American Museum of Natural History

Educator's Guide

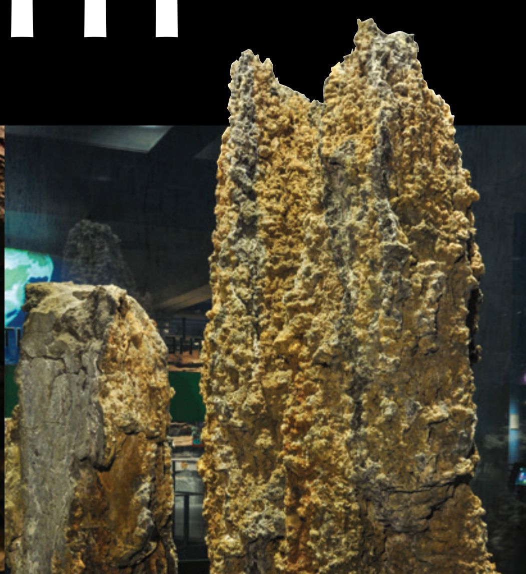
Gottesman Hall of PLANET EARTH

INSIDE

- Map of the Hall
- Essential Questions
- Teaching in the Hall
- Come Prepared Checklist
- Correlation to Standards
- Glossary

ONLINE

- Science & Literacy Activities
- Additional Resources



amnh.org/planet-earth-educators

ESSENTIAL QUESTIONS

Essential Questions correspond to map locations; red terms are defined in the Glossary

How has Earth evolved?

Our solar system formed 4.7 billion years ago. Along with all the other planets, Earth was created from clouds of dust orbiting our infant Sun. Molten at first, the planet differentiated into a molten iron **core** and a silicate outer layer—within a few tens of millions of years. Shortly thereafter the Moon formed, possibly from material ejected when a Mars-sized object smashed into early Earth. As Earth's surface cooled enough for a new **crust** to solidify, **water vapor** and other gases were driven from the interior to form an ocean and **atmosphere**. By at least 3.5 billion years ago, photosynthetic bacteria had evolved and began introducing oxygen into the ocean and atmosphere. After approximately 1.8 billion years, the atmosphere and ocean were saturated with oxygen.

Why are there ocean basins, mountains, and continents?

Earth's solid **mantle** ceaselessly churns. **Convection** transports heat from the deep interior to the surface as hotter, less dense solid rock rises and cooler, denser solid rock sinks. This slow churning drives plate tectonics (the movement of rocky **plates** that make up the solid shell of the planet), which forms ocean basins, shifts **continents**, pushes up mountains, and causes **volcanoes** to erupt. Most **earthquakes** occur along the margins of these plates. Wind and water also shape Earth's surface. Over millions of years they wear down mountains and redeposit them as sediments, carving the landscapes we live in.

How do scientists read the rocks?

All over the world, from ocean trenches to roadside **outcrops** and from riverbeds to mountaintops, geologists collect **rocks**. They observe their mineralogy and texture, and measure their composition to find out where and how the rocks formed. To determine their relative age, they observe sequences of layered rocks, and identity the fossils found in **sedimentary** rocks. Some rocks can be dated radiometrically, which gives their absolute age. All this information, combined with **geologists'** observations of processes operating today, makes it possible for them to reconstruct geologic history in order to deduce what happened long ago.

The Grand Canyon tells a story of erosion by water and wind, with steep walls of hard rock and slopes of softer, more easily eroded sedimentary rock.

What causes climate and climate change?

