

Exploring Geology: What-To-Know List

(Derived from the Before You Leave This Page Lists)

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Chapter 1: The Nature of Geology

1.1 How Does Geology Influence Where and How We Live?

- Sketch or list some ways that geology determines where it is safe to live.
- Summarize some ways in which geology influences the distribution of natural resources.
- Summarize how geologic studies help understand ecosystems.

1.2 How Does Geology Help Explain Our World?

- Summarize some ways in which geology is used to help explain the world around us.
- Describe some things we can learn about Earth's past by observing its landscapes, rocks, and fossils.

1.3 What Is Inside Earth?

- Draw a sketch of the major layers of Earth
- Summarize the difference between continental crust and oceanic crust and between lithosphere and asthenosphere
- Discuss and sketch how the principle of isostasy can explain differences in regional elevation.

1.4 What Processes Affect Our Planet?

- Sketch and summarize the major processes that affect our planet.
- Describe or sketch internal forces, external forces, and sources of energy, and explain how they affect Earth.
- Summarize the importance of gravity for moving material on Earth's surface.

1.5 How Do Rocks Form?

- Distinguish the origins of the four families of rocks.
- Sketch or summarize at least five settings where sedimentary rocks form.
- Sketch or summarize one setting each for where metamorphic and hydrothermal rocks form.

1.6 What Can Happen to a Rock?

- Sketch a simple version of the rock cycle, labeling and explaining, in your own words, the key processes.
- Describe why a rock might not experience the entire rock cycle.

1.7 How Do the Atmosphere, Water, and Life Interact with Earth's Surface?

- Draw a sketch that includes the major ways that water moves over, on, and under Earth's surface.
- Summarize how moving water, ice, and wind can sculpt Earth's surface.
- Explain how sunlight heats the atmosphere.
- Explain the connections between life and the atmosphere.

1.8 What Is Earth's Place in the Solar System?

- Sketch a view of the solar system, from the Sun outward to Jupiter.
- Explain why the Sun and the Moon are the most important objects to Earth.
- Summarize how the outer planets are different from the inner planets.

1.9 Application: How Is Geology Expressed in the Black Hills and in Rapid City?

- Briefly explain or sketch the landscape around Rapid City and how geology affects this landscape.
- Identify and explain ways that geology affects the people of Rapid City.
- Summarize the events that led to the Rapid City Flood of 1972 and why there was so much damage.

Chapter 2: Investigating Geologic Questions

2.1 What Can We Observe in Landscapes?

- Summarize or sketch the main components of a relatively simple landscape, like those shown here.
- Summarize the different features you can observe in a landscape.
- Summarize the strategies for observing a landscape, roadcut, or photograph of a geologic scene.

2.2 How Do We Interpret Geologic Clues?

- Describe the overall philosophy used to infer the environment in which a rock formed.
- Summarize or sketch what is meant by trading location for time.
- Sketch or summarize four principles used to determine the relative ages of rocks and features.

2.3 How Do We Investigate Geologic Questions?

- Explain how observations become data.
- Describe how data differs from an interpretation, and provide at least one example of each.
- Summarize how data and interpretations lead to new explanations.
- Describe how a single visual observation led to an explanation for changing lake levels at Yellowstone.

2.4 How Do Scientific Ideas Get Established?

- Explain the logical steps taken to evaluate an explanation.
- Summarize how a hypothesis becomes an established theory.
- Describe what causes changes in scientific understandings.
- Discuss why scientific explanations are never proven to be “true.”

2.5 How Was the Hypothesis of Continental Drift Conceived and

- Summarize the observations that Wegener used to support the hypothesis of continental drift.
- Summarize why the hypothesis was not widely accepted.
- List some discoveries that brought a renewed interest in the idea of continental drift.

2.6 How Are Earth's Surface and Subsurface Depicted?

- Summarize how different types of maps depict Earth's surface.
- Sketch or describe the types of diagrams geologists use to represent the subsurface and sequences of rock units.
- Sketch or describe what is shown by a series of evolutionary diagrams.

2.7 How Are Geologic Problems Quantified?

- Explain how qualitative data differ from quantitative data.
- Describe several types of quantitative data that geologists use.
- Explain why graphs are useful.
- Provide an example of a geologic question that can be answered using numeric data and calculations.

2.8 How Do We Measure Geologic Features?

- Explain what units we use to measure length, area, and volume.
- Calculate the area and volume of simple objects.
- Explain elevation, depth, and topographic relief.
- Describe what weight and density are and how to calculate density.

2.9 How Do Geologists Refer to Rates and Time?

- Give an example of a rate and how a rate is calculated.
- Summarize or sketch the four main chapters (eras) of Earth history, showing which era is longest and which era is shortest.
- Discuss what the geologic time scale is and the kinds of data that were used to construct it.

2.10 What Are Some Strategies for Approaching Geologic Problems?

- Explain why some geologic problems are unique.
- Summarize an example of viewing a problem from different scales.
- Explain how you could simplify a complex problem.
- Summarize an example of the problem of incomplete data.

2.11 What Does a Geologist Do?

- Summarize the kinds of questions geologists investigate with field studies.
- Summarize how geologists find energy and mineral resources.
- Summarize how geologists help us avoid geologic hazards.
- Summarize some places or questions that geologists investigate using techniques other than field studies.

2.12 Application: How Did This Crater Form?

- Summarize or sketch the three explanations for the origin of the crater and which observations support or do not support each explanation.
- Summarize how geologists interpret Meteor Crater to have formed

Chapter 3: Plate Tectonics

3.1 What Are the Major Features of Earth?

- Identify on a world map the named continents and oceans.
- Identify on a world map the main types of features on the continents and in the oceans.
- Summarize the main characteristics for each type of feature, including whether it is found in the oceans, on continents, or islands.

3.2 Where Do We Find Earthquakes, Volcanoes, and Mountain Belts?

- Show on a relief map of the world the major belts of earthquakes and volcanoes.
- Describe how the distribution of volcanoes corresponds to that of earthquakes.
- Compare the distributions of earthquakes, volcanoes, and elevations.

3.3 What Causes Tectonic Activity to Occur in Belts?

- Explain what plate tectonics is and the three types of plate boundaries.
- Compare the three types of plate boundaries with the distributions of earthquakes, volcanoes, mountain belts, mid-ocean ridges, and trenches.

3.4 What Happens When Plates Move Apart?

- Sketch, label, and explain an oceanic divergent boundary.
- Sketch, label, and explain a divergent boundary within a continent (i.e., a continental rift).
- Sketch, label, and explain how continental rifting can lead to the formation of a new ocean basin.

3.5 What Happens When Plates Converge?

- Sketch, label, and explain the three types of convergent boundaries, including the features and processes associated with each.
- Sketch, label, and explain the steps leading to a continental collision (continent-continent convergent boundary).

3.6 What Happens When Plates Slip Past One Another?

- Sketch, label, and explain an oceanic transform boundary related to seafloor spreading at a mid-ocean ridge.
- Sketch, label, and explain the motion of transform faults along the West Coast.
- Locate on a map modern examples of a transform fault associated with a mid-ocean ridge.

3.7 How Do Plates Move and Interact?

- Summarize the driving forces of plate tectonics.
- Describe the typical rates of relative motion between plates.
- Describe some ways to directly measure plate motion.
- Sketch, label, and explain how a plate boundary can change its type as its orientation changes.

3.8 What Geologic Features Does Plate Tectonics Help Explain?

- Predict the relative ages of seafloor from place to place using a map of an ocean with a mid-ocean ridge.
- Summarize how plate tectonics can explain similar continental outlines and geology on opposite sides of an ocean.
- Describe the characteristics of a linear island chain and summarize how they are related to hot spots.

3.9 Application: Why Is South America Lopsided?

- Summarize or sketch the present plate tectonic setting of South America and describe how it explains the large features on the continent and adjacent oceans.
- Summarize the plate tectonic evolution of South America over the last 140 million years.

Chapter 4: Earth Materials

4.1 What Is the Difference Between a Rock and a Mineral?

- Explain the difference between a rock and a mineral.
- Explain each characteristic that a material must have to be called a mineral, and provide for each characteristic an example that is a mineral and an example that is not a mineral.
- Explain the relationship between rocks, minerals, and chemical elements.
- Explain the difference between a mineral in a vitamin pill and a geologic mineral.

4.2 How Are Minerals Put Together in Rocks?

- Explain the difference between a clastic rock and crystalline rock.
- Explain the difference between the general environments in which clastic and crystalline rocks form.
- Summarize or sketch four general characteristics to observe in rocks.
- Describe three instances in which minerals in a rock can be too small to see without a microscope.

