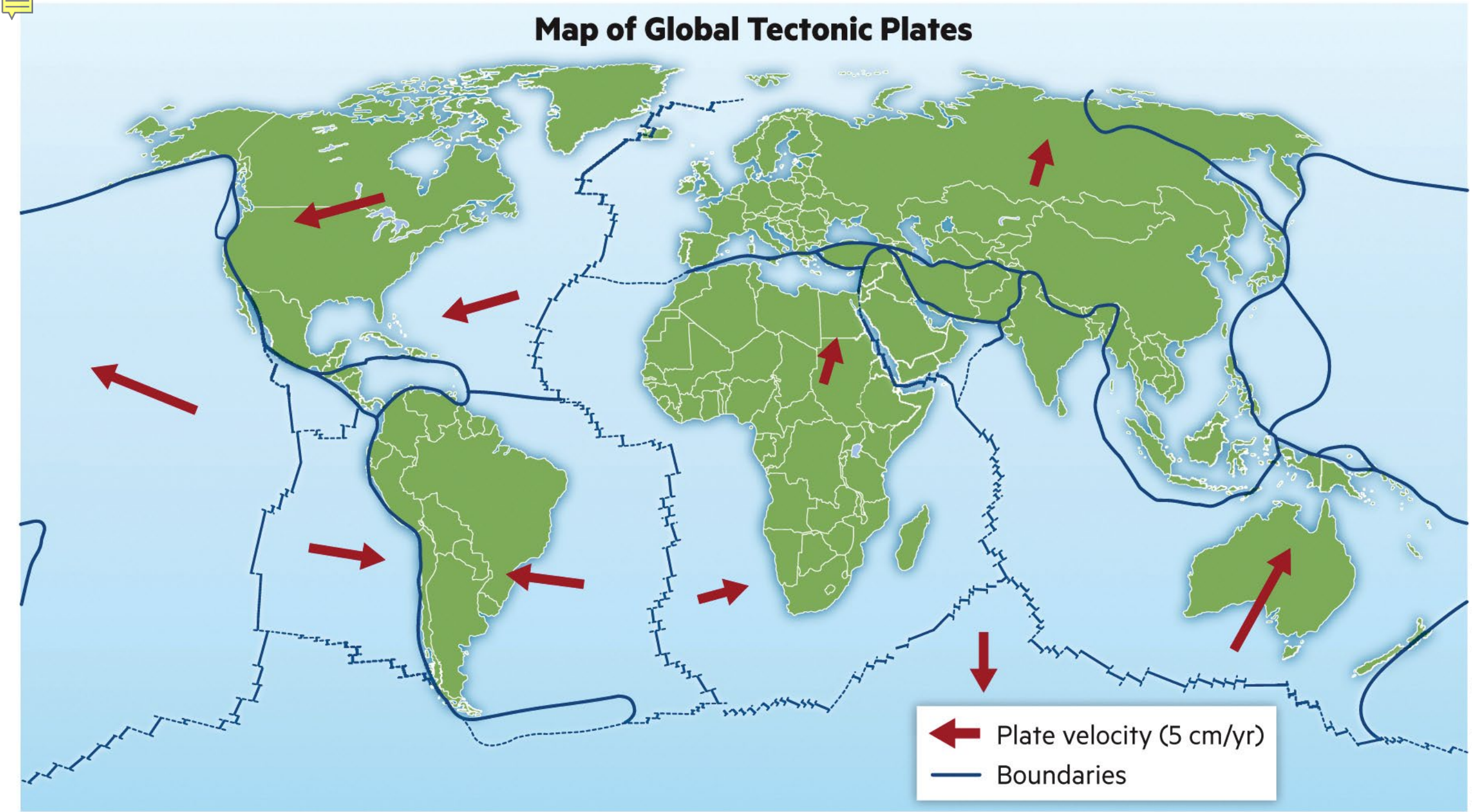
CHAPTER 9 Minerals to Rocks

Land: How Does It Shape Us?



Adapted from Marshak (2018)

Map of Global Tectonic Plates



Adapted from Marshak (2018)

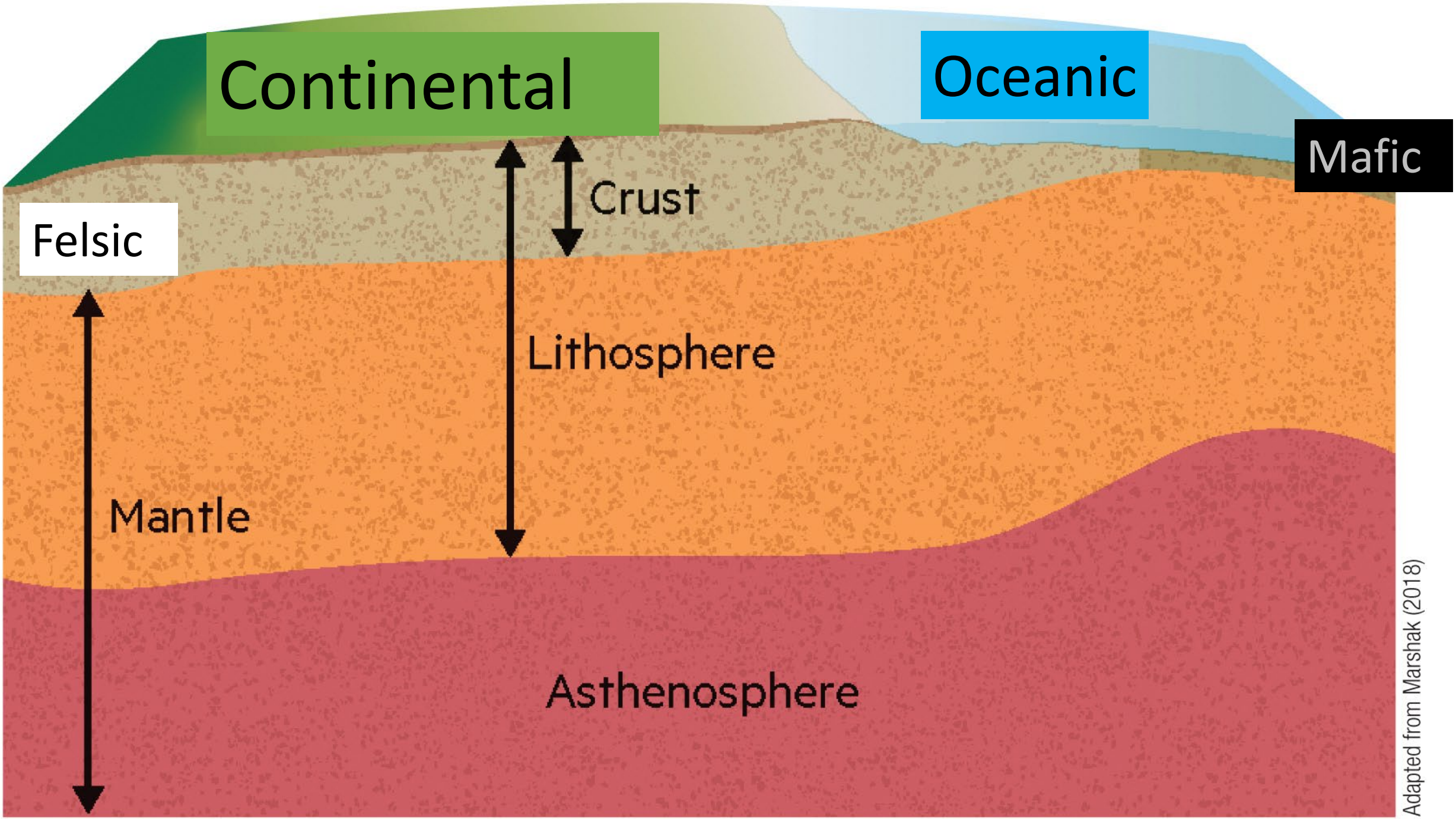

Continental
Oceanic
Mafic
Felsic
Crust
Lithosphere
Mantle
Asthenosphere
Adapted from Marshak (2018)

Plate Tectonics

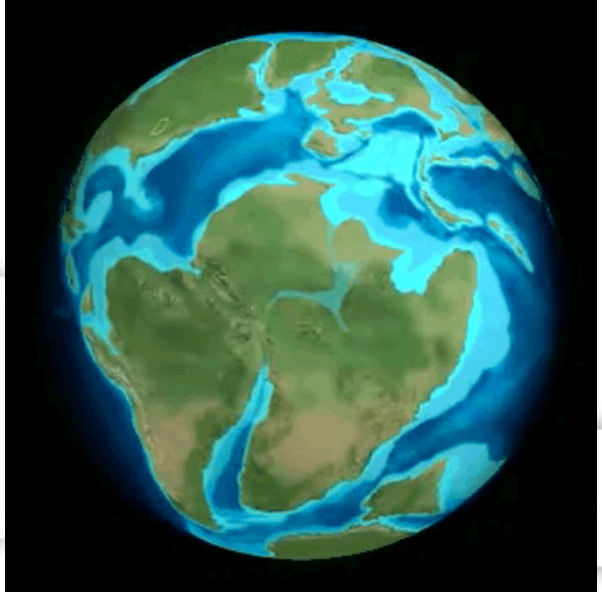
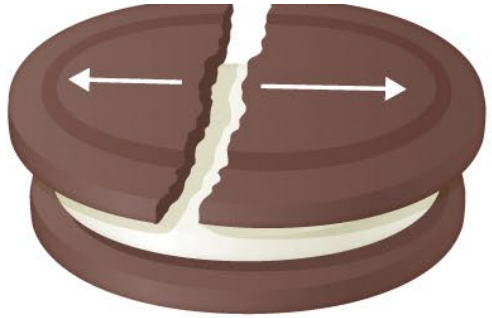


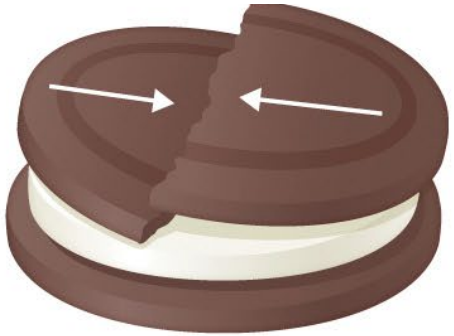
Plate tectonic movements

Divergent



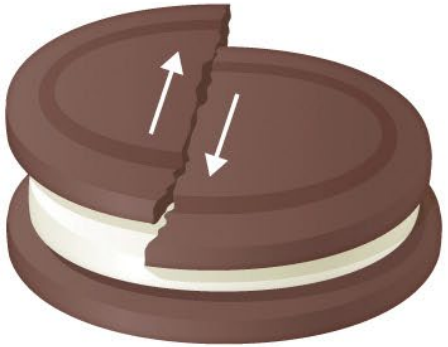
Martin Harvey/Alamy Stock Photo

Convergent



Jeffrey Isaac Greenberg 14+/Alamy Stock Photo

Transform



Kip Evans/Alamy Stock Photo

Periodic Table of the Elements

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H Hydrogen 1.008 1																	2 He Helium 4.0026 2
3 Li Lithium 6.94 2-1	4 Be Beryllium 9.0122 2-2											5 B Boron 10.81 2-3	6 C Carbon 12.011 2-4	7 N Nitrogen 14.007 2-5	8 O Oxygen 15.999 2-6	9 F Fluorine 18.998 2-7	10 Ne Neon 20.180 2-8
11 Na Sodium 22.98976928 2-8-1	12 Mg Magnesium 24.305 2-8-2											13 Al Aluminium 26.982 2-8-3	14 Si Silicon 28.085 2-8-4	15 P Phosphorus 30.974 2-8-5	16 S Sulfur 32.06 2-8-6	17 Cl Chlorine 35.45 2-8-7	18 Ar Argon 39.948 2-8-8
19 K Potassium 39.0983 2-8-8-1	20 Ca Calcium 40.078 2-8-8-2	21 Sc Scandium 44.955908 2-8-9-2	22 Ti Titanium 47.867 2-8-10-2	23 V Vanadium 50.9415 2-8-11-2	24 Cr Chromium 51.9961 2-8-13-1	25 Mn Manganese 54.938044 2-8-13-2	26 Fe Iron 55.845 2-8-14-2	27 Co Cobalt 58.933 2-8-15-2	28 Ni Nickel 58.693 2-8-16-2	29 Cu Copper 63.546 2-8-18-1	30 Zn Zinc 65.38 2-8-18-2	31 Ga Gallium 69.723 2-8-18-3	32 Ge Germanium 72.630 2-8-18-4	33 As Arsenic 74.922 2-8-18-5	34 Se Selenium 78.971 2-8-18-6	35 Br Bromine 79.904 2-8-18-7	36 Kr Krypton 83.798 2-8-18-8
37 Rb Rubidium 85.4678 2-8-18-8-1	38 Sr Strontium 87.62 2-8-18-8-2	39 Y Yttrium 88.90584 2-8-18-9-2	40 Zr Zirconium 91.224 2-8-18-10-2	41 Nb Niobium 92.90637 2-8-18-12-1	42 Mo Molybdenum 95.95 2-8-18-13-1	43 Tc Technetium (98) 2-8-18-13-2	44 Ru Ruthenium 101.07 2-8-18-15-1	45 Rh Rhodium 102.91 2-8-18-16-1	46 Pd Palladium 106.42 2-8-18-18	47 Ag Silver 107.87 2-8-18-18-1	48 Cd Cadmium 112.41 2-8-18-18-2	49 In Indium 114.82 2-8-18-18-3					
55 Cs Caesium 132.90545196 2-8-18-18-8-1	56 Ba Barium 137.327 2-8-18-18-8-2	57-71 Lanthanides	72 Hf Hafnium 178.49 2-8-18-32-10-2	73 Ta Tantalum 180.94788 2-8-18-32-11-2	74 W Tungsten 183.84 2-8-18-32-12-2	75 Re Rhenium 186.21 2-8-18-32-13-2	76 Os Osmium 190.23 2-8-18-32-14-2	77 Ir Iridium 192.22 2-8-18-32-15-2	78 Pt Platinum 195.08 2-8-18-32-17-1	79 Au Gold 196.97 2-8-18-32-18-1	80 Hg Mercury 200.59 2-8-18-32-18-2	81 Tl Thallium 204.38 2-8-18-32-18-3					
87 Fr Francium (223) 2-8-18-32-18-8-1	88 Ra Radium (226) 2-8-18-32-18-8-2	89-103 Actinides	104 Rf Rutherfordium (267) 2-8-18-32-32-10-2	105 Db Dubnium (268) 2-8-18-32-32-11-2	106 Sg Seaborgium (269) 2-8-18-32-32-12-2	107 Bh Bohrium (270) 2-8-18-32-32-13-2	108 Hs Hassium (277) 2-8-18-32-32-14-2	109 Mt Meitnerium (278) 2-8-18-32-32-15-2	110 Ds Darmstadtium (281) 2-8-18-32-32-17-1	111 Rg Roentgenium (282) 2-8-18-32-32-17-2	112 Cn Copernicium (285) 2-8-18-32-32-18-2	113 Nh Nihonium (286) 2-8-18-32-32-18-3					