Earth's **climate** has been changing naturally over its entire history. The significant, ongoing changes that began in the middle of the 19th century, however, are due to human activity. The major natural driver of climate is the Sun: Because of Earth's spherical shape, more solar radiation (sunlight) falls on equatorial regions than on the poles. This difference in heat causes the movement of many components of Earth's climate system, including ocean and wind currents. Greenhouse gases in the atmosphere, including carbon dioxide (CO_2), serve as an insulating layer, trapping the Sun's heat. Human activity—particularly burning **fossil fuels** for transportation, industry, and home energy—is now causing atmospheric CO_2 to increase rapidly, raising global average temperatures. Because the components of the climate system are interconnected, this rise in CO_2 and temperature has many effects. For example: sea ice and **glaciers** are melting rapidly; dissolved CO_2 is making the ocean more acidic, affecting ocean life; sea levels are rising; and intense **weather** events, such as droughts and severe storms, are becoming more frequent. These and other changes are affecting all life on Earth, including us.

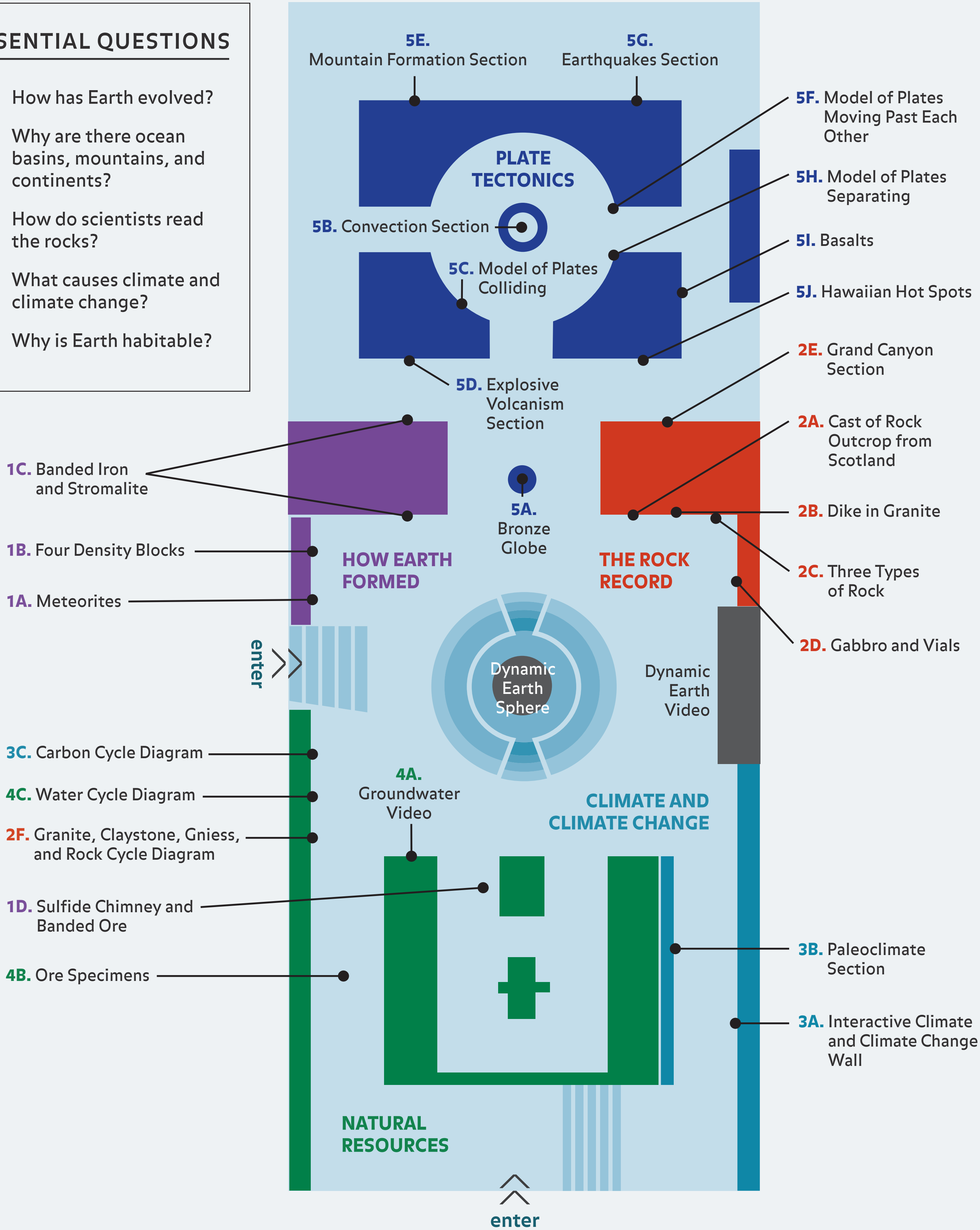
Why is Earth habitable?

