Massachusetts Tests for Educator Licensure®

TEST INFORMATION BOOKLET

14 Earth Science

MA-SG-FLD014-04

Massachusetts Department of Education

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Test Overview Chart: Earth Science (14)

Subareas	Approximate Number of Multiple-Choice Items	Number of Open-Response Items
I. Scientific Inquiry	14–16	2
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The Earth Science test is designed to assess the candidate's knowledge of the subject matter required for the Massachusetts Earth Science Teacher certificate. This subject matter knowledge is delineated in the Massachusetts Department of Education *Regulations for the Certification of Educational Personnel in Massachusetts* (April 1995), 603 C.M.R. 7.12, "Competencies for Specific Certificates," Section (12) (a) 2. "Competency I: Subject Matter Knowledge."

The Earth Science test assesses the candidate's proficiency and depth of understanding of the subject at the level required for a baccalaureate major, according to Massachusetts standards. Candidates are typically nearing completion of or have completed their undergraduate work when they take the test.

The multiple-choice items on the test cover the subareas as indicated in the chart above. The open-response items may relate to topics covered in any of the subareas and will typically require breadth of understanding of the earth science field and the ability to relate concepts from different aspects of the field. Responses to the open-response items are expected to be appropriate and accurate in the application of subject knowledge, to provide high-quality and relevant supporting evidence, and to demonstrate a soundness of argument and understanding of the earth science field.

1. A town has detected nitrates in its water supply, which is drawn from a reservoir and from a number of wells that tap a small aquifer. The nitrates have been traced to wells in one area. Which of the following is the most likely source of the contamination?

   A. leakage from underground gasoline storage tanks

   B. ash and particulates from upwind industrial stacks

   C. leachate from naturally occurring minerals

   D. runoff from farms and feedlots

2. **Use the passage below to answer the question that follows.**

   Scientists have had difficulty using previously reliable computer models to predict accurately the duration of El Niño episodes. In the past, available computer models have accurately projected the duration of El Niño episodes. However, the models, which simulate the interaction between atmospheric and oceanic conditions, predicted that the El Niño that began in mid-1991 would end by late 1992. Instead, El Niño conditions strengthened and persisted well past that time.

   The problems experienced with the computer models described in this passage were most likely caused by the fact that the models:

   A. include significant accuracy errors in the data used to develop them.

   B. focus on isolated data points rather than exploring patterns and relationships in data gathered over time.

   C. rely too heavily on empirical data, which makes it difficult to use the models to recognize and predict qualitative changes.

   D. do not accurately represent the influence and interactions of every variable that may affect the system.

3. Which line of the table matches an event on the sun with a likely consequence on earth when that event occurs?

Line	Solar Event	Consequence on Earth
1	an increase in the release of neutrinos	disruption of television and radio communications
2	increase in solar wind intensity	changes in the upper-level jet stream direction
3	eruption of a solar flare	strong display of the aurora borealis
4	reaching a higher than normal sunspot maximum	damage to the ozone layer

A. Line 1

B. Line 2

C. Line 3

D. Line 4

4. At a location in Utah, core samples have been taken of sedimentary rocks that formed in a tidal area nearly one billion years ago. These rocks have bands that scientists believe were formed by tides. The bands indicate that at the time the sediments were laid down, the lunar month was shorter than it is now. They also suggest that the length of a day was about 21 hours. Which of the following conclusions are supported by these observations?

    I. The moon was once closer to the earth than it is now.

    II. The earth used to tilt less on its axis than it does now.

    III. The difference between spring and neap tides was less than it is now.

    IV. The earth used to rotate faster on its axis than it does now.

    A. I and II only

    B. I and IV only

    C. II and III only

    D. III and IV only

5. A cumulus cloud begins to form in a warm air mass that is ascending rapidly through a slightly cooler air mass. Which of the following is the most likely cause of the condensation in the warm air mass?