57	58	59	60	61	62	63	64	65	66	67
La Lanthanum 138.91 2-8-18-18-9-2	Ce Cerium 140.12 2-8-18-19-9-2	Pr Praseodymium 140.91 2-8-18-21-8-2	Nd Neodymium 144.24 2-8-18-22-8-2	Pm Promethium (145) 2-8-18-23-8-2	Sm Samarium 150.36 2-8-18-24-8-2	Eu Europium 151.96 2-8-18-25-8-2	Gd Gadolinium 157.25 2-8-18-25-9-2	Tb Terbium 158.93 2-8-18-27-8-2	Dy Dysprosium 162.50 2-8-18-28-8-2	Ho Holmium 164.93 2-8-18-29-8-2
89	90	91	92	93	94	95	96	97	98	99
Ac Actinium (227) 2-8-18-32-18-9-2	Th Thorium 232.04 2-8-18-32-18-10-2	Pa Protactinium 231.04 2-8-18-32-20-9-2	U Uranium 238.03 2-8-18-32-21-9-2	Np Neptunium (237) 2-8-18-32-22-9-2	Pu Plutonium (244) 2-8-18-32-24-8-2	Am Americium (243) 2-8-18-32-25-8-2	Cm Curium (247) 2-8-18-32-25-9-2	Bk Berkelium (247) 2-8-18-32-27-8-2	Cf Californium (251) 2-8-18-32-28-8-2	Es Einsteinium (252) 2-8-18-32-29-8-2

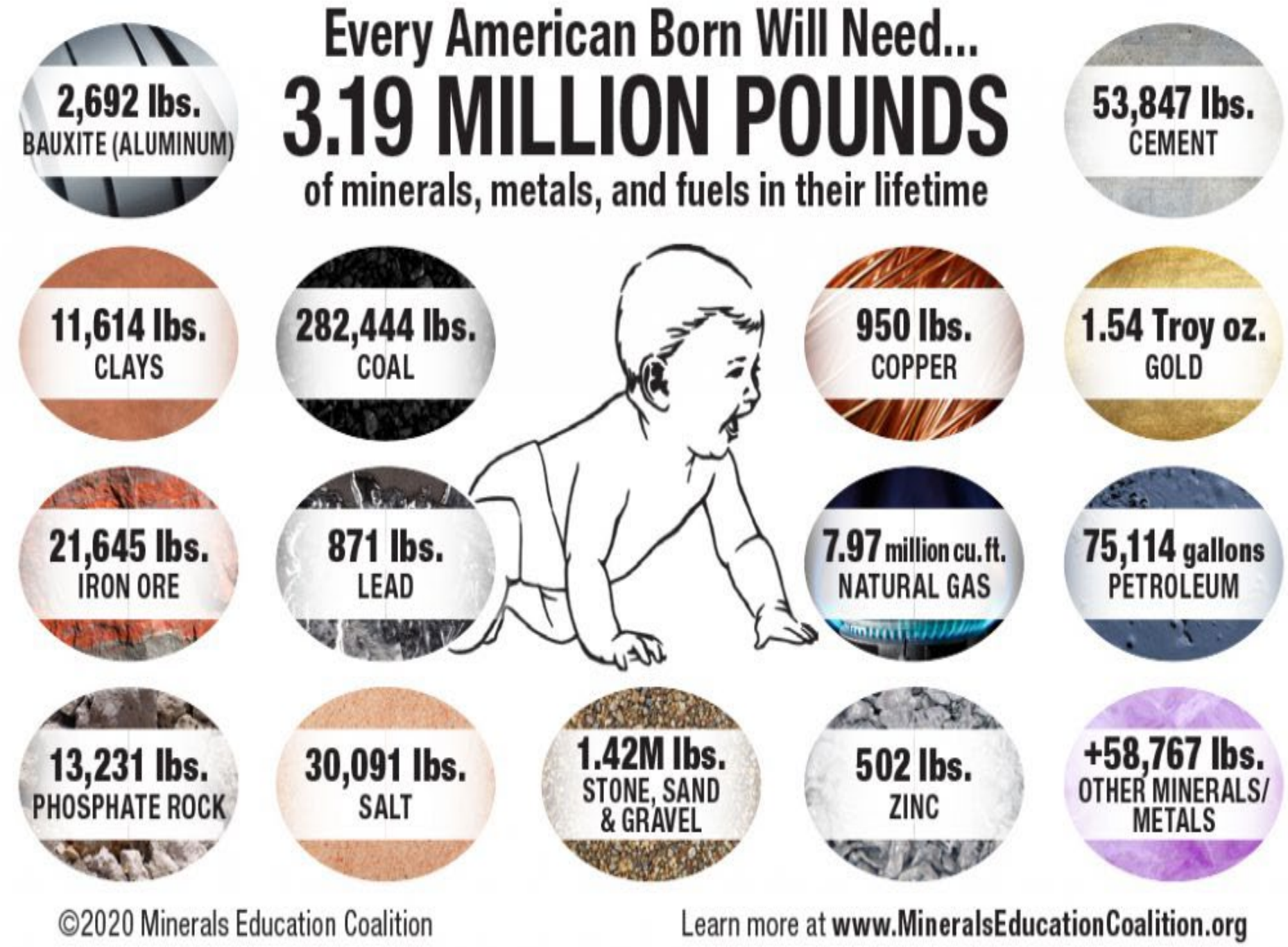
Atomic Number → 1 H ← Symbol
Name → Hydrogen
Electrons per shell → 1
1.008 ← Atomic Weight

State of matter (color of name)
GAS LIQUID SOLID UNKNOWN

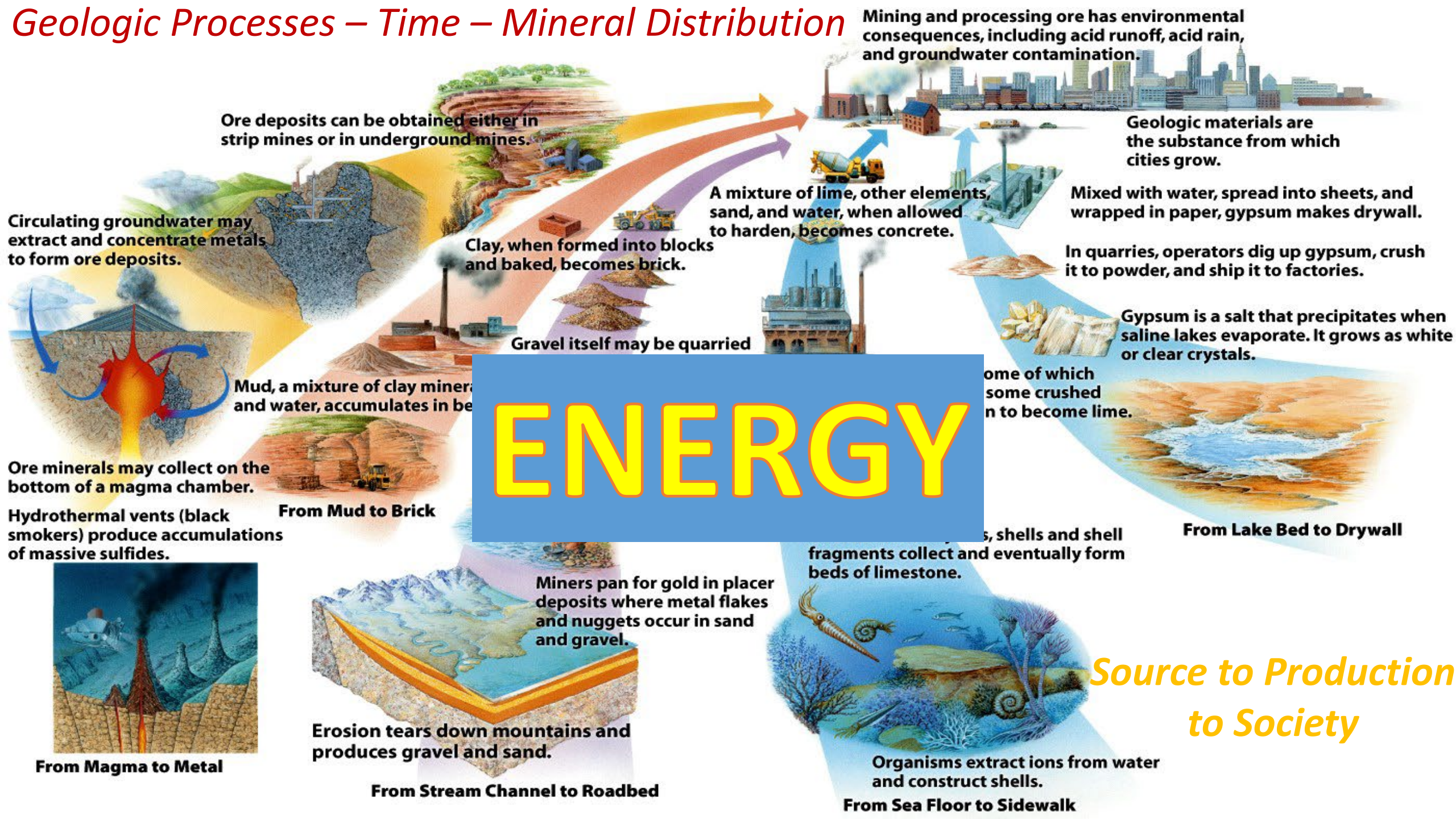
Subcategory in the metal-metalloid-nonmetal trend (color of background)
- Alkali metals
- Alkaline earth metals
- Transition metals
- Lanthanides
- Actinides
- Post-transition metals
- Metalloids
- Reactive nonmetals
- Noble gases
- Unknown chemical properties