Life on Earth is possible because its ideal distance from the Sun and balance of greenhouse gases allow for liquid water to exist on its surface. Early life, which may have begun in the ocean, evolved with the planet over huge stretches of time. Energy and the elements necessary for life circulate through the biosphere (the living portion of our planet), the atmosphere, the ocean, and the solid Earth. Key biogeochemical cycles include the **water cycle**, **carbon cycle**, and **rock cycle**. Because of this cycling, there is oxygen in the air to breathe, an **ozone layer** to help block ultraviolet radiation, and relatively moderate surface temperatures that are conducive to life.

MAP OF THE HALL Gottesman Hall of Planet Earth

ESSENTIAL QUESTIONS

- How has Earth evolved?
- Why are there ocean basins, mountains, and continents?
- How do scientists read the rocks?
- What causes climate and climate change?
- Why is Earth habitable?



TEACHING IN THE HALL

Numbers correspond to map locations

DYNAMIC EARTH

- **VIDEO:** Over billions of years, the Sun's energy, Earth's rotation, and heat from the planet's interior transformed a molten ball into a planet with oceans and continents hospitable to life. Over tens of millions of years, colliding tectonic plates push up mountain ranges. Over minutes and even seconds, tornadoes form and earthquakes reshape the land-scape. Have students watch this three-minute video for an overview of how Earth is constantly changing.
- **SPHERE:** Suspended from the ceiling, it recreates a view of Earth from space. Watch the layers of clouds, vegetation, ice, and ocean peel away to reveal the underlying rocky surface.

1 HOW EARTH FORMED

1A. Meteorites (#1-3): The most important clues to the composition of the early solar system come from meteorites. *Have students observe these three meteorites and discuss the evidence about Earth's formation that they contain.*

1B. Four Density Blocks (#4-7): When Earth was forming, heavier materials like iron sank to the center to form the core and lighter ones like silicates rose to the surface. *Have students take turns lifting the samples and exploring the diagrams. Ask them to connect this experiment to how Earth's layers are organized.*

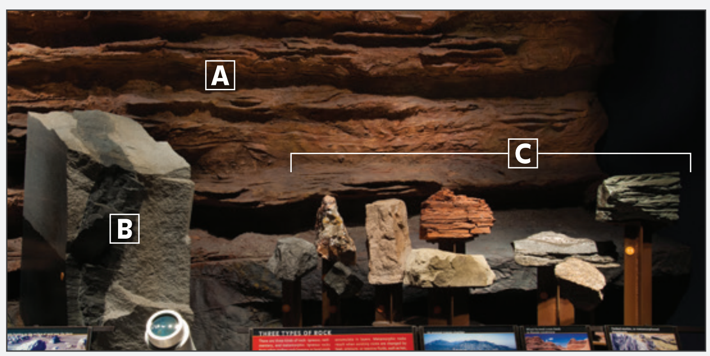
1C. Banded Iron (#23, 15) and Stromatolite (#14): Rocks can contain important clues about the atmosphere. In early Earth, metals like iron were released into the ocean from hot springs but remained in solution in the water. When photosynthetic organisms began producing oxygen, it reacted with the iron in the seawater and precipitated as iron oxide to form the banded iron formation. Eventually, oxygen began to accumulate in the atmosphere.

Have students observe both banded iron formations and the stromatolite (the fossilized remains of early oxygen-producing microbes). Ask them to use the "How Do We Know About the Early Atmosphere?" diagram to explore the way these two rocks formed and what this tells us about the early atmosphere.

