THE ROCK CYCLE

AREA TIME EMPHASIS	TOPIC	TITLE	TIME
37 DAYS	IX	The Erosional Process	6 days
	X	The Depositional Process	6 days
	XI	The Formation of Rocks	12 days
	XII	The Dynamic Crust	13 days

How Is the Earth's Crust Affected by Its Environment?

Time Emphasis: 6 days

TOPIC ABSTRACT

Major Behavioral Objectives

At the completion of this topic, the student should be able to:

A. Analyze and measure earth materials to obtain evidence of weathering.

B. Analyze and measure earth materials to obtain evidence of erosion, and draw inferences from observations about the factors which affect erosion.

Approach

Consideration of the weathering process should provide a bridge from climate and climate factors, which were dealt with in topic VIII, to the effects of the environment on the earth's crust, which will be dealt with in this topic and in topic X.

Erosion of rock materials should be approached through the concept of a transporting *system* to dramatize the complex nature of the erosion process in nature. It should be stressed that a "system" includes the agent or agents, the "driving" forces, and the material transported. The interrelationships between erosion and deposition are treated at the end of topic X after the basic factors affecting them have been developed.

It may be desirable to have students investigate the characteristics of a local stream (erosion system) if one is readily accessible.

Landscape features produced by erosional systems are considered in topic XIV.

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TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A. Weathering		
A-1 Evidence of weathering	**A-1** ***What is some evidence that earth materials weather?*** **IX-A-1**	
A-1.1 Weathering processes	A-1.11 Weathering occurs when rocks are exposed to the hydrosphere and the atmosphere.	CCO-1, 4, 6, 7, 12
	A-1.12 The weathering process involves the physical and chemical breakdown of material.	PIO-3, CCO-1, 2, 4, 6, 7
	A-1.13 The weathering process is affected by climatic conditions.	CCO-3, 4, 6, 7
A-1.2 Weathering rates	A-1.21 The weathering rate of rock material varies inversely with the particle size.	PIO-1, 3; CCO-1, 2, 4, 6, 7
	A-1.22 Rock particles weather at different rates depending on mineral composition.	CCO-1, 2, 4, 6, 7

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A-1.3 Soil formation	A-1.31 Soil horizons develop as a result of weathering processes and biologic activity.	A-1.31 Emphasis should be placed on how soils develop rather than on types of soils and their names. PIO-3; CCO-4, 6, 7, 9, 12
	A-1.32 The complex interrelationships of living organisms are significant factors in soil formation.	CCO-6, 7
A-1.4 Soil solution	A-1.41 The end product of weathering is a solution of ionic material, the minerals present in all surface and ground water.	A-1.41 Relate to topic VIII. CCO-1, 2, 4, 6, 7
B. Erosion		
B-1 Evidence of erosion	***B-1 What evidence suggests that rock materials are transported?***	**IX-B-1**
B-1.1 Displaced sediments		B-1.1 A field trip, or observation from a previous field trip, can be used to examine evidences of erosion. Slides or aerial photographs may also be used.
	B-1.11 Sediments displaced from their source are evidence of erosion.	PIO-2; CCO-4, 10, 11, 12
	B-1.12 Transported material is far more common than residual material.	CCO-12
B-1.2 Properties of transported materials	B-1.21 Transported materials may possess distinctive properties indicative of the transporting medium.	CCO-1, 2, 4, 7, 12
B-2 Factors affecting transportation	***B-2 How does the transportation of rock materials take place?***	**IX-B-2**
B-2.1 Gravity	B-2.11 Gravity is the primary force which motivates all transporting systems.	CCO-4
	B-2.12 Gravity may act alone in transporting earth materials.	CCO-4
B-2.2 Water erosion		B-2.2 Comparisons between model streams and streams in nature should be treated cautiously. Usually more than one factor is changing and they are not of equal importance.
	B-2.21 For a given portion of a stream channel, an increase in the discharge increases the average velocity of water.	PIO-1, 2, 3, 4; CCO-1 2, 4, 6

