

EARTH 121: Intro. Earth Sciences

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Textbook:

Tarbuck et al.

Earth: An Introduction to Physical Geology

4th Canadian Edition

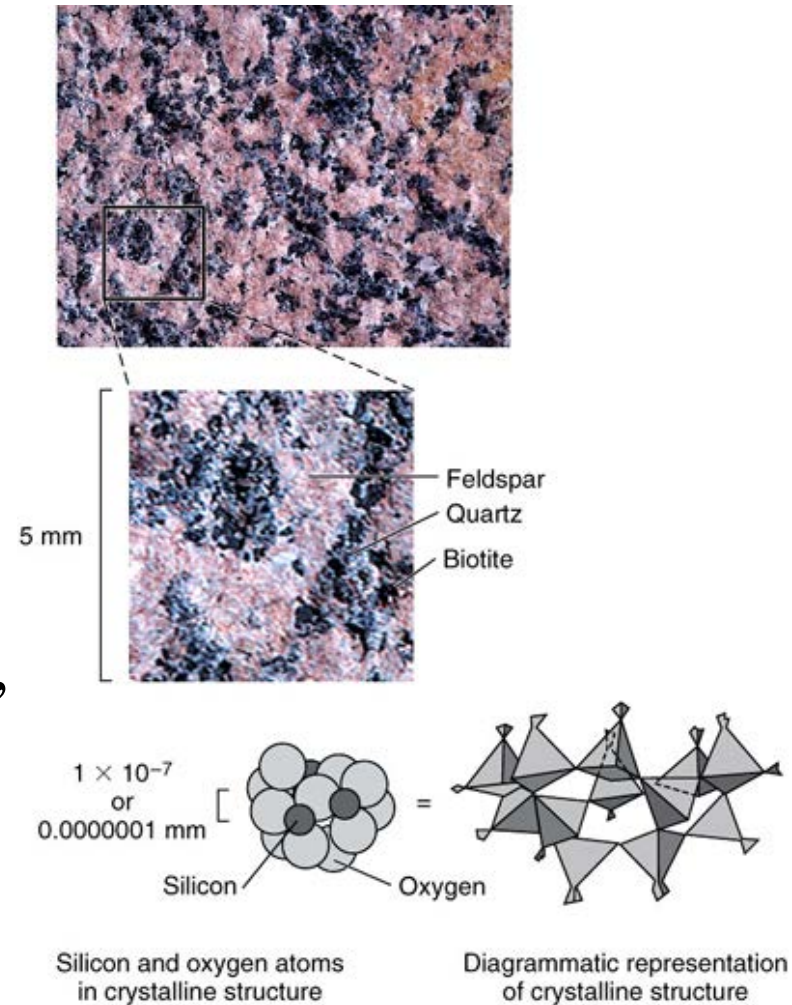
Earth Chapter 2: Minerals

- Minerals: the Building Blocks of Rocks
 - (TLTH, p. 34-35)
 - The Structure of Minerals
 - (TLTH, p. 41-43)
 - Physical Properties of Minerals
 - (TLTH, p. 43- 47)
 - Mineral Groups
 - (TLTH, p. 47-56)

Lecture slides available on LEARN

? Minerals ?

- A *mineral* is a crystalline solid, formed by natural geological processes, with a specific chemical composition.
- Form in the geosphere (most minerals), hydrosphere (e.g., halite), biosphere (e.g., calcite), and even the atmosphere (e.g., water ice, as snow)
- Consistent and recognizable *physical and chemical properties*



Minerals: the Building Blocks of Rocks

What is a rock?

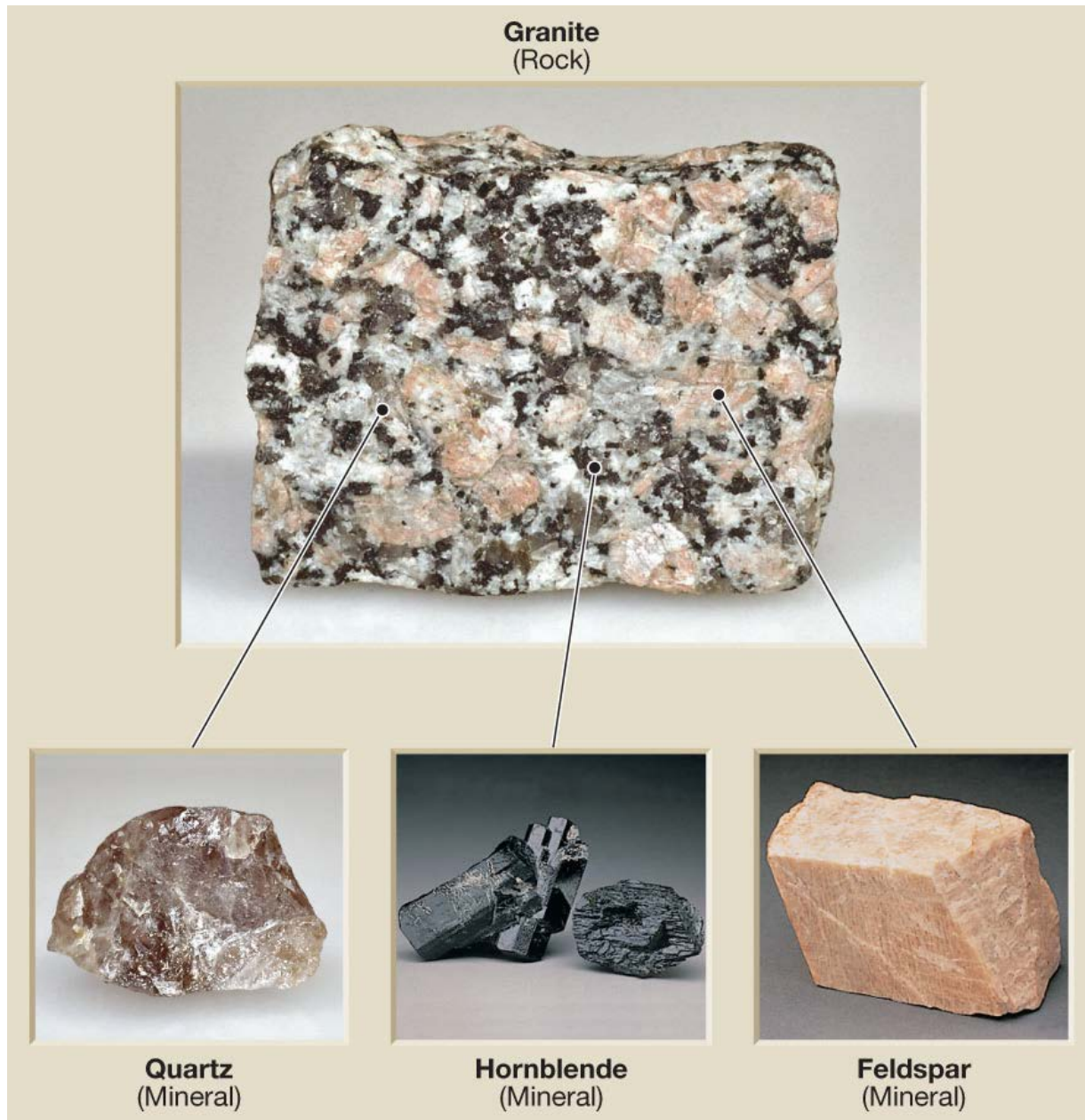
- Any solid mass of mineral or mineral-like matter that occurs naturally as part of planets



TLHL fig 2.2

Most rocks are aggregates of several kinds of minerals, but some are single-mineral (e.g., obsidian, limestone composed of impure calcite)

Minerals: the Building Blocks of Rocks



Minerals are everywhere in our products

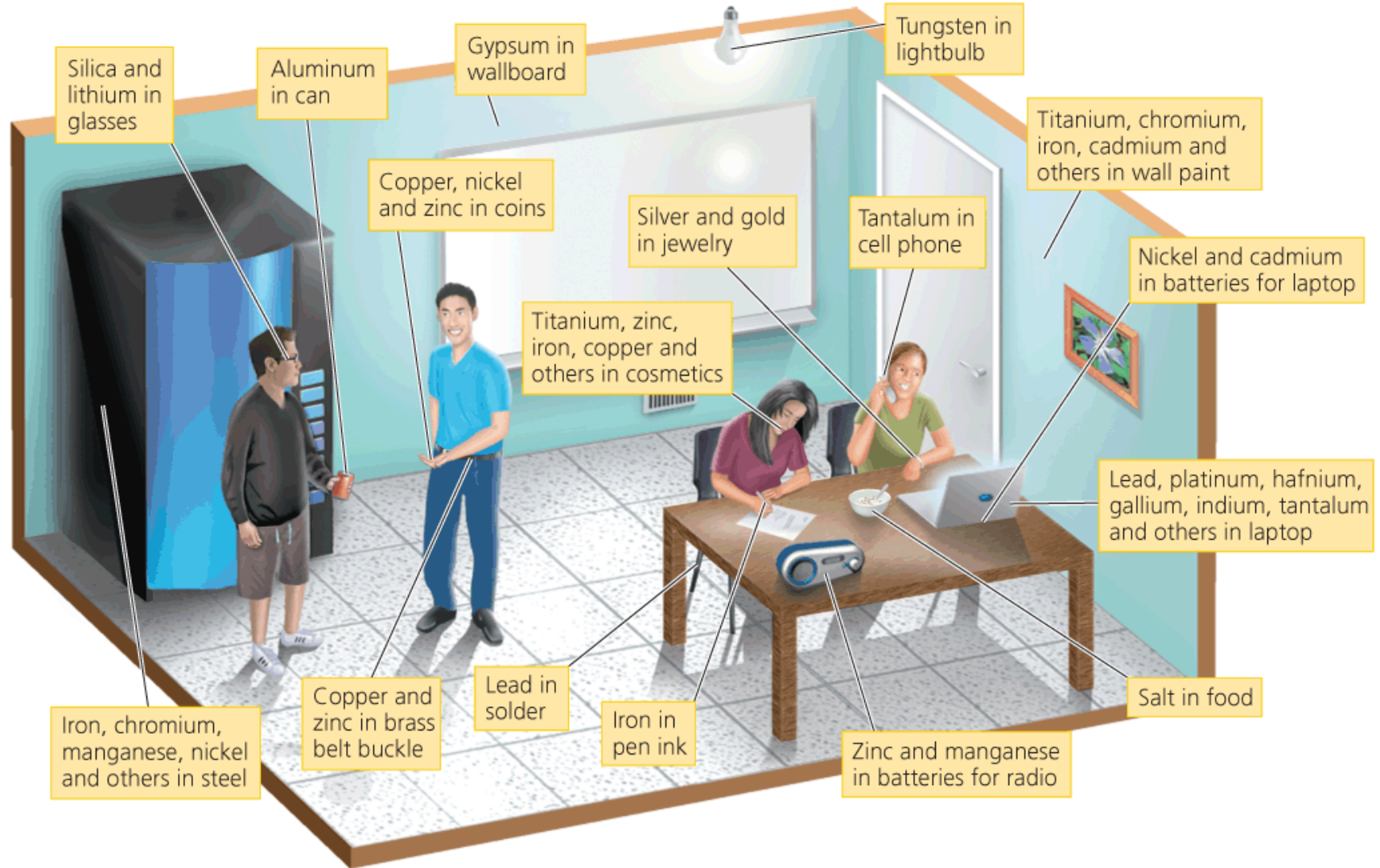


FIGURE 11.1 Elements from minerals that we mine are everywhere in the products we use in our everyday lives. This scene from a typical student lounge points out just a few of the many elements from minerals that surround us.

