Chapter 4
EARTH MATERIALS:
MINERALS AND ROCKS

“Diamonds are ‘forever’”

4.1 The mineral calcite is found in the shells of many organisms, such as foraminifers. [Andrew Syred/Photo Researchers.]

Electron structure of the carbon atom (carbon-12). The electrons, each with a charge of –1, are represented as a negatively charged cloud surrounding the nucleus, which contains six protons, each with a charge of +1, and six neutrons, each with no charge. Size of the nucleus is greatly exaggerated in these drawings.

Carbon atoms in diamond are arranged in regular tetrahedra... ...that share an electron with each of four neighboring atoms.

FIGURE 4.1 The mineral calcite is found in the shells of many organisms, such as foraminifers. [Andrew Syred/Photo Researchers.]

Ionic bonds of sodium chloride – transfer or exchange of electrons.
Sizes of ions as they are commonly found in rock-forming minerals. Ionic radii are given in $10^{-8}$ cm. [After L. G. Berry, B. Mason, and R. V. Dietrich, Mineralogy. San Francisco: W. H. Freeman, 1983.]

Halite crystals precipitating within a modern hypersaline lagoon, San Salvador Island, Bahamas.

A perfect crystal is rare in nature, but no matter how irregular the shapes of the faces may be, the angles are always exactly the same. [Breck P. Kent.]

Graphite and diamond are polymorphs, alternative structures formed from a single chemical compound, carbon. [John Grotzinger/Ramón Rivera-Moret/ Harvard Mineralogical Museum.]

Graphite is formed at lower pressures and temperatures than diamond. Its carbon atoms are joined by strong bonds, while in diamond, weak bonds connect carbon atoms in alternating sheets.

Graphite and diamond are polymorphs, alternative structures formed from a single chemical compound, carbon.
Silicate ion is the basic building block of all silicate mineral structures.

Carbonate minerals, such as calcite (calcium carbonate, CaCO$_3$), have a layered structure. (a) Calcite. (John Grotzinger/Ramón Rivera-Moret/Harvard Mineralogical Museum.) (b) Top view of the carbonate ion, composed of a carbon ion surrounded in a triangle by three oxygen ions, with a net charge of –2. (c) View of the alternating layers of calcium and carbonate ions in calcite.

Oxide minerals.

Gypsum is a sulfate formed when seawater evaporates. (John Grotzinger/Ramón Rivera-Moret/Harvard Mineralogical Museum.)

Pyrite, a sulfide mineral, is also known as “fool’s gold.”

Oxide minerals. spinel.
Cleavage of mica. The diagram shows the cleavage plane in the crystal structure, oriented perpendicular to the plane of the page. Horizontal lines mark the interfaces of silica-oxygen tetrahedral sheets and the sheets of aluminum hydroxide bonding the two tetrahedral sheets into a sandwich. Cleavage takes place between tetrahedral–aluminum hydroxide sandwiches. The photograph shows thin sheets of mica separating along the cleavage planes. [Chip Clark.]  

Hematite may be black, red, or brown, but it always leaves a reddish brown streak when scraped along a ceramic streak plate.  

Trace elements give gems their colors. Sapphire (left) and ruby (center) are formed of the same common mineral, corundum (aluminum oxide). Small amounts of impurities produce the intense colors that we value. Ruby, for example, is red because of small amounts of chromium, the same element that gives emerald (right) its green color. [John Grotzinger/Ramón Rivera-Moret/Harvard Mineralogical Museum.]
selenite crystals are a gem-quality form of gypsum (calcium sulfate)

Asbestos (chrysotile). Fibers are readily combed from the solid mineral. [Runk/Schoenberger/Grant Heilman Photography]

Rocks are naturally occurring aggregates of minerals.

The three families of rocks are formed in different environments by different geological processes. [Granite and gneiss: John Grotzinger/Ramón Rivera-More/Harvard Mineralogical Museum. Sandstone: John Grotzinger/Ramón Rivera-More/MIT]

The three families of rocks are formed in different environments by different geological processes. [Granite and gneiss: John Grotzinger/Ramón Rivera-More/MIT]

Rocks are naturally occurring aggregates of minerals.

Weathering breaks down rocks into fragments and dissolved materials that are then carried downhill and downstream by erosion to be deposited as layers of sediment.
Metamorphic rocks form under conditions of high temperatures and pressures.

The rock cycle results from the interaction of the plate tectonic and climate systems.

Native gold on a quartz crystal. [Chip Clark.]

Many ore mineral deposits are found in veins formed by hydrothermal solutions rising from magmatic intrusions. This quartz vein deposit (about 1 cm thick) in Oatman, Arizona, contains gold and silver ores.

Metal sulfide ores. Sulfides are the most common types of metallic ores. [Chip Clark.]
Copper ores. Chalcopyrite and chalcocite are copper sulfide ores. Malachite is a carbonate of copper found in association with sulfides of copper. [Chip Clark.]

Kennecott Copper Mine, Utah, an open-pit mine. Open-pit mining is typical of the large-scale methods used to exploit widely disseminated ore deposits. [David R. Frazier/The Image Works.]

Chromite (chromium ore, visible as dark layers) in a layered igneous intrusion in the Bushveldt Complex, South Africa. [Breuer/Corbis.]

Panning for gold was popularized by “forty-niners” during the California gold rush and is still popular in the San Gabriel River today. [Bo Zaunders/CORBIS]