    A. a decrease in temperature caused by a decrease in atmospheric pressure

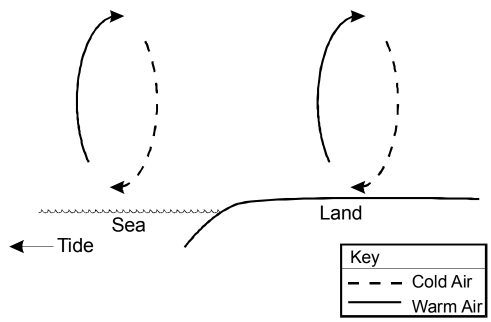
    B. a decrease in temperature caused by heat exchange between the two air masses

    C. an increase in relative humidity caused by an increase in water content

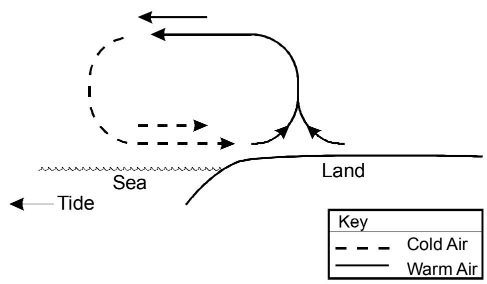
    D. an increase in relative humidity caused by an increase in the dew point

6. Which of the following most accurately represents the air circulation patterns likely to develop on a hot summer afternoon in a coastal area?

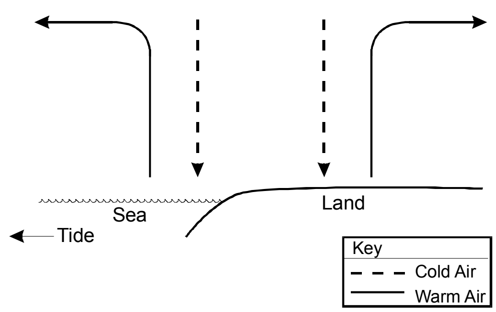
A.



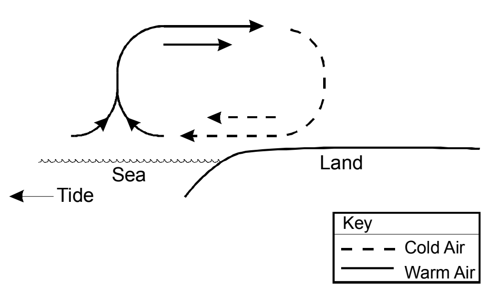
B.



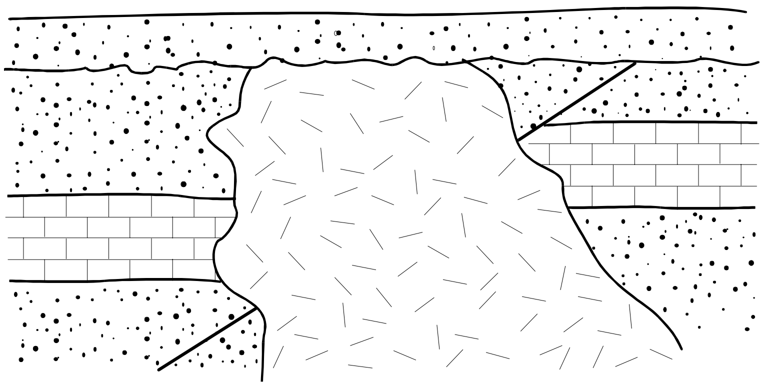
C.



D.



7. **Use the diagram below to answer the question that follows.**



Based on the cross-sectional diagram above, which of the following was the most likely sequence of geologic events?

A. sedimentation–faulting–intrusion–erosion–sedimentation

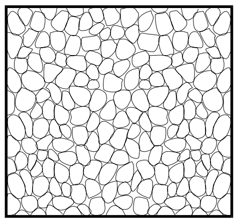
B. sedimentation–intrusion–erosion–faulting–sedimentation

C. sedimentation–folding–faulting–erosion–sedimentation

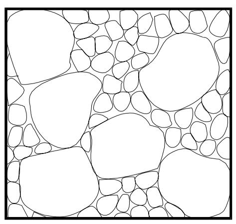
D. sedimentation–erosion–sedimentation–erosion–faulting

8. A sediment with which of the following structures would have the greatest permeability?

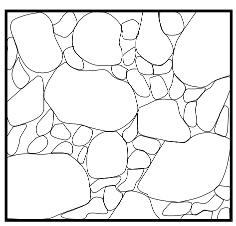
A.



