6-12 Geologic Time Scale Activity

South Carolina Aquarium

Overview

Focus Questions
How old is the Earth? How is Earth's history broken up by scientists? What are significant events in Earth's history? What are some trends you notice throughout time?

Activity Synopsis
Students will estimate when humans emerged on Earth and then as a class they will develop or investigate the timescale using a rope to get a concept for the timeline to scale. Students will then do an activity to create their own timeline and research significant events. Students will discover that life is recent on Earth and that organisms start as simple and became more complex over time.

Objectives
The learner will be able to:

- Learn the age of Earth
- Understand Earth's history to scale
- Create a timeline of the earth's history
- Describe events and trends in Earth's history

Time Frame
90 minutes

Student Key Terms
- Geologic Time Scale
- BYA – Billion Years Ago
- MYA – Million Years Ago
- Eon
- Era
- Period
- Epoch
- Precambrian
- Phanerozoic
- Hadean
- Archean
- Proterozoic
- Paleozoic
- Mesozoic
- Cenozoic

Teacher Key Terms
- Protoplanet

Standards

South Carolina College- and Career-Ready Science Standards 2021

6th Grade: 6-ESS1-4, 6-ESS2-1, **6-ESS2-2, 6-ESS2-3**
7th Grade: 7-LS2-4, 7-ESS3-1
8th Grade: 8-LS4-1, 8-LS4-2
Biology: B-LS4-1, B-LS4-5
Earth and Space Science: E-ESS1-2, **E-ESS1-5, E-ESS1-6, E-ESS2-1**, E-ESS2-2, E-ESS2-5, **E-ESS2-7**

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***Bold standards are the main standards addressed in this activity**

Sixth Grade Performance Expectations

6-ESS1-4 Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.
6-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
6-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
6-ESS2-3 Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

Seventh Grade Performance Expectations

7-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
7-ESS3-1 Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

Eighth Grade Performance Expectations

8-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operated in the past as they do today.
8-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer their ancestral relationships.

Biology Performance Expectations

B-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
B-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Earth and Space Science Performance Expectations

E-ESS1-2 Construct an explanation of the Big Bang Theory based on evidence to show that the universe is changing over time.
E-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.
E-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.
E-ESS2-1 Use evidence to argue how Earth's internal and external processes operate to form and modify continental and ocean-floor features throughout Earth's history.
E-ESS2-2 Analyze data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
E-ESS2-5 Investigate the ways that water (given its unique physical and chemical properties) impacts various Earth systems.
E-ESS2-7 Communicate scientific information that illustrates how Earth's systems and life on Earth change and influence each other over time.

Cross Curricular Standards

South Carolina College and Career Standards for ELA

Inquiry (I) – 1.1, 2.1
Reading (RI) – 12.1
Writing (W) – 2.1, 3.1
Communication (C) – 1.2, 2.1, 2.2, 2.3

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Background

Key Points

- Paleontologists and geologists study the earth materials to learn the unwritten history of our planet. The earth is very old, approximately 4.6 billion years ago. The history of the earth is broken up into **eon**s, **era**s, **period**s, and **epoch**s.
- A majority of earth's history (90%) is covered in the **Precambrian** supereon. Although on most geological timelines the Precambrian seems small and the other time periods seem much larger. There are several reasons for this: 1) more is known about more recent historical events because of preserved fossil records, 2) life got more complex over time, and 3) there were big explosions of life in more recent history.
- The Precambrian supereon consist of the **Hadean**, **Archean**, and **Proterozoic** eons. During this time the Earth was formed and was a boiling ball of lava. The layers of the earth settled and over time cooled and water then covered earth's surface. Single cell life formed the ocean and over time stromatolites, photosynthesizing colonial bacteria, formed in shallow water and released oxygen.
- The **Phanerozoic** Eon comes next and consists of the Paleozoic, Mesozoic, and Cenozoic Eras. This is an eon where life changes in complexity dramatically over time.
- The **Paleozoic** era consists of 5-6 periods and begins with the Cambrian period. The Cambrian is known as the Cambrian explosion. Invertebrate animals diversified and some with hard exoskeletons formed which were more likely to preserve in the fossil record. Along with invertebrates like trilobites, jellyfish, sponges, echinoderms, and brachiopods, were the first primitive vertebrates - Pikaia.
- The Ordocivian period continues to diversify the seas including nautiloids, but ends with the first mass extinction event – ice age – that eliminates 85% of life in the seas.
- The Silurian period brings jawless fish, graptolites, and the invasion of life to land. Vascular plants and animals begin transition on to land.
- The Devonian is the Age of Fish and we see the first sharks teeth. Land invertebrates diversity and our first land vertebrates appear. Gymnosperms, seed bearing plants 1st appeared. The Devonian experiences the Earth's 2nd Mass Extinction event that heavily effected shallow seas were 70% of invertebrates vanish.
- The Carboniferous period (also known as the Mississippian and Pennsylvanian periods) is known as the Coal Age and the Age of Amphibians. Flying giant insects appeared and the first large trees. Oxygen levels were high at about 20%. Huge swamps and forests create the coal mined and used as energy in modern day. The first reptiles evolve laying eggs out of the water.
- The Permian period furthered the development of reptiles on land and mollusk in the seas. The Permian period is famous for its ending the Permian extinction event also known as the Great Dying. 96% of species died out and the 4% lead way to all the animals that we know today. The extinction was most likely caused by extensive volcanic eruptions and flood basalts in Siberia.
- The Phanerozoic Eon now continues with the Mesozoic era which is comprised of the Triassic, Jurassic, and Cretaceous periods. This is a time known as the Age of the Dinosaurs or the Age of Reptiles.
- The Triassic period is the start of development of the dinosaurs. It also brings the 1st mammal-like animals. Pangea forms and breaks up in the Triassic as well. The Triassic-Jurassic extinction event occurred and killed about 50% of species. Each extinction event brought opportunity for the surviving species to exploit available resources.
- The Jurassic period has most major kinds of dinosaurs and also develops the 1st feathered birds.
- The Cretaceous period is most famous for the ending, the K-T extinction event, the end of the dinosaurs, ammonites, and the pterosaurs (flying reptiles). Before this extinction dinosaurs dominated the land, the 1st flowering plants (angiosperms) evolved, and mammals developed more strongly. The K-T extinction event was most likely caused by a large asteroid that hit Earth at the Yucatan peninsula. This extinction of dinosaurs gave way to the opportunity to others species and the rise of the mammals on Earth.
- The Phanerozoic Eon now continues with the Cenozoic era which is comprised of the Paleogene, Neogene, and Quaternary periods. This is a time known as the Age of the Mammals.
- The Paleogene Period is further divided into the Paleocene, Eocene, and Oligocene Epochs. This time period is known for the further development mammals and birds. Whales and other marine mammals 1st appear. Sharks diversify and this is the time of the Megalodon sharks. Land mammals diversify as rodents, hooved animals, carnivores, primates, and more.

