The Age of the Earth: Deep time, mass extinctions and radiometric decay

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Is there even a controversy?

- Scientists agree universally on age of Earth
  - 4.5 Ga, based on ages of meteorites
- Students struggle to internalize the age
  - Long time periods are difficult to understand
  - Meteorites not intuitive to Earth age
  - Radiometric decay processes is challenging
  - Creationist arguments
- Explaining non-intuitive with non-intuitive

Deep time is difficult to comprehend

- Sequences of events, reconstructing environments
  - Libarkin et al. 2007
  - Dodick & Orion 2003
  - Trend 1997, 1998, 2000, 2001
- Maturation between grades 7-8 and 9-12
  - Increased ability to conceptualize deep time
  - Most high school students don't take Earth Science

PA teachers exemplify this situation

- Self-selected teachers in plate tectonics w'shop
- Grades from upper elementary through 9-12
- Sequencing of biological events correct overall
- Dates of biological events show confusion
  - Events in correct order: 94% correct
  - Earth forms: 70%
  - First life (3-4 Ga): 41%
  - Humans appear: 29%
  - Dinosaurs appear: 18%

Guertin et al., 2011 GSA presentation

Earth age: Direct evidence not intuitive

- Oldest rocks 3.8-3.9 Ga
  - Sedimentary minerals 4.1-4.2 Ga
  - Australia, Africa, N. America, Asia, Greenland (>3.5)
  - Establishes minimum age only
- Meteorites coeval formation but no recycling
  - Multiple isotopic approaches, ~70 samples
  - Ages cluster 4.55 Ga
  - Assume uniform Pb, U distribution in original "stuff"
- Individual meteorites don't look like Earth

Improve teaching of radiometric decay

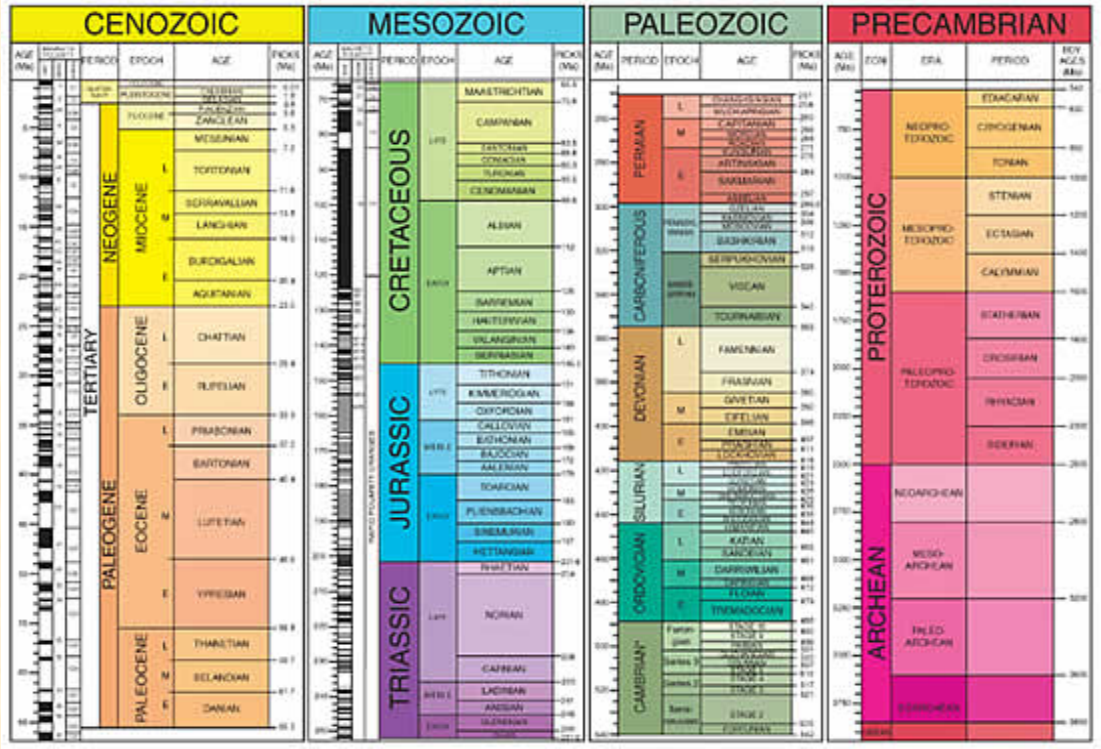
- Most labs involve candy
  - Remove “decayed” candy
  - Half-life concept okay
  - Radiometric decay not okay
- ^{14}C dating more clear
  - Root element stays constant
  - Not applicable to most rocks
  - Not applicable to deep time
- **Improve by teaching elements, mineral context**

Finally, a use for rocks & minerals

- Suitable minerals almost always igneous, met'c
- Ages reflect time since cooling (diffusion stops)
- Potassium is found in:
  - K-feldspar
  - micas
  - amphibole
- Uranium is found in:
  - zircon
  - apatite
  - sphene

