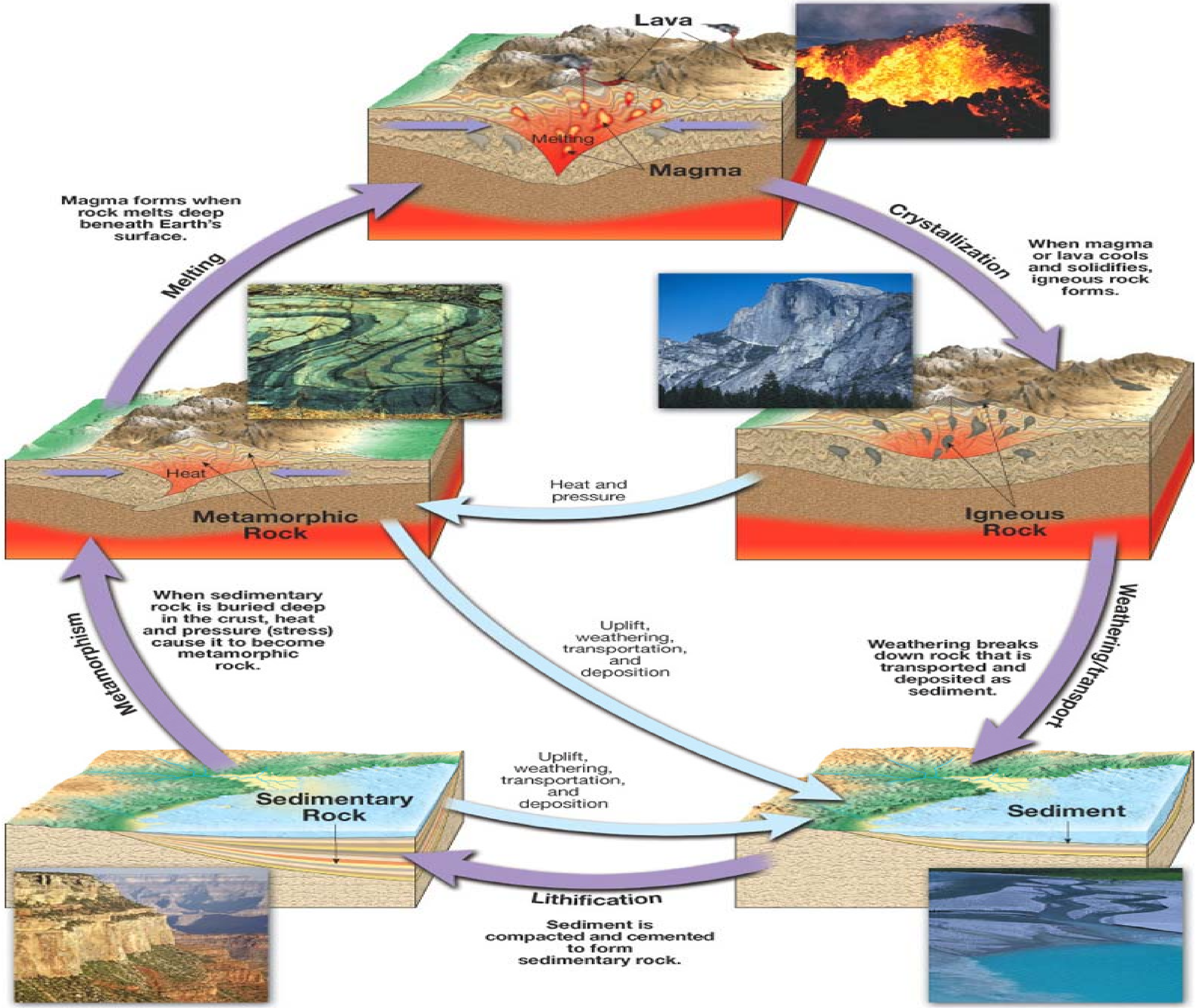
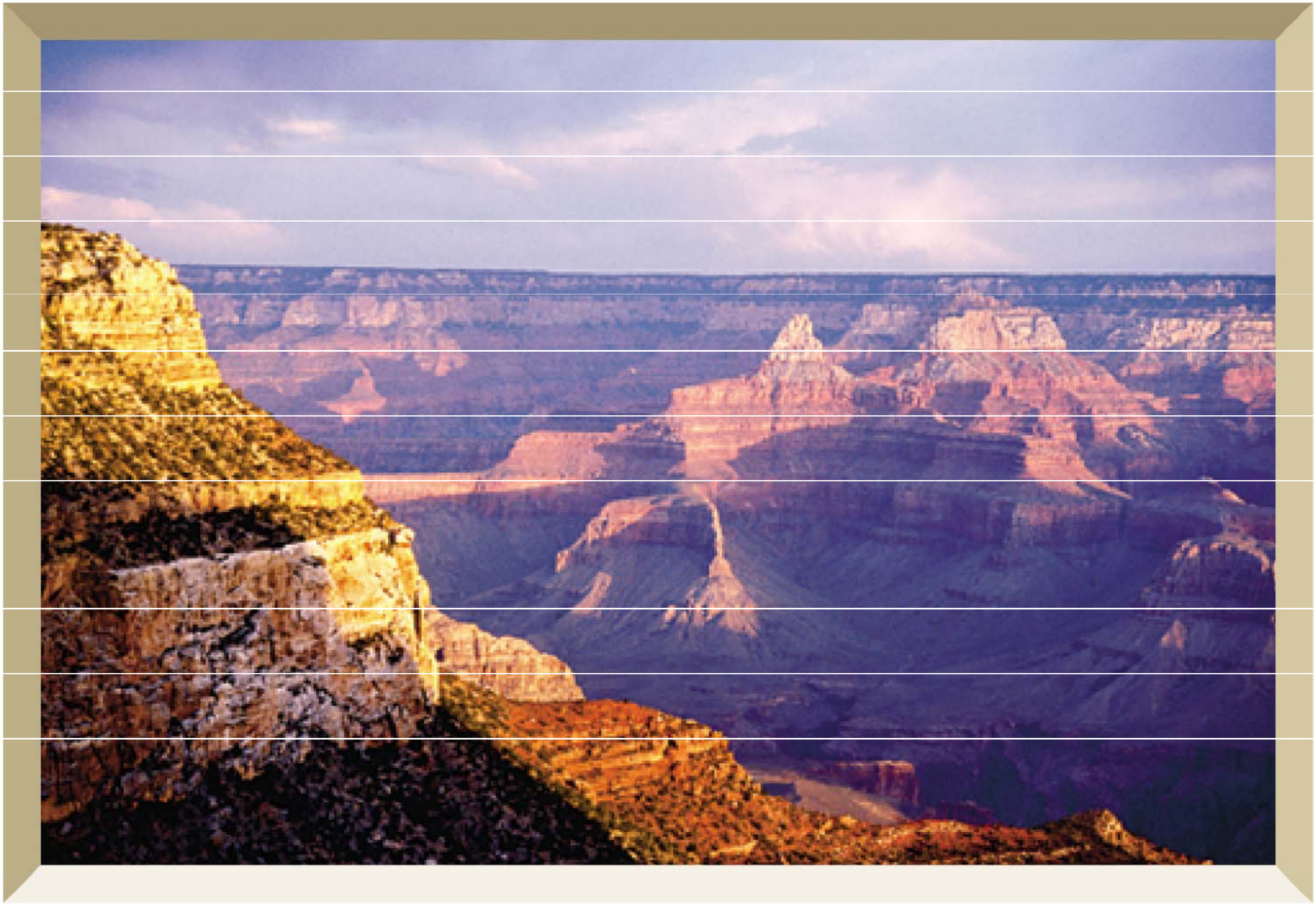
Geologic Time

Chapter 21



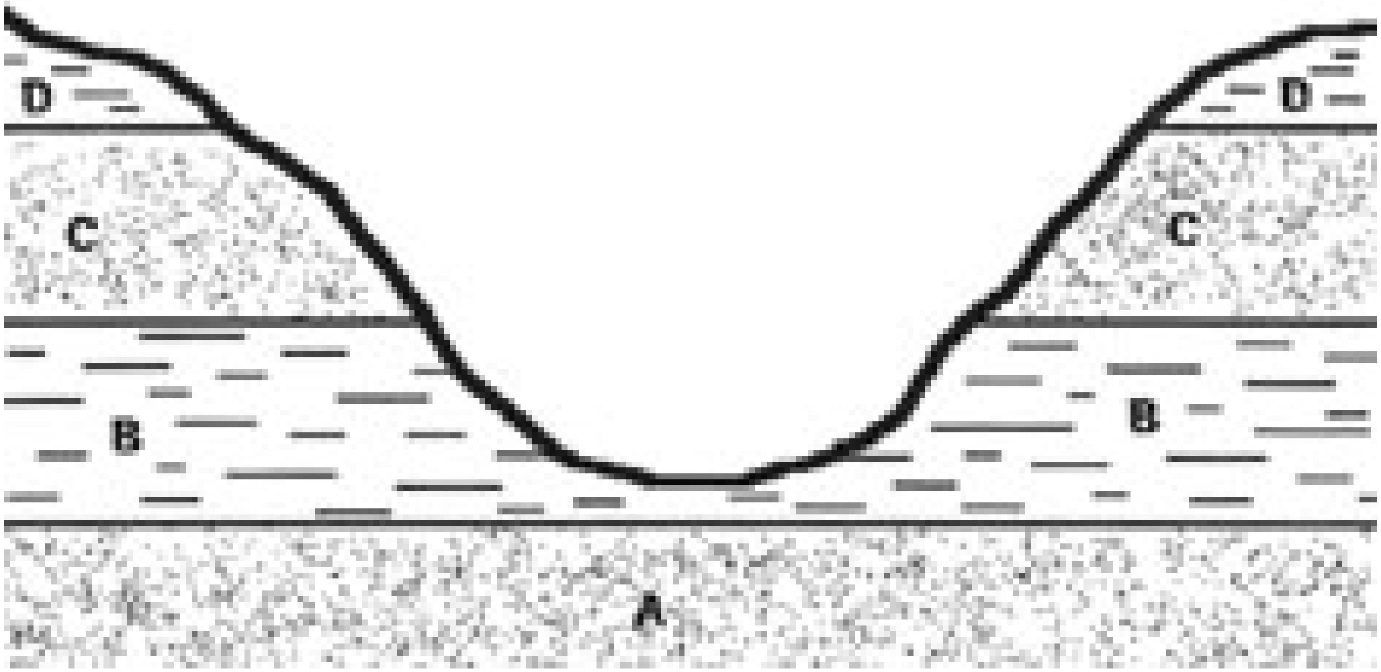
Earth Sc., 11th ed.