4.3 How Do We Distinguish One Mineral from Another?

- Explain the properties of a mineral that can be observed without using a test.
- Summarize how to test for hardness, effervescence, streak, and magnetism.
- Explain the meaning of a mineral's specific gravity.
- Explain Mohs Hardness Scale.

4.4 What Controls a Crystal's Shape?

- Explain or sketch how the internal arrangement of atoms is reflected in the crystal form of halite.
- Explain a crystal lattice.
- Sketch three common ways in which atoms are arranged in a mineral.
- Sketch or explain how the shape of a crystal is affected by the environment in which it grows.

4.5 What Causes Cleavage in Minerals?

- Explain or sketch the relationship between the arrangement and strengths of bonds.
- Explain what happens if no planes along which a mineral may cleave exists.
- Sketch and describe five types of cleavage.
- Explain the difference between cleavage in minerals and rocks.

4.6 How Are Minerals Classified?

- Describe what the Periodic Table shows and where the main groups of chemical elements (metals, transition metals, nonmetals, and noble gases) are located.
- Summarize the major classes of minerals and the main chemical characteristic of each class.
- Describe two types of asbestos and the health controversy over asbestos.

4.7 What Is the Crystalline Structure of Silicate Minerals?

- Sketch or explain a silica tetrahedra and how two tetrahedra can join.
- Explain or sketch how silica tetrahedra link in different geometries to produce five silicate mineral groups.
- Explain the differences between silicon, silica, and silicone.

4.8 What Are Some Common Silicate Minerals?

- Describe what all silicate minerals have in common.
- Describe the main light- and dark-colored silicate minerals, including their general characteristics, such as color, cleavage, and chemical components.
- Summarize the characteristics of clay minerals and how they form.

4.9 What Are Some Common Nonsilicate Minerals?

- Summarize the key chemical constituents for each of the five mineral groups presented here.
- Describe the major nonsilicate minerals, including their general characteristics such as color, cleavage, and any diagnostic attributes.
- Describe how minerals are used in some of the products that are in your medicine cabinet.

4.10 Where Are Different Minerals Abundant?

- Identify the most common class of mineral in the crust, mantle, and inner core.
- List the four most abundant elements in the crust and in Earth as a whole, and explain why silicate minerals are so abundant in the crust and mantle.

4.11 What Are the Building Blocks of Minerals?

- Describe the relationships among a mineral, the elements with which it is composed, and individual atoms of one of the elements.
- Explain or sketch the structure of an atom, including its main particles.
- Sketch the general shape of the Periodic Table and explain the significance of its rows and columns.

4.12 How do Atoms Bond Together?

- Explain the different types of bonds and how electrons cause each type.
- Explain how the Periodic Table helps explain which kind of bond will form, and provide a mineral example for each kind of bond.

4.13 How Do Chemical Reactions Help Minerals Grow or Dissolve?

- Describe how halite dissolves and crystallizes in water.
- Sketch a water molecule and illustrate why it has polarity.
- Describe the properties of water that are attributable to hydrogen bonding and those that are attributable to polarity.
- Explain why water in the mantle is important for magma formation.

4.14 Application: How Are Minerals Used in Society?

- Distinguish the two main ways that minerals are used in society.
- Describe some chemical uses of common minerals.
- Describe some ways we use the physical properties of minerals.
- Describe the geologic environments in which some gemstones form.

Chapter 5: Igneous Environments

5.1 What Textures Do Igneous Rocks Display

- Summarize the various textures displayed by igneous rocks.
- Sketch an igneous system and show where the main igneous textures form.

5.2 How Are Igneous Rocks Classified?

- Summarize or sketch how igneous rocks are classified.
- List some common igneous rocks and a few characteristics of each.
- Summarize the main differences between felsic and mafic rocks.

5.3 How Do Igneous Rocks Form?

- Sketch and describe the processes involved in forming igneous rocks.
- Sketch or describe how melting can influence magma composition.
- Sketch or describe how partial crystallization, assimilation, and magma mixing can change a magma.
- Summarize why the composition of the Bushveld Igneous Complex varies.

5.4 How Do Temperature and Pressure Vary Inside Earth?

- Describe the events that made the early Earth hot.
- Describe alpha decay and how radioactivity heats Earth.
- Summarize three ways that heat is transferred from a warmer mass to a cooler one and an example of conduction and convection by plate tectonics.

5.5 How Do Rocks Melt?

- Describe how thermal vibrations affect a mineral lattice.
- Draw a graph showing how increasing temperature, decreasing pressure (decompression), or adding water to a hot system causes melting.
- Describe how the temperatures and pressures of melting are determined in the laboratory.

5.6 How Do Magmas Form Along Divergent Plate Boundaries?

- Sketch or describe why melting occurs along mid-ocean ridges and why the resulting magmas are basaltic (mafic).
- Summarize the types of igneous rocks that form along mid-ocean ridges.
- Describe how melting occurs in continental rifts and how it results in diverse igneous rocks.
- Summarize how an ophiolite compares to a section through oceanic crust.

5.7 How Do Magmas Form Along Convergent Plate Boundaries?

- Describe and sketch how magma is generated in a subduction zone.
- Summarize what happens when subduction-derived magma encounters overlying crust.
- Explain and sketch how magma forms during continental collisions.
- Summarize how water gets into a subduction zone.
- Explain partial melting of continental crust and the kinds of magma formed.

5.8 How Are Magmas Generated Away from Plate Boundaries?

- Sketch or explain a mantle plume and its magmatic expression in both oceanic and continental plates.
- Sketch or describe how a hot spot can form a sequence of volcanic islands on a moving oceanic plate.
- Sketch or describe how magmatism occurs away from plate boundaries.
- Sketch or explain how we infer from chemical analyses the tectonic setting of an ancient basalt.

5.9 How Does Magma Move?

- Describe three ways that magmas rise through the crust.
- Summarize factors that influence how far a magma rises toward the surface.
- Explain the factors that control the viscosity of magma.
- Describe what factors might be combined to form very high viscosity or very low viscosity.

5.10 How Does Magma Solidify?

- Explain or sketch how a magma cools.
- Describe or sketch the cooling history of a magma as it rises through the crust.
- Explain the order in which minerals crystallize from a magma (Bowen's Reaction Series), and compare it to the order in which they melt.
- Describe how the rate of magma cooling affects the size and shape of crystals that form.
- Explain how the crystallization of minerals can change the composition of remaining magma.

5.11 How Do large Magma Chambers Form and Evolve?

- Summarize what a magma chamber is and the processes that occur in one.
- Sketch or summarize the tectonic settings in which large magma chambers form.
- Sketch the different geometries of large magma chambers and summarize how these are expressed in the landscape.
- Summarize the character of the White Mountain batholith and how it is interpreted to have formed.

5.12 How Are Small Intrusions Formed and Expressed in the Landscape?

- Sketch the difference between a dike and a sill, and explain why each has the orientation that it does.
- Sketch or discuss the geometry of laccoliths.
- Sketch and explain two ways that a volcanic neck can form.
- Describe how columnar joints form.

5.13 Application: How Did the Sierra Nevada Form?

- Describe the Sierra Nevada batholith and what rocks it contains.
- Sketch the plate-tectonic setting that formed the Sierra Nevada batholith.
- Sketch or describe how the magmas of the batholith formed.
- Summarize how the deep batholithic rocks ended up on Earth's surface.
- Briefly summarize the kinds of data geologists collect in studying the batholith.

Chapter 6: Volcanoes and Volcanic Hazards

6.1 What Is and Is Not a Volcano?

- Summarize or sketch the diagnostic characteristics of a volcano.
- Describe or sketch why every hill composed of volcanic rocks is not a volcano.
- Sketch and describe the four main types of volcanoes that construct hills and mountains.
- Sketch the relative sizes of different types of volcanoes.

6.2 What Controls the Style of Eruption?

- Describe four ways that magma erupts.
- Summarize the difference between eruption columns and pyroclastic flows, and the role that gas plays in eruptive style.
- Explain how gas in magma behaves at different depths.
- Describe how a magma's viscosity could lead to an explosive eruption.
- Describe how water and gas are dissolved in magma and what happens when they come out.

6.3 What Features Characterize Scoria Cones and Basaltic Lava Flows?

- Explain the characteristics of cinder cones and basalt flows, including how you might distinguish between young and old examples of each.
- Describe how vesicular and nonvesicular basalt rocks differ in appearance and formation.
- Describe how basaltic magma may form a scoria cone, lava flow, or both.

6.4 How Do Shield Volcanoes Form?

- Describe the general characteristics, including the type of magma that is erupted, of a shield volcano.
- Explain how shield volcanoes erupt.
- Sketch or summarize how you would recognize a shield volcano in the landscape.
- Summarize how active the two main volcanoes on Hawaii, Mauna Loa and Kilauea, have been.

