UNIT 4 GUIDE

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Unit 4—Our Solar System & Earth

Unit 4 Driving Question: How and why do theories become generally accepted?

Learning Outcomes

1. Explain why planets are more complex than stars.
2. Use evidence to explain how the Earth and its atmosphere developed and changed over time.
3. Explain the basic mechanisms and key pieces of evidence for plate tectonics, and how plate tectonics impacts life on Earth.
4. Define geology, the types of questions geologists ask, and the tools they use to answer those questions.
5. Explain why geology is important to understanding the history of the Earth.
6. Understand how geologists can work with scientists and historians from other disciplines to form a deeper understanding of the history of the Earth.

Key Concepts

In this unit, students learn how elements combined to form new kinds of matter, creating the conditions required for the emergence of more complex things including the Sun and planets like our Earth. The formation of the Earth and our Solar System is the fourth threshold of increasing complexity in this course. Students learn what the young Earth was like and how it has changed over 4.5 billion years to become the planet it is today. They also learn about plate tectonics, and the important role that geologists play in understanding the history of the Earth.

The Formation of the Earth and Solar System

Unlike the very first stars, all later stars, including our Sun, developed from clouds of matter containing not just hydrogen and helium, but also small amounts of all the other elements. Like all stars, our Sun lit up when the center of a collapsing cloud of matter reached a temperature of about 10 million degrees Celsius. Although most of the matter in the collapsing cloud became part of the star, there was enough left over for the formation of planets and other objects. Once the Sun had formed, the remaining matter spun around it, flattening out like pizza dough. Energized by the heat of the Sun and hurled around by its gravitational pull, tiny particles of dust and ice joined together to form larger lumps, a bit like comets or asteroids. Lumps combined within each orbit to form huge planetesimals; eventually, all the matter in most orbits was absorbed within a single large object, a planet.

The Early Earth

Our Earth formed through the violent process of accretion. The young Earth was extremely hot, with its heat coming from three main sources: the large numbers of collisions with other bodies orbiting the Sun; the presence of large amounts of radioactive material; and increasing pressure as the Earth itself grew in size.

Plate Tectonics

The surface of the Earth is constantly changing. Like a cracked eggshell, the Earth's crust is divided into a number of distinct plates that are carried across its molten mantle. Oceanic plates can dive under continental plates, plates can collide to form mountains, and plates can also grind past one other. Most earthquakes and volcanoes occur at the dividing lines between plates. We can roughly trace the historical movement of crustal plates and see that plates periodically gathered together into huge supercontinents, later breaking apart into the separate continents that we know today. These changes had a powerful impact on global climates and the distribution of living species.

The Discipline of Geology

Geologists are scientists who study the physical attributes of Earth. Often out in the field looking at rocks, fossils, and natural formations, geologists are interested in the history of the planet as well as in the processes in operation within the Earth itself. Understanding how geologists work, the type of questions they ask, and evidence they use to help answer those questions adds another dimension to understanding the interdisciplinary nature of Big History.

Misconceptions and Teaching Challenges

The Geologic Time Scale

As with the astronomical time scale and temperature scale in previous units, the quantities of time involved in Earth history can be hard to comprehend. Visuals of the geologic time scale may not be much help in this regard, as those that break time into eons, era, periods, and epochs are full of detail. If you do present a geologic time scale, choose one that is as simple as possible. Additionally, you might help your students work through this potential problem by referencing previous examples of scale and working with them to look at the concept through a variety of different comparisons.

The Idea of Continents Moving May Confuse and Surprise Students

On the one hand, the continents are huge landmasses, and their movement occurs slowly over vast expanses of time. This movement is so slight on a year-to-year basis that the very idea of plate tectonics may be difficult for students to grasp. Explain that geological and astronomical time scales are a way to understand the Earth's history as something quite brief in contrast to the history of the Universe itself. On the other hand, some students may have observed firsthand changes in the surface of the Earth. Ask students if they can identify, from their own experiences or in their own lives, any perceptible changes in terrain, coastline, or other land feature. This may help counter the idea of a stationary, unchanging Earth.

Vocabulary

accretion — The process by which an object collects matter. For example, planet formation takes place as material orbiting a star gathers together through gravitational or electrostatic attraction, forming larger and larger bodies over time.