Leaves of History



Grand Canyon National Park

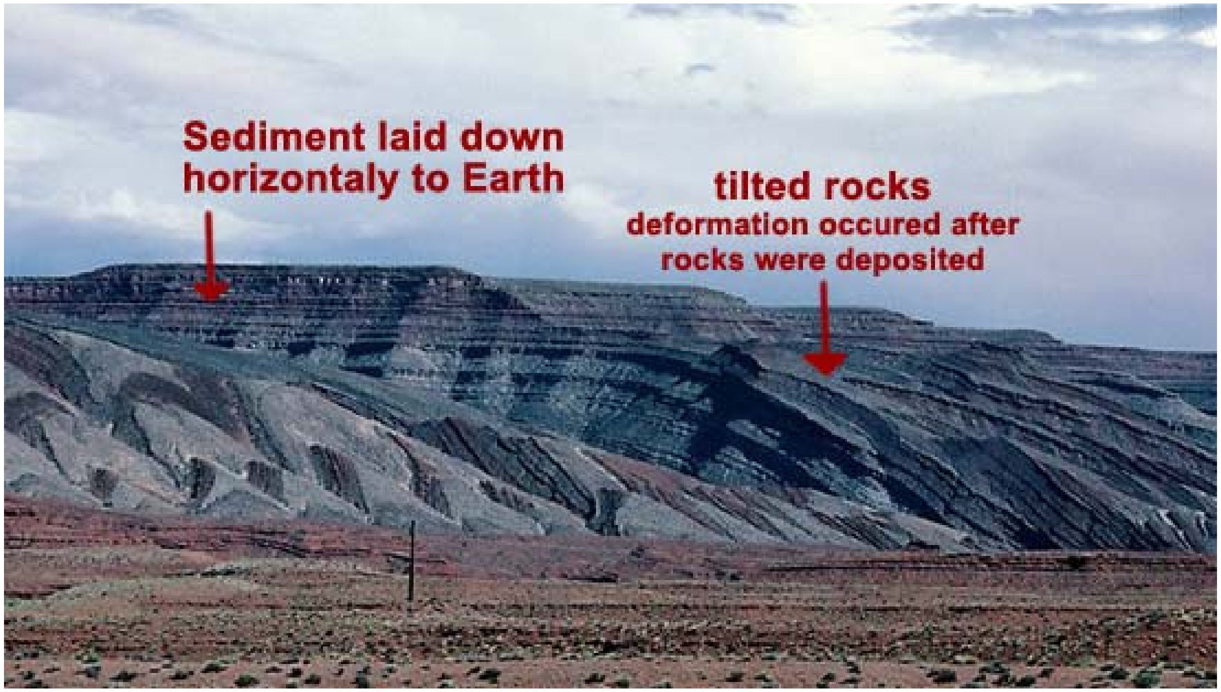
Lateral Continuity



http://cse.cosm.sc.edu/hses/RelatDat/pages/lateral.htm

Principle of Original Horizontality

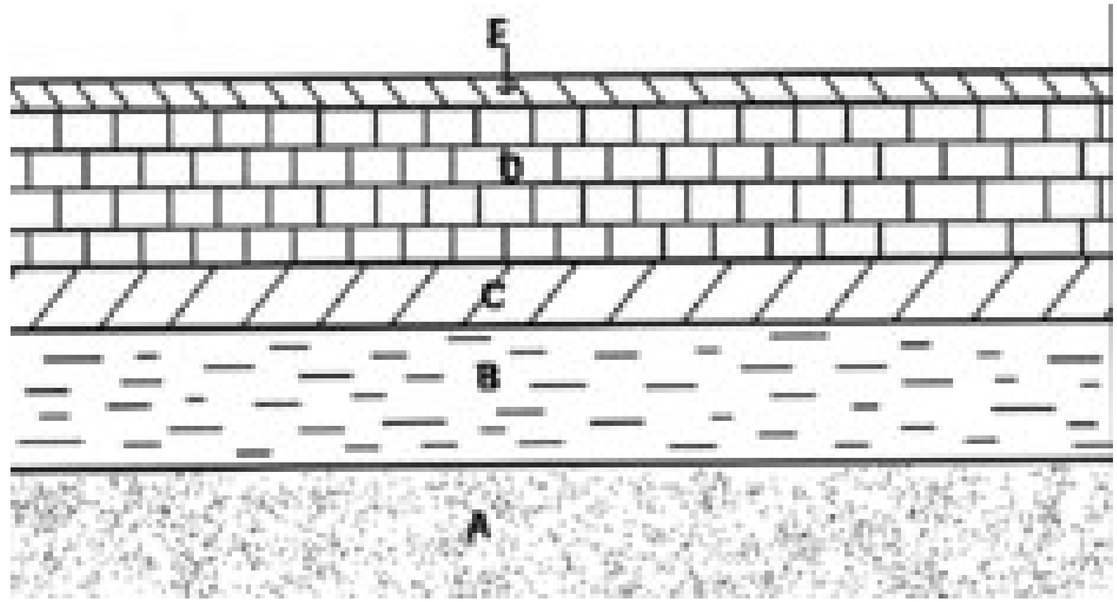
- Sediment is deposited horizontally



http://faculty.icc.edu/easc111lab/labs/labf/orig_horizontality.jpg

Principle of Superposition

- Oldest rock A
- Younger rocks above
- E is the youngest



http://cse.cosm.sc.edu/hses/RelatDat/pages/superpos.htm

Principles of Relative Dating

Nicolaus Steno 1636-1686

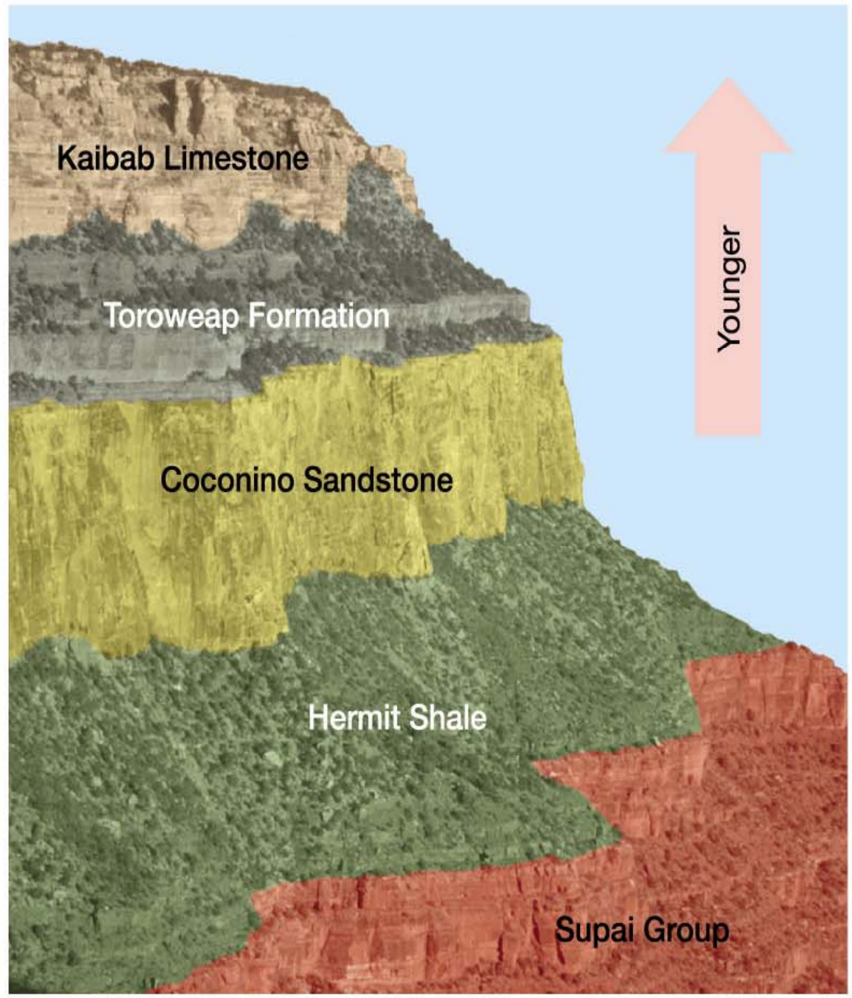
1669 work relates to deposition of sediment

- Principle of original horizontality
- Principle of lateral continuity
- Principle of superposition

http://www.ucmp.berkeley.edu/history/steno.html

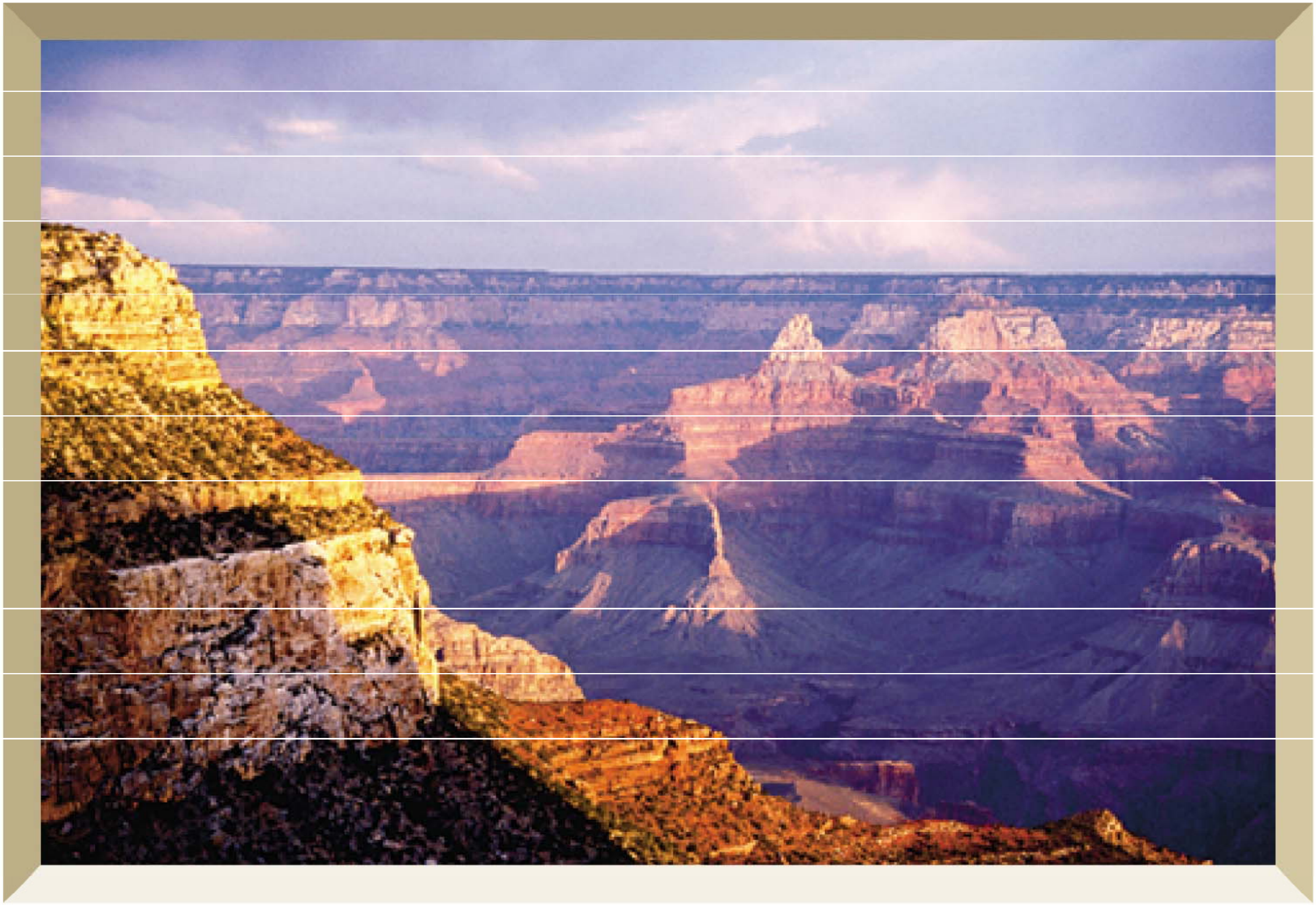
Superposition is well illustrated by the strata in the Grand Canyon

A.



B.

Lateral Continuity



Grand Canyon National Park

Relative dating

Placing rocks and events in proper sequence of formation

Deciphering Earth’s history from clues in the rocks

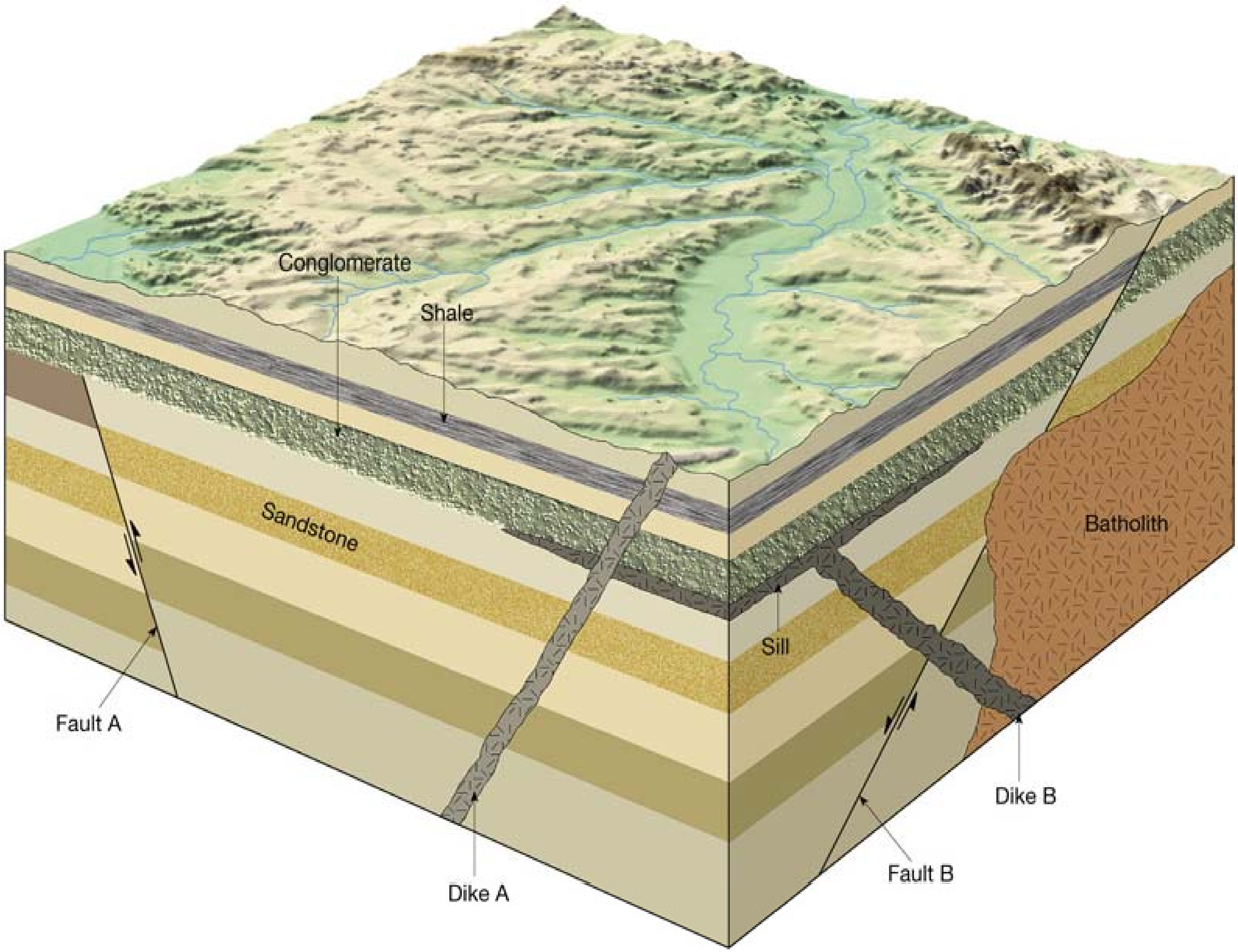
Principles of Relative Dating

- Principle of original horizontality
- Principle of lateral continuity
- Principle of superposition
- Principle of cross-cutting relationships

Principle of Cross-cutting Relationships

- Younger feature cuts through an older feature
  - Something must exist first to be cut by another thing
- The ‘things’ cutting may be ‘things’, such as igneous intrusions
- Or they may be events, like fault breaks, folding, or erosion periods

