Earth and Planetary Materials

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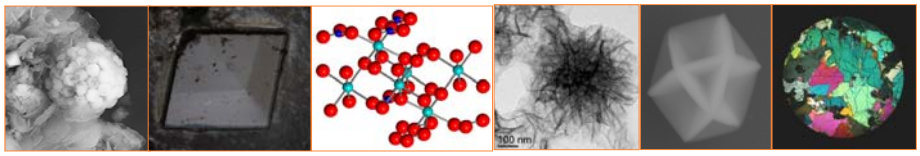
- Mineralogy and petrology: Fundamental principles and applications
- To understand the composition of surface and subsurface materials on Earth and other planetary bodies
- Chemical composition and structures of important mineral classes
- How mineral assemblages and micro-textures record the conditions of rock formation and alteration
- Introduction of a range of laboratory techniques
- Hands on lab experience, tour of user facilities



Composition of the earth

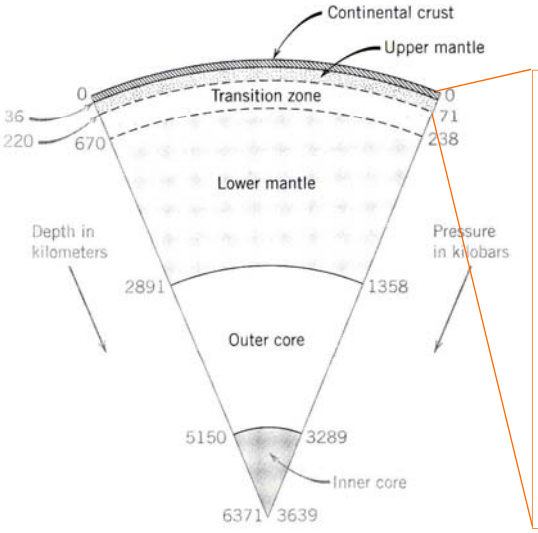
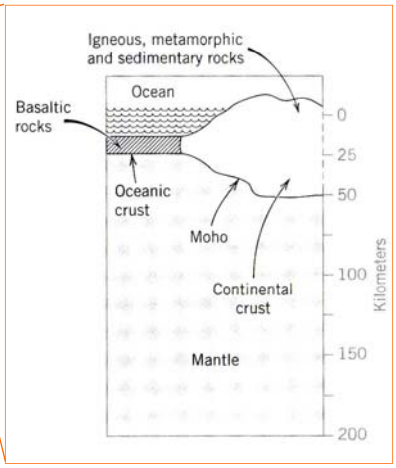


Figure 5.1. Major subdivisions of the Earth's interior.



Earth's lithosphere (crust and upper mantle)

Most common elements in the Earth's crust

	Weight percent*	Atom percent	Ionic+ radius (Å)	Volume percent
O	46.60	62.55	1.36	~ 94
Si	26.72	21.22	0.26 [4]	
Al	8.13	6.47	0.39 [4]	
Fe	5.00	1.92	0.78 [6]	
Ca	3.63	1.94	1.00 [6]	~ 6% in total
Na	2.83	2.64	1.02 [6]	
K	2.59	1.42	1.51 [8]	
Mg	2.09	1.84	0.72 [8]	
	98.59	100.00		

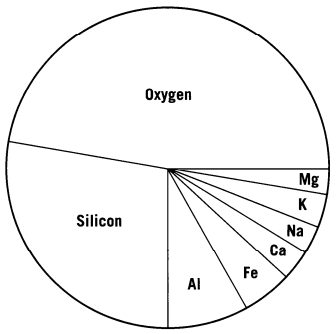


FIG. 3.2 The eight most common elements in the Earth's crust. From B. Mason, and C. B. Moore, 1982, *Principles of Geochemistry*, 4th ed. (New York: Wiley). †Ionic radii taken from Table 3.11. Numbers in square brackets refer to coordination number.

