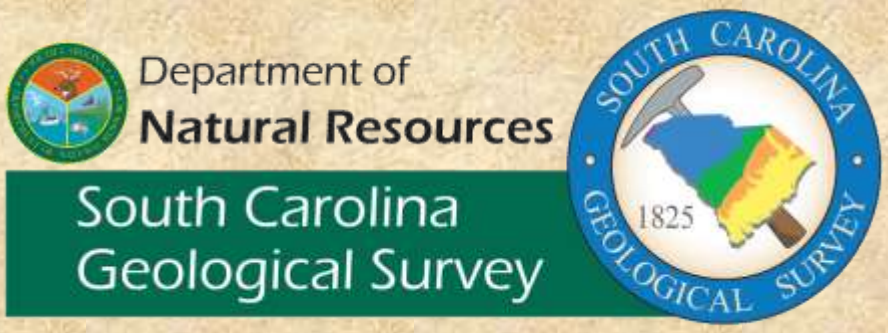
Geologic Time and Earth's Biological History

Designed to meet South Carolina Department of Education 2005 Science Academic Standards



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What is the Geologic Time Scale?

Standard 8-2.4: Recognize the relationship among the units – era, epoch, and period – into which the geologic time scale is divided.

What does the time scale represent?

- The geologic time scale divides up the history of the earth based on life-forms that have existed during specific times since the creation of the planet. These divisions are called **geochronologic units** (*geo*: rock, *chronology*: time).

- Most of these life-forms are found as **fossils**, which are the remains or traces of an organism from the geologic past that has been preserved in sediment or rock. Without fossils, scientists may not have concluded that the earth has a history that long precedes mankind.

- The Geologic Time Scale is divided by the following divisions:

✓ **Eons**: Longest subdivision; based on the abundance of certain fossils

✓ **Eras**: Next to longest subdivision; marked by major changes in the fossil record

✓ **Periods**: Based on types of life existing at the time

✓ **Epochs:** Shortest subdivision; marked by differences in life forms and can vary from continent to continent.

What is the Geologic Time Scale, continued?

- Due to the fact that early geologists had no way of knowing how the discoveries of the Earth were going to develop, geologist over time have put the time scale together piece by piece. Units were named as they were discovered. Sometimes unit names were borrowed from local geography, from a person, or from the type of rock that dominated the unit.

Examples

- Cambrian: From the Latin name for Wales. Named for exposures of strata found in a type-section in Wales by British geologist Adam Sedgwick.
- Devonian: Named after significant outcrops first discovered near Devonshire, England
- Jurassic: Named for representative strata first seen in the Jura Mountains by German geologist Humboldt in 1795)
- Cretaceous: From the Latin "creta" meaning chalk by a Belgian geologist

- The earliest time of the Earth is called the Hadean and refers to a period of time for which we have no rock record, and the Archean followed, which corresponds to the ages of the oldest known rocks on earth. These, with the Proterozoic Eon are called the **Precambrian Eon**. The remainder of geologic time, including present day, belongs to the **Phanerozoic Eon**.

- While the units making up the time scale are called geochronologic units, the actual rocks formed during those specific time intervals are called chronostratigraphic units. The actual rock record of a period is called a system, so rocks from the Cambrian Period are of the Cambrian system.

GEOLOGIC TIME SCALE

MYA	ERA	PERIOD	EPOCH	PLATE TECTONICS	LIFE
0.01	**Cenozoic** "Age of Mammals"	Quaternary	Holocene	Beaches and barrier islands form	-Mastadons become extinct -Human culture flourishes -Accelerating extinction of many species
1.8			Pleistocene	Ice sheets form	-Modern humans develop -Asians arrive and settle the Americas
5.3		Tertiary	Pliocene	-Volcanic activity in North America and Africa -Grand Canyon forms	Hominids develop
23.8			Miocene	Sandhills form in S.C.	Horses, mastadons, mammoths, tigers, and camels live in South Carolina
33.7			Oligocene	Appalachians uplift; erosion increases	Cats, dogs, and apes appear
54.8			Eocene	Sea levels rise; deposits of marine sediments – limestone in S.C.; land bridges form	-Grass spreads widely -Diverse array of animals develop, including whales, rhinos, and elephants
65.0			Paleocene	Earthquakes common; Georgia Embayment, Cape Fear Arch forms in Southeast	-First horses appear (size of a cat) -Tropical plants dominate
144	**Mesozoic** "Age of Reptiles"	Cretaceous		Mass extinction occurs at the end of the period caused by a meteorite impact (Dinosaurs, ammonites and 25% of marine life become extinct)	-T-Rex develops but number of dinosaur species decline -Snakes appear and first primates appear -Angiosperms appear
206		Jurassic		Western US: orogeny of Rockies; North America continues to rotate away from Africa	-First birds appear -Golden age of dinosaurs
248		Triassic		-Pangea begins to break apart -Rocky Mountains and Sierra Nevada form	First dinosaurs, mammals, crinoids, and modern echinoids appear
290		Permian		-Pangea forms -Appalachians rise	-90% of Earth's species become extinct, including trilobites, blastoids, fish and amphibians because of heavy volcanism in Siberia

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320	**Paleozoic** "Age of Invertebrates"	Carboniferous	Pennsylvanian		Great swamps develop (future coal deposits	-Reptiles develop from amphibians -Flying insects appear
354			Mississippian		Much of North America is under water	-First seed plants appear -Sea life flourishes including coral, brachiopods, blastoids, and bryozoa
417		Devonian			Acadian Orogeny – SC metamorphism	-Dominant animals: fish -Amphibians, evergreens and ferns appear
443		Silurian			Extensive erosion	First land plants appear and land animals follow
490		Ordovician			-Beginning of the construction of South Carolina -Great extinction due to growth of ice caps including in what is now northern Africa	-First animals with bones appear -Dominant animals: marine invertebrates including corals and trilobites
540		Cambrian			S.C. near the equator; island arc continues to move toward North America	-Explosion of life -All existing phyla came into being here -Life forms in warm seas as oxygen levels rose enough to support life -Dominant animals: trilobites and brachiopods
4600	**Precambrian** (Hadean, Archean, and Proterozoic Ages)				Earth takes 10 million years to cool: initial atmosphere escapes into space (H&He) and the core forms (Fe&Ni) Volcanic outgassing of water and carbon dioxide occurred for millions of years, helping to build atmosphere and then oceans At 3 billion years ago, banded iron formation rocks appear due to rising oxygen levels in the atmosphere and sea	No life possible as the Earth initially forms 4.6 billion years ago. Simple, single-celled forms of life appear 3.8 billion years ago. They will become more complex and successful over the next 3 billion years: Prokaryotes then Eukaryotes Cyanobacteria begins producing free oxygen (photosynthesis)

Modified after Carolina Rocks, contributed by J. Westmoreland

Principles Behind Geologic Time

- **Nicholas Steno**, a Danish physician (1638-1687), described how the position of a rock layer could be used to show the relative age of the layer. He devised the three main principles that underlie the interpretation of geologic time:

✓ **The principle of superposition**: The layer on the bottom was deposited first and so is the oldest

✓ **The principle of horizontality**: All rock layers were originally deposited horizontally.

✓ **The principle of original lateral continuity**: Originally deposited layers of rock extend laterally in all directions until either thinning out or being cut off by a different rock layer.

- These important principles have formed the framework for the geologic area of stratigraphy, which is the study of layered rock (strata).