We obtain minerals and metals by mining

- **Mining** = systemic removal of rock, soil, or other material for the purpose of extracting minerals of economic interest
 - Because most minerals are widely spread but in low concentrations, miners and geologists try to locate concentrated sources
- **Metal** = type of chemical element that typically is shiny, opaque, and malleable, and conduct heat and electricity
 - Most metals are present in ore, a rock in which valuable minerals have been concentrated
- **Tailings** = waste rock and minerals that are not valuable

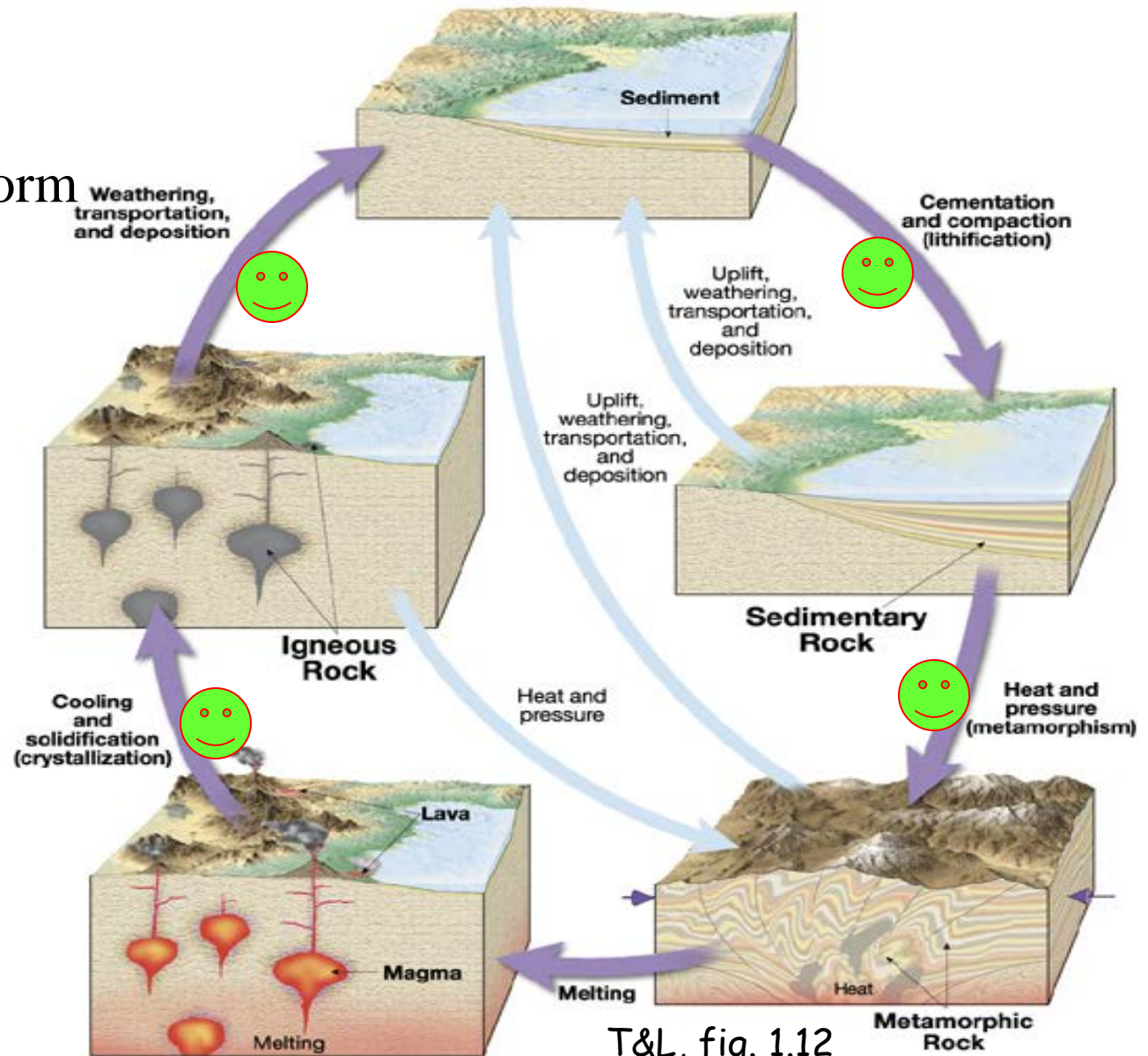
Canada: World Mining Leader

The TSX is the world's largest exchange for metal mining stocks



Mineral Resources and Geologic Processes

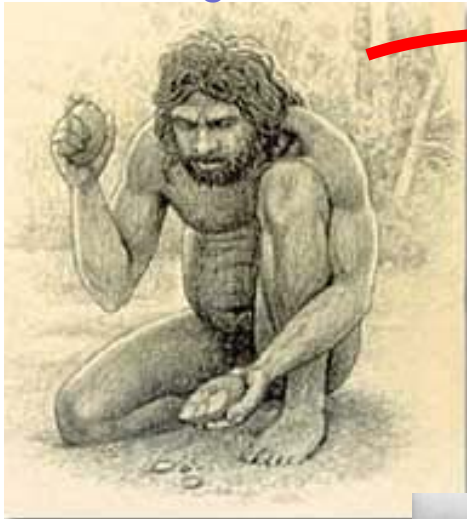
Mineral deposits form as part of geologic processes



T&L, fig. 1.12

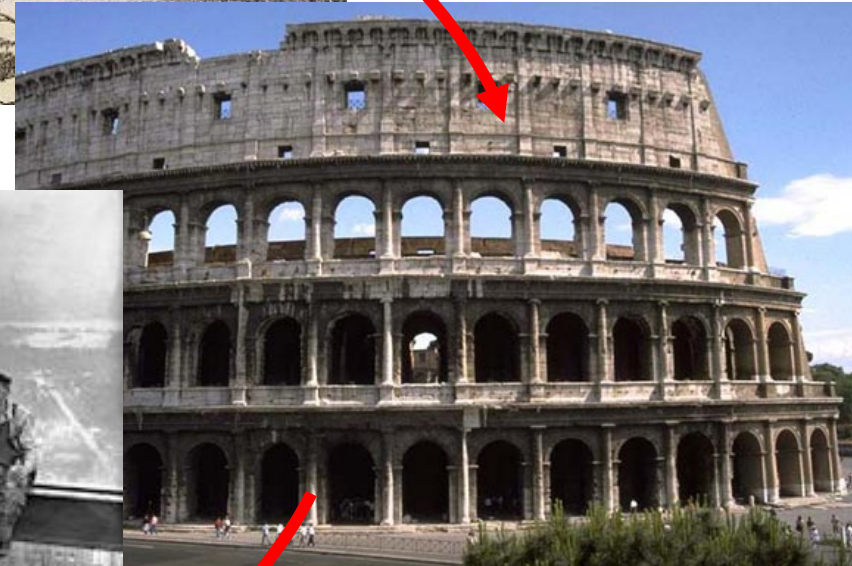
Evolution of humans & minerals

Stone Age...a long
time ago



Bronze Age...
1000 BC

Concrete &
roman
coliseum...
0 BC

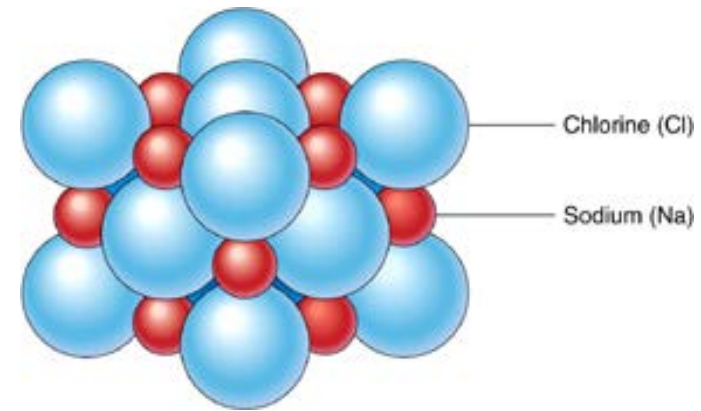


RCA building,
Rockefeller
Center, New
York...1932



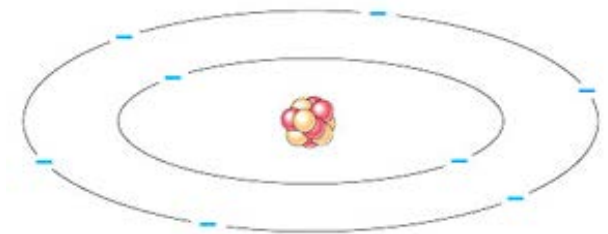
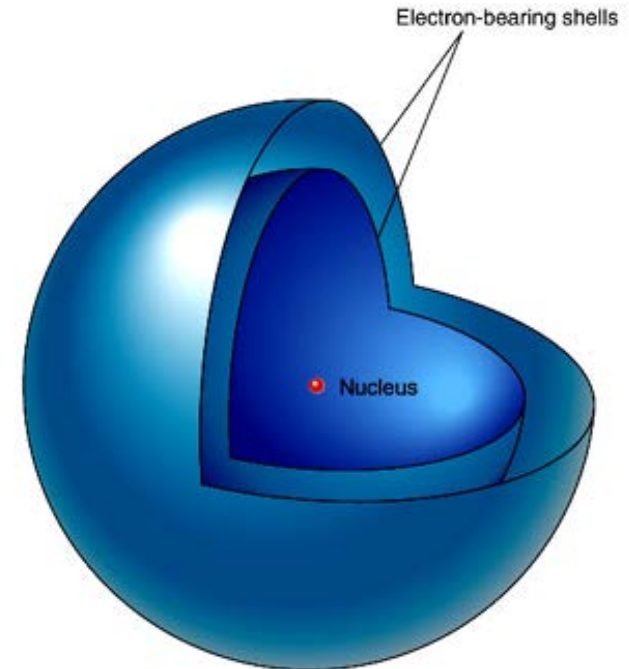
Atoms and Elements

- An *element* is a substance that can not be broken down into others by ordinary chemical reactions
- An *atom* is the smallest unit of a substance that retains the properties of that element
 - Composed of 3 types of subatomic particles
 - Protons (positively charged)
 - Neutrons (zero net charge)
 - Electrons (negatively charged)
- A *molecule* is the smallest unit of a compound that retains the properties of that substance



