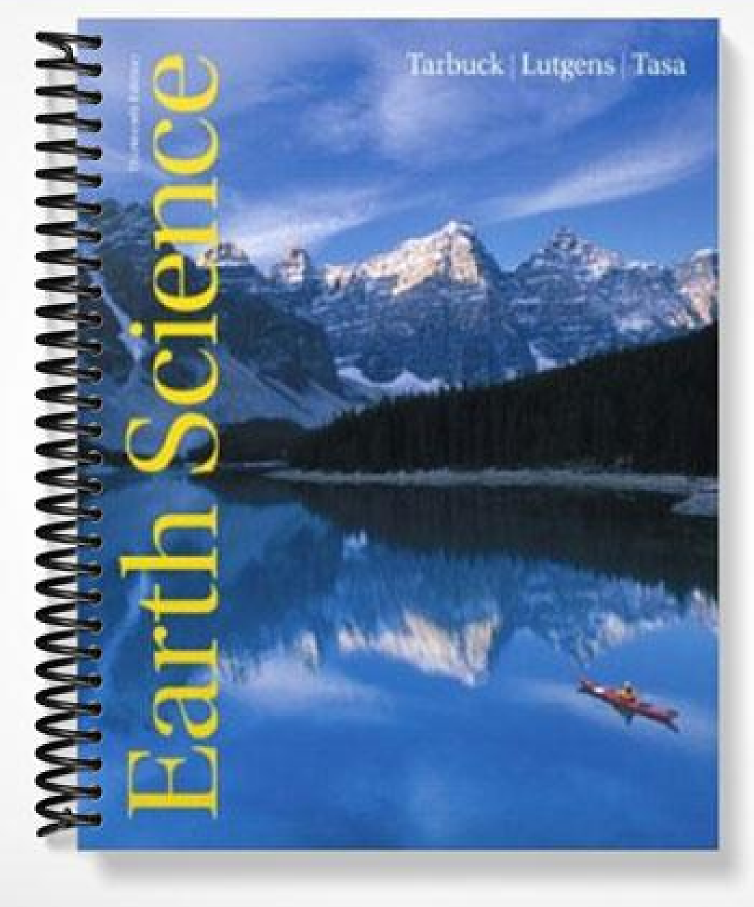
SOLUTIONS MANUAL



INSTRUCTOR MANUAL

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Earth Science

Thirteenth Edition

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Contents

Chapter 1

Introduction to Earth Science

Introduction to Earth Science opens with a definition and explanation of Earth science and overview of the text. Following a brief discussion of the origin of Earth, Earth's "spheres" are examined. After an introduction to Earth system science, the importance of understanding basic Earth science principles when examining resources and environmental issues is presented. The chapter closes with a discussion of the nature of scientific inquiry.

Learning Objectives

After reading, studying, and discussing the chapter, students should be able to:

- List the sciences traditionally included in Earth science.
- Summarize the early evolution of Earth.
- Describe Earth's "spheres."
- Briefly discuss Earth's internal structure.
- Explain the mobile nature of the geosphere.
- List the principal divisions and features of Earth's surface.
- Discuss Earth system science and Earth as a system.
- Summarize some of the relationships between people and the natural environment.
- Describe the nature of scientific inquiry.

Chapter Outline

I. Earth science
  A. Encompasses all sciences that seek to understand
    1. Earth
    2. Earth's neighbors in space
  B. Includes
    1. Geology—literally the "study of Earth"
      a. Physical geology examines the materials composing Earth
      b. Historical geology is the study of the origin and development of Earth
    2. Oceanography
      a. Not a separate and distinct science
      b. Oceanography integrates
        1. Chemistry
        2. Physics
        3. Geology
        4. Biology
    3. Meteorology—the study of the atmosphere and the processes that produce weather
    4. Astronomy—the study of the universe