Cross-cutting relationships



Folding occurred after deposition

http://rst.gsfc.nasa.gov/Sect2/Sect2_6.html

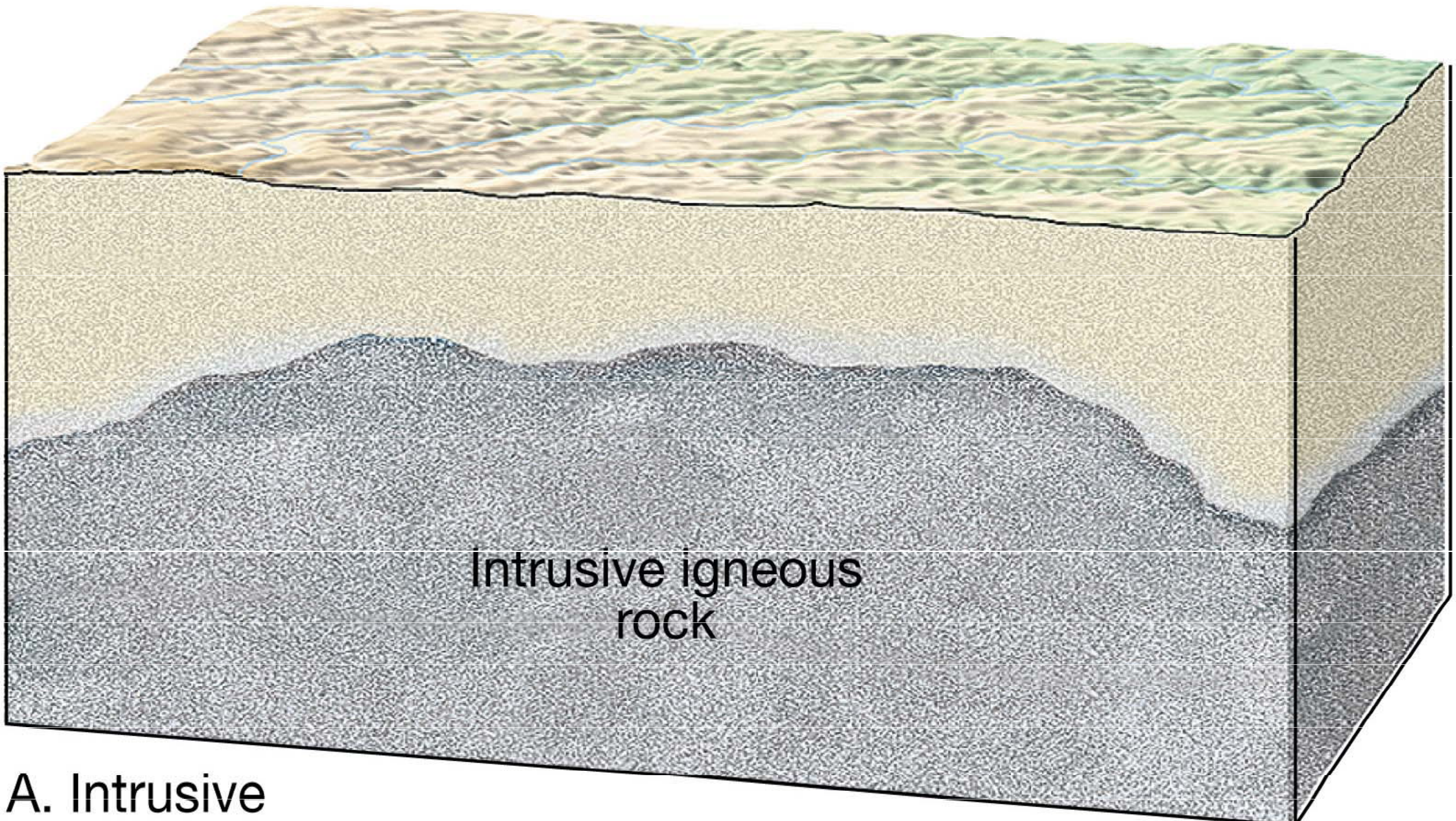
Principles of Relative Dating

- Principle of original horizontality
- Principle of lateral continuity
- Principle of superposition
- Principle of cross-cutting relationships
- Principle of inclusion

Inclusions

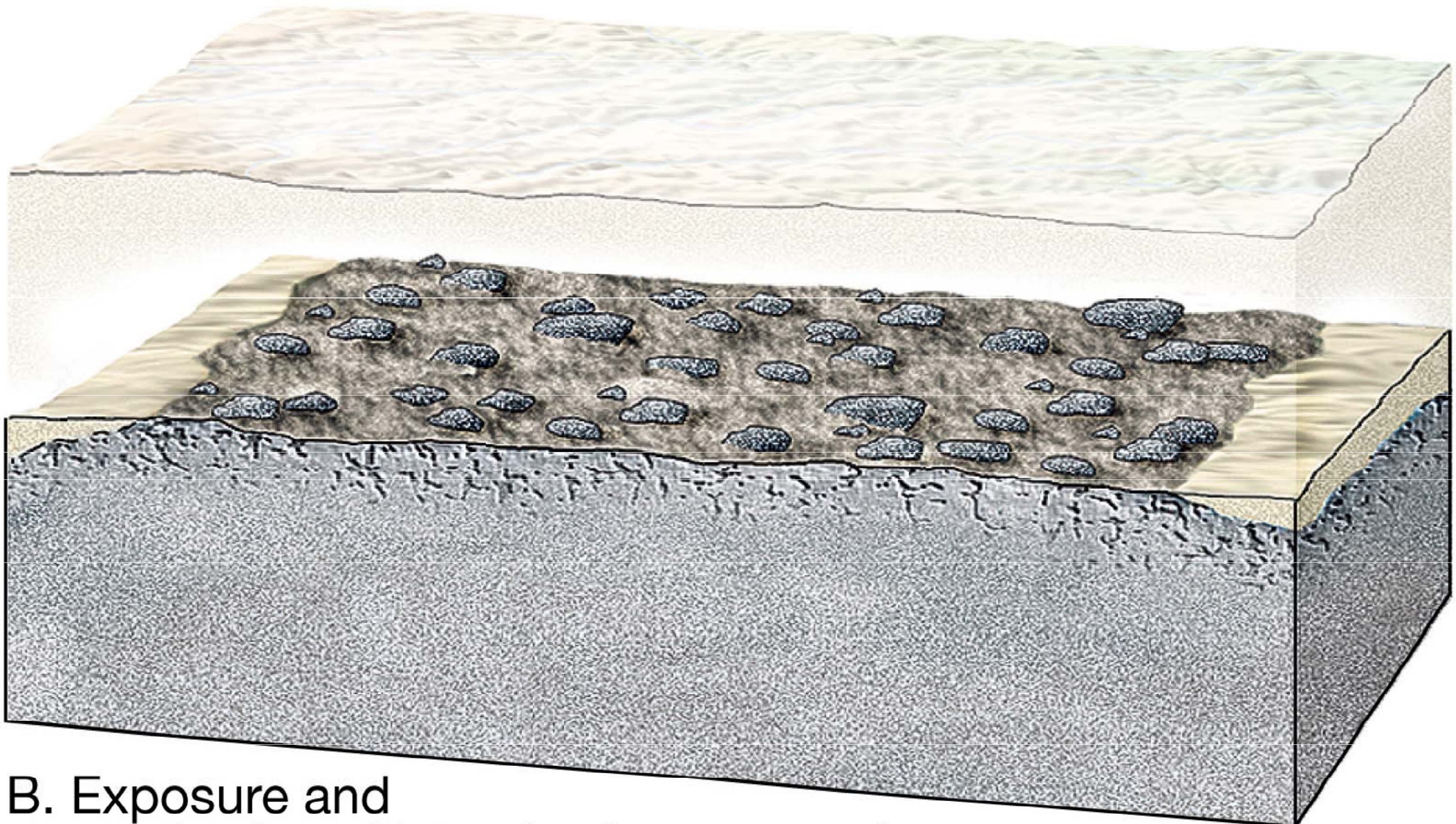
- One rock contained within another
- Rock containing the inclusions is younger than the one the inclusions are derived from

How inclusions form



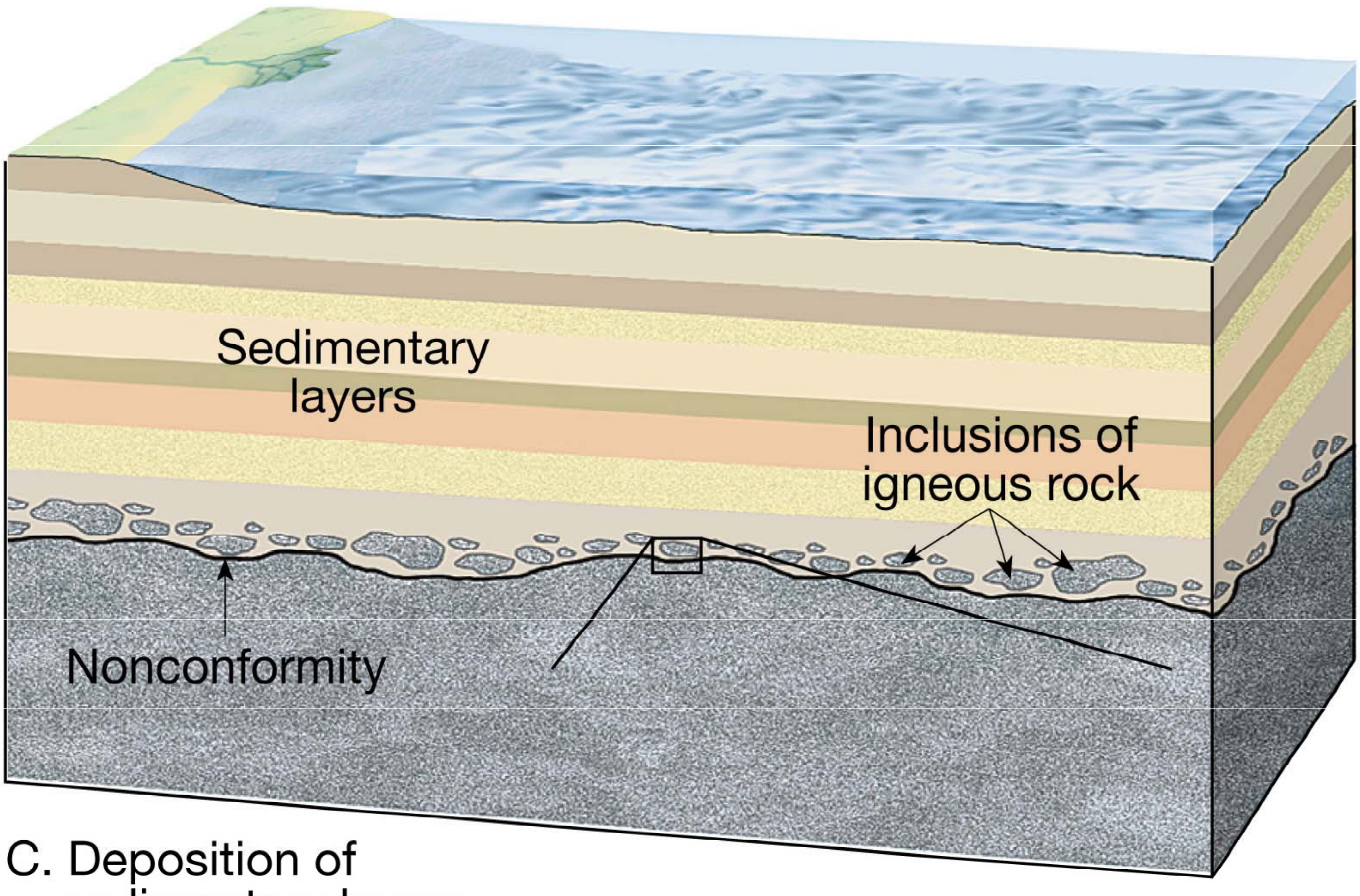
A. Intrusive
igneous rock

Formation of Inclusions



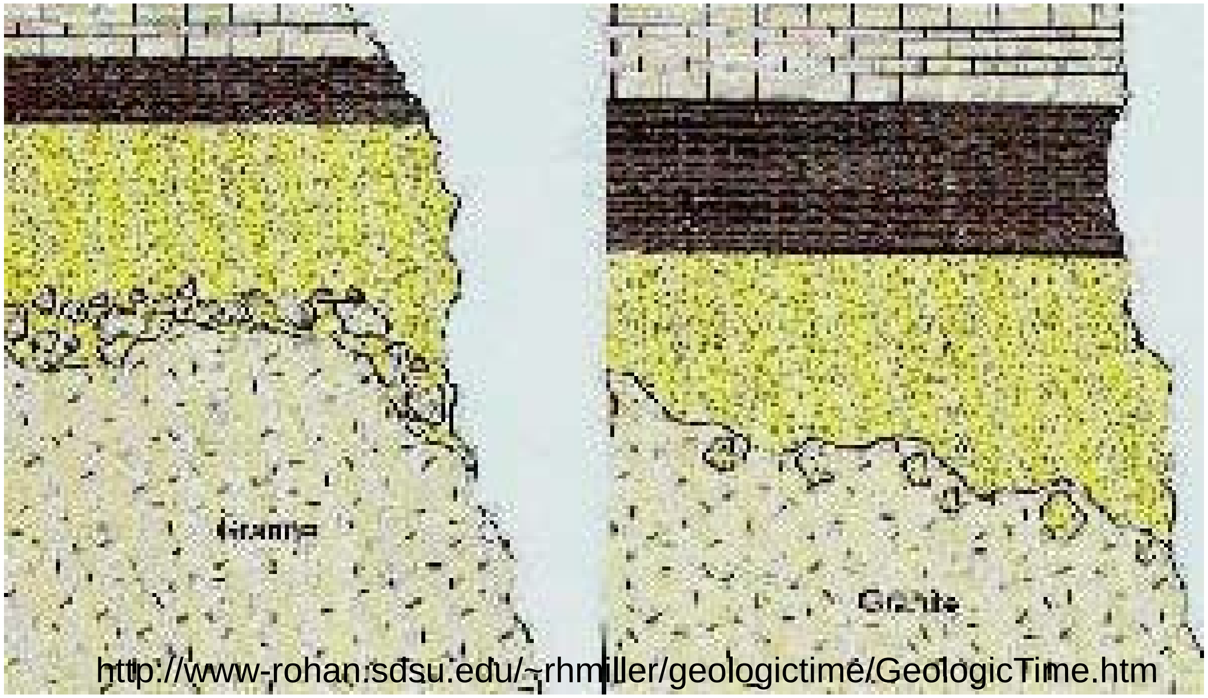
B. Exposure and
weathering of intrusive igneous rock

The fragments are included with the deposition of rock on top of the weathered surface