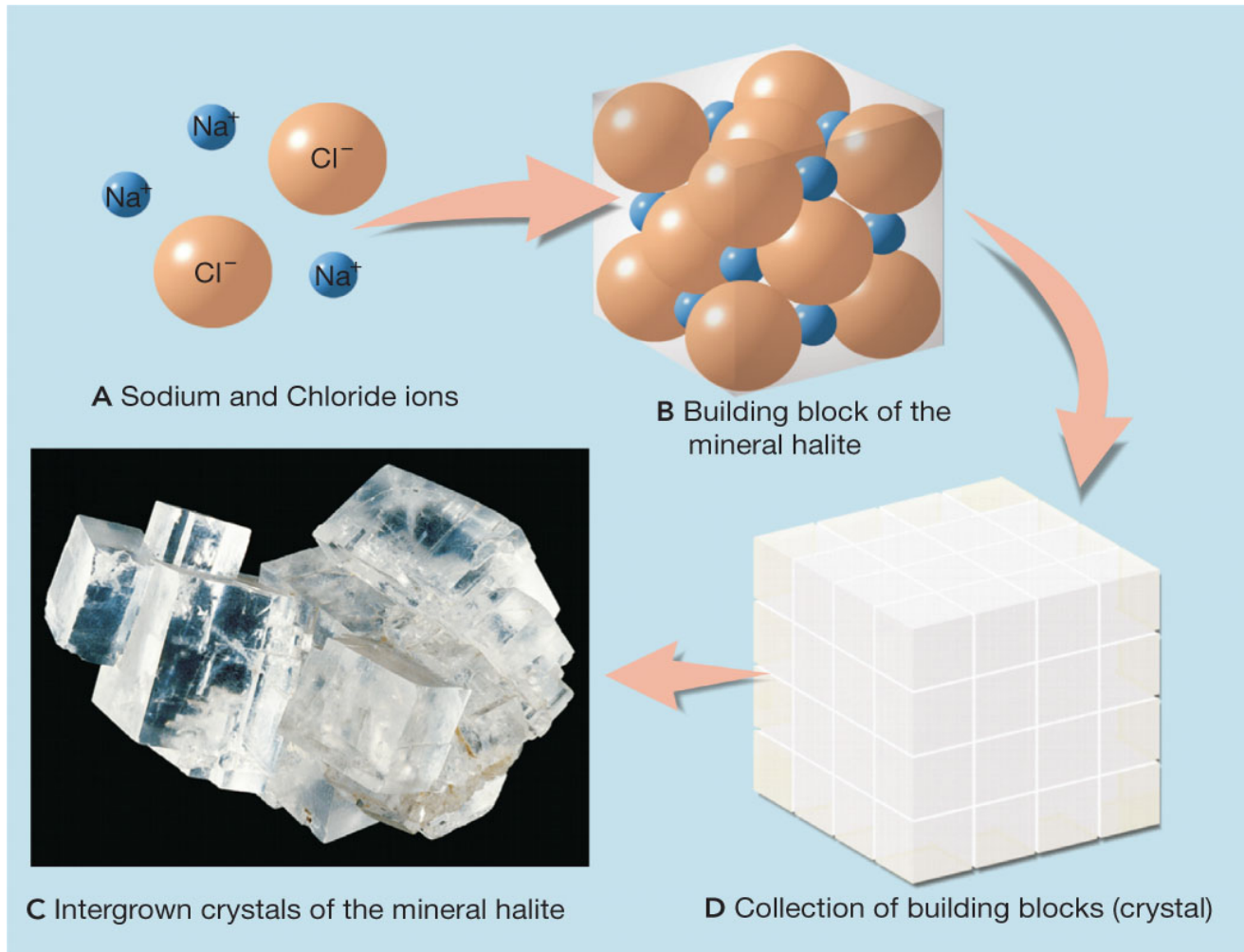
Atomic Structure

- Protons and neutrons form the *nucleus* of an atom
 - Represents tiny fraction of the volume at the center of an atom, but nearly all of the mass
- Electrons orbit the nucleus in discrete *shells* or energy levels
 - Shells represent nearly all of the volume of an atom, but only a tiny fraction of the mass
 - Numbers of electrons and protons are equal in a neutral atom
 - Ordinary chemical reactions involve only outermost shell (valence) electrons



- Protons (8 are present)
- Neutrons (usually 8 are present)
- Electrons

The Structure of Minerals

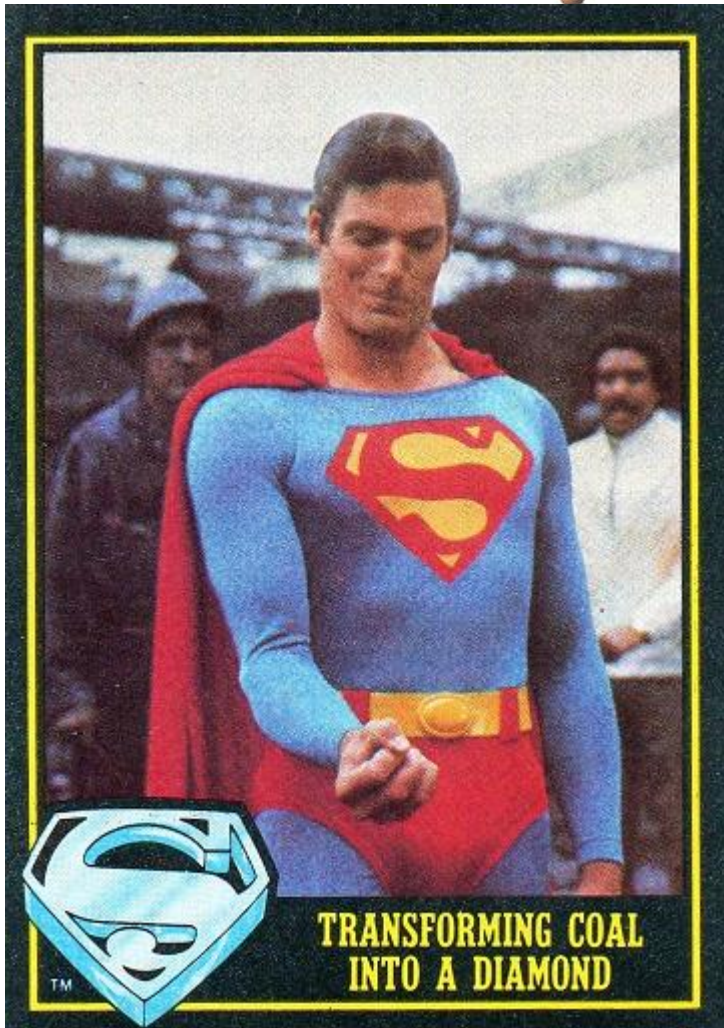


◆ **Figure 2.9** The structure of sodium chloride. **A, B.** The orderly arrangement of sodium and chloride ions in the mineral halite. **C, D.** The orderly arrangement at the atomic level produces the regularly shaped salt crystals shown in this photograph. (Photo by M. Clay/Jacana Scientific Control/Photo Researchers, Inc.)

The Structure of Minerals

- *A mineral* consists of an ordered array of atoms chemically bonded to form a particular crystalline structure
- **Polymorph** – some elements can join in more than one geometric arrangement
 - Chemical composition stays the same
 - Physical properties differ
 - Example: diamond and graphite

The Structure of Minerals



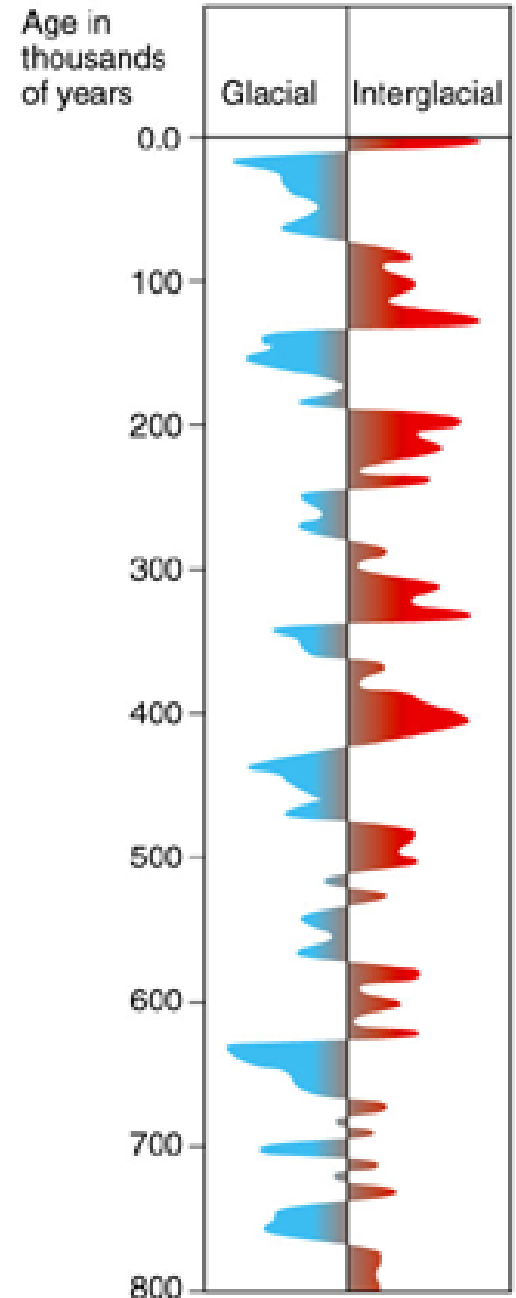
nd and graphite. Both are natural substances with the same
their internal structure and physical properties reflect the fact that
bon atoms in diamond are covalently bonded into a compact,
the extreme hardness of the mineral. B. In graphite the carbon atoms
in a layered fashion by very weak electrical forces. These weak bonds allow the
making graphite soft and slippery, and thus useful as a dry lubricant.
of Smithsonian Institute; photo B by E. J. Tarbuck)

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Diamond and graphite are polymorphs of carbon.

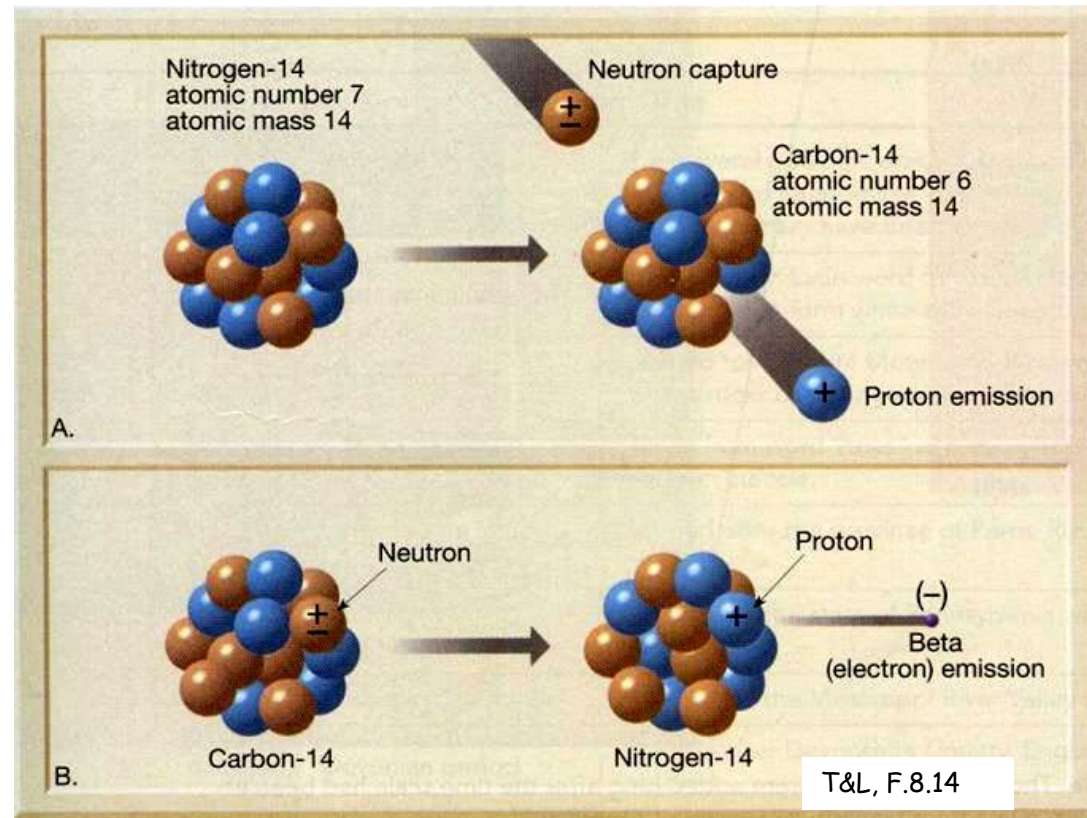
Isotopes

- Atoms of an element with different numbers of neutrons are called *isotopes*
- Isotopes may be either stable or unstable
 - *Stable* isotopes retain all of their protons and neutrons over time
 - Unstable or *radioactive* isotopes spontaneously lose subatomic particles from their nuclei
- Stable isotopes can be used to track climate change over time



Radiocarbon Dating Method (up to about 70,000 years ago)

- **Carbon** is an important element in nature, and is one of the basic elements found in all forms of life.
- Three isotopes: Carbon 12 and 13 are stable, whereas **carbon 14 (C¹⁴) is radioactive**. Dating is based on the ratio of **C¹⁴** to **C¹²**.
- All carbons are absorbed in a **nearly constant ratio** by all living organisms. When an organism dies, **C¹⁴** is not replenished and the ratio of **C¹⁴** to **C¹²** decreases.