Geologist studying the stratigraphy in the Copper Basin, Idaho. These rock layers were deposited horizontally, and uplifted later so they are now tilted at an angle (along the red arrow).
(Photo contributed by K. McCarney-Castle)

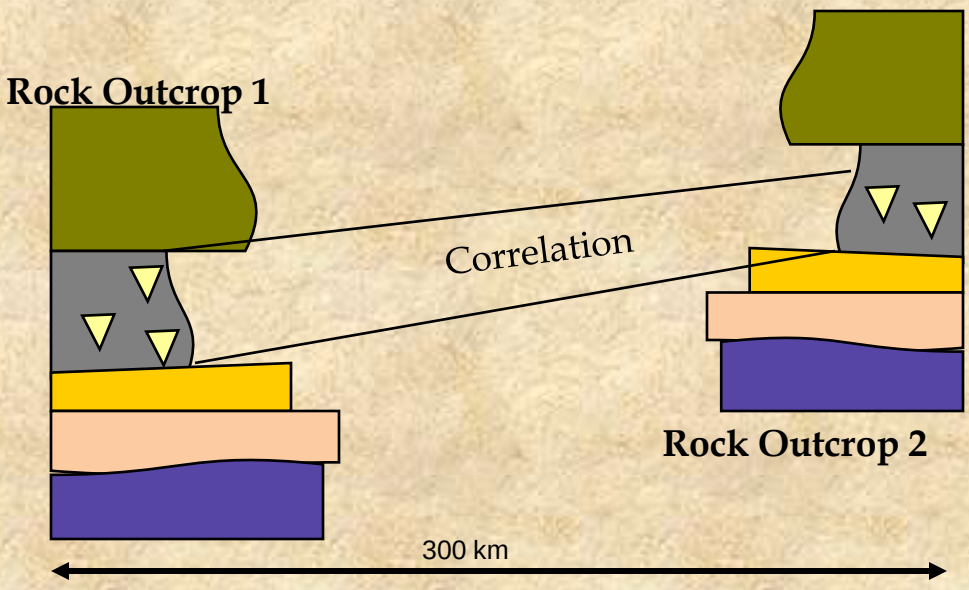
- Decades later, other European scientists rediscovered 'Steno's Laws' and began applying them. Abraham Gottlob Werner became famous for his proposal that all rocks came from the ocean environment. He and his followers were called "Neptunists." An opposing view (by Voisins) argued that all rocks of the earth came from volcanic environments. These scientist were called "plutonists."

Principles Behind Geologic Time, continued

- **James Hutton**, a Scottish physician and geologist (1726-1797), thought the surface of the earth was an ever-changing environment and "the past history of our globe must be explained by what can be seen to be happening now." This theory was called "uniformitarianism," which was later catch-phrased as "the present is the key to the past."

- **William Smith** was a surveyor who was in charge of mapping a large part of England. He was the first to understand that certain rock units could be identified by the particular assemblages of fossils they contained. Using this information, he was able to correlate strata with the same fossils for many miles, giving rise to the principle of biologic succession.

  ✓ **The principle of biologic succession:** Each age in the earth's history is unique such that fossil remains will be unique. This permits vertical and horizontal correlation of the rock layers based on fossil species.



Even though these two outcrops are separated by a large distance, the same rock layer can be correlated with the other because of the presence of the same shark teeth. This lets scientists know that the two layer were deposited at the same time, even if the surrounding rocks look dissimilar from each other.

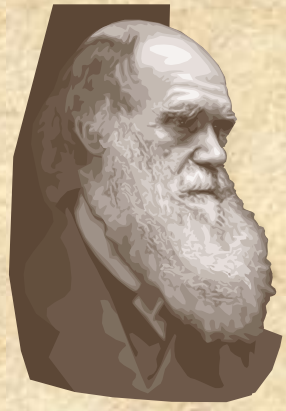
Principles Behind Geologic Time, continued

- During the early 1800's, English Geologist, **Charles Lyell** published a book called "Principles of Geology," which became a very important volume in Great Britain. It included all of Hutton's ideas, and presented his own contemporary ideas such as:

✓ **The principle of cross-cutting relationships**: A rock feature that cuts across another feature must be younger than the rock that it cuts.

✓ **Inclusion principle**: Small fragments of one type of rock but embedded in a second type of rock must have formed first, and were included when the second rock was forming.

- **Charles Darwin** (1809-1882) was an unpaid naturalist who signed up for a 5-yr expedition around the world aboard the H.M.S. Beagle. On this trip, he realized two major points. In spite of all species reproducing, no one species overwhelmed the Earth, concluding that not all individuals produced in a generation survive. He also found that individuals of the same kind differ from one another and concluded that those with the most favorable variations would have the best chance of surviving to create the next generation.



- The theory of natural selection was credited to Darwin (along with Alfred Russel Wallace) and he went on to write the famous "*Origin of Species*." Darwin's two goals in that work were:

1. To convince the world that evolution had occurred and organisms had changed over geologic time
2. The mechanism for this evolution was natural selection.

Relative Age Dating

*Standard 8-2.6: Infer the relative age of rocks and fossils from **index fossils** and the ordering of the rock layers.*

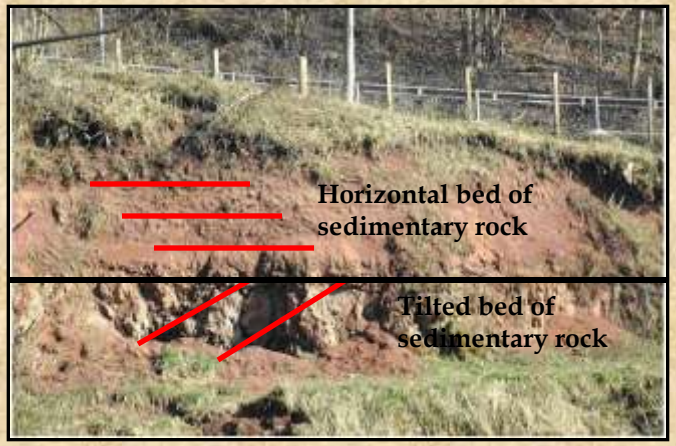
- "Relative age" means the age of one object compared to the age of another, not the exact age of an object. This method can only be used when the rock layers are in their original sequence.

- All six of the original stratigraphic principles may be applied to determine the age of a rock. This process is called age dating. **Correlation** of strata by rock unit type (lithology) or fossil type (biology) using species, composition, or texture leads scientists to extrapolate relationships over large areas of land. Because rock layers can be "matched up," we can guess that they were formed during the same period, so they usually are the same age.

- Using the principles of original horizontality and superposition, we can conclude that oldest rock is always on the bottom because is was deposited 1st.

- Deciphering the sequence of a rock outcrop is sometimes complicated by a features within the rock record called unconformities, which are specific contacts between rock layers. There are three types of unconformities that help us **determine relative ages of rock layers**:

1. **Angular:** Horizontal beds are uplifted and tilted or eroded followed by new deposition of horizontal beds. The figure to the right is an angular unconconformity.
2. **Disconformity**: Episodes of erosion or non-deposition between layers
3. **Nonconformity:** Sediment is deposited on top of eroded volcanic or metamorphic rock (indicates very long passage of time)



Wikipedia (public domain)

- Relative ages can also be determined using Lyell's principle of cross-cutting relationships. In the figure to the right, both the gray and the yellow horizontal strata needed to be in place for the pink layer to cut them, therefore, the pink layer is the youngest. *(Image from Plummer/ McGeary, 7th edition, 1996)*

Relative Age dating with index fossils

- Biostratigraphy is the correlation of stratigraphic units based on fossil content. Biostratigraphically useful species are known as **index fossils** (or guide fossils) because they can be used as guides for recognition of chronostratigraphic units.

- Index fossils are widespread, have short temporal durations resulting from rapid life spans, are abundant throughout their geographic and geologic ranges, and are easily recognized (unique).

- Trilobites are a commonly used index fossil because they are easy to recognize. We know exactly when certain species became extinct, such that we can compare rock layers that contain trilobites with a second rock layer and, based on position, determine if the second rock layer is younger. The photo to the right is a trilobite from the Mississippian period *(photo courtesy of K. McCarney-Castle)*

- Fossils found in many rock layers have lived for long periods of time and cannot be used as index fossils.