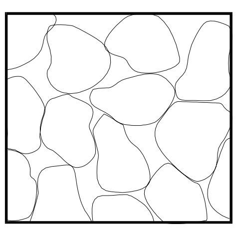
B.



C.



D.



9. A geologist observes that although the same minerals are present along the two-mile length of an escarpment, the size of the mineral crystals increases from west to east along the escarpment. Which of the following would best explain this observation?

A. The escarpment is metamorphic. The greatest heat and pressure occurred at the western end.

B. The escarpment is sedimentary. The eastern end is older than the western end.

C. The escarpment is igneous. The western end cooled more quickly than the eastern end.

D. The escarpment is metamorphic at the western end and igneous at the eastern end.

10. Which of the following best explains why the most productive marine fishing areas tend to be in coastal waters along the continental shelves or in areas where upwelling of deep ocean waters occurs?

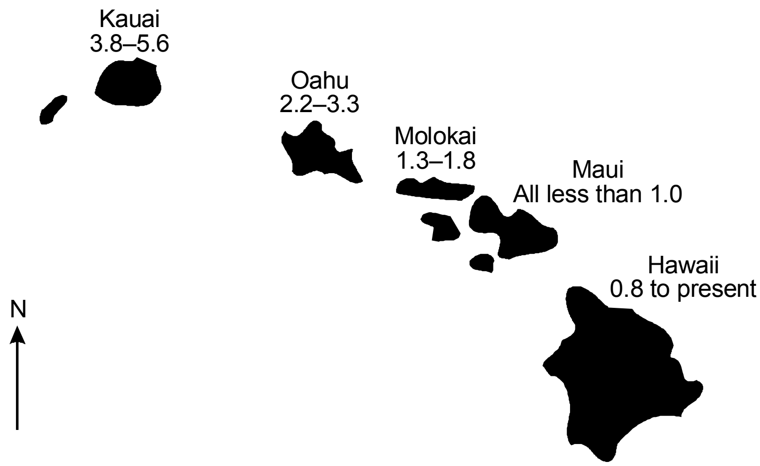
A. There are high levels of suspended solids in the water, which protect plankton from harmful ultraviolet radiation.

B. There is an ample supply of nutrients from land runoff and from ocean sediments.

C. The water tends to have low salinity, which allows a great diversity of organisms to survive in these areas.

D. The warmer water in these areas permits high rates of growth and reproduction.

11. **Use the map and the information below to complete the exercise that follows.**



Dates in Millions of Years

The map above indicates the approximate ages, in millions of years, of the Hawaiian Islands. Using your knowledge of geologic processes, describe the geologic history of the islands. In your essay:

- identify the relationship between the Hawaiian Islands and the Pacific Plate;
- describe the forces that move the Pacific Plate and the Hawaiian Islands; and
- explain the geologic processes that created the Hawaiian Islands and how these processes account for the pattern seen in the ages of the islands.

Answer Key and Sample Responses: Earth Science (14)