II. Early evolution of Earth
  A. Origin of Earth
    1. Most researchers believe that Earth and the other planets formed at essentially the same time from the same primordial material as the Sun
    2. Nebular hypothesis
      a. Solar system evolved from an enormous rotating cloud called the solar nebula
      b. Nebula was composed mostly of hydrogen and helium
      c. About 5 billion years ago the nebula began to contract

- d. Assumed a flat, disk shape with the protosun (pre-Sun) at the center
- e. Inner planets began to form from metallic and rocky clumps of substances with high melting points
- f. Larger outer planets began forming from fragments with a high percentage of ices of water, carbon dioxide, ammonia, and methane

B. Formation of Earth's layered structure
1. As Earth formed, the decay of radioactive elements and heat from high-velocity impacts caused the temperature to increase
    - a. Iron and nickel began to melt and sink toward the center
    - b. Lighter rocky components floated outward, toward the surface
2. Gaseous material escaped from Earth's interior to produce the primitive atmosphere

III. Earth's "spheres"

A. Hydrosphere
1. Ocean—the most prominent feature of the hydrosphere
    - a. Nearly 71% of Earth's surface
    - b. About 97% of Earth's water
2. Also includes freshwater found in streams, lakes, and glaciers, as well as that found underground

B. Atmosphere
1. Thin, tenuous blanket of air
2. Half lies below 5.6 kilometers (3.5 miles)

C. Biosphere
1. Includes all life
2. Concentrated near the surface in a zone that extends from the ocean floor upward for several kilometers into the atmosphere
3. Influences other three spheres

D. Solid Earth
1. Based on compositional differences, it consists of
    - a. Core
    - b. Mantle
    - c. Crust
2. Divisions of outer portion are based on how materials behave
    - a. Lithosphere—rigid outer layer
        1. Crust
        2. Uppermost mantle
    - b. Divisions of Earth's surface
        1. Continents
        2. Ocean basins

IV. Earth system science

A. Earth is a dynamic body with many separate but highly interacting parts or spheres

B. Earth system science studies Earth as a system composed of numerous parts, or subsystems

C. System—any size group of interacting parts that form a complex whole
1. Closed systems are self-contained (e.g., an automobile cooling system)
2. In open systems, both energy and matter flow into and out of the system (e.g., a river system)

D. Feedback mechanisms
1. Negative feedback mechanisms resist change and stabilize the system
2. Positive feedback mechanisms enhance the system

E. Earth as a system
1. Consists of a nearly endless array of subsystems (e.g., hydrologic cycle)
2. Sources of energy
    - a. Sun drives external processes
        1. Weather and climate
        2. Ocean circulation
        3. Erosional processes
    - b. Earth's interior drives internal processes
        1. Volcanoes
        2. Earthquakes
        3. Mountains
3. Humans are part of the Earth system

V. People and the environment
- A. Environment
  - 1. Surrounds and influences organisms
  - 2. Physical environment encompasses
    - a. Water
    - b. Air
    - c. Soil
    - d. Rock
  - 3. Term *environmental* is usually reserved for those aspects that focus on the relationships between people and the natural environment
- B. Resources
  - 1. An important focus of the Earth sciences
  - 2. Types
    - a. Water
    - b. Soil
    - c. Minerals
    - d. Energy
  - 3. Two broad categories
    - a. Renewable
      - 1. Can be replenished
      - 2. Examples
        - a. Plants
        - b. Energy from flowing water and wind
    - b. Nonrenewable
      - 1. Fixed quantities
      - 2. Examples
        - a. Metals
        - b. Fuels
- C. Population
  - 1. Population of the planet is growing rapidly
  - 2. Rate of mineral and energy usage has climbed more rapidly than the overall growth of population
- D. Environmental problems
  - 1. Local, regional, and global
  - 2. Human-induced and accentuated
    - a. Urban air pollution
    - b. Acid rain
    - c. Ozone depletion
    - d. Global warming
  - 3. Natural hazards
    - a. Earthquakes
    - b. Landslides
    - c. Floods
    - d. Hurricanes
  - 4. World population pressures