C. Deposition of sedimentary layers

Two different modes of inclusion



Inclusions of granite in sedimentary deposit—formed later than granite

Inclusions of sediment in granite—granite formed later than sediment

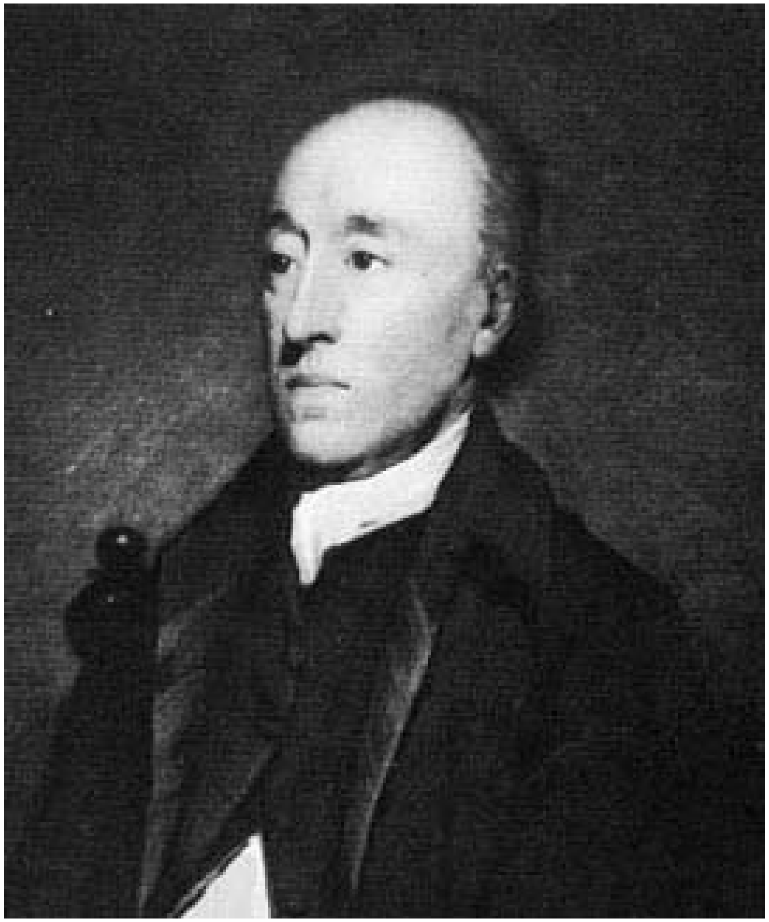
Modern geology

- Uniformitarianism
- Fundamental principle of geology "The present is the key to the past“

James Hutton 1726-1797

1785 lectures *Concerning the system of the Earth, its duration, and stability* to the Royal Society of Edinburgh

- Principle of crosscutting relationships
- Principle of inclusions



http://www-history.mcs.st-andrews.ac.uk/Mathematicians/Hutton_James.html

Unconformities

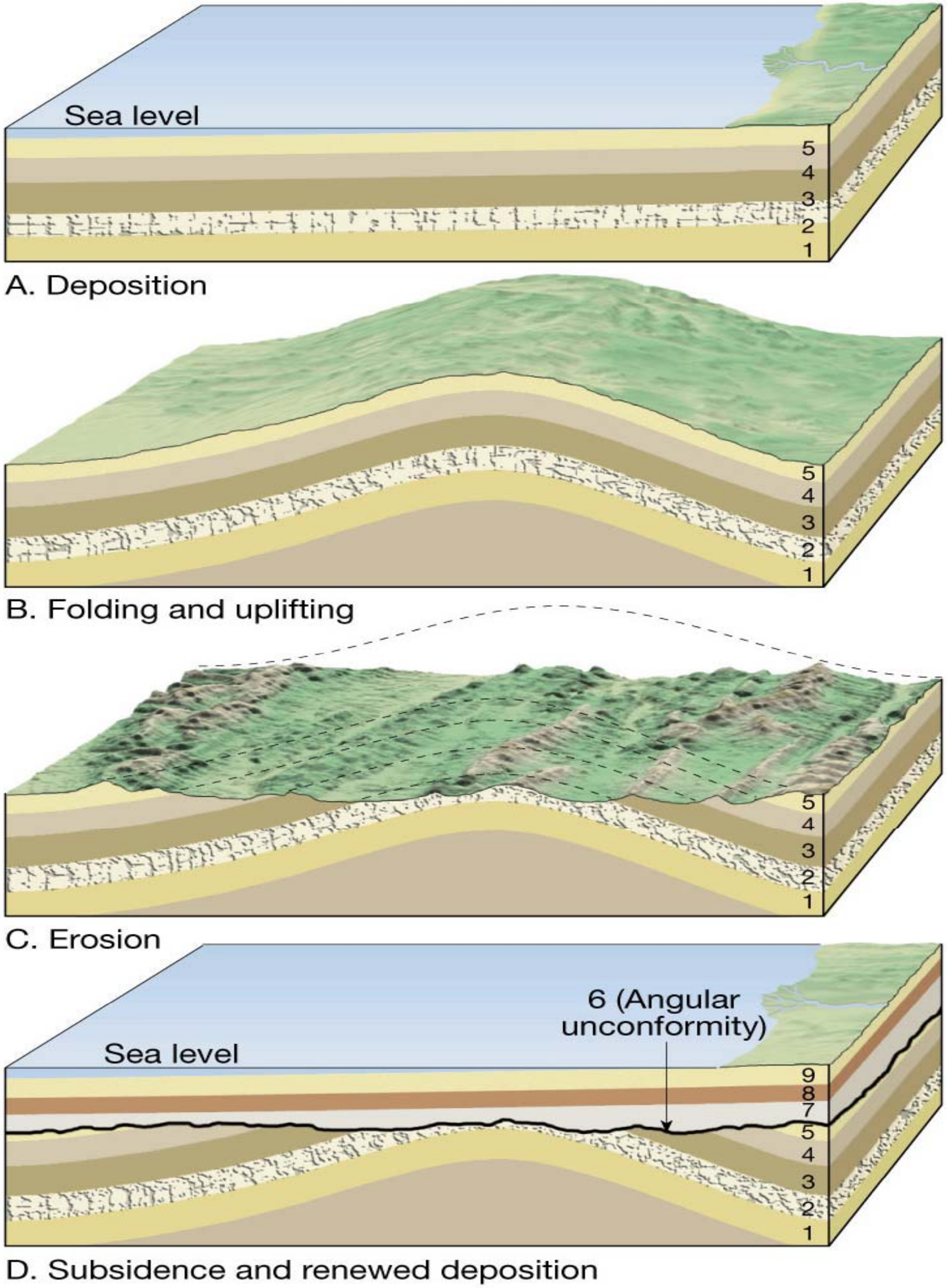
A break in the rock record

- Three types of unconformities
  - Angular unconformity –
  - Disconformity – strata on either side are parallel
  - Nonconformity

Angular Unconformity

- Tilted rocks are overlain by flat-lying rocks
- Remember the principle of original horizontality?

