

# Minerals and their Engineering Properties

Engineering Geology  
Fall 2016

- Rock =  $\Sigma$  minerals
- About 2000 minerals and 100 chemical elements
- Mineral = inorganic crystalline structure
- Homogeneous substance, definite chemical composition, definite internal structure
- Under ideal conditions = crystals

# Ten critical elements found in most rocks and soils



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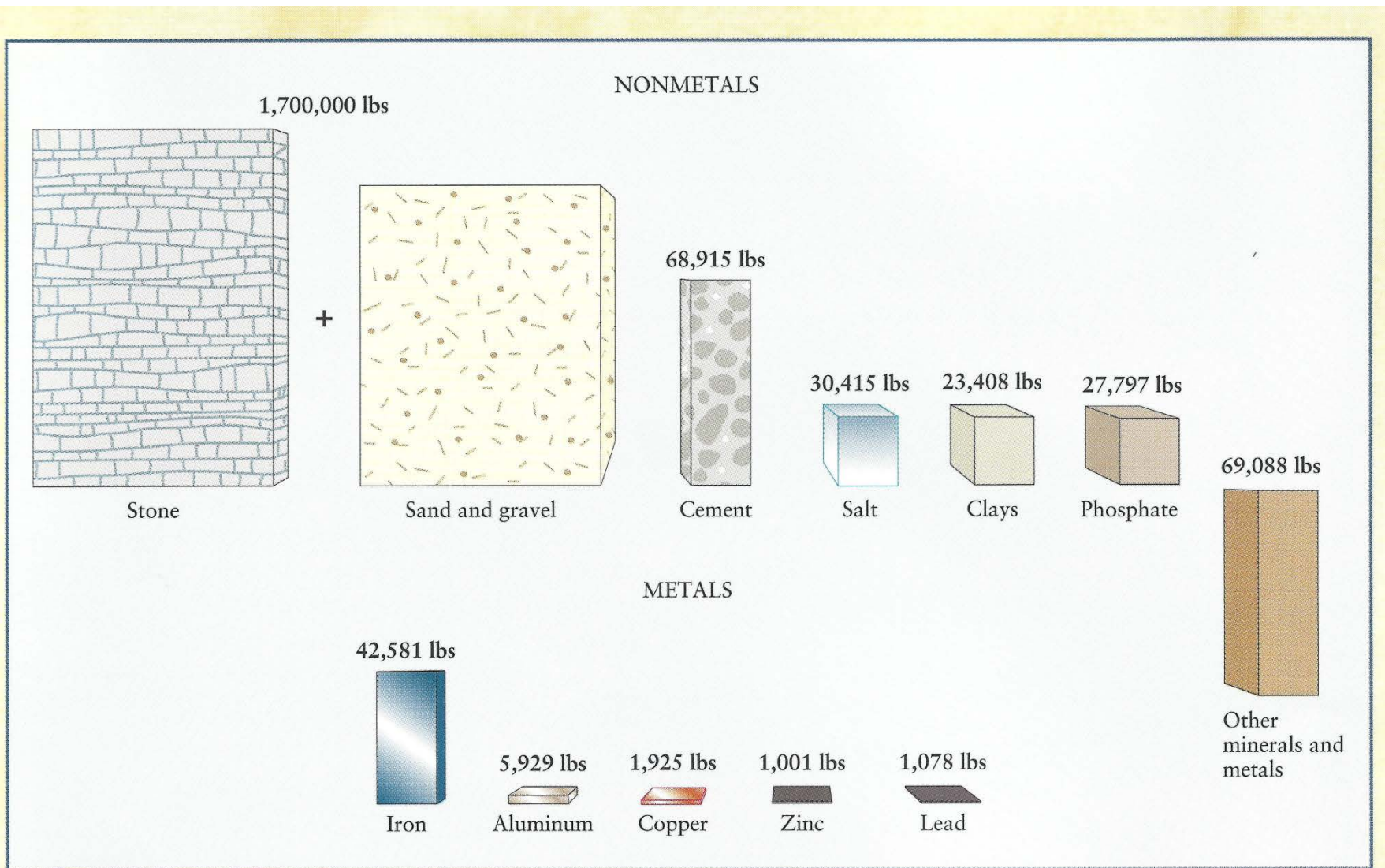
$$\text{Sum} = 100\%$$

# Element Bonding

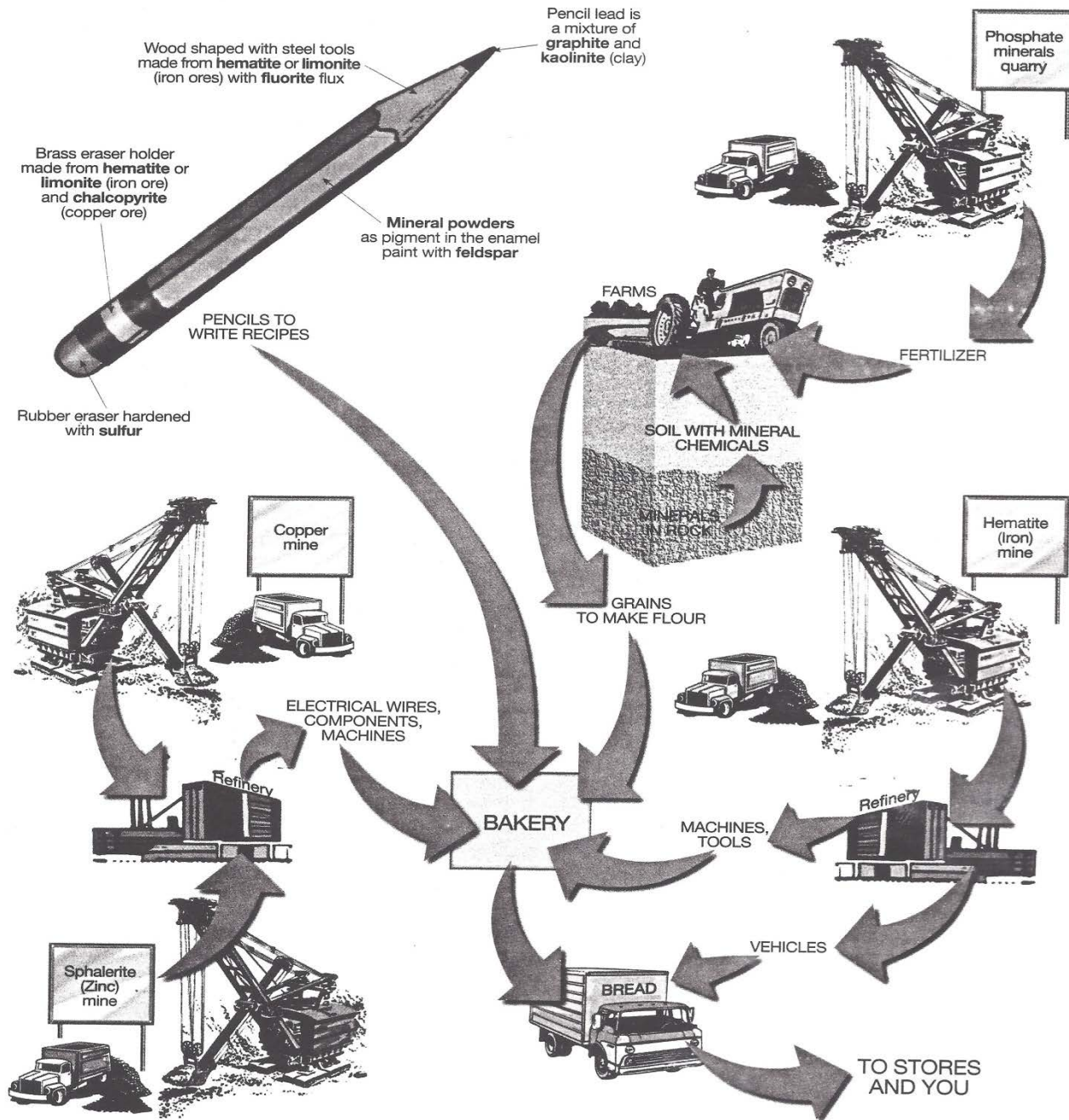
- **Ionic bonds** – weak and can be attacked by water molecules  
Minerals: reactive, soluble, breakdown
- **Covalent bonds** – strong  
Minerals: durable and inert