VI. Scientific inquiry
- A. Science assumes the natural world is
  - 1. Consistent
  - 2. Predictable
- B. Goal of science
  - 1. To discover patterns in nature
  - 2. To use the knowledge to predict future events
- C. An idea can become a
  - 1. Hypothesis (tentative or untested explanation)
  - 2. Theory (tested and confirmed hypothesis)
  - 3. Paradigm (a theory that explains a large number of interrelated aspects of the natural world)
- D. Scientific method
  - 1. Gather facts through observation
  - 2. Formulate
    - a. Hypotheses
    - b. Theories
- E. Scientific knowledge is gained through
  - 1. Following systematic steps:
    - a. Collect facts
    - b. Developing a hypothesis
    - c. Conduct experiments
    - d. Reexamine the hypothesis and
      - 1. Accept
      - 2. Modify
      - 3. Reject
  - 2. Theories that withstand examination
  - 3. Totally unexpected occurrences

Introduction to Earth Science

Answers to Earth System Questions

1. (a) rock: geosphere; (b) people: biosphere; (c) running water: hydrosphere; (d) algae on the rocks: biosphere

2. Geosphere: The earth materials involved in the mudflow are part of the geosphere.
   Atmosphere: The heavy rains played a key role in this event.
   Biosphere: The mudflow removed the vegetation from the hillside and also probably affected organisms living on the slope.
   Hydrosphere: The precipitation is part of the circulation of water in the hydrosphere.

3. Answers will vary for each student.

Answers to "Give It Some Thought"

1. The light switch is broken. The light source (bulbs, tubes, etc.) are "burned out" and no longer working. The electricity to the room is not turned on or has been disconnected.

2. a) hypothesis – it is a tentative explanation; b) observation; c) theory – well tested and widely accepted by the scientific community; d) observation – direct measurement of how far the glacier has moved; e) theory

3. Warmer temperatures would promote melting of glaciers and ice caps, thus reducing the reflection of solar radiation by ice and snow. This would result in a further warming of Earth and the result is a positive feedback mechanism. Increased evaporation would actually put more water vapor into the atmosphere, resulting in an increase in cloud cover. Clouds tend to reflect more sunlight back into space, which diminishes the radiation which reaches the surface of Earth. The result is an increase in global temperatures and this is an example of a negative feedback mechanism.

4. Figures 1.1 B, 1.A, 1.B, 1.5 A, 1.5 B

5. At least three and probably four of the main components of the Earth system were involved in the natural disaster at Caraballeda, Venezuela. The atmosphere was most definitely involved with the heavy rains that triggered the massive debris flow as well as the hydrosphere because of the role of water in the disaster. The geosphere played a critical role, both in the types of earth materials in the region and the topographic setting at the mouth of a steep canyon. The disaster also impacted the biosphere in the large loss of human life and the destruction of plants and other animals.

6. Hydrosphere – atmosphere: Evaporation of surface waters provides the majority of water vapor that is present in the atmosphere. Atmosphere – biosphere: Exchange of gases between living organisms (both plants and animals) is one of the fundamental interactions on our planet. Biosphere – hydrosphere: Absorption of water by plants is one of the key exchanges necessary for life on Earth. Biosphere – geosphere: Death and decay of certain organisms provide the materials necessary to form various rocks (limestone, coal, etc.). Geosphere – atmosphere: Oxidation (some of the oxygen comes from the atmosphere) often results in the breakdown of various rocks and minerals and the formation of new ones. Geosphere – hydrosphere: Erosion by surface waters is a key process in the formation of detrital sedimentary rocks.

Lecture outline, art-only, and animation PowerPoint presentations for each chapter of *Earth Science*, 13e are available on the IRC DVD (ISBN 0321720253).

Chapter 2 Matter and Minerals

Matter and Minerals begins with an explanation of the difference between rocks and minerals. The brief comparison is followed by a formal definition of a mineral. Elements, atoms, compounds, ions, and atomic bonding are discussed. Also investigated are isotopes and radioactivity. Following descriptions of the properties used in mineral identification, the silicate and nonsilicate mineral groups are examined. The chapter concludes with a presentation of mineral resources, reserves, and ores.