Question Number	Correct Response	Test Objective*
1.	**D**	Understand types and uses of natural resources, the effects of human activities on the environment, and the need to preserve the environmental integrity of the earth's ecosystems.
2.	**D**	Understand how to create, use, and interpret physical and mathematical models (e.g., maps, charts, graphs, diagrams) commonly used in earth science.
3.	**C**	Understand the structure, composition, and features of the sun (including its production and transmission of energy) and the importance of the sun to Earth processes.
4.	**B**	Understand the properties, features, and movements of the earth's moon; the interactions among the earth, moon, and sun (including phases, tides, and eclipses); and the role of technology and exploration in obtaining knowledge about the earth, moon, and sun.
5.	**A**	Understand the properties of water, conditions in the atmosphere that favor phase changes, and the energy relationships among phase changes, cloud formation, and precipitation.
6.	**B**	Understand characteristics of broad-scale weather systems and local weather, the relationship between them, and the methods and instruments used to collect weather data.
7.	**A**	Understand characteristics of the major geologic time divisions and theories and supporting evidence of the earth's geologic history.
8.	**D**	Understand the hydrologic cycle and the processes by which water moves on and beneath the earth's surface, and use this knowledge to analyze local water budgets.
9.	**C**	Understand the processes of mineral and rock formation, the characteristics of different types of minerals and rocks, and the methods used to identify and classify them.
10.	**B**	Understand marine life and the marine habitat.

*Each test objective is clarified and further described by a descriptive statement, which provides examples of the types of knowledge and skills covered by the test objective. The test objectives for the Earth Science test begin on page 43.

The sample response below reflects a weak knowledge and understanding of the subject matter.

The Hawaiian Islands sit in the middle of the Pacific Ocean far from any continents. They also sit on the Pacific Plate, which forms the ocean floor for the Pacific Ocean. Many land areas in and around the Pacific Ocean are subject to frequent earthquakes or volcanoes, and Hawaii is no exception. Moving rocks on the ocean floor cause earthquakes and hot molten rock coming up from deep below the earth's surface cause volcanoes, which is the case in the Hawaiian Islands

The Hawaiian Islands were probably once part of one huge volcanic island in the Pacific, but over millions of years, weathering and erosion has broken the land apart into separate land areas divided by water. The age of an island is directly related to how long ago the piece of land was isolated by water. So, Kauai, which is the oldest island, was isolated the longest time ago, and Hawaii, the youngest island was isolated the shortest time ago.

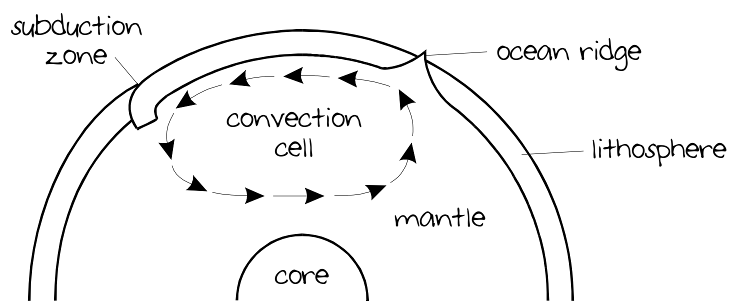
The same geologic processes that have happened elsewhere on the earth to create and shape the land created the Hawaiian Islands and account for their age pattern. The processes include erosion by wind and water, and land redistribution caused by earthquakes.

The sample response below reflects a strong knowledge and understanding of the subject matter.

The Hawaiian Islands are somewhat unusual geologically because they are tectonically and volcanically active, despite the fact that they are located far from any plate margins. The vast majority of the earth's tectonic and volcanic activity occurs where two or more plates meet. However, the Hawaiian Islands are located practically in the middle of the Pacific Plate between the North American and Asian continents.

Based on various observations and pieces of evidence, geologists have developed a theory that such tectonically active areas in the middle of plates are the result of hot spots. Geologists theorize that slowly moving convection currents originating in the deep mantle create plumes of molten rock that rise to the surface through the crust. The origins and mechanics of how hot spots work are still poorly understood, but evidence indicates that they tend to remain stationary, even as plates of the crust move over them.

The exact mechanism of lithospheric plate movements is not yet known, but many geologists believe that convection currents in the mantle play a role in moving the plates. According to this model, colder, denser rock near the surface tends to sink into the mantle, and as the rock heats, it becomes less dense and tends to rise back toward the surface, setting up a convection cell. The plates are thought to be carried along on the currents created by the convection cell. (See the diagram below.)