# Paragenesis

- Community of minerals
  - Igneous
  - Sedimentary
  - Metamorphic
- Identification of Minerals
  - Examination of hand specimen
  - Examination of thin slices (0.03 mm) using optical properties of minerals

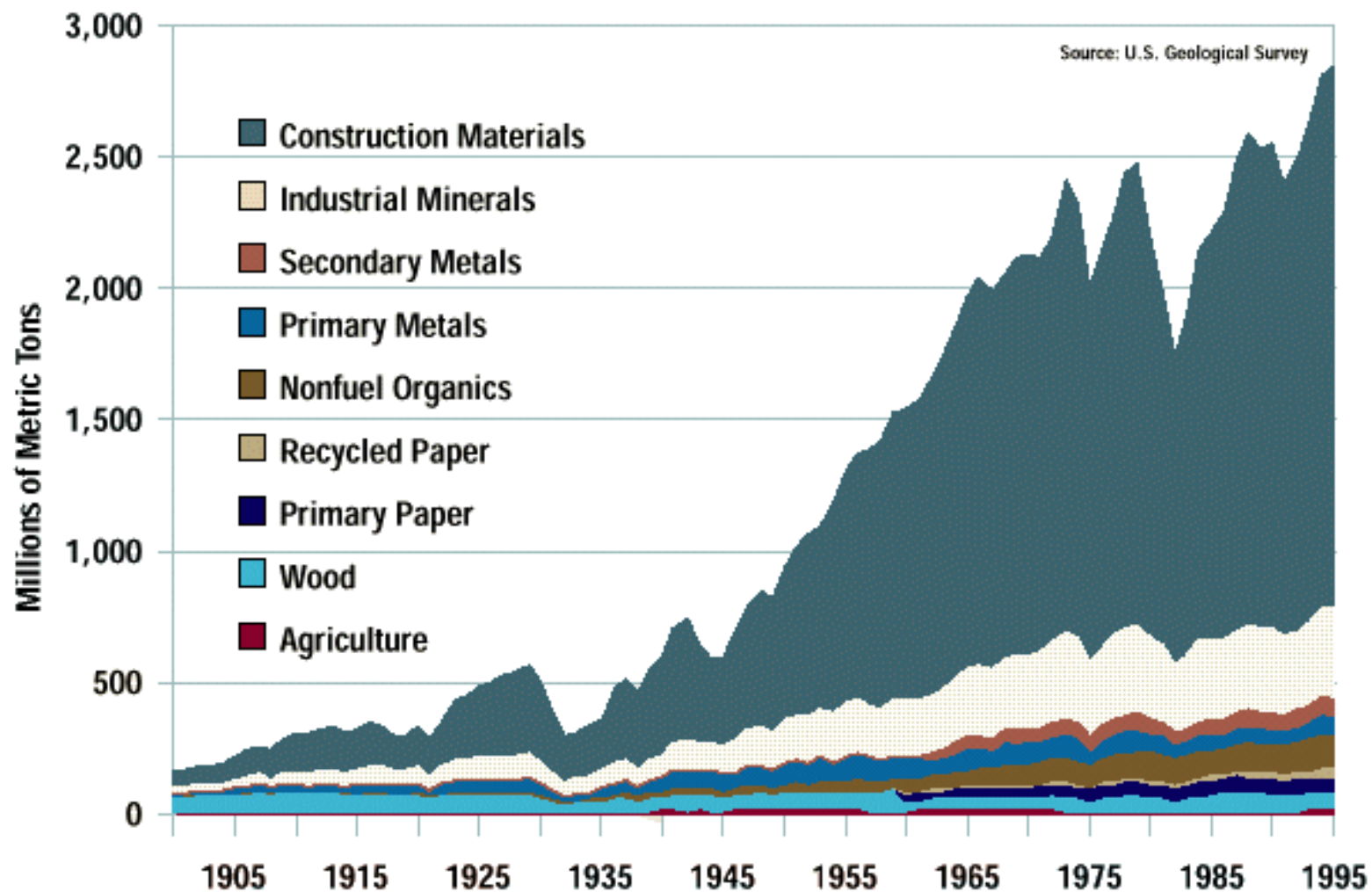


**Figure 1** Every American born will need nearly 2 million pounds of minerals and metals in a lifetime. (Mineral Information Institute, 2000).



**FIGURE 2.2** Descriptions of how minerals have been used to manufacture some common items that you probably use everyday.