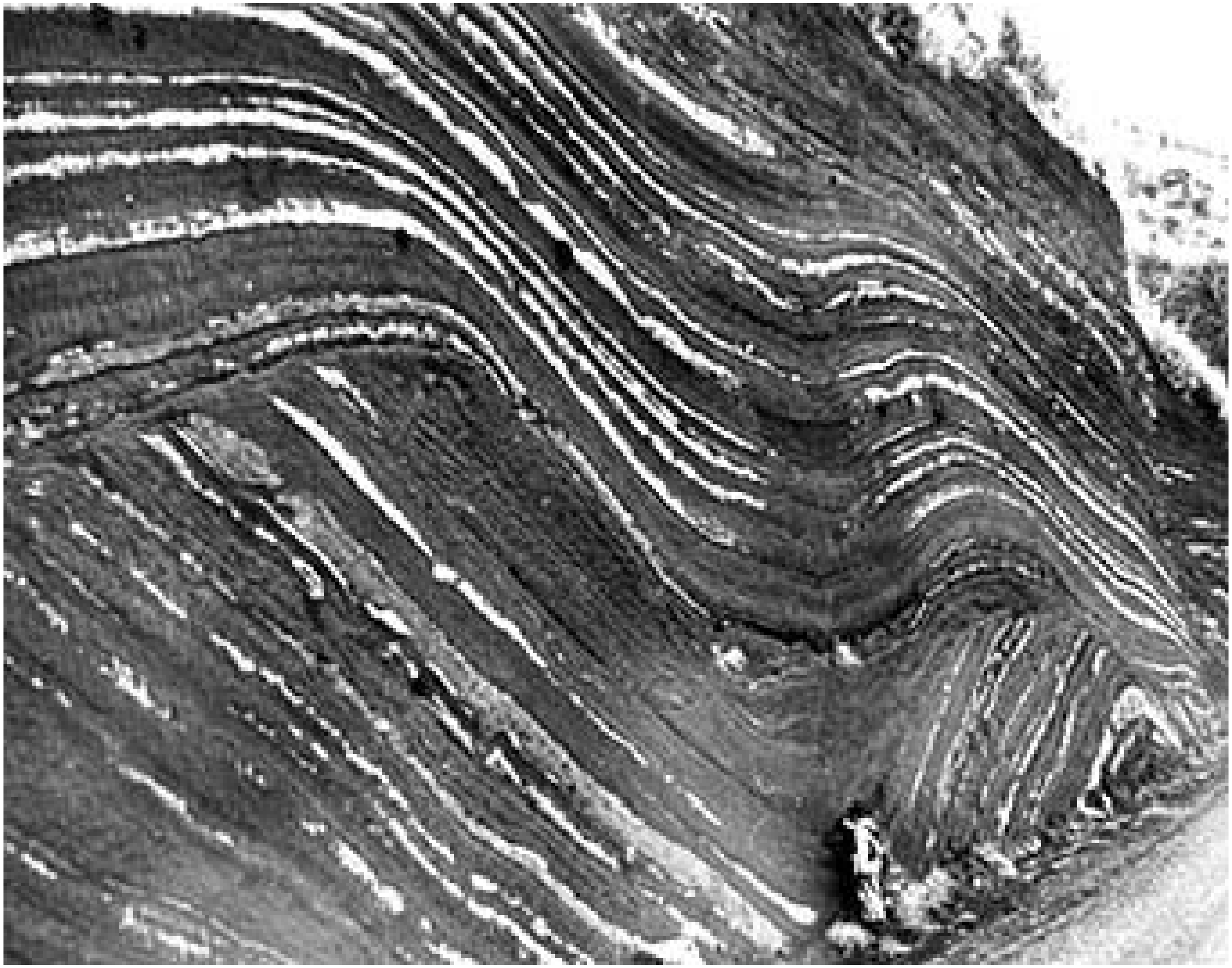
Formation of an angular unconformity



Simple angular unconformity

http://www.grisda.org/colorado/index.htm

Folding, erosion, deposition, folding

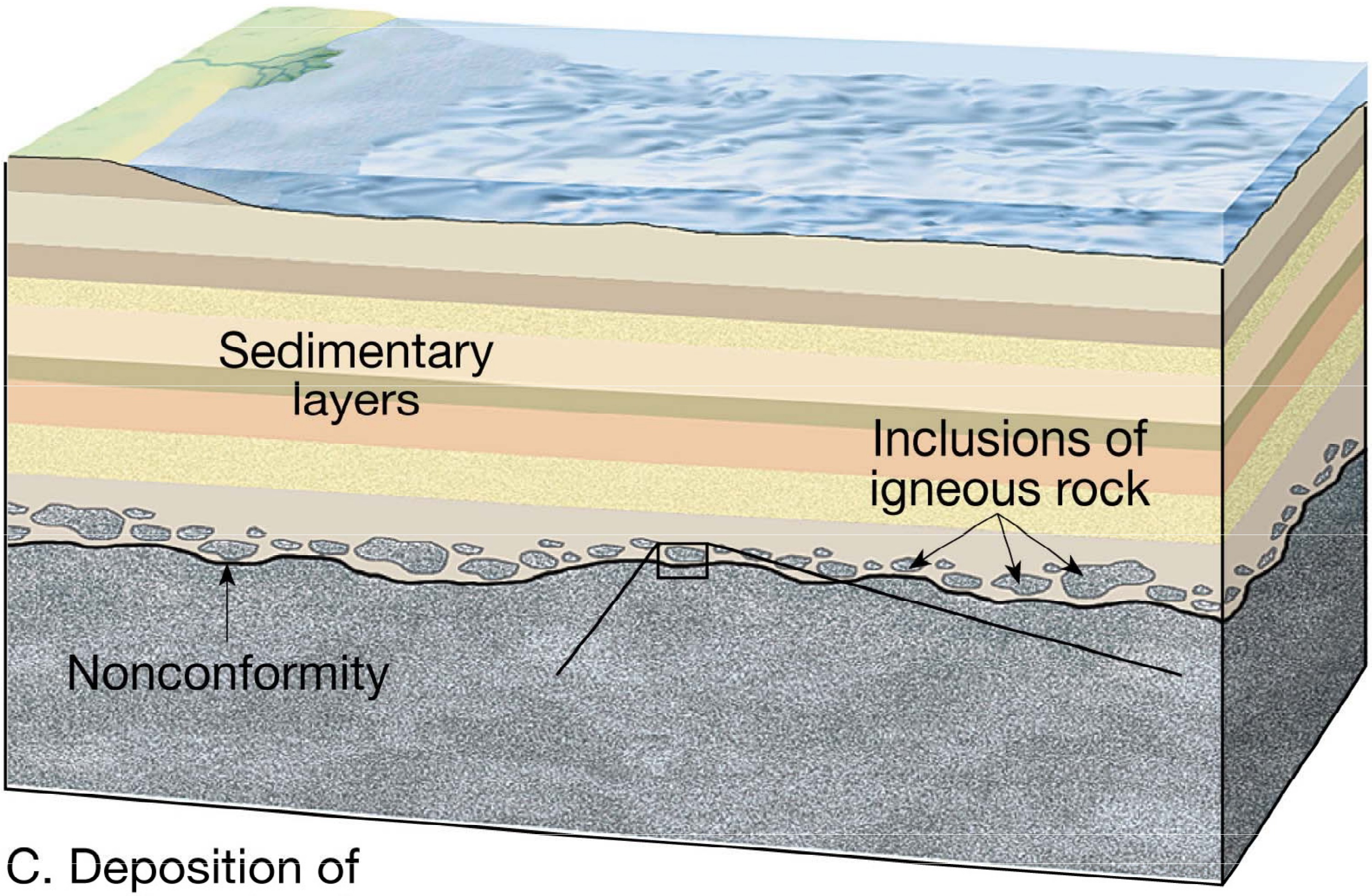


http://rst.gsfc.nasa.gov/Sect2/Sect2_6.html

Nonconformity

- Metamorphic or igneous rocks below
- Younger sedimentary rocks above

Nonconformity

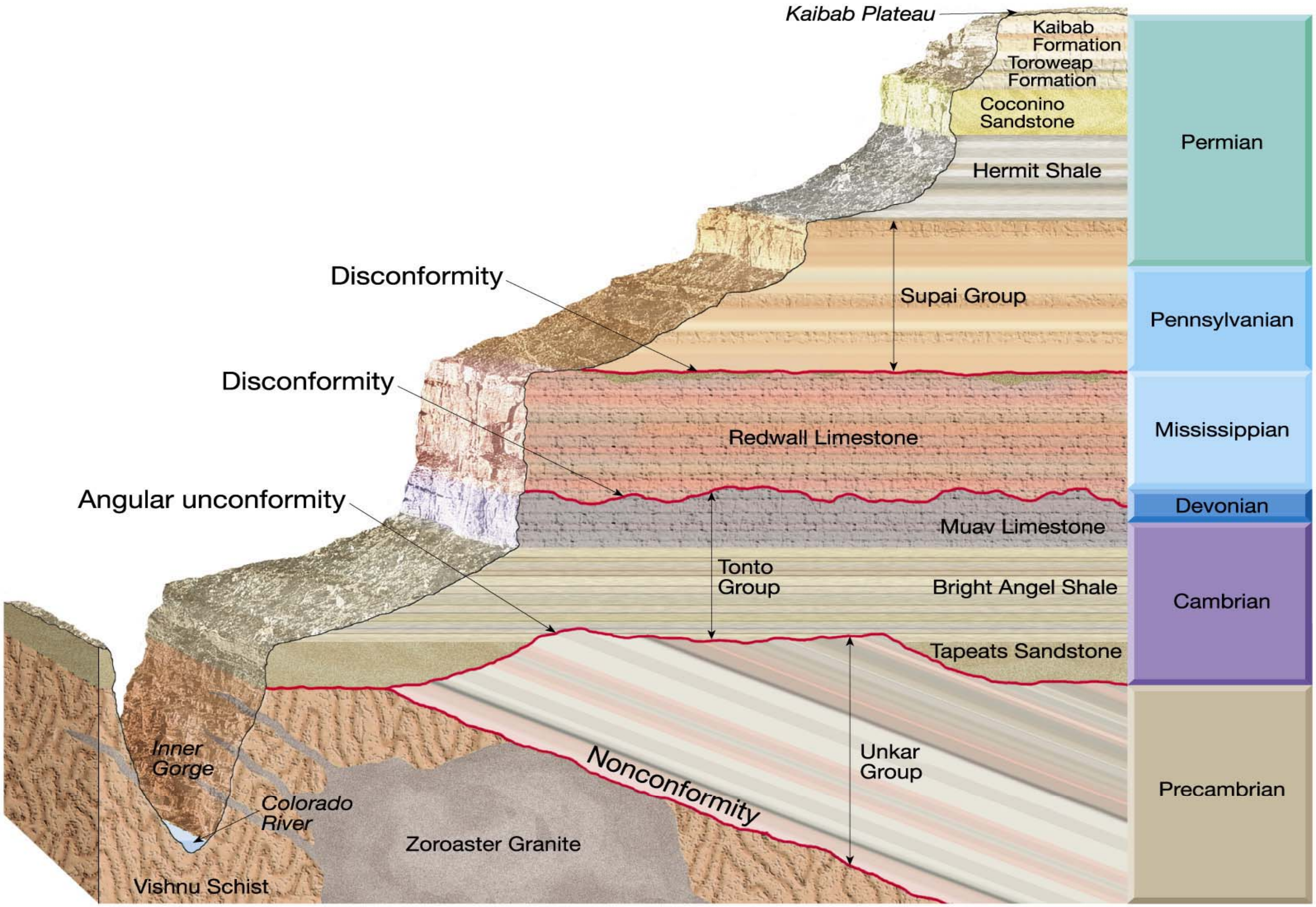


C. Deposition of
sedimentary layers

Disconformity

- Gap in sedimentation that may have erosion also
- Represents an interval in geologic time without rock deposited
- Most difficult of the three unconformities to detect
- Strata on either side are parallel

Several unconformities are present in the Grand Canyon



Principles of Relative Dating

- Superposition
- Original Horizontality and Lateral Continuity
- Inclusions
- Crosscutting Relationships
- Unconformities

Principles of Relative Dating

- Principle of original horizontality
- Principle of lateral continuity
- Principle of superposition
- Principle of cross-cutting relationships
- Principle of inclusion
- Principle of faunal succession

Absolute Geologic Time

- Radiometric Dating
- Igneous rocks contain potassium, uranium thorium and rubidium that are radioactive
- Careful measurement of ratios of these and their daughter products, or of the isotopes of them that are not radioactive can be used to calculate absolute ages

Table 10.1 Radioactive isotopes frequently used in radiometric dating.

Radioactive Parent	Stable Daughter Product	Currently Accepted Half-Life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years

Radiometric dating

- Known Half-life
- Closed system
- Cross-checked for accuracy
- Yields numerical dates

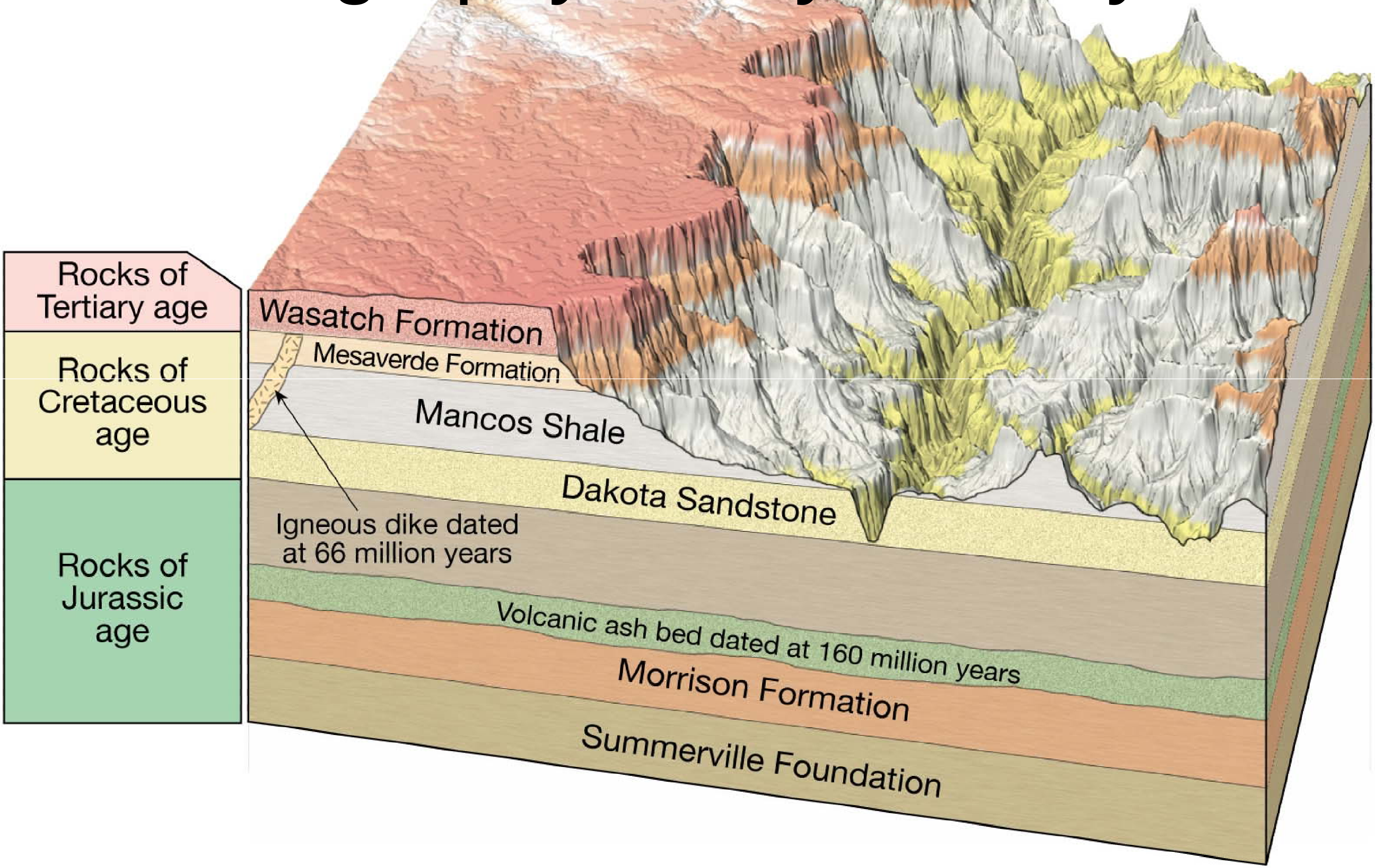
Absolute Ages

- Only possible for igneous rocks
- Need to have crosscutting relationships
- Can bracket age of sediments, geologic events like faulting, folding, erosion

Importance of radiometric dating

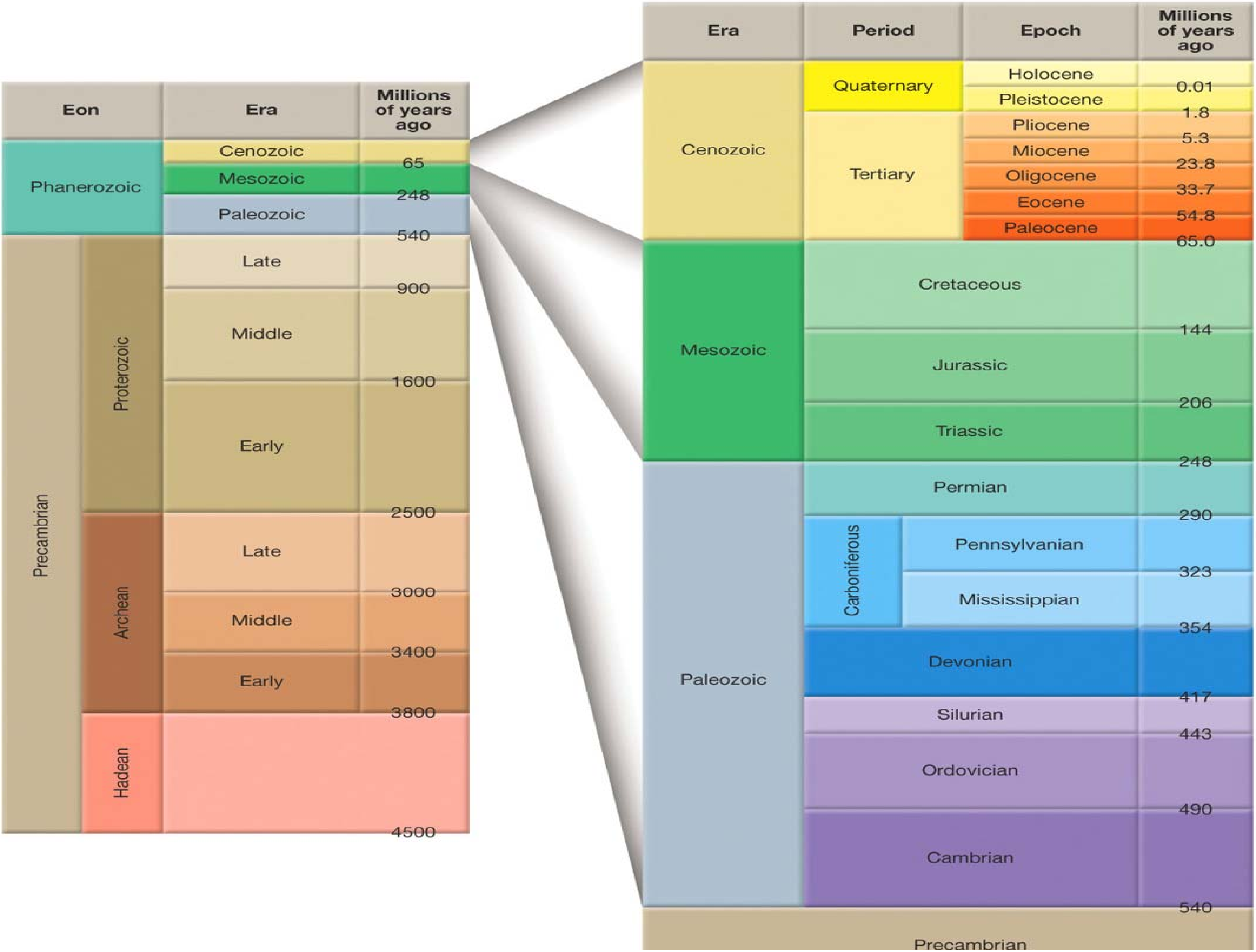
- Confirms the idea that geologic time is immense
- Rocks from several localities have been dated at more than 3 billion years
- Radiometric dating is a complex procedure that requires precise measurement

Stratigraphy of Bryce Canyon



Geologic time scale

- Divides geologic history into units
- Originally created using relative dates
- Bracket events and arrive at ages



Eon
Era
Millions of years ago
Phanerozoic
Cenozoic
65
Mesozoic
248
Paleozoic
540
Precambrian
Proterozoic
Late
900
Middle
1600
Early
2500
Archean
Late
3000
Middle
3400
Early
3800
Hadean
4500
Era
Period
Epoch
Millions of years ago
Cenozoic
Quaternary
Holocene
0.01
Pleistocene
1.8
Tertiary
Pliocene
5.3
Miocene
23.8
Oligocene
33.7
Eocene
54.8
Paleocene
65.0
Mesozoic
Cretaceous
144
Jurassic
206
Triassic
248
Paleozoic
Permian
290
Carboniferous
Pennsylvanian
323
Mississippian
354
Devonian
417
Silurian
443
Ordovician
490
Cambrian
540
Precambrian

Subdivisions

- Eons
  - Eras
    - Periods
      - Epochs

Eon

Greatest expanse of time

- Four eons
  - Phanerozoic ("visible life") – the most recent eon: started 543 Ma
  - Proterozoic: 2500 – 543 Ma
  - Archean: 3800 – 2500 Ma
  - Hadean – oldest eon 4500 – 3800 Ma

Eras of the Phanerozoic eon

- Cenozoic ("recent life"): 65 Ma – now
- Mesozoic ("middle life"): 248 – 65 Ma
- Paleozoic ("ancient life"): 543 – 248 Ma