Klein. Mineral Science.
22nd Ed. P41; 23rd Ed. p92

Mineralogy and petrology

Mineralogy

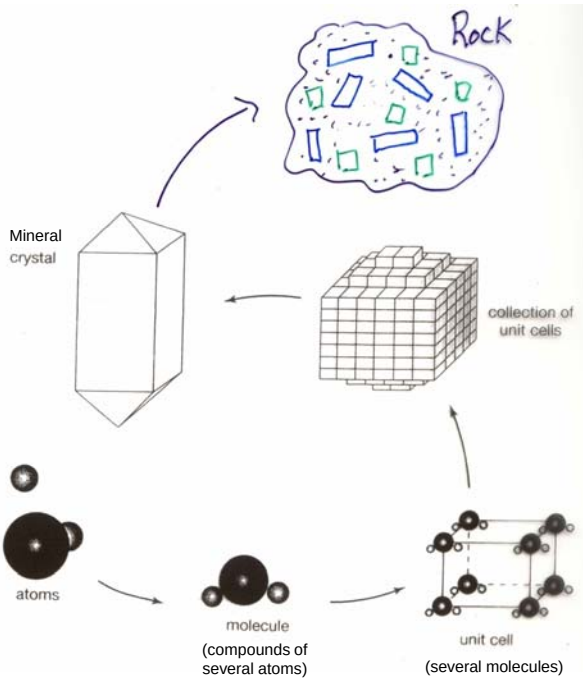
Study of minerals

- composition
- structure (= arrangement of atoms)
- physical properties
- classification
- occurrence
- Stability

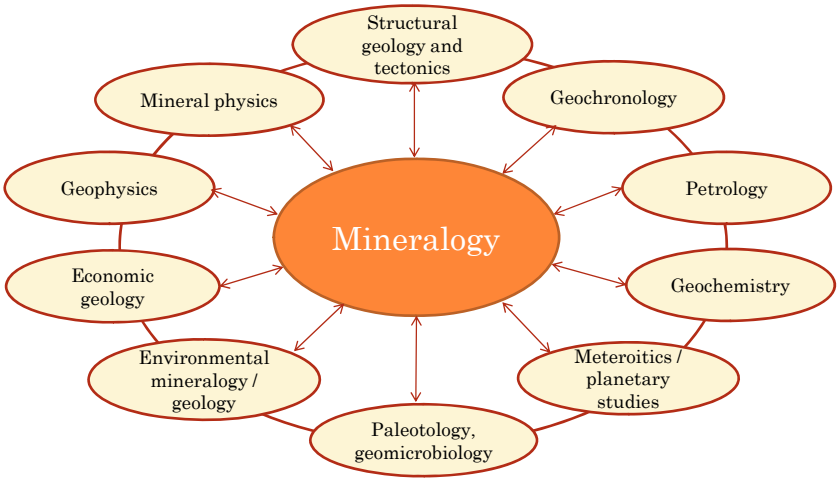
Petrology

Study of rocks

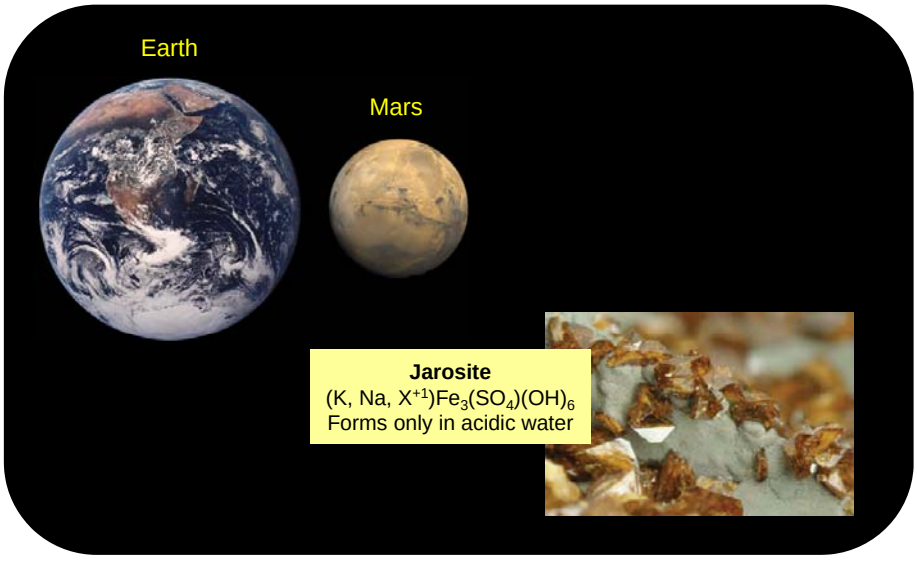
- Rocks (mostly) are composed of **minerals**