Learning Objectives

After reading, studying, and discussing the chapter, students should be able to:

- Explain the difference between a mineral and a rock.
- Describe the basic structure of an atom and explain how atoms combine.
- List the most important elements that compose Earth's continental crust.
- Explain isotopes and radioactive decay.
- Describe the physical properties of minerals and how they can be used for mineral identification.
- List the basic compositions and structures of the silicate minerals.
- List the economic use of some nonsilicate minerals.
- Distinguish among mineral resources, reserves, and ores.

Chapter Outline

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

II. Composition and structure of minerals
  A. Elements
    1. Basic building blocks of minerals
    2. More than 100 are known
  B. Atoms
    1. Smallest particles of matter
    2. Have all the characteristics of an element

III. Structure of atoms
  A. Nucleus contains
    1. Protons—positive electrical charge
    2. Neutrons—electrically neutral
  B. Energy levels or shells
    1. Surround nucleus
    2. Contain electrons—negative electrical charge
  C. Atomic number, the number of protons in an atom's nucleus, identifies element
  D. Bonding of atoms
    1. Compounds are formed from two or more elements
    2. Ions are atoms that have gained or lost electrons
  E. Isotopes
    1. Vary in the number of neutrons
    2. Have different mass numbers—the sum of the neutrons plus protons
    3. Many isotopes are radioactive and emit energy and particles

IV. Minerals
- A. Properties of minerals
  1. Crystal form
  2. Luster
  3. Color
  4. Streak
  5. Hardness
  6. Cleavage
  7. Fracture
  8. Specific gravity
  9. Other properties
     - a. Taste
     - b. Smell
     - c. Elasticity
     - d. Malleability
     - e. Feel
     - f. Magnetism
     - g. Double refraction
     - h. Reaction to hydrochloric acid
- B. A few dozen minerals are called the *rock-forming minerals*
  1. 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)
  2. The most abundant atoms in Earth's crust are
     - a. Oxygen (46.6% by weight)
     - b. Silicon (27.7% by weight)
- C. Mineral groups
  1. Rock-forming silicates
     - a. Most common mineral group
     - b. Contain the silicon–oxygen tetrahedron
       1. Four oxygen atoms surrounding a much smaller silicon atom
       2. The silicon–oxygen tetrahedra join together in a variety of ways
     - c. Feldspars are the most plentiful group
     - d. Most silicate minerals crystallize from molten rock as it cools
  2. Nonsilicate 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
- D. Mineral resources
  1. Reserves—profitable, identified deposits
  2. Ores—metallic minerals that can be mined at a profit
  3. Economic factors may change

Answers to the Earth System Questions

1. (Answers will vary depending on the mineral commodity selected)

2. (Answers will vary depending on the mineral commodity selected)

Answers to "Give It Some Thought"

1. a) mineral – gold is an example of a mineral classified as a native element; b) seawater is not a mineral – minerals by definition are solids; c) quartz is a mineral; d) cubic zirconia is not a mineral – it is not naturally occurring; e) obsidian is not a mineral because it lacks an internal arrangement of atoms, however, it is an igneous rock; f) ruby is a mineral – it is a gemstone variety of the mineral corundum; g) glacial ice is a mineral as it meets all of the criteria; g) amber is not a mineral since it has an organic origin.

Matter and Minerals

2. a) The element is uranium. b) 92 electrons c) 146 neutrons

3. Sodium is more likely to form chemical bonds because of its tendency to lose one electron, resulting in an overall +1 charge.

4. Potassium-39 has 19 protons and 20 neutrons; Potassium-40 has 19 protons and 21 neutrons; Potassium-41 has 19 protons and 22 neutrons

5. Specimens A, B, and D have a nonmetallic luster. Specimens C and E have a metallic luster.

6. a) 6 b) 3 c) no

7. 5 gallons of water = 40 lbs. x 20 (specific gravity of gold) = 800 lbs.

