HIGH SCHOOL: EARTH CHEMISTRY

Standards Bundle

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon the potential for related phenomena that can be used throughout a unit.

HS-ESS1-5 Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks. (SEP: 7; DCI: ESS1.C, ESS2.B, PS1.C; CCC: Patterns) [Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust decreasing with distance away from a central ancient core of the continental plate (a result of past plate interactions).]

HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. (SEP: 2; DCI: ESS2.A, ESS2.B; CCC: Stability/Change) [Clarification Statement: Design a visual representation to demonstrate the varying spatial and temporal scales of Earth's internal and surface processes, showcasing their roles in shaping both continental and ocean-floor features.]

HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. (SEP: 4; DCI: ESS2.A, ESS2.D; CCC: Stability/Change) [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

HS-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. (SEP: 6; DCI: ESS1.C, PS1.C; CCC: Stability/Change) [Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

The outermost layer of Earth, the crust, covers the planet. The crust floats on the molten mantle and is divided into two types: the continental crust and the oceanic crust. The sections of the crust, the tectonic plates, move because of the convection currents below the mantle. The mid-Atlantic ridge, a divergent boundary, provides us with the evidence that the seafloor is older the farther it is from the ridge. In addition, as the rock cools from molten lava, its magnetic particles align with the magnetic pole of Earth at the time. Scientists can compare the directional magnetism of rock particles to the direction of the magnetic field in the rock's current location and estimate where the plate was when the rock formed.

A cross-section of Earth shows the inner solid core, outer liquid core, mantle, and crust. The density of each layer varies with the lowest density layer being Earth's crust and the greatest density layer being the inner core. Looking at evidence of how seismic waves travel through Earth; the core's composition is known. The inner solid core heats the outer liquid core via convection which in turn heats the mantle and causes convection currents within the mantle. The metallic nature of iron and nickel in the inner and outer cores causes a magnetic field to be produced as a result of the free-flowing sea of electrons. The alignment of the magnetic fields in crustal rocks along oceanic ridges provides evidence that Earth's magnetic pole flips. Heated by Earth's core, the mantle is not one consistent temperature. The less dense, hot areas rise, and the more dense, cooler areas sink. Near the surface, Earth's crust splits and spreads. As the rock spreads and releases heat, the edges of cooler rock subduct below, causing the continents to move. As Earth's crust falls inward, its surface is heated by the mantle, causing carbon dioxide gas to be formed and released into the atmosphere through a volcanic eruption.

Various ancient Earth materials can be used as evidence to make a timeline of Earth's formation and to describe Earth's early history. These ancient Earth materials are metamorphic rocks, minerals, moon rocks, meteorite fragments, and lead ores. Using radiometric dating on rocks, meteorites, and lead ores, the age of Earth is calculated.

Phenomena

Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- In the northern latitudes, it is possible to be touching two continents simultaneously.
- We can feel earthquakes miles away from the epicenter.
- Volcanoes are a powerful result of plate tectonics.
- Telescopes allow us to look at impact cratering on the moon.
- The largest impact crater in the United States is the Chesapeake Bay.
- Museums around the world showcase ancient moon rocks.
- Hubble telescope took pictures of impact cratering on planetary bodies in our solar system.
- Using radiometric dating techniques, the age of an ancient material can be found.

Storyline

This section aims to decode not only the DCI connections but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence ● Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. **Developing and Using Models** ● Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **Constructing Explanations and Designing Solutions** ● Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**ESS1.C: The History of Planet Earth** ● Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. ● Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** ● Plate tectonics is the unifying theory that explains the past and current movements of the rocks at the Earth's surface and provides a framework for understanding its geologic history. (Secondary) ● The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. **PS1.C: Nuclear Processes** ● Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. (secondary) **ESS2.A: Earth Materials and Systems** ● Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle, and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior.	**Patterns** ● Empirical evidence is needed to identify patterns. **Stability/Change** ● Feedback (negative or positive) can stabilize or destabilize a system. **Technology** ● New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of technology decisions.

Evidence of the unifying theory of plate tectonics can be used to explain and evaluate the ages of crustal rocks. Patterns can be identified in the ages of the oceanic crust that increase with distance from mid-ocean ridges because of seafloor spreading. A pattern in the ages of the North American continental crust can be identified. This pattern decreases with distance away from a central ancient core of the continental plate because of past plate interactions. Continental rocks are older than the rocks of the ocean floor.