6.5 What Causes Flood Basalts?

- Describe the characteristics of flood basalts and how they erupt.
- Identify at least three areas on Earth that contain flood basalts.
- Sketch and describe the interpreted relationship between flood basalts and mantle plumes.
- Summarize how flood basalts could affect climate and life on Earth.

6.6 What Are the Hazards of Basaltic Eruptions?

- Explain how risk is different than hazard, and provide an example of each.
- Summarize the difference between hazards associated with scoria cones and hazards associated with basaltic flows.
- Explain how a volcanic eruption can cause a flood.
- Summarize the effects of the Laki eruption of 1783.

6.7 What Are Composite Volcanoes?

- Describe or sketch the characteristics of a composite volcano, including its internal structure.
- Describe the processes on composite volcanoes and the rocks they form.
- Describe the tectonic setting of most composite volcanoes.
- Identify some examples of composite volcanoes from around the world.

6.8 What Disasters Were Caused by Composite Volcanoes?

- Summarize the type of eruption that occurred at Vesuvius and the cause of most of the deaths.
- Summarize the eruption at Mt. Pelée and events that preceded it.
- Summarize the eruption of Mount St. Helens, and the data that warned of its dangers.

6.9 How Do Volcanic Domes Form?

- Describe the characteristics of a volcanic dome.
- Explain or sketch the two ways by which a volcanic dome can grow.
- Explain or sketch how a volcanic dome can collapse or be destroyed by an explosion.
- Describe how you might recognize a volcanic dome in the landscape.
- Summarize the types of rocks associated with volcanic domes.

6.10 How Do Huge Ash Eruptions Form Calderas?

- Describe or sketch the characteristics of a caldera, including its geometry in the subsurface.
- Describe how you could recognize a recent caldera and an ancient caldera.
- Sketch and explain the stages in the formation of a caldera.
- List the kinds of rocks you might find in a caldera from top to bottom.
- Explain the formation of Crater Lake.

6.11 What Disasters Were Related to Calderas?

- Explain how a volcanic eruption destroyed Santorini.
- Describe what happened during the eruption of Krakatau.
- Summarize the volcanic history of Yellowstone, including the distribution of volcanic ash.
- Summarize or sketch how volcanism at Yellowstone is related to a hot spot.

6.12 What Areas Have the Highest Potential for Volcanic Hazards?

- Summarize ways to assess the potential danger of a volcano and to identify which areas around a volcano have the highest potential hazard.
- Summarize which parts of the world have the highest potential for volcanic eruptions, and explain why.
- Summarize how the plate tectonic setting of a region influences its potential for volcanic hazards.

6.13 How Are Volcanoes Monitored?

- Discuss why seismic measurements are helpful for predicting an eruption.
- Explain why and how volcanic gases and thermal energy are measured.
- Summarize how topographic changes of a volcano could precede an eruption and how they are measured.
- Briefly discuss how a volcano-related mudflow can be detected remotely.

6.14 Application: What Volcanic Hazards Are Posed by Mt. Rainier?

- Describe the type of volcano that Mount Rainier is and the types of rocks it contains.
- Sketch and explain a cross section showing the plate tectonic setting of Mount Rainier.
- Summarize the volcanic hazards near Mount Rainier.
- Briefly summarize how active the Cascade volcanoes have been during the last 4,000 years.

Chapter 7: Sedimentary Environments

7.1 What Sedimentary Environments Occur on Land?

- Summarize or sketch the main sedimentary environments on land, and describe some characteristics of each.

7.2 What Sedimentary Environments Are Near Shorelines and In

- Summarize or sketch the main sedimentary environments in oceanic and near shore environments.

7.3 Where Do Clasts Come From?

- Summarize the main processes of physical and chemical weathering.
- Summarize how the rock type, degree of fracturing, and solubility of starting materials influence the type of sediment that is produced.
- Summarize how rocks can be broken during transport.

7.4 What Are the Characteristics of Clastic Sediments?

- Sketch and describe how sediments are classified according to size, sorting, and shape of clasts.
- Describe how clast transport affects the size, shape, and sorting of clasts.
- Explain three factors that influence the type of sediment that is transported.

7.5 What Type of Rocks Do Clastic Sediments Form?

- Describe what happens to clastic sediment as it becomes buried and converted into rock.
- Summarize the natural cements that are common in sedimentary rocks.
- Summarize or diagram the classification of common clastic sedimentary rocks.

7.6 What Are Nonclastic Sedimentary Rocks and How Do They Form?

- Describe how some sedimentary rocks form through evaporation, precipitation, or other chemical reactions.
- Describe how limestone forms.
- Describe how some sedimentary rocks form from the accumulation of plant materials.

7.7 Why Do Sedimentary Rocks Have Layers?

- Summarize or sketch the types of layers that sedimentary rocks contain, including how their thickness varies, whether their boundaries are sharp or gradational, and what defines the layers.
- Describe how layers, including graded beds and cross beds, form.

7.8 How Do Breccia and Conglomerate Form?

- Summarize or sketch the characteristics of a breccia, and identify some environments in which this rock forms.
- Summarize or sketch the characteristics of a conglomerate, and identify some environments in which this rock forms.
- Contrast breccia and conglomerate, and explain reasons why one might form instead of the other.

7.9 Where Does Sandstone Form?

- Summarize the characteristics of sandstones, including their expression in landscapes.
- Describe the land environments in which sandstone forms, and how you might distinguish sandstone formed by sand dunes from those formed by rivers.
- Describe how sandstone forms along shorelines and in offshore environments.

7.10 How Do Fine-Grained Clastic Rocks Form?

- Summarize the main characteristics of shale and siltstone, including which rock has the finest particles.
- Describe the land environments in which shale and siltstone form.
- Describe the environments near shorelines and farther offshore in which shale and siltstone form.
- Describe how some shales and siltstones are expressed in the landscape, including some of the landscape features they form.

7.11 How Do Carbonate Rocks Form?

- Summarize the characteristics of limestone and dolostone.
- Summarize the environments in which limestone and other deposits of calcium carbonate form.
- Describe how dolostone forms.
- Describe how carbonate rocks are expressed in the landscape, including sinkholes and limestone pillars.

7.12 How Do Changing Environments Deposit a Sequence of Sediments?

- Summarize or sketch what happens during a transgression and a regression, including which way sedimentary facies shift.
- Sketch an example of a sequence of rocks formed during a transgression and contrast it with a sequence formed during a regression.
- Summarize or sketch two reasons why sedimentary layers end.

7.13 How Do We Study Sedimentary Sequences?

- Summarize the attributes that we observe in sedimentary rocks and how each indicates something about the rock's origin and environment.
- Given a list of key attributes, interpret the environment of a rock.

7.14 Why Are Sedimentary Rocks Important to Our Society?

- Summarize or sketch some of the main resources that occur in sedimentary rocks.
- Summarize how sedimentary rocks help us understand modern and ancient environments, events, and life.
- Describe what the phrase sand and gravel means and how we use these important materials.

7.15 Application: How Did Sedimentary Layers West of Denver Form?

- Summarize how the characteristics and sequence of sedimentary rocks can be used to reconstruct the geologic history of an area. Use examples from sedimentary rocks west of Denver.

Chapter 8: Deformation and Metamorphism

8.1 What Processes Can Deform and Change a Rock After It Forms?

- Describe or illustrate the concept of stress.
- Summarize or sketch the three ways that a mass of rock can respond to stress.
- Sketch or describe how temperature and pressure varies with depth.
- Summarize the differences in structural behavior, mineral response, and effect of fluids between shallow and deep environments.
- Describe how we study the conditions at which a specific mineral is stable.

8.2 How Do Rocks Respond to Stress, Temperature, and Fluids?

- Sketch the difference between confining pressure and differential stress.
- Sketch and summarize how the strength of rocks varies with depth.
- Sketch and describe the three types of stress, and provide examples of the structures that each type forms at shallow and deep levels of the crust.

8.3 How Do Rocks Fracture?

- Sketch and describe the two main ways that fractures form.
- Sketch and summarize how the orientation of joints indicates the orientation of stresses.
- Summarize how different joints form and are expressed in the landscape.
- Summarize how a fault forms relative to compression and why faults form with different orientations.

8.4 What Are Different Types of Faults?

- Sketch and describe the concepts of strike, dip, footwall, and hanging wall.
- Sketch and describe the three main types of faults, showing the relative displacement and the type of stress.
- Sketch and describe a horst and graben.

8.5 What Are Folds and How Are They Shaped?

- Sketch a fold showing its hinge, limb, and axial surface, and summarize how the orientation of these fractures can vary.
- Sketch a cross section of an anticline, syncline, and monocline.
- Describe a dome and a basin.