- The Neogene period is broken down into the Miocene and Pliocene Epochs. This is the time of further diversification of animals and more variety of mammals. The first apes appear and evidence of hominoid ancestors - the Lucy fossils and human-like foot prints in Africa.
- The Quaternary period is our present day period and breaks down into the Pliestocene and Holocene epochs. The Plioestocene is the known as the Great Ice Age and is the age that Homo sapiens our own species evolved. The Holocene is known as the Age of Man and is the world we live in today.
- While all species impact the earth to some degree, no species has impacted it as strongly as humans with exploiting resources, pollution, habitat destruction, and unsustainable practices. Our own species could lead to next mass extinction. It is up to us to predict solutions, research, and make changes write a future history that we can be proud of.

Detailed Information

Detailed Information gives more in-depth background to increase your own knowledge, in case you want to expand upon the activity or you are asked detailed questions by students.

The Earth is approximately 4.6 billion years old. We can estimate the age of the Earth by finding and studying the oldest pieces of material we can find on earth. A few grains of the mineral, Zircon, found in sandstone from western Australia is currently of the oldest minerals on Earth dating 4.404 billion years. Zircon contains trace amounts of uranium which can be analyzed using radiometric dating allowed scientist to get a reliable age. There are different types of radiometric dating depending on the material and isotopes. Carbion-14 dating can only go back 70,000 years, because Carbon-14 has a shorter half-life. Unanium, on the other hand, has the half-life of 4.5 billion years, which makes it extremely useful for dating materials to find out earth's history. Zircons in Tonalite Gneiss date 4.03 billion years old and this rock was found at the Acasta River in the Northwest Territories, Canada. Furthermore, scientist have aged meteorites on Earth to 4.56 billion years.

Paleontologists and geologists are using evidence from rocks to piece together the story of Earth. We continue to piece together Earth's history with more and more fossil finds, mineral analysis, and collaboration throughout the global community. That being said, the Geological Timeline is not "set in stone." Science is constantly shifting and changing as we make new discoveries and technology improvements which allow more exact measures. The most current timescale is updated annually and can be found on the International Commission on Stratigraphy website: http://www.stratigraphy.org/index.php/ics-chart-timescale.

When we think about Earth's history, 4.6 billion years, it's far too much for us to grasp. So scientists break Earth's history into different units of time that are divided by significant events and developments. This is similar to how we discuss time in years, months, week, days, hours, and seconds. With geological time eons are the largest unit of time. Eons can then be subdivided into periods. Periods can be broken up into smaller units of time called epochs. There is not a set quantity for any of these geological units of time – **eons, eras, periods, or epochs**. For example, the Devonian period covered approximately 61 million years and Quaternary period covers a much smaller amount of time - 2.588 million years. Rather than being a set quantity of years, the units of time in the **geologic time scale** are divided by major events and changes in history.

When you see a table or timeline of Earth's history it is very deceiving on and does not give people a grasp of the scale of time. The earth's Earth's history is generally divided into two major Eons – **PreCambrian** and **Phanerozoic**. The PreCambrian covers 4,059 million years (4.059 billion years), while the Phanerozoic covers 541 million years.

All geologic time before the Paleozoic era is called Precambrian. The Precambrian supereon covers about 90% of all geologic time, from the beginning of earth about 4.6 billion years ago (**BYA**) to 541 million years ago (**MYA**). Precambrian simply means "before Cambrian". The Precambrian is subdivided into 3 eons – **Hadean, Archean, and Proterozoic**.

The Precambrian starts with the **Hadean** eon (4.6 – 4.0 BYA) – the beginning of earth. The name Hadean comes from the Greek mythology underworld Hades. During this eon the solar system was created, including Earth. Earth was formed from a mass of dust and gas that gravity pulled together. This process caused a huge amount of heat through the decay of radioactive elements and melting of materials. The earth's surface was an ocean of boiling liquid rock. Lava covered the surface with temperatures around 2000 degrees Fahrenheit. Around 4.5 BYA a **protoplanet** named Theia, the size of Mars, collides with Earth changing the surface of the Earth and creating a debris ring around Earth. The debris forms a ball and Earth's moon is created. This was a turbulent time in the solar system. Crater evidence on the moon and other planets dates 4.0 – 3.8 BYA. The Earth eventually began to cool and this cooling allowed material to separate into different layers of the Earth – the core, mantel, and outer crust. Over hundreds of millions

of years, lava flowed over the surface of earth eventually cooled. Earth's temperature is now a scorching 170 degrees F. Many scientists believe meteors from space bombarded Earth and brought with it crystals that with minuet drops of water in each meteor. As meteors rained on the Earth water began to be covered with water and oceans. Volcanic activity formed volcanic islands that will eventually come together as the first continents. The oldest formation of rocks from this eon are still preserved on the surface of the Earth. In Canada, the Acasta gneiss was found to be one of the oldest known rocks on Earth with Zircon minerals dating 4.03 BYA. This rock metamorphosed from the Earth's earliest continental crust that formed before 4.03 BYA.

The Hadean eon is followed by the **Archaean** eon (4.0-2.5 BYA). The name comes from the ancient Greek word meaning "ancient" which referred to the earliest rock formations. These ancient rocks were formed between around 2.5 and 4 billion years ago. By the start of the Archaean eon Earth's crust had cooled and plate tectonics begins to establish on Earth. During the Archean eon is when primitive, simple life first appeared on earth, within one billion years of Earth's formation. At around 3.8 BYA meteors have carried not only water to Earth, but also minerals, carbon, and primitive protein amino acids. At the bottom of the ocean, thermal vents and combine with the meteors materials and create a chemical soup. These chemicals are believed to have formed the earliest forms of life on Earth. Scientists have found fossil evidence of single-celled organisms that formed about 3.5 BYA. These earliest forms of life are similar to simplified bacteria that we see today. The conditions were inhospitable for life by our standards, but single-celled life evolved despite the tough conditions. Single-celled organisms may have remained the only form of life for around 2 million years. By the end of the Archaean eon, more complex life, stomatolites, evolved in shallow ocean waters between 3.5 – 2.7 billion years ago. Stomatolites are living bacteria colonies that use photosynthesis and slowly fill the ocean with oxygen. Photosynthetic life reduced the carbon dioxide levels and the byproduct oxygen slowly began to fill the oceans and atmosphere. Modern stomatolites can still be found in the waters off Australia, the Bahamas, and Belize.