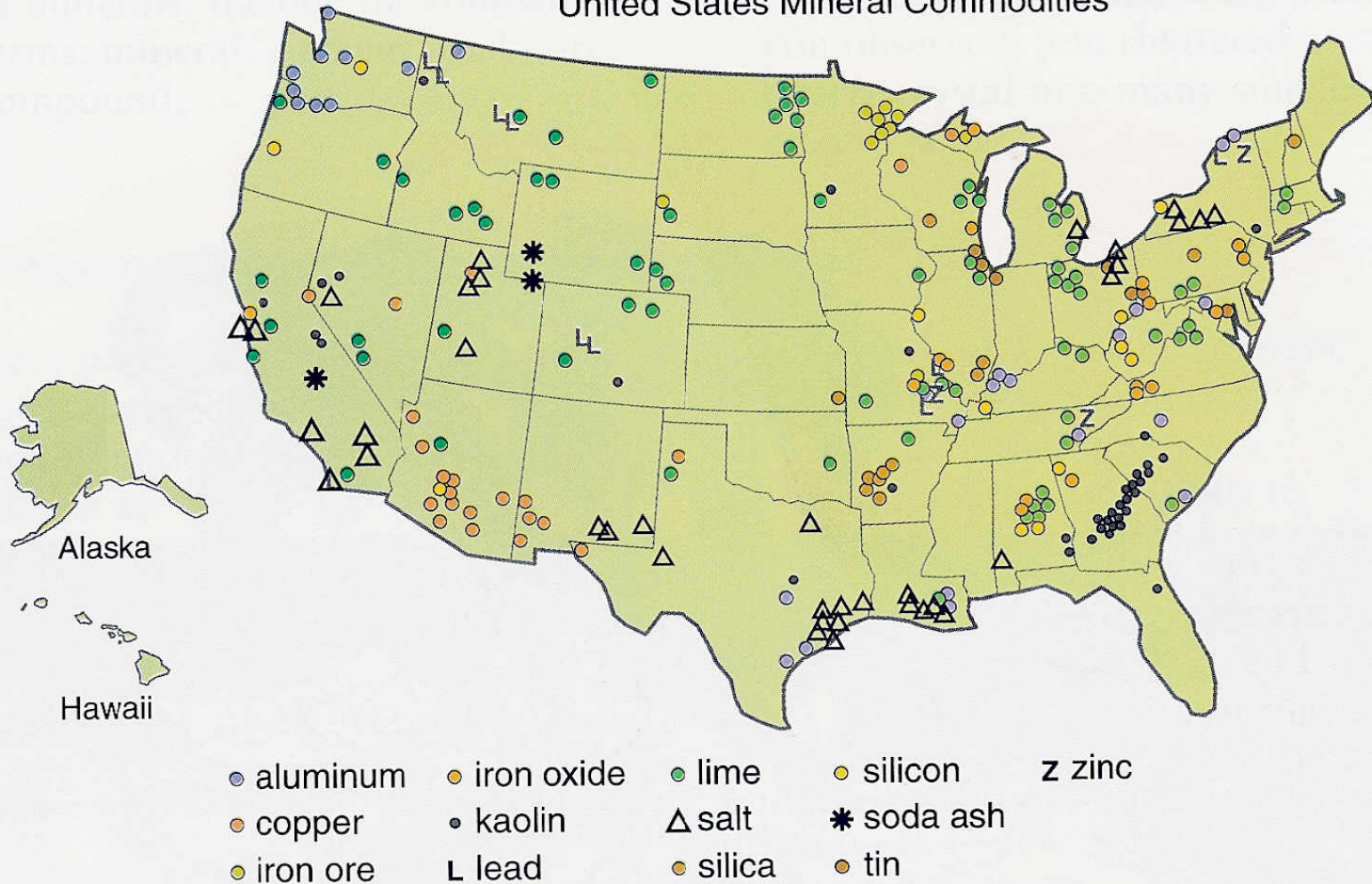




[Additional Maps](#)



## United States Mineral Commodities



<http://minerals.usgs.gov/>

<http://pubs.usgs.gov/of/2014/1082/pdf/ofr2014-1082.pdf>

## Display



A mobile device's glass screen is very durable because glassmakers combine its main ingredient, **silica** (silicon dioxide or quartz) **sand**, with ceramic materials and then add potassium.



Layers of indium-tin-oxide are used to create transparent circuits in the display. Tin is also the ingredient in circuit board solder, and **cassiterite** is a primary source of tin.



Gallium provides light emitting diode (LED) backlighting. **Bauxite** is the primary source of this commodity.



**Sphalerite** is the source of indium (used in the screen's conductive coating) and germanium (used in displays and LEDs).



## Electronics and Circuitry



The content of copper in a mobile device far exceeds the amount of any other metal. Copper conducts electricity and heat and comes from the source mineral **chalcopyrite**.



**Tetrahedrite** is a primary source of silver. Silver-based inks on composite boards create electrical pathways through a device.



**Silicon**, very abundant in the Earth's crust, is produced from the source mineral quartz and is the basis of integrated circuits.



**Arsenopyrite** is a source of arsenic, which is used in radio frequency and power amplifiers.



Tantalum, from the source mineral **tantalite**, is added to capacitors to regulate voltage and improve the audio quality of a device.



**Wolframite** is a source of tungsten, which acts as a heat sink and provides the mass for mobile phone vibration.

## Battery



**Spodumene** and subsurface brines are the sources of lithium used in cathodes of lithium-ion batteries.



**Graphite** is used for the anodes of lithium-ion batteries because of its electrical and thermal conductivity.

## Speakers and Vibration



**Bastnaesite** is a source of rare-earth elements used to produce magnets in speakers, microphones, and vibration motors.