Archaean eon — The second eon in Earth's history, a time from 3.8 to 2.5 million years ago, during which the first living organisms appeared.

asteroid — Small rocky, icy, and metallic celestial bodies left over from the formation of the Solar System which can range from a few meters to several hundred kilometers in width.

atmosphere — The mixture of gases surrounding a planet. The composition of the Earth's atmosphere has played a critical role in the development of life on Earth.

circadian rhythm — The "master clock" that controls the body's coordinated timing system, telling it when to work, eat, and sleep. Based on the Sun's 24-hour cycle, circadian rhythms speed up the body's metabolism before sunrise to provide energy, and prepare it for sleep at night by lowering blood pressure and slowing the activity of the brain.

continental drift — The idea that the Earth's continents move in relation to each other, so that continents currently separated by oceans were joined together in the past. The theory of plate tectonics explains why continental drift occurs.

convergent plate boundaries — Found where two plates move toward each other and collide. Depending on what types of plates are colliding, one may dive beneath the other to be recycled back into the mantle while the other rises up, or both may rise to form a new system of mountains.

core (of the Earth) — The dense center of the Earth, made mostly of iron, and some nickel. The movement of molten iron and nickel in the outer core generates the Earth's magnetic field.

crust (of the Earth) — The solid outer layer of the Earth, consisting of moving plates both of the continental (lighter, made of granite) and oceanic (heavier, made of basalts) varieties.

differentiation (chemical) — A process early in the Earth's history that produced different layers within the Earth's interior, with denser metals sinking to form the Earth's core, while progressively lighter materials formed the upper layers.

divergent plate boundaries — Found where two plates move away from each other. When both of the separating plates are oceanic plates, material from the mantle rises up and creates new seafloor.

Earth — The third planet from the Sun in our Solar System, home to many complex life forms and modern human society.

exoplanet — A planet outside of our Solar System.

gas giant — A type of planet that is composed primarily of gases rather than rock or other solid material. Examples from our own Solar System include Jupiter, Saturn, Uranus, and Neptune.

geology — The scientific study of the Earth, including its composition and history.

greenhouse effect — A process by which certain trace gases in the Earth's atmosphere trap heat near the Earth's surface and so keep the Earth's climate warmer than it would be otherwise. The Earth emits some of the radiation it receives from the Sun back into space, but greenhouse gases trap some of this radiation before it can escape, thus warming up the climate on Earth, as in a greenhouse.

Hadean eon — The earliest period in Earth's history (4.5 to 4.0 billion years ago), the "hellish era," when the planet's formation was still ongoing and was unsuited to life.

light spectrum — Electromagnetic radiation arranged in the order of its wavelength; a rainbow is a natural spectrum of visible light from the Sun. Human eyes can only perceive light within the range of the visible light spectrum. We cannot perceive infrared (slightly less energetic) or ultra- violet (slightly more energetic) light.

mantle (of the Earth) — The layer of the Earth between the core and the crust; it is mostly solid, but over long periods of time can flow like a thick syrup. Convection currents in the mantle drive plate tectonics.

orbit — The path of a body's motion through space, often dictated by the gravitational pull of one or more larger bodies.

ozone — A molecule consisting of three oxygen atoms, in contrast to the more common form consisting of just two oxygen atoms. A thin layer of ozone high in the atmosphere shields the Earth's surface from harmful forms of ultraviolet radiation.

Pangaea — The vast supercontinent formed more than 200 million years ago as plate movements joined the major continental plates together. It is probable that such supercontinents have formed periodically throughout Earth's history. The existence of a single huge landmass probably reduced biodiversity.

planet —A spherical ball of rock, gas, or both, that's in orbit around a star. Unlike a dwarf planet, a planet clears the area around its orbit of smaller objects through accretion.

planetesimal — An object, at least a kilometer or so across but much smaller than a planet, that forms through accretion during the early stages of planet formation. Planetesimals may combine with one another to form protoplanets and eventually planets.

plate tectonics — The idea that the Earth's crust (together with the upper mantle) is broken up into separate plates that are in constant motion, explaining continental drift as well as the distribution of earthquakes, volcanoes, mountain ranges, and other rock structures, and many other features of the planet. Plate tectonics has been a central unifying theory in modern Earth sciences (geology) since the 1960s.

protoplanetary disk — A rotating disk of gas and dust grains surrounding a newly formed star or protostar. Over time, accretion within the disk tends to produce planets.

rocky (or terrestrial) planets — A type of planet that is composed primarily of rock and other solid material. Examples from our own Solar System include Mercury, Venus, Earth, and Mars.

seafloor spreading — A process in which new ocean floor is created as molten material from the Earth's mantle rises and spreads out at the boundary between two plates.