Big Idea

Humans depend on Earth for resources



Geologic Processes – Time – Mineral Distribution



Source to Production to Society

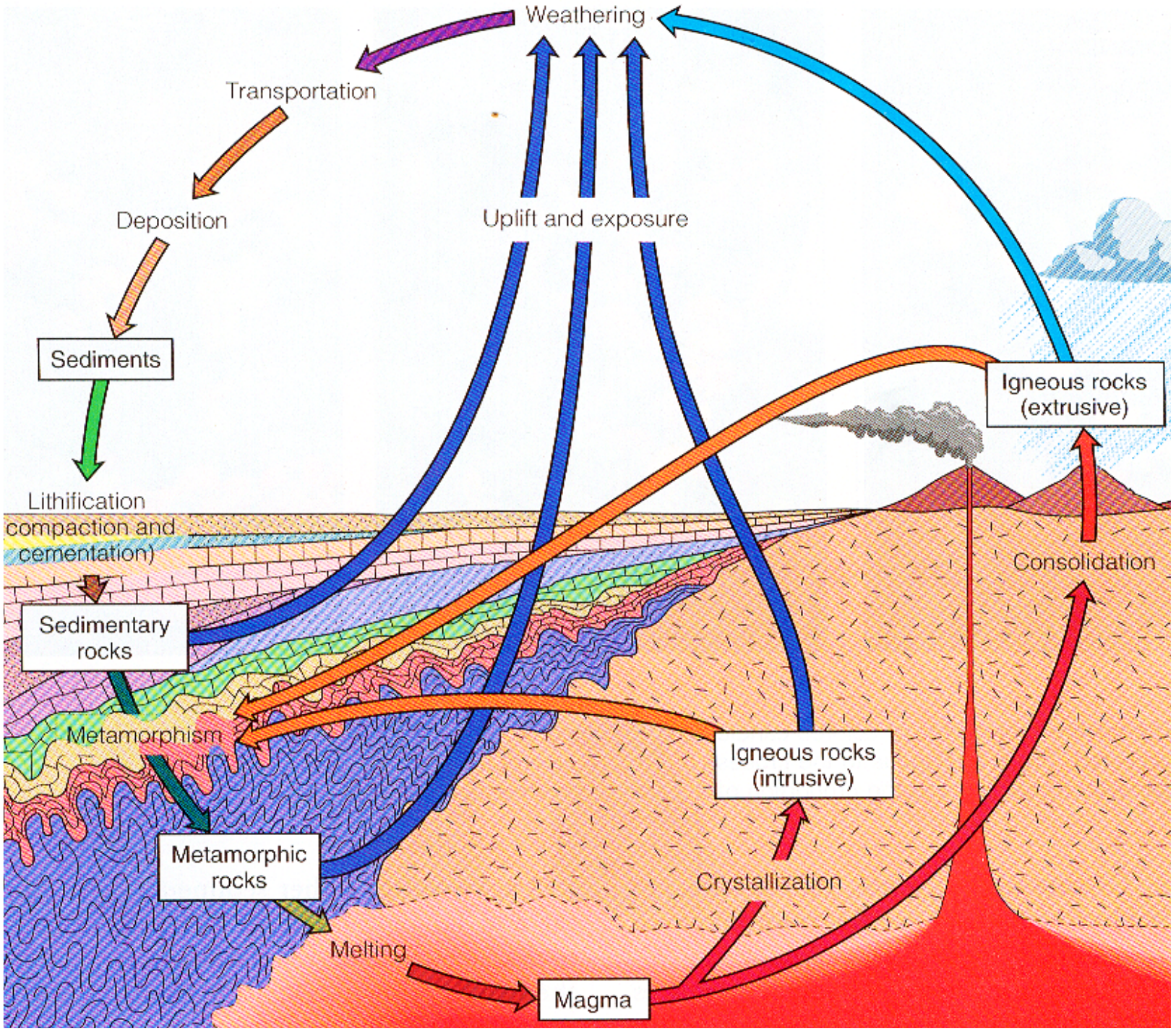
Minerals

Rocks

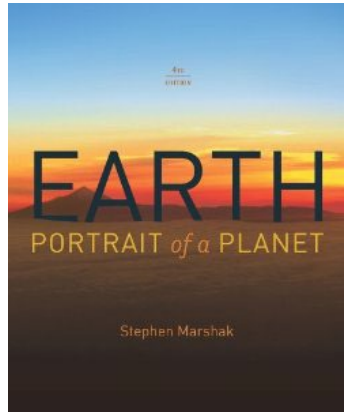
Igneous

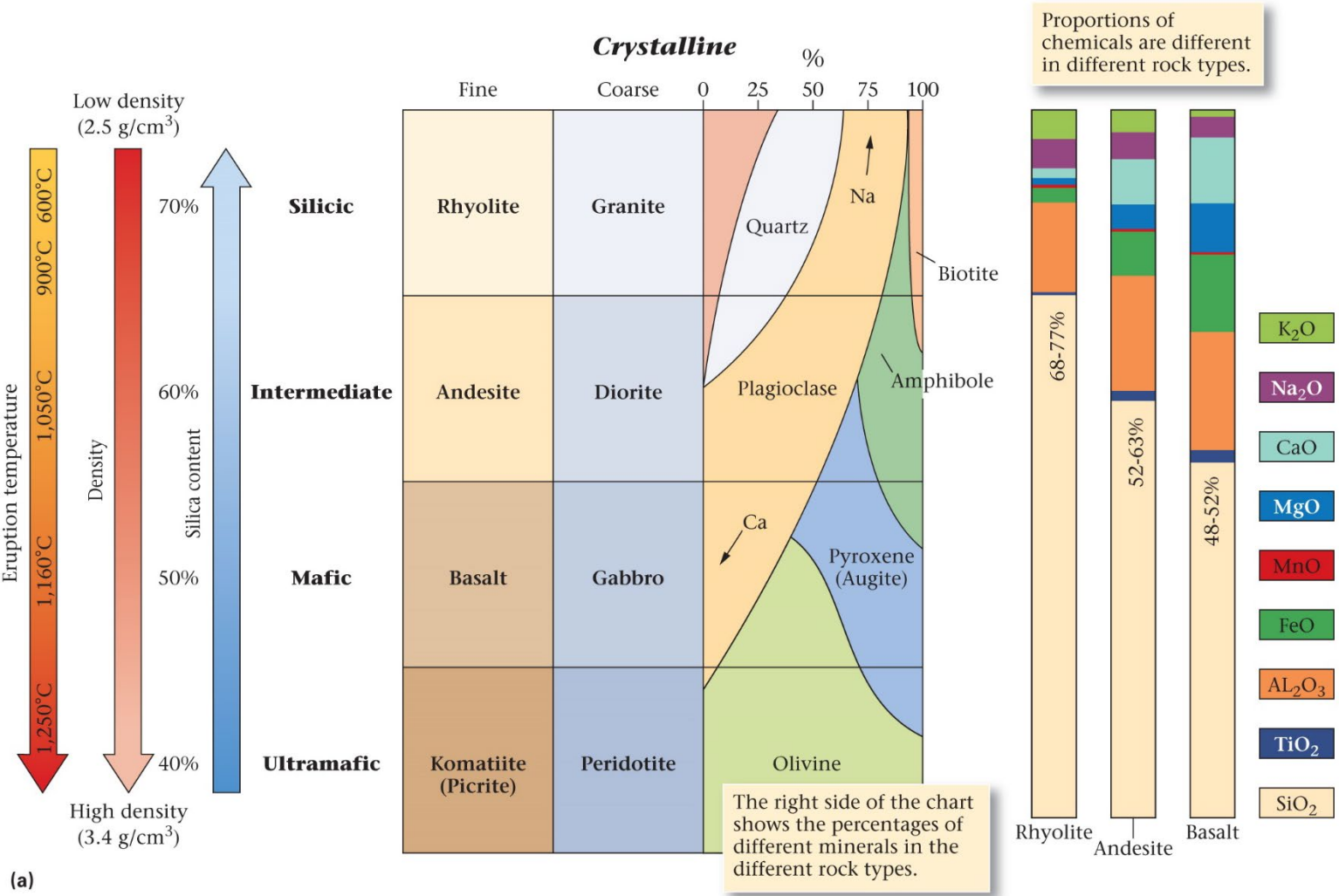
Sedimentary

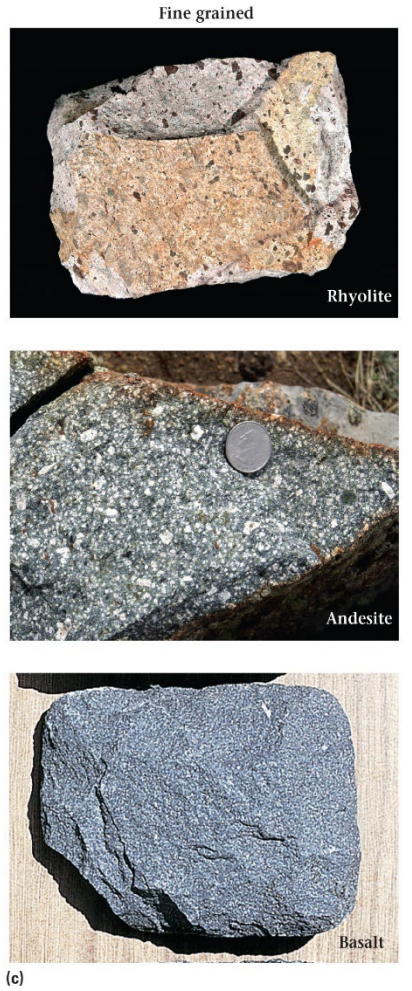
Metamorphic

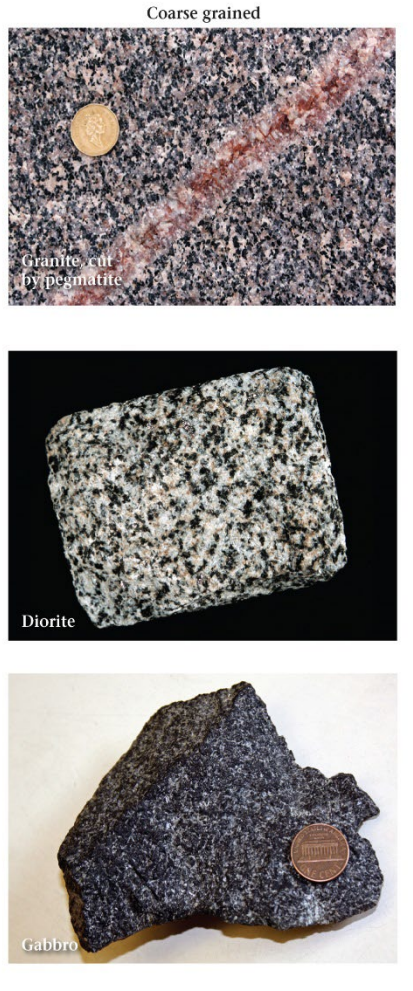


Extended concepts (Igneous Intrusive vs Extrusive rocks)