The Archaeon eon is followed by the **Proterozoic** eon (2.5 BYA – 541 MYA) – the final eon of the Precambrian. The name Proterozoic comes from the Greek words meaning "first" and "life". We now know earlier fossils were found in the Archaean, but for years ancient fossils were found in the Proterozoic rock strata. Around 2.5 BYA organisms began using photosynthesis - using the sun to make their food. This resulted in oxygen being released into the ocean at the end of the Archaean and beginning of Proterozoic Eons. The oxygen attached to trace iron in the ocean creating rust that fell to the bottom of the ocean forming sedimentary deposits known as banded iron formations (BIFs). Today these deposits are mined for iron ore. Once much of the iron participated out of the water, oxygen was then released into the atmosphere. Free oxygen is now in the atmosphere. While Archaean atmosphere was oxygen-poor, the Proterozoic is now an oxygen-rich atmosphere starting 2.3 BYA. As the level of oxygen increased, organisms evolved that used oxygen. Some of these organisms include jellyfish and segmented worms. These soft-body organisms are similar to modern day worms and sponges. There are few fossils of these soft-body organisms, since they don't preserve easily. While life could be found in the ocean, the land looked more like a barren Mars. During the Proterozoic eon around1.2 BYA, the Earth's crust breaks into plates and volcanic islands combined together to form the supercontinent Rodinia (Russian word for "homeland"). Extensive glaciation occurred at least twice during the Proterozoic eon. Huge glaciers that began at the poles extended across the Earth causing what is known as "snowball earth" for several billion years. An Earth that began as a boiling ball of hot magma and lava now is a ball of ice. Life still survived in hostile ocean environments - hydrothermal vents. The snowball earth phase ended when volcanoes broke through the ice releasing Carbon Dioxide in the air and building up a layer to absorb the suns heat and warm the Earth.

All the rest of geologic time is in the **Phanererozoic** eon – from 541 million years ago (MYA) to today. The Phanerozoic eon is subdivided into 3 eras – Paleozoic, Mesozoic, and Cenozoic eras. This eon may be short when thinking about the entirety of Earth's history, but it is when life became more abundant and more complex life forms began developing over time.

The **Paleozoic** era ranges from 541 MYA to 252 MYA and the era is further divided into 6 periods – Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. Paleozoic is Greek for "old life". This is the time of an explosion of life on Earth. The Paleozoic Era is known as the age of ancient life. The Paleozoic era is notable for two major events:

1. It began with an explosion in animal life, the Cambrian explosion.
2. It ended with the largest mass-extinction event, the Permian extinction.

The Cambrian period (541-485 MYA) is named after Cambria, the Roman name for Wales, where rocks of this age were first found. This is the 1st period of the Paleozoic era and it marks an explosion of life in a short amount of time. This is known as the Cambrian Explosion. Many different kinds of animals evolved at the beginning of the Paleozoic era. A lot of these animals look nothing like any animal that's alive today. Before this time Earth did have multicellular life, but organisms were soft bodied or microbial. Now we see life diversifying – invertebrates (*mollusk, trilobites, arthropods, brachiopods, echinoderms, corals, sponges*) and primitive vertebrates

(chordates). The Cambrian Explosion is when we first see shells and exoskeletons on animals which allowed more fossilized remains to be preserved. The Cambrian period brought about unique animals like the backboned swimming animal *Pikaia*, soft-bodied *Wiwaxia*, the famous trilobites, the five-eyed *Opabiniam*, or the dominate predator *Anomalocaridids*. The supercontinent, Rodinia, broke up during the Cambrian period and move toward the warm equator. Gondwana is now a continent. The masses of ice from snowball earth during the Proterozoic eon have now melted and flood the continental plates. Warm shallow waters offer an explosion of life and future limestone all over the world. The ocean is a sea of life with thousands of plant and animal species. On the other hand, land would have looked more like Mars, with no life at this time. The Burgess Shale in British Columbia, Canada is famous for its unusual preservation of the soft bodied organisms from the Cambrian explosion.

The Ordovician period (485 – 443 MYA) follow the Cambrian period. The Ordovician period is named after the Ordovices, a Celtic tribe. Continued marine diversification continues in the Ordovician period with *brachiopods*, robust *bryozoans*, *trilobites*, straight coned *nautiloids*. This is when we first see *graptolites* and *conodonts* which are important animals used in biostratigraphy (estimating the age based on animals that lived for shorter periods of time). There is a decline in stromatolites due to the new grazing organisms. More complex reef ecosystems formed. Our first land organisms appear, *lichen* and *bryophytes.* Gondwana moved to the South Pole and glaciers formed. The Ordovician period ends with a massive ice age and the 1st mass extinction event. The Ordovician-Silurian mass extinction has been blamed on an ice age event, where a huge ice sheet in the southern hemisphere changed the chemistry of the seas and wiped out a possible 85% of sea life. This is the 3rd largest extinction event known in Earth's history.

The Silurian period (443-419 MYA) follows the Ordovician period. The Silurian period is also named after a Celtic tribe, the Silures. In the oceans we continue to see *corals*, *brachiopods*, *bryzoans*, and *graptolites*. Large coral reefs can be seen for the first time and marine life is continues to diversify. *Jawless fish* (*agnathans*) can be found throughout the aquatic ecosystems. This period is famous for the invasion of land – a significant start to life on dry land. A few organisms leave the water. A few small *vascular plants* and *Arthropods* (related to millipedes and centipedes) now can be found on land. This is a huge evolutionary transition. Organisms that tackle this transition to life out of the water have the advantage of no predators, but must overcome ultra violet rays and extreme dryness out of the water. This is the first time we see vascular plants, plants that have special tissues for carrying fluid through their stems. Land animal and plants were limited to wet areas. Most animals probably fed on detritus. *Sea Scorpions* were the dominate predators "large" predators ranging from centimeters to a meter.