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
	B-2.22 For a given stream channel shape, an increase in slope tends to increase the velocity of the water.	PIO-1, 2, 3, 5; CCO-1, 2, 4, 6
	B-2.23 The size of the particle that can be transported increases as water velocity increases.	CCO-4, 6
	B-2.24 The position of maximum velocity in a stream cross section varies with changes in the direction of the stream flow.	CCO-1, 2, 4, 6, 7
	B-2.25 Streams carry material by solution, by suspension, and by rolling materials along their beds.	CCO-1, 2, 4, 6, 7
B-2.3 Wind and ice erosion	B-2.31 Wind and ice may act as transporting agents of rock materials.	CCO-1, 2, 4, 6
	B-2.32 The factors affecting wind erosion and ice erosion are similar to the factors affecting erosion by running water.	CCO-1, 2, 4, 6, 11, 12
B-2.4 Effect of erosional agents	B-2.41 Each agent of erosion produces distinctive changes in the material that it transports.	B-2.41 Students should be given the opportunity to examine and compare materials transported by wind, water, and ice. CCO-1, 2, 7, 11, 12
B-2.5 Effect of man	B-2.51 Man adds to the erosion of the land through activities of the individual and his societies.	B-2.51 Relate to topic XIV. CCO-7
B-2.6 Predominant agent	B-2.61 Running water is the predominant agent of erosion on the earth.	PIO-3; CCO-7, 12

How Does Sedimentation Occur?

Time Emphasis: 6 days

TOPIC ABSTRACT

Major Behavioral Objectives

At the completion of this topic, the student should be able to:

A. Analyze and measure the deposition of particles in a medium, and draw inferences about the process.

B. Analyze patterns of erosion and deposition by a medium, and draw inferences about the characteristics of the system.

Approach

The basic factors affecting deposition of particles are considered here. Deposition of materials from solution will be treated in topic XI. The final section of this topic involves the analysis of an erosion-deposition system.

In later topics, the student will examine past evidence of erosion and deposition. From this evidence, he will be expected to draw inferences about the environment at the time erosion and deposition were taking place.

In topic XIV, the erosion-deposition system will be considered in connection with landscape development.

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TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A. Deposition		
A-1 Factors	**A-1 What factors affect the deposition of particles in a medium?**	**X-A-1**
A-1.1 Size	A-1.11 Other factors being equal, smaller particles settle more slowly than larger particles.	A-1.11 Develop a simplified model of deposition which can be related to the more common and more complex case of deposition in a moving medium. PIO-2, 3, 5; CCO-9, 11
	A-1.12 Particles of colloidal size and smaller may remain suspended indefinitely.	PIO-2, 3, 5; CCO-9, 11
	A-1.13 When a mixture of sediment sizes settles in a quiet medium (water or air), sorting into horizontal layers takes place.	PIO-3, 5; CCO-8, 9, 11
A-1.2 Shape	A-1.21 Other factors being equal, the shape of a particle may determine its settling rate.	PIO-2, 3, 5; CCO-9, 11

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A-1.3 Density	A-1.31 Other factors being equal, high density particles settle faster than low density particles.	PIO-2, 3, 5; CCO-9, 11
A-1.4 Velocity	A-1.41 As the velocity of a sediment laden flow decreases, the particles of greater weight and density settle out first.	A-1.41 PIO-2, 3, 5; CCO-9, 11
	A-1.42 Decreasing velocity produces horizontal sorting. Smaller particles are usually carried farther.	A-1.42 Relate to topic XIII. PIO-2, 3, 5; CCO-9, 11
	A-1.43 The velocity of particles in a moving medium is not necessarily the same as the velocity of the fluid.	A-1.43 PIO-2, 3, 5; CCO-9, 11
	A-1.44 Sorting in a quiet, solid medium, such as ice, is more complex than in a fluid medium.	PIO-3, 5; CCO-0, 11, 12
B. Erosional-depositional system		
B-1 Characteristics	***B-1 What are some characteristics of an erosional-depositional system?***	**X-B-1**
B-1.1 Erosional-depositional change	B-1.11 The erosional and depositional processes produce characteristic changes which can be observed.	B-1.11 Relate to topic XIV PIO-3, 5, CCO-4, 7, 8, 9, 11
B-1.2 Dominant process	B-1.21 Either erosion or deposition may be dominant depending on the condition at a particular location.	
B-1.3 Erosional-depositional interface	B-1.31 An interface between erosion and deposition can often be located.	B-1.31 Relate to topic XIV PIO-3, 5; CCO-1, 4, 8, 9, 11
B-1.4 Dynamic equilibrium	B-1.41 A state of dynamic equilibrium exists within the system in which the erosional and depositional rates are equal.	PIO-3, 5; CCO-1, 4, 9
B-1.5 Energy relationships	B-1.51 The erosion phase of the erosional-depositional system results from a transfer from potential to kinetic energy.	PIO-3, 5; CCO-1, 2, 4, 6
	B-1.52 The depositional phase of the erosional-depositional system results from a loss of energy.	PIO-3, 5; CCO-1, 2, 4 6
	B-1.53 Energy transformations between potential and kinetic energy may occur in an erosional-depositional system.	PIO-3, 5; CCO-1, 2, 4
	B-1.54 In an erosional-depositional system, the total energy within the system is decreasing.	PIO-3, 5; CCO-1, 2, 4

How Are Rocks Formed?