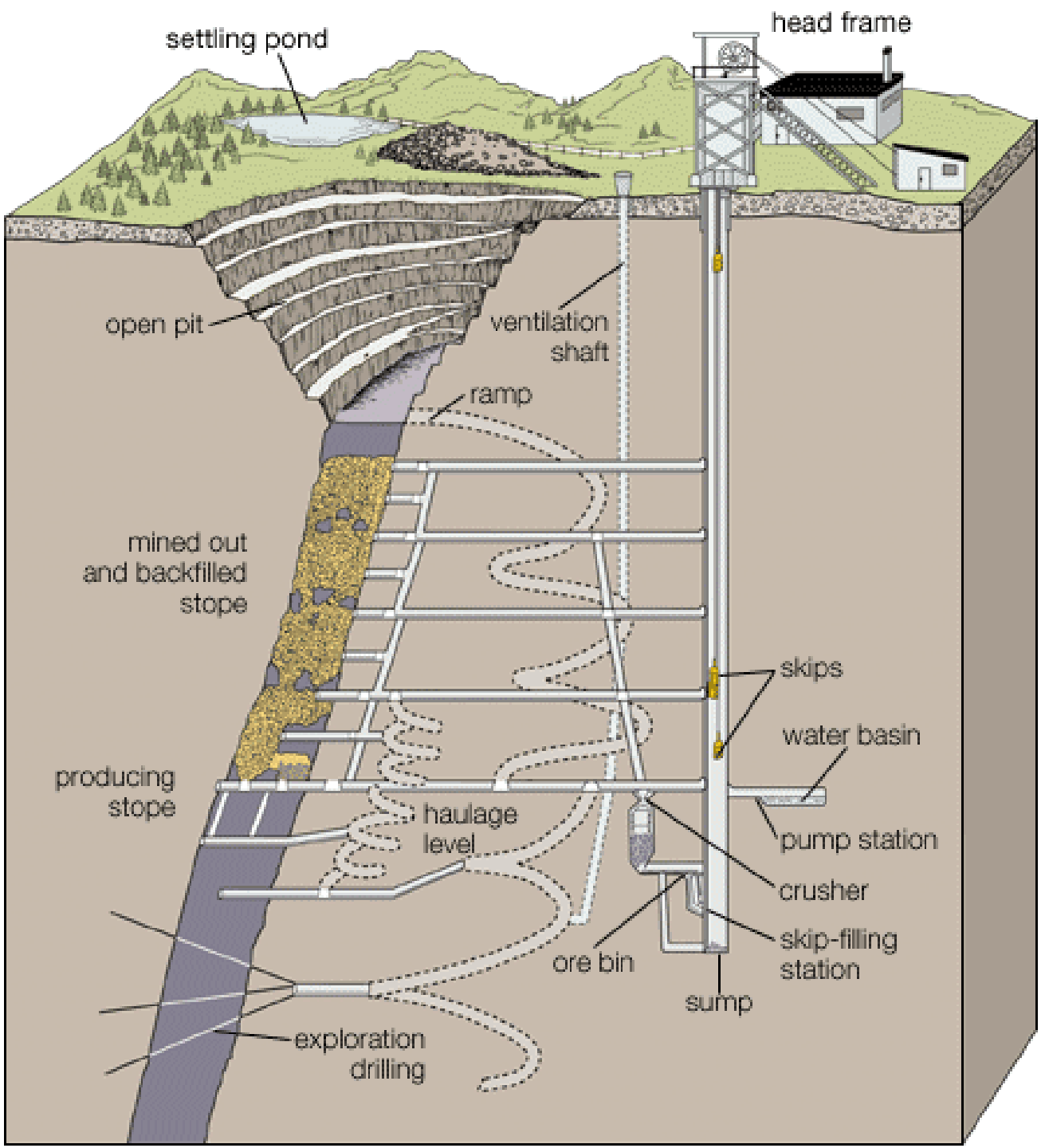




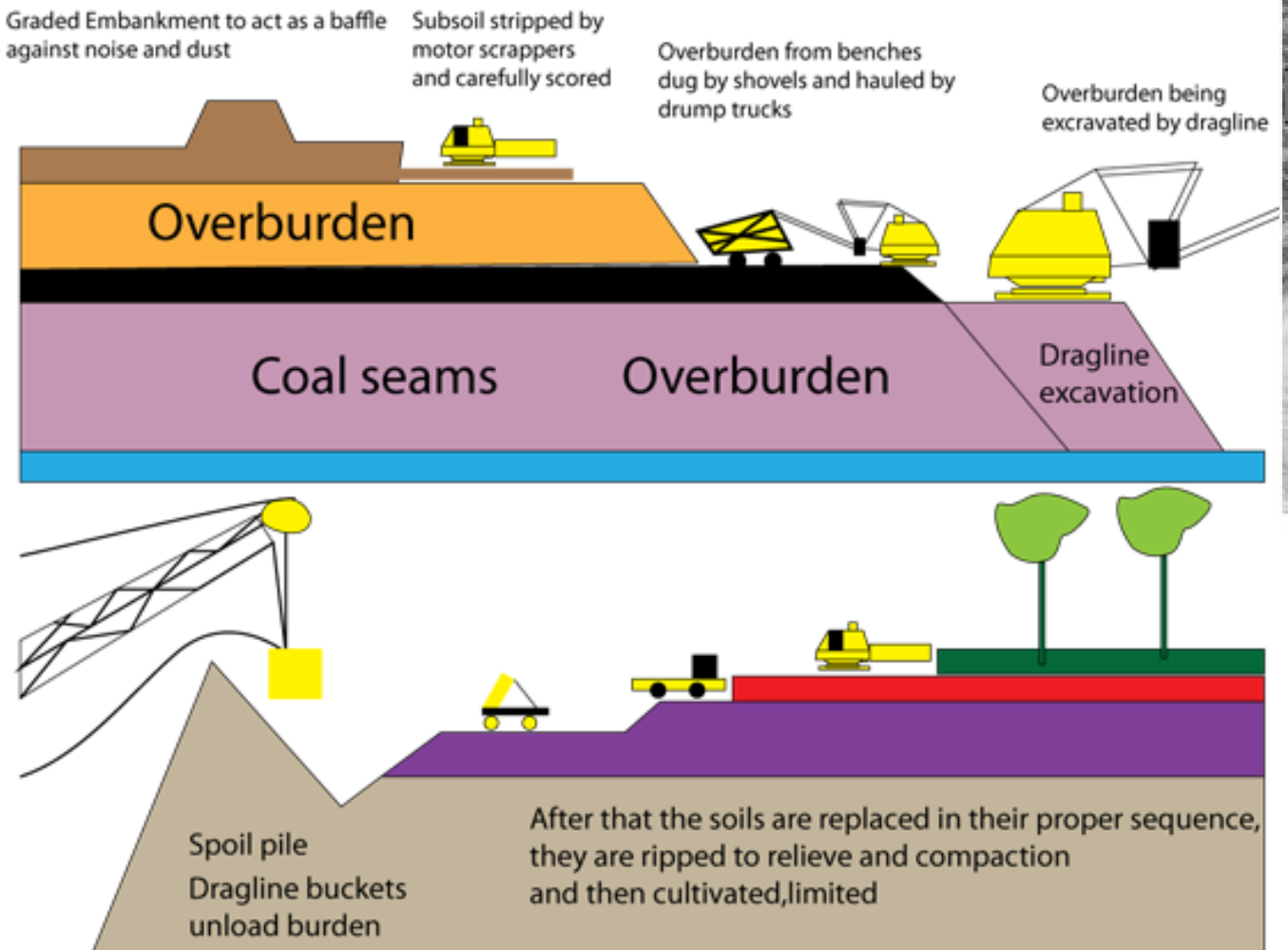


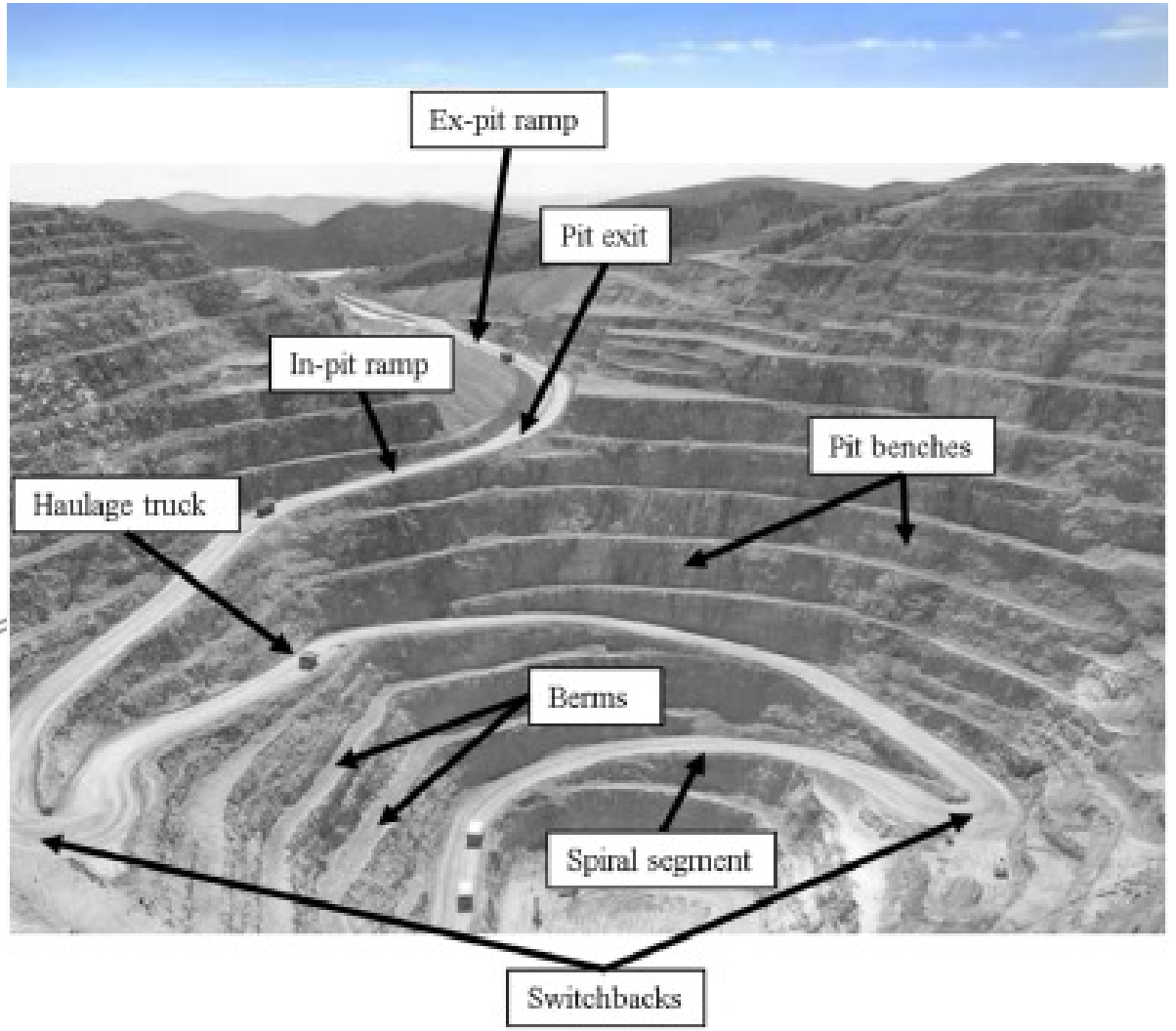
Mining

If you cannot grow it, you must mine it.



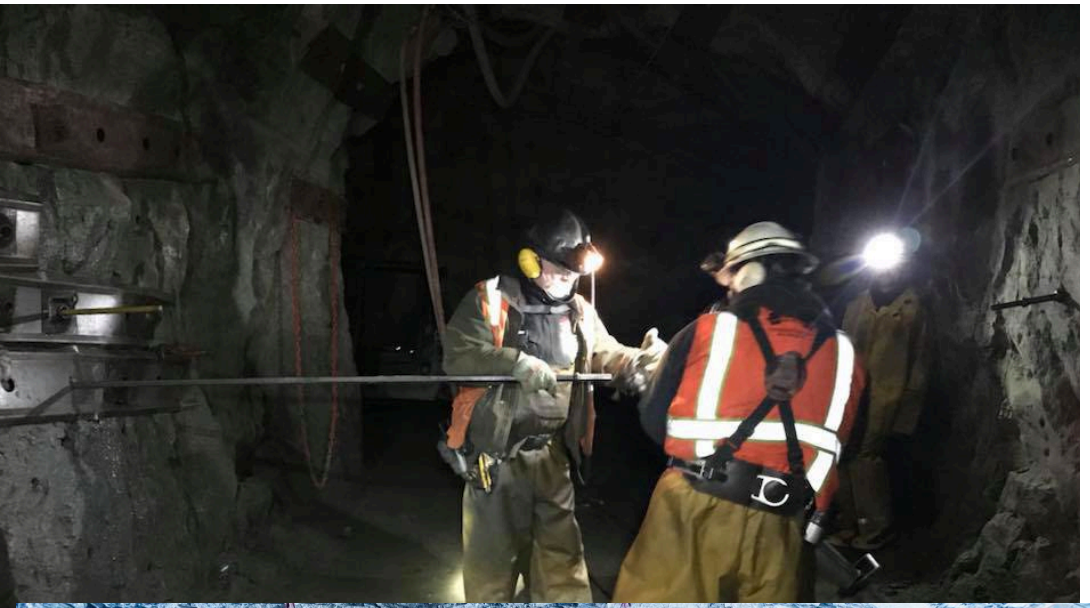
Open Pit mining

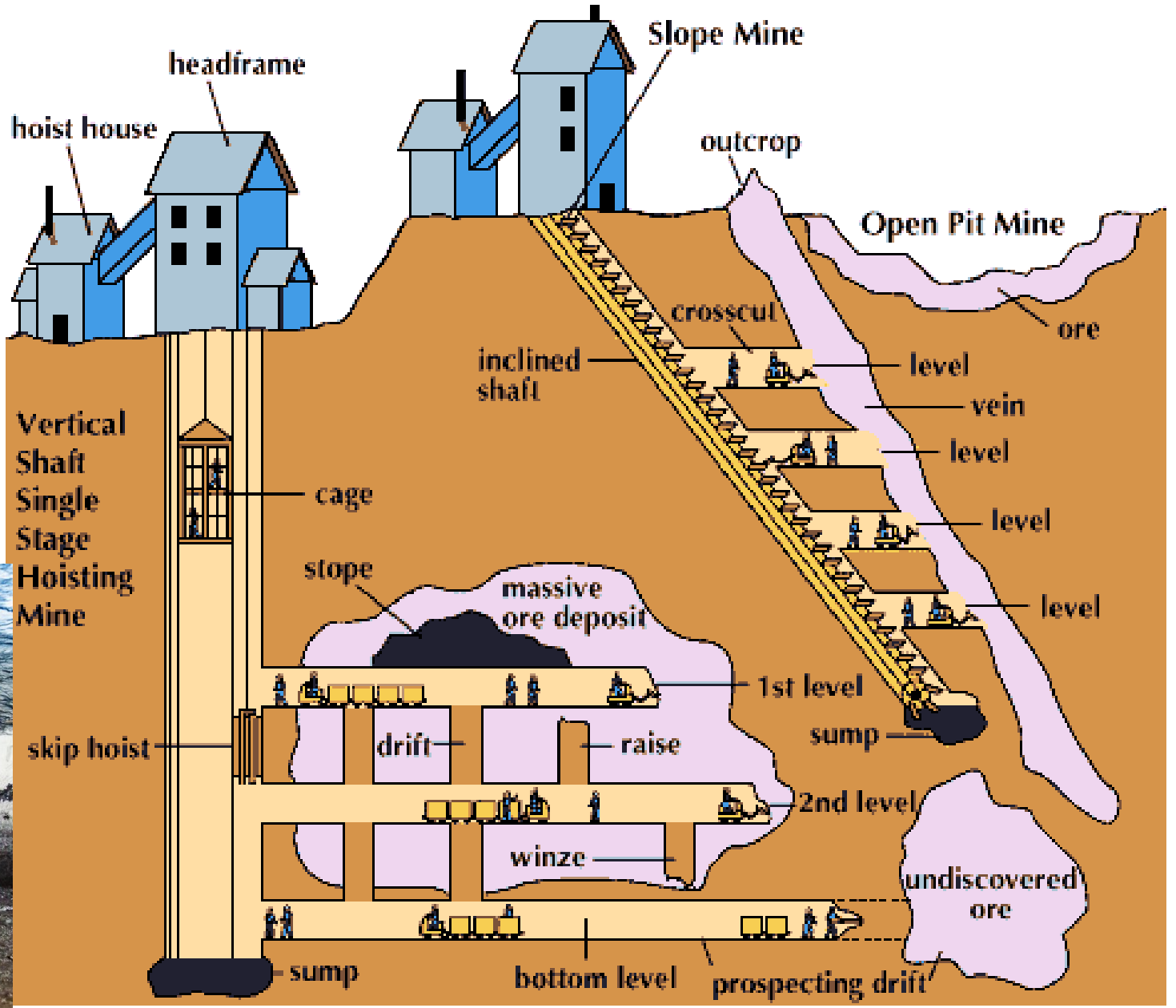




Reclamation

Underground mining





Igneous Rocks = Source material for…

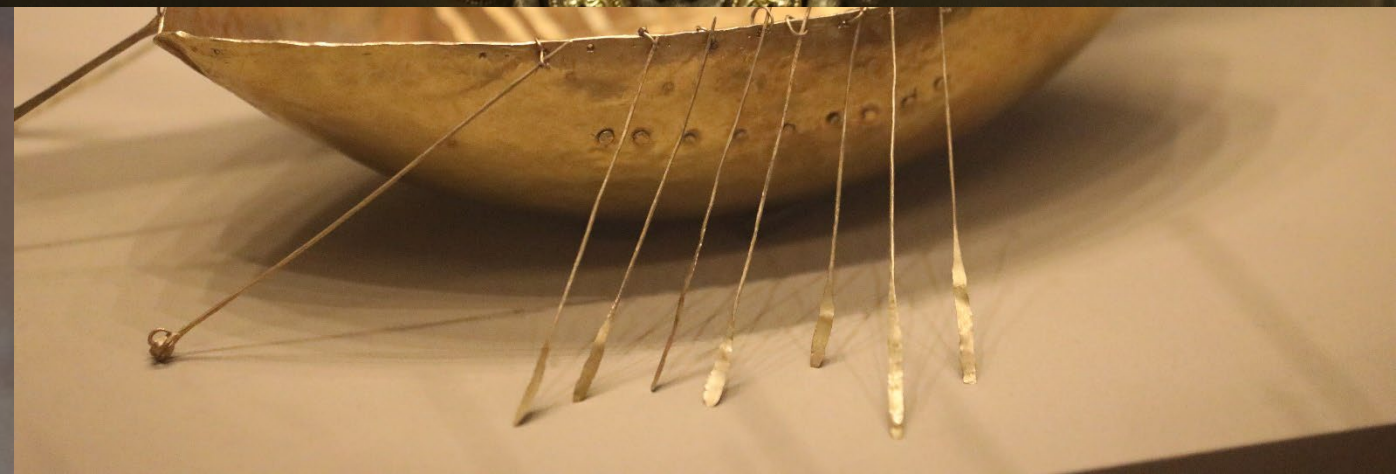
Hard minerals = Hard rocks

- Metals
  - Base
  - Precious
  - Rare-Earth
- Building materials
- Gemstones
  - Diamond, Tourmaline, Topaz
- Construction/Production

Base metals – common E.g. Iron, Copper, Nickel, Lead

Cross of Cong,
1123
True Cross
Remnant

Precious Metal



REE

Lutetium

Neodymium

Yttrium

LED light bulbs

Electric Motors

Cancer treatments

Rare Earth Elements

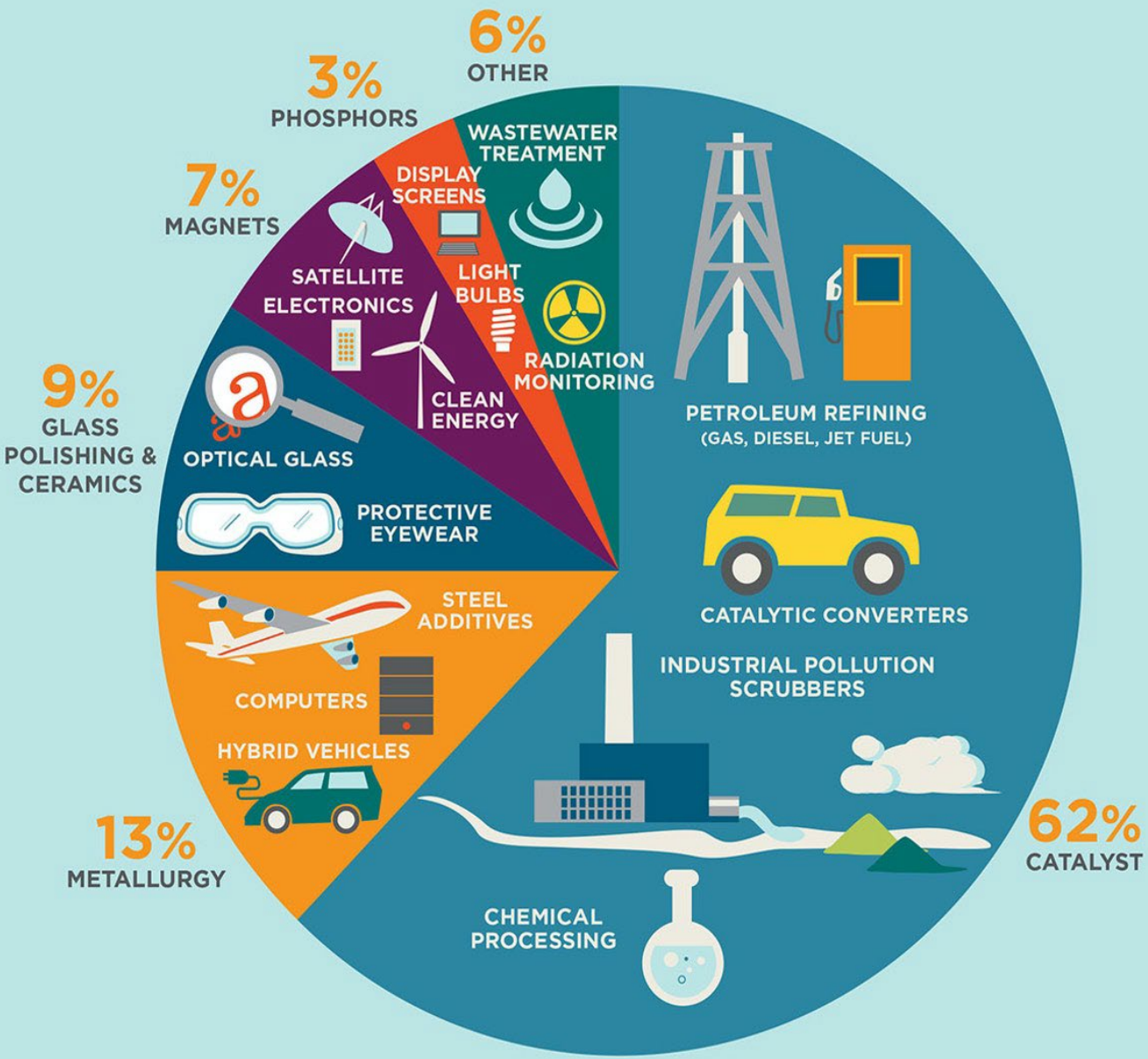
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Light Rare Earth Element