8. Answers may vary slightly depending on which websites are utilized by students.

9. Answers will vary.

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Chapter 3 Rocks: Materials of the Solid Earth

Rocks: Materials of the Solid Earth opens with a discussion of the rock cycle that presents a general overview of the origins and processes involved in forming the three major rock groups—igneous rock, sedimentary rock, and metamorphic rock. A discussion of the crystallization of magma is followed by an examination of the classification, textures, and compositions of igneous rocks. After presenting the processes of mechanical and chemical weathering, the chapter discusses the classification of sedimentary rocks, as well as some of their common features. The chapter also examines the agents of metamorphism, the textural and mineralogical changes that take place during metamorphism, and some common metamorphic rocks. In conclusion, resources from rocks and minerals are investigated.

Learning Objectives

After reading, studying, and discussing the chapter, students should be able to:

- Diagram and discuss the rock cycle
- List the geologic processes involved in the formation of each rock group.
- Briefly explain crystallization of magma.
- List the criteria used to classify igneous rocks.
- List the names, textures, and environments of formation for the most common igneous rocks.
- Briefly explain Bowen’s reaction series and how it relates to magmatic differentiation.
- Discuss the origin of materials that accumulate as sediment.
- List the criteria used to classify sedimentary rocks.
- Explain the difference between detrital and chemical sedimentary rocks.
- List the names, textures, and environments of formation for the most common sedimentary rocks.
- List the common features of sedimentary rocks.
- Describe the agents of metamorphism.
- List the criteria used to classify metamorphic rocks.
- List the names, textures, and environments of formation for the most common metamorphic rocks.
- Discuss metallic and nonmetallic mineral resources.

Chapter Outline

I. Rock cycle
  A. Shows the interrelationships among the three rock types
  B. Earth as a system: the rock cycle
    1. Magma
      a. Crystallization
    2. Igneous rock
      a. Weathering
      b. Transportation
      c. Deposition
    3. Sediment
      a. Lithification
    4. Sedimentary rock
      a. Metamorphism
    5. Metamorphic rock
      a. Melting
    6. Magma
  C. Full cycle does not always take place owing to “shortcuts” or interruptions; for example,
    1. Sedimentary rock melts
    2. Igneous rock is metamorphosed
    3. Sedimentary rock is weathered

4. Metamorphic rock weathers

II. Igneous rocks
- A. Form as magma cools and crystallizes
  - 1. Rocks formed inside Earth
    - a. Called plutonic or intrusive rocks
  - 2. Rocks formed on the surface
    - a. Formed from lava (a material similar to magma, but without gas)
    - b. Called volcanic or extrusive rocks
- B. Crystallization of magma
  - 1. Ions arrange themselves into orderly patterns
  - 2. Crystal size is determined by the rate of cooling
    - a. Slow rate produces large crystals
    - b. Fast rate produces microscopic crystals
    - c. Very fast rate produces glass
- C. Classification is based on the rock's texture and mineral constituents
  - 1. Texture
    - a. Size and arrangement of crystals
    - b. Types
      - 1. Fine-grained—fast rate of cooling
      - 2. Coarse-grained—slow rate of cooling
      - 3. Porphyritic (two crystal sizes)—two rates of cooling
      - 4. Glassy—very fast rate of cooling
  - 2. Mineral composition
    - a. Explained by Bowen's reaction series, which shows the order of mineral crystallization
    - b. Influenced by crystal settling in the magma
- D. Nomenclature of igneous rocks
  - 1. Granitic rocks
    - a. Composed almost entirely of light-colored silicates—quartz and feldspar
    - b. Also referred to as felsic: *fe*ldspar and *si*lica (quartz)
    - c. High silica content (about 70 percent)
    - d. Common rock is granite
  - 2. Basaltic rocks
    - a. Contain substantial dark silicate minerals and calcium-rich plagioclase feldspar
    - b. Also referred to as mafic: *ma*gnesium and *fe*rrum (iron)
    - c. Common rock is basalt
  - 3. Other compositional groups
    - a. Andesitic (or intermediate)
    - b. Ultramafic

