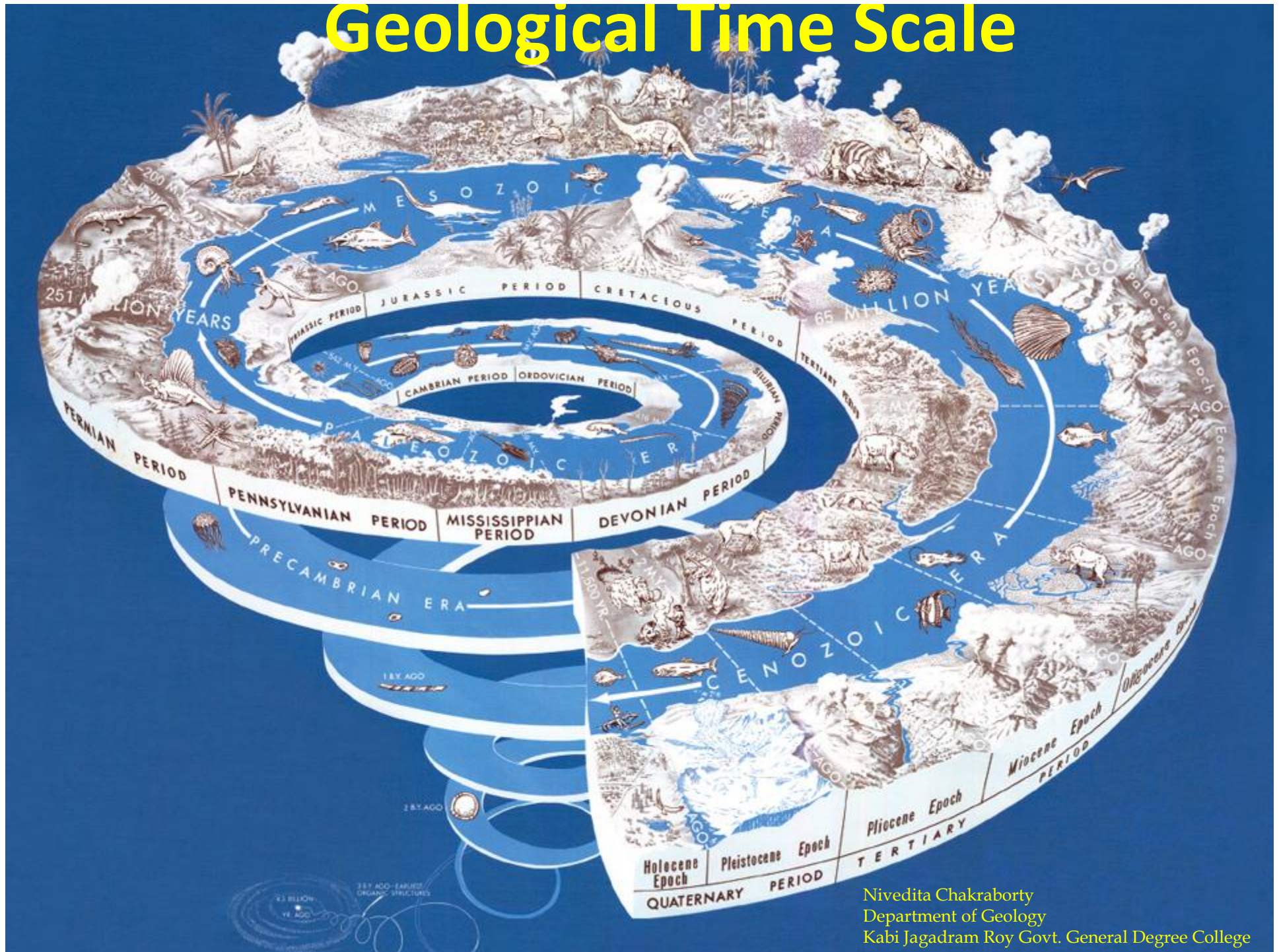


Geological Time Scale



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GEOLOGICAL TIME

Relating time in geology:

- **Relative:** Placing events in a sequence based on their position in geological record.
- **Chronological:** placing a specific number of years on an event or rock sample.

GEOLOGICAL TIME SCALE

A combination of both types of age determination:

- A relative sequence of lithological units; established using logical principles
- Measured against a framework of chronology.

What is the Earth's time scale?

- The **Geological time scale** is a record of the life forms and geological events in Earth's history.
- Scientists developed the time scale by studying rock layers and fossils world wide.
- Radioactive dating helped to determine the absolute divisions in the time scale.

Decay

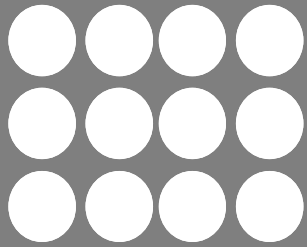
Unstable nuclei in parent isotope emits subatomic particles and transform into another isotopic element (daughter).

does so at a known rate, measured in the lab

Half-life

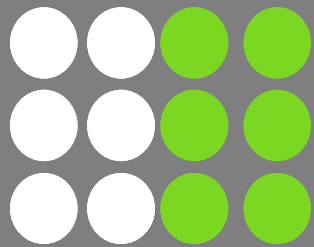
The amount of time needed for one-half of a radioactive parent to decay into daughter isotope.

Rate of Decay



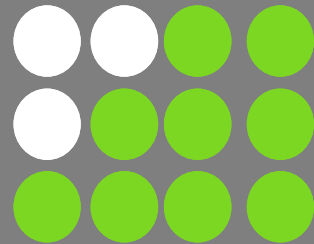
t_0

All atoms are parent isotope or some known ratio of parent to daughter



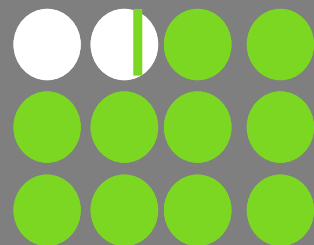
t_1

1 half-life period has elapsed, half of the material has changed to a daughter isotope (6 parent: 6 daughter)



t_2

2 half-lives elapsed, half of the parent remaining is transformed into a daughter isotope (3 parent: 9 daughter)