8.6 What Are Some Metamorphic Structures?

- Summarize how cleavage and foliation are expressed in metamorphic rocks.
- Summarize the types of features that define lineation and how each type of lineation forms.
- Describe some other features that may be present in metamorphic rocks.

8.7 What Are Common Metamorphic Rocks?

- Describe the changes different sedimentary rocks undergo and the metamorphic rocks they become as they are metamorphosed.
- Describe the changes different igneous rocks undergo and the metamorphic rocks they become as they are metamorphosed.
- Describe the origin of hornfels.

8.8 What Occurs During Metamorphism?

- Summarize causes of metamorphism.
- Describe or sketch the physical and chemical processes that can accompany metamorphism.
- Describe how stress controls whether a metamorphic rock has foliation, foliation and lineation, or neither.

8.9 Why Does Metamorphism Occur?

- Discuss or sketch the processes that cause metamorphic conditions.
- Summarize, perhaps by using a graph, the difference between high-T/low-P, high-P/low-T, and normal P-T metamorphism and how each type of condition can develop.

8.10 How Are Different Structures and Metamorphic Features Related?

- Sketch or describe how joints, faults, folds, cleavage, and shear zones can be associated with one another.
- Describe and sketch how cleavage relates to bedding in folds.
- Briefly describe how thrust faulting and normal faulting can influence the conditions of metamorphism.

8.11 What Types of Deformation and Metamorphism Occur in

- Summarize or sketch the features associated with a fold and thrust belt.
- Summarize or sketch the settings along continental collision and ocean-continent convergent plate margins in which deformation and metamorphism occur.

8.12 What Types of Deformation and Metamorphism Occur in Extensional

- Describe or sketch how deformation and metamorphism occur in oceanic rifts, continental rifts, continental margins, and rifts within plates.
- Sketch or describe a fault block and how movement on normal faults can be accompanied by tilting of layers.

8.13 What Deformation and Metamorphism Occur Along Zones of Shear?

- Explain the meaning of a strike-slip fault and a metamorphic shear zone, and describe some common features along each type of structure.
- Summarize or sketch how folds can form along a strike-slip fault zone.

8.14 How Are Geologic Structures and Metamorphic Rocks Expressed in

- Identify joints in a photograph of a landscape and describe or sketch how joint sets weather and erode.
- Summarize or sketch the features that form when tilted or folded layers are eroded.
- Summarize or sketch how you might identify a fault in the landscape.
- Describe some characteristics displayed by metamorphic rocks in the landscape.

8.15 How Do We Study Geologic Structures?

- Summarize how we observe and measure geologic features and the ways we record this information.
- Sketch or describe things we would observe to infer the age of a fault.
- Summarize some things we might observe in a metamorphic rock to learn something about its history of metamorphism and deformation.

8.16 Application: What Is the Structural and Metamorphic History of New

- Briefly summarize the types of rocks exposed in New England.
- Summarize the types of geologic and metamorphic structures in the region.
- Briefly summarize how the grade of metamorphism varies from east to west across the region.

Chapter 9: Geologic Time

9.1 How Do We Infer the Relative Age of Events?

- Sketch and explain each of the five principles of relative dating.
- Apply the principles of relative dating to a photograph or sketch showing geologic relations among several rock units, or among rock units and structures.

9.2 How Are Ages Assigned to Rocks and Events?

- Explain how to determine how many half-lives have passed based on the ratio of parent to daughter atoms.
- Summarize how a mass spectrometer is used to determine numeric ages.
- Describe the different ways that radiometric dating is used for dating geologic events.

9.3 How Do We Investigate the Ages of Landscapes and Erosion Surfaces?

- Describe the sequence of events represented in a typical landscape of flat-lying sedimentary rocks.
- Summarize or sketch how you could assess the age of a landscape surface.

9.4 What Is the Significance of an Unconformity?

- Summarize or sketch the three main types of unconformities and what sequence of events is implied by each type.

9.5 What Are Fossils?

- Describe the different ways in which a plant or animal can be preserved as a fossil.
- Describe two types of commonly encountered trace fossils.
- Describe the two main factors that influence whether a creature is preserved as a fossil.
- Describe two features that can be mistaken for a fossil.

9.6 How and Why Do Fossils Vary with Age?

- Summarize the four chapters of Earth history and how the boundaries are defined.
- Summarize some factors that affect survival and extinction.
- Describe the difference between observed fossil changes (evolution) and evolutionary theory.

9.7 How Are Fossils Used to Infer Ages of Rocks?

- Summarize how fossils can change through a section of rocks.
- Provide examples of using index fossils, abrupt boundaries between fossils, and fossil overlaps to precisely infer the age.
- Describe or sketch the ways we use fossils and rock types to correlate two rock sequences.
- Briefly summarize the meaning of faunal succession and how it was discovered.

9.8 How Was the Geologic Time Scale Developed?

- Briefly summarize how the geologic time scale was developed.
- From oldest to youngest, list the four main geologic chapters and periods.
- Explain or sketch how numeric ages are assigned to the time scale and how the time scale is used to assign numeric ages to fossil-bearing rocks.

9.9 What Is the Evidence for the Age of Earth?

- Summarize early methods for determining the age of Earth and why they proved to be inaccurate.
- Summarize evidence that suggests Earth has a long history, including radiometric ages on basement rocks in North America.
- Describe how meteorites and Moon rocks are used to interpret the age of Earth.

9.10 What Were Some Milestones in the Early History of Life on Earth?

- Summarize the environments of early life and some important evolutionary events that took place during Earth's early history.
- Briefly describe what happened during the Cambrian explosion, including fossils of the Burgess Shale.
- Explain four possible causes for the Great Dying, the largest extinction event in Earth history.

9.11 What Were Some Milestone in the Later History of Life on Earth?

- Contrast the kinds of organisms that lived during the Mesozoic Era with those that appeared during the Cenozoic Era.
- Describe some of the variety observed in dinosaurs, and summarize the two popular theories for why dinosaurs became extinct.
- Briefly describe how dinosaurs and mammals were able to diversify after major extinctions.

9.12 How Do Reconstruct Geologic Histories?

- Summarize or sketch the principles by which two sequences of rocks can be correlated.
- Describe or sketch why layers can change from one sequence to another.
- Reconstruct the sequence of events from a cross section or block diagram.

9.13 Why Do We Investigate Geologic History?

- Describe or sketch how geologic ages help evaluate geologic hazards and mineral, energy, and water resources.
- Provide an example of how knowing the ages of rocks and structures help to understand landscapes at a larger scale.
- Discuss dating techniques used to investigate early human sites.

9.14 Application: What Is the History of the Grand Canyon?

- Summarize examples of how different methods of dating events and rocks were used to reconstruct the geologic history of the Grand Canyon.
- Summarize why the Canyon does not represent all of geologic time.

Chapter 10: The Seafloor and Continental Margins

10.1 How Do We Explore the Seafloor?

- Summarize the four methods we use to explore the topography and rocks of the seafloor (sonar, submersibles, drilling, and satellites).
- Summarize the kinds of information we can obtain from cores drilled in the seafloor.
- Describe the seismic-reflection method for mapping the geometry of geologic units beneath the seafloor.

10.2 How Is Paleomagnetism Used to Study the Ocean Floor?

- Describe how Earth's magnetic field is generated.
- Summarize how magnetic reversals help with dating rocks.
- Describe or sketch how magnetic patterns develop on the seafloor.
- Calculate the rate of seafloor spreading if given the width and duration of a magnetic stripe.

10.3 What Processes Occur at Mid-Ocean Ridges?

- Summarize or sketch the processes that accompany the formation of new oceanic crust at mid-ocean ridges.
- Summarize or sketch the differences between fast-spreading and slow spreading mid-ocean ridges.
- Describe black smokers, how they form, and where the hot water originates and how it gets heated.
- Describe the type of life that exists around hydrothermal vents and where the different creatures derive their food.

10.4 What Are Major Features of the Deep Ocean?

- Sketch or describe some features of the deep seafloor.
- Describe how the patterns of the age of the seafloor relate to mid-ocean ridges, depths of the seafloor, and sediment thicknesses.

10.5 How Do Oceanic Islands, Seamounts, and Oceanic Plateaus Form?

- Summarize or sketch how a mantle plume can form oceanic islands, providing several examples.
- Summarize how oceanic plateaus are thought to have formed.

10.6 What Processes Form Island Arcs?

- Summarize the processes that occur within, in front of, and behind island arcs.
- Summarize why island arcs and their associated trenches are curved.
- Describe some examples of island arcs.