The Devonian period (419-358 MYA) follows the Silurian period. The Devonian period is named after Devonshire, England, where rock from this ager were first found. The Devonian period is known as the "Age of Fishes" because this is the first time we see vertebrates with jaws (*gnathostomes*). A marine predator of this time is the giant *Dunkleosteus,* a placoderm that had sharpened boney plates instead of teeth. While cartilaginous fish survived the Ordovian extinction, they thrived during the Devonian period when scientists find our first known sharks teeth. Bony fish and Lobed fish appear. Our first *ammonites* are found in the seas and trilobites decrease. Some of the most extensive coral reefs in history were built during the Devonian period. Colonization of land occurs with the diversification of land invertebrates and the first land vertebrates. This is the time for the orgins for the *tetrapods* which appeared around 360 MYA, which means animals with "four feet". During the Devonian period lobed-finned fish appear and lead way to the first land vertebrates around 280 MYA when they moved from water to land. Over time their body parts adapted to make movement and life on land easier. The tetrapods of the Devonian period were still aquatic and didn't become fully terrestrial until the Carboniferous period. We see our first insects and large plants. The early Devonian plants required moist environments to reproduce. Middle Devonian plants were the first shrub and tree like plants. Late Devonian plants included our first true trees, *Archaeopteris*, with fern like leaves and tree structures. The end of the Devonian was a huge step for plants with the first non-flowing seed bearing plants, *Gymnosperms*. The development of the seed allowed plants to move farther into drier environments. The Late Devonian also has our 2nd Mass Extinction which consisted of a series of small extinction events that occurred over 20 million years and led to 70% of all invertebrate species vanishing. The shallow seas and reefs were effected the most and they didn't recover until new coral evolved over 100 million years later. There are many hypothesis, but no clear cause for the extinction events of the late Devonian period.

The Carboniferous period (358- 298 MYA) follows the Devonian period. The Carboniferous is sometimes subdivided into the Mississippian and Pennsylvanian periods. The Mississippian period (358- 323 MYA) was named after the Mississippi River valley, which has good examples of rocks from this age. While many tetrapods were still semiaquatic, this is when the first terrestrial tetrapods appeared. However these land vertebrates were still tied to the water. Like modern amphibians, these early tetrapods depended on the water to deposit their porous eggs. The land plants continued to develop was seed plants dominated the drier environments and mosses (*lycopsids*) stayed close to wetter environments. Winged insects first developed to expand their range. In

the seas sharks were common along with a variety of bony fish. Other predators include ammonites and cephalopods. During the Mississippian period the Appalachian Mountains formed when the supercontinent, Gondwana, collided with Euramerica, a minor supercontinent. The Pennsylvanian (323 - 298 MYA) period is also known as the Coal Age and is named after the state of Pennsylvania were rocks of this time period can be found. Plant growth was lush and extensive during the Pennsylvanian period huge dense forest and lowland swamps. Layers and layers of generations of dead plants later create the coal used by humans today. These Coal Forest were home to giant dragonflies, *Meganeura,* with 27inch wingspans. Giant spider-like animals and millipede-like animals, , *Arthropleura*, over 6 feet long. Insects diversified in a big way, but mainly ate live or dead plant matter. Early tetrapods also diversify, but mainly feed as carnivores or insectivores. Land vertebrate herbivores evolve in the Permian period. This is also known as the "Age of Amphibians" with diversification for example: semiaquatic eel-like forms, *aistopods*, and *anthracosaurs*. The earliest reptiles evolved with the advantage of laying eggs out of the water. Amniotes are a group of vertebrates that have the advantage of producing eggs with amniotic fluid-filled membranes to protect and nourish their offspring. This was a game changer. Now animals can expand farther from aquatic environments.

The Permian period (298-252 MYA) is the final period of the Paleozoic era. The Permian period is named after the providence of Perm, Russia, where rocks of this age were first found. Land vertebrates – amphibians, *Synapsids* (mammal-like reptiles), and *diapsids* (reptiles/amniote tetrapods) continue to diversify. *Dimetrodon* which is often found in toy dinosaur kits actually lived during the Permian period as a large carnivorous predator. We see our first vertebrate herbivores. Seed plants like the conifers dominated the tropic lands. Permian plants become much more adaptable to dry environments. Insects diversified into the early *hemipteriods* (cicadas, lice) and *holometabola* (beetles, flies, wasp, and moths). The Permian period ends the Paleozoic era with the *Permian mass extinction*. 96% of species died out with this mass extinction causing it to be nicknamed The Great Dying. All life on the planet today evolved from the 4% of species that survived this mass-extinction. Those that survived the Permian extinction were able to adapt from the lush forests to a harsh environment. This extinction killed 70% of land vertebrate species. *Archosaurs* became the dominate land predator after the extinction. It was the greatest loss of insect species in our known history. In the oceans 90% of marine animal species disappeared – trilobites, placoderm fishes, blastoid echinoderms, and some corals and foraminiferans were wiped out. Sharks, brachiopods, ammonites, bony fish, crinoids, ostracods, and echinoderms lost many species, but survived. This extinction was most likely caused by massive series of volcanic eruptions in Siberia, which created flood basalts, an outpour of lava 2/3 the size of the US. This had a domino effect that changed the environment in such a rapid manner, it wiped out 96% of species.

Following the Paleozoic (Ancient life) era is the **Mesozoic** era (252 – 66 MYA). Mesozoic is Greek for middle life. Since this era falls between the Paleozoic and Cenozoic eras, "middle life" is very fitting. This era is also known as the Age of Dinosaurs or the Age of Reptiles. The Mesozoic era ranges from 252 MYA to 66 MYA and the era is further divided into 3 periods popular periods – Triassic, Jurassic, and Cretaceous.

The Triassic period (252 - 201 MYA) is the first period of the Mesozoic era. The Triassic period is named after the threefold division of rock in Germany from this age. Since the continents first were formed, they were on the move and at the start of the Triassic period supercontinent Pangea completed its formation. The Late Permian and Triassic period are known for a vast desert that formed on the supercontinent Pangea, whose vast size made it so that the oceans moisture never made it to large parts of the supercontinent. Land and Aquatic life forms were sparse after the start Permian extinction, but over several million years life diversified. From a devastated planet, life recovered. The first dinosaurs, first flying reptiles (pterosaurs), ancient crocodile-like animals, turtles, frogs, and even the first mammals in the Middle to Late Triassic. The oldest amniote egg fossil is from the Early Triassic period, 200 million years after this form of reproduction evolved. Mammal-like reptiles, *Synapsis*, lead to the first mammals appearing in the Triassic alongside the appearance of dinosaurs. Mammals of this time include *dicynodonts* (herbivores), *gorgonopsians* (carnivores), *tritylodonts* (insectivores), and even the dinosaur eating - *Repenomamus robustus.* Most mammals remain small while dinosaurs rise as the dominate land predators. Archosaurs which include dinosaurs, pterosaurs, and crocodyliforms dominated the land, air, and sea of the Triassic. Mosses were the dominate plants at the start of the Triassic. Over time new ferns (*Dicroidium)*, conifers, and cycads (palm-like plants) recovered. In the Panthalassia Ocean giant 75 foot reptiles dominated (ichthyosaurs), ammonites diversified more than ever before, echinoderms flourished (1st sea urchins & starfish), and modern reefs formed. By the end of the Triassic the supercontinent, Pangea, already started to split up. At the end of the Triassic and beginning of the Jurassic, Pangea began to split, which was the beginnings of the Atlantic Ocean. The Triassic period has two or three phases of extinction that are combined to create the Triassic-Jurassic mass extinction event. The causes of theses extinctions is unclear, but roughly 50% of all the species alive became extinct.