Absolute Age Dating

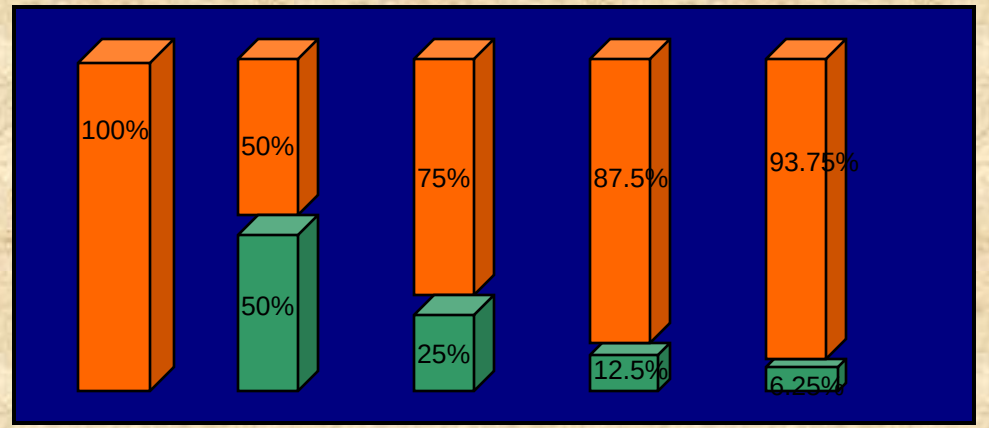
- Absolute ages, or geochronometric ages, of rock can be assigned to the geologic time scale on the basis of properties of atoms that make up the minerals of a rock. Unlike relative dating, which relies on sequencing of rock layers (i.e. younger vs. older), absolute dating can produce an actual age in years.

- The number of neutrons in a nucleus of an atom determines the isotope of the element, just like the number of protons determines the identity of an element.

- Some isotopes are unstable and break down into other isotopes through a process called radioactive decay. Radioactive decay is characterized by beta decay, where a neutron changes into a proton by giving off an electron, and alpha decay, when isotopes give off 2 protons and 2 neutrons in the form of an alpha particle and changes into a new product. The original isotope is called the parent and the new isotope product is called the daughter.

- ***What is a Half-Life?***
  - Each radioactive parent isotope decays to its daughter product at a specific and measurable rate. This measurement is reported in half-lives. The **half-life** of an isotope is the time it takes for ½ of the parent atoms in the isotope to decay.
  - If an isotope has a half-life of 4000 years, then after 4000 years ½ of the parent isotope remains. After another 4000 years, ½ of ½ remains, or ¼ of the original amount of parent isotope. In another 4000 years (12,000 years total), ½ more of the remaining amount decays, so after 3 half-lives, there only remains 1/8 (½ of ½ of ½) of the original parent isotope.
  - If a scientist knows the half-life of the parent and measures the proportion of parent isotope to daughter isotope, he/she can calculate the absolute age of the rock. This valuable method is called **radiometric dating**.

***Note**: Radioactive isotopes can be found in the rock record because radioactive isotopes are incorporated into the crystals of igneous rock as it cools.*



Radioactive Decay

Scientists used the proportion of parent material remaining to the proportion of daughter material produced in order to predict the age of the rock. During each half-life, only one-half of the parent material decays to the daughter product.

- Isotopes with very long half-lives are not suitable for dating rocks younger than ~1 million years because there are too few daughter atoms to be measured accurately.
- Experimental error limits measurements to those rocks younger than about 12 half-lives of the isotope used.

Radiocarbon Dating

- Radiocarbon dating is a common method used to date anything that was once alive (including plants) and up to 70,000 years old.
- All living things take in carbon from the environment in the form of carbon-12 and carbon-14. When an organism dies, carbon intake stops and the carbon-14 begins to decay at a known rate. Scientists can determine how much C-14 remains in an organism by measuring radiation emitted by the C-14 isotopes.
- Carbon dating can be used on wood, plants, humans, and even old paper made out of papyrus.
- The half-life of C-14 is 5,730 years. Because of this, it should not be used with material older than ~70,000 years or 12 half-lives.

Commonly used radioactive isotopes

Parent	Daughter	half-life	Mineral or Material
Uranium238	Lead 206	4.56 BY	Zircon, Uraninite, Pitchblende
Uranium 235	Lead 207	704 MY	Zircon, Uraninite, Pitchblende
Potassium 40	Argon 40	1.251 BY	Muscovite, biotite, hornblende, K-feldspar, volcanic rock, glauconite, conodonts
Rubidium 87	Sr 87	48.8 BY	K-mica, K-feldspar, Biotite, Metamorphics
Thorium 230	Lead 206	75 KY	Ocean sediments
Thorium 232	Lead 208	1.39 BY	Zircon, Uraninite, Pitchblende
Carbon 14	Nitrogen 14	5730 yr	Wood, bone, shell

KY- thousand years. MY- million years. BY- billion years

Uranium-Lead decay series (U-Pb series)

- Unlike carbon-14 dating, uranium dating cannot be used to date formerly living things; however, it is the most commonly used method in igneous rock dating because of the abundance of zircon minerals.
- The subscripts of 235 and 238 are the atomic mass numbers of the element. Though each isotope has 92 protons in its nucleus, U-235 has 143 neutrons and U-238 has 146 neutrons.
- Igneous rocks, or the magma from which it was formed, often intrudes overlying sedimentary rocks. By dating the magma, one can get at least a minimum age for the sedimentary rock.

How Old is Old?

- From the time of Hutton, scientists were convinced that the earth was much older than the 6000 years predicted by the religious scholars.
  - Charles Lyell tried to estimate the age of the earth through the amount of evolution exhibited by marine mollusks in a specific time system.
  - Another method was to estimate the rate of deposition for sedimentary rocks.
  - Sir Edmund Halley proposed to estimate the age of the earth using salt content of the oceans, assuming that the oceans were once non-saline and that salt addition to the oceans corresponded in some linear fashion with time.
  - Lord Kelvin estimated the age of the Earth at 24-40 million years. He proposed that the Earth has been cooling since it formed, and he calculated the rate of cooling using principles of heat conduction.
  - It wasn't until Henri Becquerel discovered radioactivity in 1896 and Madame Curie isolated radium 2 years later that people realized that the Earth had it's own source of heat. Thus it became one of the most useful tools for future scientists.
- The oldest rocks found so far on Earth (based on zircon grains from Australia) have been dated at 4.1-4.2 billion years.
- Meteorites have also been dated at 4.6 billion years. Meteorites are considered to be remnants of a plant or asteroid that originally formed at the same time as the Earth, so that the Earth's age is currently estimated to be 4.6 billion years.
- The oldest fossils are preserved remains of stromatolites, which are layers of lithified blue-green algae, dating to approximately 3.5 billion years before present.

Eons:

Precambrian: Earliest span of time

Phanerozoic: Everything since

Eras:

Paleozoic

Mesozoic

Cenozoic

Periods:

Paleozoic ("Age of Invertebrates")
- Cambrian
- Ordovician
- Silurian
- Devonian
- Carboniferous *(Missipp. & Pennsylvanian)*
- Permian