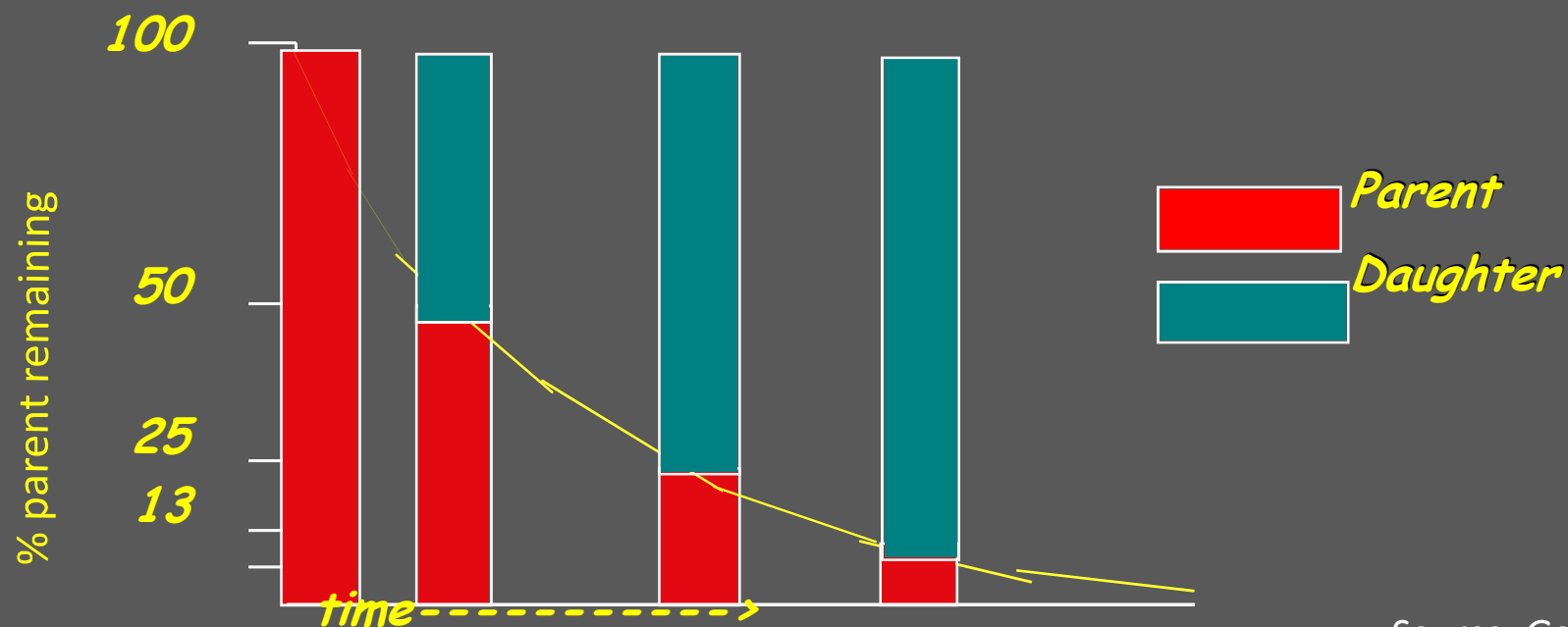


t_3

3 half-lives elapsed, half of the parent remaining is transformed into a daughter isotope (1.5 parent: 10.5 daughter)
We would see the rock at this point.

Radioactive Isotopes

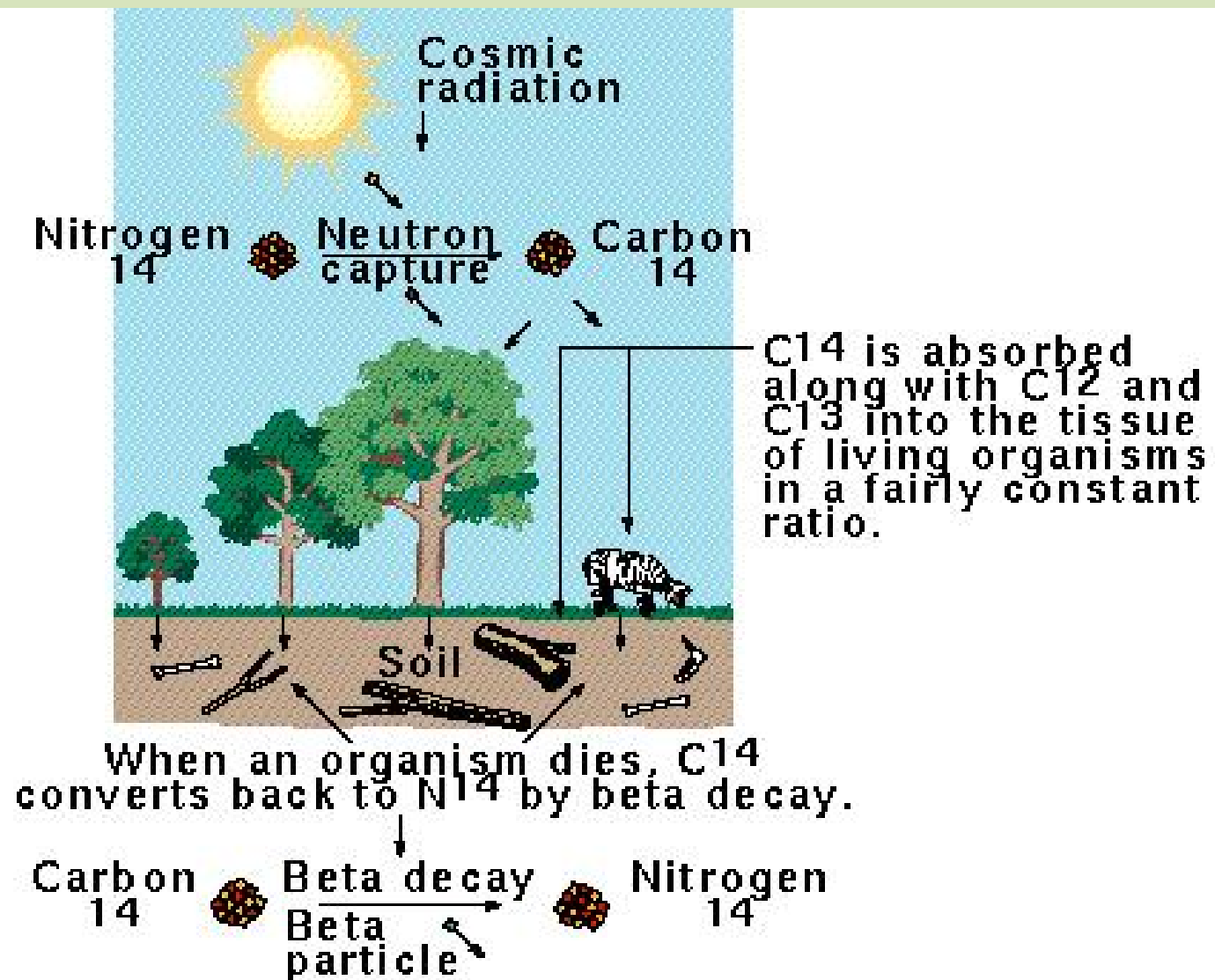
- analogous to sand in an hour glass
 - we measure how much sand there is
 - > represents the mass of elements
 - we measure the ratio of sand in the bottom to sand in the top
 - at the end (present)
 - > daughter (b) and parent (t)
 - we know at what rate the sand falls into the bottom
 - > the half life of the radioactive element
 - how long would it take to get the amount sand in the observed ratio starting with all of it in the top?