6-12 Geologic Time Scale Activity

The Jurassic period (201 -145 MYA) is named after the Jura Mountains between France and Switzerland, where rocks of this age were first found. The Jurassic is the "Age of the Dinosaurs", when dinosaurs diversified. Most dinosaurs were similar to those of the Triassic, but by the end of Jurassic Behemoth herbivores dominated the land. *Brachiosaurus*, *Apatosaurus*, and *Diplodocus* could reach lengths of 120 feet and 60 tons in weight with their long necks and tails. By the end of the Jurassic most major kinds of dinosaurs existed varying from small to large. The Late Jurassic also brought about the first feathered birds, *Archaeopteryx,* which looked like theropod dinosaurs with feathers. The skies were still dominated by *pterosaurs*, flying reptiles, big and small. Insects diversified and we now see a group of insects, *Kalligrammatidae,* similar to butterflies with big "eyespots" on their wings for protection. Flowering plants and grasses are still not seen. Without grasses to hide in mammals remained small and many hide underground or in trees. In the ocean, warm shallow waters allowed a diversity of life and reef development. Ammonites and belemnites shared the sea with sharks and marine reptiles, *Ichthyosaurs*. The 1st marine crocodiles appeared and the 1st teleost fish, which now are the most diverse vertebrates on the planet.

The Cretaceous period (145-66 MYA) is known as the "End of the Dinosaurs". This is the last period of the Mesozoic era. Cretaceous comes from the latin word creta which means chalk and this period left rocks of its age, the White Cliffs of Dover along the English Channel in Great Britain. These chalk deposits formed by the deaths of billions of single celled marine algae called *coccolithophores*. The oceans of the Cretaceous was diverse with sharks, fish, and a new 45 foot marine lizard predator, *Mosasaur.* The Cretaceous was not only a big time for big marine animals, but also for the small marine life. Diatoms, a type of phytoplankton, first appeared and many other planktons diversified. At the beginning of the Cretaceous period new dinosaurs appeared – Triceratops & duck-billed dinosaurs. In the middle of the Cretaceous, the 1st monotremes, marsupial, and placental mammals appear. Plants diversified and 1st angiosperms (flowering plants) developed. There was a rapid coevolution of plants and insects. The Cretaceous period is most famous for its ending – the 2nd greatest mass extinction This extinction, the **K-T extinction event**, is famous for the end of the dinosaurs, but it was also the extinction of almost 50% of the world's species from flying reptiles in the sky, species of insects and plants on land, and large mosasaurs to microscopic plankton in the seas. This is also the extinction of ammonites and the pterosaurs. The specifics of what caused of such a large extinction event is still under debate, but paleontologists agree that an asteroid about 6.2 miles in diameter hit the Yucatan peninsula in Mexico. The asteroid had a global impact. Probably initial forest fires; dust and smoke blocking sunlight, cooling the earth, suffocating many animals; followed by a rise in temperature event due to the release of Carbon Dioxide. The extreme environmental changes was devastating to many species, but ultimately helped other species. The end of the Age of the Dinosaurs left holes in the ecological niches for mammals to spread and evolve.

This **Cenozoic** era is the most recent era from 66 MYA to today and is also the era that follows the Mesozoic era. Cenozoic comes from the Greek word meaning "new life". The Cenozoic era is known as the age of recent life, but it's also known as the Age of Mammals. With dinosaurs now extinct, mammals can prosper in the Cenozoic era. The Cenozoic era is divided into 3 periods – Paleogene, Neogene, and Quaternary.

The Paleogene period (66 - 23 MYA) is the first period of the Cenozoic era. Paleogene come from the Greek words meaning "ancient-born". This period is also sometimes called the by its traditional name, Tertiary period (consisting of the Paleogene and Neogene periods). The traditional name of the Tertiary period shows how much paleontology and geology is changing with new information. In the 1800's geologic events were dived into just 4 periods and named based off of the latin words for 1st, 2nd, 3rd, and 4th. Tertiary means "third". Today we use a different system and have much more than 4 periods, but the traditional name is still used by some. The Paleogene period it known for rapid development of mammals and birds. The Paleogene period consists of 3 epochs – Paleocene, Eocene, and Oligocene Epochs.

The *Paleocene* Epoch (66-56 MYA) is the first epoch in the Paleogene period. Paleocene is named after the Greek words palaois which means old and ceno which means new. So this is the old of the recent life on Earth. The name Paleocene comes from the Greek words meaning "ancient" and "recent", representing the oldest epoch of the recent era. The end of the dinosaurs paved the way for mammals and birds to become the main vertebrates on land. Mammals diversified and the largest known mammals of this time was the *Pantolambda*, which was the size of a small pony. Mammal insectivores, carnivores, herbivores, and even early relatives to primates developed. Rodents also appeared in the fossil record in the late Paleocene. The oceans also slowly rebounded with bony fish (teleosts), sharks (mackerel, sand tiger, and small white toothed), urchins, foraminiferans, and the surviving marine reptiles (turtles and crocodiles). At the end of the Paleocene a warming event caused methane to be released from the sea floor. This killed off 50% of foraminiferans in the deep ocean and created a global warming event.

The *Eocene* Epoch (56 - 33 MYA) is named after the Greek words eos meaning dawn and ceno meaning new. The Eocene began with a 5 million year warming event that had the highest temperatures seen in the Cenezoic Era. Even the polar regions had fossil evidence of warm weather animal and plant species, including flying lemurs and cold-blooded reptiles. Over time the Earth cooled and was drier than the rainier climate of before. This is the time of marine mammal evolution – our first whales and sea cows. *Basilosaurus,* an early whale reached lengths of 60 feet. The seas also saw modern requiem sharks increase, while other shark species died out. This is the appearance of giant-toothed white sharks – the famous Megalodon. On land we also see many mammals diversify as herbivores, hoofed mammals, true primates, and rodents that populate the land. During this time the Rockies were formed with uplift and the Himalayas formed with the collision of the Indian and Asian subcontinents. This was the birth of Mt. Everest the highest mountain known today.

The *Oligocene* Epoch (33-23 MYA) is named after the Greek words oligos which means little or few and ceno which means new. In central North America, the landscape changed from woodlands to open forest and grasslands which allowed grazing animals to increase. This is the appearance of most living families of mammals. Hoofed-mammals (ungulates) became very diverse. Fossils show a variety of animals - camels, horses, rhinoceros, saber-toothed cats, armadillos, sloths, and ground birds (phorusrhacids), marsupials (bohyaenids), and many more. In the oceans we begin to see our two orders of whales – toothed and baleen. The Oligocene brings out first pinnipeds (seals and sea lions).