III. Sedimentary rocks
- A. Form from sediment (weathered products)
- B. Constitute about 75 percent of all rock outcrops on the continents
- C. Used to reconstruct much of Earth's history
  - 1. Contain clues to past environments
  - 2. Provide information about sediment transport
  - 3. Often contain fossils
- D. Economic importance
  - 1. Coal
  - 2. Petroleum and natural gas
  - 3. Sources of iron and aluminum
- E. Classification of sedimentary rocks
  - 1. Two groups based on the source of the material
    - a. Detrital rocks
      - 1. Material is solid particles
      - 2. Classified by particle size
      - 3. Common rocks are
        - a. Shale (most abundant)
        - b. Sandstone
        - c. Conglomerate
        - d. Siltstone
    - b. Chemical rocks
      - 1. Derived from material that was once in solution and precipitated to form sediment
        - a. Directly precipitated as the result of physical processes
        - b. Precipitated through life processes (biochemical origin)
      - 2. Common sedimentary rocks
        - a. Limestone—the most abundant chemical rock
          - 1. Coquina
          - 2. Chalk
          - 3. Travertine
        - c. Microcrystalline quartz (precipitated quartz)
          - 1. Chert
          - 2. Flint
          - 3. Jasper

            4. Agate
        d. Evaporites
            1. Rock salt
            2. Gypsum
        e. Coal
            1. Lignite
            2. Bituminous
    F. Produced through lithification
        1. Loose sediments are transformed into solid rock
        2. Lithification processes
            a. Compaction
            b. Cementation by
                1. Calcite
                2. Silica
                3. Iron oxide
    G. Features
        1. Strata, or beds (most characteristic)
        2. Bedding planes separate strata
        3. Fossils
            a. Contain traces or remains of prehistoric life
            b. Are the most important inclusions
            c. Help determine past environments
            d. Are used as time indicators
            e. Are used for matching rocks from different places

IV. Metamorphic rocks
    A. Rocks that have changed form
    B. Produced from preexisting
        1. Igneous rocks
        2. Sedimentary rocks
        3. Other metamorphic rocks
    C. Metamorphism
        1. Takes place where preexisting rock is subjected to temperatures and pressures unlike those in which it formed
        2. Degrees of metamorphism
            a. Exhibited in the rock's texture and mineralogy
            b. Types
                1. Low-grade (e.g., shale becomes slate)
                2. High-grade (causes the original features to be obliterated)
    D. Metamorphic settings
        1. Contact, or thermal, metamorphism
            a. Near a mass of magma
            b. Change is driven by a rise in temperature
        2. Regional metamorphism
            a. Result of directed pressures and high temperatures during mountain building
            b. Produces the greatest volume of metamorphic rock
    E. Metamorphic agents
        1. Heat
        2. Pressure (stress)
            a. From burial (confining pressure)
            b. From differential stress during mountain building
        3. Chemically active fluids
            a. Mainly water and other volatiles
            b. Promote recrystallization by enhancing ion migration
    F. Metamorphic textures
        1. Foliated texture
            a. Minerals in a parallel alignment
            b. Minerals perpendicular to the compressional force
        2. Nonfoliated texture
            a. Contains equidimensional crystals
            b. Resembles a coarse-grained igneous rock
    G. Common metamorphic rocks
        1. Foliated rocks
            a. Slate
                1. Fine-grained
                2. Splits easily
            b. Schists
                1. Strongly foliated
                2. "Platy"
                3. Types based on composition (e.g., mica schist)
            c. Gneiss
                1. Strong segregation of silicate minerals
                2. "Banded" texture
        2. Nonfoliated rocks
            a. Marble
                1. Parent rock—limestone
                2. Large, interlocking calcite crystals
                3. Used as a building stone
                4. Variety of colors
            b. Quartzite
                1. Parent rock—quartz sandstone
                2. Quartz grains are fused