Five Radioactive Isotope Pairs

Isotopes		Half-Life (Years)	Effective Dating Range of Parent (Years)	Minerals and Rocks That Can Be Dated
<i>Parent</i>	<i>Daughter</i>			
Uranium 238	Lead 206	4.5 billion	10 million to 4.6 billion	Zircon Uraninite
Uranium 235	Lead 207	704 million		
Thorium 232	Lead 208	14 billion	48.8 billion	Muscovite Biotite
Rubidium 87	Strontium 87	4.6 billion	10 million to 4.6 billion	Potassium feldspar Whole metamorphic or igneous rock
Potassium 40	Argon 40	1.3 billion	100,000 to 4.6 billion	Glaucinite Muscovite Biotite Hornblende Whole volcanic rock

Carbon-14 dating is based on the ratio of C-14 to C-12 in an organic sample





INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

www.stratigraphy.org

International Commission on Stratigraphy

v 2018/08



Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Cenozoic	Quaternary	Holocene	Meghalayan	present	0.0000
				Northgrippian	0.0002	0.0002
				Greenlandian	0.0117	0.0117
		Pleistocene	Upper	Calabrian	0.126	0.126
				Gelasian	0.781	0.781
				Calabrian	1.80	1.80
		Pliocene	Middle	Gelasian	2.58	2.58
				Piacenzian	3.600	3.600
				Zanclean	5.333	5.333
	Neogene	Miocene	Lower	Tortonian	7.246	7.246
				Serravallian	11.63	11.63
				Langhian	13.82	13.82
				Burdigalian	15.97	15.97
				Aquitanian	20.44	20.44
				Chattian	23.03	23.03
		Oligocene	Upper	Rupelian	27.82	27.82
				Priabonian	33.9	33.9
				Bartonian	37.8	37.8
				Lutetian	41.2	41.2
				Ypresian	47.8	47.8
				Thanetian	56.0	56.0
	Paleogene	Paleocene	Lower	Selandian	59.2	59.2
				Danian	61.6	61.6
				Maastrichtian	66.0	66.0
		Eocene	Upper	Campanian	72.1 ± 0.2	72.1 ± 0.2
				Santonian	83.6 ± 0.2	83.6 ± 0.2
				Coniacian	86.3 ± 0.5	86.3 ± 0.5
Mesozoic	Cretaceous	Upper	Lower	Turonian	89.8 ± 0.3	89.8 ± 0.3
				Cenomanian	93.9	93.9
				Albian	100.5	100.5
				Aptian	~ 113.0	~ 113.0
				Barremian	~ 125.0	~ 125.0
				Hauterivian	~ 129.4	~ 129.4
		Lower	Upper	Valanginian	~ 132.9	~ 132.9
				Berriasian	~ 139.8	~ 139.8
					~ 145.0	~ 145.0

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Mesozoic	Jurassic	Upper	Tithonian	152.1 ± 0.9	152.1 ± 0.9
				Kimmeridgian	157.3 ± 1.0	157.3 ± 1.0
				Oxfordian	163.5 ± 1.0	163.5 ± 1.0
		Middle	Lower	Callovian	166.1 ± 1.2	166.1 ± 1.2
				Bathonian	168.3 ± 1.3	168.3 ± 1.3
				Bajocian	170.3 ± 1.4	170.3 ± 1.4
	Triassic	Lower	Upper	Aalenian	174.1 ± 1.0	174.1 ± 1.0
				Toarcian	182.7 ± 0.7	182.7 ± 0.7
				Pliensbachian	190.8 ± 1.0	190.8 ± 1.0
				Sinemurian	199.3 ± 0.3	199.3 ± 0.3
				Hettangian	201.3 ± 0.2	201.3 ± 0.2
				Rhaetian	~ 208.5	~ 208.5
		Upper	Lower	Norian	~ 227	~ 227
				Carnian	~ 237	~ 237
				Ladinian	~ 242	~ 242
				Anisian	247.2	247.2
				Olenekian	251.2	251.2
				Induan	251.902 ± 0.024	251.902 ± 0.024
Phanerozoic	Paleozoic	Permian	Upper	Changhsingian	254.14 ± 0.07	254.14 ± 0.07
				Wuchiapingian	259.1 ± 0.5	259.1 ± 0.5
				Capitanian	265.1 ± 0.4	265.1 ± 0.4
				Wordian	268.8 ± 0.5	268.8 ± 0.5
				Roadian	272.95 ± 0.11	272.95 ± 0.11
				Kungurian	283.5 ± 0.6	283.5 ± 0.6
	Carboniferous	Permian	Lower	Artinskian	290.1 ± 0.26	290.1 ± 0.26
				Sakmarian	293.52 ± 0.17	293.52 ± 0.17
				Asselien	298.9 ± 0.15	298.9 ± 0.15
				Gzhelian	303.7 ± 0.1	303.7 ± 0.1
				Kasimovian	307.0 ± 0.1	307.0 ± 0.1
				Moscovian	315.2 ± 0.2	315.2 ± 0.2
Paleozoic	Carboniferous	Mississippian	Upper	Bashkirian	323.2 ± 0.4	323.2 ± 0.4
				Serpukhovian	330.9 ± 0.2	330.9 ± 0.2
				Visean	346.7 ± 0.4	346.7 ± 0.4
				Tournaisian	358.9 ± 0.4	358.9 ± 0.4

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Mesozoic	Devonian	Upper	Famennian	372.2 ± 1.6	372.2 ± 1.6
				Frasnian	382.7 ± 1.6	382.7 ± 1.6
				Givetian	387.7 ± 0.8	387.7 ± 0.8
		Middle	Lower	Eifelian	393.3 ± 1.2	393.3 ± 1.2
				Emsian	407.6 ± 2.6	407.6 ± 2.6
				Pragian	410.8 ± 2.8	410.8 ± 2.8
	Paleozoic	Silurian	Upper	Lochkovian	419.2 ± 3.2	419.2 ± 3.2
				Pridoli	423.0 ± 2.3	423.0 ± 2.3
				Ludlow	425.6 ± 0.9	425.6 ± 0.9
				Gorstian	427.4 ± 0.5	427.4 ± 0.5
				Homerian	430.5 ± 0.7	430.5 ± 0.7
				Sheinwoodian	433.4 ± 0.8	433.4 ± 0.8
Phanerozoic	Paleozoic	Silurian	Lower	Telychian	438.5 ± 1.1	438.5 ± 1.1
				Aeronian	440.8 ± 1.2	440.8 ± 1.2
				Rhuddanian	443.8 ± 1.5	443.8 ± 1.5
				Hirnantian	445.2 ± 1.4	445.2 ± 1.4
		Ordovician	Upper	Katian	453.0 ± 0.7	453.0 ± 0.7
				Sandbian	458.4 ± 0.9	458.4 ± 0.9
	Paleozoic	Ordovician	Middle	Darriwilian	467.3 ± 1.1	467.3 ± 1.1
				Dapingian	470.0 ± 1.4	470.0 ± 1.4
				Floian	477.7 ± 1.4	477.7 ± 1.4
				Tremadocian	485.4 ± 1.9	485.4 ± 1.9
		Cambrian	Lower	Stage 10	~ 489.5	~ 489.5
				Jiangshanian	~ 494	~ 494
				Paibian	~ 497	~ 497
				Guzhangian	~ 500.5	~ 500.5
				Drumian	~ 504.5	~ 504.5
				Wuliuan	~ 509	~ 509
Phanerozoic	Paleozoic	Cambrian	Series 2	Stage 4	~ 514	~ 514
				Stage 3	~ 521	~ 521
				Stage 2	~ 529	~ 529
		Terreneuvian	Lower	Fortunian	541.0 ± 1.0	541.0 ± 1.0