The Neogene period (23 -2.58 MYA) is the middle period of the Cenozoic era. The name Neogene means “new born.” The Neogene was traditionally called the Tertiary period meaning “third”. Primates and hominids further developed in the Neogene. The Neogene period breaks down into 2 epochs: Miocene and Pliocene Epochs.

The *Miocene* Epoch (23-5.33 MYA) is named after the Greek words meion meaning less and ceno which means new. On land open grasslands stretch across North American and Eurasia. The mammals take advantage of this open habitat include horses, camels, antelopes-like animals, and rhinoceros. On land horses diversified into several different forms but only 2 survived past this epoch: three-toed lineage which died out in the ice ages, and single-toed lineage what lead to modern zebras and horeses. Also successful during this time were the grazing horned and un-horned ruminant mammals. This group leads to our modern day animals including deer, cows, sheep, goats and even giraffes. The largest known land mammals of this time are the elephant-like gomphotheres. Also notable is that the first apes appeared in Africa. The seas see circulation changes and the formation of gyres in the North and South hemispheres. These changes encourage more diversification of whales, seals, sea lions, and walruses. Half of the marine invertebrates of this time are still on earth today. An odd marine mammal of the Miocene is the desmostylus which became extinct at the end of the Miocene. The most famous marine shark of this time was the *Carcharodon megalodon*, a great predator of the seas. The first known kelp forests appear in the Miocene.

The *Pliocene* Epoch (5.33 – 2.58 MYA) is also named after Greek words – pleion meaning more and ceno meaning new. On land this is a time of migration. The land bridge of Panama linked North and South America allowing the animals to migrate to new continents and became known as the Great American Faunal Interchange. Armadillos, giant ground sloths, flightless birds, marsupials, and porcupines moved north from South America. Meanwhile cats, dogs, breas, tapirs, camels, and rodents moved south from North America. Some of these species became extinct because of these changes and competition. Migration also continued between Asia and North America with the Bering land bridge. Mastodons and true horses (Equus), glyptodonts, and camels roamed the North American landscape. In Africa, early evidence of human ancestors was discovered from this time near the rift valley. The famous fossil find “Lucy”, Australopithecus afarensis, hominoid lineage dates over 3 MYA. Trace fossil evidence of human-like foot prints revealed that our ancestors moved to walking upright on 2 (bipedalism). The Pliocene had a warming phase and cooling phase that is evident by rock strata, micofossils from core samples in the deep ocean, and pollen from core samples on land.

The Quaternary period (2.58 – present) is the last period of the Cenozoic era and it is the period that we live now. Quaternary is named after the Latin word quatern meaning four at a time. The names of this period shows how much our geologic timeline has changed over time. Originally the eras were named Primary, Secondary, Tertiary, and Quaternary. Quaternary is the only original era name that remains. The Quaternary period is known for the impact of both climate change with the ice ages and modern humans spreading across the earth. The Quaternary period is further divided into the Pleistocene epoch and the Holocene epoch.

The *Pliestocene* epoch (2.58-.0117 MYA) is the first epoch in the Quaternary period and is known as “The Great Ice Age”. Pleistocene is named after the Greek words pleistos meaning most and ceno meaning new. This is also a time of climate fluctuations and widespread glaciers that impacted species survival especially large mammals. There is geological evidence for 20 cycles of advancing

and retreating glacial changes. The Pliestocene glaciers were extreme, covering up to 30% of the Earth's surface, with glaciers over 2.5 miles tall. With so much water captured in the glaciers the sea levels dropped globally over 450 feet. During the Pliestocene the Colorado River began carving out the Grand Canyon. Many of the animals and plants look remarkably similar to their modern forms today. This is the time of major human adaptations, expansion, and culture. This is the epoch that *Homo sapiens* our own species evolved in Africa about 200,000 years ago. Humanoid species spread throughout the world. *Homo erectus* fossils were found in Africa, Asia, and Europe. Fossils of *Homo neanderthalensis*, the Neanderthals were found in Germany in the late Pleistocene. The migration of early humans continued. *Homo sapiens*, spread to Australia and the Americas by late Pleistocene. The Pleistocene is the first time that we see human influenced extinctions, with human migration to North America and many large mammals becoming extinct. The fluctuating climate may have also been a factor in these extinctions. Mammoths, Mastadons, saber-tooth cats, and ground sloths went completely extinct. In North America lamas, camels, tapirs, horses, and musk oxen died out.

The *Holocene* epoch (.0117 MYA – present) is the current epoch. It's named after the Greek words halos meaning entire and ceno meaning new. The Holocene epoch is the world that we live in today, all the way back to the ice age 11,700 years ago. For the last 11,700 years the world has been relatively warm with the exception of a "Little Ice Age" between 1200 and 1700 A.D. This epoch is known as the "Age of Man" although Homo sapiens spread around the world in the Pliestocene epoch. The Holocene does contain all of Earth's recorded history, every rise and fall of civilizations, and all of the development of technology and science that help us unveil the unwritten history of Earth. While all species throughout history have influenced their environment, none have had influenced and changed the Earth as much as our species. A vast majority of the scientists agree that human activity is impacting and increasing global temperatures. Human activity with habitat destruction, pollution, and unsustainable practices have caused ongoing mass extinctions of plants and animals. Some predictions expect 20% of species to go extinct in the next 25 years if human activity continues along its current path. With science and technology developments we can learn more about our earth and its history. We can make better understand changes and their impacts on life on earth. With human development and informed decision, we can make a difference on the future of our earth.

Procedures

Materials

- Pre-measured Rope (46 feet)
- Measuring Tape
- 3 Colors of tape (red, orange, green)
- Green yarn
- Marker to mark years (black sharpie works best)
- Geologic Time Scale Intro PowerPoint
- Geologic Time Scale Cards
- Measurements Chart
- Earth History Chart https://stratigraphy.org/chart

Procedure

- You can prepare the Earth's geologic timeline rope ahead of time with a 46 feet of rope as an example to cut down on the class time spent on this activity or you can do this with the class. Mark Eons with red tape, Eras with orange tape, and Periods with green tape and yarn to scale. The dates and measurements below are based off of the 2015 International Chronostratigraphic Chart. This chart is updated annually and the lasted version can be located at International Commission on Stratigraphy website at https://stratigraphy.org/chart. Use the Measurements Chart to create Earth's geologic timeline on the rope.

1. Talk about the Earth's history using the Intro PowerPoint. Intro will highlight the following:
    a. Estimate when humans emerge in Earth's history
    b. Age of Earth
    c. Earth's history broken down into parts
    d. Predict organisms oldest to most recent and reveal answers.