10.7 How Did Smaller Seas of the Pacific Form?

- Summarize or sketch the different ways in which smaller seas formed in the Pacific Ocean, providing an example of each.
- Summarize the history of the Gulf of California and how it is related to the boundary between the Pacific and North American plates.

10.8 How Did Smaller Seas Near Eurasia Form?

- Summarize or sketch the origin of the North, Baltic, Black, and Red Seas.
- Summarize or sketch how the Persian Gulf is related to the collision of Arabia and Asia.

10.9 How Do Reefs and Coral Atolls Form?

- Describe the different kinds of reefs and where they form.
- Summarize the stages of atoll formation.
- Name some locations with large reefs.

10.10 What Is the Geology of Continental Margins?

- Summarize or sketch the features of continental margin, such as the continental shelf, slope, and rise.
- Summarize or sketch the rocks, sediments, and structures that occur along a typical continental margin.
- Summarize turbidity currents, submarine canyons, fans, and landslides.

10.11 How Do Marine Salt Deposits Form?

- Summarize how salt forms near continental margins.
- Describe how salt can occur in salt domes, salt glaciers, and some folded mountain belts.
- Summarize how salt structures are expressed in the Gulf Coast region.

10.12 How Did Earth's Modern Oceans Evolve?

- Summarize the major changes in the Earth's oceans since 180 million years ago, including approximately when the Central Atlantic, South Atlantic, North Atlantic, and Indian Ocean formed and which continents rifted apart to form each ocean.
- Describe or sketch why growth of the Atlantic Ocean must have caused the Pacific Ocean to shrink over time.

10.13 Application: How Did the Gulf of Mexico and Caribbean Region Form?

- Summarize the main physical features of the Caribbean and Gulf of Mexico, describing how they relate to modern plate-tectonic boundaries.
- Briefly summarize the main events that shaped the Gulf and Caribbean.
- Describe how the geologic history of the region was studied, both on land and beneath the sea.

Chapter 11: Mountains, Basins, and Continents

11.1 Why Are Some Regions High in Elevation?

- Summarize or sketch the factors that control regional elevation.
- Summarize or sketch what causes variations in crustal thickness.
- Summarize several ways to increase elevation and to decrease elevation.
- Explain the observation that led to the discovery of isostasy.

11.2 Where Do Mountain Belts and High Regions Form?

- Summarize the main tectonic settings of high regions, explaining reasons for the high elevations in each setting.
- Summarize the explanation for high elevations in the world's main mountain ranges and plateaus.
- Summarize the differences in elevation across North America.

11.3 How Do Local Mountains Form?

- Summarize how mountains are created by volcanism.
- Describe or sketch how thrust faulting, normal faulting, and folding can each build mountains.
- Describe some ways that erosion can result in a mountain, ridge, or mesa.

11.4 Where Do Basins Form?

- Describe the different ways that a basin can form.
- List some basins in the U.S. and describe what caused each to form.
- Describe how you might determine whether a unit was older, younger, or the same age as a basin.

11.5 How Do Mountains and Basins Form at Convergent Continental

- Summarize how mountains and basins form in an ocean-continent convergent margin.
- Summarize how mountains and basins form in a continental collision.
- Summarize how a basin formed in New York during the Paleozoic.

11.6 How Does Continental Extension Occur?

- Summarize where extension can occur in a plate above a subduction zone.
- Summarize one factor that favors shortening versus extension in a plate above a subduction zone.
- Describe or sketch the formation of non-rotating and rotating fault blocks and how you can distinguish them.

11.7 What Are the Characteristics and History of Continental Hot Spots?

- Summarize the features that are typical of continental hot spots, providing an example of each type of feature.
- Summarize or sketch how continental hot spots evolve over time.
- Describe or sketch how hot spots influence continental outlines, providing an example.

11.8 What Features Characterize the Interior of Continents?

- Summarize or sketch what features are common in continental interiors.
- Describe what types of regional or global effects can influence the geology of a continental interior.
- Describe one way that a mountain can exist in the middle of a continent.

11.9 What Are Tectonic Terranes?

- Summarize the characteristics used to recognize a terrane.
- Describe a few of the main tectonic settings in which terranes originate.
- Summarize or sketch how we determine when two terranes were brought together.

11.10 How Do Continents Form?

- Identify the oldest (Precambrian) parts of North America and some areas that were added as terranes in Paleozoic or Mesozoic-Cenozoic times.
- Briefly describe why different parts of a continent can be different ages.
- List the types of terranes added to or displaced in California.

11.11 How Did the Continents Join and Split Apart?

- Briefly summarize the general positions of the continents in the past, especially since 280 million years ago.
- Identify times when the continents were joined in the supercontinents of Gondwana, Laurasia, Pangaea, and Rodinia.
- Summarize three ways that geologists reconstruct past positions of continents.

11.12 Application 1: How Did the Appalachian and Ouachita Mountains Form?

- Summarize, using simple maps or cross sections, the main sequence of events that affected the Appalachian and Ouachita Mountain regions.
- Identify the causes of the Taconic, Acadian, and Alleghenian orogenies.
- Describe why geologists say that continents, such as North America, go through a cycle where oceans open, close, and reopen.

11.13 Application 2: What Is the Geologic History of the Western United States?

- Briefly summarize or sketch the main tectonic events that affected the western U.S. during Paleozoic, Mesozoic, and Cenozoic times.

Chapter 12: Earthquakes and Earth's Interior

12.1 What Is an Earthquake?

- Explain what a hypocenter and epicenter each represent.
- Sketch and describe the types of faults that cause earthquakes.
- Describe some other ways earthquakes or seismic waves are formed, including volcanoes and ways that humans can cause earthquakes.

12.2 How Does Faulting Cause Earthquakes?

- Describe or sketch how the build up of stress can flex rocks, leading to an earthquake.
- Describe or sketch how a rupture begins in a small area and grows over time, including how it ruptures Earth's surface.
- Describe some characteristics of fault scarps and ruptures.
- Describe how stress changes through time along a fault according to the earthquake-cycle model.

12.3 Where Do Most Earthquakes Occur?

- Explain why subduction zones have earthquakes at various depths, whereas mid-ocean ridges have only shallow earthquakes.
- Summarize how subduction and continental collisions cause earthquakes, identifying differences between these two settings.
- Describe how an earthquake can occur within a continental plate.

12.4 How Do Earthquake Waves Travel Through Earth?

- Describe the characteristics of P-waves, S-waves, and surface waves.
- Sketch or describe how seismic waves are recorded, and the order in which they arrive at a seismometer.
- Describe why earthquake amplitude and period are important considerations for designing buildings.

12.5 How Do We Determine the Location and Size of an Earthquake?

- Observe different seismic records of an earthquake and tell which one was closer to the epicenter.
- Describe how to use arrival times of P- and S-waves to locate an epicenter.
- Explain or sketch how we calculate local magnitude.
- Explain what a Modified Mercalli intensity rating indicates.

12.6 How Do Earthquakes Cause Damage?

- Describe how earthquakes can cause destruction, both during and after the main earthquake.
- Describe some ways to limit earthquake risk.
- Discuss ways to reduce personal injury during an earthquake.

12.7 What Were Some Major North American Earthquakes?

- Describe some large North American earthquakes and how they were generated.
- Describe the various ways these earthquakes caused damage.
- Summarize why the eastern United States has earthquake risks.

12.8 What Were Some Major World Earthquakes?

- Briefly describe some of the world's most significant earthquakes and the tectonic settings in which these deadly earthquakes formed.
- Summarize the role that building collapse plays in earthquake deaths.

12.9 How Does a Tsunami Form and Cause Destruction?

- Describe the different mechanisms by which tsunamis are generated.
- Summarize the kinds of damage tsunamis have caused.
- Briefly describe how tsunamis are monitored to provide an early-warning system.

12.10 How Do We Study Earthquakes?

- Summarize the kinds of field and remote measurements geologists use to investigate recent earthquakes.
- Summarize the methods of investigating prehistoric earthquakes on faults, including observations within trenches dug across a fault.

12.11 Can Earthquakes Be Predicted?

- Describe areas of the world that experience a high risk of earthquake activity.
- Summarize why certain areas of the United States experience earthquakes, while others do not.
- Summarize ways geologists do long-range forecasting and short-range prediction.

12.12 What Is the Potential for Earthquakes Along the San Andreas Fault?

- Briefly summarize the main segments of the San Andreas fault and whether they have had major earthquakes.
- Summarize or sketch how you might recognize the fault from the air.

12.13 How Do We Explore What Is Below Earth's Surface?

- Summarize how volcanic inclusions, exposed geology, drill holes, and mines provide observations of the subsurface.
- Briefly summarize what is measured by the various types of geophysical surveys (seismic, magnetic, gravity, and electrical).