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Proterozoic	Neoproterozoic	Upper	Ediacaran	~ 635	~ 635
				Cryogenian	~ 720	~ 720
				Tonian	1000	1000
		Mesoproterozoic	Lower	Stenian	1200	1200
				Ectasian	1400	1400
				Calymnian	1600	1600
	Archean	Paleoproterozoic	Upper	Statherian	1800	1800
				Orosirian	2050	2050
				Rhyacian	2300	2300
				Siderian	2500	2500
		Neoarchean	Lower	Neoarchean	2800	2800
				Mesoarchean	3200	3200
				Paleoarchean	3600	3600
				Neoarchean	4000	4000
		Hadean	Lower	Hadean	~ 4600	~ 4600

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website <http://www.stratigraphy.org>. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (–) is provided.

Ratified Subseries/Subepochs are abbreviated as U/L (Upper/Late), M (Middle) and L/E (Lower/Early). Numerical ages for all systems except Quaternary, upper Paleogene, Cretaceous, Triassic, Permian and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012); those for the Quaternary, upper Paleogene, Cretaceous, Triassic, Permian and Precambrian were provided by the relevant ICS subcommissions.

Colouring follows the Commission for the Geological Map of the World (<http://www.cgmw.org>)

Chart drafted by K.M. Cohen, D.A.T. Harper, P.L. Gibbard, J.-X. Fan (c) International Commission on Stratigraphy, August 2018

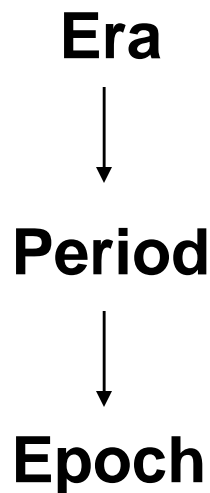
To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

URL: <http://www.stratigraphy.org/ICSChart/ChronostratChart2018-08.pdf>



Divisions of Geologic Time: Eons

Eons are divided into Eras. Eras are subdivided into periods...periods are subdivided into epochs.



ERA	PERIOD	START OF EACH PERIOD (in millions of years)	FLORA & FAUNA
Cenozoic	Quaternary	1	Modern species of mammals, extinction of large forms, such as mammoth; dominance of human
	Tertiary	54	Rise of birds and placental mammals
Mesozoic	Cretaceous	65	Dominance of flowering plants; extinction of large reptiles and ammonites by end of period
	Jurassic	145	Reptiles dominant on land, sea and in air; first birds; archaic mammals
	Triassic	208	First dinosaurs, turtles, ichthyosaurs, plesiosaurs; cycads and conifers dominant
Paleozoic	Permian	245	Radiation of reptiles, which displace amphibians as dominant group; widespread glaciation
	Carboniferous	286	Ferns as dominant plant group; sharks and crinoids abundant; radiation of amphibians; first reptiles
	Devonian	360	Age of fishes (mostly freshwater); first trees and first amphibians
	Silurian	408	Invasion of the land by plants and arthropods; brachiopods; primitive jawless vertebrates
	Ordovician	438	Appearance of vertebrates (armoured fishes); brachiopods and cephalopods dominant
	Cambrian	505	Appearance of all invertebrate phyla and many classes; dominance of trilobites and brachiopods;

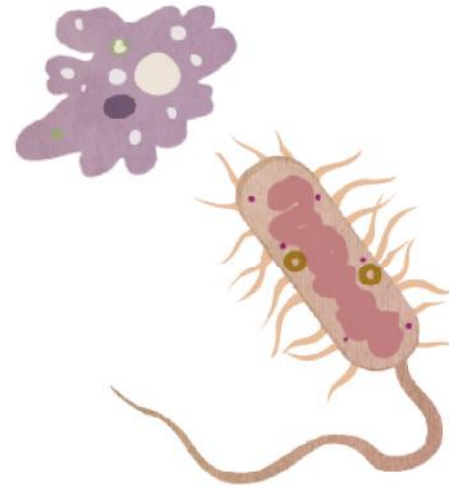
Source: Google.com

FOUR ERAS

- **PRE-CAMBRIAN** – 88% of earth's history
- **Paleozoic (ancient life)**
 - 544 million years ago...lasted 300 million yrs
- **Mesozoic (middle life)**
 - 245 million years ago...lasted 180 million yrs
- **Cenozoic (recent life)**
 - 65 million years ago...continues through present day

Precambrian

- The **earliest living organisms** were microscopic bacteria, which show up in the fossil record as early as 3.4 billion years ago.



- Some three billion years ago the Earth's atmosphere was virtually devoid of oxygen.
- It's thought the final stages of Precambrian time were marked by a prolonged global ice age.

Paleozoic Era (Ancient Life)

- The Cambrian period is the 1st period of the Paleozoic Era. “Age of the Trilobites”
- Explosion of life in the oceans began during this era.
- Most of the continents were covered in warm, shallow seas.
 - Invertebrates were dominate - Trilobites
 - Fish emerged during this time
 - Fish led to the arrival of amphibians
 - The end of the Paleozoic era is called the “Age of Amphibians”
 - Early land plants including mosses, ferns and cone-bearing plants.
 - The early coal forming forests were also formed during this time.