Fossils: evidence of past life

Remains or traces of prehistoric life

Petrified

Petrified

Formed by replacement

Cell material is removed and replaced with mineral matter

Mold

Shell or other structure is buried and then dissolved by underground water

http://www.ammonoid.com/Manning.html

Shape is preserved in the surrounding sediment

Cast

Hollow space of a mold is filled with mineral matter

B

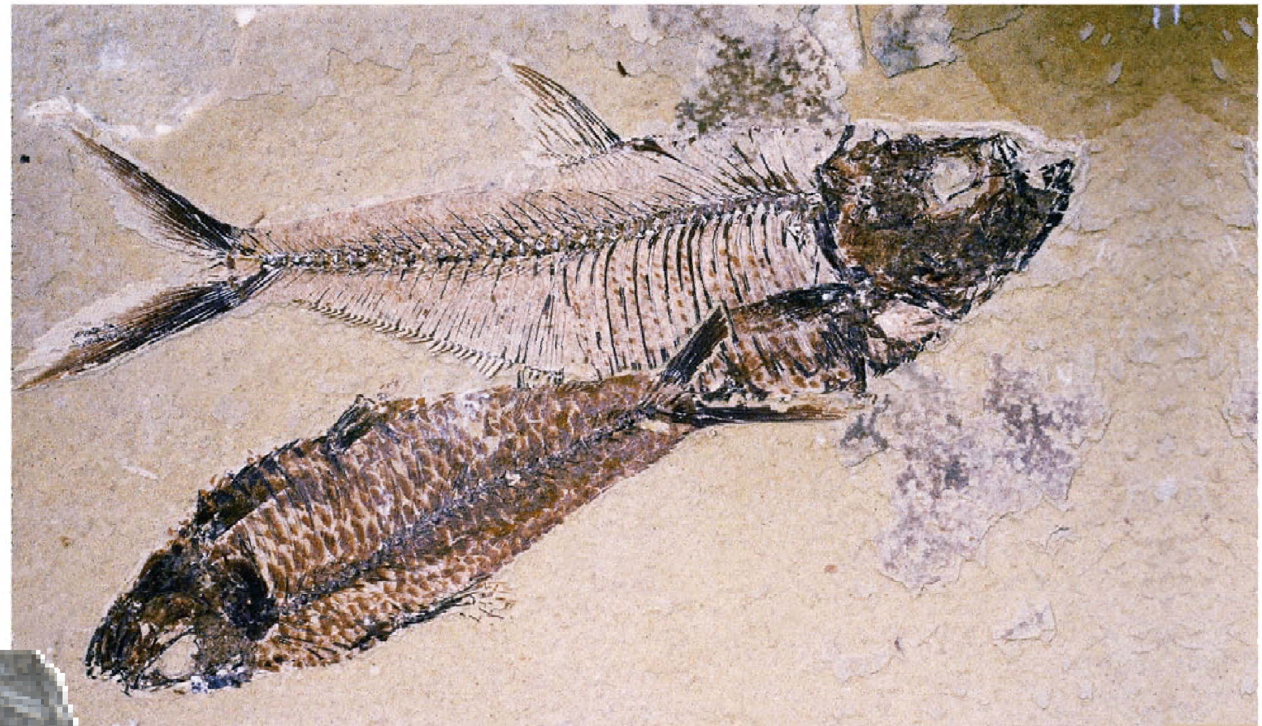
Carbonization

Organic matter becomes a thin residue of carbon. This is a ‘compression’ of the original organism

c

Impression

Replica of the fossil's surface preserved in fine-grained sediment



http://www.lfbuffalo.org/exhibitions/map/t/

Preservation in amber

E

Indirect Evidence Includes

- Tracks
- Burrows
- Coprolites
  - fossil dung and stomach contents
- Gastroliths
  - stomach stones used to grind food by some extinct reptiles

Tracks

Dinosaur footprint in fine-grained limestone near Tuba City, Arizona.

F

Types of fossils

- Petrified
- Formed by replacement
- Mold
- Cast
- Carbonization
- Impression
- Preservation in amber
- Indirect evidence

Conditions favoring preservation

- Rapid burial
- Possession of hard parts

Fossils and correlation

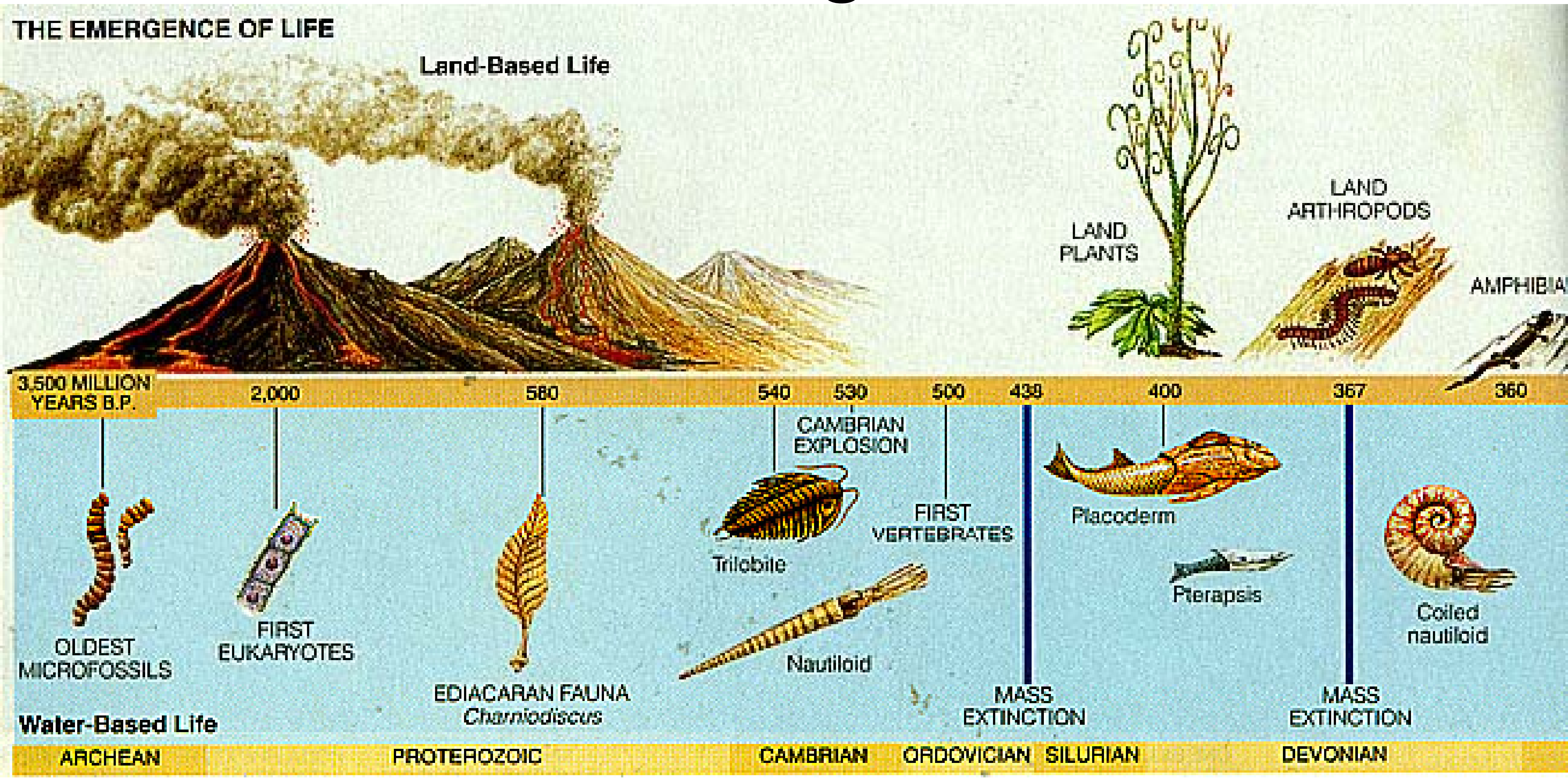
- Principle of faunal succession
- Index fossils

Principle of faunal succession

- Proposed by William Smith – late 1700s
- Fossil organisms succeed one another in a definite and determinable order, therefore any geologic time interval can be recognized by its fossil content

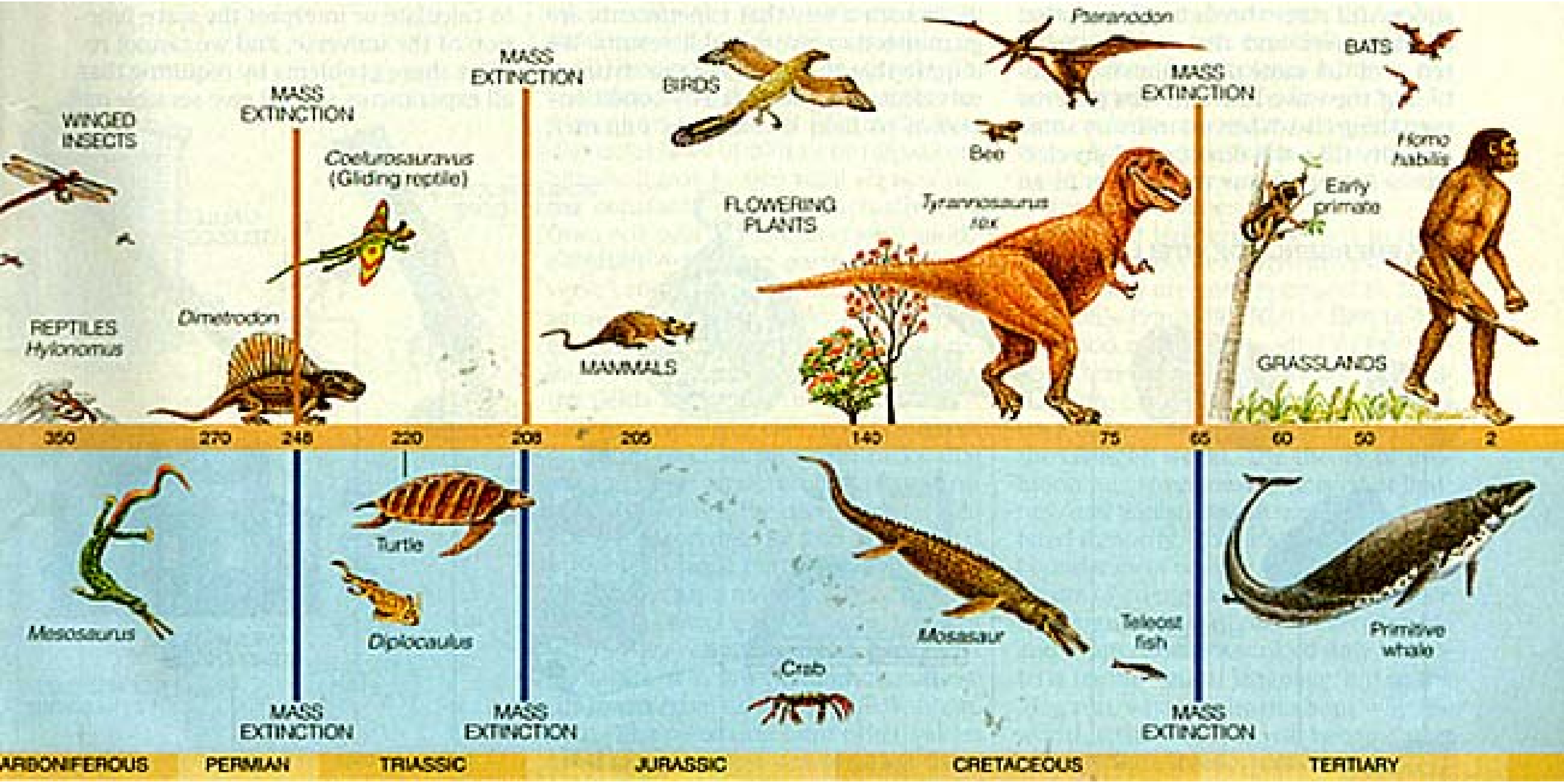
http://www.lfbuffalo.org/exhibitions/map/a/

Archean through Devonian



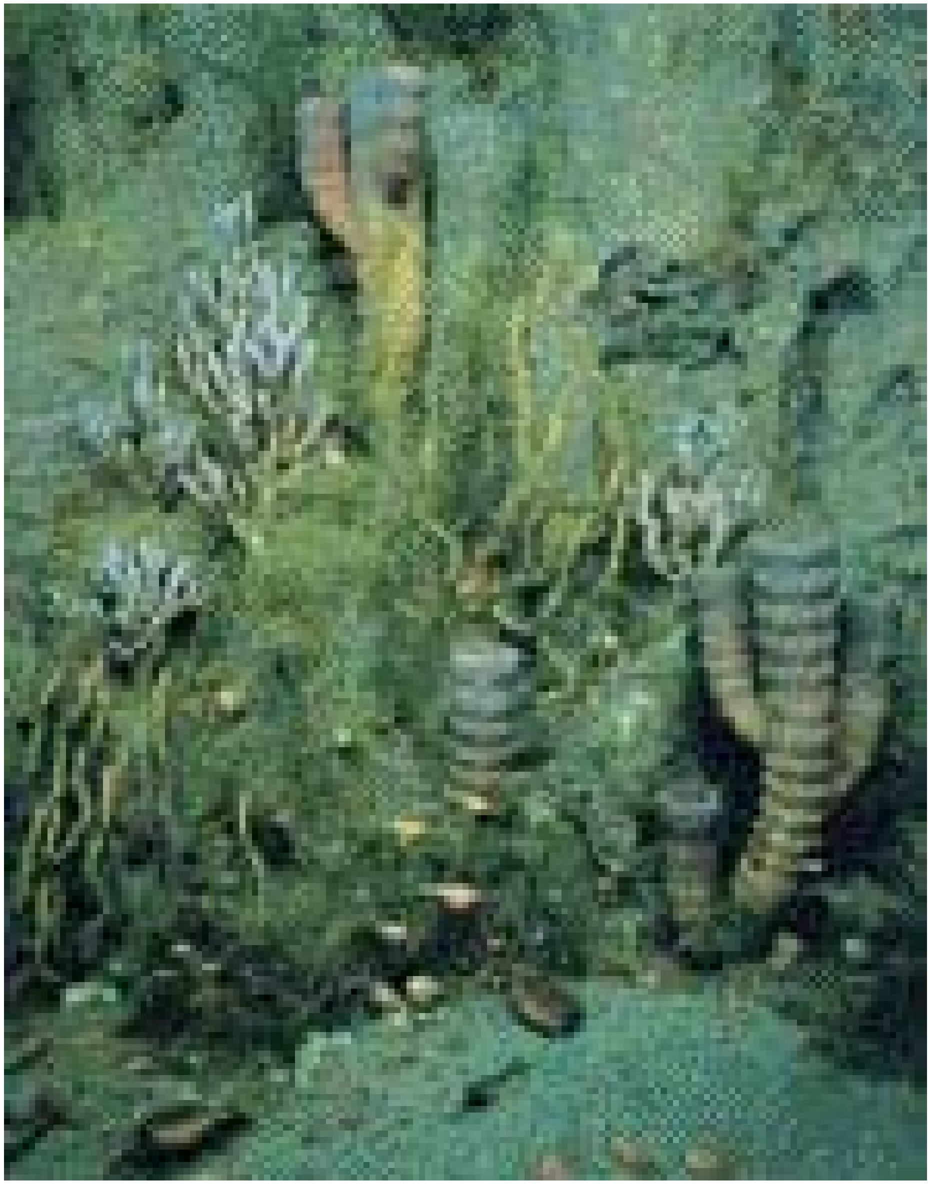
http://rst.gsfc.nasa.gov/Sect2/Sect2_1b.html

