

# Geological Events

Precambrian Time (4567 to 542 mya)

**Hadean Eon** (4567 to 3800 mya)

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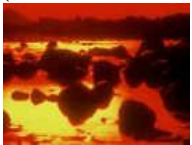


- 4650 mya: Formation of [chondrules](#) in the Solar Nebula
- 4567 mya: Formation of the Solar System Sun was only 70% as bright as today.
- 4500 mya: Formation of the Earth.
- 4450 mya: The Moon accretes from fragments of a collision between the Earth and a planetoid; Moon's orbit is beyond 64,000 km from the Earth.[33] Earth day is 7 hours long[34]
- Earth's original hydrogen and helium atmosphere escapes Earth's gravity.
- 4455 mya: Tidal locking causes one side of the Moon to face the Earth permanently.[30]
- 3900 mya: Cataclysmic meteorite bombardment. The Moon is 282,000 km from Earth.[34] Earth day is 14.4 hours long[34]
- Earth's atmosphere becomes mostly carbon dioxide, water vapor, methane, and ammonia.
- Formation of carbonate minerals starts reducing atmospheric carbon dioxide.
- There is no geologic record for the Hadean Eon.

**Archean Eon** (3800 to 2500 mya)

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- 3800 mya: Surface of the Earth changed from molten to solid rock.
- Water started condensing in liquid form.
- Earth day is 15 hours long
- 3500 mya: Monocellular life started (Prokaryotes). First known oxygen-producing bacteria: cyanobacteria (blue-green algae) form stromatolites



- 3000 mya: Atmosphere has 75% nitrogen, 15% carbon dioxide.
- Sun brightens to 80% of current level.
- Oldest record of Earth's magnetic field.

## **Proterozoic Eon** (2500 to 542 mya)

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### **Paleoproterozoic Era** (2500 to 1600 mya)

#### **Siderian Period** (2500 to 2300 mya)

- Stable continents first appeared.
- 2500 mya: First free oxygen is found in the oceans and atmosphere.



- 2400 mya: Great Oxidation Event, also called the Oxygen Catastrophe. Oxidation precipitates dissolved iron creating banded iron formations.[14]

Anaerobic organisms are poisoned by oxygen.

- 2400 mya: Start of Huronian ice age

#### **Rhyacian Period** (2300 to 2050 mya)

- 2200 mya: Organisms with mitochondria capable of aerobic respiration appear.
- 2100 mya: End of Huronian ice age

#### **Orosirian Period** (2050 to 1800 mya)

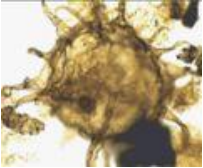
- Intensive orogeny (mountain development)
- 2023 mya: ☀️ Meteor impact, 300 km crater Vredefort, South Africa [9]
- 2000 mya: Solar luminosity is 85% of current level.
- Oxygen starts accumulating in the atmosphere
- 1850 mya: ☀️ Meteor impact, 250 km crater Sudbury, Ontario, Canada [9]

#### **Statherian Period** (1800 to 1600 mya)

- Complex single-celled life appeared.
- Abundant bacteria and archaeans.

## **Mesoproterozoic Era** (1600 to 1000 mya)

### **Calymmian Period** (1600 to 1400 mya)



- Photosynthetic organisms proliferate.
- Oxygen builds up in the atmosphere above 10%.
- Formation of ozone layer starts blocking ultraviolet radiation from the sun.
- 1500 mya: Eukaryotic (nucleated) cells appear.

#### **Ectasian Period** (1400 to 1200 mya)

- Green (Chlorobionta) and red (Rhodophyta) algae abound.

