

## Geologic Time

Study rocks - history of the earth.

Sedimentary rocks provide best evidence of earth history because:

- 1) often contain fossils, properties to establish environments, and
- 2) often provide geologic age of materials.

**Geologic Time Scale** - put rocks into a time perspective.

We distinguish two types of geologic time:

**1) Relative ages or dating**

- a) to determine how old rocks are in relation to one another;
- b) to determine the proper sequence or chronology of geologic or rock events (layering).

**2) Absolute age**

- a) the exact age of the rock body
- b) how many years ago it formed.

Uses the physics of radioactive decay to pinpoint this age.

### Relative Dating and the Stratigraphic Record

Stratification, or layering of sedimentary rocks, is basic to two simple principles that are used to interpret geologic events from the sedimentary rock record. They are:

**1) the principle of original horizontality** - sediments are deposited as essentially horizontal beds; and

**2) the principle of superposition** - each layer of sedimentary rock in a tectonically undisturbed sequence is younger than the one beneath it and older than the one above it.

This principle allows us to:

- a) view a series of layers as a kind of vertical time line, and
- b) view a partial or complete record of time elapsed from deposition of the lowest bed to deposition of uppermost bed.

Using these relative principles, we can determine which rock is older, but we do not know how much older.

### Lithostratigraphy

To describe rocks - define **lithostratigraphic units**:

bodies of sedimentary, extrusive igneous, metavolcanic or metasedimentary rock distinguished on the basis of lithologic (observable rock) characteristics.

commonly stratified or in tabular form.

Boundaries between two units can be placed at a precise contact or in an arbitrary zone of gradation. **They carry no connotation of age.**

Generally map and identify **formations**.

**formation** - The fundamental unit of lithostratigraphy:

a) a lithologically distinguishable stratigraphic unit based on distinctive lithological properties including mineralogic composition, texture, color, sedimentary structures, fossils, etc.

b) large enough in scale to be mapped at the surface and traced into the subsurface, and

c) distinguished above, below, and adjacent to other formations by stratigraphic position and lithological properties.

### **Contacts Between Units - The Mark of Missing Time**

Layers of rock are said to be **conformable** when they have been deposited essentially without interruption - Termed **gradational**.

However, the deposition of sediment is typically interrupted resulting in a surface or boundary called an **unconformity** - a surface of nondeposition or erosion. The actual time loss is called a **hiatus**.

**e.g.** deposition ceased, erosion removed previously formed rocks, and then deposition resumed.

### **Types of unconformities:**

1) **angular unconformity** - a surface separating tilted or folded strata from overlying undisturbed strata;

2) **disconformity** - a surface of unconformity separating essentially parallel strata;

### **Other methods of relative dating**

1) **Principle of cross-cutting relationships** - when igneous intrusions or faults cut through other rocks, they are assumed to be younger than the rocks they cut.

2) **Inclusions** - are pieces of one rock unit that are contained within another. The rock mass adjacent to the one containing the inclusions must have been there first in order to provide the rock fragments.

**Facies** - are the set of characteristics of a rock body representing a particular local geologic environment.

**Facies Change** - is a lateral change in the characteristics of an ancient body of rock which reflects lateral changes in the depositional environment.

Facies changes are often related to changes in the shoreline.

The process of **progradation** (seaward growth by the accumulation of sediment; e.g. a delta) produces **regression**, or seaward migration of the shoreline.

**Transgression** - is the landward migration of the shoreline. Commonly the result of sea-level rise.

Two types of sea-level change:

- 1) **Relative sea-level changes** - affect sea-level locally.  
occur as a result of tectonic uplift or downwarping.

**Eustatic sea-level** - changes are worldwide changes on all continents simultaneously. They are attributed to continental glaciation during the past 30 Ma. important because if sea level drops suddenly throughout the world and then rises again rapidly, the resulting unconformities may represent fairly accurate time markers.

### **Fossils as Time Pieces**

relative stratigraphy alone cannot be used to compare two widely spaced geologic areas.

to detect missing time intervals and to correlate the ages of rocks at different locations - need fossils.

one of the most important tools for constructing a geologic time scale that is accurate for the entire planet.

#### **Fossils - are the remains of ancient organisms.**

macrofossils - shells, bones, teeth, impressions of plants  
most common fossils - shells of invertebrates including clams and oysters.

trace fossils - animal tracks, burrows

microfossils - foraminifera, calcareous nannoplankton, siliceous nannoplankton (e.g. diatoms, radiolarians), and pollen and spores.

We call the study of history of ancient life and fossils - **paleontology**.

19th century divided the rock record into systems (e.g. Cambrian) based largely on the fossils found in the various strata.

Fossils have primary importance in determining the relative age of rock strata.

The study of the age relationships of layered rocks usually begins with the examination of a **stratigraphic section** - a local outcrop or series of adjacent outcrops that displays the rocks vertical sequence. By the process known as **correlation**, the fossils of two spatially separated stratigraphic sequences can be shown to have the same geologic age.

## Correlation

William Smith (1793) - surveyor in southern England  
 fossils could date relative ages of sedimentary rocks.  
 different layers contained different kind of fossils  
 distinguish one layer from another by different fossil type.