Minerals: the Building Blocks of Rocks

What is a mineral?

- “A naturally occurring, inorganic, crystalline solid.”
- Crystalline = *regular internal structure*
- Minerals have narrowly defined chemical composition and *characteristic properties* such as density, colour and hardness.



Minerals

- Although over 4000 minerals have been identified, only a few hundred are common enough to be generally important to geology (rock-forming or \$\$)



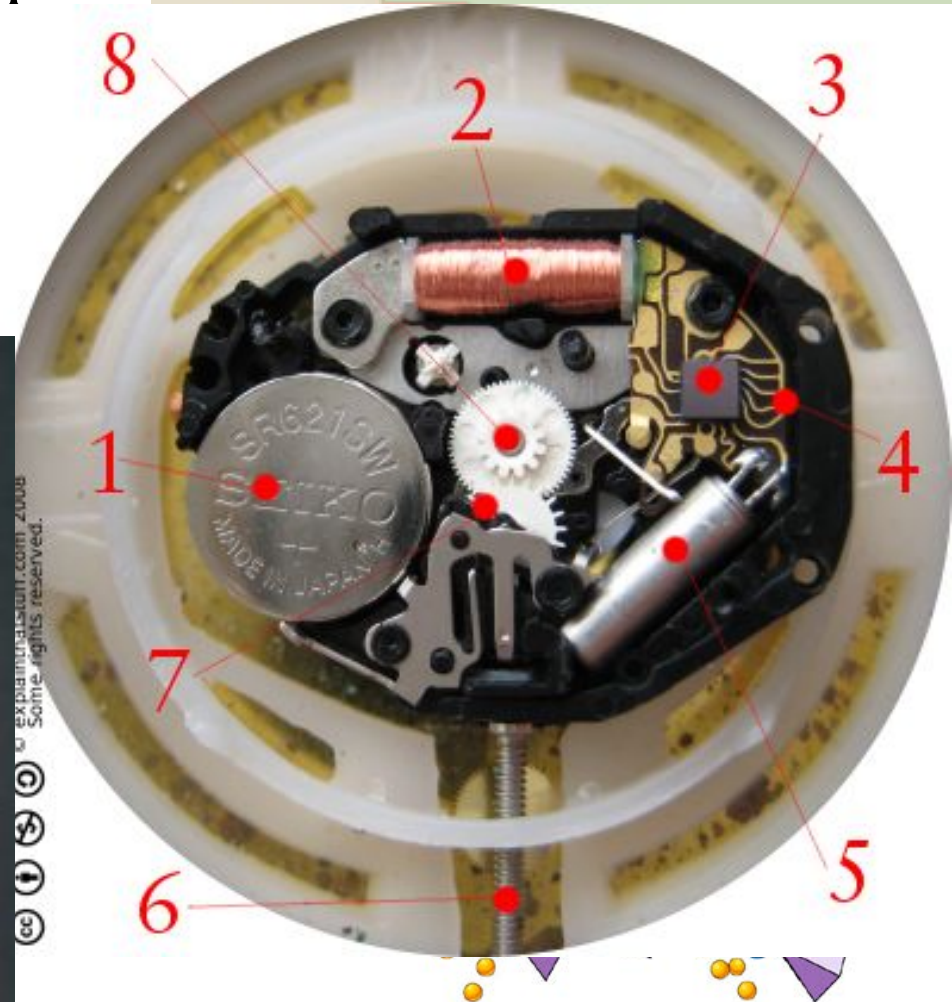
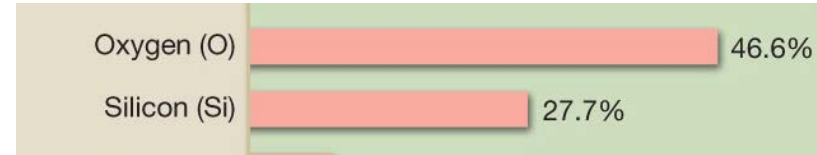
- Over 90% of Earth's crust is composed of minerals from only 5 groups (feldspars, pyroxenes, amphiboles, micas, quartz)

Composition of Earth's Crust

- Common elements

- Nearly 97% of the atoms in Earth's crust are represented by the 8 most common elements

- O, Si, Al, Fe, Ca, Na, K

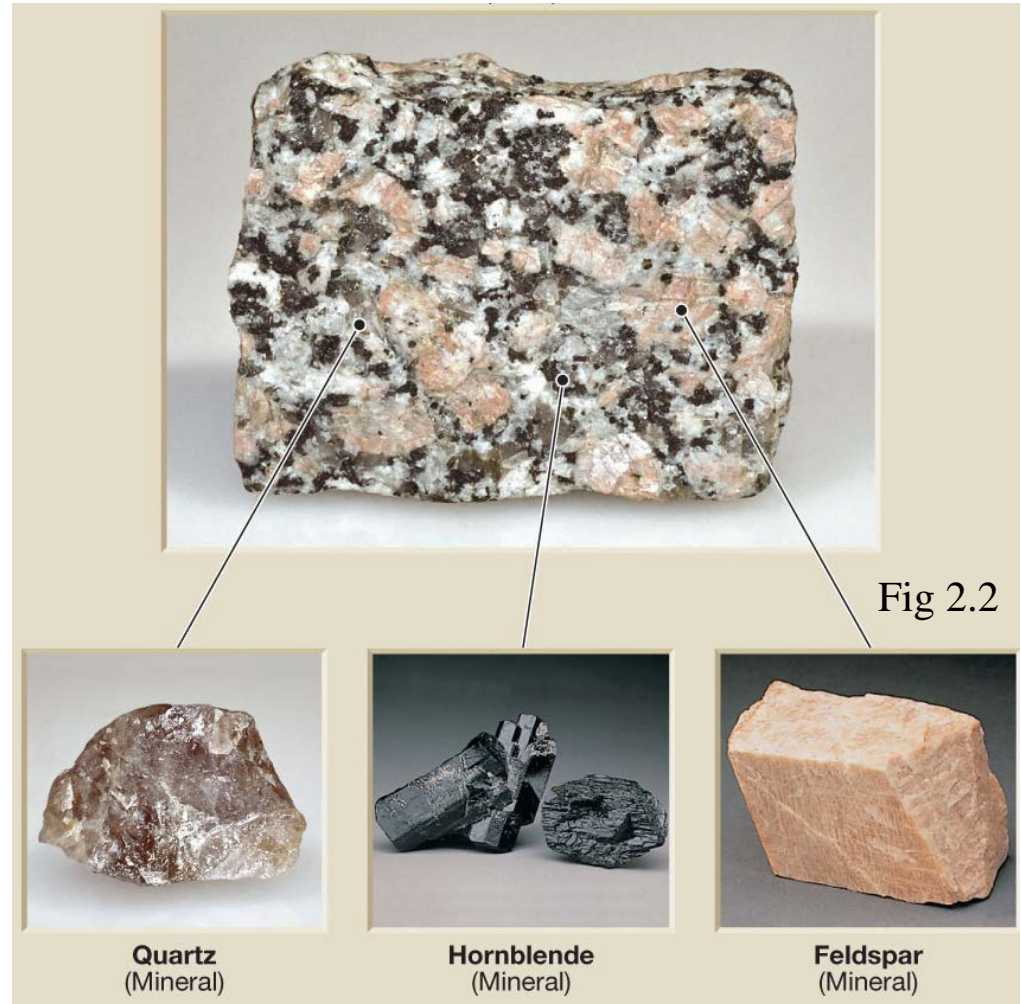


Important Rock-Forming Minerals

- Rocks comprise *solid aggregates* of grains of one or more minerals (except obsidian and coal).
- Only a few minerals are *common* enough to be classified as rock-forming minerals.
- Other minerals = *accessory* minerals.

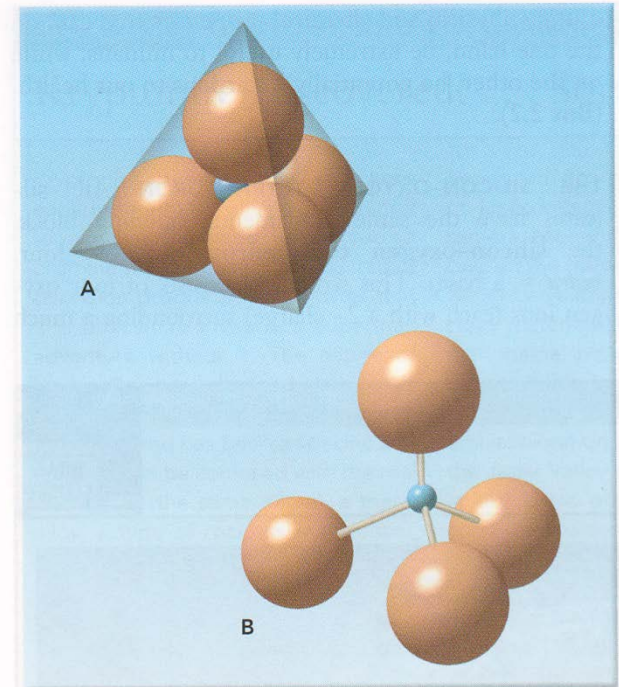
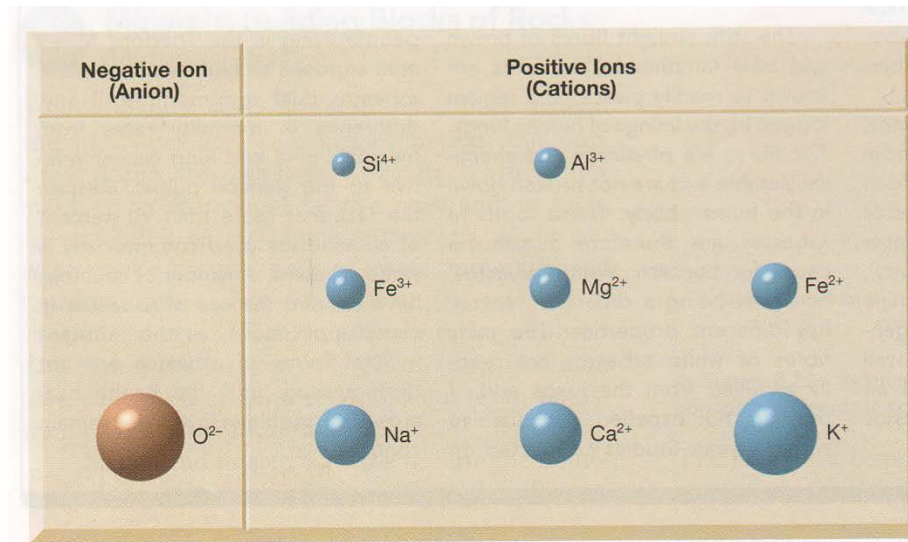
Granite(s):

largely potassium feldspar and quartz; with minor sodium plagioclase feldspar; biotite or hornblende or muscovite or rarely pyroxene



Mineral groups

1. Silicates
2. Oxides & Hydroxides
3. Sulfides
4. Sulfates
5. Native Elements
6. Halides
7. Carbonates
8. Phosphates



◆ **Figure 2.21** Two representations of the silicon–oxygen tetrahedron. A. The four large spheres represent oxygen ions, and the blue sphere represents a silicon ion. The spheres are drawn in proportion to the radii of the ions. B. An expanded view of the tetrahedron using rods to depict the bonds that connect the ions.