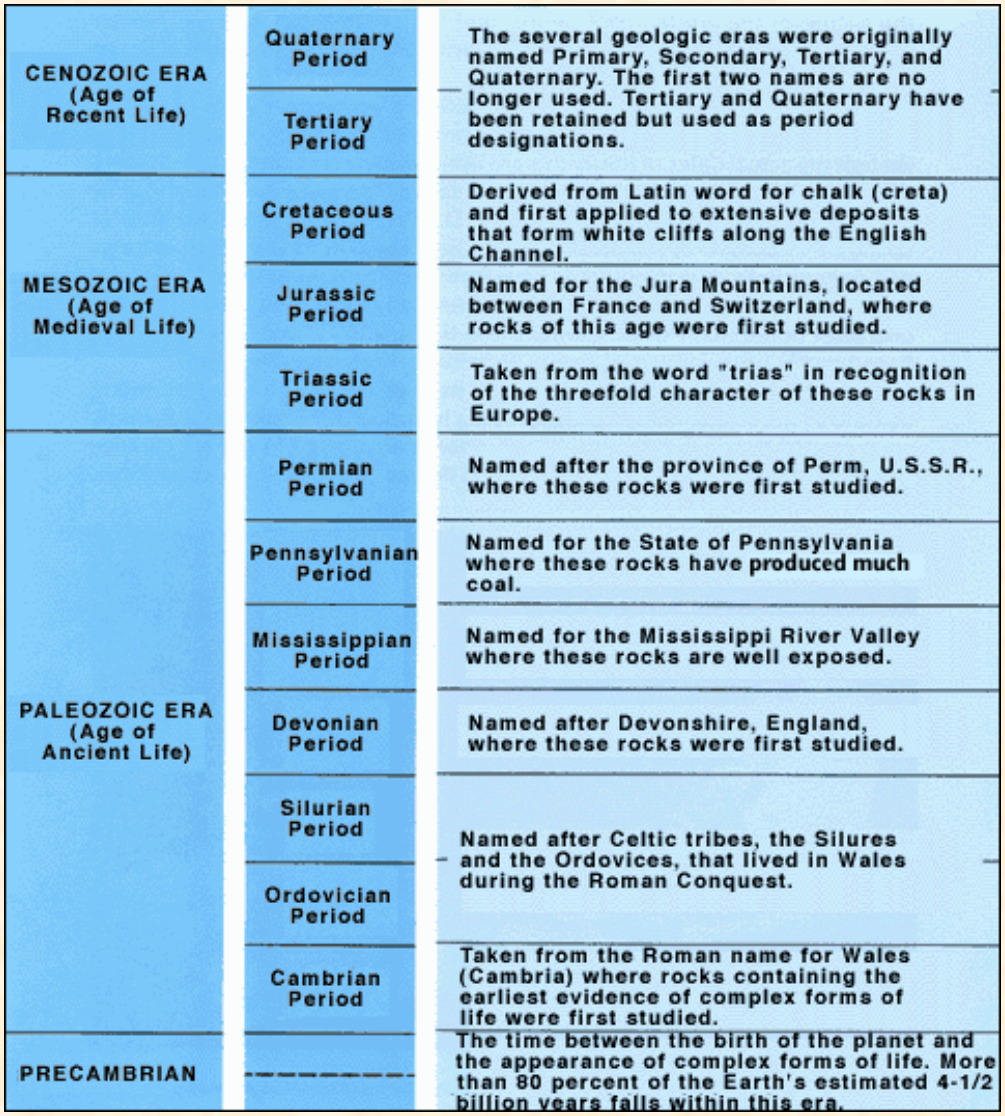
From Pam Gore: http://facstaff.gpc.edu/~pgore/geology/geo102/radio.htm

Develop the geological time scale



- Interdisciplinary approach by community
- Igneous, met'c rocks indicate ages, dates
- Sedimentary rocks indicate fossils, extinctions

Geological time scale can make sense



CENOZOIC ERA (Age of Recent Life)	Quaternary Period	The several geologic eras were originally named Primary, Secondary, Tertiary, and Quaternary. The first two names are no longer used. Tertiary and Quaternary have been retained but used as period designations.
	Tertiary Period	
MESOZOIC ERA (Age of Medieval Life)	Cretaceous Period	Derived from Latin word for chalk (creta) and first applied to extensive deposits that form white cliffs along the English Channel.
	Jurassic Period	Named for the Jura Mountains, located between France and Switzerland, where rocks of this age were first studied.
	Triassic Period	Taken from the word "trias" in recognition of the threefold character of these rocks in Europe.
PALEOZOIC ERA (Age of Ancient Life)	Permian Period	Named after the province of Perm, U.S.S.R., where these rocks were first studied.
	Pennsylvanian Period	Named for the State of Pennsylvania where these rocks have produced much coal.
	Mississippian Period	Named for the Mississippi River Valley where these rocks are well exposed.
	Devonian Period	Named after Devonshire, England, where these rocks were first studied.
	Silurian Period	Named after Celtic tribes, the Silures and the Ordovices, that lived in Wales during the Roman Conquest.
	Ordovician Period	
	Cambrian Period	Taken from the Roman name for Wales (Cambria) where rocks containing the earliest evidence of complex forms of life were first studied.
PRECAMBRIAN	----------	The time between the birth of the planet and the appearance of complex forms of life. More than 80 percent of the Earth's estimated 4-1/2 billion years falls within this era.

- Names are explained
  - Locations have meaning
  - Dates have meaning
- Cross-cutting themes
  - Literacy
  - Numeracy
- Mass extinctions define every one of the horizontal lines

http://pubs.usgs.gov/gip/geotime/divisions.html

Finding a home in the curriculum

- Age of the Earth not just a statement
- Meteorites not the easy access point
- Key minerals reveal ages of their formation
  - Mineral compositions, origins important
- Geological time scale excellent vehicle
  - Relative time / sedimentary rocks
  - Absolute time / igneous & met'c rocks
  - Integrate literacy, numeracy, history, geography

Closing words and thoughts

- Seek buy-in for method, not for result
- Younger students cannot comprehend scale
- Older students, adults may not have background
- Context of mineral compositions
- Context of geological time chart