Roles of mineral science



Planetary science



Paleoclimate

- Recording the formation condition
- Composition reflects surrounding environmental conditions

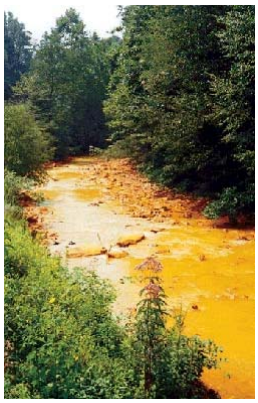
speleotherm (calcite, aragonite, or gypsum)

Coral (aragonite)

Acid mine drainage

- Abandoned sub-surface mines
- Exposure to air/water causes the oxidation of metal sulfides (often pyrite FeS_2)
- Increased acidity

fool's gold



Medical mineralogy and human health

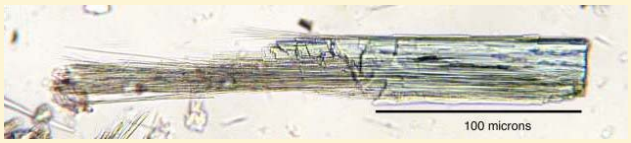
Chromium toxicity

chromite $FeCr_2O_4$

Chromium (III)
- Relatively insoluble
- Low mobility
- Low bioavailability
- Essential micronutrient

Chromium (VI)
- Highly soluble
- High mobility
- High bioavailability
- Toxic and carcinogenic

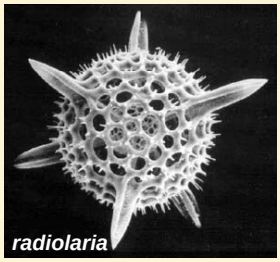
Asbestos
Serpentine group
Causes asbestosis and lung cancer



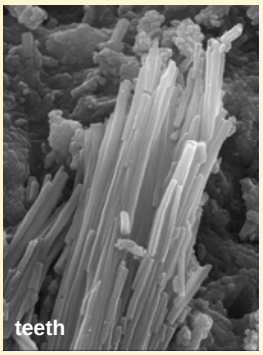
Biomineralization – Biologically controlled

- ✓ **Biologically regulated**
- ✓ **Allow the organism to precipitate minerals that serve some physiological purpose**

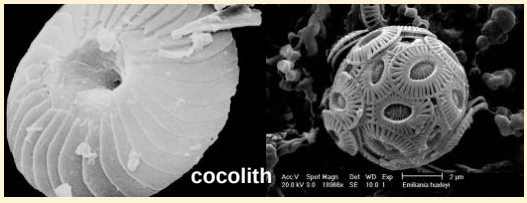
Silica biomineralization



Apatite biomineralization



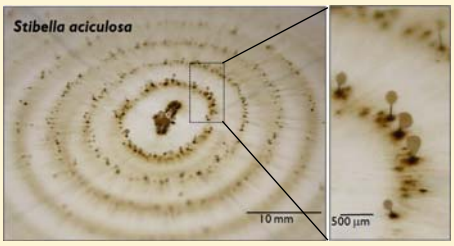
$CaCO_3$ biomineralization



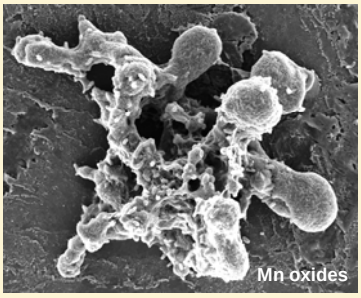
Biomineralization – Biologically induced

- ✓ **Not biologically regulated**
- ✓ **Byproducts of cell's metabolic activity**

Reactive metabolites



Templated growth

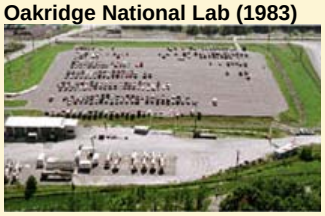


Remediation of contaminants

Uranium contamination

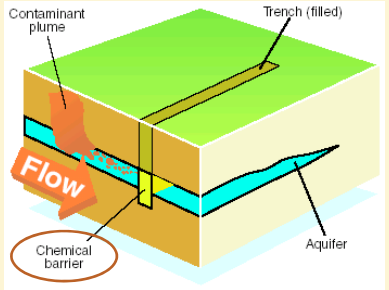
Oakridge National Lab (1951)