1D. Sulfide Chimney (#28) and Banded Ore (#26): Chimneys form today when iron and other metals from underwater hot springs react with seawater and precipitate, in this case as sulfide minerals. *Walk past the Dynamic Earth Sphere to observe the chimneys at the other end of the hall. Have students examine the "Deep-Sea Vents and Ore Deposits" panel and discuss the way these two very different ore deposits formed.*

2 THE ROCK RECORD

2A. Cast of Rock Outcrop from Scotland: One way geologists learn about Earth's history is to interpret the structure of rock formations. In general, sedimentary rocks are deposited in horizontal layers, and younger beds lie atop older ones. *Have students examine this cast to identify and observe its two main rock types and to infer what they tell us about the formation of this part of Earth's crust. At the bottom are vertical layers of gray slate which had been deposited in water. These must have been uplifted, tilted, and eroded. The dark red, horizontal layers of sandstone were later deposited on the eroded surface. Tell students that this boundary represents a discontinuity, or gap in time, in processes that occurred over millions of years.*



The dike in granite (B) and three types of rocks (C) are silhouetted against a cast of the famous Scottish outcrop (A) known as Hutton's Unconformity.

2B. Dike in Granite (#3): Dikes are planar bodies of once-molten rock that intruded across the layering of older rocks. *Have students examine this sample and identify which rock formed first.*

2C. Three Types of Rocks (#4-12): Geologists use different characteristics to categorize rocks. *Have students read about sedimentary, igneous, and meta-morphic rocks on the panel and connect these characteristics to what they observe about the rocks on display.*

2D. Gabbro and Vials (#16): Geologists can date some rocks radiometrically by chemically analyzing them in the lab.

Have students examine the mineral grains in the vials and the related panel to learn about half-life and radioactive dating techniques.

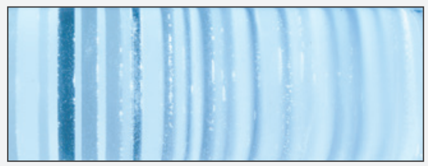
2E. Grand Canyon Section: Geologists construct maps to understand how the Grand Canyon and other Earth features formed.
Have students look at the large geologic map on the left. Ask them to examine the cross-section views on the right to explore what they tell us about rock formations and age. Then have students observe the rocks (#18-22) and correlate them to the cross-sections in the "Building the Canyon's Layers" diagram. Help them infer that the location of different types of rocks and structures can reveal the story of the Grand Canyon's formation.

2F. Granite (#15), Claystone (#16), Gneiss (#17), and Rock Cycle Diagram: Rocks form and transform, some many times over vast expanses of geologic time.
Help students connect the characteristics of the three types of rocks (see 2C) to processes at work in the rock cycle.

3 CLIMATE AND CLIMATE CHANGE

3A. Interactive Climate and Climate Change Wall: Many kinds of data show that human activity is the primary driver of the dramatic changes in our climate happening over the past century and a half.
On the upper section of the large screen, students can read messages about climate change while viewing the accompanying images. At interactive stations and related panels, students can observe the consequences of human-induced climate change, examine the evidence for it, and find out more about how the climate system works.

3B. Paleoclimate Section: Evidence of Earth's past climate can be found in a variety of natural records. These records reveal that carbon dioxide and warming are closely linked, and that atmospheric CO_2 is now higher than at any time in the past 800,000 years or more.
Have students explore the evidence of climate change in different natural records: an ice core (past 100,000 years), deep-sea sediment cores (55–56 million years ago; 15,000–12,000 years ago), a lake sediment core (420,000–378,000 years ago), a tree core (1792–2006), a tree ring section (1722–2005), and a coral core (1937–1994).