Mesozoic ("Age of Reptiles")
- Triassic
- Jurassic
- Cretaceous

Cenozoic ("Age of Mammals")
- Paleogene
- Neogene
- Quaternary

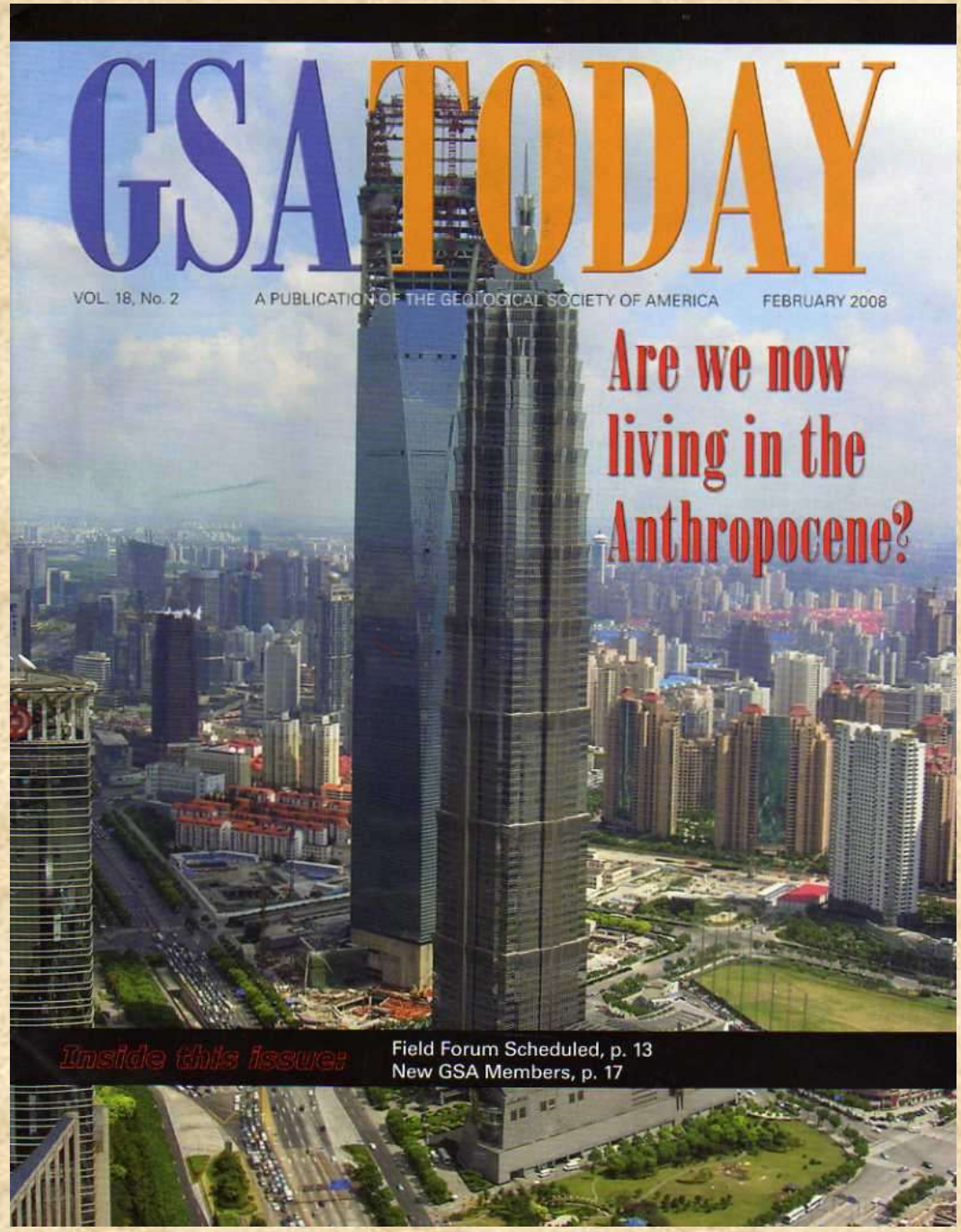
Epochs:

Paleogene
- Paleocene
- Eocene
- Oligocene

Neogene
- Miocene
- Pliocene

Quaternary
- Pleistocene
- Holocene

We are living in the Phanerozoic Eon, Cenozoic Era, Quaternary Period, Holocene Epoch……..BUT



A new concept has been gaining momentum since it's introduction by Paul Crutzen in 2000. He proposed that the Holocene Epoch is over and a new geological epoch called the Anthropocene has begun.

Mans' impact on the Earth's climate and ecosystems since the Industrial Revolution is quite evident. Support for this theory comes from data derived from glacial ice cores showing the growth in greenhouse gases starting from the 1800's.

Does this justify a new Epoch on the Geological Time Scale? Some scientists question this, however, there is no doubt that there has been a shift in Earth's atmosphere and biosphere as we emerge from the most recent ice age which ended approximately 10,000 years ago.

This is strong indication that geologic time is not a thing of the past!

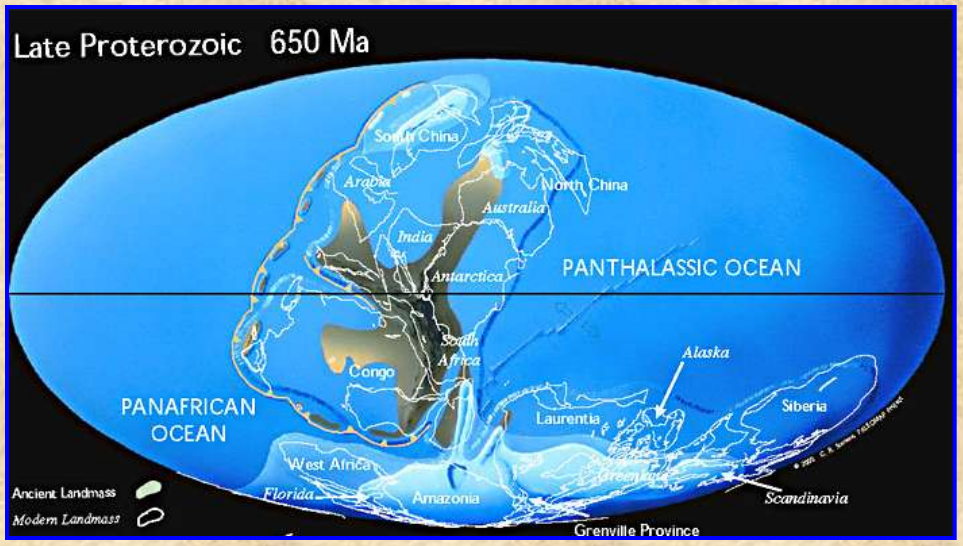
Photo used with permission from the cover of GSA Today, Geological Society of America, Vol. 18, 2, Feb. 2008.

The Earth Through Time

Standard 8-2.5: Illustrate the vast diversity of life that has been present on Earth over time by using the geologic time scale.

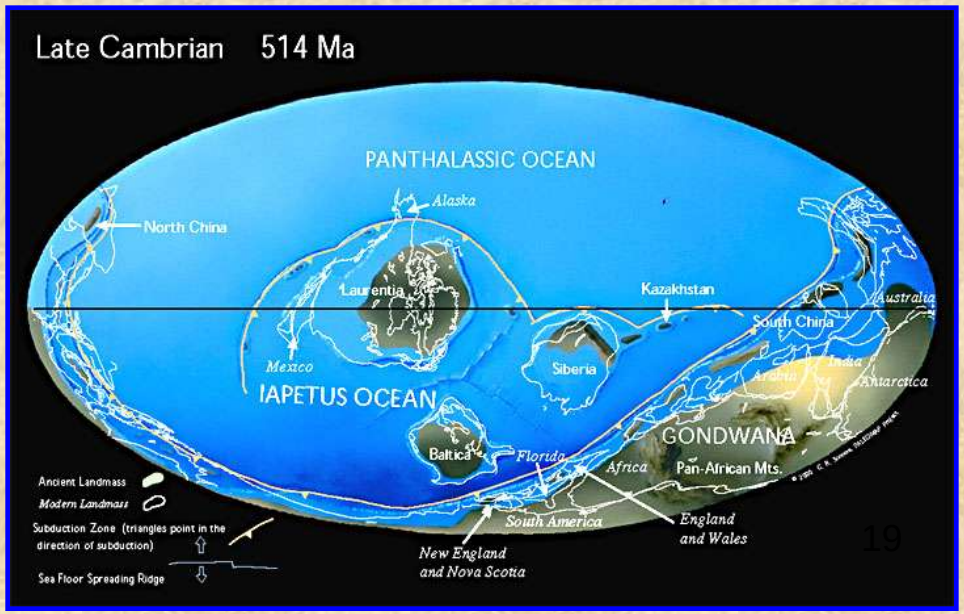
The Proterozoic:

- No life possible as the Earth initially forms 4.6 billion years ago.
- Simple, single-celled forms of life appear 3.8 billion years ago, becoming more complex and successful over the next 3 billion years: Prokaryotes then Eukaryotes
- Cyanobacteria begins producing free oxygen (photosynthesis)
- Land masses gather to make up a continent called "Rodinia"