Carboniferous through Quaternary



http://rst.gsfc.nasa.gov/Sect2/Sect2_1b.html

Cambrian Marine Life



http://www.handprint.com/PS/GEO/geoevo.html

Trilobite

http://www.ststephens.it/biology/fossils.html

Crinoid—

http://www.lsa.umich.edu/exhibitmuseum/exhibits/temporary_exhibits/

Ordovician sea floor

http://www.uwsp.edu/geo/faculty/hefferan/Geol106/CLASS6/MAIN%20PAGE.htm

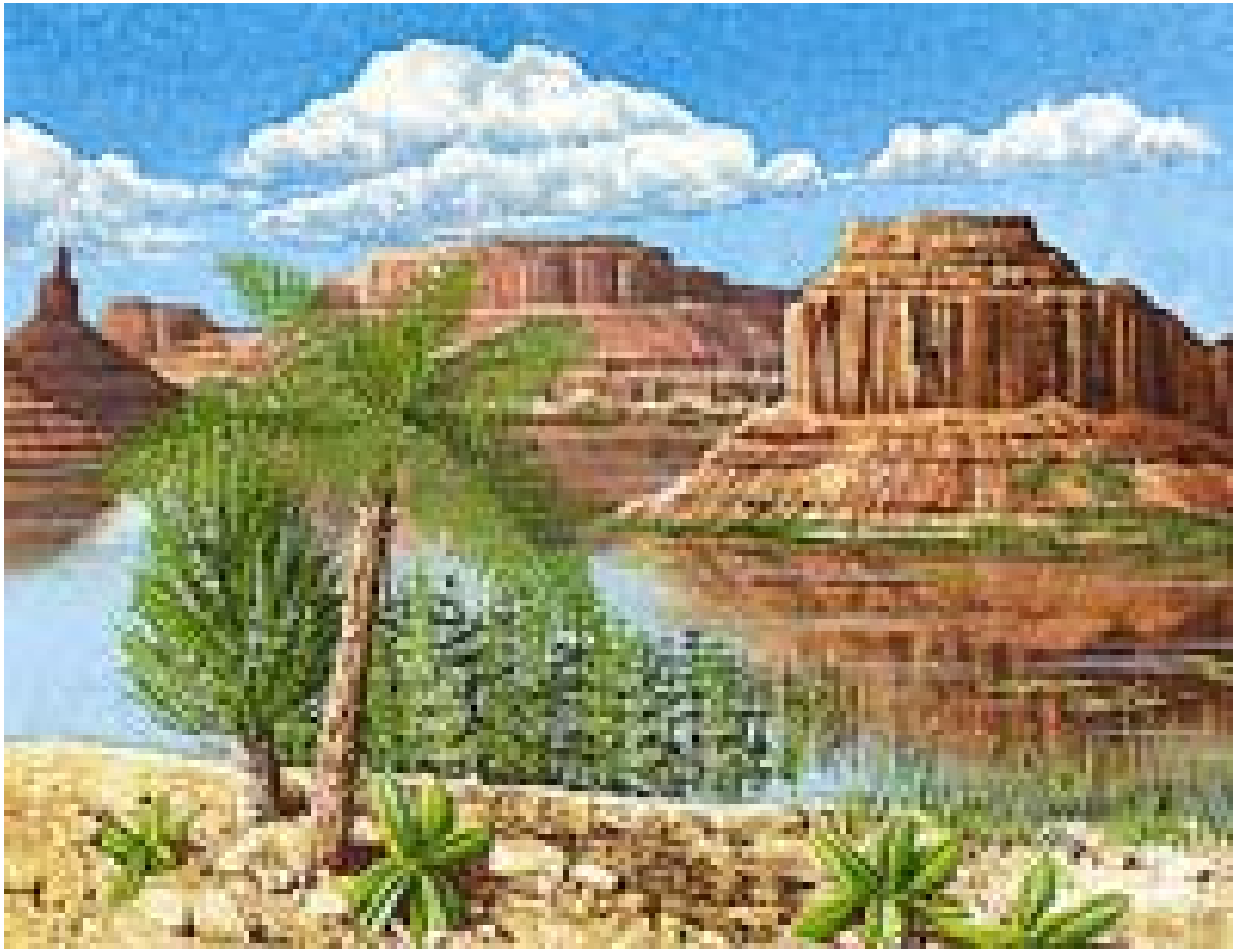
Ordovician Invertebrates

http://www.handprint.com/PS/GEO/geoevo.html

- Silurian Reef

http://hoopermuseum.earthsci.carleton.ca/camex/1rpaleoreef.html

Silurian Landscape



http://www.nasa.gov/worldbook/earth_worldbook.html

Devonian Sea

http://www.handprint.com/PS/GEO/geoevo.html

Mid Paleozoic

FIGURE 6.10 – The Paleozoic Age saw many forms of life flourishing on planet Earth. In this artist's conception, some life ekes out a sparse living—mostly in the sea, such as the trilobites and sponges on the ocean floor and the jellyfish-like creatures nearer the ocean surface. Yet, as suggested by this painting, simple life forms were beginning to make their way onto the land. (Smithsonian)

http://www.tufts.edu/as/wright_center/cosmic_evolution/docs/text/text_bio_4.html

Late Paleozoic

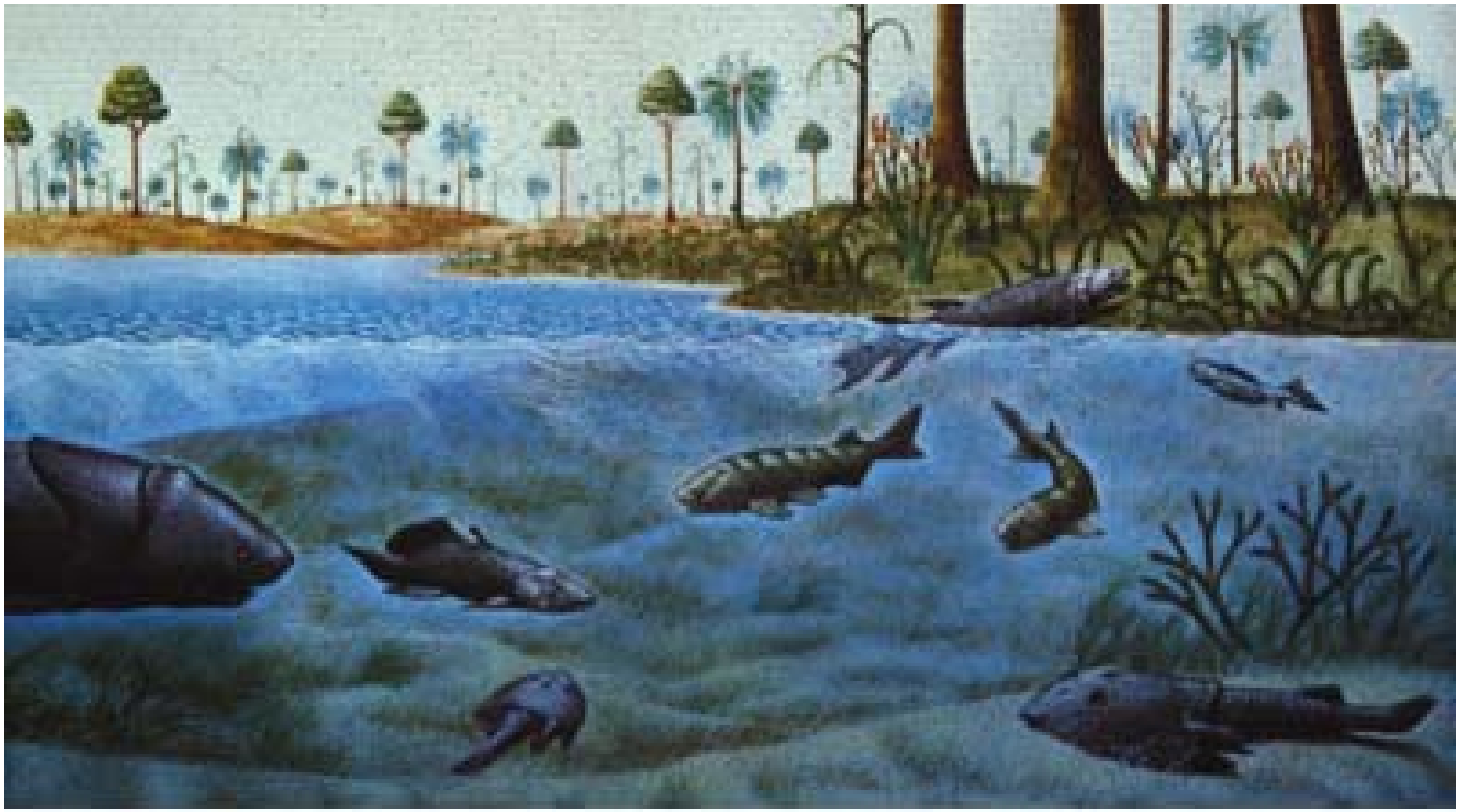


FIGURE 6.12 – This painting captures a scene toward the late-Paleozoic Life had diversified and become more robust—as depicted here both by the variety of (now extinct) fish and also by an increased presence of plants on the land. (Smithsonian)

http://www.tufts.edu/as/wright_center/cosmic_evolution/docs/text/text_bio_4.html

Carboniferous Fern Forests

http://www.handprint.com/PS/GEO/geoevo.html

Permian Sea

http://www.handprint.com/PS/GEO/geoevo.html

Permian Reptiles

http://www.handprint.com/PS/GEO/geoevo.html

Permian Extinction

- Link to hypotheses of the Permian Extinction http://en.wikipedia.org/wiki/Permian_extinction
- 80-95% of marine species died out
- 70%+ of terrestrial vertebrates
- Largest extinction episode in geologic record

Mesozoic

http://geography.berkeley.edu/ProgramCourses/CoursePagesFA2002/Geog40/Geog40.Week7.html

Mesozoic

http://serc.carleton.edu/introgeo/earthhistory/dinosaur.html

Mesozoic

http://geography.berkeley.edu/ProgramCourses/CoursePagesFA2002/Geog40/Geog40.Week7.html

Mesozoic

FIGURE 6.13 — The Mesozoic Age saw a continued increase in the diversity of life forms especially among the land plants, and not least the first appearance of the mammals—all of which, however, were completely dominated by the dinosaurs.

http://www.tufts.edu/as/wright_center/cosmic_evolution/docs/text/text_bio_4.html

Archeopteryx

http://www.researchcasting.ca/sculpt%20miami.htm

Mesozoic Mammal

- Eomaia

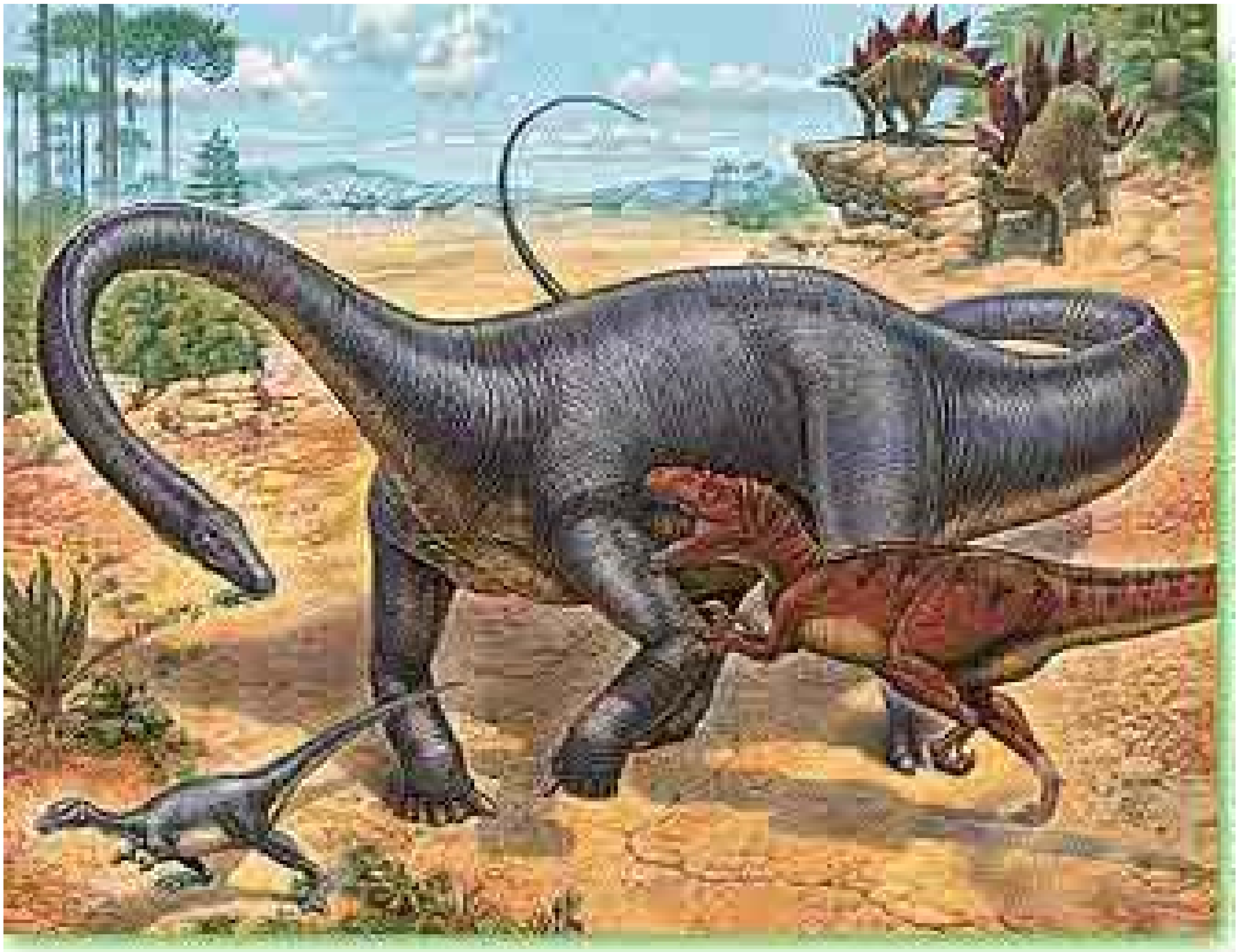
http://www.amnh.org/exhibitions/dinosaurs/diorama/