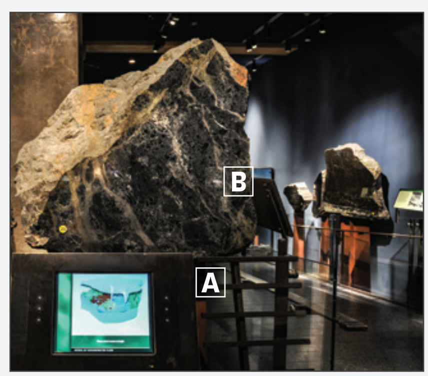
A model of a Greenland ice core shows alternating bands of ice: cloudy ones laid down in winter, clear in summer.

3C. Carbon Cycle Diagram: The concentration of CO_2 in the atmosphere strongly influences climate.
Have students explore how carbon moves through the Earth system and describe the different roles of short- and long-term reservoirs (e.g. the ocean versus the crust).

4 NATURAL RESOURCES

4A. Groundwater Video: One of the most important processes in the formation of Earth's resources—from oil and gas to metal ores and freshwater—is the flow of fluids through rock.
Have students watch the videos to learn why and how scientists model groundwater flow.

4B. Ore Specimens (#1-8, 18-25): An ore is a concentration of economically important minerals.
Have students explore this group of specimens, which illustrates how ores form. Ask them to select one specimen and explain what resource it provides.



Ore samples (B) loom above the groundwater video (A) and line the passageway to the right.

4C. Water Cycle Diagram: Water is part of Earth, its atmosphere, and all of its living organisms.
Have students identify groundwater and discuss its role in creating Earth's resources.

5 PLATE TECTONICS

What is Plate Tectonics?

5A. Bronze Globe: This is an accurate model of the solid Earth, with vertical measurements exaggerated by a factor of 22.5.
Have students compare the familiar topography of the continents with the less familiar topography of the ocean basins. Point out the "slice of crust" model hanging overhead. Invite students to use the diagram below to find the region on the globe that's represented in the model above. Tell them that the topographic features they see are shaped by the movement of tectonic plates.

5B. Convection Section: Earth's mantle is made up of solid rock that is so hot and under so much pressure that it bends and flows, allowing for convection. Convection in Earth's interior drives the processes that shape its surface.
Have students watch the animation that shows how convection works in the atmosphere, oceans, mantle, and core. Then have them watch the two videos about convection in the liquid, outer core and in the solid mantle, which will help them to understand the 3-D convection model.

This scientific model represents a snapshot in time. Solid mantle rock is represented in three ways: The hottest rock is shown as yellow; the coolest is shown as red; and the rock with temperatures in between the two is shown as empty space. Over time, as hot, less dense solid rock rises, cooler, denser solid rock sinks to take its place.

When Plates Collide

5C. Model of Plates Colliding: When an oceanic plate meets a continental plate, the oceanic plate descends, or subducts, beneath the continental plate and sinks into the mantle.
Have students explore the model and use their hands to simulate how one plate subducts beneath another.

5D. Explosive Volcanism Section: Most explosive eruptions occur in volcanoes above subduction zones, where one plate dives beneath another.
Have students watch the video and explore samples from Medicine Lake Volcano, California (#5-10).

5E. Mountain Formation Section: When two continental plates meet, one is thrust over the other to form mountain ranges like the Alps and the Himalayas.
Have students watch the video, examine the sand model, and discuss how the model helps scientists understand the way plates interact to form mountain ranges. Then have them observe the rock samples (#1-7) that illustrate the processes (uplifting, folding, crustal thickening, and faulting).

When Plates Move Past Each Other

5F. Model of Plates Moving Past Each Other: When oceanic or continental plates slide past each other in opposite directions, or move in the same direction but at different speeds, a fault forms.
Have students explore the model and use their hands to simulate how plates slide past each other.

5G. Earthquakes Section: Earthquakes occur along fault lines (cracks near plate boundaries where the crust on opposites sides moves).
Have students explore the earthquake video to see how monitoring helps scientists estimate the odds of an earthquake taking place within a certain period of time. Then have students find the faults on the two large casts and the samples (#1-2) and describe what they tell us.