Time Emphasis: 12 days

TOPIC ABSTRACT

Major Behavioral Objectives

At the completion of this topic, the student should be able to:

A. Analyze rocks and sediments, and compare their characteristics to determine the degree of similarity.
B. Analyze rocks to determine their composition, and identify the characteristics of minerals.
C. Devise models for the formation of sedimentary and nonsedimentary rocks.
D. Construct a model from available evidence that illustrates the cyclic nature of rock-forming processes.

Approach

Previous topics have dealt with the processes of weathering, erosion, and deposition. In this topic, rock-forming processes should be considered in detail.

Students should investigate the characteristics of rocks which should enable them to infer a model for rock formation. Minerals should be studied as indicators of the rock-forming processes.

Rock properties will be used as indicators of large scale change in Topic XII. With the assumption made that most changes are cyclic, the attention in this topic should be directed toward the evidence that suggests cyclic processes of rock formation.

Care should be taken to develop understanding of the relationships between the inferred rock-forming processes that leads to the concept of the rock cycle.

When considering the rock-forming processes, it is important that the student distinguish inferences from facts.

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TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A. Rocks and sediments		
A-1 Comparative properties	**A-1 *What similarities do rocks have with sediments?***	**XI-A-1**
A-1.1 Similarities	A-1.11 Some rocks have properties such as discrete layers, fragmental particles, organic composition, a range of particle size, or a predominance of one particle size which strongly resembles sediments.	Relate to topic X PIO-5; CCO-4, 6, 7, 9, 10
A-1.2 Differences	A-1.21 Some rocks have properties such as crystalline structure, banding, distortion of structure, and crystal alignment. These do not resemble sediments.	PIO-5; CCO-4, 6, 7, 9, 10

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
B. Minerals		
B-1 Relation to rocks	**B-1 *What is the composition of rock?***	**XI-B-1**
B-1.1 Composition	B-1.11 Rocks are composed of minerals.	CCO-10, 11
	B-1.12 Some rocks are monominerallic; others are polyminerallic.	CCO-10, 11
	B-1.13 Most rocks have a number of minerals in common.	CCO-10, 11
B-2 Characteristics	**B-2 *What are some characteristics of minerals ?***	**XI-B-2**
B-2.1 Physical, chemical properties	B-2.11 Minerals are identified on the basis of well-defined physical and chemical properties.	CCO-10
B-2.2 Chemical composition	B-2.21 Of the many naturally occurring elements, only a few comprise most minerals.	PIO-3; CCO-4,6, 7
	B-2.22 Of the elements comprising most minerals, oxygen is the most abundant by weight and volume. Silicon is the second most abundant by weight.	CCO-10, 11, 12
B-2.3 Structure	B-2.31 The elements oxygen and silicon unite to form a tetrahedral unit.	PIO-3; CCO-11, 12
	B-2.32 The physical properties of minerals can be described as a function of the arrangements of their constituents' units.	PIO-3; CCO-7, 12
C. Rock formation		
C-1 Sedimentary rocks	**C-1 *How are sedimentary rocks formed?***	**XI-C-1**
C-1.1 Compression cementation	C-1.11 Some sedimentary rocks form as a result of sediments undergoing compression and/or cementation.	PIO-3, 5; CCO-9
C-1.2 Chemical processes	C-1.21 Some sedimentary rocks form as a result of chemical processes such as evaporation and precipitation.	PIO-3, 5; CCO-9
C-1.3 Biological processes	C-1.31 Some sedimentary rocks form as a result of biologic processes.	PIO-3, 5; CCO-9
C-2 Nonsedimentary rocks	**C-2 *How are nonsedimentary rocks formed?***	**XI-C-2**
C-2.1 Solidification process	C-2.11 Some nonsedimentary rocks form as a result of solidification of molten material.	PIO-3, 5; CCO-9
	C-2.12 Crystal sizes seem to vary as a function of time, temperature, and pressure.	PIO-3, 5; CCO-9
C-2.2 Recrystallization process	C-2.21 Some nonsedimentary rocks form as a result of the recrystallization of unmelted material under high temperature and pressure.	PIO-3, 5; CCO-9