Heavy Rare Earth Element

US Rare Earths Usage



DATA SOURCE: UNITED STATES GEOLOGICAL SURVEY (2013)

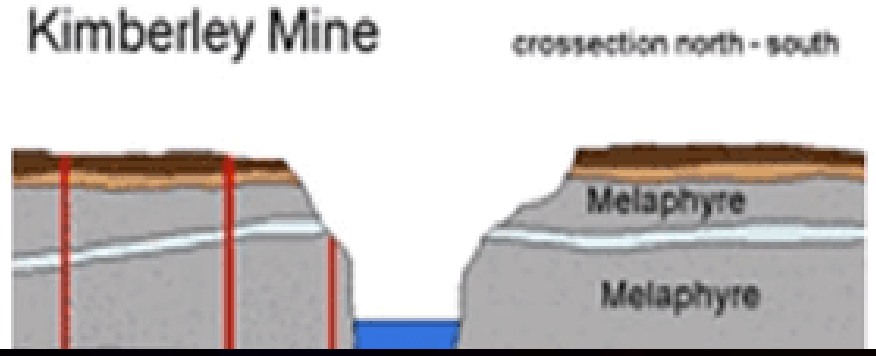
REEs

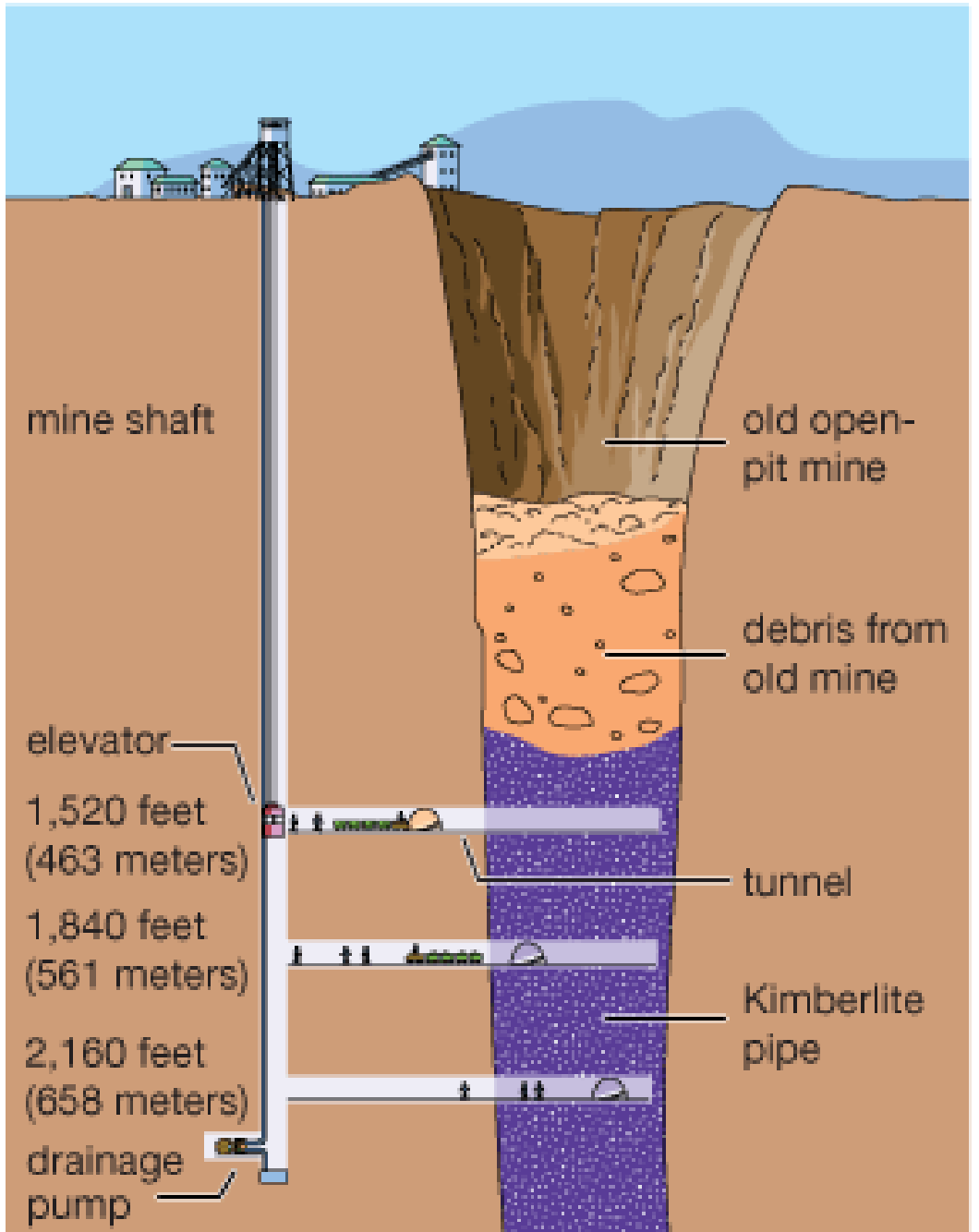
TABLE 9.1 Rare Earth Elements and Their Applications

Element	Example Applications
Yttrium	Metal alloys, visual displays, lasers, lighting
Lanthanum	Optical glass, nickel-metal-hydride batteries
Cerium	Colored glass (flat-panel displays), automobile catalytic converters
Praseodymium	Super-strong magnets, metal alloys, specialty glass, lasers
Neodymium	Permanent magnets
Samarium	Permanent magnets, nuclear reactor control rods, lasers
Europium	Optical fibers, visual displays, lighting
Gadolinium	Shielding in nuclear reactors, X-ray and magnetic resonance imaging scanning systems
Terbium	Visual displays, fuel cells, lighting
Dysprosium	Permanent magnets, lighting
Holmium	Lasers, high-strength magnets, glass coloring
Erbium	Glass coloring, fiber-optic cables
Thulium	Lasers, portable X-ray machines
Ytterbium	Stainless steel, lasers
Lutetium	Petroleum refining

Adapted from Van Gosen et al. (2019).

Kimberlites

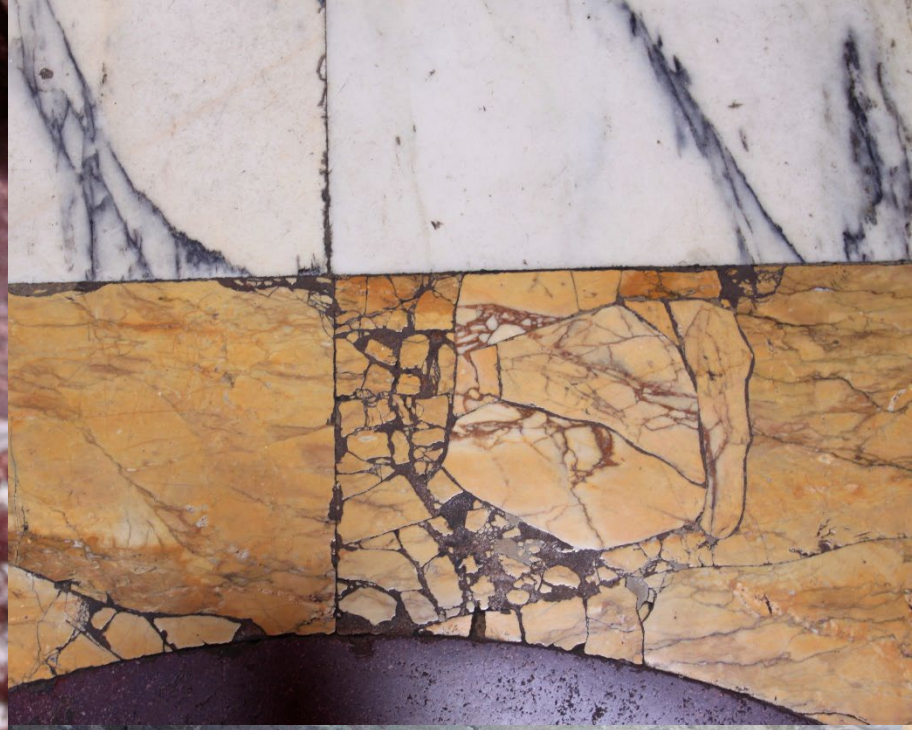




Construction Production

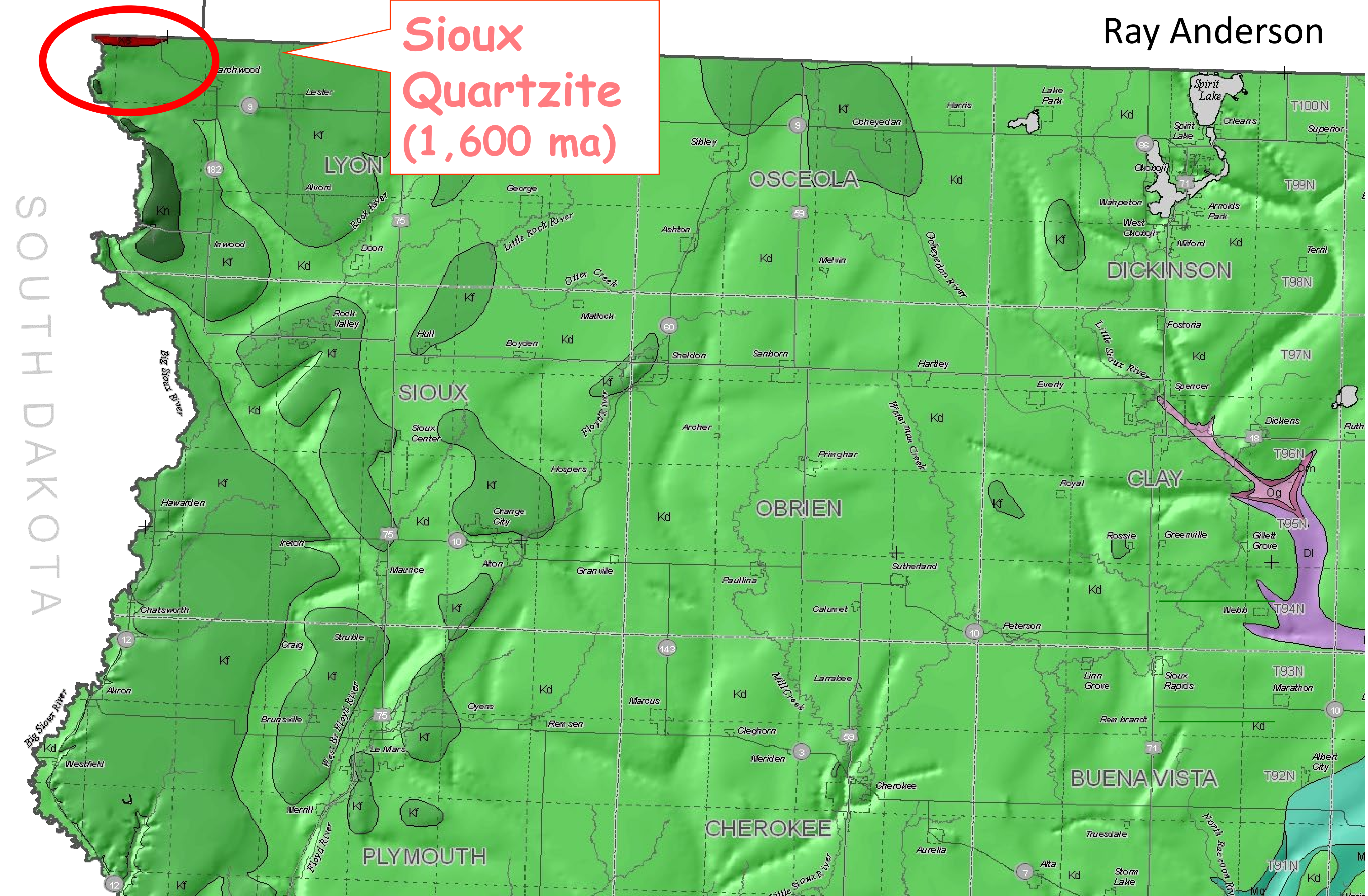
Gustav Vigeland Sculpture Park

https://vigeland.museum.no/en/vigelandpark



Ray Anderson

Sioux Quartzite (1,600 ma)



Sioux Quartzite

- Gitchi Manitou State Preserve
  - 1969
- The rock is still quarried near Sioux Falls, SD
- Was mistaking called Sioux Granite

Sioux Quartzite

- Correlates to Baraboo Quartzite
  - Occurs in eastern IA at great depths

Federal building in Sioux Falls, SD

Rock Co. Court House, MN



Sedimentary Rock Types

Clastic

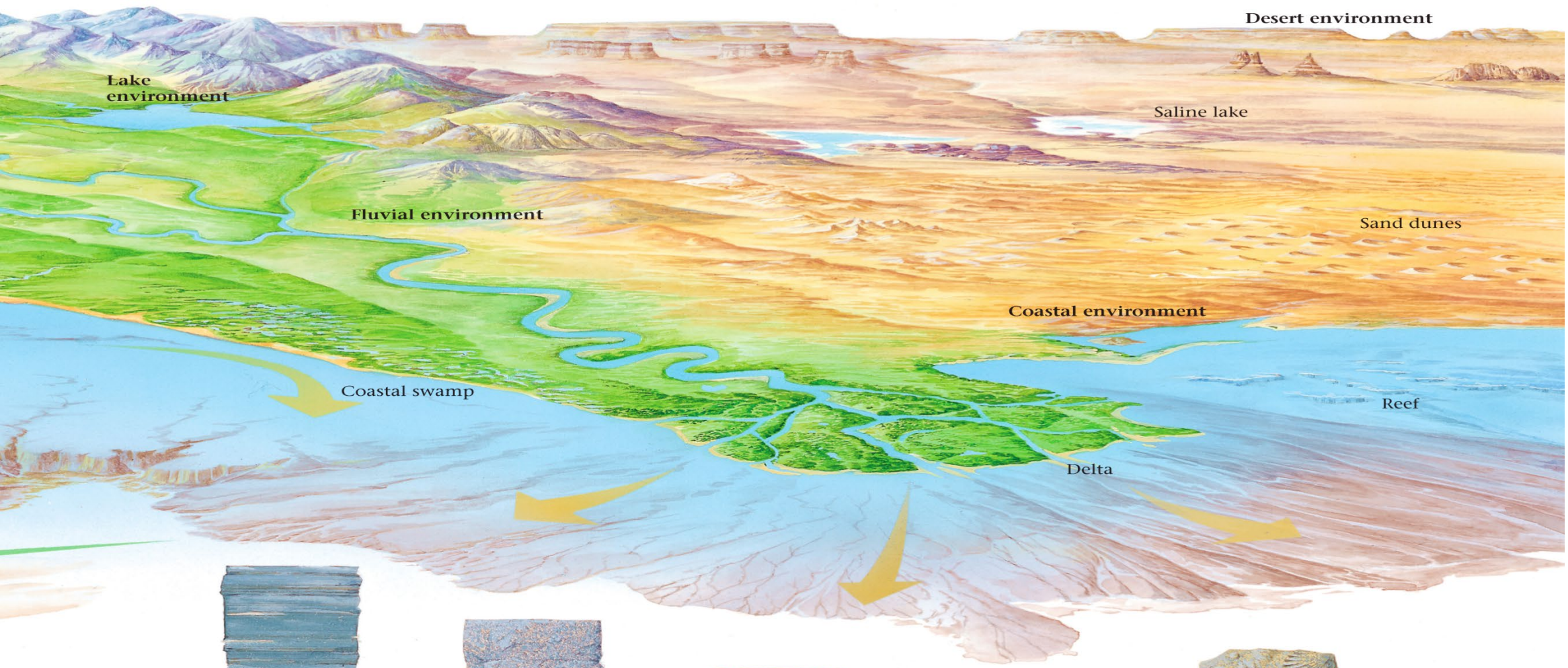
- Boulder
- Cobble *Breccia or Conglomerate*
- Pebble
- Sand *Sandstone*
- Silt *Siltstone*
- Clay *Shale*