Trilobites



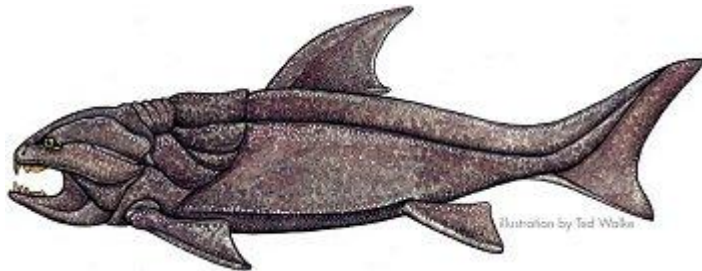
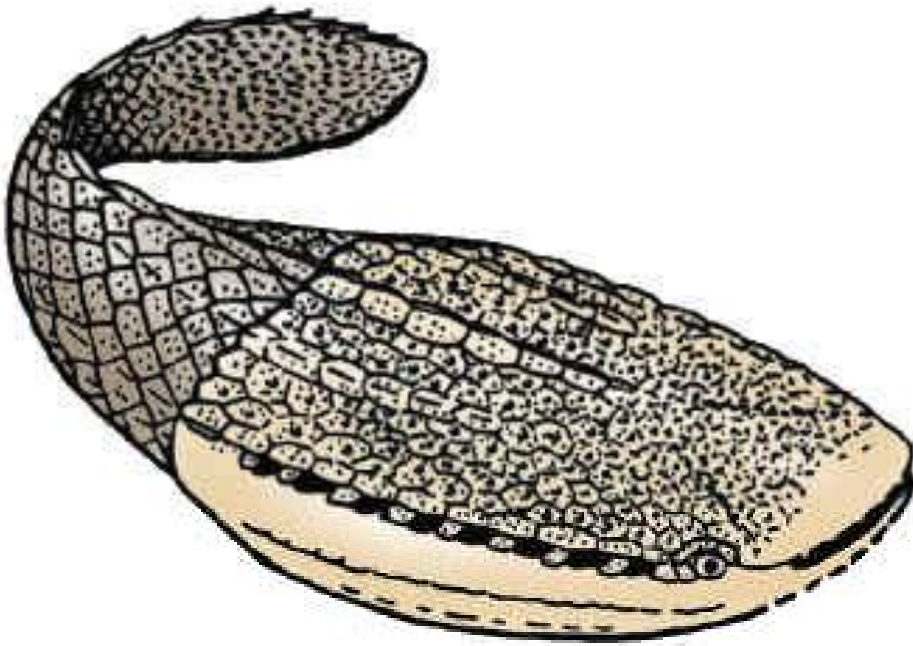
- Lived in Earth's ancient seas
- Cambrian Period is known as the "Age of the Trilobites" (put in on table)

Source: Google.com



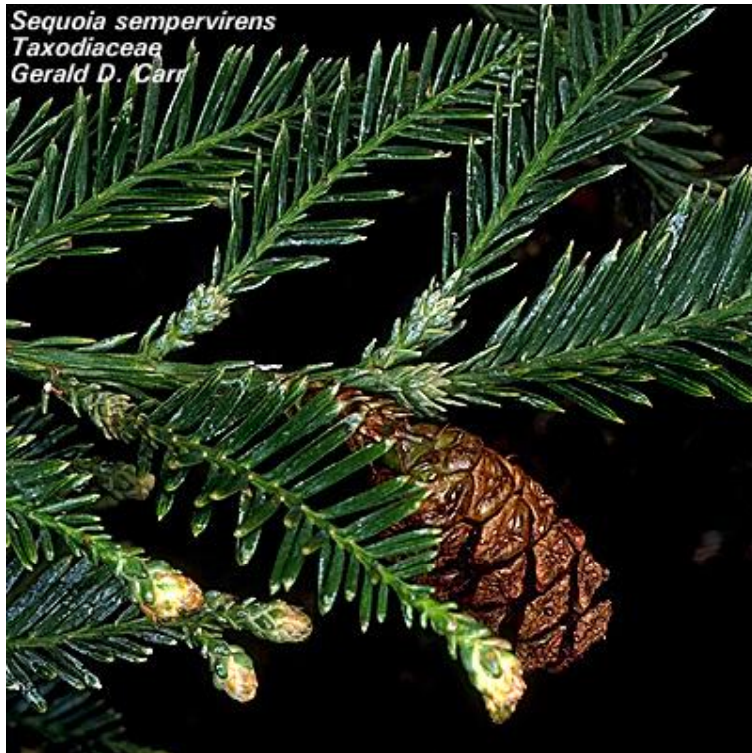
***Sphaerocoryphe robusta* Walcott 1875**
M. Ordovician, Trenton Grp., Rust Fm.
Trenton Falls, New York, USA
image courtesy Sam Stubbs & Neal Immega

Early Fish



- Early fish did not have jaws.
- Some species of sharks were in existence at this time.

Early Land Plants



Cone bearing plants

Source: Google.com

Mosses



Ferns



Paleozoic Era

- Much of the **limestone** and **coal** deposits were formed during the Paleozoic.
- The Cambrian (beginning) opened with the breakup of the world-continent **Rodinia** and closed with the formation of **Pangaea**, as the Earth's continents came together once again.
 - This event is thought to have caused the climate changes that led to mass extinction event.
- The Appalachian mountains were formed during this time.

PERMO-TRIASSIC (P-T) BOUNDARY

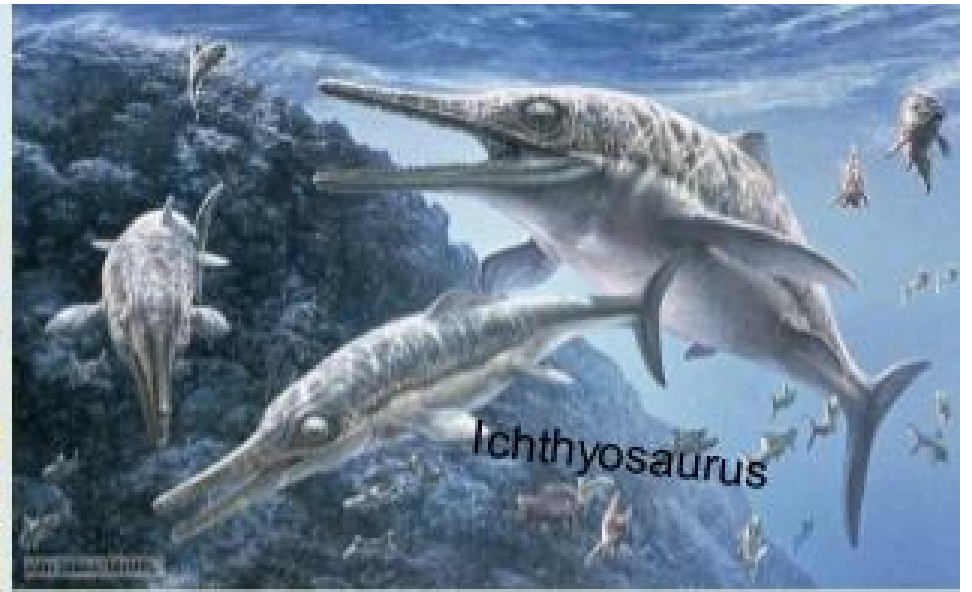
- At the end of the Paleozoic, the *largest mass extinction in history* wiped out approximately 90% of all marine animal species and 70% of land animals.
 - Possible causes of this Mass Extinction Event
 - Lowering of sea levels when the continents were rejoined as Pangaea (convergent boundary)
 - Increased volcanic activity (ash and dust)
 - Climate changes – cooler climate