12.14 What Do Seismic Waves Indicate About Earth's Interior?

- Sketch or describe reflection and refraction of seismic waves.
- Sketch and explain how seismic waves pass through the crust and mantle.
- Describe how seismic waves are used to identify the diameter of the core and to show that the outer core is molten.

12.15 How Do We Investigate Deep Processes?

- Describe four ways we can investigate or model the Earth's interior.
- Summarize how seismic tomography identifies different regions within the Earth.
- Describe some ideas about flow in the mantle that have arisen from seismic tomography.

12.16 Application: What Happened During the Great Alaskan Earthquake of 1964?

- Summarize events during associated with the Alaskan earthquake, including effects on land and sea, and how USGS studies of this area helped lead to the theory of plate tectonics.

Chapter 13: Climate, Weather, and Their Influences on Geology

13.1 What Causes Winds?

- Summarize events during associated with the Alaskan earthquake, including effects on land and sea, and how USGS studies of this area helped lead to the theory of plate tectonics.
- Describe the characteristics of low- and high-pressure zones.
- Summarize the causes of global wind patterns, including the role of the Coriolis effect in deflecting air flow.

13.2 How Does Wind Transport Materials?

- Explain the ways in which the wind transports sediment and other loose material.
- Describe the characteristics of dust storms and whirlwinds.
- Describe common types of wind-blown deposits.
- Describe some features formed by wind erosion.

13.3 Why Does It Rain and Snow?

- Describe the processes of water evaporation and atmospheric condensation, including the formation of raindrops and snowflakes.
- Sketch and describe how water evaporates and condenses, causing rainfall along a mountain front and a rain shadow on the downward side.
- Summarize how large-scale atmospheric air flow affects precipitation.

13.4 How Do Hurricanes, Tornados, and Storms Develop?

- Describe how hurricanes form and where they get the energy to grow.
- Sketch and summarize the various characteristics of a supercell thunder storm.
- Describe the characteristics of tornados, what they represent, and where in the United States they are common.

13.5 How Do Ocean Currents Influence Climate?

- Sketch and describe the main flow of surface currents in the Northern and Southern Hemispheres and how they influence sea temperatures.
- Describe the thermohaline conveyor.
- Summarize how ocean currents influence temperature and precipitation on adjacent lands.

13.6 What Causes Short-Term Climatic Variations?

- Explain what a monsoon is and how it affects rainfall, using India as an example.
- Summarize some common manifestations of drought and three causes of drought.
- Explain el Niño and la Niña conditions.

13.7 What Controls the Location of Rainforests?

- Describe the characteristics and vertical structure of a rainforest.
- Summarize where rainforests occur and what conditions produce enough precipitation to form a rainforest.
- Explain the many threats to rainforests and why rainforests are ecologically and genetically important.

13.8 What Are Deserts and How Do They Form?

- Describe what deserts are and where they occur.
- Summarize how and where different kinds of deserts form.
- Describe desertification.

13.9 What Features Are Common in Deserts?

- Describe some features of deserts and how each forms.

13.10 What Is the Evidence for Global Warming?

- Describe what global warming means and explain how it might be measured.
- Summarize the major lines of direct measurements and proxy evidence indicating global warming in the last one hundred years.
- Explain the NAS conclusions using the comparisons of different temperature reconstructions.

13.11 What Factors Influence Global Warming?

- Describe the greenhouse effect.
- Summarize the major factors, both natural and anthropogenic, that influence atmospheric temperature.
- Summarize the evidence for increased greenhouse gas concentrations in the atmosphere, and for correspondence between increases in these gases and increases in temperature.

13.12 What Is the Relationship Between Climate, Tectonics, and Landscape Evolution?

- Describe how plate tectonics affects climate.
- Summarize different ways that the arrangement of plates affects climate.
- Explain how landscapes are a product of tectonics and climate.

13.13 How Does Geology Influence Ecology?

- Explain the factors that control where life can exist.
- Describe some ways that geology influences ecology, the distribution of ecosystems, and agriculture.

13.14 Application: What Occurred During the Hurricane Season of 2004?

- Describe how the intensity of hurricanes is expressed using the Saffir-Simpson scale.
- Summarize or sketch the climatic conditions that caused 2004 to be worse for hurricanes than previous years.

Chapter 14: Shorelines, Glaciers, and Changing Sea Levels

14.1 What Processes Occur Along Shorelines?

- Summarize or sketch the types of processes that affect shorelines.
- Summarize or sketch how different factors affect the appearance of a shoreline.

14.2 What Causes High Tides and Low Tides?

- Describe or sketch what tides are.
- Sketch and describe how tides relate to the position of the Moon and why.
- Sketch or summarize how the gravity of the Moon and Sun cause spring tides and neap tides.

14.3 How Do Waves Form and Propagate?

- Sketch and label the parts of a wave, including the height, wavelength, and wave base.
- Explain how the propagation of a wave differs from the motion of the water through which the wave travels.
- Sketch and explain why a wave rises and breaks as it reaches shallow water.
- Explain why waves bend if they approach the shore at an angle.

14.4 How Is Material Eroded, Transported, and Deposited Along Shorelines?

- Describe how waves erode material from the shoreline and how the shape of a coastline influences wave erosion.
- Sketch and describe how waves move sand and other sediment on the beach.
- Summarize the factors controlling whether a shoreline gains or loses sand over time.

14.5 What Landforms Occur Along Shorelines?

- Describe the different types of shoreline features.
- Sketch and summarize a way that a sea stack, spit, baymouth bar, and barrier island can each form.
- Identify the types of features that are present on Cape Cod, and how these types of features typically form.

14.6 What Are Some Challenges of Living Along Shorelines?

- Summarize some of the hazards that affect beaches and other coastlines.
- Describe the approaches used to address coastal erosion and loss of sand, including not building in high-risk areas and trying to restore the system to a natural state.

14.7 How Do Geologists Assess the Relative Risks of Different Stretches of Coastline?

- Describe how studying the geologic features along a coast can help identify areas of highest risk.
- Summarize how LIDAR data are collected and provide an example of how they can be used to document changes in a shoreline.

14.8 What Happens When Sea Level Changes?

- Summarize how much sea level has risen or fallen in the past 120 million years and how such changes affected the position of the coastline.
- Summarize what a submergent coast is, and what types of features can indicate that sea level has risen relative to the land.
- Summarize what an emergent coast is, and what types of features can indicate that sea level has fallen relative to the land.

14.9 What Causes Sea-Level Change?

- Summarize how continental glaciation, rates of seafloor spreading, ocean temperatures, and position of the continents affect sea level.
- Summarize how loading and unloading affect land elevations using the example of northeastern Canada.

14.10 What Is the Evidence for Past Glaciations and Their Effect on the Oceans?

- Describe evidence used to infer that glaciers once covered a landscape.
- Discuss how glaciations can be expressed in the ocean, and how we can use this record to interpret when glaciation occurred.

14.11 How Do Glaciers Form, Move, and Melt Away?

- Sketch and describe how snow is transformed by pressure into ice.
- Summarize or sketch the differences in a glacier above and below the equilibrium line.
- Describe how glaciers move and what happens when they encounter a lake or the sea.

14.12 What Are Mountain Glaciers and What Landscape Features Do They Form?

- Summarize the landscape features associated with mountain glaciers and how each type of feature formed.
- Recognize a landscape formed by mountain glaciers.

14.13 What Are Continental Ice Sheets and What Record Do They Leave Behind?

- Summarize some characteristics of continental ice sheets.
- Sketch and describe the features associated with continental glaciers, and how each type of feature formed.

14.14 What Features Are Peripheral to Glaciers?

- Describe the characteristics of different deposits related to glacial episodes and how each type forms.
- Describe permafrost and where it occurs.
- Describe several large ice-age lakes and some of the features they formed, either while full or while emptying.

14.15 What Starts and Stops Glaciers?

- Sketch and describe how variations in Earth's rotation and orbit influence global climate.
- Describe how global climate can be affected by atmospheric gases, volcanic ash and dust, and the amount of snow, ice, and cloud cover.
- Describe the role of ocean currents and continental positions on glaciations.

14.16 Application: What Would Happen to Sea Level If the Ice in West Antarctica Melted?

- Briefly summarize the settings where ice occurs in West Antarctica.
- Calculate how much a block of ice will raise water levels in a tub, if you know the dimensions of the block and tub.
- Discuss why calculations about West Antarctica are important to people living along coasts everywhere in the world, including the East Coast of the United States.