◆ **Figure 2.22** Relative sizes and electrical charges of ions of the eight most common elements in Earth's crust. These are the most common ions in rock-forming minerals.

Mineral Groups: Silicates



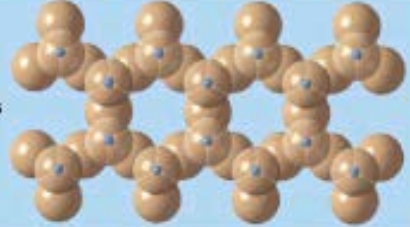
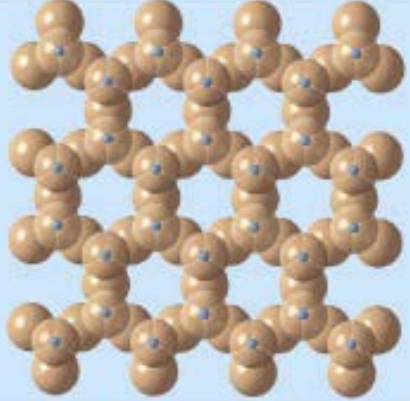

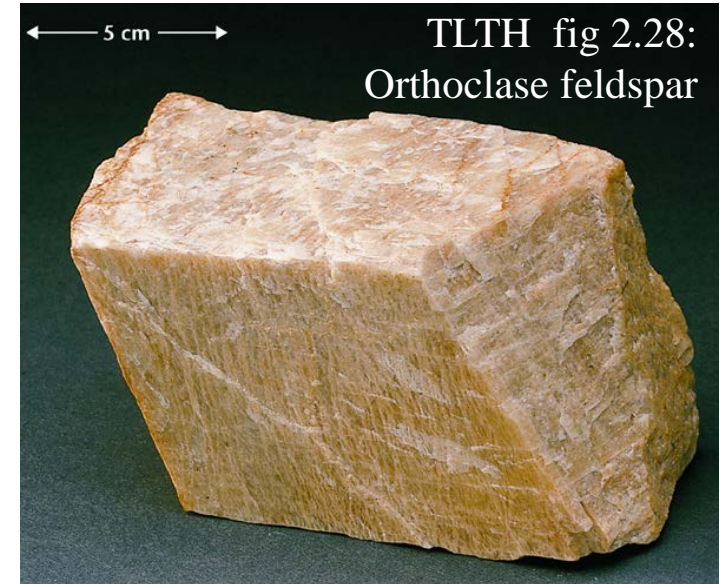
Mineral		Idealized Formula	Cleavage	Silicate Structure
Olivine		$(\text{Mg, Fe})_2\text{SiO}_4$	None	Single tetrahedron 
Pyroxene group (Augite)		$(\text{Mg, Fe})\text{SiO}_3$	Two planes at right angles	Single chains 
Amphibole group (Hornblende)		$\text{Ca}_2(\text{Fe, Mg})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$	Two planes at 60° and 120°	Double chains 
Micas	Biotite	$\text{K}(\text{Mg, Fe})_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$	One plane	Sheets 
	Muscovite	$\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$		
Feldspars	Orthoclase	KAlSi_3O_8	Two planes at 90°	Three-dimensional networks 
	Plagioclase	$(\text{Ca, Na})\text{AlSi}_3\text{O}_8$		
Quartz		SiO_2	None	

Fig 2.24
(Structures of
common silicate
minerals)

Common Silicate Minerals

Non-Ferromagnesian Silicate Group

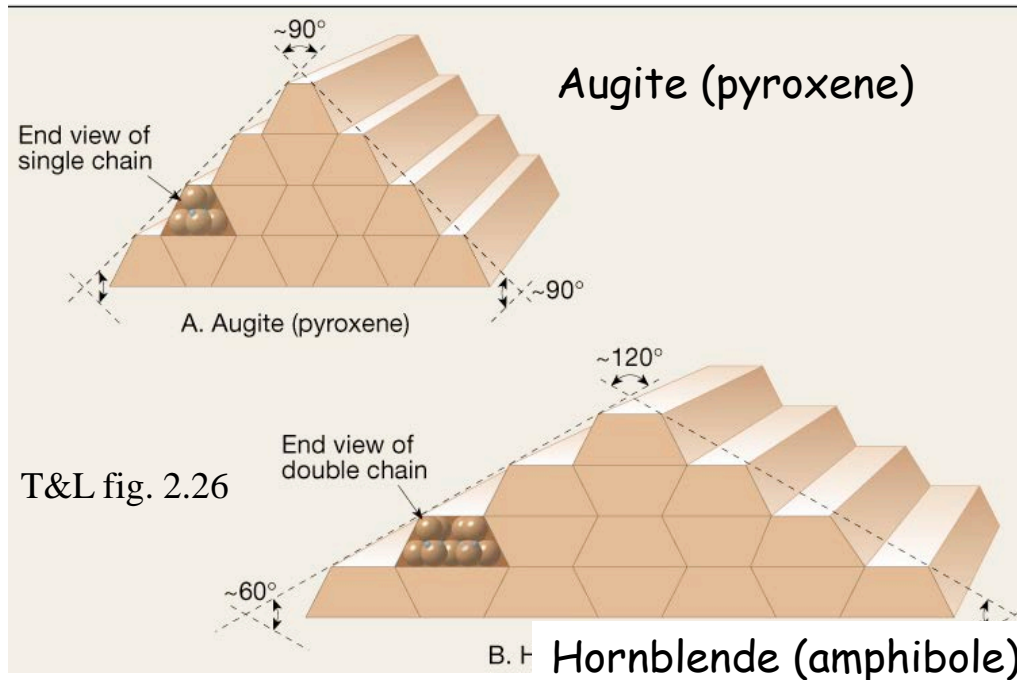
- Feldspar:
 - potassium feldspar = microcline and orthoclase; pinkish hue
 - plagioclase feldspar = white to cream colour
 - cleave along two internal planes of weakness
 - common in all three major rock groups
- Quartz
- Muscovite (mica, but colourless)



Common Silicate Minerals

- Ferromagnesian Silicate Group
 - Olivine, pyroxenes, amphiboles and biotite mica.
 - Silicate minerals containing iron, magnesium or both.
 - Commonly dark colored, and generally denser than non-ferromagnesian silicates.

How to distinguish pyroxenes from amphiboles: cleavage angle



T&L fig 2.25:
Hornblende amphibole,
a common silicate mineral

Non-silicate Minerals

- **Carbonates**
 - Contain CO_3 in their structures (e.g., calcite - CaCO_3)
- **Sulfates**
 - Contain SO_4 in their structures (e.g., gypsum - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)
- **Sulfides**
 - Contain S (but no O) in their structures (e.g., pyrite - FeS_2)
- **Oxides**
 - Contain O, but not bonded to Si, C or S (e.g., hematite - Fe_2O_3)
- **Native**
 - Composed entirely of one element (e.g., diamond - C; gold - Au)

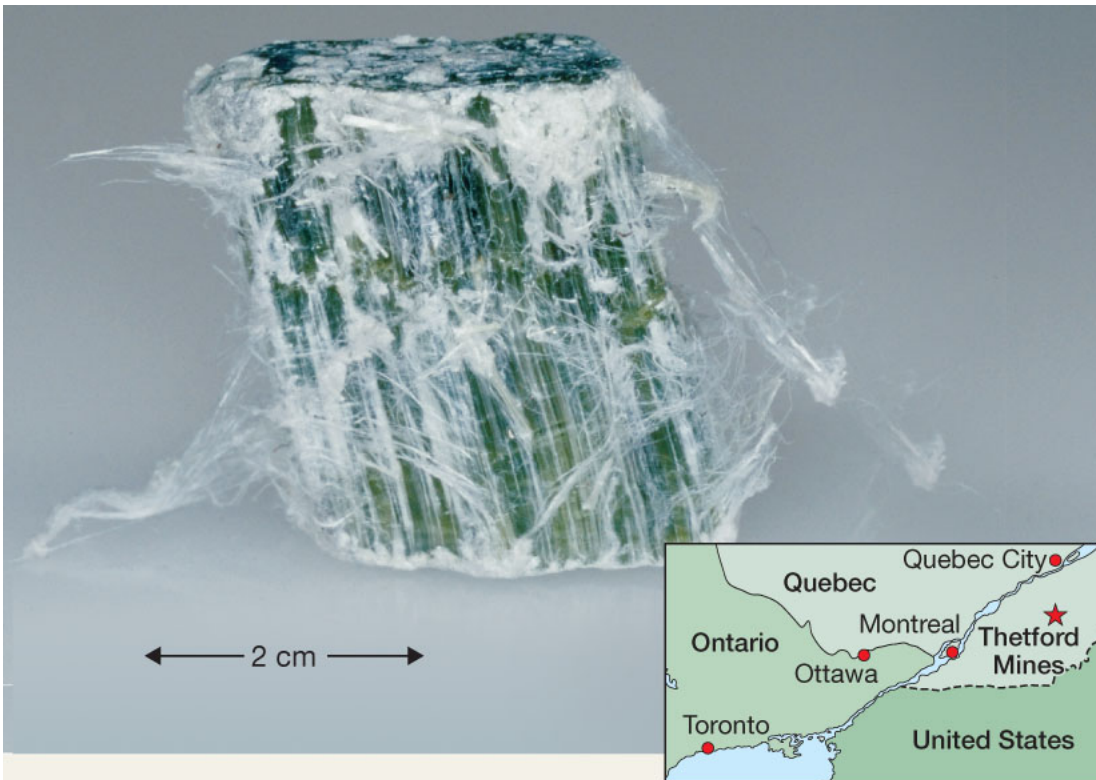
Asbestos: Risks?

Mineral which easily separates into long, thin, strong fibres.

Heat resistant and inert material used commonly in insulation, fireproof fabrics, cement, floor tiles, automobile brakes, and siding for older homes.

Canada (Quebec) is the world's top exporter and second largest producer of chrysotile (white asbestos).

Cancer and lung problems originate with brown and blue asbestos (amphibole), leading to a number of countries banning the substance outright.



