A typical rock formation

Relative dating: some principles to follow...

1. Principle of superposition

2. Principle of original horizontality

3. Principle of lateral continuity

4. Principle of cross-cutting relationships

5. Principle of inclusions
Principles of unconformities (missing time)

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>
<thead>
<tr>
<th>Method</th>
<th>Parent isotope</th>
<th>Daughter isotope</th>
<th>Half life</th>
<th>Dating range</th>
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<tbody>
<tr>
<td>Rubidium-strontium</td>
<td>Rb-87</td>
<td>Sr-87</td>
<td>47 by</td>
<td>10 m-4.6 b</td>
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<tr>
<td>Uranium-lead</td>
<td>U-238</td>
<td>Pb-206</td>
<td>4.5 by</td>
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<td>Uranium-lead</td>
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<td>Pb-207</td>
<td>71.3 my</td>
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<td>Thorium-lead</td>
<td>Th-232</td>
<td>Pb-208</td>
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<td>Potassium-argon</td>
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<td>Ar-40</td>
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<td>.1 m-4.6 b</td>
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<td>Carbon-14</td>
<td>C-14</td>
<td>N-14</td>
<td>5730 y</td>
<td>100-100,000</td>
</tr>
</tbody>
</table>

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.
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.

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.

Taphonomy: The study of the process of fossilization, from death of the organism to discovery by the paleontologist.

Microfossils

“Invertebrates”

Diatoms

Foraminifera

Foraminifera

Diatoms
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

Endosymbiosis hypothesis for the origin of organelles

- Organelles originated in symbiotic union of ancestral prokaryotes

Cambrian Explosion
Family diversity through time

Small shelly fauna from the Tommotian age

Cyclomedusa (bottom-dwelling jelly fish-like creature)

Dickinsonia (annelid worm, cnidarian polyp?)

Tribrachidium (bizarre three-part symmetry; cnidarian, echinoderm?)

Kimberella (bilaterally symmetric; perhaps related to molluscs)
Burgess Shale

Charles Walcott

Aysheaia (velvet worm)

Pikaia (primitive chordate)

Canadia (polychaete worm)

Ottoia (priapulid worm)

Hallucigenia (onychophoran: velvet worm)
Marrella
(primitive arthropod)

Olenoides
(trilobite)

Opabinia
(???)
(five eyes and proboscis!)

Wiwaxia
(???)

What caused the Cambrian explosion?
- rising oxygen levels allowed larger body sizes
- evolution of key developmental genes
- evolution of skeletons (allowing larger body size)
- predation (arms race between predators and prey)

Is the Cambrian explosion an illusion?
- Major phyla originated much earlier, but Cambrian/pre-Cambrian marks the passing of a taphonomic threshold.
- Some molecular phylogenetic analyses support an earlier divergence of phyla.
Morphological Disparity

• Gould: Diversity in the Cambrian was much greater (witness the Burgess Shale Creatures), and today's diversity in body forms is a result of a perhaps random winnowing of the Cambrian diversity.

• Conway-Morris: Most of the Burgess Shale creatures can be placed with modern phyla.