Chapter 15: Weathering, Soils, and Unstable Slopes

15.1 What Physical Processes Affect Rocks On the Surface?

- Sketch or describe four ways that joints form.
- Describe how joints are expressed in the landscape.
- Sketch or describe physical weathering processes.
- Sketch or explain why fracturing aids weathering.

15.2 How Do Chemical Processes Affect Rocks Near the Surface?

- Describe several reasons why minerals formed at depth may not be stable at the surface.
- Summarize how limestone dissolves and what features are formed by dissolution.
- Briefly summarize the processes of oxidation, hydration, and dehydration.
- Explain why the ocean is salty.

15.3 How Do Different Rocks and Minerals Weather?

- Describe differences in the weathering of quartz, feldspar, mafic minerals, and calcite.
- Explain the origin of the three main weathering products (sand, clay minerals, and dissolved ions).
- Summarize the factors that control how different minerals weather.

15.4 What Factors Influence Weathering?

- Summarize or sketch how weathering is affected by the properties of a rock.
- Summarize or sketch how weathering is affected by the setting of a rock.
- Describe ways that weathering is expressed in the landscape, including its role in rounding off corners.

15.5 How Do Soils Form?

- Describe what a soil is and the processes by which it forms.
- Sketch and describe the main soil horizons and the processes and materials that occur in each horizon.
- Discuss the different soils formed in different climates and the factors responsible for these differences.

15.6 Why Are Soils Important to Society?

- Summarize activities that can threaten soil and its protective cover of vegetation.
- Describe some problems associated with certain soil types.
- Describe two ways that weathering can enrich a mineral deposit enough so the deposit can be mined.

15.7 What Controls the Stability of Slopes?

- Describe or sketch the role that gravity plays in slope stability.
- Describe the concept of the angle of repose and its landscape expressions.
- Describe some factors that control slope stability, and events that trigger slope failure.

15.8 How Do Slopes Fail?

- Describe slope failures and some ways they are expressed in the landscape.
- Summarize the classification of slope failures, and describe the different types of movement, types of material, and rates of movement.

15.9 How Do Materials on Slopes Fall and Slide?

- Sketch and describe a rock or debris fall, a slide, and a rotational slide.
- Sketch how the geometry of layers, faults, and other features could allow a rock slide to begin.
- Describe the Vaiont landslide disaster and factors that caused it to happen.

15.10 How Do Materials Flow Down Slopes?

- Sketch and describe what happens during the following: creep, debris slide, earth flow, debris flow, and debris avalanche. Compare how each of these features flows.
- Describe what happened at La Conchita. Was it a good idea to build, or rebuild there?

15.11 How Do Slope Failures Affect Society?

- Briefly describe factors involved in landslides in the U.S.
- Summarize some factors that make some areas of the U.S. have high risks for landslides or for debris flows.
- Identify whether you live in an area with a high potential for landslides.

15.12 How Do We Study Slope Failures and Assess the Risk for Future Events?

- Describe some ways that geologists investigate slope failures.
- Summarize characteristics used to identify prehistoric slope failures.
- Summarize some aspects that might indicate that an area has a high potential for slope failure.

15.13 Application: What Is Happening with the Slumgullion Landslide in Colorado?

- Describe the setting and morphology of the Slumgullion landslide.
- Summarize the types of studies geologists conducted on the landslide, and what each type of study revealed about what was happening with the landslide.

Chapter 16: Rivers and Streams

16.1 What Are River Systems?

- Sketch and describe the variables plotted on a hydrograph and what this type of graph indicates.
- Describe how the shape and slope of a drainage basin affects discharge.
- Sketch or describe how the distribution of tributaries influences a river's response to precipitation.
- Sketch three kinds of drainage patterns and discuss what controls each type.

16.2 How Do River Systems Change Down Stream or Over Short Time Frames?

- Sketch and describe how a river or stream transports solid and dissolved material.
- Sketch and explain the processes by which a river or stream erodes into its channel and which sites are most susceptible to erosion.
- Sketch and describe turbulent flow.
- Describe some aspects of erosion and deposition in bedrock channels.

16.3 How Do Rivers Transport Sediment and Erode Their Channels?

- Describe, sketch, and show how to calculate a gradient for a river.
- Describe how gradient and other parameters change downstream.
- Describe how velocity relates to sediment size and capacity.
- Describe why discharge, or any other parameter, might exhibit changes at several different time scales.

16.4 What Factors Influence Profiles of Rivers?

- Sketch and describe the typical profile of a river.
- Describe the concept of base level and how it is expressed in a typical mountain-to-sea- landscape.
- Sketch or describe factors that can influence or change a stream profile.

16.5 Why Do Rivers and Streams Have Curves?

- Sketch and describe the difference between braided, low-sinuosity, and high-sinuosity rivers.
- Sketch or describe how flow velocity and channel profile vary in a meandering river, and what features form along different parts of bends.
- Sketch or describe the evolution of a meander, including how a cutoff meander forms and how it can lead to an oxbow lake.

16.6 What Features Characterize Mountain Rivers and Streams?

- Describe how channels form.
- Describe some of the landforms associated with the headwaters of mountain rivers and streams.
- Describe why some canyons are narrow and deep.
- Describe why sediment is deposited along mountain fronts in alluvial fans.
- Describe where mountain streams get their sediment.

16.7 What Features Characterize Braided Rivers?

- Describe the characteristics and setting of braided rivers and streams.
- Describe the types of sediment that braided rivers carry and deposit.
- Describe how and why river processes are investigated in laboratory tanks.

16.8 What Features Characterize Low-Gradient Rivers?

- Sketch or describe the features that accompany low-gradient rivers.
- Describe the character of meander scars and oxbow lakes on the floodplains of meandering rivers.
- Sketch or describe how natural levees form, and describe the benefits and problems associated with levees.

16.9 What Happens When a River Reaches Its Base Level?

- Describe what happens when a river enters an ocean or lake.
- Sketch and describe the stratigraphy of delta sediments and the setting in which each type of sediment formed.
- Describe what happens when a dam is built, including the effect on sediment transport and longevity of the dam.

16.10 How Do Rivers Change Over Time?

- Describe how rivers can be old or young, using the Mississippi River as an example.
- Describe how river systems respond to changes imposed by climate, tectonism, geology, and human engineering.
- Summarize the effect that glaciers have on river systems.

16.11 What Happens During River Incision?

- Sketch and explain a series of steps showing how river terraces form.
- Describe one way in which entrenched meanders form.
- Explain how antecedent and superposed rivers are different.

16.12 What Is and Is Not a Flood?

- Sketch and describe a flood that overflows the channel versus a flow that stays within the channel. Include hydrographs in your sketch.
- Sketch the difference between a hydrograph showing a protracted flood versus one of brief duration.
- Summarize some causes of flooding.

16.13 How Do We Measure Floods?

- Describe the cause of flooding along the Mississippi River in 1993, and how this event affected local floodplains.
- Discuss the cause and consequences of the Big Thompson Flood of 1976.
- Briefly describe other circumstances that caused notable floods.

16.14 What Were Some Devastating Floods?

- Describe what stream discharge is and how it is measured and calculated.
- Sketch and describe how a precipitation event might appear on a downstream station's hydrograph.
- Explain in how the probability of flooding is influenced by the length of time during which we have stream gauge measurements.

16.15 Application: How Does the Colorado River Change As It Flows Across the Landscape?

- Describe where the Colorado River is located, from its headwaters to its mouth.
- Describe the features that occur along the river and how each formed.
- Describe the record of flooding for the Colorado River at Lee's Ferry.
- Explain why stream-flow data collected over the last 100 years may not accurately indicate the maximum flood possible on a river.

Chapter 17: Water Resources

17.1 Where Does Water Occur on Our Planet?

- Summarize where most of Earth's total water resides.
- Describe the different settings where freshwater occurs, identifying which settings contain the most water.
- Describe or sketch the hydrologic cycle, summarizing the processes that shift water from one part to another.

17.2 How Do We Use Fresh Water Supplies?

- Describe ways we use freshwater, and which four uses consume the most.
- Describe how we use and store freshwater.
- Describe in familiar terms how much water is in an acre-foot.
- Describe what a drinking water standard is, who sets the limits, and to whom they do and do not apply.

17.3 What Is the Setting of Groundwater?

- Sketch how groundwater accumulates and occurs in rocks and sediment.
- Sketch and describe what the water table represents.
- Discuss porosity and permeability, distinguishing between the two and providing examples of materials with high and low values for each attribute.

17.4 How and Where Does Groundwater Flow?

- Sketch and describe the typical geometry of the water table beneath a hill and a valley, showing the direction of groundwater flow.
- Summarize two factors that control the rate of groundwater flow.
- Sketch or describe an unconfined, confined, and artesian aquifer.
- Describe how we can determine the age of groundwater.