6-12 Geologic Time Scale Activity

2. Assign each student or pair of students a Geological Time Scale Card (15 total cards). Have them research their eon/era/period to learn about what was occurring on the earth at that time. They should be prepared to share this information with the class through the activity.
3. As a class use 46 feet of rope to represent 4.6 billion years of time (the age of the Earth). Mark these spots to get started:

- At one end of the rope use red tape and a marker to indicate "today"
- At the other end of the rope (46 feet) use red tape and a marker to indicate 4.6 billion years ago
- Starting at "today" use a marker to mark every 10 feet to give a visual of every 1 billion years
    - 100 MYA = 1 foot
    - 10 feet = 1 BYA

4. Earth is broken up into 4 main Eons. The Precambrian SuperEon includes 3 Eons, the Proterozoic, Achaean and Hadean Eons. The most recent Eon is the Phanerozoic Eon. Use red tape to mark the beginning of each of these Eons on the rope at these spots:

   For the Precambrian SuperEon (4.6 BYA – 541 MYA)
   - Hadean Eon begins at 4.6 BYA = 46 feet from today
   - Archaean Eon begins at 4 BYA = 40 feet from today
   - Proterozoic Eon begins at 2.5 MYA = 25 feet from today

   For the Phanerozoic Eon (541 MYA – present), begins at 5.41 feet from today

5. For each of the Precambrian Eons, have a student hold the correct Geological Time Scale Card while standing on the rope at where the eon begins. Have the student describe the earth using the images and bulleted information.
6. The rest of history is the Phanerozoic Eon. Most Geologic Timelines focus heavily on this Eon. Why? Because we see more life and more changes in a relatively "quicker" amount of time. The Phanerozoic Eon represents 10% of Earth's history, but has a lot of activity. Scientists divide the Phanerozoic Eon up into smaller units of time because so many more changes have been recorded.
7. The next step on the timeline is to divide the Phanerozoic Eon into Eras and the Periods.
8. Let's start with the Paleozoic Era. Use orange tape to mark the beginning of the Paleozoic Era at 5 feet 5 inches from today (541 MYA).
9. Now use green yarn and tape to mark each Period within the Paleozoic Era at the following spots on the rope:
    a. Cambrian Period begins at 541 MYA = 5 feet 5 inches from today
    b. Ordovician Period begins at 485.4 MYA = 4 ft 10 in from today
    c. Silurian Period begins at 443.8 MYA = 4 ft 5 in from today
    d. Devonian Period begins at 419.2 MYA = 4 ft 2 in from today
    e. Carboniferous Period begins at 358.9 MYA = 3 ft 7 in from today
    f. Paleozoic Period begins at 298.9 MYA = 3 ft from today
10. Now that the Paleozoic Periods have been marked, have a student hold the correct Geological Time Scale Card while standing on the rope at where the Period begins. Have the student describe the earth using the images and bulleted information.
11. Next up is the Mesozoic Era of the Phanerozoic Eon. Use orange tape to mark the beginning of the Mesozoic Era at 2 feet 6 inches from today (252.17 MYA).
12. Now use green yarn and tape to mark each Period within the Mesozoic Era at the following spots on the rope:
    a. Triassic Period begins at 252.17 MYA = 2 feet 6 inches from today
    b. Jurassic Period begins at 201.3 MYA = 2 ft from today
    c. Cretaceous Period begins at 145 MYA = 1 ft 5 in from today
13. Now that the Mesozoic Periods have been marked, have a student hold the correct Geological Time Scale Card while standing on the rope at where the Period begins. Have the student describe the earth using the images and bulleted information.
14. Next up is the Cenozoic Era of the Phanerozoic Eon. Use orange tape to mark the beginning of the Cenozoic Era at 8 inches from today (66 MYA).
15. Now use green yarn and tape to mark each Period within the Cenozoic Era at the following spots on the rope:
    a. Paleogene Period begins at 66 MYA = 8 inches from today

   b. Neogene Period begins at 23.03 MYA = 3 inches from today
   c. Quaternary Period begins at 2.58 MYA = 0.3 in from today
16. Now that the Cenozoic Periods have been marked, have a student hold the correct Geological Time Scale Card while standing on the rope at where the Period begins. Have the student describe the earth using the information they researched as well as the card.
17. Finish the activity by completing the last few slides from the Geologic Time Scale PowerPoint. These slides will review how immense Earth's History is and how we are learning more every day.

At-home Learning and Virtual Modifications

At-home Learning: Send this google slide presentation and assignment home with your students (https://docs.google.com/presentation/d/1xjUo6rCiEkPDUpLwcXuV8-n1jgNlea_2Z22z1iFP8AA/edit?usp=sharing). This assignment has two parts the first provides background information on geologic time through PBS a video and links to trustworthy websites. The second portion is the assignment. The assignment consist of a geologic timeline where they can move the names of the eons, eras, and periods to the correct portion of the timeline and a request for them to research an eon and create a poster that explains what happened during that time.

Instruction to assign the presentation in google classroom:
1. Save the Geologic Time Scale Slideshow to your Google Drive
2. Open your Google Classroom and create a new assignment
3. Select Add > Google Drive
4. Be sure to choose "Make a copy for each student"
5. You'll be able to see their answers and interactions

Instructions if sending through email:
1. Save the Geologic Time Scale Slideshow to your Google Drive
2. Download the slideshow as a PowerPoint
3. Send to your students
4. Have students complete the PowerPoint and send it back to you

Virtual: Prior to the lesson, assign each student or pair of students a geologic eon, era, or period to research. They should know the start and end dates for their selected geologic time and 2-3 important things that occurred during the time.

Introduce the concept of geologic time using the Geologic Time Scale Intro PowerPoint and then explain that you will be building the geologic timeline with your students. Using a white board, piece of paper under a document scanner, or other useful resource start to build a timeline by drawing an arrow across. Make a vertical line at the beginning and mark with 4.6 BYA. This is the start of your timeline. As you add to your timeline, have you students report out on the eon, era, or period that they were assigned to.

Follow-up questions

- How has the Earth changed over time?
- How do organisms change over time?

Assessment

Assessment 1

Have students label their own Geologic Time Scale using the Geologic Time Scale Worksheet. Help them set it up by folding over the paper on right side of page 1 so that the line ends where they fold the paper. They should then tape the papers together to make one long horizontal line. The line represent the Earth's Geologic Time. Per the directions on the worksheet, they will start by labeling the Eons then move on to labeling the Eras of the Phanerozoic Eon. Lastly they will label the Periods within the Paleozoic, Mesozoic and Cenozoic Eras. Here is the Geologic Time Scale Worksheet Answer Key.