Oakridge National Lab (1983)



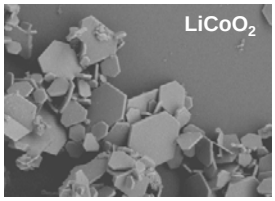
Bioreduction to form insoluble U(IV) oxides

permeable reactive barrier

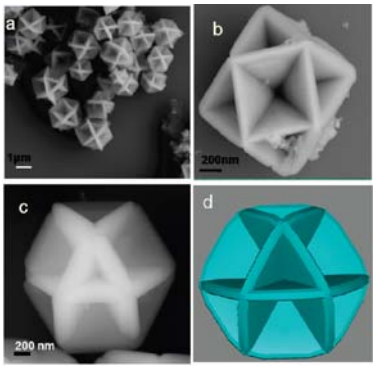


Functional nanomaterials

- Morphologically controlled growth of nanomaterials to improve performance



battery materials



What is a mineral?

A mineral is a naturally occurring solid with a highly ordered atomic arrangement and a definite (but not necessarily fixed), homogeneous chemical composition. Minerals are usually formed by inorganic processes.

What is a mineral?

- Naturally occurring: synthetic counterpart
- Solid: ~~gases or liquids~~
- Structured, periodic (3D) arrangement of atoms: crystalline vs amorphous?
- Definite chemical composition: can vary within limits. Example: dolomite $CaMgCO_3$ (pure), $Ca(Mg,Fe,Mn)CO_3$ (natural/general formula)
- Homogeneous: same composition throughout its volume regardless of the location sampled
- Produced by inorganic processes: arguable!

Example

- Water vs. Ice ?
- Obsidian (volcanic glass)?
  - Glass lacks a periodic arrangement of atoms, not crystalline. Also, no definite chemical composition.
- Rock that is not made of minerals?
  - Coal: made of organic materials
  - Others?

Mineraloids

Substances that meet the other criteria of minerals but that lack long-range internal order.

Examples:

- Naturally occurring glasses, e.g., volcanic glass (obsidian)
- Liquids (water, mercury)
- Opal ($SiO_2 \cdot nH_2O$): Originally considered completely amorphous (no internal structure). Later electron beam studies show internal ordered arrangement of small SiO_2 spheres. (Mineral or not?)

Crystalline vs. amorphous

- possesses a 3-dimensional periodic arrangement of atoms
- antonym of crystalline; no periodic arrangement of atoms
- distinguished based on whether substance diffracts X-rays; requires periodicity over distances of about 20nm.

How many minerals?

- There are about 3500 named mineral species
- IMA (International Mineralogical Association) decides whether a newly discovered substance qualifies as a new mineral species

Common minerals

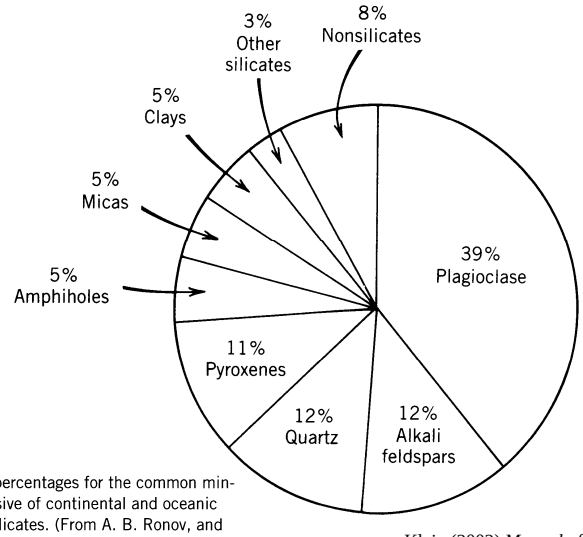


FIG. 11.1. Estimated volume percentages for the common minerals in the Earth's crust, inclusive of continental and oceanic crust. Ninety-two percent are silicates. (From A. B. Ronov, and A. A. Yaroshevsky, 1969, Chemical composition of the Earth's crust. American Geophysical Union Monograph no. 13, p. 50.)

Klein (2002) *Manual of Mineralogy*.
22nd Ed. John Wiley, p. 441
23rd Ed., p. 435