Determining geological ages

- Relative age dates – placing rocks and events in their proper sequence of formation
- Numerical dates – specifying the actual number of years that have passed since an event occurred (known as absolute age dating)
Principles of relative dating

• Law of superposition
  - Developed by Nicolaus Steno in 1669
  - In an undeformed sequence of sedimentary rocks (or layered igneous rocks), the oldest rocks are on the bottom

Superposition is well illustrated by the strata in the Grand Canyon

Superposition, Original Horizontality and Lateral Continuity
Principles of relative dating

- Principle of original horizontality
  - Layers of sediment are generally deposited in a horizontal position
  - Rock layers that are flat have not been disturbed
- Principle of cross-cutting relationships
  - Younger features cut across older feature

Cross-cutting relationships

Principles of relative dating

- Inclusions
  - An inclusion is a piece of rock that is enclosed within another rock
  - Rock containing the inclusion is younger
- Unconformity
  - An unconformity is a break in the rock record produced by erosion and/or non-deposition of rock units
Principles of relative dating

• Unconformity
  • Types of unconformities
    – Angular unconformity – tilted rocks are overlain by flat-lying rocks
    – Disconformity – strata on either side of the unconformity are parallel
    – Nonconformity – metamorphic or igneous rocks in contact with sedimentary strata

Several unconformities are present in the Grand Canyon
Fossils: evidence of past life

• Fossil – the remains or traces of prehistoric life

• Types of fossils
  • The remains of relatively recent organisms – teeth, bones, etc.
  • Entire animals, flesh included
  • Given enough time, remains may be petrified (literally “turned into stone”)

Fossils: evidence of past life

• Types of fossils
  • Molds and casts
  • Carbonization
  • Others
    – Tracks
    – Burrows
    – Coprolites (fossil dung)
    – Gastroliths (polished stomach stones)

Fossils: evidence of past life

• Correlation of rock layers
  • Matching of rocks of similar ages in different regions is known as correlation
  • Correlation often relies upon fossils
    – William Smith (late 1700s–early 1800s) noted that sedimentary strata in widely separated areas could be identified and correlated by their distinctive fossil content
Fossils: evidence of past life

• Correlation of rock layers
  • Correlation often relies upon fossils
  - Principle of fossil succession – fossil organisms succeed one another in a definite and determinable order, and therefore any time period can be recognized by its fossil content
  - Index fossils
    – Widespread geographically
    – Limited to short span of geologic time

Determining the ages of rocks using fossils

Using radioactivity in dating

• Reviewing basic atomic structure
  - Nucleus
    – Protons – positively charged particles with mass
    – Neutrons – neutral particles with mass
    – Electrons – negatively charged particles that orbit the nucleus
Using radioactivity in dating

• Radioactivity
  • Spontaneous changes (decay) in the structure of atomic nuclei
  • Age of a rock is determined by study of the isotopic ratios of elements in the minerals of the rock
  • Sophisticated and highly precise chemical techniques are used

Types of radioactive decay

Using radioactivity in dating

• Parent – an unstable radioactive isotope
• Daughter product – the isotopes resulting from the decay of a parent
• Half-life – the time required for one-half of the radioactive nuclei in a sample to decay
The radioactive decay curve

Geologic time scale

- The geologic time scale – a “calendar” of Earth history
  - Subdivides geologic history into units
  - Originally created using relative dates
- Structure of the geologic time scale
  - Eon – the greatest expanse of time
Geologic time scale

• Structure of the geologic time scale
  • Names of the eons
    – Phanerozoic (“visible life”) – the most recent eon, began about 540 million years ago
    – Proterozoic
    – Archean
    – Hadean – the oldest eon

Geologic time scale

• Structure of the geologic time scale
  • Era – subdivision of an eon
  • Eras of the Phanerozoic eon
    – Cenozoic (“recent life”)
    – Mesozoic (“middle life”)
    – Paleozoic (“ancient life”)
  • Eras are subdivided into periods
  • Periods are subdivided into epochs
Several unconformities are present in the Grand Canyon.
Figure 1. Map of the Colorado Plateau province showing major drainage and section boundaries. (After Hunt, 1956.)

Grand Staircase-Escalante NM