When Plates Separate

5H. Model of Plates Separating: When plates move away from one another, new crust forms. Most spreading plate boundaries are found in ocean basins.
Have students explore the model and use their hands to simulate how plates separate.

5I. Basalts: Most volcanoes erupt basalt, a fluid lava from the mantle that forms flows. Most basalt erupts from cracks in the seafloor, but some basaltic lava flows occur on continental crust.
Have students compare the shapes of the underwater (#9-17) and flood basalts (#18), and discuss their formation.

When Plates Move Over Hot Spots

5J. Hawaiian Hot Spots: Basaltic lava also erupts at hot spots, where molten rock, or magma, forms in plumes of hot rock that rise from deep in Earth to penetrate a moving plate above.
Have students watch the video and explore the various specimens to find out what the pattern of the Hawaiian island chain reveals about how the Pacific plate is moving.

GLOSSARY

atmosphere: the mixture of gases (78% nitrogen, 21% oxygen, 0.9% argon, and 0.03% carbon dioxide, by volume) that surrounds Earth

carbon cycle: the continuous flow of carbon through living things (biosphere), the solid Earth (lithosphere), the oceans (hydrosphere), and the atmosphere

climate: global or regional average weather (including extremes) over several decades or longer

continent: one of Earth's large land masses

convection: the process by which hotter, less dense material rises and is replaced by colder, denser material

core: the mass of metallic iron and nickel at the center of Earth. The fluid outer core begins at 5100 kilometers (3170 miles) below the surface and the solid inner core at 2900 kilometers (1800 miles).

crust: Earth's outermost solid layer, consisting of a continental crust averaging 45 kilometers (28 miles) thick and an oceanic crust averaging 8 kilometers (5 miles) thick

earthquake: a shaking of the ground caused by the abrupt release of accumulated strain when a fault ruptures

erosion: the processes that wear down rocks and transport the loosened sediment

fossil fuels: coal, oil, and natural gas, which formed from the remains of organisms that lived millions of years ago

geologist: a scientist who studies Earth, e.g. its history, composition, structure, and the processes that shape it

glacier: a large, semi-permanent, slowly flowing river of ice on land formed primarily from compacted snow

igneous rock: rock formed when magma (molten rock) solidifies

mantle: the layer between the core and the crust of the planet. Its properties, such as density and viscosity (resistance to flow), change with depth.

metamorphic rock: rock formed when sedimentary, igneous, or other metamorphic rocks recrystallize into new rock forms, typically under the influence of heat and pressure

mineral: any naturally occurring, inorganic solid with a specific composition and an orderly crystalline structure

outcrop: bedrock exposed at Earth's surface

ozone layer: the region of the upper atmosphere that contains about ninety percent of Earth's ozone (molecules made up of three atoms of oxygen)

plates: the blocks that make up Earth's rigid, cold, outermost shell, averaging 100 kilometers (62 miles) thick and consisting of crust and uppermost mantle

radiometric dating: a technique for measuring the age of geologic materials based on the decay of naturally occurring radioactive isotopes

rock: a naturally occurring aggregate of one or more minerals

rock cycle: the cycle in which sedimentary, igneous, and metamorphic rocks are transformed into other rock types through processes such as melting, crystallization, erosion, deposition, lithification (the process by which sediments are turned into rock), and recrystallization

sedimentary rock: rock formed when sediments accumulate and lithify, or when minerals precipitate directly from water