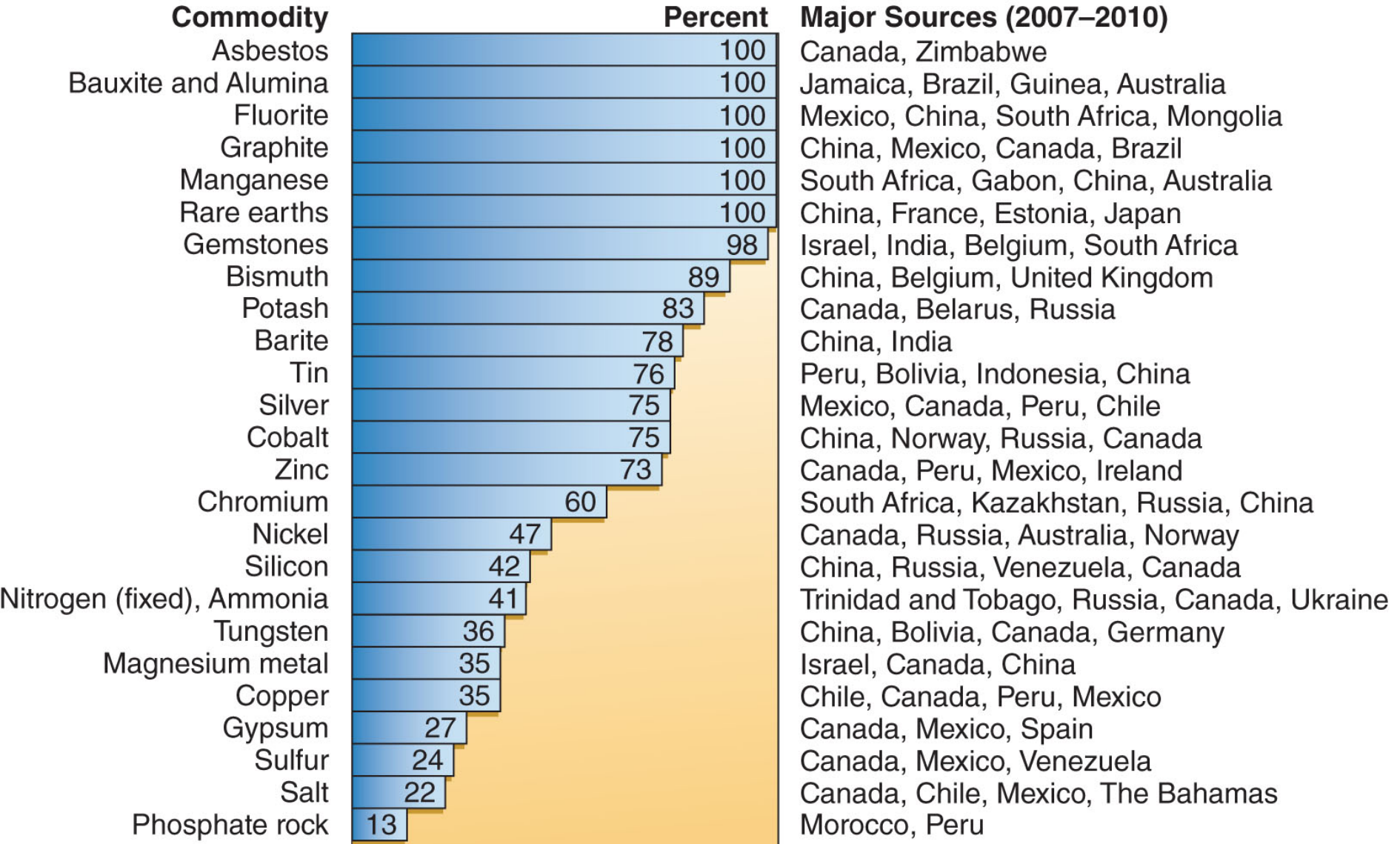
◆ **Figure 2.B** Chrysotile asbestos. This sample is a fibrous form of the serpentine group.
Inset: Thetford Mines, Quebec, the source of all Canadian chrysotile asbestos.
(Photo by E. J. Tarbuck)

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Asbestos (Thetford Mine, Quebec)



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Kryptonite? What?



◆ **Figure 2.A** Core sample of jadarite, a newly discovered mineral with nearly the same chemical composition as the fictional kryptonite—Superman's least favourite substance.

(© Natural History Museum, London)

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Superman Returns (2006) defined Kryptonite as:
Sodium lithium boron silicate hydroxide with fluorine.

Jadarite discovered in the Jadar Valley of Serbia is composed of:
Sodium lithium boron silicate hydroxide



<http://tvtropes.org/pmwiki/pmwiki.php/Main/KryptoniteFactor/>

Silicate Structures

- The Silicon-Oxygen tetrahedron
 - Strongly bonded silicate ion
 - Basic structure for silicate minerals
- **Sharing of O atoms in tetrahedral**
 - The more shared O atoms per tetrahedron, the more complex the silicate structure
 - Isolated tetrahedra (none shared)
 - Chain silicates (2 shared)
 - Double-chain silicates (alternating 2 and 3 shared)
 - Sheet silicates (3 shared)
 - Framework silicates (4 shared)

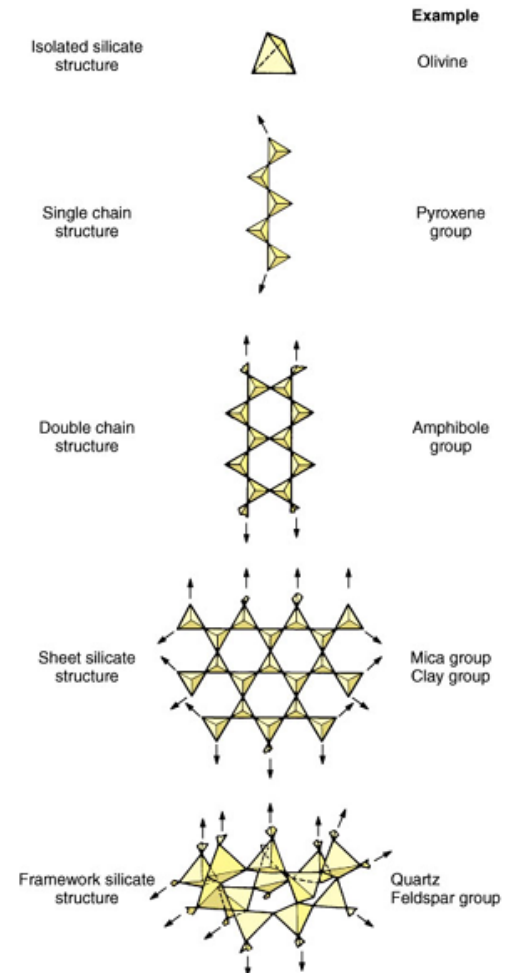
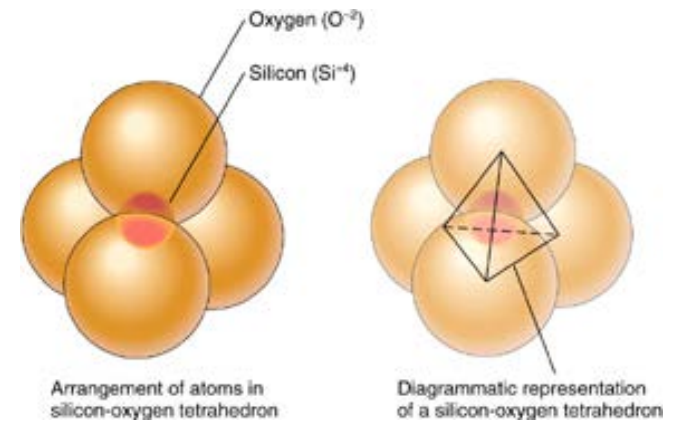


Fig 2.8 & 2.23

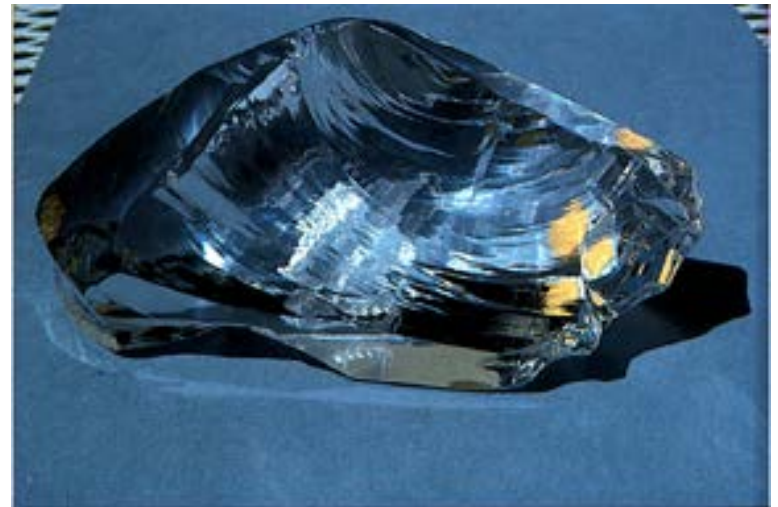
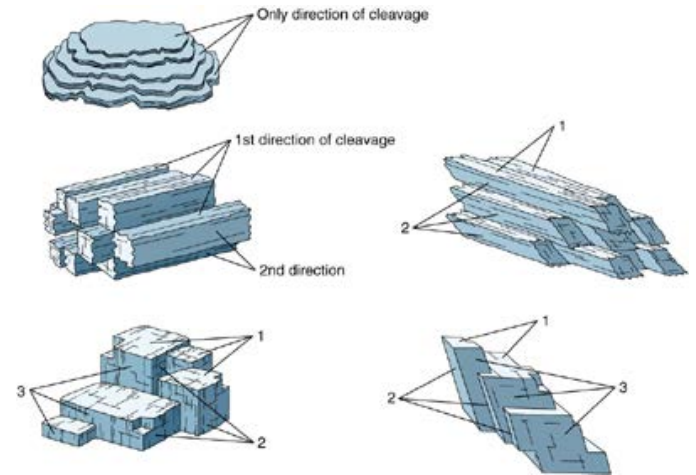
Mineral Properties – The Definitions

- **Color**
 - Visible hue of a mineral
- **Streak**
 - Color left behind when mineral is scraped on unglazed porcelain
- **Luster**
 - Manner in which light reflects off surface of a mineral
- **Hardness**
 - Scratch-resistance
- **Crystal form**
 - External geometric form



Mineral Properties (cont.)

- **Cleavage**
 - Breakage along flat planes
- **Fracture**
 - Irregular breakage
- **Specific gravity**
 - Density relative to that of water
- **Magnetism**
 - Attracted to magnet
- **Chemical reaction**
 - Calcite fizzes in dilute HCl



Physical Properties of Minerals: Crystal Form

- When a mineral is permitted to grow freely it will develop well-formed crystal faces
- Most of the time intergrowth of crystals occurs and often none exhibit its crystal form



FIG 2.17

Physical Properties of Minerals: Lustre

- **Lustre** may be *metallic* or *non-metallic*:
 - Metallic: reflects light only from the surface of the mineral; may have “brilliant” or “dull” appearance
 - Non-metallic: reflects light from within as well as from the surface of the mineral



Mineral Lustre (Press & Siever)

Metallic	Strong reflections produced by opaque substances
Vitreous	Bright, as in glass
Resinous	Characteristic of resins, such as amber
Greasy	The appearance of being coated with a fatty substance
Silky	The sheen of fibrous materials, such as silk
Pearly	The whitish iridescence of such materials as pearl
Adamantine	Brilliant, like a diamond

ADJECTIVES!

Physical Properties of Minerals: Colour

- **Colour** may vary as a result of minute amounts of *impurities*.
- General guidelines for colour:
 - Ferromagnesian silicates (Fe, Mg-bearing) are generally black, brown or dark green.
 - Non-ferromagnesian silicates are often light in appearance.