Solar System — The Sun and the objects that orbit it; the area in space in which the Sun's gravitational pull is the dominant force.

spectrum (light) — Electromagnetic radiation (light) arranged in the order of its wavelength; a rainbow is a natural spectrum of visible light from the Sun.

subduction zones — An area of convergence (collision) between two tectonic plates where the heavier plate sinks downward beneath the lighter one, which rises up. As the lighter plate rises, it forms volcanic mountains (if the rising plate has continental crust) or volcanic islands (if the plates are converging on the seafloor).

Sun — The star at the center of our Solar System.

tectonic plates — The huge rigid slabs of rock that the Earth's crust (together with the upper mantle) is broken up into, which are in constant motion. Some plates carry continents, producing continental drift that dramatically changes the relative locations of continents over millions of years.

transform plate boundaries — Found where two plates grind past each other without either producing or destroying crust.

Lesson and Content Overview

Lesson name	Lesson description	Content	Activity
4.0—Earth & the Formation of Our Solar System	Earth formed from the leftovers of the Sun accumulating over time. Despite its violent and unstable beginning, Earth slowly became the world we know today.	• Watch: Threshold 4 – Earth & the Solar System • Watch: How Did Earth and the Solar System Form? • Watch: The Sun – H2 • Read: "How Our Solar System Formed"	• Opening: Planet Card Sort • Activity: Active Accretion • Vocab Activity: Memorization • Closing: This Threshold TodayThis Threshold Today
4.1—What Was Young Earth Like?	As giant hunks of rock, metal, and ice slammed into the Earth's surface, it became a planet with three layers. The interplay between the layers resulted in the Earth as we know it.	• Watch: What Was the Young Earth Like? • Watch: The Early Atmosphere	• Opening: It's Alive! The Universe Verse Book 2 • Activity: Evaluating Writing • Closing: DQ Notebook
4.2—Why Is Plate Tectonics Important?	Towering mountains and trembling earthquakes — the surface of our Earth is constantly in motion. Plate tectonics is responsible for the shape and position of our land.	• Watch: Our Shifting Globe • Read: "Why We're All Lava Surfers"	• Vocab Activity: Comprehension/Application • Activity: Claim Testing—Geology and the Earth's Formation • Closing: Biography of a Continent
4.3—Ways of Knowing: Our Solar System and Earth	The history of our planet is written in rock record, along with clues about the future. Rock detectives — geologists — study these clues and often observe Earth's changes first hand.	• Watch: Introduction to Geology • Read: "Alfred Wegener & Harry Hess" • Read: "Eratosthenes" • Watch: Introduction to the Geologic Time Chart • Read: "Principles of Geology"	• Opening: DQ Notebook • Activity: What Do You Know? What Do You Ask? • Closing: Investigation 4
Investigation: When and why do people accept a theory?	This investigation uses Alfred Wegener's theory of continental drift as a case study for how a new scientific idea comes to be accepted by the scientific community.	• Wegener's Hypothesis and Diagrams • Evidence of Continental Drift • Response to Wegener's Hypothesis • Vine-Matthews-Morely Hypothesis • Acceptance of Continental Drift	• Worksheets • Timeline of a theory's acceptance

Lesson name	Lesson description	Content	Activity
Additional content	Additional content items, including image galleries, can be used to augment lessons or customize your own unit.	• Earth & the Solar System (gallery) • Geology (gallery) • The Codex Leceister (reading) • Learning tips • Random facts • Related galleries, images, websites, and videos • Web links	
Assessments	Unit 4 has no required assessments.	• Unit Quiz (optional)	• Glossary Challenge
Actions	The Unit Log is required for every unit.	• Unit Log	