A two-dimensional model of Earth's interior may be developed that reflects the solid inner core, liquid outer core, mantle, and crust with these layers represented from most dense to least dense respectively. The gravitational movement of denser materials toward the center is the driving force behind the cross-sectional layers of Earth. The two-dimensional model of Earth also reflects the motion of the mantle and its plates due to thermal convection. In addition, the radioactive decay of unstable isotopes generates energy within the crust and mantle of Earth providing a primary source of heat that drives the mantle convection. The outward flow of energy from Earth's inner core through the outer core and mantle is the driving force for thermal convection. A three-dimensional model of Earth may be developed based on evidence from seismic waves and the movement of tectonic plates. As the movement of tectonic plates occurs, various changes in Earth's three-dimensional structure occur. The improvement of technology to analyze the evidence of movements also can be used to improve the model.

Scientific reasoning may be applied to link the evidence of meteorites, ancient Earth materials, and other planetary surfaces to construct an explanation of Earth's early history and age. Although many of Earth's ancient materials have been destroyed or eroded, other pieces of evidence such as lunar rocks, asteroids, and meteorites, can be used to construct an account of Earth's early history. Knowledge of radioactive decay and radiometric dating may be used to predict the age of an artifact. The number of half-lives that an artifact has gone through may be calculated and the age of the artifact can then be predicted.

Formative Assessment

Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given bundle, standard, or lesson-level performance expectation.

SEP Engaging in Argument from Evidence

- Using plate tectonics as evidence, explain the age of crustal rocks.
- Using a mid-ocean ridge, explain the relationship between the age of crustal rocks and distance from the ridge.
- Using the central ancient core of the continental plate, explain the relationship between the age of the North American continental crust and distance from a central ancient core.

SEP Developing and Using Models

- Develop a one-dimensional model of Earth that depicts its radial layers determined by density from the evidence of seismic waves.
- Develop a three-dimensional model of Earth to demonstrate the movement of plate tectonics due to mantle convection.
- Identify a constraint using a model on convection in the outer core.
- Identify the composition of Earth's layers from high-pressure laboratory experiments.

SEP Constructing Explanations and Designing Solutions

- Construct an account of Earth's formation and early history using radiometric dating.
- Construct an account of Earth's formation and early history using impact cratering in our solar system.
- Construct an account of Earth's formation and early history using plate tectonics.
- Construct an account of Earth's formation and early history using recorded seismic waves.
- Construct an account of Earth's formation and early history using rates of change of Earth's magnetic field.
- Construct an account of Earth's formation and early history using ancient materials such as meteorites and moon rocks through radioactive dating.

CCC Patterns

- What pattern exists between the age of crustal rocks and the distance from mid-ocean ridges?
- What pattern exists in the Earth's magnetic field over time?

CCC Stability/Change

- How can the movement of divergent, convergent, and transform boundaries cause a change in the Earth's three-dimensional structure?
- How do convection currents within the Earth's mantle affect the upper lithosphere and crust?
- What would happen if the convection currents within the Earth were to cease?
- How does the change that occurs in parent and daughter isotopes over time result in knowing the age of an artifact?
- How has impact cratering on Earth caused change in Earth's surface?

CCC Technology

- How has the technology improved our ability to detect seismic waves?
- How have high-pressure experiments allowed us to identify the composition of Earth's layers?

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Explain how** *crustal materials of different ages are arranged on Earth's surface in a pattern* that can be attributed to plate tectonic activity and the formation of new rocks from magma rising where plates are moving apart.
- **Use the measurement of the ratio of parent to daughter atoms produced during radioactive decay as evidence** to determine the ages of rocks.