The model regarding hot spots and the model of lithospheric plate movements together explain the age and spatial patterns evident in the Hawaiian Islands. Given that the island of Hawaii is the youngest of the islands and is still growing as the result of active volcanoes, it can be concluded that the hot spot is currently located near that position. The fact that the islands get progressively older in the northwestward direction, from Hawaii to Kauai, suggests that the Pacific Plate has moved over the hot spot in that direction. At one time, the area that is now Kauai was once over the hot spot, creating that island, but as the Pacific Plate continued to move, new volcanic material stopped being added to the island at least 3.8 million years ago. As the area where Oahu is now located moved over the hot spot, volcanic material built up to form that island over the course of about a million years. Eventually the areas where Molokai and Maui are now located moved over the hot spot in turn, forming those islands. Scientists can even calculate how fast the Pacific Plate is moving by using the ages of the islands and the distances between them.

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In addition to the islands that make up the Hawaiian Islands, there is a string of smaller, older islands that continue in the northwestward direction from the Hawaiian Islands. Even further to the northwest, there are submerged islands, which presumably were once larger islands that formed as the Pacific Plate moved over the same hot spot much longer ago. This chain of submerged islands eventually turns in a more northward direction, which suggests that the Pacific Plate used to move to the north rather than to the northwest. Perhaps in a few million years, the Hawaiian Islands will follow the fate of these older islands and become submerged, while newer volcanic islands continue to form over the hot spot.

SUBAREAS:

SCIENTIFIC INQUIRY
ASTRONOMY
METEOROLOGY
GEOLOGY AND OCEANOGRAPHY

SCIENTIFIC INQUIRY

0001 Understand types and uses of natural resources, the effects of human activities on the environment, and the need to preserve the environmental integrity of the earth's ecosystems.

For example: the classification, uses, and importance of natural resources and methods of locating and obtaining natural resources; the positive and negative effects of human activities on the earth's environment (e.g., reclamation of strip mines, ocean dumping); and strategies for dealing with environmental problems.

0002 Understand the nature of scientific inquiry, the role of observation and experimentation in science, and the relationships between earth science, technology, and other fields of knowledge.

For example: processes by which new scientific knowledge and hypotheses are generated and rejected; ethical issues related to earth science (e.g., accurately reporting experimental results); evaluating the appropriateness of a specified experimental design to test a given hypothesis in earth science; the role of communication among scientists in promoting scientific progress; and similarities and differences between science and technology (e.g., science as investigating the natural world, technology as solving human adaptation problems).

0003 Understand the processes of gathering, organizing, reporting, and interpreting scientific data in the context of earth science investigations.

For example: evaluating the appropriateness of a given method or procedure for collecting data for a specified purpose; appropriate and effective graphic representations (e.g., graph, table, diagram) for organizing and reporting given experimental data; procedures and criteria for formally reporting experimental procedures and data to the scientific community; and relationships between factors (e.g., inverse, direct, linear) as indicated by experimental data.

0004 Understand how to create, use, and interpret physical and mathematical models (e.g., maps, charts, graphs, diagrams) commonly used in earth science.

For example: alternative models for conveying given information from earth science; methods by which given physical and graphic models are created; classifying different types of maps (e.g., topographic, geologic) used in earth science and analyzing the information conveyed by each type of map; and interpreting diagrams relating to earth science (e.g., crustal movements).

0005 Understand proper and safe use of equipment and materials used in earth science investigations.

For example: operating principles for various instruments; basic safety procedures in a laboratory or field situation (e.g., wearing safety glasses); and applying proper procedures for dealing with given accidents and injuries in the earth science laboratory or in the field.

ASTRONOMY

0006 Understand the physical characteristics and motions of the earth as well as the evidence of and methods used to determine these characteristics and motions.

For example: historical methods used to study the characteristics and motions of the earth (e.g., Foucault pendulum); the physical characteristics of the earth (e.g., diameter, tilt of axis, distance from the sun) and how they can be determined; interpreting evidence of the earth's motions (e.g., satellite photos, apparent motion of the sun); and the consequences of the earth's motions (e.g., length of day, change of seasons, length of year).