Chemical

- Limestone
- Dolostone
- Chert
- Evaporates

Sedimentary Rocks = Source material for

- Building materials
- Energy (Coal, oil, gas, *different presentation*)
- Secondary gemstones
  - Jasper, Garnet, Zircon, Opal
- Agriculture
  - Weathering to Sediment to Soil
- Food
  - E.g. Salt



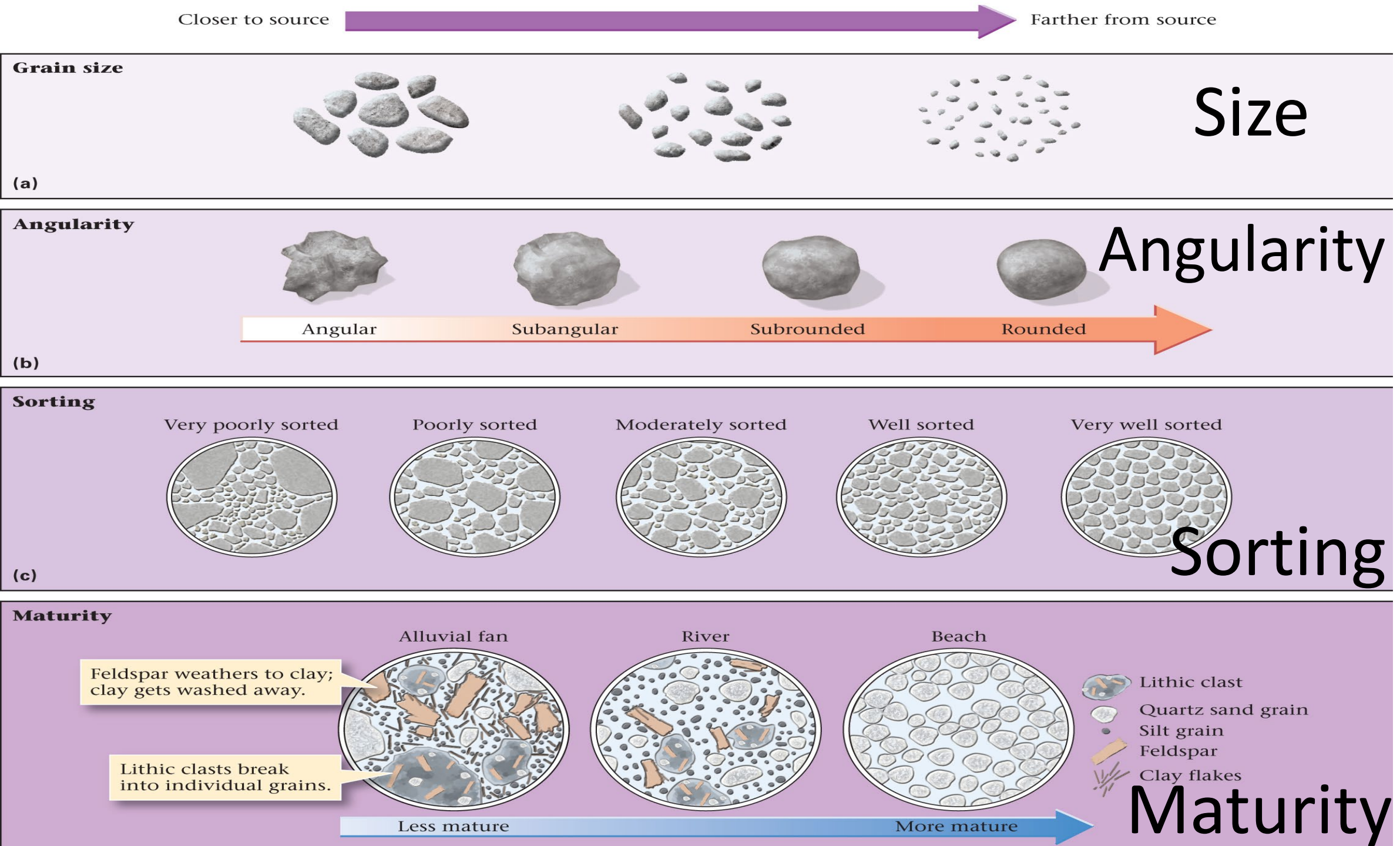
Shale

Siltstone

Sandstone

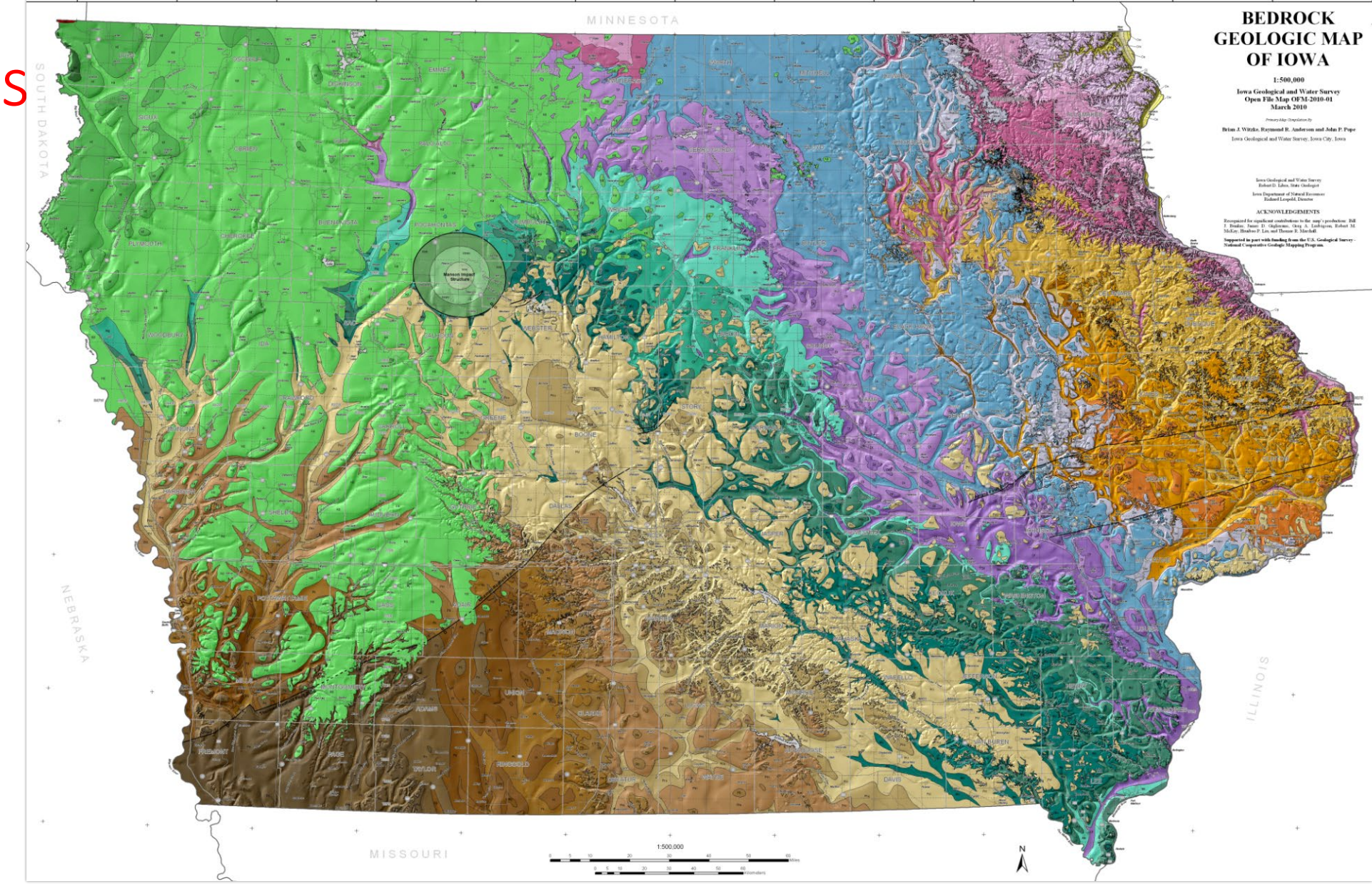
Conglomerate

Fossiliferous limestone


Closer to source
Farther from source
Grain size
(a)
Size
Angularity
Angular
Subangular
Subrounded
Rounded
(b)
Angularity
Sorting
Very poorly sorted
Poorly sorted
Moderately sorted
Well sorted
Very well sorted
(c)
Sorting
Maturity
Alluvial fan
River
Beach
Feldspar weathers to clay; clay gets washed away.
Lithic clasts break into individual grains.
Lithic clast
Quartz sand grain
Silt grain
Feldspar
Clay flakes
Less mature
More mature
Maturity

Iowa's Minerals and Rocks

- Galena
  - Lead
  - Zinc
- Gypsum
- Silica sand
- Iron



BMG

Martin Marietta Materials

IOWA LIMESTONE
PRODUCERS ASSOCIATION
Your limestone resource since 1945!

www.limestone.org

RIVER PRODUCTS COMPANY
IOWA CITY, IOWA

Wendling Quarries Inc.

Iowa - Lead and Zinc

- Near Dubuque, Iowa
  - Start approx. 1650
  - Peak 1830 to 1860
  - End 1910

Iowa – Iron ore

- Waukon, Allamakee County
- Iron Hill deposit
- First mined in 1899
- Missouri Iron Company of St. Louis operated a plant in Iowa until 1918.

Non – Metallic , Mineral Resources

Iowa – Clay

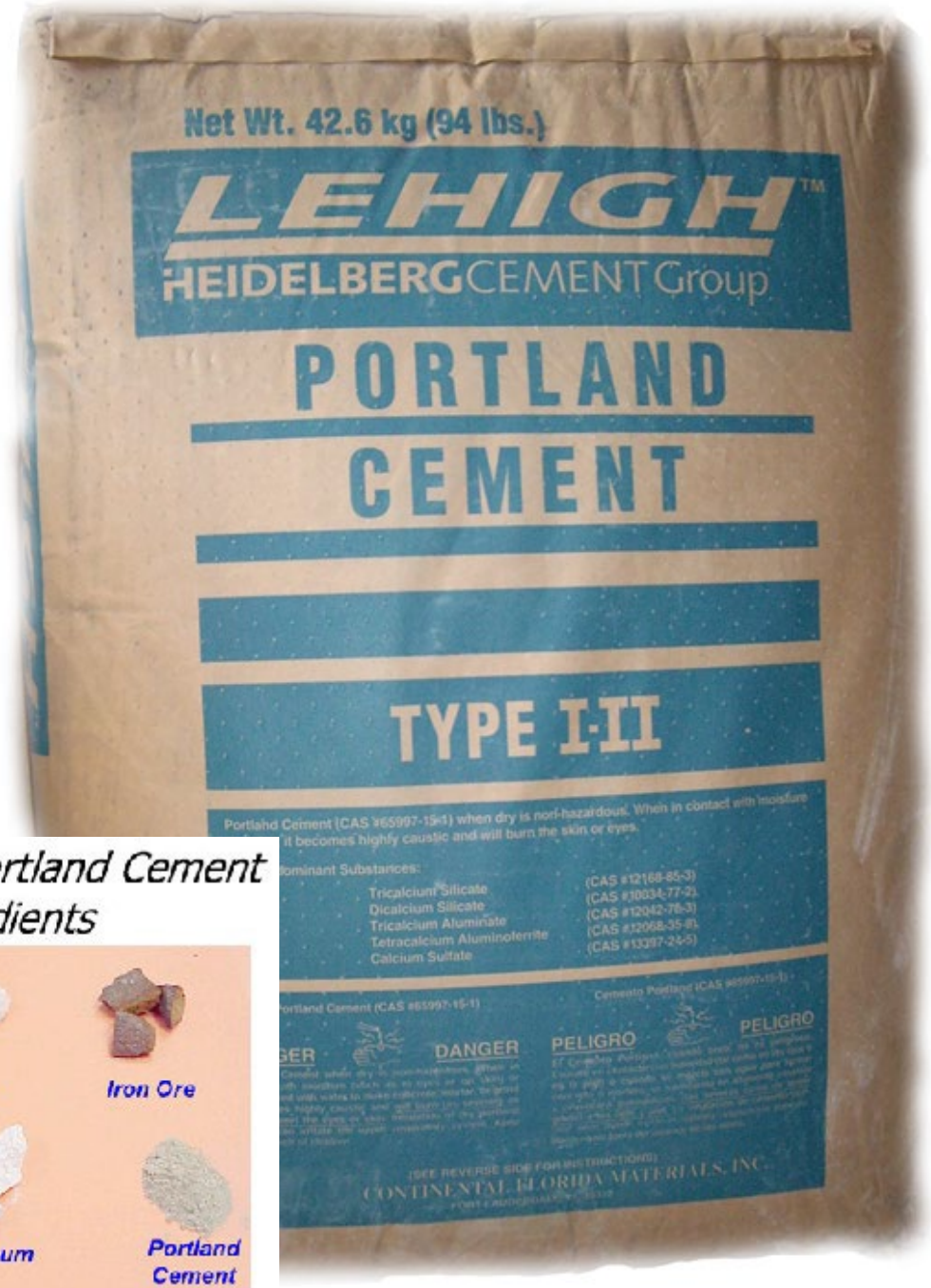
- In 1900 there were 381 clay companies operating in 89 of Iowa's counties!
- Shale bedrock, river alluvium, glacial sediment
- Produced brick and tile
- Today only 3 companies mine clay for bricks in Dallas and Woodbury counties

Iowa – Cement

- Burnt lime via kiln fired limestone.
  - Calcining to produce quicklime or calcium oxide
  - $CaCO_3$ + Heat → CaO + CO_2(g)
- Silurian Age Dolostone
  - Hopkinton Formation
    - Farmers Creek Member
    - Marcus Member
- Jackson and Cedar Counties

Iowa - Portland Cement

- Hardens underwater
- Put Kiln burning out of business
- Four plants continue to operate in Cerro Grodo, Polk, and Scott counties.
- Accounts for approx. 40% of mineral production today in Iowa.