- **Use the locations of continental rocks, to argue** the ages of the crustal rocks.
- **Use the locations of rocks found on opposite sides of mid-ocean ridges as evidence, to argue** the ages of the rocks.
- **Compare** the type and location of plate boundaries to the type, age, and location of crustal rocks.
- **Describe how** *the pattern of the continental crust being older than the oceanic crust* **supports the explanation** about the ages of crustal rocks.
- **Describe how** *the pattern that the ages of oceanic crust are greatest nearest the continents and decrease in age with proximity to the mid-ocean ridges* **supports the explanation** about the ages of crustal rocks.
- **Use mid-ocean ridges as evidence, to describe the relationship between** *the motion of continental plates and the patterns in the relative ages of crustal rocks.*
- **Use continental centers and plate boundaries as evidence, to describe the relationship between** *the motion of continental plates and the patterns in the* relative ages of crustal rocks.
- **Use subduction zones as evidence, to describe the relationship between** *the motion of continental plates and the patterns in the* relative ages of crustal rocks.
- **Develop a model to identify and describe** Earth's interior in cross-section and radial layers (crust, mantle, liquid outer core, solid inner core) determined by density.
- **Develop a model to identify and describe** *the patterns of* the plate activity in the outer part of the geosphere.
- **Develop a model to identify and describe** radioactive decay and residual thermal energy from the formation of Earth as a source of *energy*.
- **Develop a model to identify and describe** *the loss of heat at the surface of the earth as an output of energy*.
- **Develop a model to identify and describe** *the process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center)*.
- **Describe the relationship between** *energy released* by radioactive decay in the Earth's crust and mantle and residual thermal energy from the formation of Earth which drives the flow of matter in the mantle.
- **Describe the relationship between** *thermal energy released* at the surface of the Earth as new crust is formed and cooled.
- **Describe the relationship between** *the flow of matter* by convection in the solid mantle and the sinking of cold, dense crust back into the mantle which exerts forces on crustal plates that then move, producing tectonic activity.
- **Describe the relationship between** *the flow of matter* by convection in the liquid outer core that generates Earth's magnetic field.
- **Describe the relationship between** *matter cycled between the crust and the mantle at plate boundaries;* where plates are pushed together, cold crustal material sinks back into the mantle, and where plates are pulled apart, mantle material can be integrated into the crust, forming new rock.
- **Use a model to describe** *the flow of matter* in the mantle that causes crustal plates to move as evidence of the cycling of matter by thermal convection in Earth's interior.
- **Use a model to describe** *the flow of matter i*n the liquid outer core that generates the Earth's magnetic field, including evidence of polar reversals (e.g., seafloor exploration of changes in the direction of Earth's magnetic field).
- **Use a model to describe** the radial layers determined by density in the interior of Earth.

- **Use a model to describe** *the addition of a significant amount of thermal energy released* by radioactive decay in Earth's crust and mantle.
- **Construct** an account of Earth's formation and early history that includes that Earth formed along with the rest of the solar system 4.6 billion years ago.
- **Construct** an account of Earth's formation and early history that includes that the early Earth was bombarded by impacts just as other objects in the solar system were bombarded.
- **Construct** an account of Earth's formation and early history that includes that erosion and plate tectonics on Earth have destroyed much of the evidence of this bombardment, explaining the relative scarcity of impact craters on Earth *by finding evidence in patterns*.
- **Describe** the age and composition of Earth's oldest rocks, lunar rocks, and meteorites as determined by radiometric dating.
- **Describe** the composition of solar system objects.
- **Describe observations** of the size and distribution of impact craters on the surface of Earth and the surfaces of solar system objects (e.g., the moon, Mercury, and Mars). **Describe** the activity of plate tectonic processes, such as volcanism, and surface processes, such as erosion, operating on Earth.
- **Construct an explanation** *by finding evidence in patterns* of Earth's formation and early history using as evidence radiometric ages of lunar rocks, meteorites, and the oldest Earth rocks point to an origin of the solar system 4.6 billion years ago, with the creation of a solid Earth crust about 4.4 billion years ago.
- **Construct an explanation** of Earth's formation and early history using planetary surfaces and *their patterns* of impact cratering to infer that Earth had many impact craters early in its history.
- **Construct an explanation** *by finding evidence in patterns* of Earth's formation and early history using as evidence the relative lack of impact craters and the age of most rocks on Earth compared to other bodies in the solar system which is attributed to processes such as volcanism, plate tectonics, and erosion that have reshaped Earth's surface, and that this is why most of Earth's rocks are much younger than Earth itself.