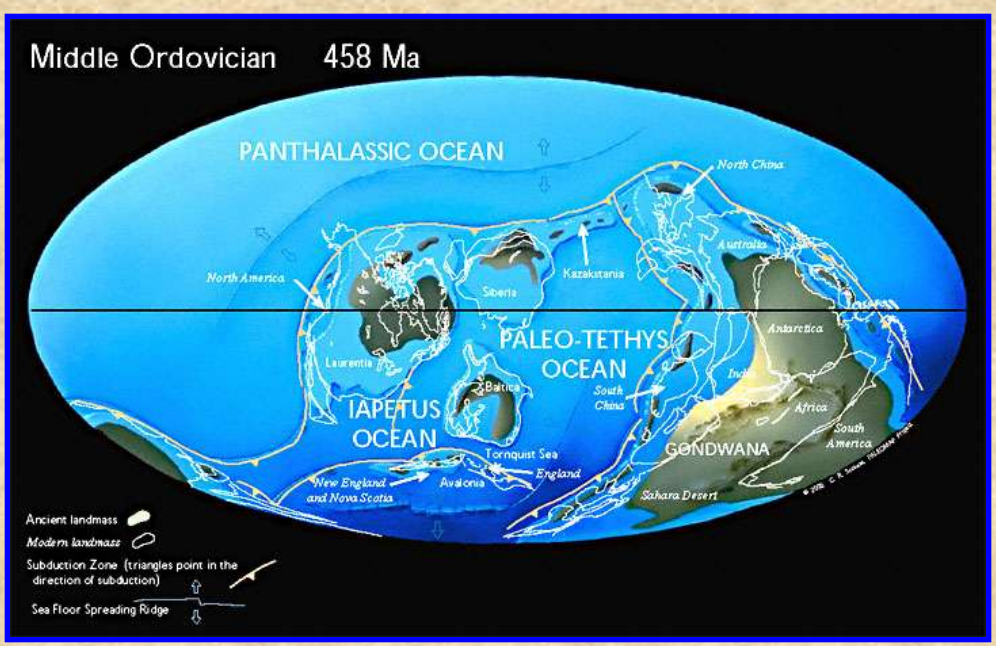
Cambrian:

- Explosion of life
- All existing phyla come into being at this time
- Life forms in warm seas as oxygen levels rise enough to support life
- Dominant animals: Marine invertebrates (trilobites and brachiopods)
- Supercontinent Gondwana forms near the South Pole (note position of present-day Florida)



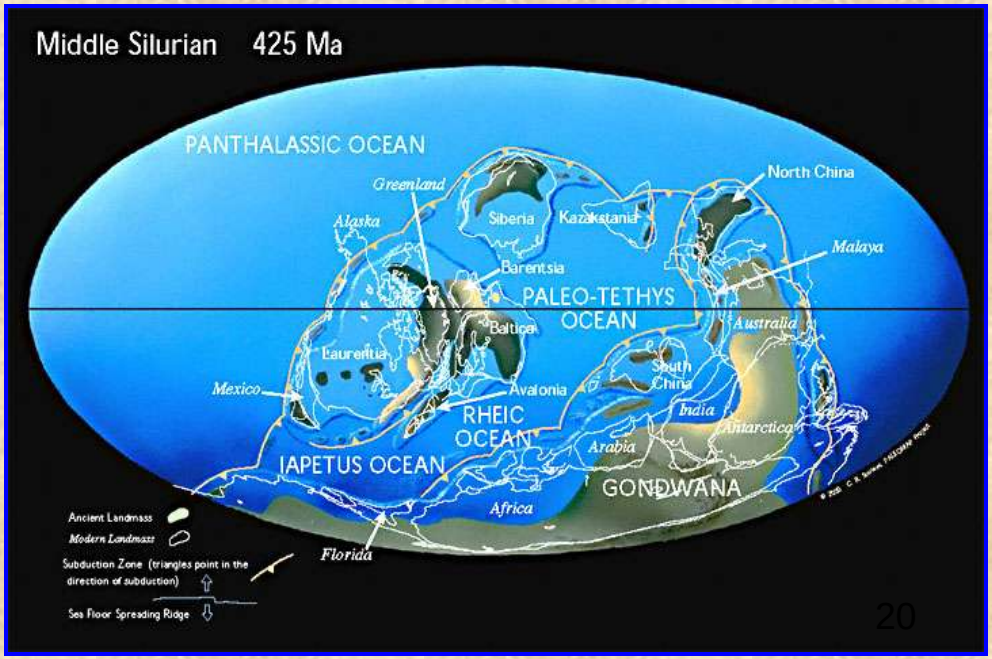
Ordovician:

- The 1st animals with bones appear, though dominant animals are still trilobites, brachiopods and corals
- The beginning of the construction of South Carolina
- A very cold time in Earth's history: there was a great extinction due to ice caps in present-day Africa
- Four main continents: Gondwana, Baltica, Siberia and Laurentia



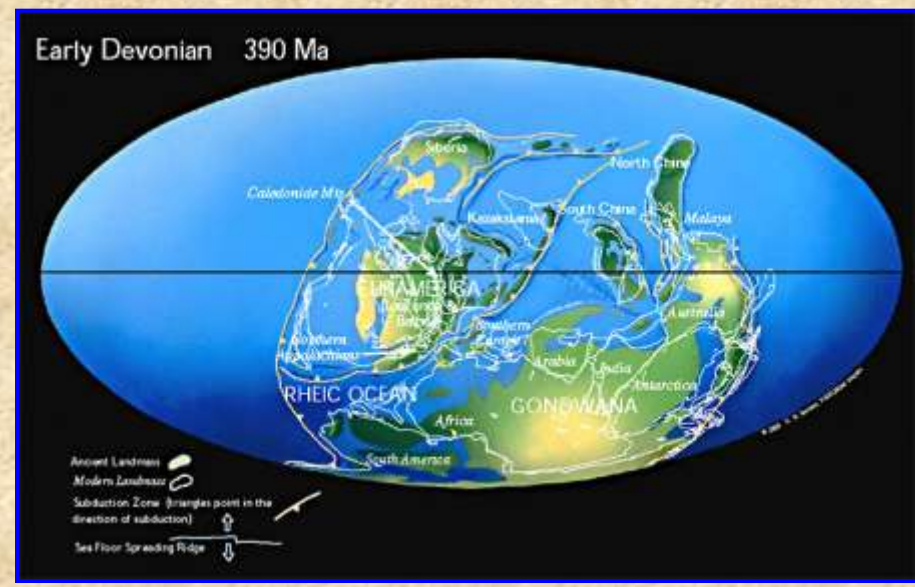
Silurian:

- First land plants appear and land animals follow
- Laurentia collides with Baltica and closes Iapetus Sea.
- Coral reefs expand and land plants begin to colonize barren land.
- First millipede fossils and sea scorpions (Euryptides) found in this period



Devonian (Age of the Fish)

- Pre-Pangea forms. Dominant animal: fish
- Oceans still freshwater and fish migrate from southern hemisphere to North America.
- Present-day Arctic Canada was at the equator and hardwoods began to grow.
- Amphibians, evergreens and ferns appear
- The Acadian Orogeny, leading to S.C. metamorphism



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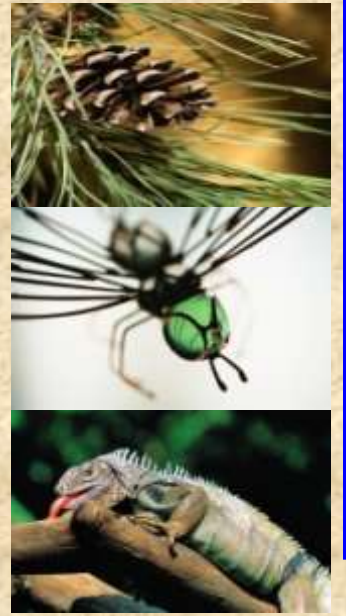
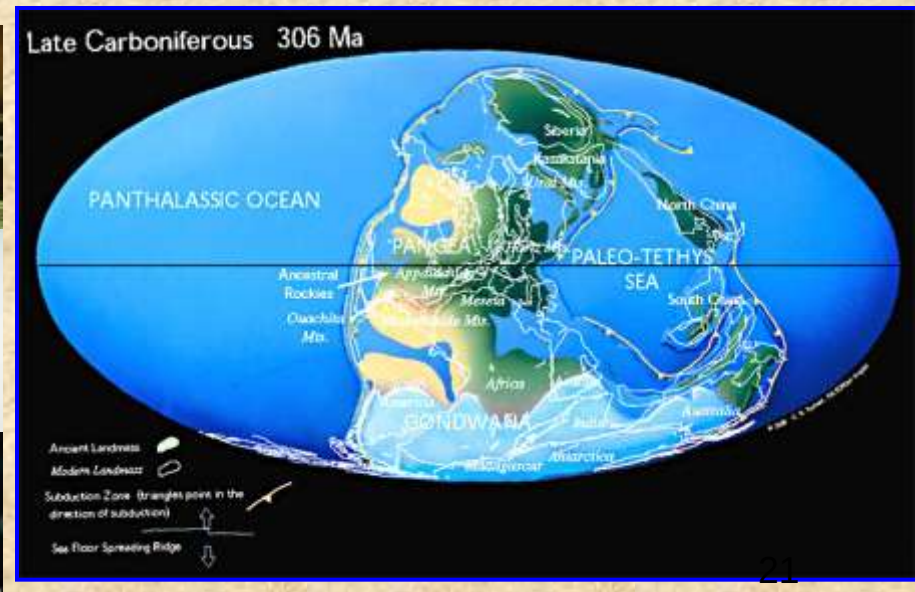
Mississippian:

- First seed plants appear
- Much of North America is covered by shallow seas and sea life flourishes (bryoza, brachipods, blastoids)



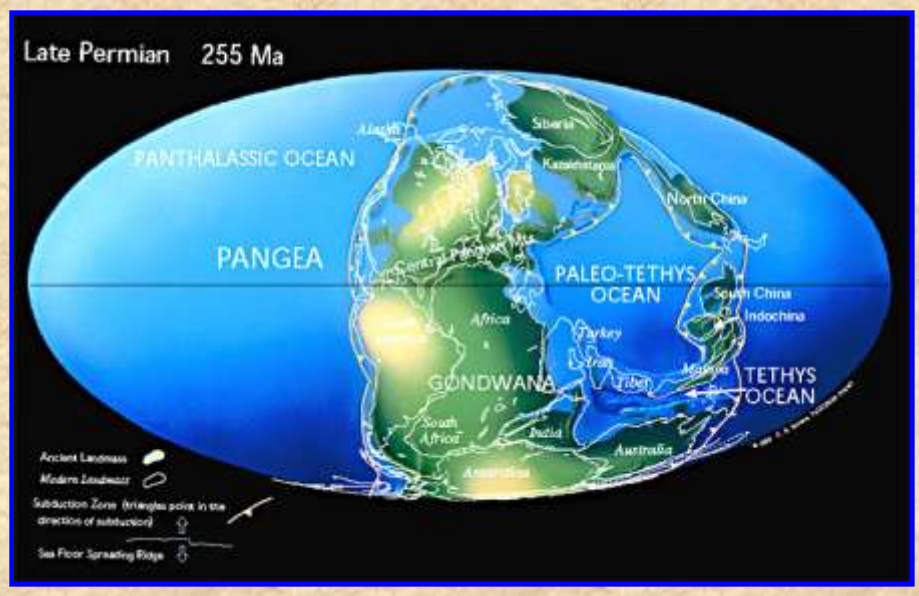


Pennsylvanian:

- Modern North America begins to form
- Ice covers the southern hemisphere and **coal** swamps formed along equator.
- Lizards and winged insects first appear.

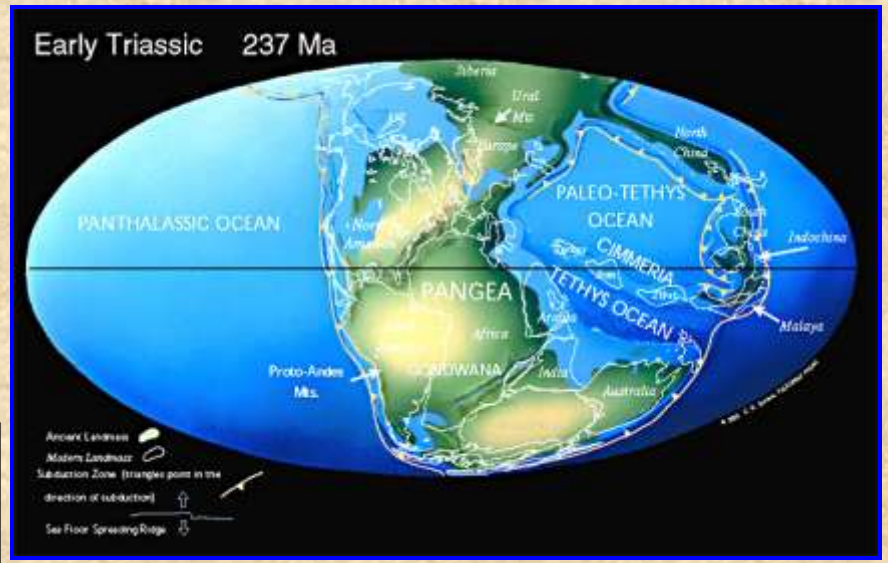
Permian:

- Last period of the Paleozoic
- Pangea forms. Reptiles spread across continents.
- The Appalachians rise
- 90% of Earth's species become extinct due to volcanism in Siberia. This marks the end of trilobites, ammonoids, blastoids, and most fish.



Triassic:

- First dinosaurs appear
- First mammals- small rodents appear
- Life and fauna re-diversify
- Rocky Mountains form.
- First turtle fossil from this period
- Pangea breaks apart



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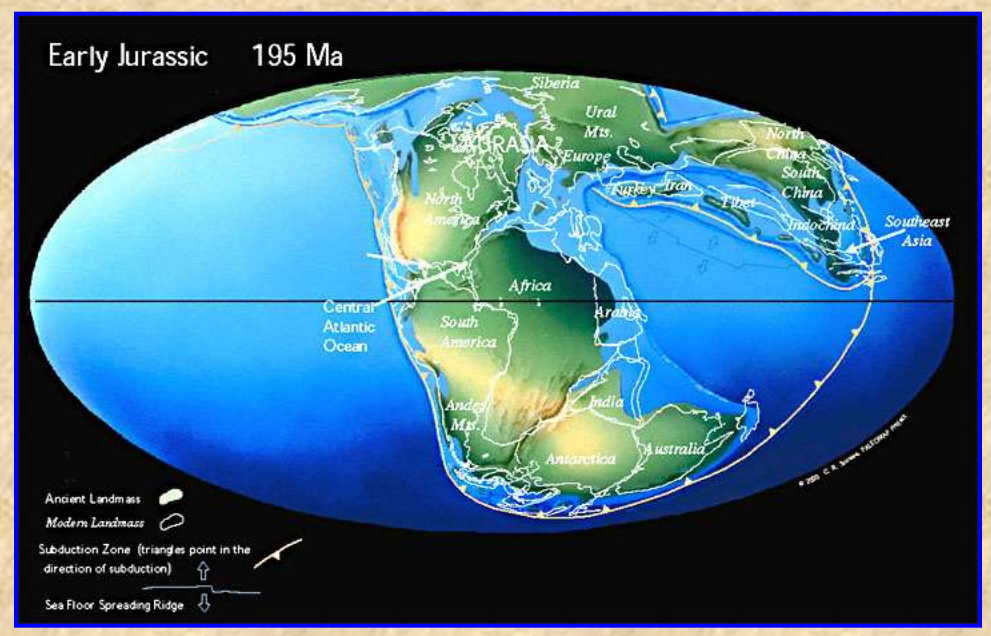
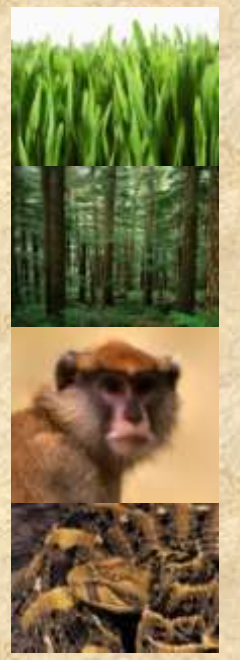
Jurassic:

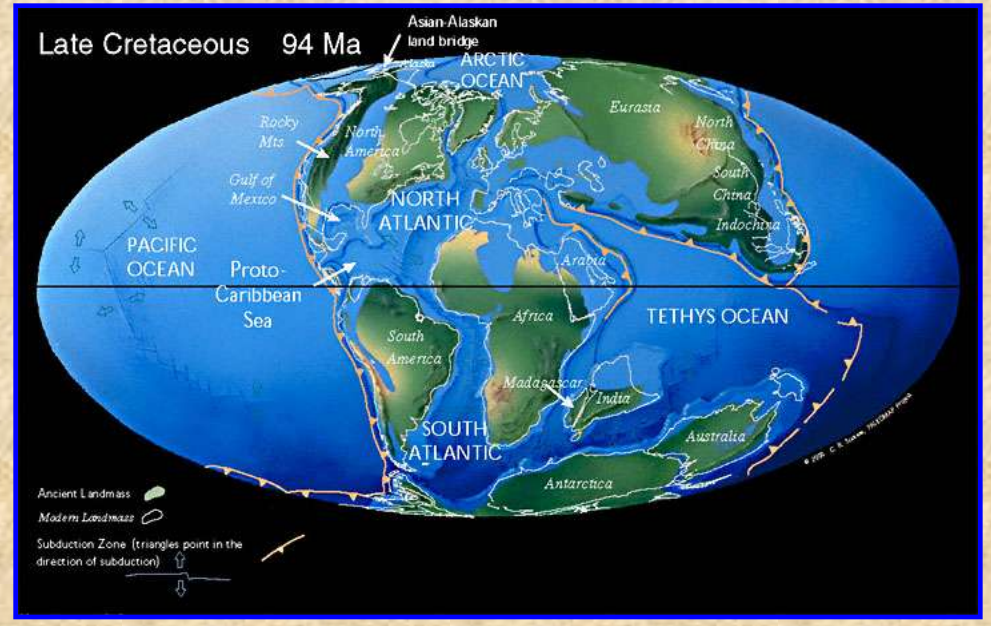
- Pangea still breaking apart
- Dinosaurs flourish "Golden age of dinosaurs"
- First birds appear
- North America continues to rotate away from Africa



Cretaceous:



- T-Rex develops
- First snakes and primates appear
- Deciduous trees and grasses common
- First flowering plants
- Mass extinction marks the end of the Mesozoic Era, with the demise of dinoaurs and 25% of all marine life.

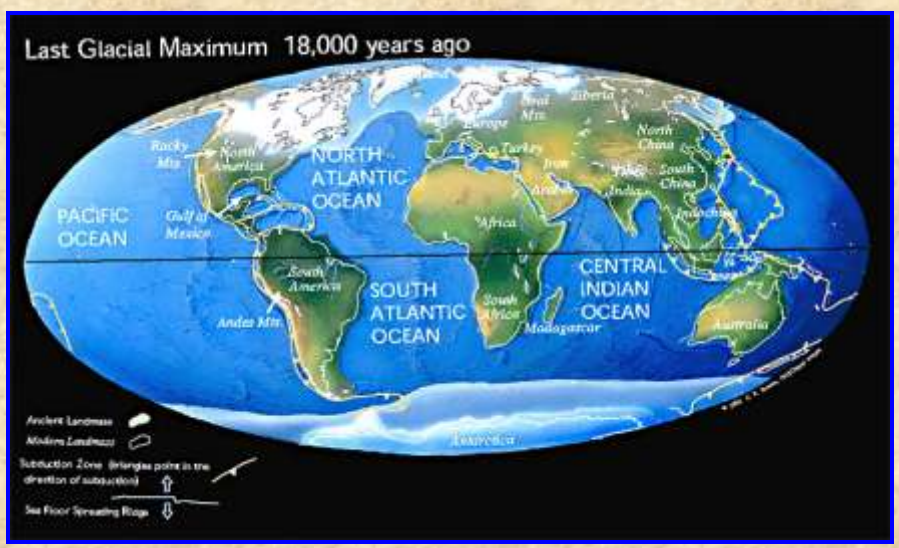


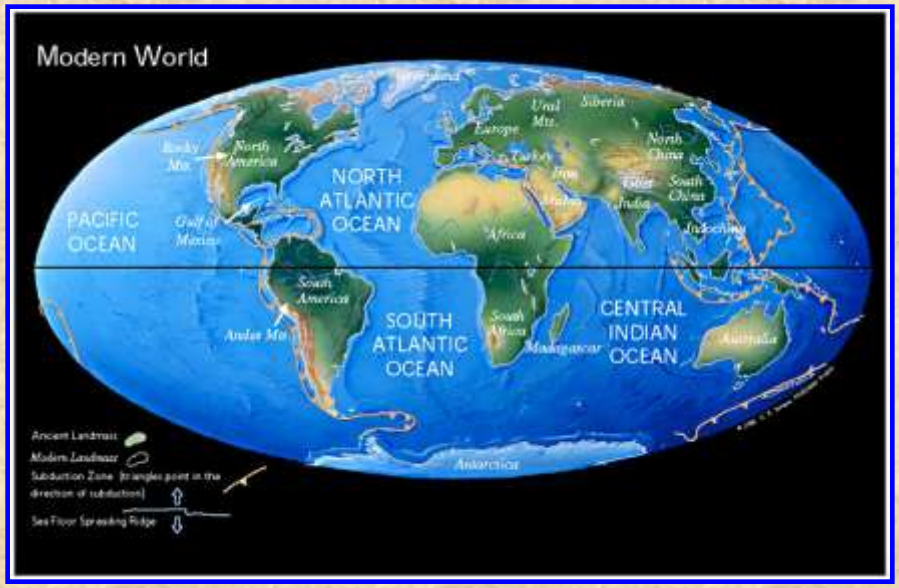
Tertiary:

- First horses appear and tropical plants dominate (Paleocene)
- Grasses spread and whales, rhinos, elephants and other large mammals develop. Sea level rises and limestone deposits form in S.C. (Eocene)
- Dogs, cats, and apes appear (Oligocene)
- Horses, mastadons, camels, and tigers roam free in S.C. (Miocene)
- Hominids develop and the Grand Canyon forms (Pliocene)

Quaternary:

- Modern humans develop and ice sheets are predominant- Ice age (Pleistocene)
- Holocene Humans flourish (Holocene)





Adaptation and 'Survival of the Fittest'

Standard 8-2.1: Explain how biological adaptations of populations enhance their survival in a particular environment.

- Some populations, whether mammals, amphibians, or reptiles are better adapted to living conditions than others, even within the same species, so they are better at surviving than others. Because their chances of surviving are increased, their chances of reproducing offspring are better, and their offspring will possess the same strong traits. This is the basis for natural selection over long periods of time.

- Natural selection refers to the process where over long periods of time, helpful variations can appear in a species while "unfavorable" one disappear. For example, a group of frogs living on the rocky side of an island may, over time, adapt a gray skin color to help blend in with their rocky environment in while a group of frogs living on the more lush, vegetated side of the island may develop a green skin color to blend in with their particular environment. Even though the frogs are of the same species, they are able to incorporate different traits to help them survive in their environments.

- The theory of natural selection, sometimes referred to as 'Survival of the fittest,' started with Charles Darwin's 5-year trip around the world on the HMS Beagle. During this time, he noticed variations within the same species, especially in the Galapagos Turtles, and noted that some of the variations were favorable and some were not. He concluded that not all members of a species survive, which is why the world is not overpopulated by any one species. The practicality of their adaptation must be a determining factor for who survives and who does not. He published his findings on his return to England and wrote the classic work "The Origin of Species."