17.5 What Is the Relationship Between Surface Water and Groundwater?

- Sketch and describe how the interaction of the water table with topography determines which way water moves between the surface and subsurface.
- Sketch or describe what is required to form a spring and some possible settings where this occurs.
- Sketch and describe ways that lakes and wetlands relate to groundwater.
- Describe gaining and losing streams and two ways that a losing river or stream can lose its water entirely.

17.6 What Features Are Associated with Groundwater?

- Summarize the character and formation of caves, sinkholes, karst topography, solution valleys, and travertine along streams.
- Briefly summarize how stalactites, stalagmites, and flowstone form.
- Describe features on the surface that might indicate an area has favorable conditions for caves at depth.

17.7 How Do We Explore for Groundwater?

- Summarize the types of information that hydrogeologists collect and what each indicates about the subsurface.
- Describe how a contour map of water table elevations is constructed and how it would be used to predict the direction of groundwater flow.
- Describe factors to show in a cross section or block diagram if groundwater is the focus of the study.

17.8 What Problems Are Associated with Groundwater Pumping?

- Sketch a cone of depression in cross section, describing how it forms and which way groundwater flows.
- Sketch how a cone of depression can cause a well to become polluted.
- Describe some other problems associated with overpumping, including subsidence, earth fissures, and salt-water incursion.

17.9 How Can Water Become Contaminated?

- Describe the many ways that surface water and groundwater are contaminated.

17.10 How Does Groundwater Contamination Move and How Do We Clean It Up?

- Sketch a plume of contamination, showing how it relates to the source of contamination and the direction of groundwater flow.
- Describe some ways that geologists investigate groundwater contamination.
- Sketch how chemical analyses define a plume of contamination, and one way this plume could be remediated.

17.11 Application: What Is Going On with the Ogallala Aquifer?

- Summarize the location, characteristics, and origin of the Ogallala aquifer.
- Summarize the water balance for the aquifer and what has happened to the water levels in the last 50 years.

Chapter 18: Energy and Mineral Resources

18.1 How Do Oil and Natural Gas Form?

- Summarize where the organic material in petroleum comes from.
- Summarize how oil and gas are produced by burial and heating.
- Sketch or describe how oil and gas move through rocks and how they can end up on the surface or be trapped at depth.
- Briefly describe the La Brea Tar Pits.

18.2 In What Settings Are Oil and Gas Trapped?

- Describe the role of a reservoir rock and impermeable cap.
- Sketch and describe how petroleum is trapped by an anticline, salt dome, fault, unconformity, and facies change.
- Briefly summarize where petroleum basins are and are not located in the lower 48 states.

18.3 How Do Coal and Coal-Bed Methane Form?

- Summarize how coal forms.
- Describe the different types of coal, ranking them from lowest quality to highest quality.
- Summarize or sketch how coal is mined from strip mines and underground mines.
- Summarize how coal is used and some of the environmental downsides.

18.4 What Are Other Types of Hydrocarbons?

- For coal-bed methane, oil shale, and tar sand, summarize what the substance is, how it forms, where it is most abundant, and how it is, or could be, extracted.
- Describe gas hydrate, where it occurs, and what its known or potential hazards might be.

18.5 How Do We Explore for Fossil Fuels?

- Describe aspects to consider regarding an area's potential for fossil fuels.
- Summarize the types of field studies geologists conduct in exploring for fossil fuels.
- Summarize or sketch how geologists infer what is in the subsurface, and describe the tools they use to visualize these data.
- Describe why exploration is so costly.

18.6 How Is Nuclear Energy Produced?

- Summarize how nuclear fission releases energy and how this energy is used to generate electricity.
- Summarize or sketch some settings in which uranium deposits form.
- Summarize positive and negative aspects of the use of nuclear energy.
- Briefly describe Yucca Mountain's importance for nuclear waste.

18.7 How Is Water Used to Generate Electricity?

- Sketch or describe how electricity is generated by hydroelectric dams and from tides and ocean currents.
- Summarize how geology affects the location of a dam.
- Summarize some advantages and disadvantages of hydroelectric dams.

18.8 What Are Some Other Sources of Energy?

- Describe or sketch the surface and subsurface geologic factors favorable for geothermal energy.
- Summarize how electricity is produced from the wind.
- Describe how energy is produced from solar power, biomass, ethanol, and fuel cells.
- Discuss some of the trade-offs involved in each of the various energy sources.

18.9 What Are Mineral Deposits and How Do They Form?

- Explain the meaning of mineral deposit, mineralization, and ore.
- Summarize geologic and nongeologic factors that determine whether a mineralized body can be mined.
- Summarize the processes that can form a mineral deposit.
- Describe how diamond-bearing deposits form.

18.10 How Do Precious-Metal Deposits Form?

- Describe or sketch the main geologic settings for gold and silver deposits.
- Identify where gold is mined in the United States and describe the type of gold deposits in each region.
- Describe the geologic setting of the world's largest platinum deposit.
- Explain why precious metal mines can afford to be so deep.

18.11 How Do Base-Metal Deposits Form?

- Describe or sketch two ways that iron deposits form.
- Describe or sketch ways that copper deposits form, and what happens when a deposit is weathered.
- Summarize how the Mississippi Valley lead-zinc and Sudbury nickel deposits formed.
- Discuss a few of the environmental issues involved with mining and processing ore.

18.12 How Do We Explore for Mineral Deposits?

- Describe how we explore for mineral deposits, including buried ones.
- Describe why the plate-tectonic setting of a region is an important consideration for mineral exploration.
- Briefly summarize how minerals are extracted and processed.
- Discuss how much minerals we use.

18.13 Why Are Industrial Rocks and Minerals So Important to Society?

- Summarize how limestone is used to make cement, concrete, and lime.
- Summarize where the gypsum in wallboard and plaster comes from.
- Discuss why sand, gravel, and other aggregate are our most-used mineral resource.
- Briefly describe the origins and uses of silica sand, salt, clay, and phosphate rock.

18.14 Application: Why Is Wyoming So Rich in Energy Resources?

- Summarize or sketch in cross section the main geologic features of Wyoming.
- Summarize how large-scale geologic features control the distribution of oil, gas, oil shale, coal, coal-bed methane, uranium, and geothermal energy.

Chapter 19: Geology of the Solar System

19.1 How Do We Explore Other Planets and Moons?

- Briefly explain why we put telescopes in orbit to better observe space.
- Sketch and describe what radar observations indicate about a planetary surface.
- Discuss how we remotely observe the temperature of materials.
- Describe the ways we collect information by landing or crashing probes onto the surface of an object in space.

19.2 Why Is Each Planet and Moon Different?

- Summarize the factors and processes that affect the appearance of a moon or planet.
- Summarize the characteristics of an impact crater and how one forms.
- Explain why smaller objects are more likely to be tectonically or volcanically inactive compared to larger objects.
- Explain how crater density can be used to estimate the age of a planetary surface.

19.3 What Is the Geology of the Inner Planets?

- Explain why the surface of Mercury is so heavily cratered.
- Describe why radar was required to investigate the surface of Venus, and what type of features were found.
- Discuss the factors that make the surface of Earth so different from its neighbors.
- Summarize the materials and features present on the surface of Mars.
- Describe what asteroids are and where most are located.

19.4 What Is the Geology of Our Moon?

- Summarize the physical characteristics and rock compositions of the lunar highlands, maria, and craters, and explain how each feature formed.
- Sketch and describe what causes the phases of the Moon.
- Summarize one model for how the Moon and its different parts formed.

19.5 What Is Observed on Jupiter and Its Moons?

- Summarize the key characteristics of Jupiter, such as its size, internal composition, and atmospheric composition.
- Briefly summarize the main characteristics of each Galilean moon.

19.6 What Is Observed on Saturn and Its Moons?

- Summarize the key characteristics of Saturn, such as its size and composition.
- Describe what materials compose the rings of Saturn.
- Summarize the main characteristics of the four moons of Saturn described here and the geologic processes expressed on the surface of each.

19.7 What Is the Geology of the Outer Planets and Their Moons?

- Describe some key features of Uranus and Neptune, and explain how they are similar.
- Describe the unusual features on the moons Ariel, Miranda, and Triton, and identify the materials that comprise the surfaces of these moons.
- Describe what is known about Pluto and its companions.
- Describe what comets are, and identify their most distinctive features.

19.8 Application: What Have We Learned About the Geology of Mars?

- Summarize two of the ways that geologists have explored Mars.
- Describe some features found by orbiting spacecraft and what they imply about processes that have occurred on the surface of the planet.
- Describe some features discovered by the rovers Spirit and Opportunity.
- Explain how Opportunity's discoveries were made possible by prior spacecraft measurements.