He established a general order for the sequence of fossils and strata. Regardless of the location of any new outcrop he came across, he could predict the stratigraphic position of particular strata from the fossil assemblages he found in them.

**faunal succession** - the stratigraphic ordering of the fossils where fossils are arranged according to their age: *fossil organisms succeed one another in a definite and determinable order, and any time period can be recognized by its fossil content - evolution.*

Smith was the first to use faunal succession to **correlate**, or match, rocks from different outcrops.

**index fossils** - fossil species and genera that are especially well suited to correlation procedures:

- 1) easily distinguishable from other taxa;
- 2) geographically widespread so can be used to correlate rocks over a large area;
- 3) occur in many kinds of sedimentary rocks and therefore can be found in many places; and
- 4) They are restricted to narrow stratigraphic intervals and thus allow for precise correlations.

Of course few index fossils exhibit all of these traits.

Basic laws of **stratigraphy** - or study of strata.

**Rock Stratigraphic Units** - mappable assemblages of strata distinguishable by physical criteria. (*Groups, formations, members*).

**Geologic Time Units** - consist of segments of continuous geologic time distinguished on the basis of the rock record. (*Eras, periods, epochs, ages*).

**Time Stratigraphic units** - time represented by a body of rock. They are strata deposited during finite portions of geologic time and preserved as part of the stratigraphic record. They often can be defined only by their fossils. (*System, series, stages*).

## Radioactivity and Radioactive Dating

Used to get absolute age dates.

Most atoms are stable - do not change.  
some are unstable and release heat as their nuclei break apart (decay)

Atoms are composed of protons, electrons, and neutrons  
protons are positive and electrons are negative  
neutrons are actually protons and electrons combined.

Practically all of the mass of the atom is in the nucleus  
**atomic mass number** - the sum of protons and neutrons;  
**atomic number** - the number of protons.

**Isotopes**- have the same atomic number but different mass number.

Some isotopes have unstable nuclei that spontaneously break apart or decay involving the emission of particles and of radiant energy - **radioactivity**.

Radioactive decay - results in changes of the **atomic number (Z)** and **(N) neutrons** that leads to the transformation of an atom of one element into an atom of another.

This causes the **parent** to decay into a **daughter** product, which can also be radioactive.

### Three types of radioactivity:

**1. Alpha decay** - where alpha particles may be emitted from the nucleus.  
An alpha particle is composed of 2 protons and 2 neutrons  
mass number is reduced by four and the atomic number by 2;  
the daughter is an isotope of a different element;

**2. Beta decay** - where a beta particle, or electron (negatron) is given off from the nucleus, and mass number remains unchanged.

Since the electron came from the neutron, the nucleus contains one more proton than before and the atomic number increases by one; neutron number decreases by one.  
Also involves the emission of gamma rays.  
Transformation of a neutron into a proton and an electron.

**3. Electron Capture Decay** - where a nucleus captures one of its electrons.  
The electron combines with a proton and forms a neutron.  
The mass number remains unchanged, while the atomic number drops by one.

Radioactivity provides a reliable means of calculating the ages of rocks and minerals - **radiometric dating**.

- 1) The rates of decay of many isotopes have been precisely measured and do not vary;
- 2) Each radioactive isotope has been decaying at a fixed rate since the formation of the rocks in which it occurs;
- 3) The products of decay have been accumulating at a corresponding rate.

**half-life** - time required for 1/2 of the nuclei in a sample to decay.

So, if the age of the half life is known, and we can calculate the parent - daughter ratio, we can calculate the age.

To date very old events:

Parent/Daughter	Half-Life	Dating Range	Min
1: Uranium-238/Lead-206	4.5 billion	10m-4.6b	zircon
2. Rubidium-87/Strontium-87	47 billion	10m-4.6b	micas, K-spar
3. Potassium-40/Argon-40	1.3 billion	50,000-4.6b	Micas, horn.
4. Carbon-14/Nitrogen-14	5730	100-70,000	wood, bone, water

For recent events, carbon-14 (**radiocarbon**) is used because its half life is 5730 years. Dating back to 75,000 years.

### The Geologic Time Scale

delineated in the nineteenth century in Western Europe and Great Britain when absolute dating was unavailable.

Used principles of relative dating.

The time scale divides the 4.6 b.y. earth into many units which can provide meaning to the major events of the geologic past.

First major break between the **Precambrian** and the **Phanerozoic** at **570 Ma** where rocks begin to contain an abundance of life.

We subdivide the **Phanerozoic Eon** into:

**1) Paleozoic Era - ancient life; 570-245**

**2) Mesozoic Era - middle life 245-65;**

Age of Reptiles

**3) Cenozoic Era - recent life 65--1**

Age of Mammals

Each era is subdivided into **periods**.

**Precambrian represents 85% of earth history.**

First abundant fossil evidence in **Cambrian Period**. Prior to this simple life forms existed.

## **Geomagnetic Polarity Time Scale**

Produced by correlating magnetic reversals with radiometric timescale.

First done in 1968.

Also made on assumptions about the rate of seafloor spreading to generate ages older than ~3.4 Ma (Gilbert/Gauss boundary).

Marine magnetic anomalies are effectively the standard global reference for geomagnetic reversals extending back to the Jurassic Period.

Dated K/T boundary with Ar-40/Ar-39 at 65.0 m.y. in Montana