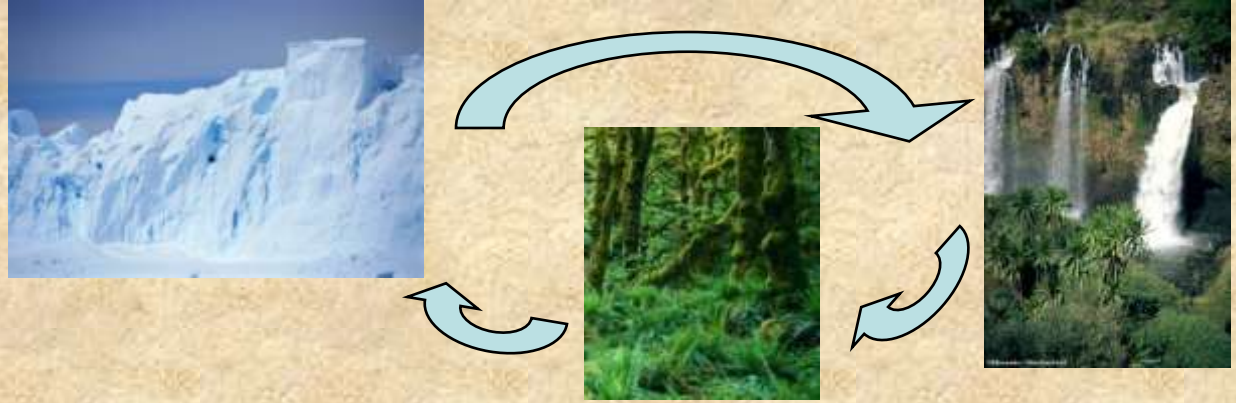
Punctuated Events Through Geologic Time

Standard 8-2.3: Explain how Earth's history has been influenced by catastrophes (including the impact of an asteroid or comet, climatic changes, and volcanic activity) that have affected the conditions on Earth and the diversity of its life-forms.

- Environmental changes on earth are usually an indicator of a species extinction (or a species addition). These changes can be brought about by an asteroid or comet impact, volcanic activity, or climatic changes like the onset of ice ages.

1. Impact:

- The most well-known extinction is the extinction of the dinosaurs. Scientists think that this mass extinction was caused by a large comet that impacted the earth in present-day Mexico, causing a massive quantity of dust to rise up into the atmosphere, possibly blocking out the sun and affecting the oxygen levels Earth. Many plants died, and the animals that depended on those plant for life died as well. In addition, it may have become very cold in a short period of time.
- It took millions of years for the earth to recover, and when it did, the large dinosaurs were gone forever.
- Certain species of birds, however, did survive and began to flourish. Birds are thought to be direct descendants of dinosaurs.



2. Climate Changes

- Climate has always been a constantly changing phenomenon. The earliest atmosphere was devoid of free oxygen, and it wasn't until the earliest life forms evolved that the present-day atmosphere began to form approximately 600 million years ago.
- During the Paleozoic, warm shallow seas and tropical climates were common. Life forms that could not adapt to these conditions disappeared.
- Throughout the Mesozoic era, plate movement shifted the continents and only the animals and plants with the greatest ability to adapt could survive the extreme changes in temperatures that occurred as a consequence. Plants with seed coverings and animals with constant internal temperatures (warm-blooded) lived during this era.
- Climate continued to change during the Cenozoic and continues to change to this day, as issues of "Global Warming" have been on the fore-front for over a decade. It was only ~12,000 years ago that the world was in an "ice age" mode. Also, many mountain ranges formed during this era, causing climate differences due to elevation changes.
- Ice ages have occurred many times in Earth's history. Climate shifts like these may be caused by magnetic polar reversals or variation in the tilt of the earth (called Milankovitch cycles). Obviously, not all life can adapt to the extreme cold. Also, not all animals can adapt to the warming climate at the end of an ice age, which probably contributed to the extinction of the wooly mammoth.

3. Volcanic Activity

- Significant volcanic activity, which produced ash clouds in the air and lava flows on the Earth's surface, was common during the Precambrian. It was extremely hot, and most life forms could not exist in these conditions.
- Volcanism is a common byproduct of tectonic plate collision. If one plate collides with another and is pulled underneath it, a subduction zone is formed underneath the plates and a volcanic arc forms on the Earth's surface. During the Paleozoic and Mesozoic, continents were regularly colliding with each other and volcanism was common. Plate boundaries are still the most common sites of volcanoes today.
- If volcanism is significant enough to produce mass quantities of ash and volatile gases, wind can carry these into the upper atmosphere all around the world, potentially enveloping the earth in semi-darkness and reducing insulation on earth. Obviously, this would have an effect on all living things on Earth.

- A cause and effect phenomenon, catastrophic events impact life on Earth, whether through an extinction or creation of new traits for adaptation to already existing plants and animals.

Why Extinction?

Standard 8-2.7: ***Summarize*** *the factors, both natural and man-made, that can contribute to the extinction of a species.*

- Extinction of a species occurs when no more members of a particular species remains. Extinction through time is very common, and, in fact, nearly 90 percent of all species that ever lived on Earth are now extinct.
- Organisms that cannot survive a catastrophic or significant change in earth's climate usually become extinct. Extinctions are a way of clearing the path for new kinds of life that is potentially more advanced. This is a natural part of life's process.
- Natural phenomena that can contribute to the extinction of a species include global climate changes, volcanic explosions, and celestial impacts.
- The influence of humans on the environment do not include comet impacts or volcanism; however, man has caused extinctions all the same. Over the past few hundred years, man has cut rainforests and woodland forests, destroying natural habitats. Pollution from industrial plants and vehicles has also affected the air we breath and contributed to greenhouse gases, which drive global warming. We are looking at the potential extinction of many species due to this warming trend.
- In addition to threatening less-adaptive creatures than ourselves, man is negatively impacting biological resources that our own species need. Man can adapt to many things with the help of technology.

Standard 8-2.2

The study of Fossils

Summarize *how scientists study Earth's past environment and diverse life-forms by examining different types of fossils (including molds, casts, petrified fossils, preserved and carbonized remains of plants and animals and trace fossils)*

- A fossil is the preserved remains of an organism that has died. Fossils tell scientists, called paleontologists, about living things such as their biology and environmental conditions over earth's history through the rock record. In addition, they give clues to the conditions of the earth (i.e. climate) at the time that the fossil was preserved and possibly relate changes of an organism over time.

- Definitions of fossil types:

  - Mold fossils: when sediments bury an organism and the sediment hardens into rock. The organism decays slowly inside the rock, leaving an cavity in the shape of the organism.

  - Cast fossil: The cavity or mold mentioned above can filled in with mud. When the mud hardens, it takes on the shape of the organism.

  - Petrified fossil or permineralized fossil: Minerals like calcium can soak into the buried remains of an organism. The mineral replaces the remaining bone and changes it into rock.

  - Carbonized fossil: When organism parts are pressed between layers of mud or clay that hardens over time, squeezing the decaying organism away and leaving a carbon imprint in the rock, since all living things contain carbon.

  - Trace fossil: When the mud or sand hardens into rock where a footprint, trail or burrow was left behind.

- The fossil record, like the rock record, is an important record for understanding life on earth before the dawn of man.
- Extinctions and new life forms are also found within the fossil record.
- Fossils can also show structural similarities and differences in organisms over time revealing the diversity of life forms on earth. Nearly 90 percent of organisms that have lived on the earth are now extinct.

Carbon imprint of fish remains, age unknown

A trilobite cast from the Mississippian Period. Extinct.

Brachiopods in a sandstone matrix and an individual brachiopod cast. Extinct.

Belemnite fossil (cast), cut and polished. Related to present-day squid. Extinct.

Ammonite fossil (cast), cut and polished. Related to present-day snail. Extinct.

South Carolina Science Academic Standards: Grade 8

Standard 8-2: The student will demonstrate an understanding of Earth's biological diversity over time. (Life Science, Earth Science)

Indicators

8-2.1 Explain how biological adaptations of populations enhance their survival in a particular environment.

8-2.2 Summarize how scientists study Earth's past environment and diverse life-forms by examining different types of fossils (including molds, casts, petrified fossils, preserved and carbonized remains of plants and animals, and trace fossils).

8-2.3 Explain how Earth's history has been influenced by catastrophes (including the impact of an asteroid or comet, climatic changes, and volcanic activity) that have affected the conditions on Earth and the diversity of its life-forms.

8-2.4 Recognize the relationship among the units—era, epoch, and period—into which the geologic time scale is divided.

8-2.5 Illustrate the vast diversity of life that has been present on Earth over time by using the geologic time scale.

8-2.6 Infer the relative age of rocks and fossils from index fossils and the ordering of the rock layers.

8-2.7 Summarize the factors, both natural and man-made, that can contribute to the extinction of a species.