#### **Stenian Period** (1200 to 1000 mya)

- 1200 mya: Spore/gamete formation indicates origin of sexual reproduction.[36]

- 1100 mya: Formation of the supercontinent Rodinia



**Neoproterozoic Era (1000 to 542 mya)**

**Tonian Period (1000 to 850 mya)**

- 1000 mya: Multicellular organisms appear.
- 950 mya: Start of Stuartian-Varangian ice age
- 900 mya: Earth day is 18 hours long.
- The Moon is 350,000 km from Earth.[31]

**Cryogenian Period (850 to 630 mya)**



- 750 mya: Breakup of Rodinia and formation of the supercontinent Pannotia
- 750 mya: End of last magnetic reversal
- 650 mya: \* Mass extinction of 70% of dominant sea plants due to global glaciation ("Snowball Earth" hypothesis).
- The Moon is 357,000 km from Earth.[31]

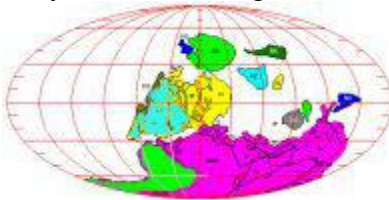


**Ediacaran (Vendian) Period (630 to 542 mya)**

- 600 mya: Earth day is 20.7 hours long.[35]
- 590 mya: ☀ Meteor impact, 90 km crater Acraman, South Australia
- 580 mya: Soft-bodied organisms developed: Jellyfish, Tribrachidium, and Dickinsonia appeared - 570 mya: End of Stuartian-Varangian ice age Shelled invertebrates appeared



- 550 mya: Pannotia fragmented into Laurasia and Gondwana



## Phanerozoic Eon

(542 mya to present)

**Paleozoic Era** (542 to 251 mya)

**Cambrian Period** (542 to 488.3 mya)

- Abundance of multicellular life.
- Most of the major groups of animals first appear

**Tommotian Stage** (534 to 530 mya)

- 510 mya: Vertebrates appeared in the ocean.
- Solar brightness was 6% less than today.

**Ordovician Period** (488.3 to 443.7 mya)



- diverse marine invertebrates, such as trilobites, became common
- First green plants and fungi on land.
- Fall in atmospheric carbon dioxide.
- 450 mya: Start of Andean-Saharan ice age.
- 443 mya: Glaciation of Gondwana.
- \* Mass extinction of many marine invertebrates.
- Second largest mass extinction event.
- 49% of genera of fauna disappeared.

**Silurian Period** (443.7 to 416 mya)



- 420 mya: End of Andean-Saharan ice age.


- Stabilization of the earth's climate
- Land plants and coral reefs appeared
- First fish with jaws - sharks
- Insects (spiders, centipedes), and plants appear on land

**Devonian Period** (416 to 359.2 mya)



- Ferns and seed-bearing plants (gymnosperms) appeared
- Formation of the first forests
- Earth day is ~21.8 hours long.
- 400 mya: Land animals appeared, wingless insects appeared.
- 375 mya: Vertebrates with legs, such as Tiktaalik



- Atmospheric oxygen level is about 16%
- First amphibians appear 
- 374 mya: \* Mass extinction of 70% of marine species. This was a prolonged series of extinctions occurring over 20 million years.
  - Evidence of anoxia in oceanic bottom waters, and global cooling. Surface temperatures dropped from about 93°F (34°C) to about 78°F (26°C)
- 370 mya: First trees appeared
- 359 mya: ☀ Meteor impact, 40 km crater Woodleigh, Australia

### **Carboniferous Period** (359.2 to 299 mya)

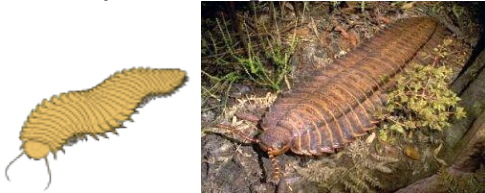
#### **Mississippian Epoch** (359.2 to 318.1 mya)

(Lower Carboniferous)



- 350 mya: Beginning of Karoo ice age.
- Large primitive trees develop
- Forests consist of ferns, club mosses, horsetails, and gymnosperms.
- Oxygen levels increase
- Vertebrates appear on land
- First winged insects.
- Seas covered parts of the continents
- Animals laying amniote eggs appear (318 mya)