V. Resources from rocks and minerals
    A. Metallic mineral resources
        1Gold, silver, copper, mercury, lead, and

others
2. Concentrations of desirable materials are produced by
   a. Igneous processes
   b. Metamorphic processes
3. Most important ore deposits are generated from hydrothermal (hot-water) solutions
   a. Contain metal-rich fluids
   b. Associated with cooling magma bodies
   c. Types of deposits include
      1. Vein deposits in fractures or bedding planes
      2. Disseminated deposits distributed throughout the rock

B. Nonmetallic mineral resources
   1. Mined for
      a. Nonmetallic elements they contain
      b. Physical or chemical properties they possess
   2. Two broad groups
      a. Building materials (e.g., limestone, gypsum)
      b. Industrial minerals (e.g., fluorite, corundum, sylvite

Answers to Earth System Questions

1. The sedimentary rock coquina is a biochemical limestone that consists of loosely cemented shells and shell fragments that have accumulated on the ocean floor. The primary Earth spheres involved in its formation are the biosphere, hydrosphere, and atmosphere (the source of the carbon dioxide for the mineral calcite found in the shells). Shale, a detrital sedimentary rock, is composed primarily of clay, a product of weathering of several different minerals, and possibly some organic matter. The spheres involved in its formation are the biosphere, hydrosphere (where the sediment accumulates), atmosphere (which is involved in the weathering process), and solid earth (which supplied the material to weather into clay).

2. Igneous and metamorphic rocks are associated with Earth's internal heat. Sedimentary rocks, because they often contain organic matter and form in the sea, where the Sun is the energy source that drives waves and currents, are allied with both solar energy and Earth's internal heat.

3. 20,000 pounds/year x 75 years = 1,500,000 pounds. If a cubic yard of rock weighs roughly 1700 pounds, the volume of rock that would be mined over 75 years is 1,500,000 pounds ÷ 1700 pounds = 882.4 cubic yards. 1 cubic yard = 27 cubic feet, so 882.4 cubic yards x 27 cubic feet/cubic yard = 23,824 cubic feet. This is the equivalent of a hole approximately 28.5 feet wide, 28.5 feet long, and 28.5 feet deep!

Answers to "Give It Some Thought"

1. The rock cycle supports the fact that sedimentary rocks are most abundant on Earth's surface because each rock type, once exposed at the surface, is subjected to uplift, weathering, and erosion. The resulting sediment will eventually be transformed into sedimentary rock.

2. No. Crystal size in igneous rocks is a direct function of the rate of cooling and since a given body of magma could experience differential rates as it cools and solidifies, different sizes of crystals in the same rock would be common.

3. A) Rapid rate of cooling resulting in mainly microscopic crystals; B) A very slow rate of cooling followed by a more rapid period of cooling as evidenced by the porphyritic texture; C) Relatively slow, steady rate of cooling resulting in larger crystals of about the same size; D) Extremely rapid rate of cooling as indicated by the glassy texture.

4. Yes, rhyolite and granite are a good example of two rocks with similar compositions. Rapid cooling of lava results in the aphanitic texture typical of rhyolite while granite exhibits large, visible crystals due to slow cooling of magma.

5. Remember that Bowen's Reaction Series not only predicts the sequence of crystallization for minerals from magmas, but it also provides the order in which those minerals will melt as temperature increases for a given rock. If only partial melting (as opposed to complete melting) occurs, the resulting magma will only contain those chemical elements from the minerals whose melting temperatures have been achieved. Therefore, the magma could have a significantly different chemical composition than the original rock. In addition, varying degrees of partial melting could produce several different magmatic compositions from the original rock.

6. The accumulation of organic debris (leaves, stems, branches, etc.) and physical debris (mud, soil, etc.) around your home and in your yard are other examples of sedimentary processes.