Iowa – Stone/aggregate

- 19th century construction
- Primary production centers include Cedar, Jones, Des Moines, Marshall, Lee, Madison and Jackson counties
- In 1982, crushed stone surpassed Portland Cement as Iowa's leading mineral commodity
- There are nearly 500 registered quarries in Iowa today

Iowa – Gypsum

- Fort Dodge, Iowa 1850
- Two million tons per year at a value of $12 million
- Products
  - Wall board
  - Portland cement

Iowa – Sand and Gravel

- Important resource for Iowa's roads and construction.
- In Iowa's river valleys past and present…
- Approx. 16 million tons per year are mined per year at a value of approx. $60 million.

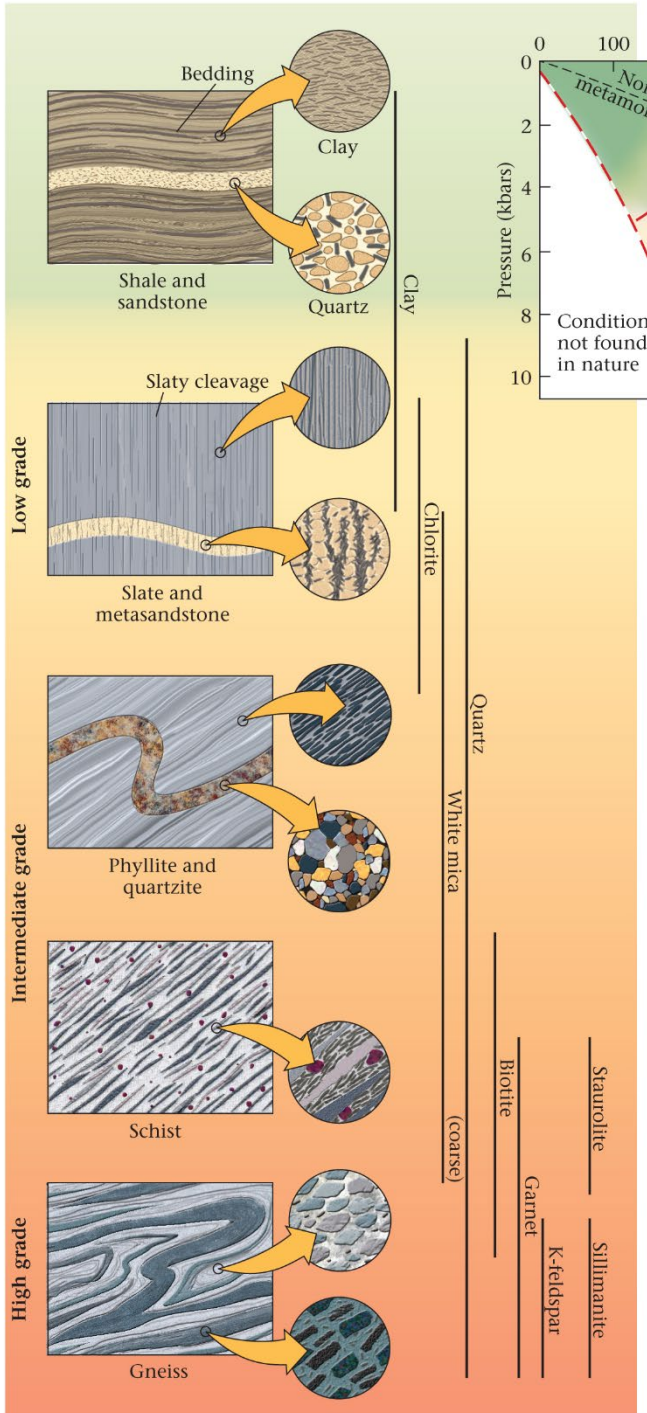
Metamorphic rocks = Source material for…

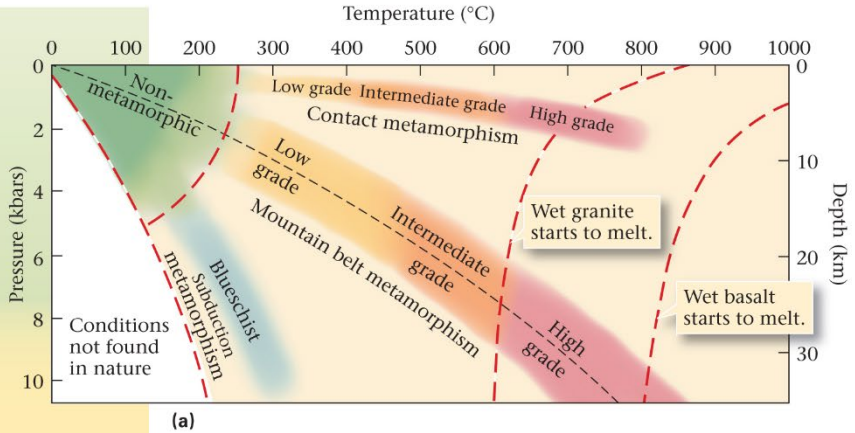
- Building material
  - Sandstone to harder Quartzite
  - Limestone to harder Marble
  - Shale to harder Slate
- Gemstones
  - Emerald, Jade, Ruby, lapis lazuli, Sapphire, Zircon

Low

Metamorphic grade

High





Increased

Heat

And

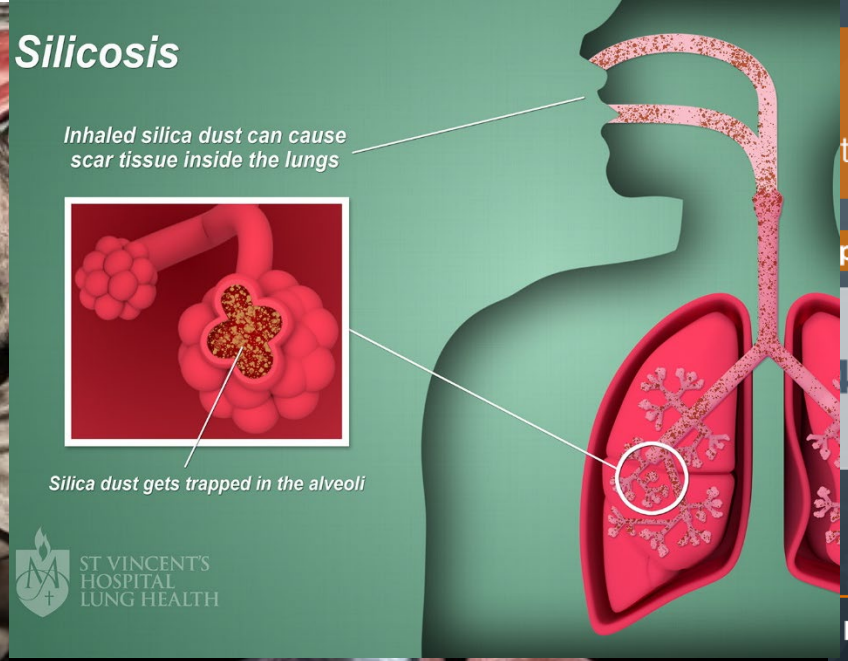
Pressure

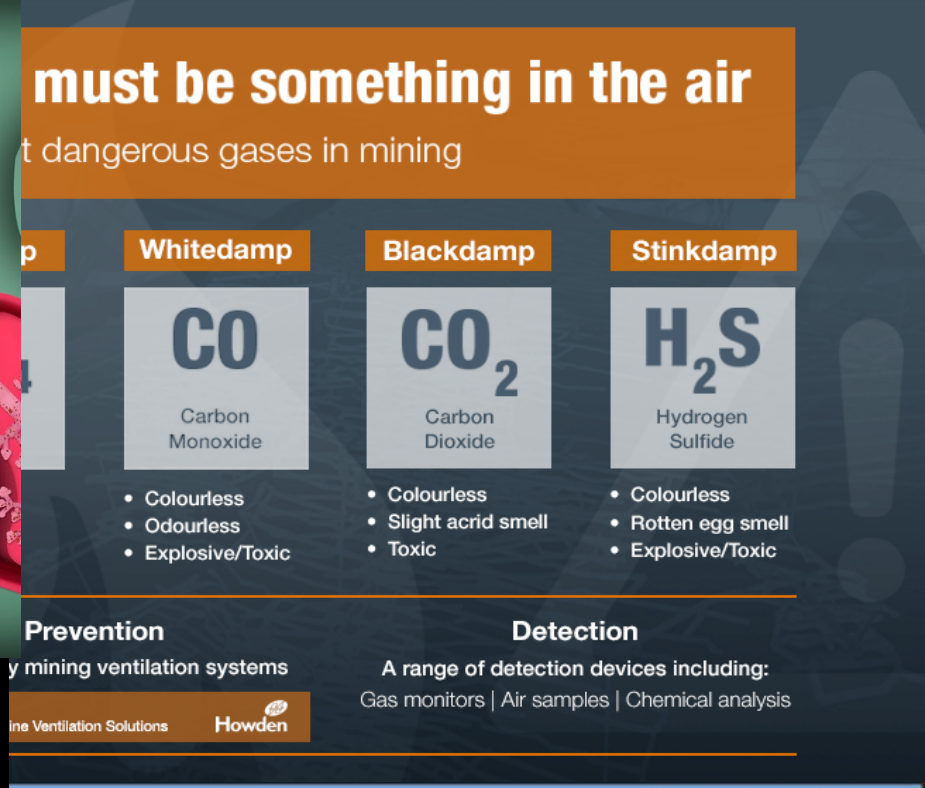
Slate

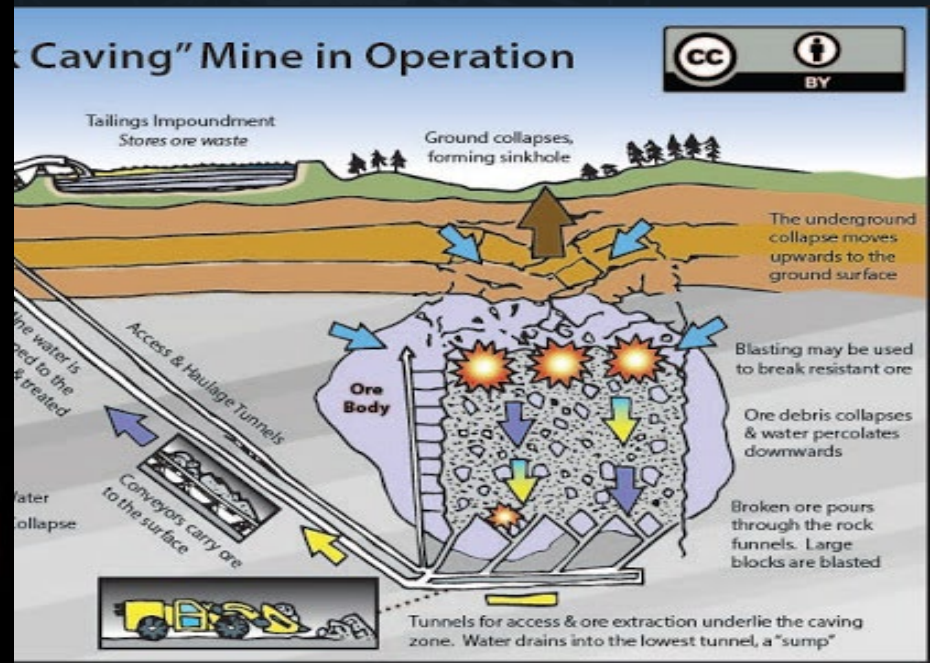
Phyllite

Schist

Gneiss


Silicosis
Inhaled silica dust can cause scar tissue inside the lungs
Silica dust gets trapped in the alveoli
ST VINCENT'S HOSPITAL LUNG HEALTH


must be something in the air
t dangerous gases in mining
Whitedamp
CO
Carbon Monoxide
• Colourless
• Odourless
• Explosive/Toxic
Blackdamp
CO_2
Carbon Dioxide
• Colourless
• Slight acrid smell
• Toxic
Stinkdamp
H_2S
Hydrogen Sulfide
• Colourless
• Rotten egg smell
• Explosive/Toxic
Prevention
mining ventilation systems
Howden
Detection
A range of detection devices including:
Gas monitors | Air samples | Chemical analysis


Caving" Mine in Operation
Tailings Impoundment
Stores ore waste
Ground collapses, forming sinkhole
The underground collapse moves upwards to the ground surface
Access & Haulage Tunnels
Ore Body
Blasting may be used to break resistant ore
Ore debris collapses & water percolates downwards
Broken ore pours through the rock funnels. Large blocks are blasted
Conveyors carry ore to the surface
Tunnels for access & ore extraction underlie the caving zone. Water drains into the lowest tunnel, a "sump"

U.S. Department of Labor

MSHA

Mine Safety & Health Administration

Risk	Affected compartments	Relevant toxic compounds
Overtopping of tailings dam	groundwater, surface water, soil	**Water emissions:** • in most cases radionuclides, mainly thorium and uranium; • heavy metals; • acids; • fluorides; **Air emissions:** • in most cases radionuclides, mainly thorium and uranium; • heavy metals; • HF, HCl, SO_2 etc.
Collapse of tailings dam by poor construction	groundwater, surface water, soil	
Collapse of tailing dam by seismic event	groundwater, surface water, soil	
Pipe leakage	groundwater, surface water, soil	
Ground of tailing pond not leak-proof	groundwater	
Waste rock stockpiles exposed to rainwater	groundwater, surface water, soil	
Dusts from waste rock and tailings	air, soil	
No site-rehabilitation after cease of mining operation	land-use, long-term contaminated land	
Processing without flue gas filters	air, soil	
Processing without waste water treatment	surface water	