Mesozoic Mammal

- Repenomamus

http://www.amnh.org/science/papers/mesozoic_mammal.php

Jurassic

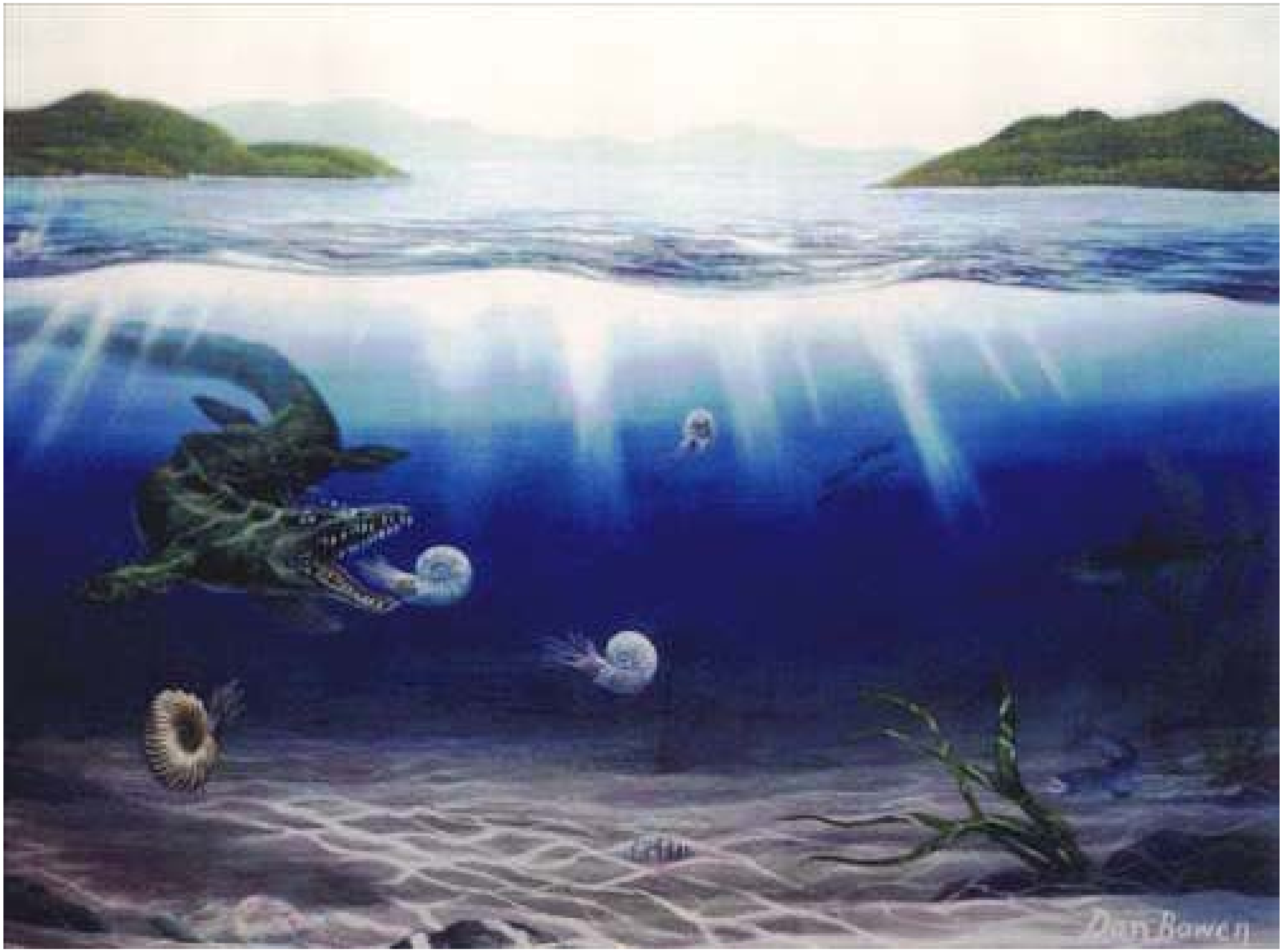


http://www.worldbook.com/features/dinosaurs/html/world_mesozoic.html

Cretaceous

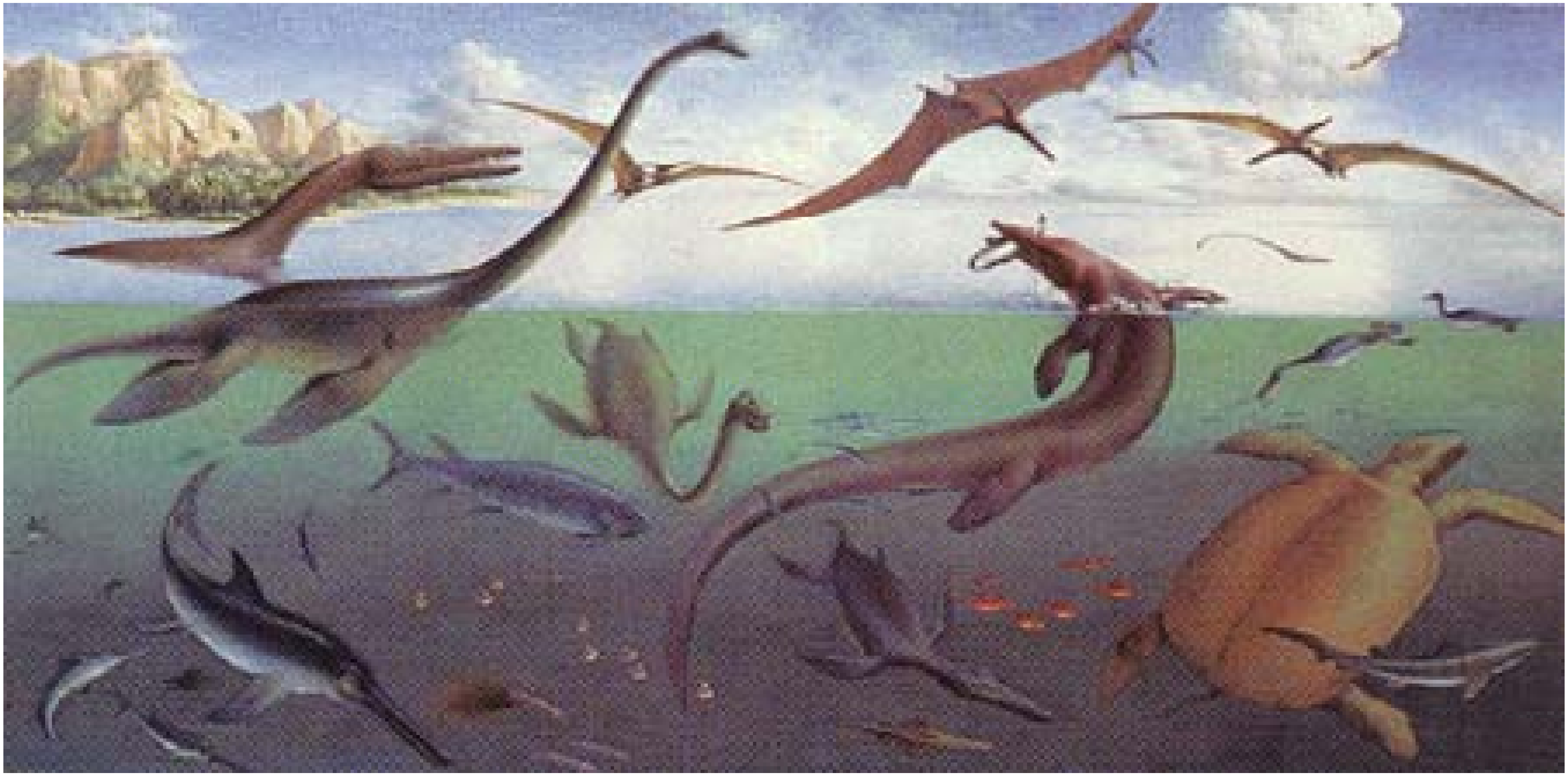
http://www.worldbook.com/features/dinosaurs/html/world_mesozoic.html

Mesozoic Sea



http://geography.berkeley.edu/ProgramCourses/CoursePagesFA2002/Geog40/Geog40.Week7.html

Mesozoic sea



http://www.uky.edu/AS/Geology/webdogs/time/mesozoic/mesozoic.htm

Cretaceous Extinction

- Perhaps 60% of species died
- Result of radical change in environment
- Perhaps Earth encountered a large meteorite—
  - 10 km in diameter
  - 90,000 km/hr
  - Equivalent to 100 megatons of TNT exploding

Cenozoic mammals

http://www.handprint.com/PS/GEO/geoevo.html

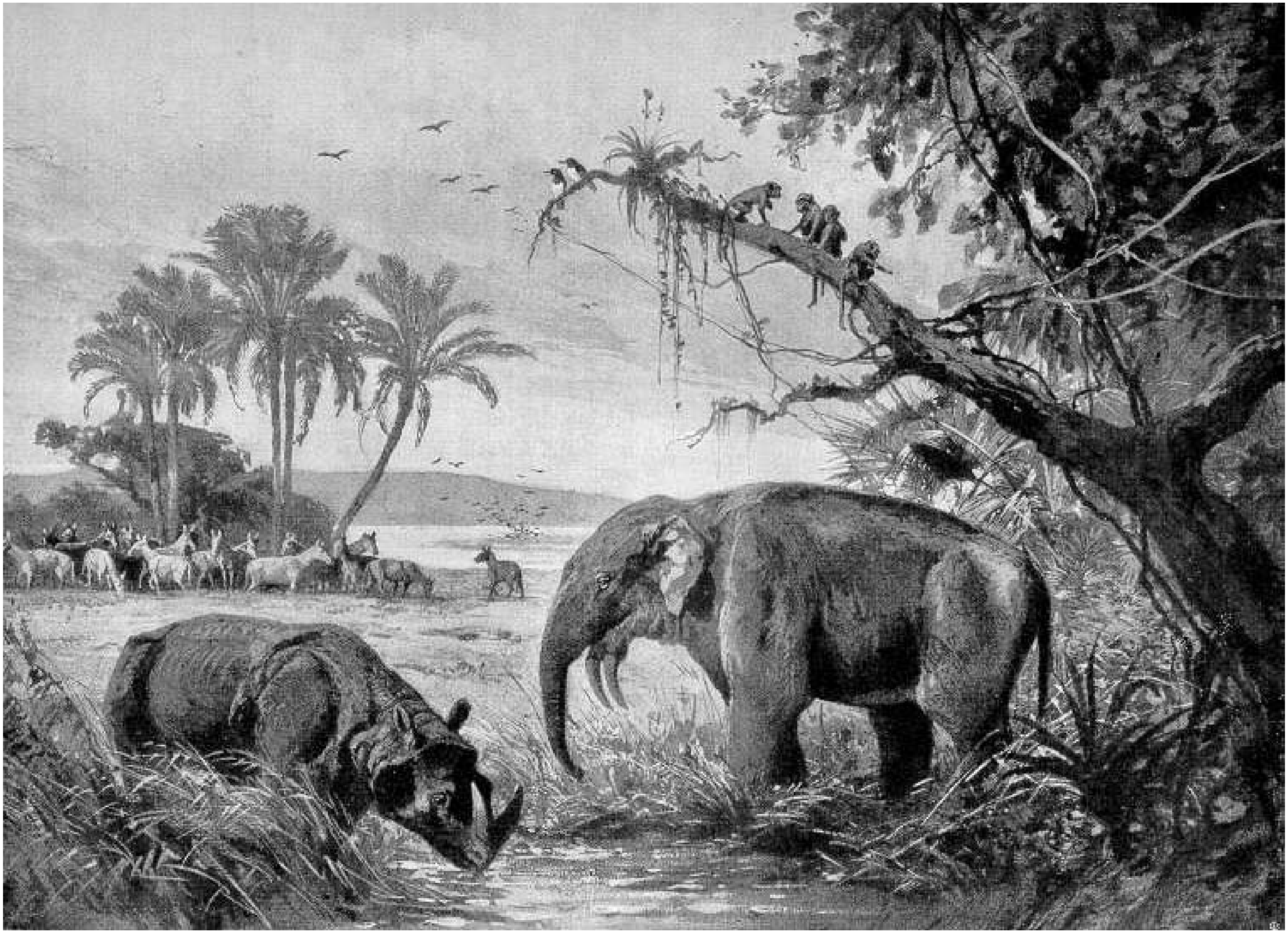
Cenozoic

http://www.handprint.com/PS/GEO/geoevo.html

Cenozoic

http://www.uky.edu/AS/Geology/webdogs/time/cenozoic/cenozoic.htm

Cenozoic



http://www.copyrightexpired.com/Heinrich_Harder/cenozoic.html