I. Minerals: the building blocks of rocks
   A. Definition of mineral
      1. Naturally occurring
      2. Inorganic
      3. Solid
      4. Possess an orderly internal structure of atoms
      5. Have a definite chemical composition
   B. Rocks are aggregates (mixtures) of minerals or mineral-like material—coal is a rock

II. Composition and structure of minerals
   A. Elements
      1. Basic building blocks of minerals
      2. More than 100 are known
      3. eight most common elements in Earth's crust: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium

III. Properties of minerals
      1. Crystal form—growth surfaces, external expression of internal arrangement
      2. Luster—reflection of light: ALL minerals have a luster!
      3. Color—may be created by minor impurities
      4. Streak—more diagnostic in identifcation
      5. Hardness—resistance to scratching, may be affected by alteration
      6. Cleavage—parallel planes of breakage, determined by strength of internal bonds, there may be intersecting sets in some minerals
      7. Fracture—description of breakage when there is no cleavage
      8. Specific gravity—comparison to an equal volume of water, heft
      9. Other properties
         a. Taste
         b. Smell
         c. Elasticity
         d. Malleability
         e. Feel
         f. Magnetism
         g. Double refraction
         h. Reaction to hydrochloric acid

IV. About 25 minerals are

A. called the *rock-forming minerals*

1. Feldspars, quartz, micas, pyroxenes, amphiboles, olivine, calcite, gypsum, dolomite, iron oxides, pyrite, garnet
2. The eight elements that compose most rock-forming minerals are oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg)
3. The most abundant atoms in Earth's crust are
    a. Oxygen (46.6% by weight)
    b. Silicon (27.7% by weight)

B. Mineral groups

1. Silicates
    a. Most common mineral group: because O & Si most common
    b. Contain the silicon–oxygen tetrahedron
        1) Four oxygens surrounding a much smaller silicon atom
        2) The silica tetrahedra join together in a variety of ways
            a) Framework
            b) Sheet
            c) Chains: single chains and double chains
    c. Feldspars are the most plentiful group: framework silicate
    d. Most silicate minerals crystallize from magma as it cools
2. Non-silicate minerals
    a. Major groups
        1) Oxides
        2) Sulfides
        3) Sulfates
        4) Halides
        5) Carbonates
        6) "Native" elements
    b. Carbonates
        1) Major rock-forming group
        2) Found in limestone and marble
    c. Halite and gypsum—found in sedimentary rocks
    d. Many have economic value

V. The rock cycle: Inter-relationship of parts of Earth system

1. Three types
   a. Igneous—crystallized from magma
   b. Sedimentary—deposited by deposition or precipitation
   c. Metamorphic—changed in the solid state
2. cycle discussion can start at any position—
   a. usually at the molten magma
      1) magma mostly Si, O
      2) minor amounts of Al, Fe, Ca, Na, K, Mg
   b. crystallizes to form silicate minerals: igneous rocks
      1) intrusive—cooling slowly below surface=coarse grained
      2) extrusive—cooling quickly at or near surface=fine grained
   c. exposure at surface results in weathering
      1) breaks down minerals chemically and physically
         a) different temperature and pressure than formed
         b) action of water, a universal solvent
      2) becomes sediment that is deposited
   d. sediment is lithified by compression and cementation
   e. addition of heat and pressure can cause atoms to reform into different minerals, or different grain sizes,
      1) without melting
      2) metamorphism, metamorphic rock is formed
   f. other paths exist across the 'cycle'
      1) igneous or metamorphic rocks can be metamorphosed
      2) sedimentary or metamorphic rocks can be weathered
      3) if there is melting, the only route is magma: igneous

VI. Sedimentary rocks

A. Rock cycle
1. magma solidifies into igneous rock
2. Surface processes weather rock, deposited as sediments—any rock type can be weathered
3. sediment is lithified by compaction and cementation
4. heat and pressure of burial change rock mineralogy in solid state to create metamorphic rock—any type can be metamorphosed
5. enough heat/pressure can cause melting→magma