Gold and its Cyanide problem

Water Consumption for Mining

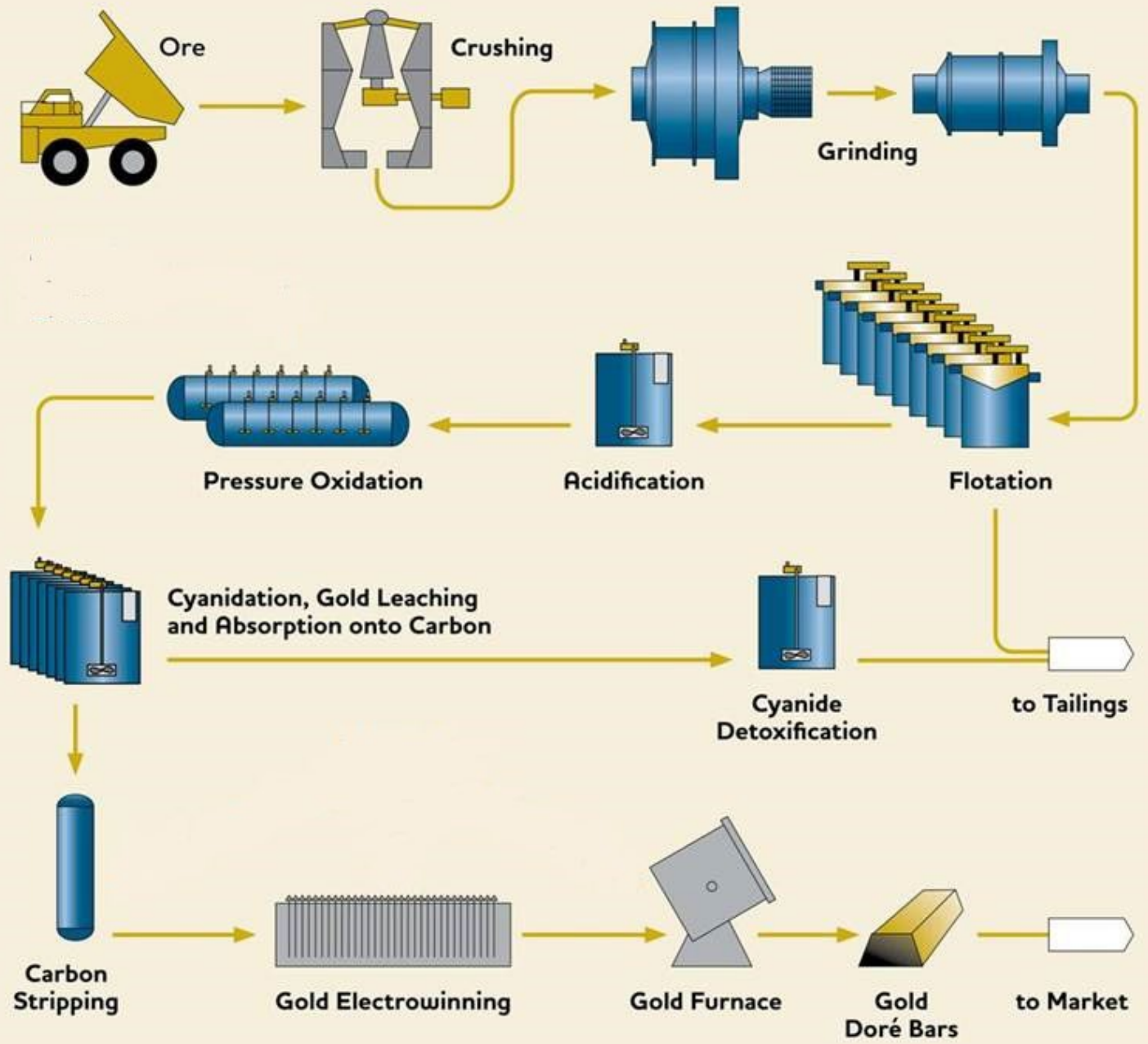
1 ton of Coal = 15m³ of water

1 ton of Nickel = 376m³ of water

1 ton of Gold = 250,000m³ of water

P2W Pollution To Water

THE MILLING PROCESS



Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

- December 11, 1980
- Law created a tax on the chemical and petroleum industries

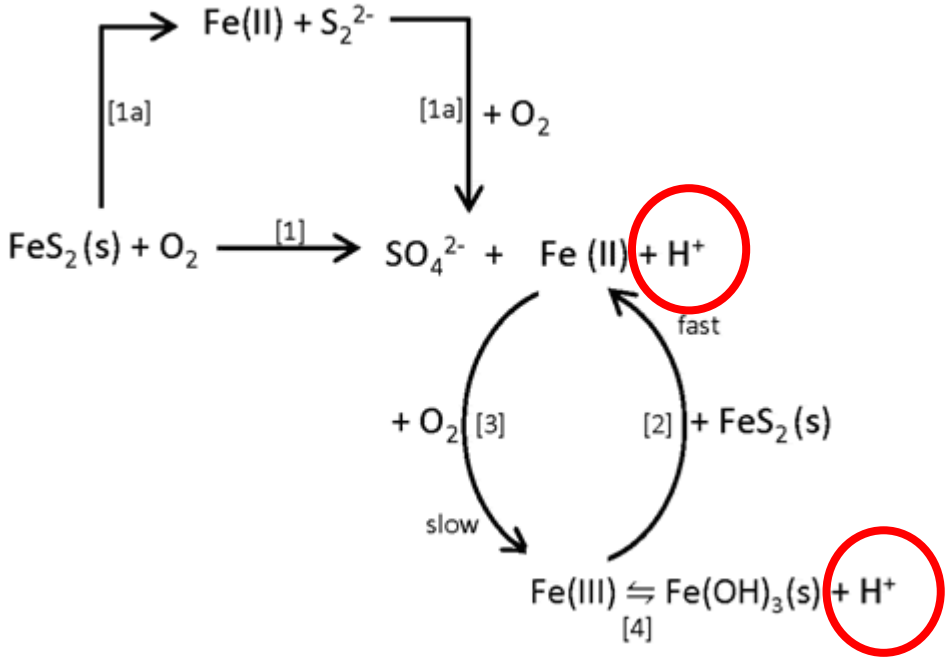
- Established prohibitions and requirements concerning closed to abandoned hazardous waste sites;
- Provided for liability of persons responsible for releases of hazardous waste at these sites; and
- Established a trust fund to provide for cleanup when no responsible party could be identified.

Superfund – EPA program – 40 yr. anniversary

- https://www.epa.gov/superfund
- Responsible for cleaning up some of the nation's most contaminated land and responding to environmental emergencies, oil spills and natural disasters.
- Does Iowa have any? Use the Website to learn more…

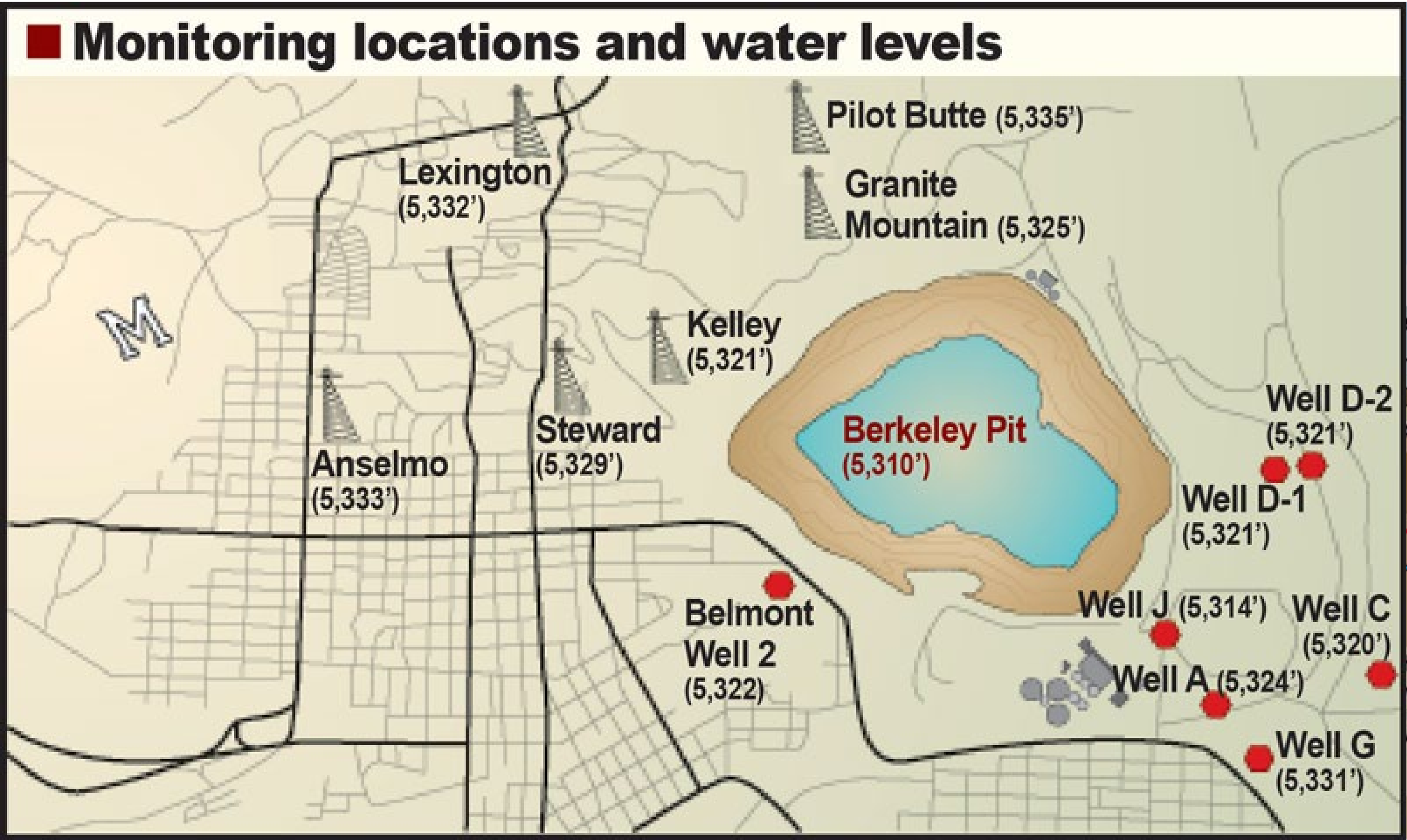
Butte, Montana Berkeley Pit -

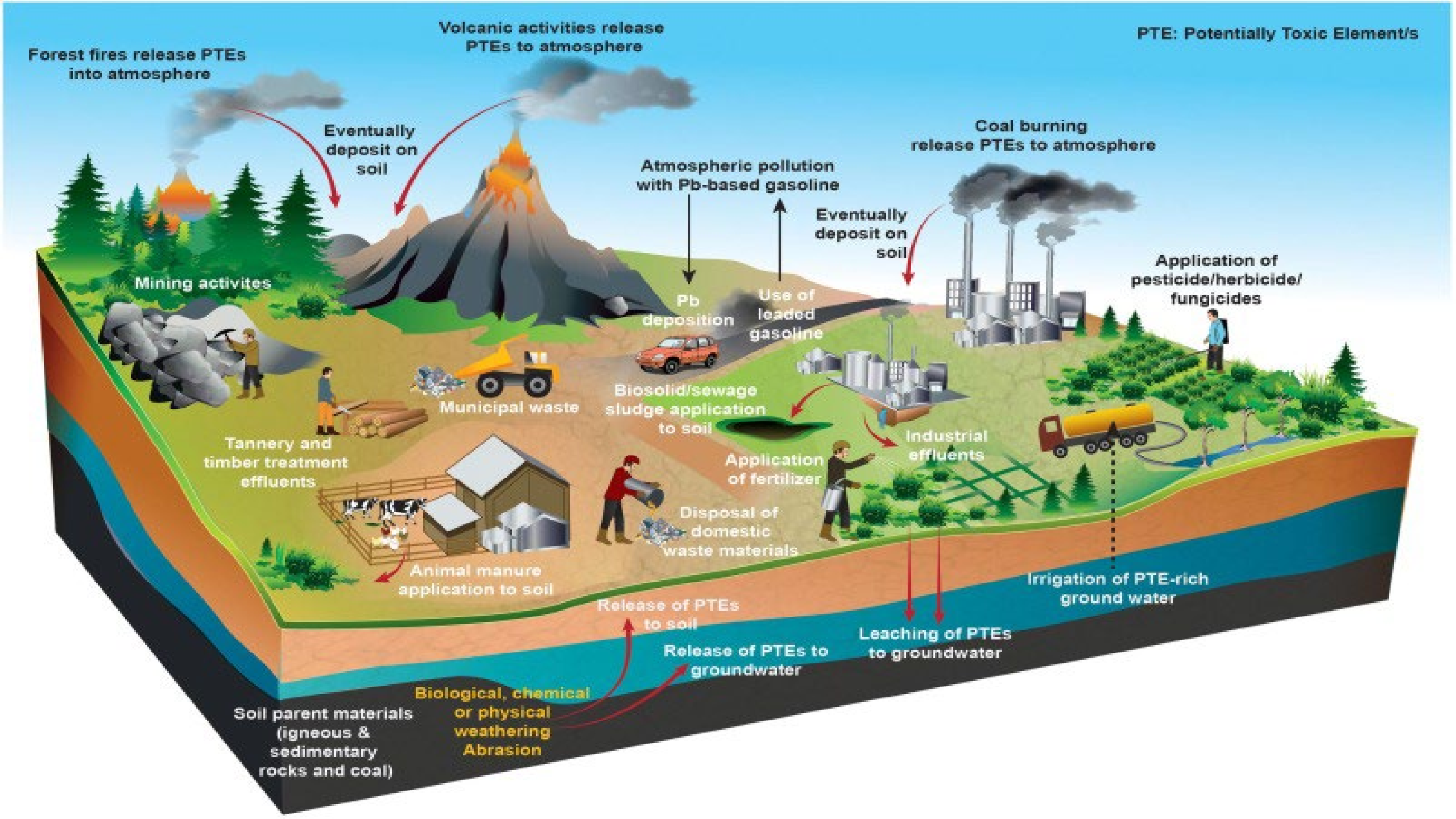
Copper Mine (opened 1955/closed Earth Day 1982)
Approx. 50 billion gal. of toxic water (pH = 2.7)
Copper, iron, arsenic, cadmium, sulfuric acid



https://serc.carleton.edu/NAGTWorkshops/health/case_studies/butte_case_stud.html

Monitoring locations and water levels




PTE: Potentially Toxic Element/s
Forest fires release PTEs into atmosphere
Volcanic activities release PTEs to atmosphere
Eventually deposit on soil
Coal burning release PTEs to atmosphere
Atmospheric pollution with Pb-based gasoline
Eventually deposit on soil
Application of pesticide/herbicide/ fungicides
Mining activites
Pb deposition
Use of leaded gasoline
Municipal waste
Biosolid/sewage sludge application to soil
Tannery and timber treatment effluents
Application of fertilizer
Industrial effluents
Disposal of domestic waste materials
Animal manure application to soil
Irrigation of PTE-rich ground water
Release of PTEs to soil
Release of PTEs to groundwater
Leaching of PTEs to groundwater
Biological, chemical or physical weathering Abrasion
Soil parent materials (igneous & sedimentary rocks and coal)