#### **Pennsylvanian Epoch** (318.1 to 299 mya)



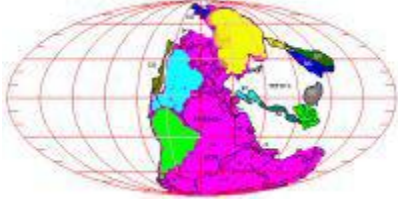
(Upper Carboniferous)

- 300 mya: First reptiles
- Atmospheric oxygen levels reach over 30%
- Earth day is ~22.4 hours long. The Moon is 375,000 km from Earth.[31]
- Giant arthropods populate the land
- Transgression and regression of the seas caused by glaciation
- Deposits of coal form in Europe, Asia, and North America

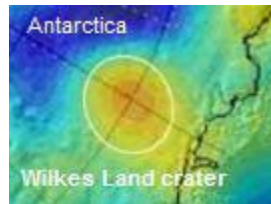
## Permian Period (299 to 251 mya)



- 275 mya: Formation of the supercontinent Pangea




- Conifers and cycads first appear
- Earth is cold and dry
- Sail-backed synapsids like *Edaphosaurus* and *Dimetrodon* appeared
- 260 mya: End of Karoo ice age.
- 251 mya: \* Mass extinction (Permian-Triassic)
- Possible 480km-wide meteor crater in the Wilkes Land region of Antarctica [26]
- Period of great volcanism in Siberia releases large volume of gases ( $\text{CO}_2$ ,  $\text{CH}_4$ , and  $\text{H}_2\text{S}$ ) [8]
- Oxygen ( $\text{O}_2$ ) levels dropped from 30% to 12% Carbon dioxide ( $\text{CO}_2$ ) level was about 2000 ppm  
Temperatures reach 50-60°C on land, and 40°C at the sea-surface.[37]
- Earth's worst mass extinction eliminated 90% of ocean dwellers, and 70% of land plants and animals.



## Mesozoic Era (251 to 65.5 mya)

### Triassic Period (251 to 199.6 mya)



- Break-up of Pangea starts
- 
- Survivors of P-T extinction spread and recolonize



- Reptiles populate the land.
- 240 mya: Sea urchins (*Arkarua*) appear
- 235 mya: Evolutionary split between dinosaurs and lizards
- Giant marine *ichthyosaurs* and *plesiosaurs* populate the seas
- First small dinosaurs such as *coelophysis* appear on land



- *Adelobasileus* proto-mammal emerged (225 mya)
- 214 mya: ☀️ Meteor impact, 100 km crater Manicouagan, Quebec, Canada [9]
- 205 mya: First evidence of mammals: *Morganucodon*
- 201 mya: Volcanism in Central Atlantic Magmatic Province [38]
- \* Mass extinction killed 20% of all marine families

### Jurassic Period (199.6 to 145.5 mya)



- Earth is warm. There is no polar ice
- Cycads, conifers and ginkgoes are the dominant plants
- Age of the dinosaurs
- Giant herbivores and vicious carnivores dominate the land



- Flying reptiles (Pterosaurs) appeared.
- 180 mya: North America separates from Africa
- 167 mya: ☀️ Meteor impact, 80 km crater Puchezh-Katunki, Russia [9]
- 166 mya: Evolutionary split of monotremes from primitive mammals



- 150 mya: First birds like *Archaeopteryx* appear
- 148 mya: Evolutionary split between marsupial and eutherian mammals
- 145 mya: ☀️ Meteor impact, 70 km crater Morokweng, South Africa [9]

### Cretaceous Period (145.5 to 65.5 mya)

- Period of Active Crust Plate Movements
- 133 mya: ☀️ Meteor impact, 55 km crater Tookoonooka, Australia [9]
- 125 mya: Africa and India separate from Antarctica



- Global warming event starts (120 mya)  
Carbon dioxide levels were 550 to 590 ppm [27]
- Flowering plants (angiosperms) appeared
- 110 mya: Crocodiles appeared
- South America breaks away from Africa (105 mya)