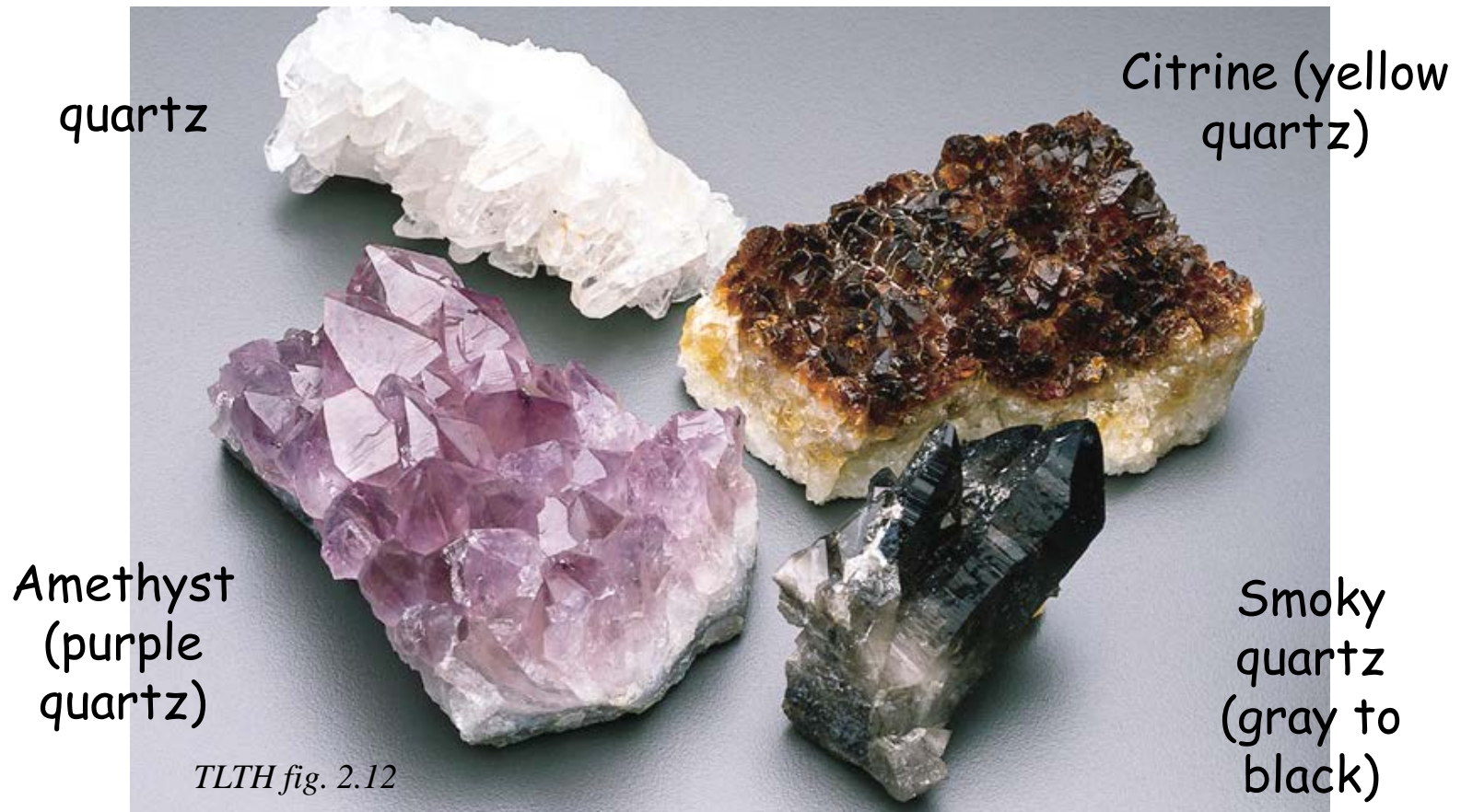


FIG 2.25



Physical Properties of Minerals: Colour

- Some minerals can have several different colours, so colour is a poor definitive identification property



Physical Properties of Minerals: Streak

- Test colour of the powdered mineral by the (ceramic) *streak plate*.
- The colour of the powdered mineral [*its streak colour*] is less prone to variation than colour of the mineral form itself.



See FIG 2.13

Physical Properties of Minerals: Hardness

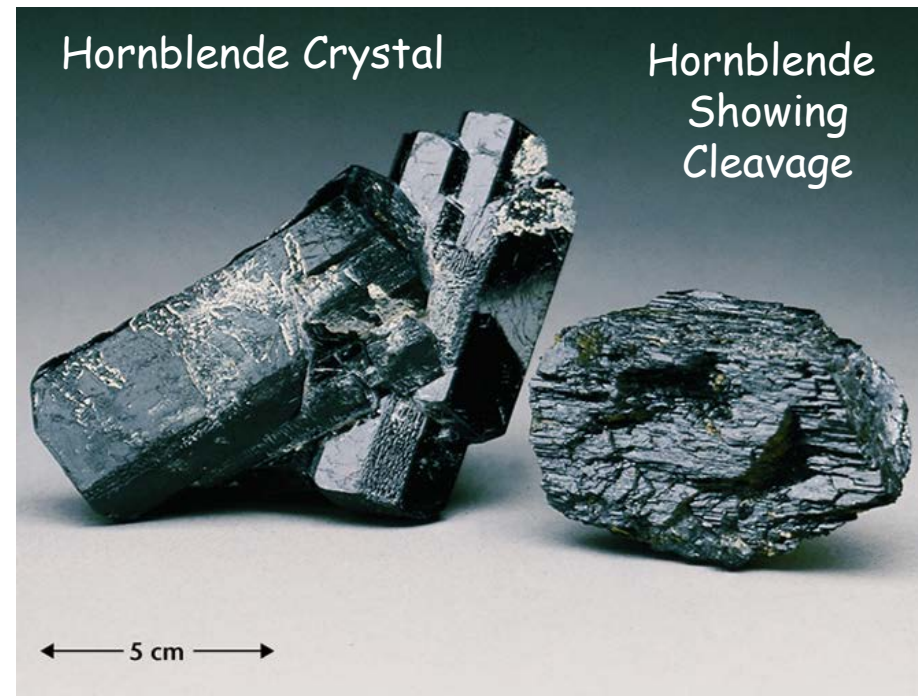
TABLE 2.2 Mohs Scale of Hardness

Relative Scale		Mineral	Hardness of Some Common Objects
Hardest	10	Diamond	
	9	Corundum	
	8	Topaz	
	7	Quartz	
	6	Potassium Feldspar	
	5	Apatite	5.5 Glass, Pocketknife
	4	Fluorite	
	3	Calcite	3 Copper Penny
	2	Gypsum	2.5 Fingernail
	Softest	1	Talc

See Table 2.1 pg 43

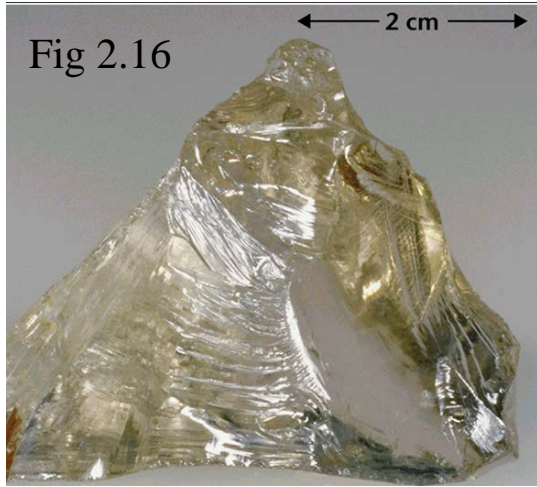
Cleavage and Fracture

- Cleavage = property of individual mineral crystals
- May split or break along lines defined by the strength of the bonds within the mineral crystal
- Cleavage can be defined in terms of:
 - *quality* (perfect, good, poor)
 - direction
 - angles of intersection of cleavage planes
- Fracture is mineral breakage along uneven surfaces.



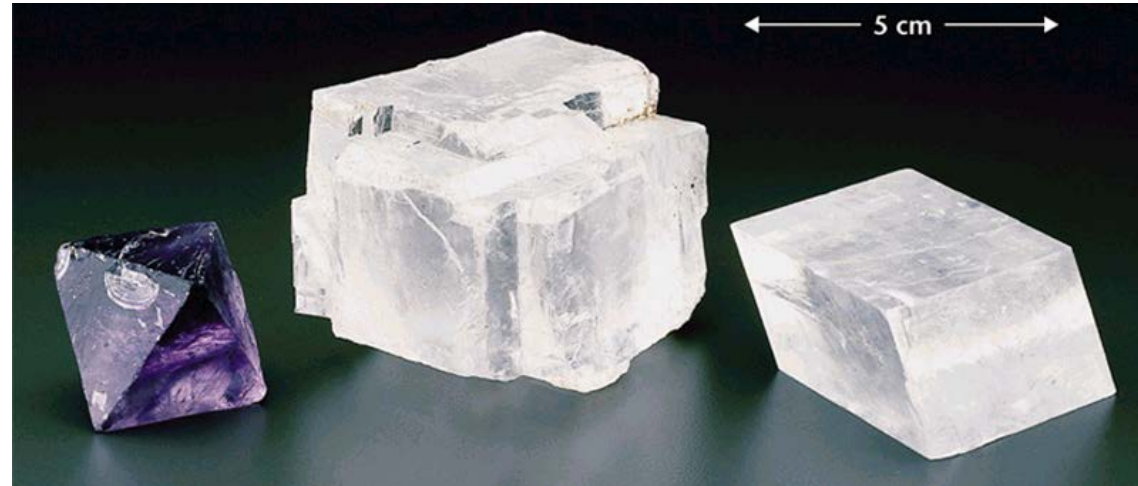
Hornblende amphibole: 2 cleavage directions at about 60 and 120 degrees (T&L, fig. 2.25)

Cleavage and Fracture cont.



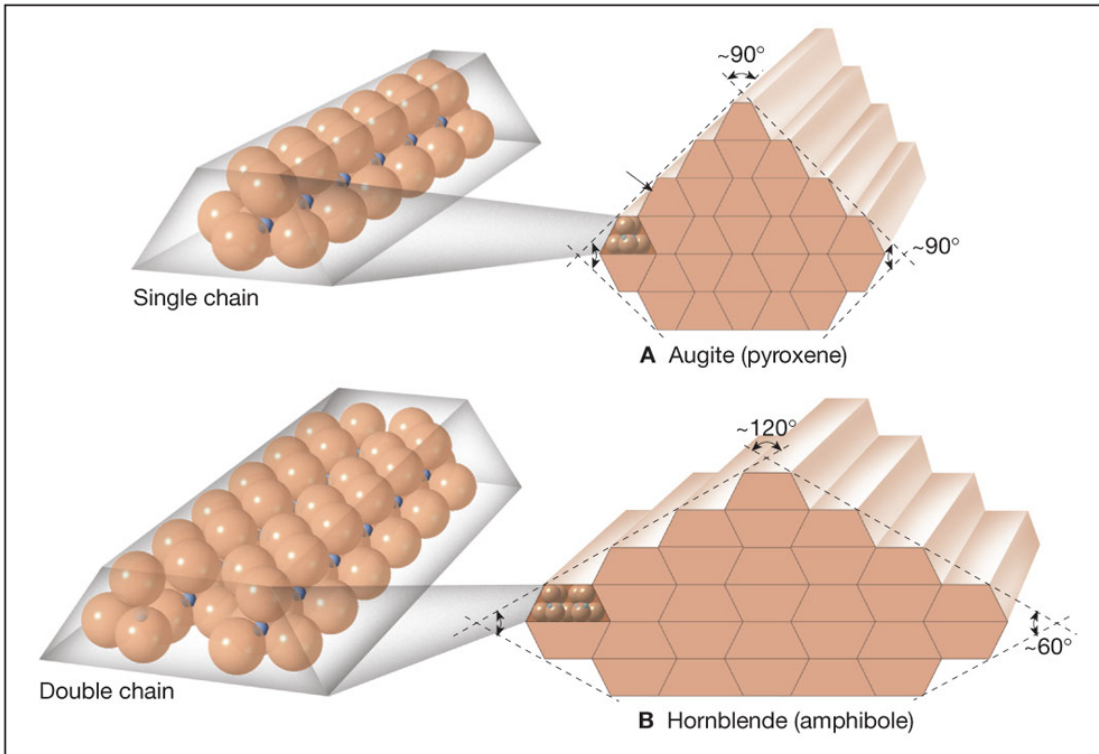
**Conchoidal Fractures
in Volcanic Glass / Obsidian**

Irregular Fractures in Quartz



Fluorite (left) exhibiting 4 cleavage planes, halite (centre) exhibiting 3 planes at right angles and calcite (right) exhibiting 3 planes at 75 degrees.