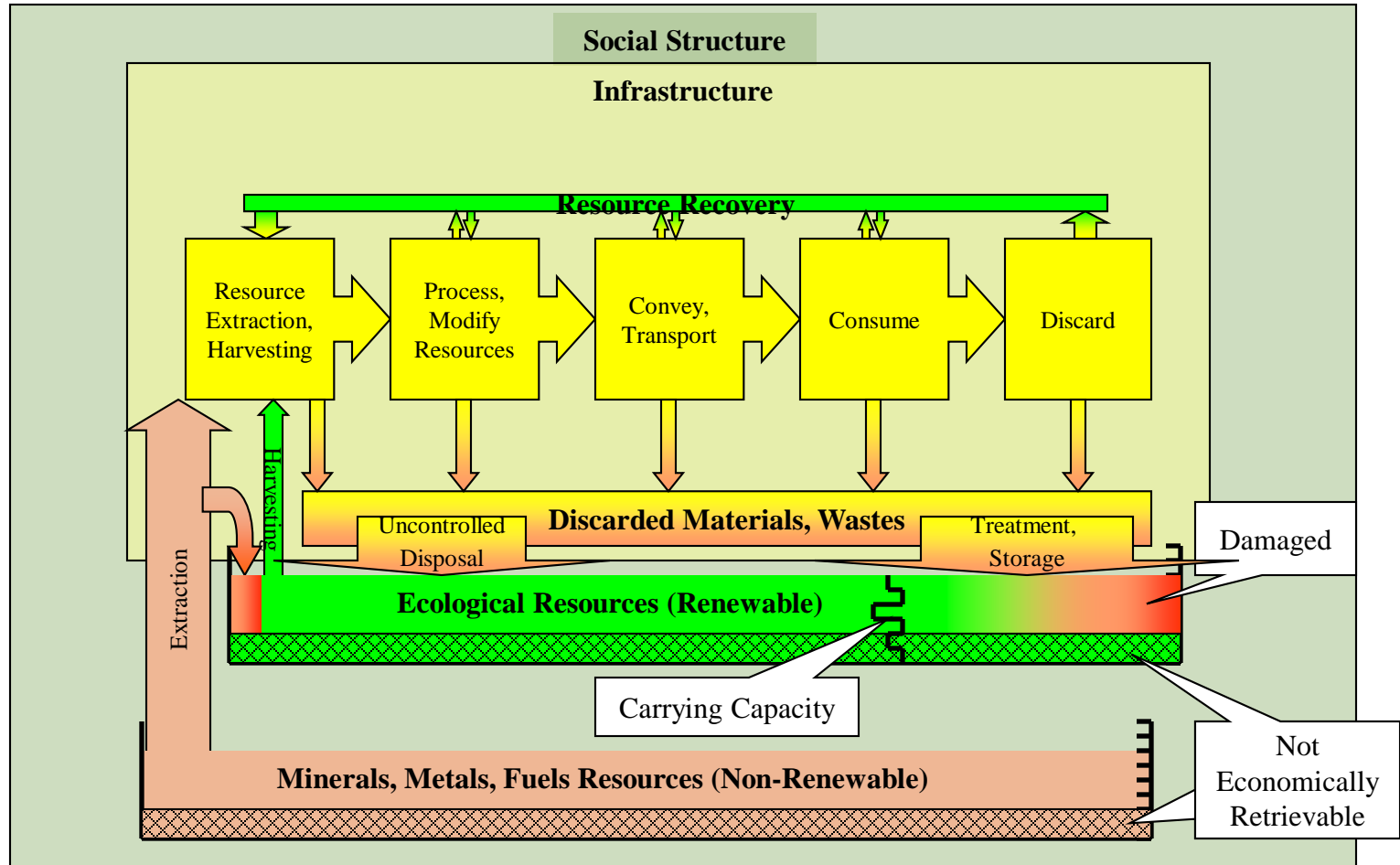
# Laptop Computer

“On an all-in basis, counting everything processed and distilled into those 10 lbs, it weighs as much as 40,000 lbs, and its manufacturers, going all the way back to the mines and wellheads, created huge abuse to Earth through extractive and polluting processes to make it.”

(Ray Anderson, 1998).

# Production-Consumption Model

Adapted from D. Roberts and W. Wallace



***Cradle to Grave (Take – Make – Waste)***



# Copper

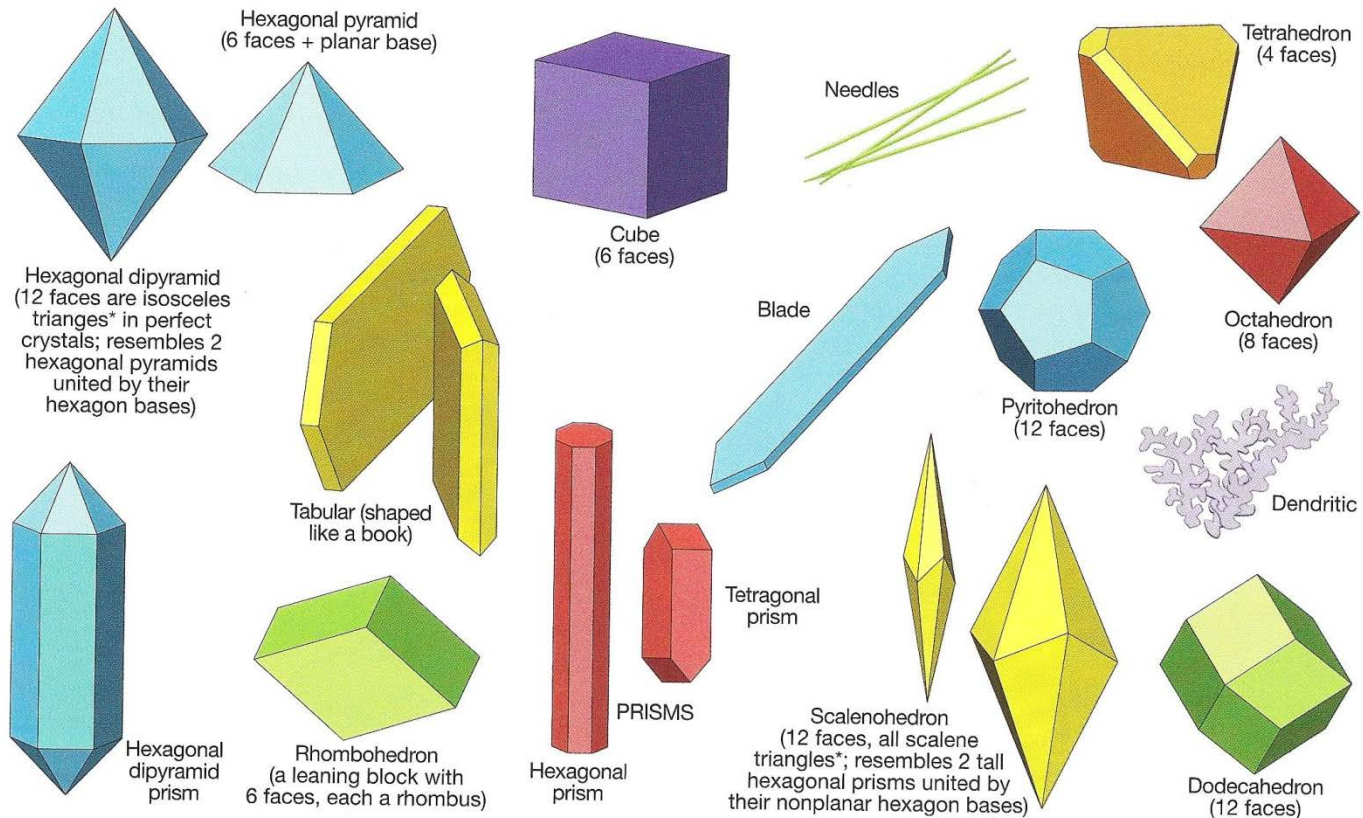
- Base metal
- 0.0058% of Earth's crust by weight
- Main rock = Chalcopyrite  $\text{CuFeS}_2$

Element	Atomic mass unit (g/mol)	Number of atoms	Total mass (g/mol)
Cu	63.54	1	63.54
Fe	55.85		
S	32.06		
			Sum ( $\Sigma$ ) =

# Identification of Minerals

<http://www.bing.com/videos/search?q=minerals+videos&FORM=VIRE13#view=detail&mid=2E1A08DEDCA54D04BA7F2E1A08DEDCA54D04BA7F>




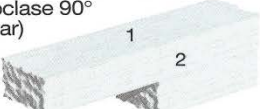

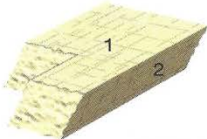


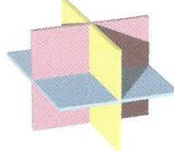
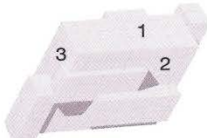

