Elaboration and Unpacking of the DCIs

Grade 11, Measurement Target 1	Students are able to evaluate evidence and apply scientific reasoning related to Earth's geologic processes and the dynamic feedback between the biosphere and other Earth systems to support an argument about the continual co-evolution of Earth's systems and life on Earth.				
	ESS1.C: The History of Planet Earth	**ESS2.B: Plate Tectonics and Large-Scale System Interactions**	**ESS2.D: Weather and Climate**	**ESS2.E: Biogeology**	**PS1.C: Nuclear Processes**
DCIs	• 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. **(HS-ESS1-5)** • 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. **(HS-ESS1-6)**	• 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 geologic history. **(HS-ESS1-5)**	• Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. (**HS-ESS2-7**)	• 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. **(HS-ESS2-7)**	• Spontaneous radioactive decays follow a characteristic exponential decay law. **(HS-ESS1-5), (HS-ESS1-6)** • Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. **(HS-ESS1-5), (HS-ESS1-6)**

Elaboration of the DCIs	**HS.ESS1C.b** • According to the theory of plate tectonics, evidence of the past and current movements of continental and oceanic crust can be used to explain the ages of crustal rocks. • Sea floor spreading adds new crust to the ocean floor. • Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. • Continental rocks can be older than 4 billion years. • Rocks of the ocean floor are less than 200 million years old. **HS.ESS1C.c** • Active geologic processes have destroyed or altered most of the very early rock record on Earth. • Some objects in the solar system have changed very little over billions of years. • Studying these objects can help deduce the solar system's age and history.	**HS.ESS2B.a** • Plate tectonics is the theory that explains the past and current movement of Earth's plates. • Plate tectonics also provides a framework for understanding Earth's geologic history.	**HS.ESS2D.b** • Plants contribute to the make-up of Earth's atmosphere by absorbing carbon dioxide and releasing oxygen. • Carbon continuously cycles from one sphere to another. • In the past, the relative amount of carbon that cycled through the hydrosphere, atmosphere, lithosphere or geosphere, and biosphere was partially due to the activity of plants and other organisms.	**HS.ESS2E.a** • Feedback (negative or positive) can stabilize or destabilize a system. • The feedbacks between life on Earth and the Earth's systems cause life on Earth to evolve and the surface of the Earth to undergo changes at the same time. • Examples of feedback include how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, thus reducing the amount of sunlight reflected from Earth's surface, which in turn increases surface temperatures and further reduces the amount of ice.	**HS.PS1C.b** • Radioactive elements found in rocks decay at a constant rate. • The half-life of a radioactive element is the time it takes for half of the radioactive atoms to decay. • Scientists compare the amount of a radioactive element in a rock with the amount of the stable element into which the radioactive element decays. • Scientists use radioactive dating to determine the absolute ages of rocks and other materials.

Elaboration of the DCIs Cont'd	• Scientists study objects in the solar system (i.e., lunar rocks, asteroids, meteorites) to search for clues about Earth's history.				
Proficiency Boundaries	• Students do not need to demonstrate comprehensive understanding of the mechanisms of how the biosphere interacts with all of Earth's other systems. • Assessment is limited to alpha, beta, and gamma radioactive decays.				
Prior Knowledge	Rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history.	Earth's plates have moved great distances, collided, and spread apart.	There are patterns of interactions in ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems.	The evolution and proliferation of living things over geological time have changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.	Some unstable but long-lived isotopes are present in rocks and minerals. Knowledge of their nuclear lifetimes allows radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present.
Student Misconceptions	• Students of all ages may hold the view that the world was always as it is now, or that any changes that have occurred must have been sudden and comprehensive. [1] The students in these studies did not, however, have any formal instruction on the topics investigated. Moreover, middle school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes and earthquakes. [2]				
Articulation of DCIs Across Grade Levels	**MS.ESS1.C** (HS-ESS1-5), (HS-ESS1-6), (HS-ESS2-1)	**MS.ESS2.B** (HS-ESS1-5), (HS-ESS1-6), (HS-ESS2-1)	**MS.ESS2.D** (HS-ESS2-1)	**NA**	**NA**

[1] Freyberg, P. (1985). Implications across the curriculum. In R. Osborne & P. Freyberg (Eds.) *Learning in Science* (pp. 125-135). Auckland, NZ: Heinemann.

[2] Duschl, R., Smith, M., Kesidou, S., Gitomer, D., Schauble, L. (1992). *Assessing student explanations for criteria to format conceptual change learning environments*. Paper presented at the annual meeting of the American Educational Research Association. San Francisco, CA.