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
C-3 Environment of formation	**C-3 *What is the environment in which a rock forms?***	**XI-C-3**
C-3.1 Inferred characteristics	C-3.11 The environment in which a rock formed is often inferred from compositional, structural, and textural characteristics.	PIO-5; CCO-7, 9, 12
C-3.2 Distribution	C-3.21 Sedimentary rocks are usually found as a thin veneer over large areas of continents. C-3.22 Nonsedimentary rocks, at or near the surface, are most frequently found in regions of volcanoes or mountains.	PIO-1, 3, 5
D. Rock cycle		
D-1 Evidence	**D-1 *What evidence suggests a cyclic model of rock formation?***	**XI-D-1**
D-1.1 Transition zones	D-1.11 Transition zones from unaltered to altered rock can be found where molten material has come in contact with the local rock.	PIO-5; CCO-6, 7, 8, 9, 12
D-1.2 Rock composition	D-1.21 The composition of some sedimentary rock suggests that the components had varied origins. D-1.22 The composition of some rocks suggests that the materials have undergone multiple transformations.	Relate to topic X. PIO-5; CCO-6, 7, 8, 9, 12

How Are Changes in the Earth's Crust Produced?

Time Emphasis: 13 days

TOPIC ABSTRACT

Major Behavioral Objectives

At the completion of this topic, the student should be able to:

A. Identify evidence of crustal changes from his observations of the earth's crust.
B. Describe the properties of earthquake waves; and from an analysis of seismic data, locate the epicenter and determine time of occurrence of an earthquake.
C. Construct inferences about the structure and composition of the earth's crust and interior from available evidence.
D. Construct inferences about the processes which may cause crustal change from the available evidence.

Approach

In this topic, the student should be provided with an opportunity to examine evidence that suggests a dynamic lithosphere. Much of the evidence examined is indirect and incomplete. *Care should be taken so that students do not mistake inferences for facts.*

While topic XII focuses on large scale crustal changes, the interpretations of local changes, past and present, are considered in later topics.

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TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A. Evidence for crustal movement		
A-1 Minor crustal changes	**A-1 *What evidence suggests minor changes in the earth's crust?***	**XII-A-1**
A-1.1 Deformed rock strata	A-1.11 Folded and tilted rock strata and faults suggest past crustal movements.	A-1.1 A series of slides or photographs may be used to illustrate deformed crustal material. PIO-3, 5; CCO-1, 4, 6, 8
A-1.2 Displaced fossils	A-1.21 Marine fossils found at high elevations above sea level suggest past uplift.	PIO-3, 5; CCO-1, 4, 6, 8, 12
	A-1.22 Shallow water fossils found at great ocean depths suggest past subsidence.	PIO-3, 5; CCO-1, 4, 6, 8, 12
A-1.3 Displaced strata	A-1.31 Displacement of strata, which may accompany earthquakes, provides direct evidence of crustal movement.	PIO-3, 5; CCO-1, 4, 6, 8, 12

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
A-2 Major crustal changes	**A-2 *What evidence suggests major changes in the earth's crust?***	**XII-A-2**
A-2.1 Zones of crustal activity	A-2.11 Zones of frequent crustal activity can be located on the earth's surface.	A-2.11 Relate to D-1.11. PIO-3, 5; CCO-1, 4, 5, 6, 8, 12
A-2.2 Geosynclines	A-2.21 Great thicknesses of sediment that were deposited in shallow water are observed in some areas.	A-2.21 Relate to D-1.31. PIO-3, 5; CCO-1, 4, 5, 6, 8, 12
	A-2.22 Shallow basins of large (regional) area which may be slowly subsiding can be observed in some areas.	A-2.22 Relate to D-1.31. CCO-1, 4, 5, 6, 8, 12
A-2.3 Vertical movements	A-2.31 Tilted shorelines, changed bench mark elevations, and other related phenomena can be observed in some areas.	A-2.31 Relate to D-1.41. PIO-3, 5; CCO-1, 4, 5, 6, 8, 11, 12
A-2.4 Ocean floor spreading	A-2.41 Igneous material along the oceanic ridges is younger than the igneous material farther from the ridges.	A-2.41 Relate to D-1.21. PIO-3, 5; CCO-1, 4, 5, 6, 8, 11, 12
	A-2.42 Strips of igneous rock parallel to the ocean ridges show reversal of magnetic orientation.	A-2.42 Relate to D-1.21. PIO-3, 5; CCO-1, 4, 5, 6, 8, 11, 12
A-2.5 Continental drift	A-2.51 The present continents appear to fit together as fragments of an originally larger land mass.	A-2.51 Relate to D-1.21. PIO-3, 5; CCO-1, 4, 6, 8, 11, 12
	A-2.52 Correlation of rock, mineral, and fossil evidence between continents suggests that the land masses were joined at some time in the past.	A-2.52 Relate to D-1.21. PIO-3, 5; CCO-1, 4, 6, 8, 11, 12
A-2.6 Magnetic poles	A-2.61 Rocks have recorded the position of the earth's magnetic poles in vastly different locations.	A-2.61 Relate to D-1.21. PIO-3, 5; CCO-1, 5, 6, 8, 11, 12
Earthquakes		
B-1 Wave properties	**B-1 *What are some properties of earthquake waves?***	**XII-B-1**
B-1.1 Types of waves	B-1.11 Earthquakes generate compressional and shear waves.	PIO-1, 5; CCO-1, 6, 11
B-1.2 Velocities	B-1.21 In the same medium, compressional waves travel at a velocity greater than shear waves.	PIO-1, 5; CCO-1, 11
	B-1.22 The velocities of seismic waves depend upon the physical properties of the materials through which the waves travel.	PIO-1, 5; CCO-1, 6, 11, 12
B-1.3 Transmission	B-1.31 Compressional waves are transmitted through solids and fluids.	PIO-5; CCO-1, 6, 11, 12
	B-1.32 Shear waves are transmitted only through solids.	PIO-5; CCO-1, 6, 11, 12