Cleavage and Fracture cont.



Copyright

Hornblende amphibole: 2 cleavage directions at different angles (T&L, fig. 2.26)



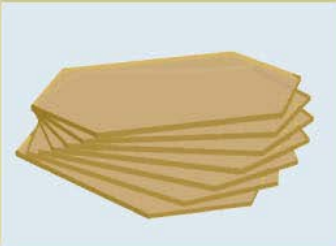
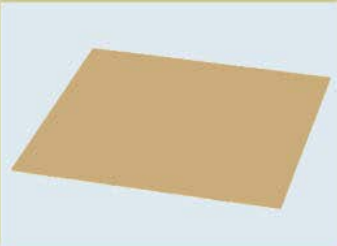

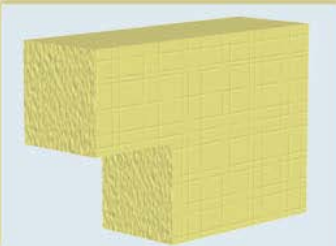
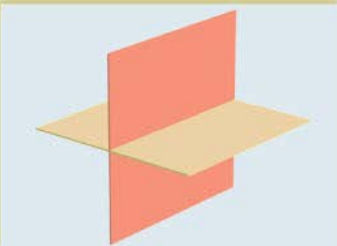
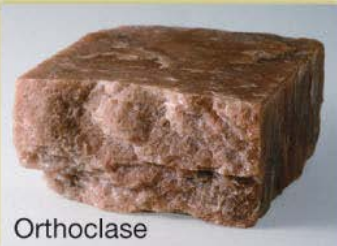
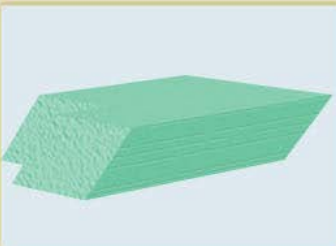
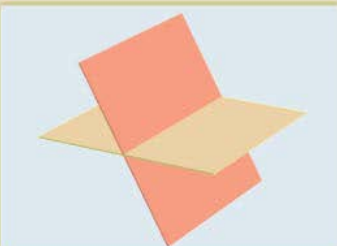

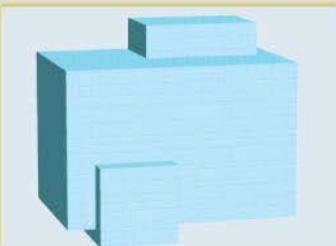


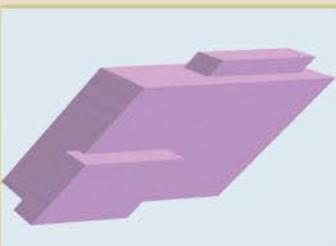
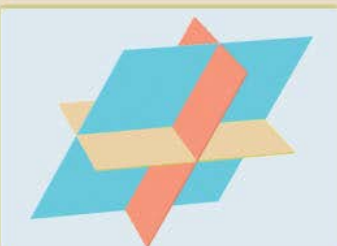

Pyroxene



Hornblende amphibole:
2 cleavage directions at
about 60 and 120 degrees (T&L, fig. 2.25)

Cleavage Directions

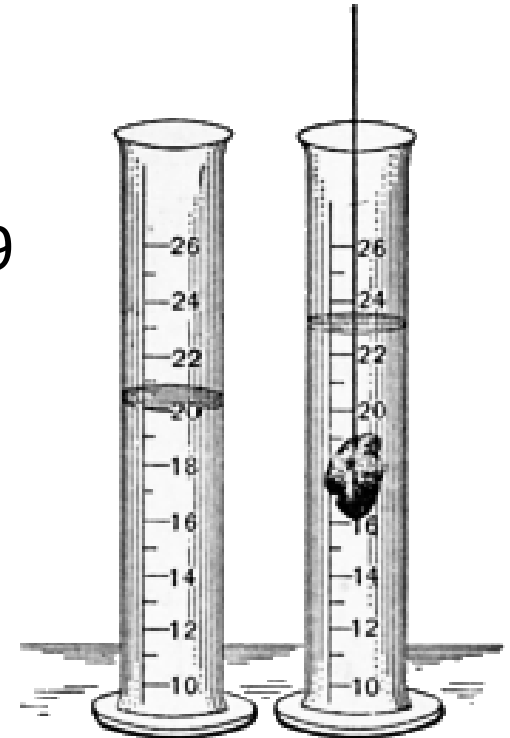
Fig 2.15

Number of Cleavage Directions	Sketch	Illustration of Cleavage Directions	Example
1			Muscovite 
2 at 90°			Orthoclase 
2 not at 90°			Amphibole 
3 at 90°			Halite 
3 not at 90°			Calcite 

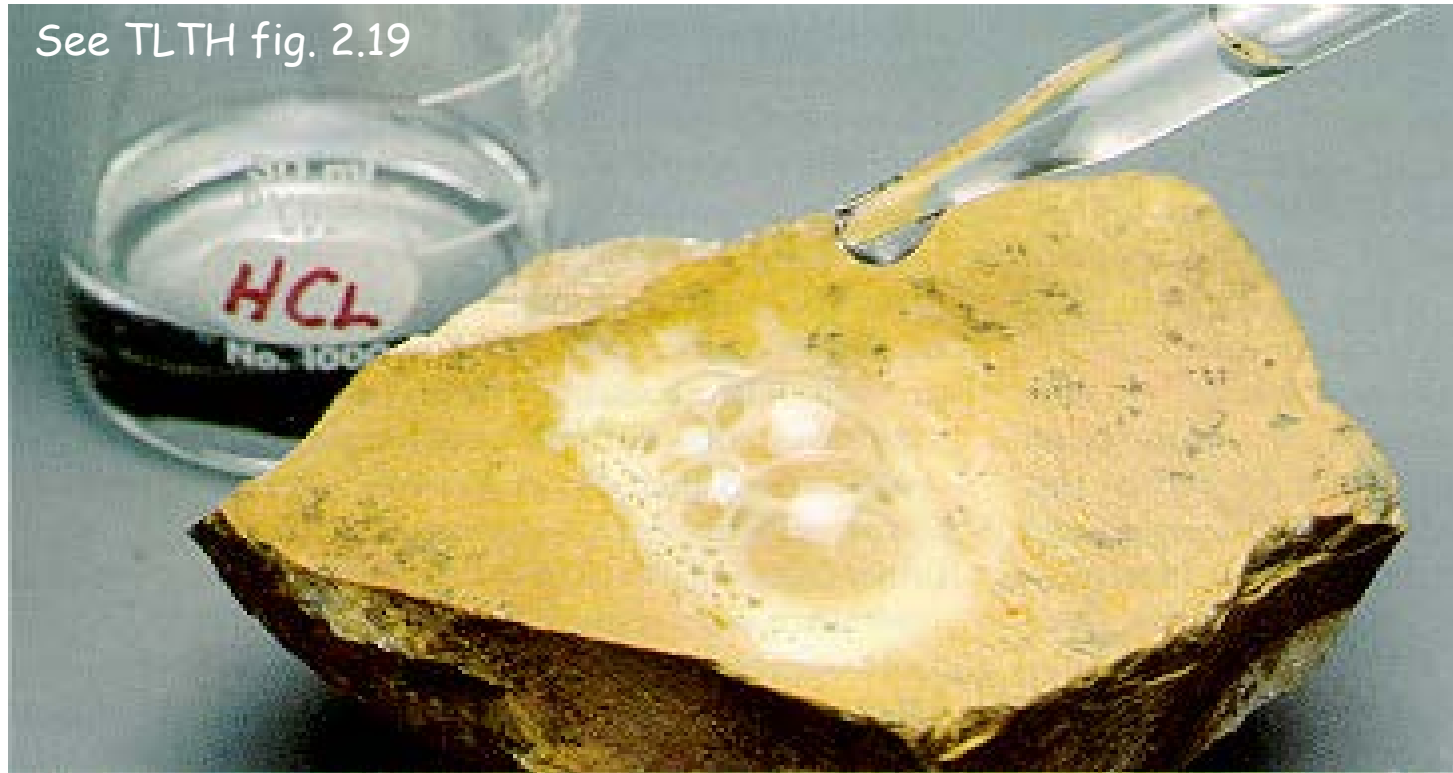
Physical Properties of Minerals: Specific Gravity

$$\text{Specific Gravity} = \frac{\text{Weight}}{\text{Weight of equivalent volume of water}}$$

- **Typical values:**
 - Ferromagnesian silicates = 2.7 to 4.3
 - Non-ferromagnesian silicates = 2.6 to 2.9
 - Galena = 7.58
 - Hematite = 5.26
 - Graphite = 2.09 to 2.33
 - Diamond = 3.5



The Acid Test: Carbonate Minerals



Calcite reacts vigorously with dilute hydrochloric acid
Dolomite does not react with acid unless it is powdered

Why does powdering dolomite create effervescence?

Important Rock-Forming Minerals

Nonsilicate Minerals

Oxides: hematite (Fe_2O_3), magnetite (Fe_3O_4)

Sulfides: galena (PbS), sphalerite (ZnS), pyrite (FeS_2)

Halides: halite (NaCl), fluorite (CaF_2)

Carbonates: calcite (CaCO_3), dolomite ($\text{CaMg}(\text{CO}_3)_2$)

Phosphates: apatite ($\text{Ca}_5(\text{F, Cl, OH})(\text{PO}_4)_3$)

Hydroxides: bauxite ($\text{Al}(\text{OH})_3$)

Why are sulfide minerals (or some of the other groups?) important to Geologists and Earth Scientists?

Chapter 2: Minerals Review

Define: mineral, crystal form, lustre, streak, cleavage, fracture, hardness, silicates, Si-O tetrahedron, rock.

Relate: cleavage to silicate structure with a mineral example of each structure.

How do you:

differentiate calcite from dolomite?

differentiate ferromagnesian minerals from non-ferromagnesian minerals (chemistry & physical properties)

What is the difference between a mineral and a rock?

Explain Mohs Hardness Scale – What are some of the Key Values?