Mesozoic Era – Middle Life

- At the beginning of this era the continents were joined as Pangaea.
- Pangaea broke up around the middle of this era.
- Reptiles became the most abundant animals because of their ability to adapt to the drier climate of the Mesozoic Era.
 - Skin maintains body fluids
 - Embryos live in shells

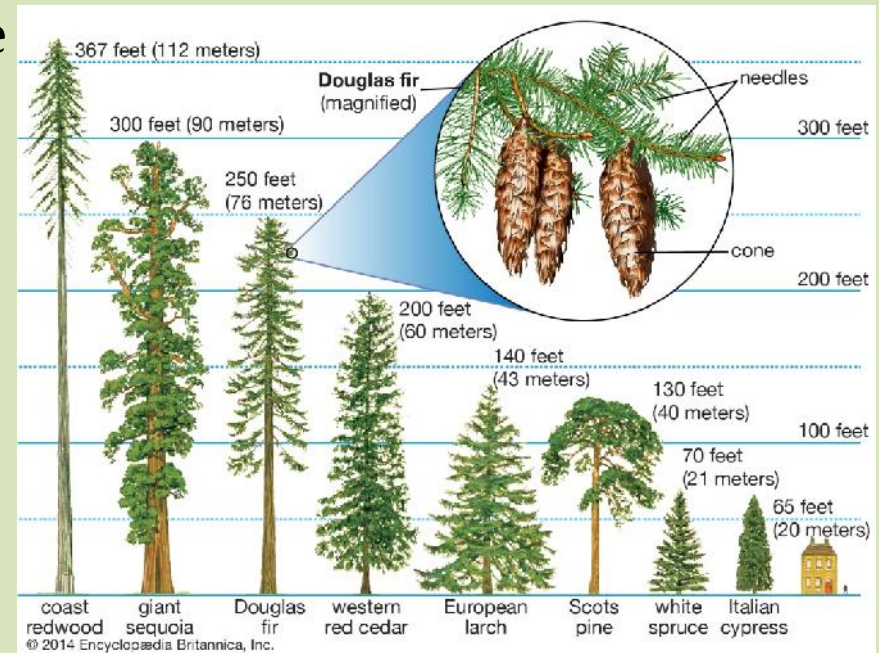
Mesozoic Era

- Dinosaurs were also very active in this era.
 - First small dinosaurs appeared in the Triassic Period.
 - Larger and more abundant dinosaurs appeared in the Jurassic Period.
- Small mammals and birds also appeared during this era.
 - The mammals were small, warm-blooded animals. Hair covering their bodies.
 - These characteristics help them survive in changing environments.



Mesozoic Era

- The main plant life of this time were Gymnosperms or plants that produce seeds, but no flowers.
- Flowering plants appeared during the *end* of this era.



Source: Google.com

CRETACEOUS-PALEOGENE (K-PG) BOUNDARY

- This era ended with a mass extinction event about 65 million years ago.
 - Many groups of animals, including the dinosaurs disappeared suddenly at this time.
- Many scientists believe that this event was caused by a comet or asteroid colliding with the Earth.



- However, not all forms of life died during this event. Many animals that you see today are descendants from the survivors of this extinction event.

Cretaceous fauna

Became extinct

- Marine animals
- Dinosaurs
- Pterosaurs
- Ichthyosaurus

Survived

- Many birds
- Fish, squid, sharks
- Many reptiles
- Some mammals

Cenozoic Era – Recent Life

- Began about 65 million years ago and *continues today!!!!*
 - Climate was warm and mild.
 - Marine animals such as whales and dolphins evolved.
- Mammals began to increase and evolve adaptations that allowed them to live in many different environments – land, air and the sea.
 - Grasses increased and provided a food source for grazing animals
- Many mountain ranges formed during the Cenozoic Era
 - Alps in Europe and Himalayas in India; Rocky Mountains in the USA

Cenozoic Era

- Growth of these mountains may have helped to cool down the climate
 - Ice Ages occurred late in the Cenozoic Era (Quaternary Period).
- As the climate changed, the animals had to adapt to the rise and fall of the oceans caused by melting glaciers.
- This era is sometimes called the “*Age of Mammals*”