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
B-2 Location of an epicenter	**B-2** *How can the epicenter of an earthquake be located?*	**XII-B-2**
B-2.1 Epicenter	B-2.11 Differences in travel times of seismic waves can be used to determine the distance to the epicenter.	PIO-1, 2, 4, 5; CCO-6, 11, 12
B-2.2 Origin time	B-2.21 The origin time can be inferred from the evidence of epicenter distance and travel time.	PIO-1, 2, 4, 5; CCO-6, 11, 12
C. Model of the earth's crust and interior		
C-1 Properties	**C-1** *What are some properties of the earth's crust and interior?*	**XII-C-1**
C-1.1 Solid and liquid zones	C-1.11 Analysis of seismic data leads to the inference that solid zones (crust, mantle, inner core) and a liquid zone (outer core) exist within the earth.	C-1.11 The characteristics of seismic waves developed in the previous section may be used to construct a more detailed model of the earth's interior than is required. PIO-1, 5; CCO-6, 7, 11, 12
C-1.2 Crustal thickness	C-1.21 The average thickness of the continental crust is greater than the average thickness of the oceanic crust.	PIO-1, 5; CCO-11, 12
C-1.3 Crustal composition	C-1.31 The oceanic and continental crusts have different compositions.	C-1.31 Relate to topic XI. PIO-1, 5; CCO-11, 12
C-1.4 Density, temperature, and pressure	C-1.41 The density, temperature, and pressure of the earth's interior increase with depth.	C-1.41 Relate to topic III. PIO-1, 5; CCO-6, 7, 11, 12
C-1.5 Interior composition	C-1.51 The composition of some meteorites suggests an earth core composed of iron and nickel.	PIO-5; CCO-6, 7, 11, 12
	C-1.52 The compositions of the crust and core suggest a different composition for the mantle.	PIO-5; CCO-6, 7, 11, 12
D. Theories of crustal change		
D-1 Inferred processes	**D-1** *What inferences can be drawn about the processes which may cause crustal changes?*	**XII-D-1**
D-1.1 Mantle convection cells	D-1.11 The occurrence of heat flow highs in areas of current mountain building, and heat flow lows in areas of shallow subsiding basins, suggests the existence of mantle convection cells.	PIO-3, 5; CCO-1, 4, 5, 6, 8, 12

TOPIC OUTLINE	MAJOR UNDERSTANDINGS	INFORMATION TO TEACHERS
D-1.2 Geosynclinal development	D-1.21 Continental growth and mountain building may be related to geosynclinal development.	PIO-3, 5; CCO-1, 4, 5, 6, 8, 12
D-1.3 Isostasy	D-1.31 Mountains of geosynclinal origin may in part be caused by isostatic adjustments of materials of different density.	PIO-3, 5; CCO-1, 4, 5, 6, 8, 12
D-1.4 Process relationships	D-1.41 The close correlation among zones of earthquake activity, volcanic activity, and mountain building suggests that these processes of crustal change are related.	PIO-3, 5; CCO-1, 4, 5, 6, 8, 12