0007 Understand the structure, composition, and features of the sun (including its production and transmission of energy) and the importance of the sun to Earth processes.

For example: methods by which the sun's diameter, surface temperature, and chemical composition are determined; the layers of the sun; the sun's source of energy (fusion reaction); the solar surface as the immediate source of energy for the earth's surface; and the sunspot cycle and its possible effects on the earth's climate.

0008 Understand the properties, features, and movements of the earth's moon; the interactions among the earth, moon, and sun (including phases, tides, and eclipses); and the role of technology and exploration in obtaining knowledge about the earth, moon, and sun.

For example: relating surface features (e.g., maria, craters, mountains) of the earth's moon to events in the history of the moon; the relationship between the height of ocean tides and the relative positions of the earth, moon, and sun; the relationship between the phases of the moon and the relative positions of the earth, moon, and sun; and how the lunar exploration program has added to our knowledge of the earth-moon system.

0009 Understand the scale and organization of the solar system, the role of gravity in the solar system, characteristics of the bodies within the solar system, and physical and mathematical models that describe these objects and their real and apparent motions.

For example: characteristics (e.g., size, density, surface temperature) of the planets; relative sizes, distances, tilts, and positions of the planets; the position of the planets on the ecliptic; the origin and properties of comets and meteors; using the apparent motion of celestial objects to infer solar system models (i.e., geocentric, heliocentric); and applying Kepler's laws to describe and predict the motions of the planets.

0010 Understand stars, their motions and life cycles, and the methods and technology used to study them.

For example: comparing types of telescopes (e.g., optical, radio, infrared, ultraviolet) and the ways in which they are used to acquire information on star characteristics; methods and uses of spectroscopy; types of stars (e.g., pulsars, Cepheid variables) and their characteristics; using the H-R diagram to analyze the life cycle of stars; and analyzing stellar life cycles to understand the formation and initial development of the solar system.

0011 Understand evidence regarding the size, structure, scale, and motions of the universe, the Milky Way galaxy, and the solar system.

For example: evidence regarding the location of the solar system within the Milky Way galaxy; historical methods of inferring the size, structure, and motions of the galaxy and the solar system (e.g., star observations and counts); the evidence for and interpretations of an expanding universe (e.g., red shift and the Doppler effect); and analyzing types of evidence used to infer scales and relative motions of the solar system, the Milky Way galaxy, and the universe (e.g., in relation to relative size and distance).

METEOROLOGY

0012 Understand the composition, structure, and properties of the earth's atmosphere and the mechanisms and effects of energy transfer involving the earth-atmosphere system.

For example: properties (e.g., density, composition, temperature) of the atmosphere from the earth's surface through the thermosphere and the significance of changes in these properties; analyzing how various wavelengths of solar radiation (e.g., ultraviolet, visible light, infrared) are affected as the radiation enters and passes through the atmosphere and is absorbed by and radiated from the earth's surface; the processes by which energy is transferred to and within the atmosphere (e.g., radiation, convection, conduction); and analyzing global wind patterns in terms of latitudinal variations in insolation and the Coriolis effect.

0013 Understand the properties of water, conditions in the atmosphere that favor phase changes, and the energy relationships among phase changes, cloud formation, and precipitation.

For example: relating the physical properties of water (e.g., high specific heat, surface tension) to the chemical structure and properties of water molecules; energy changes involved in the transition between phases of water (i.e., latent heat); atmospheric conditions under which fog and clouds with various characteristics form (e.g., adiabatic temperature changes, dew-point, atmospheric stability); conditions under which precipitation forms; and predicting the type of precipitation that will fall to the earth's surface under given conditions.

0014 Understand characteristics of broad-scale weather systems and local weather, the relationship between them, and the methods and instruments used to collect weather data.

For example: types and characteristics of air masses, their movements, and the kinds of fronts that form between air masses; the horizontal and vertical movements of air in high- and low-pressure areas; and the use of weather instruments (e.g., thermometer, psychrometer) for collecting given types of weather data.