Caution: Do not poke T. rex with your pointer



- Formation of the Atlantic Ocean
- Earth has no polar ice
- Birds and oldest group of living placental mammals developed
- 100 mya: Earth's magnetic field is 3 times stronger than today.
- 90 mya: Global warming event ends
- Western Interior Seaway separates North America into Laramidia (west) and Appalachia (east)
- 70 mya: ☀️ Meteor impact, 65 km crater Kara, Russia [9]
- 68 mya: *Tyrannosaurus rex* thrived



- 67 mya: Deccan Traps volcanic eruptions start in India and produce great volume of lava and gases.
- 65.5 mya: ☀️ Meteor impact, 170 km crater Chicxulub, Yucatan, Mexico [9]
- \* Mass extinction of 80-90% of marine species and 85% of land species, including the dinosaurs.

**Cenozoic Era** (65.5 mya to today)

**Paleogene Period** (65.5 to 23.03 mya)

**Tertiary Period** (65.5 to 2.58 mya)



**Paleocene Epoch** (65.5 to 55.8 mya)

- 63 mya: End of Deccan Traps volcanic eruptions in India
- Flowering plants become widespread.
- Social insects achieve ecological dominance.
- Appearance of placental mammals (marsupials, insectivores, lemuroids, creodonts)
- 60 mya: Earliest known ungulate (hoofed mammal)
- Formation of the Rocky Mountains
- 55.8 mya: Major global warming episode (PETM)[39]  
North Pole temperature averaged 23°C (73.4°F),  
CO<sub>2</sub> concentration was 2000 ppm.

**Eocene Epoch** (55.8 to 33.9 mya)

- 50 mya: India meets Asia forming the Himalayas
- 45 mya: Australia separates from Antarctica Earth day is 24 hours long.  
The Moon is 378,000 km from Earth.[32]
- Modern mammals appear rhinoceros, camels, early horses appear
- 35.6 mya: ☀️ Meteor impacts, 90 and 100 km craters Chesapeake Bay, Virginia, USA, and



Popigai, Russia [9,10]

- 34 mya: Global cooling creates permanent Antarctic ice sheet [21]



### Oligocene Epoch (33.9 to 23.03 mya)

- Appearance of many grasses
- First elephants with trunks
- 27.8 mya: La Garita, Colorado supervolcanic eruption

### Neogene Period (23.03 mya to today)

#### Miocene Epoch (23.03 to 5.3 mya)

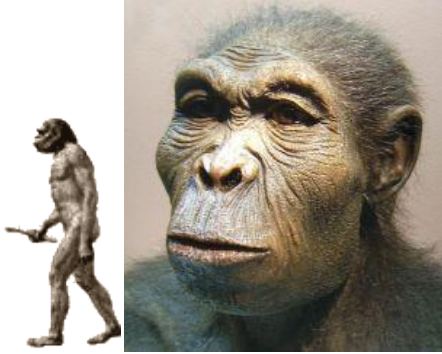
- African-Arabian plate joined to Asia
- 14 mya: Antarctica separates from Australia and South America  
circum-polar ocean circulation builds up Antarctic ice cap.
- Warmer global climates
- First raccoons appear.
- Drying of continental interiors
- Forests give way to grasslands
- 6 mya: Upright walking (bipedal) hominins appear



#### Pliocene Epoch (5.3 to 2.58 mya)

- 4.4 mya: Appearance of *Ardipithecus*, an early hominin genus.
- 4 mya: North and South America join at the Isthmus of Panama.  
Animals and plants cross the new land bridge.  
Ocean currents change in the newly isolated Atlantic Ocean.
- 3.9 mya: Appearance of *Australopithecus*, genus of hominids.
- 3.7 mya: *Australopithecus* hominids inhabit Eastern and Northern Africa.
- 3 mya: Formation of Arctic ice cap.
- Accumulation of ice at the poles
- Climate became cooler and drier.
- Spread of grasslands and savannas
- Rise of long-legged grazing animals