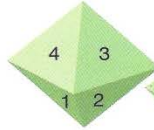



# Crystal symmetry



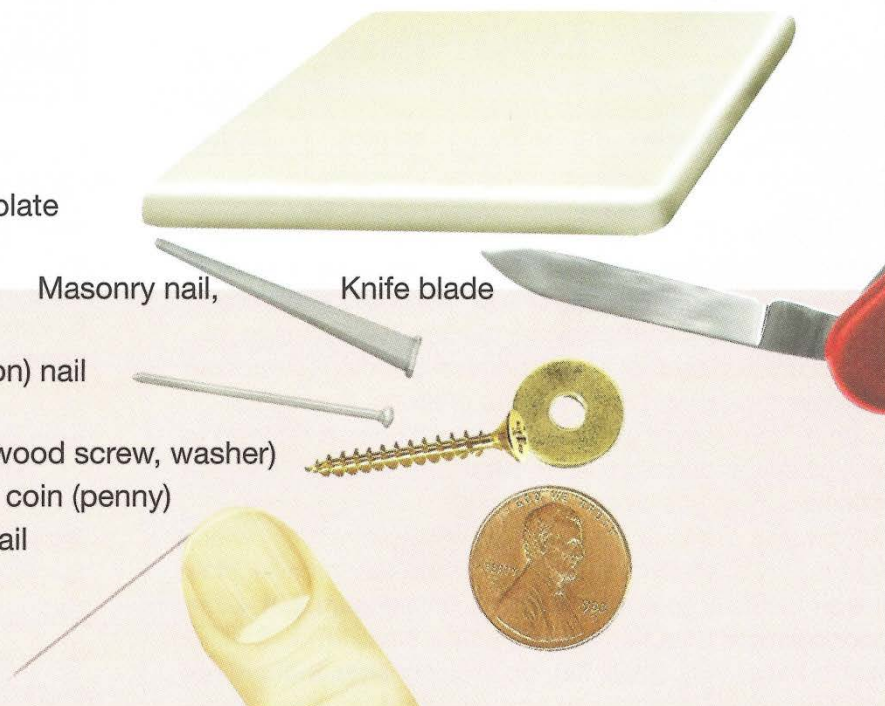
\*Isosceles triangles have two sides of equal length and scalene triangles have no sides of equal length.

**FIGURE 3.3** Some *crystal forms* (geometric shapes) or habits. The flat outer surfaces of these forms are called *crystal faces*. Crystal form is an external feature of mineral crystals. *Massive* form refers to cases where mineral crystals are so tightly intergrown that no distinguishing crystal form is visible.



Number of Cleavages and Their Directions	Name and Description of How the Mineral Breaks	Shape of Broken Pieces (Cleavage Directions are Numbered)	Illustration of Cleavage Directions
No cleavage (fractures only)	No parallel broken surfaces; May have conchoidal fracture (like glass)	 <p>Quartz</p>	None (no cleavage)
1 cleavage	<b>Basal (book) cleavage</b> "Books" that split apart along flat sheets	 <p>Muscovite, biotite, chlorite (micas)</p>	
2 cleavages intersect at or near 90°	<b>Prismatic cleavage</b> Elongated forms that fracture along short <i>rectangular</i> cross sections	<p>Orthoclase 90° (K-spar)</p>  <p>Plagioclase 86° &amp; 94°, pyroxene (augite) 87° &amp; 93°</p>	
2 cleavages do not intersect at 90°	<b>Prismatic cleavage</b> Elongated forms that fracture along short <i>parallelogram</i> cross sections	 <p>Amphibole (hornblende) 56° &amp; 124°</p>	
3 cleavages intersect at 90°	<b>Cubic cleavage</b> Shapes made of cubes and parts of cubes	 <p>Halite, galena</p>	
3 cleavages do not intersect at 90°	<b>Rhombohedral cleavage</b> Shapes made of rhombohedrons and parts of rhombohedrons	 <p>Calcite and dolomite 75° &amp; 105°</p>	
4 main cleavages intersect at 71° and 109° to form octahedrons, which split along hexagon-shaped surfaces; may have secondary cleavages at 60° and 120°	<b>Octahedral cleavage</b> Shapes made of octahedrons and parts of octahedrons	 <p>Fluorite</p>	
6 cleavages intersect at 60° and 120°	<b>Dodecahedral cleavage</b> Shapes made of dodecahedrons and parts of dodecahedrons	 <p>Sphalerite</p>	

# Hardness

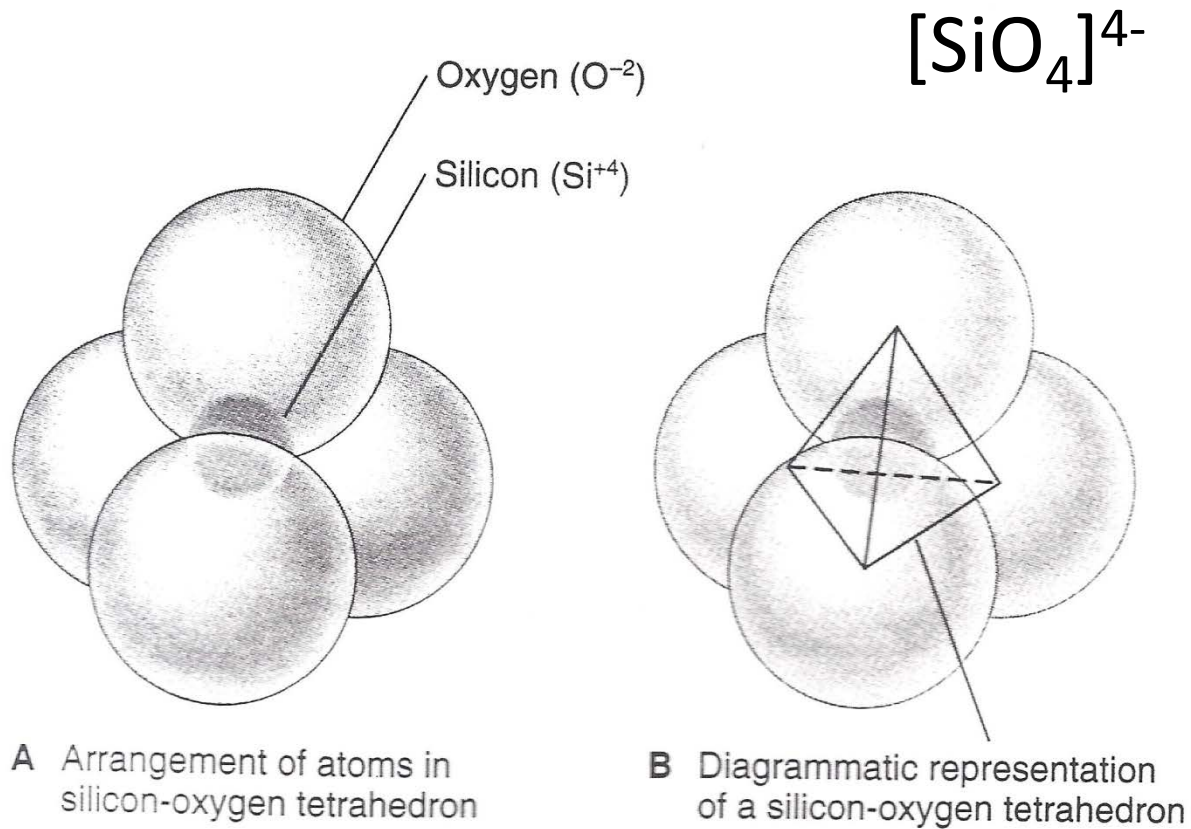
Mohs Scale of Hardness*		Hardness of Some Common Objects (Harder objects scratch softer objects)	
HARD	10 Diamond		
	9 Corundum		
	8 Topaz		
	7 Quartz		
	6 Orthoclase Feldspar		
SOFT	5 Apatite	6.5 Streak plate	
	4 Fluorite	5.5 Glass, Masonry nail, Knife blade	
	3 Calcite	4.5 Wire (iron) nail	
	2 Gypsum	3.5 Brass (wood screw, washer)	
	1 Talc	3.0 Copper coin (penny)	
		2.5 Fingernail	