0015 Understand weather maps, how they are prepared, and how they are used.

For example: interpreting symbols used on weather maps; the methods used to generate weather maps; inferring recent weather in a given location based on one or more weather maps; and predicting future weather in a given location based on one or more weather maps.

0016 Understand the principles and technology of weather forecasting and the effects of weather and weather forecasting on humans.

For example: the use of weather models in forecasting; the role of computers and satellite photographs in generating weather forecasts; types of hazardous weather; types and functions of weather precautions; and the role of the National Weather Service in issuing weather alerts.

0017 Understand the locations and characteristics of the earth's major climatic regions and analyze factors that affect local climate and the relationship between weather and climate.

For example: inferring the climatic zone in which a given area is located based on temperature and precipitation data; factors that affect the climate in a given region (e.g., insolation, wind patterns, topography); and the relationship between the climate of a region and its weather.

0018 Understand the effects of human activities and natural processes on the atmosphere, theories about the long-range effects of human activities on global climate, and methods of controlling and minimizing these effects.

For example: common air pollutants and their sources and effects; pollutants and atmospheric chemical reactions involving these pollutants; factors that affect local air pollutant concentrations (e.g., population density); and analyzing the theory of global warming due to increased levels of atmospheric carbon dioxide from the burning of fossil fuels.

GEOLOGY AND OCEANOGRAPHY

0019 Understand the processes of mineral and rock formation, the characteristics of different types of minerals and rocks, and the methods used to identify and classify them.

For example: using classification schemes (e.g., Mohs's scale of hardness, crystal form, chemical composition) to identify common rock-forming minerals; the processes by which different kinds of rocks are formed; and classifying a given rock as sedimentary, igneous, or metamorphic.

0020 Understand the structure of the earth, the constructional forces that have shaped its surface, theories and evidence of crustal movements, and the effects of crustal movements on landscape.

For example: the use of seismic waves to infer the earth's internal structure; using the theory of dynamic equilibrium (e.g., isostasy) to explain landscape development; evidence for continental drift and seafloor spreading; and applying the theory of plate tectonics to explain landscape development and geologic phenomena (e.g., volcanism, earthquakes) and to predict future movements of land masses.

0021 Understand erosional-depositional processes that change the earth's surface (e.g., weathering, erosion) and the relationship between these processes and landscape development.

For example: the processes of mechanical, chemical, and biological weathering and factors that affect the rate at which rocks weather and soils are produced; the processes of erosion by various agents (e.g., wind, water, glaciers) and factors that affect erosion rates and patterns; the processes by which given landscape features (e.g., eskers, moraines) are formed; and the effects of glaciation on the Massachusetts landscape.

0022 Understand characteristics of the major geologic time divisions and theories and supporting evidence of the earth's geologic history.

For example: the conditions and characteristic fossils of the various geologic periods; applying the laws and principles of geology (e.g., law of original horizontality, law of superposition) to interpret diagrams of rock strata; the principles, applications, and limits of radioactive dating; and using paleontological information to infer the geologic history of a given area.

0023 Understand the hydrologic cycle and the processes by which water moves on and beneath the earth's surface, and use this knowledge to analyze local water budgets.

For example: analyzing a cross-sectional diagram of a water table and surrounding rock strata to predict the movement of groundwater and the behavior of wells; factors affecting the movement of groundwater (e.g., aquifers, gradient); and the effects of various factors (e.g., vegetation, gradient, rock strata) on components of a local water budget.

0024 Understand ocean water and its movements.

For example: the circulation patterns in the oceans and factors that influence these patterns (e.g., temperature variations, wind systems, Coriolis effect); and types, causes, and effects of tidal and wave motions of ocean water.

0025 Understand the structure and topography of the ocean basin.

For example: identifying ocean zones (e.g., littoral, benthic) in terms of their physical characteristics; the major structural features of the ocean floor; and factors involved in changing the structure of the ocean floor.

0026 Understand marine life and the marine habitat.

For example: the characteristics and major groups of marine plants and animals; zonation of marine plants and animals; and relationships between marine organisms and the marine environment.