## Quaternary Period (2.58 mya to today)



### Pleistocene Epoch (2.58 mya to 11,400 yrs ago)

- Several major episodes of global cooling, or glaciations
- 2.4 mya: *Homo habilis* appeared
- 2.1 mya: Yellowstone supervolcanic eruption
- 2 mya: Tool-making humanoids emerge.  
Beginning of the Stone Age.
- 1.7 mya: *Homo erectus* first moves out of Africa
- 1.3 mya: Yellowstone supervolcanic eruption
- 1.3 mya to 820,000 yrs ago: Sherwin Glaciation
- Presence of large land mammals and birds
- 700,000 yrs ago: Human and Neanderthal lineages start to diverge genetically.
- 680,000 to 620,000 yrs ago: Günz/Nebraskan glacial period
- 640,000 yrs ago: Yellowstone supervolcanic eruption
- 530,000 yrs ago: [Development of speech in \*Homo Heidelbergensis\*](#)[15]
- 455,000 to 300,000 yrs ago: Mindel/Kansan glacial period
- 400,000 yrs ago: Hominids hunt with wooden spears  
and use stone cutting tools.
- 370,000 yrs ago: Human ancestors and Neanderthals  
are fully separate populations.



- 300,000 yrs ago: Hominids use controlled fires
- 230,000 yrs ago: Neanderthal man spreads through Europe
- 200,000 to 130,000 yrs ago: Riss/Illinoian glacial period
- 160,000 yrs ago: *Homo sapiens* appeared.  
Origin of human female lineage (Mitochondrial Eve)
- 125,000 yrs ago: Eemian stage or Riss/Würm interglacial period.  
Hardwood forests grew above the Arctic Circle.  
Melting ice sheets increased sea level by 6 meters (20 feet)
- 110,000 yrs ago: Start of Würm/Wisconsin glacial period
- 105,000 yrs ago: Stone age humans forage for grass seeds such as sorghum.
- 80,000 yrs ago: Non-African humans interbreed with Neanderthals[28]
- 74,000 yrs ago: Toba volcanic eruption  
releases large volume of sulfur dioxide
- *Homo sapiens* reduced to about 10,000 individuals.
- 70,000 yrs ago: *Tahoe* glacial maximum  
glaciers cover Canada and northern US.




- 60,000 yrs ago: Oldest male ancestor of modern humans[3]

- 46,000 yrs ago: Australia becomes arid, bush fires destroy habitat, and megafauna die off.
- 40,000 yrs ago: *Cro-Magnon* man appeared in Europe.
- 28,000 yrs ago: Neanderthals disappear from fossil record.[29]
- 26,500 yrs ago: Taupo supervolcanic eruption in New Zealand
- 22,000 yrs ago: *Tioga* glacial maximum sea level was 130 meters lower than today
- 20,000 yrs ago: Invention of fired ceramic pottery.
- 19,000 yrs ago: Antarctic sea ice starts melting.[22]
- 15,000 yrs ago: Bering land bridge between Alaska and Siberia



allows human migration to America

- 12,900 yrs ago:  [Explosion of comet over Canada](#) [23, 24, 25] causes extinction of American megafauna such as the mammoth and sabretooth cat (*Smilodon*), as well as the end of Clovis culture
- 11,400 yrs ago: End of Würm/Wisconsin glacial period. Sea level rises by 91 meters (300 ft)

### **Holocene Epoch** (11,400 years ago to today)

- Development of agriculture
- Domestication of animals.
- 9,000 yrs ago: Metal smelting started
- 5,500 yrs ago: Invention of the wheel



- 5,300 yrs ago: The Bronze Age
- 5,000 yrs ago: Development of writing
- 4,500 yrs ago: Pyramids of Giza
- 3,300 yrs ago: The Iron Age
- 2,230 yrs ago: Archimedes advances mathematics
- 250 yrs ago: Start of the Industrial Revolution
- 50 yrs ago: Space travel  
Artificial satellite orbits the earth (1957).  
Humans walk on the surface of the moon (1969).