ESS2.A: Earth Materials and Systems

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
2	• Wind and water can change the shape of the land. (2-ESS2-1)
4	• Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1)
5	• Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The ocean supports a variety of ecosystems and organisms, shapes landforms, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. (5-ESS2-1)
6	• All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (6-ESS2-1) • The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (6-ESS2-2)
Earth and Space Science	• Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedback works within and among Earth's systems is still lacking, thus limiting scientists ability to predict some changes and their impacts. The top part of the mantle, along with the crust, forms structures known as tectonic plates. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to long- term tectonic cycles. (E-ESS2-1) • Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Transfers of energy and the movements of matter can cause chemical and physical changes among Earth's materials and living organisms. (E-ESS2-2) • 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. All of Earth's processes are the result of energy flowing and matter cycling within and among Earth systems. 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. (E-ESS2-3)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
2	• Maps show where things are located. One can map the shapes and kinds of land and water in any area. (2-ESS2-2)
4	• The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. Maps can help locate the different land and water features areas of Earth. (4-ESS2-2)
6	• Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history. Plate movements are responsible for most continental and ocean floor features and for the distribution of most rocks and minerals within Earth's crust. Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (6-ESS2-3)
Earth and Space Science	• The theory of plate tectonics is supported by evidence of ocean floor spreading over time given by tracking magnetic patterns in undersea rocks and coordinating them with changes to Earth's magnetic axis data. Earth's history is still being written. Continents are continually being shaped and reshaped by competing constructive and destructive geological processes. North America, for example, has gradually grown in size over the past 4 billion years through a complex set of interactions with other continents, including the addition of many new crustal segments. (E-ESS1-5) • 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. The plates move across Earth's surface, carrying the continents, creating, and destroying ocean basins, producing earthquakes and volcanoes, and forming mountain ranges and plateaus. Most continental and ocean floor features are the result of geological activity and earthquakes along plate boundaries. The exact patterns depend on whether the plates are being pushed together to create mountains or deep ocean trenches, being pulled apart to form new ocean floor at mid- ocean ridges or sliding past each other along surface faults. (E-ESS2-1) • 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. The top part of the mantle, along with the crust, make up the moving tectonic plates of the lithosphere. Tectonic plates ride above giant convection cells that bring matter from the hot inner mantle up to the cool surface. The plates move across Earth's surface, carrying the continents, creating, and destroying ocean basins, producing earthquakes and volcanoes, and forming mountain ranges and plateaus. (E-ESS2-3)

ESS2.C: The Role of Water in Earth's Surface Processes

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
2	• Water is found in the ocean, rivers, lakes, and ponds. Water exists as solid ice and in liquid form. (2-ESS2-3)
5	• Nearly all of Earth's available water is in the ocean. Most freshwater is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. (5-ESS2-2)
6	• Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. (6-ESS2-2) • Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. Global movements of water and its changes in form are propelled by sunlight and gravity. (6-ESS2-4) • The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (6-ESS2-5) • Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (6-ESS2-6)
Earth and Space Science	• The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy as it changes state; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of the material when mixed with fluid rocks within the mantle. Each of these properties plays a role in how water affects other Earth systems (e.g., ice expansion contributes to rock erosion, or ocean thermal capacity contributes to moderating temperature variations). (E-ESS2-5)

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ESS2.D: Weather and Climate

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
K	• Weather is the combination of sunlight, wind, snow, or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.(K-ESS2-1)
3	• Weather, which varies from day to day and seasonally throughout the year, is the conditions of the atmosphere at a given place and time. Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1) • Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. (3-ESS2-2)
6	• Because these patterns are so complex, weather can only be predicted probabilistically. (6-ESS2-5) • The tilt of the earth's rotational axis causes a pattern of uneven heating and cooling that changes seasonally and establishes global patterns of climate and weather. Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (6-ESS2-6)

K-12 Conceptual Vertical Articulation of ESS2 – Earth's Systems

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
Earth and Space Science	• The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (E-ESS2-2) • The foundation for Earth's global climate systems is the electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. Climate changes, which are defined as significant and persistent changes in an area's average or extreme weather conditions, can occur if any of Earth's systems change. Scientists can infer these changes from geological evidence. Some climate changes in Earth's history were rapid shifts (caused by natural events, such as volcanic eruptions and meteoric impacts, which suddenly put a large amount of particulate matter into the atmosphere or by abrupt changes in ocean currents, or variations in solar output). Other climate changes were gradual and longer term - due, for example, to solar output variations, or atmospheric changes due to the rise of plants and other life forms that modified the atmosphere via photosynthesis. The timescale of these changes varies from a few to millions of years. Cumulative increases in the atmospheric concentrations of carbon dioxide and other greenhouse gases, whether arising from natural sources or human industrial activity, increase the capacity of Earth to retain energy. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (E-ESS2-4) • Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (E-ESS2-6)

ESS2.E: Biogeology

Grade/Course	Disciplinary Core Idea Statement with 2021 Performance Expectation Linked
K	• Plants and animals depend on and can change their environment. (K-ESS2-2)
4	• Living things affect the physical characteristics of their regions. (4-ESS2-1)
8	• Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. (secondary) (8-LS4-1)
Earth and Space Science	• As Earth changes, life on Earth adapts and evolves to those changes, so just as life influences other Earth systems, other Earth systems influence life. Life and the planet's nonliving systems can be said to co-evolve. The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (E-ESS2-7)

Adapted from *The Framework for K-12 Science Education* and the *Next Generation Science Standards.*

References:

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

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