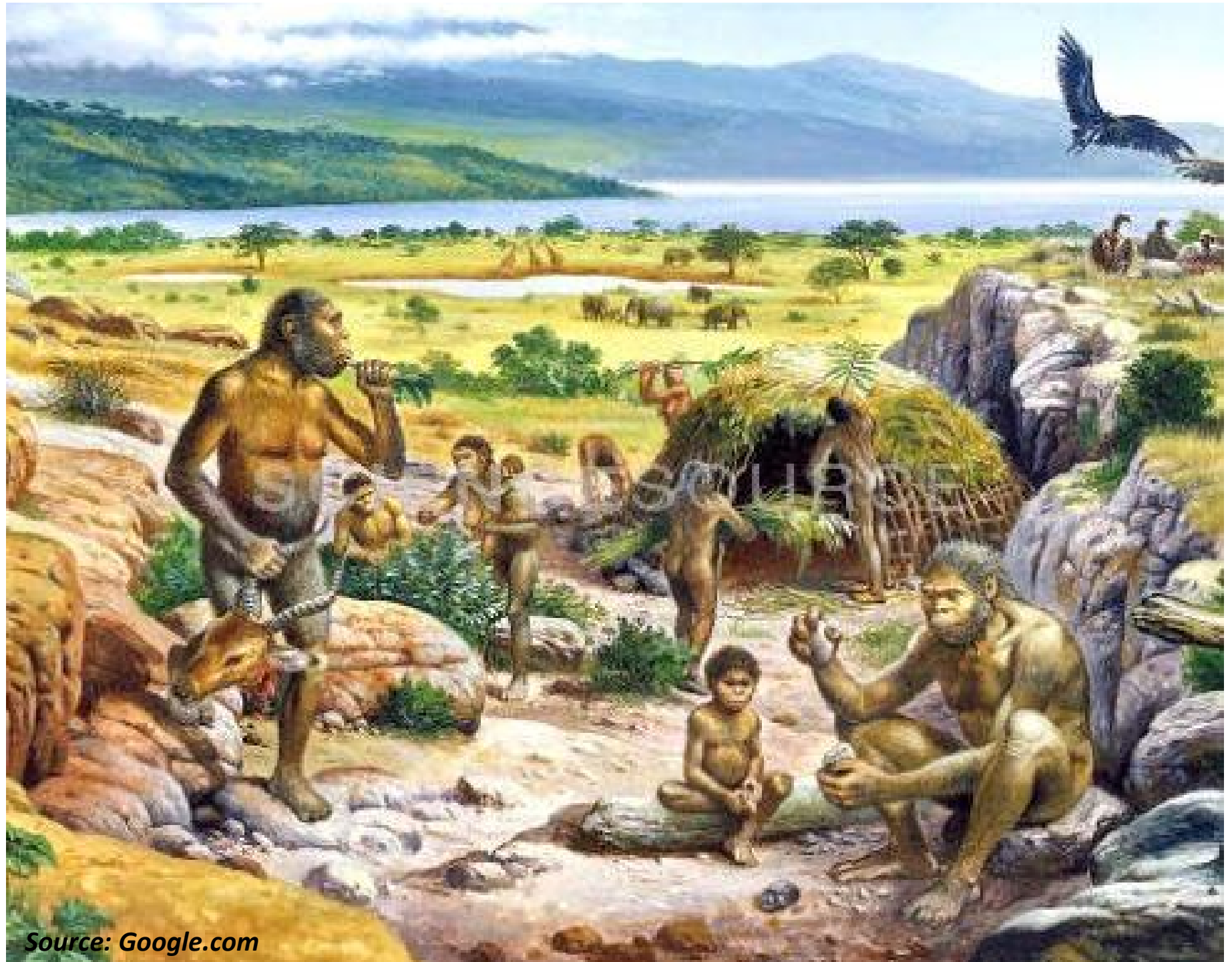
Cenozoic Era

- Marine animal examples:
 - Algae, Mollusks, Fish and Mammals
- Land animal examples:
 - Bats, Cats, Dogs, Cattle and Humans
 - Humans are thought to have appeared around 3.5 million years ago (*during the most recent period – Quaternary*).
- Flowering plants were now the most common plant life.