\* A scale for measuring relative mineral hardness (resistance to scratching).

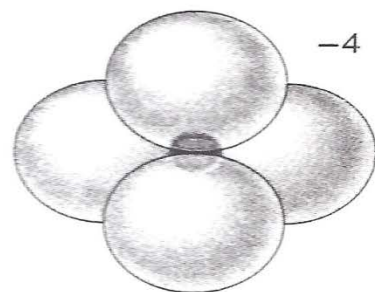
# Other properties

- Color and streak
- Specific gravity
- Transparency
- Reaction to HCL
- Magnetism
- Taste

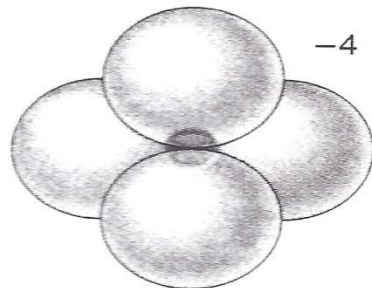
# Silicates







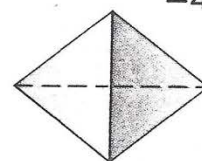
-4



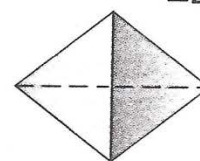
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-8

**A**



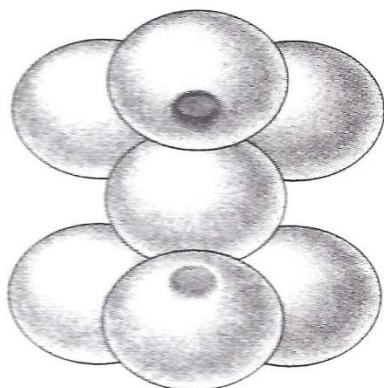
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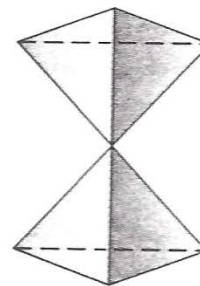
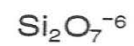
-8

**B**



-6

**C**



-6

**D**

Isolated silicate  
structure



Example

Olivine



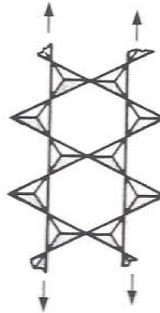
Single chain  
structure



Pyroxene  
group



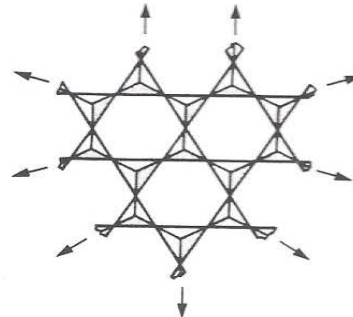
Double chain  
structure



Amphibole  
group



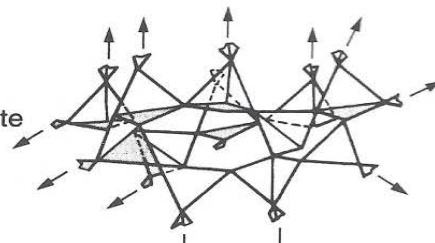
Sheet silicate  
structure



Mica group  
Clay group



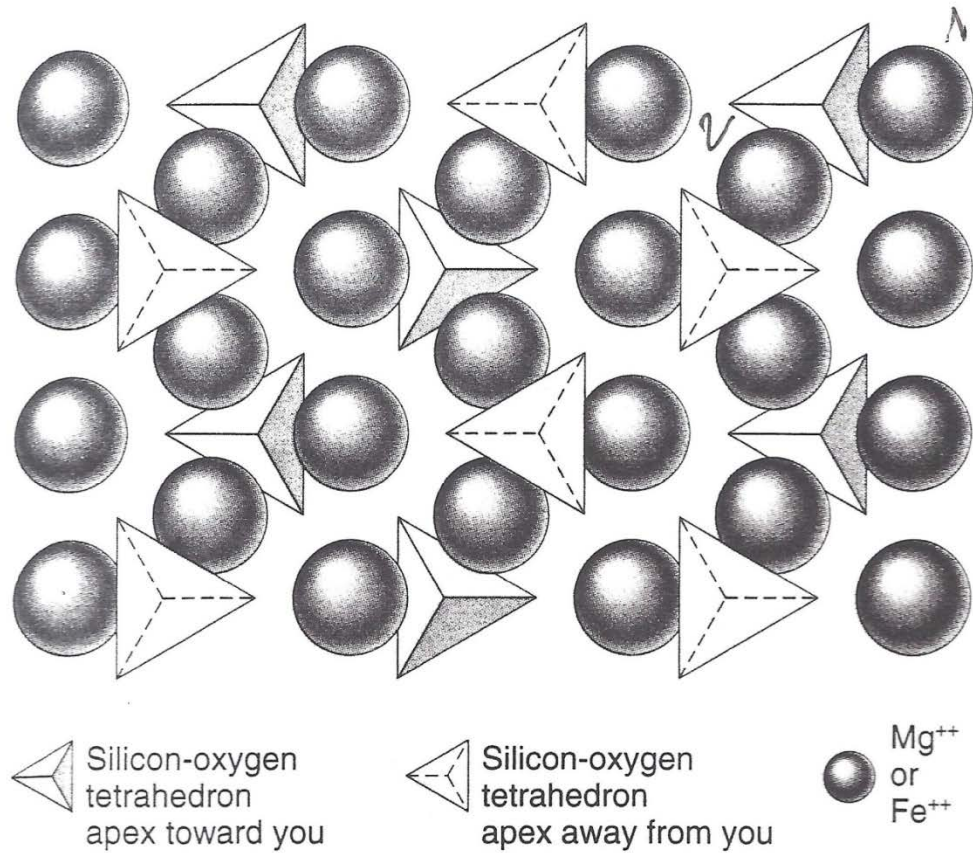
Framework silicate  
structure



Quartz  
Feldspar group



# Olivine





# Quartz ( $\text{SiO}_2$ )

- Macro-crystalline quartz (different colors due to impurities)
- Silicosis (occupational hazard)

