Relative dating: some principles to follow...
Principle of superposition
Principle of original horizontality

Original Horizontal Strata

Tilted Strata
Principle of lateral continuity

Moenkopi Formation (red rocks at the base of the cliff), Shinarump Conglomerate (thin white layer), Chinle Formation (grey, purple and red layers) and Wingate Formation (buff colored cliff at the top); note how the Shinarump Member pinches out towards the center of the image. Capitol Gorge, Capitol Reef National Park, Utah
Principle of cross-cutting relationships

Normal fault cutting across volcanic tuff layers near Kingman, Arizona

Basalt dikes cutting across bedding in the Moenkopi shales, Capitol Reef National Park, Utah

Dike cutting across the Chinle Formation, Echo Cliffs, Arizona
Principle of inclusions

Dropstone inclusions in Permian aged sediments, Hallott Cove, Australia

Xenolith inclusion in the granite at Enchanted Rock State Park, Texas
Principles of unconformities (missing time)

Disconformity in the Dakota Formation (red arrow); note the stream channel that has cut into older layers, including the Cow Spring Formation. Coal Mine Canyon, Arizona

Angular unconformity between the Furnace Creek Formation and overlying gravels, near Zabriskie Point, Death Valley National Park, CA

Nonconformity contact between Pikes Peak Granite (below) and Sawatch Sandstone (above), Manitou Springs, Colorado.
Radiometric Age Dating

• Uses unstable isotopes of naturally occurring elements. The isotopes decay: they change into different elements or different isotopes of the same element.

• The rate of decay is known (has been measured in the laboratory) for a variety of isotopes.

• When igneous rocks form, there is 100% parent and 0% daughter isotopes in the rock.

• The ratio of the parent and daughter isotopes can be measured using a mass spectrometer.
<table>
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<tr>
<th>Method</th>
<th>Parent isotope</th>
<th>Daughter isotope</th>
<th>Half life</th>
<th>Dating range</th>
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Paleomagnetics

Earth has a dipole magnetic field, with the direction in line with the axis of spin.

When rocks form, they are permanently magnetized in the direction of the current magnetic latitude.
Plate Tectonics
Fossils
A fossil is any recognizable evidence of preexisting life.

Types of fossils:
   (1) Trace fossils
   (2) Preserved material

Fossils are our only direct evidence of what organisms looked like in the past.

The fossil record is a biased one.
Where is the time?

Sandstone bedding, Sundance Formation, Black Hills of South Dakota
Taphonomy: The study of the process of fossilization, from death of the organism to discovery by the paleontologist.
Types of biases in the fossil record

• Fossils with no hard parts are rarely preserved. Fossil record is mostly a record of shells and bones.

• Organisms that lived in areas where they are likely to be preserved.

• Time averaging of fossil beds.

• Post-mortem transport, scavenging,
Diatoms

Foraminifera

Microfossils

Monday, October 25, 2010
“Invertebrates”
Stomatolites
Transitional Forms
D. *Dorudon* (Basilosauridae) from the middle to late Eocene of Egypt

C. *Rodhocetus* (Protocetidae) from the early middle Eocene of Pakistan

B. *Pakicetus* (Pakicetidae) from the earliest middle Eocene of Pakistan

A. *Elomeryx* (Anthracotheriidae) from the Oligocene of Europe, North America, Asia

Basilosaurus hind leg
Ankle bones of the archaeocetes Rodhocetus (Eocene) on the left, a pronghorn (middle) and Artiocetus (right). Note the double-pulleyed astragalus. Other features in common are a notched cuboid and a prominent fibular facet.
Tiktaalik roseae (late Devonian)
Microfossils from the Apex Chert, North Pole, Australia

About 3.465 billion years old, resembling filamentous cyanobacteria
Stromatolite, North Pole deposits, Western Australia

about 3.5 billion years old
Extant stromatolite showing closeup of cyanobacteria
Proterozoic (2.5 bya to 544 mya). Evolution of organisms with oxygenic photosynthesis caused an increase in oxygen levels. Rising oxygen levels in the world’s oceans caused the formation of iron oxide, often preserved in the banded iron formation.
Eukaryotic milestones

• 2.7 bya: chemical traces of eukaryotic-type lipids in fossil organic matter (controversial).

• 2.1 bya: Grypania spiralis, the first fairly well-accepted fossil eukaryote.

• 1.6-1.8 bya: origin of single-celled algae of unknown type, known as acritarchs.
Grypania spiralis from Michigan