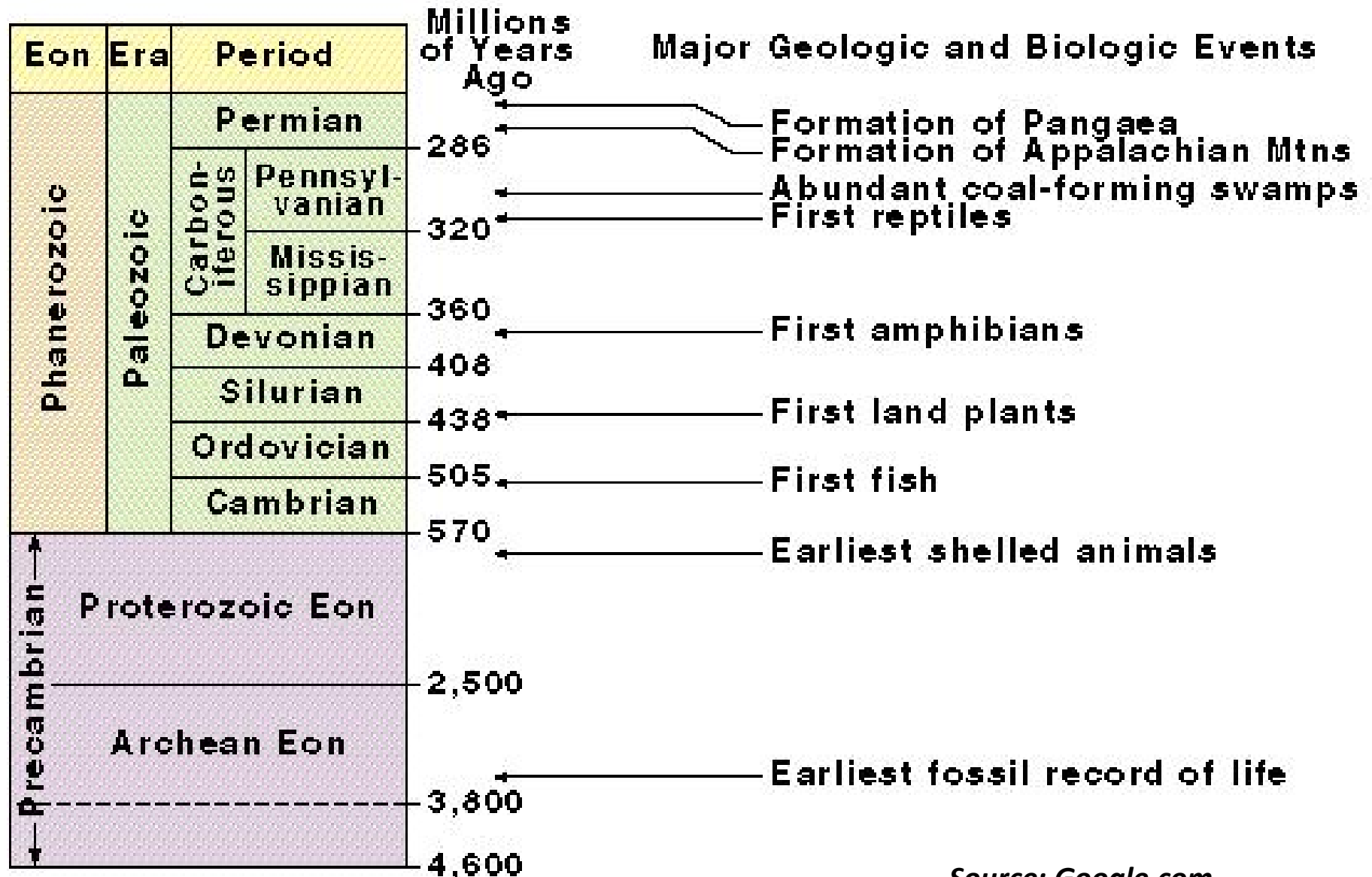


Source: Google.com



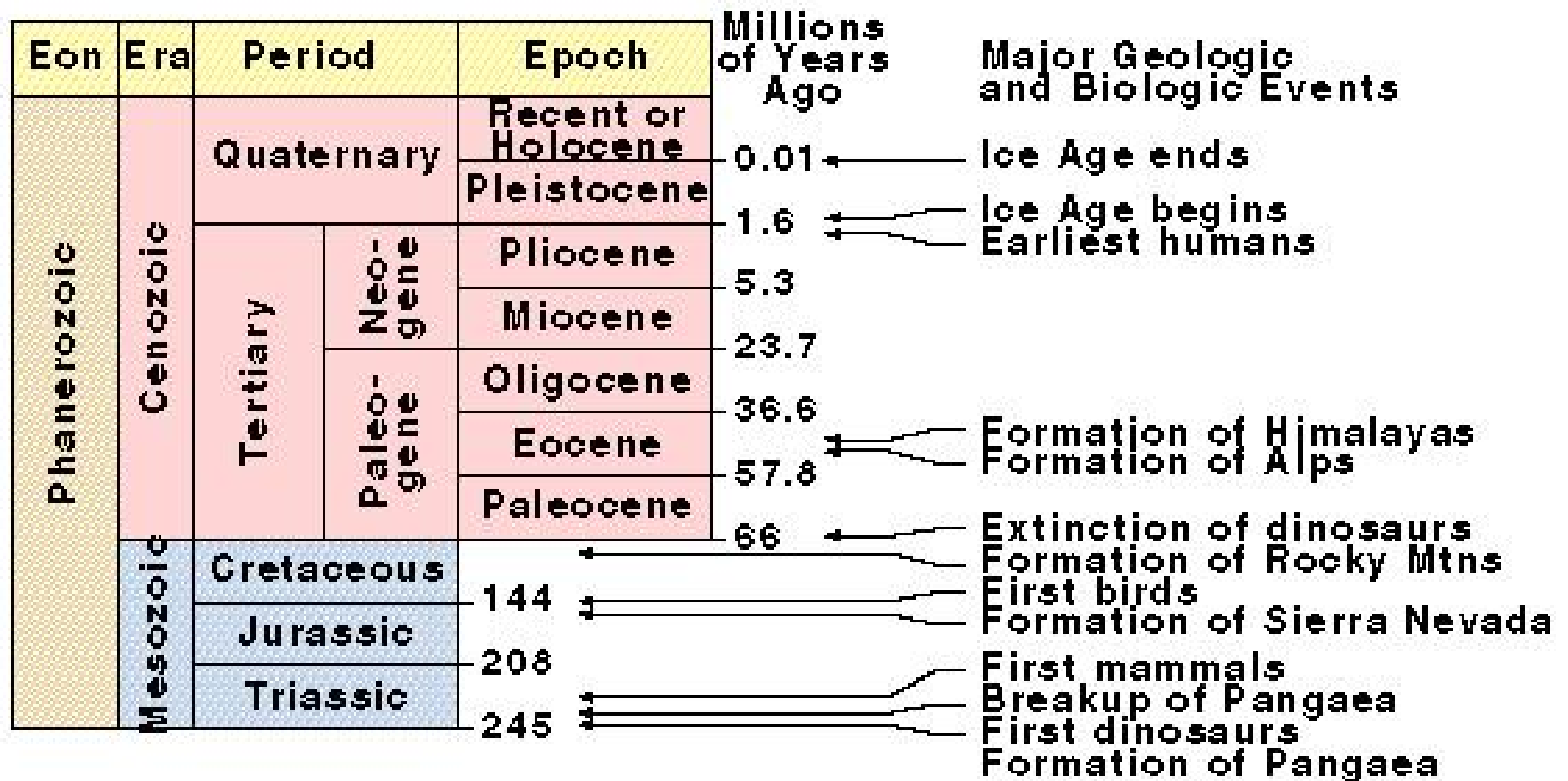
Source: Google.com

The Geologic Time Scale (1:2)



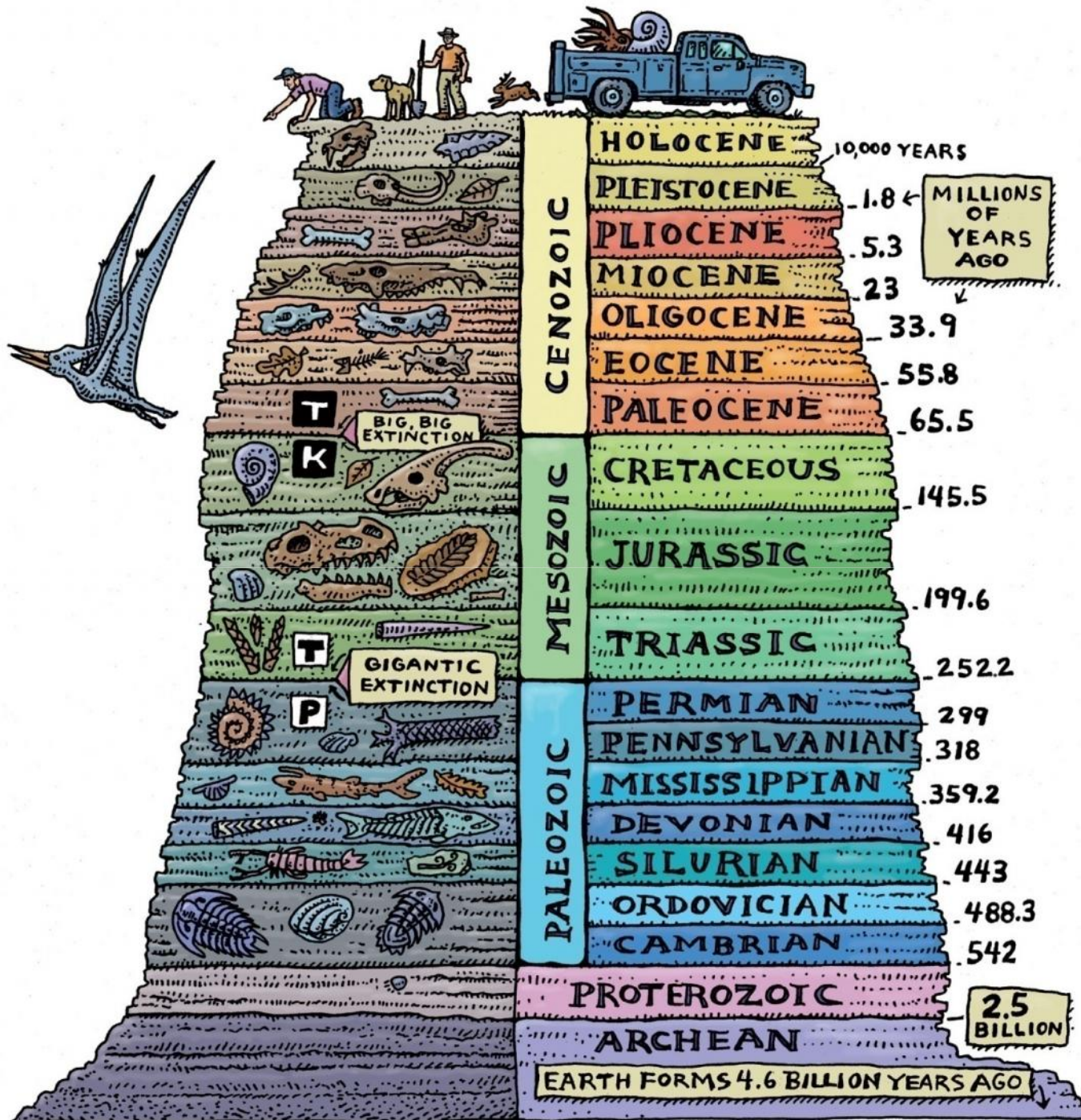
Source: Google.com

The Geologic Time Scale (2:2)



Source: Google.com

Source:
Google.com



Thank you.