6-12 Geologic Time Scale Activity

Scoring rubric for out of 100 points

Name written and papers are aligned correctly	**10 points**
Correctly labeled Eons (5 points each)	**15 points**
Correctly labeled Eras (5 points each)	**15 points**
Correctly labeled Periods (5 points each)	**60 points**

Assessment 2

Students should write an essay describing what the earth would be like in a unit of time of their choosing making sure to include, what life would be found there, how organisms react, the weather conditions, if humans could survive then and why they chose that point in history.

Scoring rubric for out of 100 points

Explain why they chose that time in history	**20 points**
Explain what life they would see	**20 points**
Explain the weather and atmosphere	**20 points**
Explain how organisms interact	**20 points**
Could humans exist in this period of time? Why or why not?	**20 points**

Cross Curricular Extensions

STEM Extension
Have each student pick an Era (Paleozoic, Mesozoic or Cenozoic) within the Phanerozoic Eon and build a model of the periods. They can build their model by hand using items from the classroom or on a computer/tablet. Remind students to be accurate to size of each period.

Math Extension

When creating the Earth's Geologic Timeline to scale (rope activity or Assessment 1), have students figure out math conversions on their own. The rope activity can be more challenging than the Assessment because it uses feet and inches and not the metric system. Students will have to take billions and millions of years and convert them into measurements (feet and inches or centimeters).

Resources

Online Resources and Interactives:

History of life on Earth. Nature – Prehistoric Life. BBC. May 2014. http://www.bbc.co.uk/nature/history_of_the_earth

The Geologic Time Scale. 2003-2008 Calvin & Rosanna Hamilton. http://scienceviews.com/dinosaurs/geologictime.html

Fossiel.net Team. http://english.fossiel.net/information/geologic_timescale.php

Berkeley. Geologic time scale. http://www.ucmp.berkeley.edu/help/timeform.php

The Paleontology Portal. http://paleoportal.org/index.php?globalnav=time_space

Wayman, Erin. *Meet the Contenders for Earliest Modern Human*. Smithsonian Magazine. http://www.smithsonianmag.com/science-nature/meet-the-contenders-for-earliest-modern-human-17801455/?no-ist

Schultz, Colin. Smart News. "How Do We Know the Earth Is 4.6 Billion Years Old?" smithsonian.com. May 16, 2014 http://www.smithsonianmag.com/smart-news/how-do-we-know-earth-46-billion-yearsold-180951483/?no-ist

Mathez, Edmond. EARTH: INSIDE AND OUT. New Press. 2000 American Museum of Natural History. "CASE STUDY: Zircon Chronology: Dating the Oldest Material on Earth"
http://www.amnh.org/education/resources/rfl/web/essaybooks/earth/cs_zircon_chronolgy.html

http://rockofagesnwt.com/cms/science-geological/

Witze, Alexandra. "Lunar rock chemistry supports big-smash theory". Nature. 05 June 2014
http://www.nature.com/news/lunar-rock-chemistry-supports-big-smash-theory-1.15356

"Early planet helped make Moon". Nature 510, 190 (12 June 2014)
http://www.nature.com/nature/journal/v510/n7504/full/510190c.html
http://www.dailygalaxy.com/my_weblog/2007/07/the-theia-hypot.html

Primordial Soup:
Singer, Emily. "How Structure Arose in the Primordial Soup - Researchers are resurrecting ancient proteins to illuminate Earth's biological dark ages." Scientific American. May 19, 2015 http://www.scientificamerican.com/article/how-structure-arose-in-the-primordial-soup/

Single Cell bacteria formation:
Greenfieldboyce , Nell. "Missing Link Microbes May Help Explain How Single Cells Became Us." May 6, 2015
http://www.npr.org/sections/health-shots/2015/05/06/404199792/missing-link-microbes-may-help-explain-how-single-cells-became-us

Stomatolites:
http://www.globalchange.umich.edu/globalchange1/current/lectures/Perry_Samson_lectures/evolution_atm/

Chordates:
NISL - http://planet.uwc.ac.za/nisl/biodiversity/loe/page_83.htm

Amniote eggs:
http://www.ucmp.berkeley.edu/science/eggshell/eggshell4.php

Carboniferous Oxygen:
http://forces.si.edu/atmosphere/02_02_06.html

Extinctions:
http://www.bbc.co.uk/nature/extinction_events
http://www.bbc.co.uk/nature/extinction_causes/Geologic_temperature_record#p00csxbq
http://www.bbc.co.uk/nature/extinction_causes/Clathrate_gun_hypothesis

Super continents:
http://scienceline.ucsb.edu/getkey.php?key=22
http://scienceviews.com/dinosaurs/paleozoic.html

Evolutionary Timeline:
http://www.talkorigins.org/origins/geo_timeline.html
http://scienceviews.com/dinosaurs/geologictime.html

Mesozoic:
http://dinosaurs.about.com/od/dinosaurbasics/a/dinosaurages.htm

The Arthropod Story – Cambrian

http://evolution.berkeley.edu/evolibrary/article/0_0_0/arthropodstory

600 million years – Victoria evolves
http://museumvictoria.com.au/melbournemuseum/discoverycentre/600-million-years/

Fossil Insects – 400 mya
http://museumvictoria.com.au/discoverycentre/infosheets/fossil-insects---400-million-years-of-evolution/

Victorian Marine Fossils - Palaeozoic Era
http://museumvictoria.com.au/discoverycentre/infosheets/marine-fossils/introduction/

Article and Images:
Dance of the Giant Continents:
http://www.burkemuseum.org/static/geo_history_wa/Dance%20of%20the%20Giant%20Continents.htm

The Origin of Tetrapods
http://evolution.berkeley.edu/evolibrary/article/evograms_04

Age of Earth: Creating a Time Line Scaled to the Outline of a Human Body
http://www.burkemuseum.org/static/bshale/ch3.pdf

Burke Museum Kid Activities
http://www.burkemuseum.org/static/bshale/kidsactivities.html

Videos

Evolution videos:
Timeline of Human Evolution Aug. 9, 2013 (3:27) https://www.youtube.com/watch?v=hSSzn4bIwZg

*Human Evolution. (Part 1) Discovery Channel. December 6, 2012. (13:59) (4.6bya – 340 mya)
https://www.youtube.com/watch?v=r_bBEYK_6wE

Human Evolution (Part 2) Discovery Channel Dec. 6, 2012 (13:59) (340mya -17mya)
https://www.youtube.com/watch?v=KRCkI2GhT0E

Human Evolution (Part 3) Discovery Channel Dec. 6, 2012 (13:50) (17mya – 0)
https://www.youtube.com/watch?v=KRCkI2GhT0E