<https://www.osha.gov/dsg/topics/silicacrystalline/index.html>

<https://www.youtube.com/watch?v=GtYErK9KjQ8c>



# Quartz ( $\text{SiO}_2$ )

- Micro-crystalline quartz (chert, flint, agate, jasper, opal, petrified wood)
- Alkali-Silica Reaction (ASR)

<https://www.concrete.org/topicsinconcrete/topicdetail/Alkali%20Aggregate%20Reaction#onlinelearning>





- **Concrete Quality**

- Loss of strength, stiffness, impermeability
- Affect concrete durability and appearance
- Premature failure of concrete structures

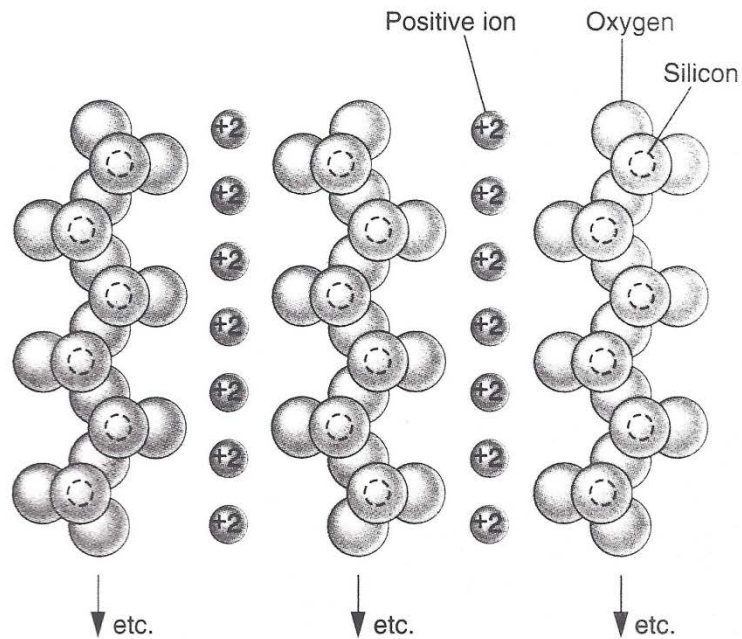
- **Economic Costs**

- Maintenance cost increased
- The life of concrete structure is reduced

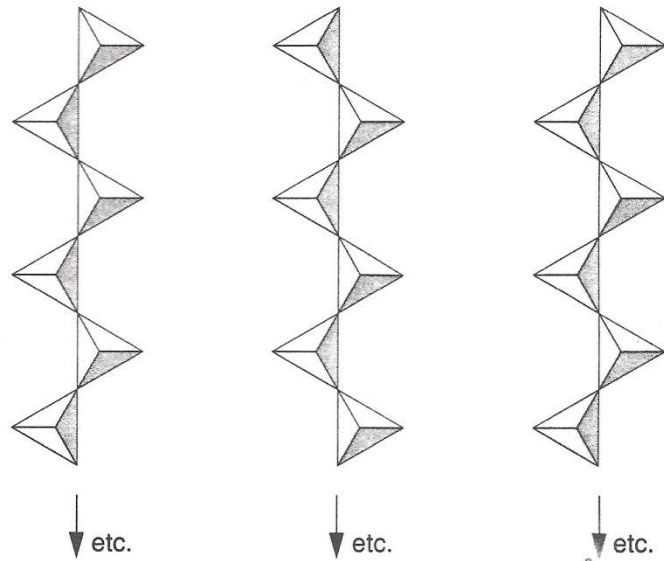
- **Overall Result**

- No concrete structures had collapsed due to ASR damage
- Some concrete structures/members were demolished because of ASR





A



B

# Pyroxenes Amphiboles

# Asbestos

Loosely used commercial term for fibrous minerals in heat-resistant fabric,

- Chrysotile (**White asbestos**): sheet structure, 95% of asbestos. Dissolves in lungs (in one year)
- Amphibole asbestos (**Blue Asbestos**) minerals: Needle structure (crocidolite, Blue asbestos, four other types). Does not dissolve in lungs

- \* Heating ducts, furnace grout/insulation, water pipe coverings.
- \* Ceramic plumbing fixtures.
- \* Room and corridor insulation and fireproofing in buildings on floors, walls, ceilings and trim.
- \* Floor tile and tile cements.
- \* Asbestos plaster used for trim in buildings.
- \* Roof coatings, sealants, cement sheets and underground sewage and water pipes.
- \* Flower pots, rugs, draperies, designer coats, buttons, mailbags, table covers, place mats.



- \* Fire-proof clothing and gloves.
- \* Artificial snow to decorate Christmas trees and window displays.
- \* Acoustical tiles.
- \* Phonograph records.
- \* Liners for ovens, toasters, hair dryers, washing machines, refrigerators, and vacuum cleaners.
- \* Brake linings for automobiles and motorcycles.
- \* Gaskets and seals in various applications.
- \* Exhaust packings.
- \* Acetylene cylinders.
- \* Sealing tapes.
- \* Shingles and siding.
- \* Fireproofing for steel structural members in buildings.

**Places where asbestos has been encountered in the home.**

(graphic Victorian House from Public Domain Exchange)





Chrysotile



Blue Asbestos

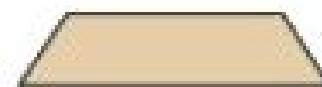
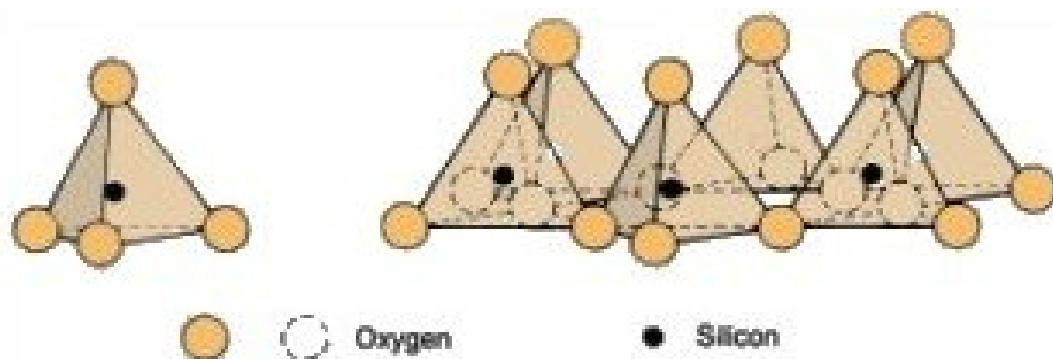
# Asbestos