B. Features of sedimentary rocks
   1. sedimentary rocks can preserve Earth-surface features
      a. evidence of past life on Earth—fossils
      b. on deposition surface showing environment of formation
         1) desiccation cracks
         2) ripple marks
   2. Strata, or beds
      a. most characteristic feature of sedimentary rocks
      b. bedding planes separate strata
   3. Fossils
      a. Traces or remains of prehistoric life
      b. Are the most important inclusions
      c. Help determine past environments
      d. Used as time indicators
      e. Used for matching rocks from different places
   4. Porosity and permeability
      a. Hold fluids such as petroleum or water
      b. Receive ore deposits by precipitation from fluids

VII. Formation of sedimentary rocks
   1. settles out of a fluid
      a. deposition of solid particles
      b. precipitation of minerals from water
      c. formed by organisms in one of the two above processes
   2. weathered debris carried by fluid
      a. running water
      b. wind
      c. ice
   3. formed at surface, so most rocks exposed at surface are sedimentary—about 75% of all rock outcrops on the continents
   4. Used to reconstruct much of Earth's history
      a. Clues to past environments, sediment transport
      b. often contain fossils indicating environment and age
   5. Economic importance
      a. Coal, Petroleum and natural gas
      b. Chemical precipitation of iron and aluminum
      c. Mechanical deposition of gold, tin, garnet
      d. Sand, gravel clay for construction and industry
   6. Classifying sedimentary rocks
      a. Two major divisions
         1) Made of particles: clastic or detrital
         2) Minerals precipitating from water: chemical
         3) Most rocks are combinations, but many are predominantly one or the other

VIII. Clastic sedimentary rocks

1. from preexisting rock
    a. Transported and rounded to place of deposition
    b. Shape, size, and sorting of clasts tells a tremendous amount about the environment of deposition
        1) Particle size named by fraction of mm
            a) Over 2 mm—gravel
            b) 1/16 to 2 mm—sand
            c) 1/256 to 1/16 mm—silt ($1/2^8$)
            d) Less than 1/256 mm—clay
        2) Sorting refers to the range of sizes present
    c. Deposition of sediment puts in a place to become lithified **process of becoming stone**
        1) Burial and compaction
        2) Precipitation of cement
            a) Brought in by water
            b) Mineral material between clasts
            c) Fills in pore spaces
            d) Calcite, silica, and sometimes iron oxide
        3) Each reduces 'pore space'
2. **Types of clastic rocks**
    a. Shale (most abundant)
        1) Composed of very fine grained sediment
        2) Tendency to split along planes (fissile)
        3) Usually gray
        4) Most common type of sedimentary outcrop
    b. Sandstone
        1) Composed of sand-size particles
        2) Between 1/16 mm and 2 mm diameter
        3) Individual mineral grains or rock fragments
        4) Quartz most common type of grain
        5) Environments include
    c. Conglomerate
        1) Composed of particles larger than 2 mm
        2) Usually particles are rock fragments
        3) Refer to shape of the clasts it is composed of, not the overall shape of the rock

IX. Chemical and organic sedimentary rocks

—lumped together as 'chemically formed sedimentary rocks'

1. Derived from material that was once in solution and precipitates to form sediment
    a. Directly precipitated: result of physical processes,
    b. Through life processes (biochemical origin)
2. Types
    a. Limestone is usually biochemical: precipitated by organisms
        1) Composed of the mineral calcium carbonate
        2) Considered an 'organic sediment'
        3) Second most common type of sedimentary rock—most common type of chemical rock
    b. Most other types from mineral precipitation directly from water
        1) Microcrystalline quartz (precipitated quartz) known as chert, flint, jasper, opal or agate
        2) Evaporites such as rock salt or gypsum
        3) Travertine (calcite), sinter (silica) from hotspring deposits