7. One reason why sedimentary rocks are more likely to contain fossils is because sediment accumulates in various environments (oceans, lakes, rivers, beaches, swamps, deserts, etc.) where both plants and animals already exist. As the organisms die, they accumulate with detrital sediments and often become incorporated into the final rock that is formed. Another reason is that the various processes involved in the formation of sedimentary rocks (erosion, deposition, and lithification) are often not so destructive as to obliterate the original form or at least some part of the original organism.

8. The geologic history of the limestone layer would perhaps be the following: 1) formation of marine limestone in a warm, shallow ocean; 2) burial and lithification of limestone over a long period of time; 3) uplift of unit, most likely related to plate tectonic forces at or near a plate boundary; 4) erosion of younger units and exposure of limestone layer at the top of a present-day mountain.

9. Outcrop "B" is composed of metamorphic rock. Photograph "A" shows layers of sediment and coarse layers of gravel typical of sedimentary rocks. Photograph "C" displays an igneous rock with some sort of intrusion cutting through it. Also, photograph "B" shows highly banded rock layers with intense folding and kink banding, typical of metamorphic rocks.

10. a) The Vishnu Schist could have formed from regional metamorphism involving increased temperatures and pressures associated with plate tectonics. This is a very different process from the various steps involved in the formation of the sedimentary rocks above it (weathering, erosion, deposition, and lithification). b) The Grand Canyon obviously had a much different geologic history involving regional metamorphism and perhaps various episodes of mountain building compared the modern erosion of the Colorado River. c) The Vishnu Schist has been exposed at Earth's surface due to uplift and the erosion of this region by the Colorado River. d) Yes, it is very likely that the Vishnu Schist exists in other areas since such rocks are typically formed by regional metamorphism (which takes place over large regions). It simply has not been exposed in most other areas.

11. a) 20,000 lbs. x 80 years = 1,600,000 lbs. b) 1,600,000 lbs. / 1700 lbs. per cubic yd. = 941.2 cubic yards c) 941.2 cubic yards x 2 = 1883 pickup truck loads

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NOTES:

Chapter 4

Weathering, Soil, and Mass Wasting

Weathering, Soil, and Mass Wasting begins with a brief examination of the external processes of weathering, mass wasting, and erosion. The two forms of weathering, mechanical and chemical, are investigated in detail—including the types, conditions, rates, and net effect of each. The soils section of the chapter begins with a description of the general composition, texture, and structure of soil. After the factors that influence soil formation, development, and classification are examined, soil erosion, as well as some ore deposits produced by weathering, are presented. Mass wasting begins with a look at the role the process plays in landform development. Following a discussion of the controls and triggers of mass wasting, a general presentation of the various types of mass wasting concludes the chapter.

Learning Objectives

After reading, studying, and discussing the chapter, students should be able to:

- Describe the processes of weathering, erosion, and mass wasting.
- Explain the difference between mechanical and chemical weathering.
- Discuss soil composition, texture, structure, formation, and classification.
- Describe the controls of mass wasting.
- List and describe the various types of mass wasting.

Chapter Outline

I. Earth's external processes include
  A. Weathering—the disintegration and decomposition of material at or near the surface
  B. Mass wasting—the transfer of rock material downslope under the influence of gravity
  C. Erosion—the incorporation and transportation of material by a mobile agent, usually water, wind, or ice

II. Weathering
  A. Two kinds of weathering
    1. Mechanical weathering
      a. Breaking of rocks into smaller pieces
      b. Four processes
        1. Frost wedging
        2. Unloading
        3. Biological activity
        4. Salt crystal growth
    2. Chemical weathering
      a. Alters the internal structures of minerals by removing or adding elements
      b. Most important agent is water
        1. Oxygen dissolved in water oxidizes materials
        2. Carbon dioxide (CO_2) dissolved in water forms carbonic acid and alters the material
      c. Weathering of granite
        1. Weathering of potassium feldspar produces
          a. Clay minerals
          b. Soluble salt (potassium bicarbonate)
          c. Silica in solution
        2. Quartz remains substantially unaltered
        3. Weathering of silicate minerals produces