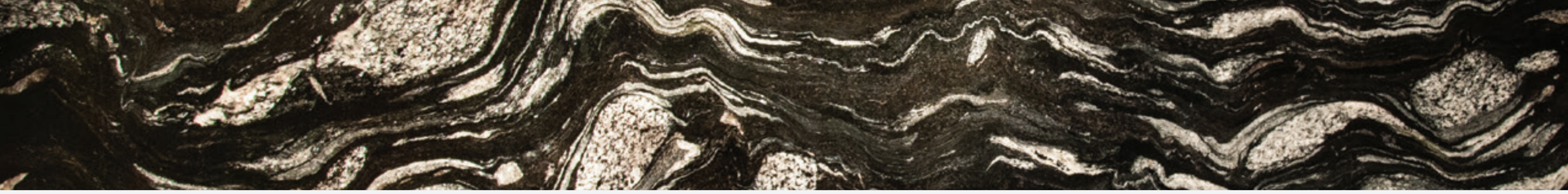
volcano: a vent in Earth's surface through which magma and associated gases and ash erupt. The ejected materials often form a conical structure.

water vapor: the gaseous state of water

water cycle: the cycling of water among oceans and lakes, land, living organisms, and the atmosphere

weather: the state of the atmosphere at a specific place and time, characterized by temperature, barometric pressure, wind velocity, humidity, cloud state, and precipitation

weathering: the physical and chemical processes that discolor, soften, and break down rocks exposed to air, water, and organic material



Come Prepared Checklist

- ☐ **Plan your visit.** For information about reservations, transportation, and lunchrooms, visit amnh.org/fieldtrips.
- ☐ **Read the Essential Questions** to see how themes in the hall connect to your curriculum.
- ☐ **Review the Teaching in the Hall** section for an advance look at what your class will encounter.
- ☐ **Download activities and student worksheets** at amnh.org/planet-earth-educators. They are designed for use before, during, and after your visit.
- ☐ **Decide how your class will explore the hall**:
  - You and your chaperones can facilitate the visit using the Teaching in the Hall section.
  - Students can use the worksheets and/or maps to explore the hall on their own or in small groups.

Correlations to Standards

Science Practices • Asking questions • Developing and using models • Analyzing and interpreting data • Obtaining, evaluating, and communicating information

Crosscutting Concepts • Patterns • Scale, proportion, and quantity • Systems and system models • Stability and change

Disciplinary Core Ideas • ESS1.C: The history of planet Earth • ESS2.B: Plate tectonics and large-scale system interactions • ESS3.B: Natural hazards • ESS3.D: Global climate change

PHOTO CREDITS

Cover: All photos, © D.Finnin/AMNH.
Essential Questions: Grand Canyon, © Ashton Applewhite.
Creating the Hall: Kawah Ijen Volcano, © D.Finnin/AMNH.
Teaching in the Exhibition: All photos, © D.Finnin/AMNH.

Creating the Hall

It took three years, dozens of reconnaissance trips, and 28 expeditions to collect the spectacular rocks on display in the Gottesman Hall of Planet Earth. Scientific teams have many responsibilities, from figuring out where to look for specific kinds of geologic evidence to transporting specimens across deserts and glaciers, through customs, and safely back to the Museum.

Museum scientists collect specimens at Kawah Ijen volcano.

The youngest specimen is a chunk of sulfur collected just days after it solidified on Indonesia's active Kawah Ijen volcano by scientists wearing masks to protect them from poisonous gases. The oldest is a zircon crystal from Jack Hills, Australia, which at 4.3 billion years is almost as ancient as Earth itself. Some samples were pried loose with a rock hammer, while massive boulders required boom trucks, helicopters, or ocean submersibles.

Then came the labor-intensive process of preparing, mounting, and installing the specimens, some weighing several tons: 168 rock samples and 11 full-scale models of outcroppings from 25 countries, including Australia, Indonesia, Italy, Kazakhstan, Mauritania, Switzerland, and Venezuela—and five regions of the ocean floor. Their stories combine to tell that of our dynamic planet.

In 2018, after two years of planning and development, the hall was reopened with comprehensive updates to a section about one of the most urgent scientific issues of our time: climate change. The new installation is anchored by a dynamic media wall where visitors can engage with the evidence for climate change; updates also include new content in the hall's sections on past climates, as well as on convection.