- Problem with misidentification of asbestos
- Regulations:
  - EPA
  - OSHA (health and safety of workers)  
<http://www.osha.gov/SLTC/asbestos/>  
<https://www.osha.gov/Publications/OSHA3507.pdf>

# Phyllosilicates

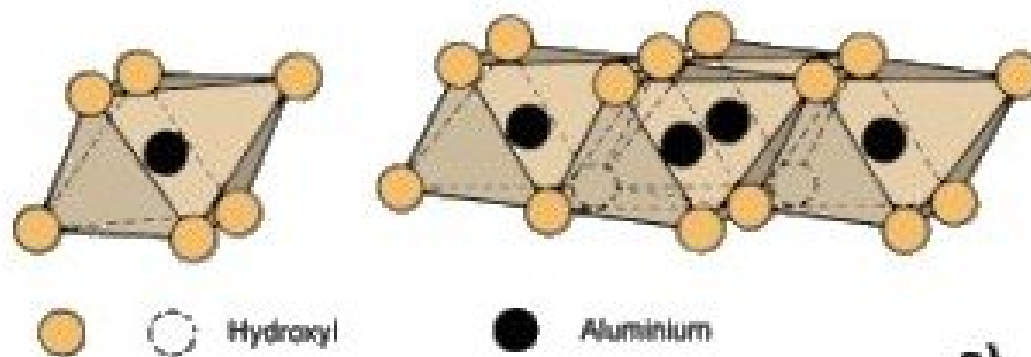
- Sheets of tetrahedron units
- Micas (Biotite and Muscovite)
- Chlorite
- Talc
- Clay Minerals (swelling and non-swelling)

# Clay Minerals

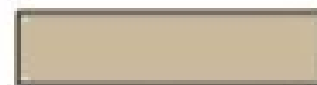


Silica sheet

Tetrahedral



Octahedral

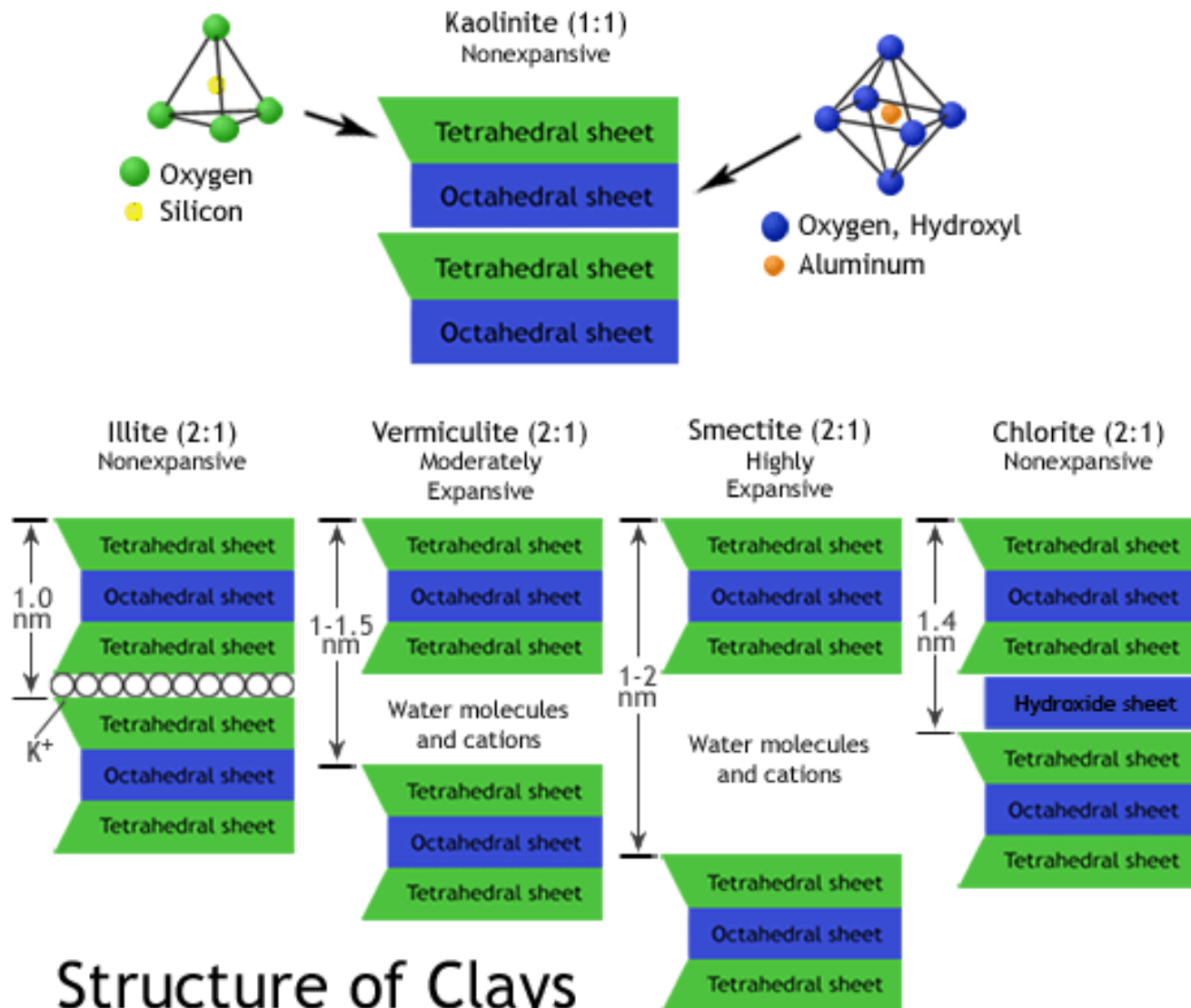


Alumina sheet

a)

b)

# Clay Minerals



Structure of Clays

Created by Josh Lory for [www.soilsurvey.org](http://www.soilsurvey.org)

# Clay Minerals

- Videos:

<https://www.bing.com/videos/search?q=swelling+clays+videos&qpv=swelling+clays+videos&view=detail&mid=5CC835922F54CF71368F5CC835922F54CF71368F&FORM=VRD GAR>

<https://www.bing.com/videos/search?q=swelling+clays+videos&qpv=swelling+clays+videos&view=detail&mid=6121AE4143C45C97BAA46121AE4143C45C97BAA4&rvsmid=3F6C2C2EC67157A034B13F6C2C2EC67157A034B1&fsscr=0&FORM=VDQVAP>