

## Geologic Time (Geochronology)

Early ideas...

*Catastrophism* – Earth formed by sudden unique events.

- Creation
- Noah's flood
- Ussher chronology – Earth 6,000 yrs old. (4004 bc)

James Hutton , Scottish doctor, farmer, chemist, natural philosopher (1726-1797) Text convoluted, popularized by his friend John Playfair, post mortem.

*Uniformitarianism* (Gradualism) = “the present is the key to the past.”

- Earth was formed by processes we see active today.
  - erosion of mountains
  - isostatic uplift and subsidence
  - deposition of sedimentary layers
- Indicates great age.

Strict uniformitarianism hindered acceptance of plate tectonics.

Now we believe but both are true. Examples of catastrophes:

- Formation of Earth
- Density segregation of Earth (“iron catastrophe”)
- Formation of moon (probably by meteor impact)
- Mass extinctions ~9 (e.g. K-T impact, 65ma, 25% of animal families)
- Earthquakes & volcanoes

# Principles of Stratigraphy

Used to establish relative ages (order) and geologic history.

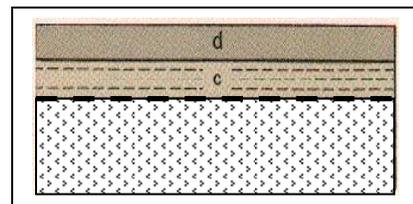
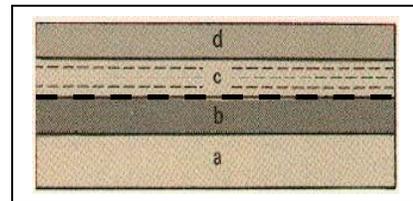
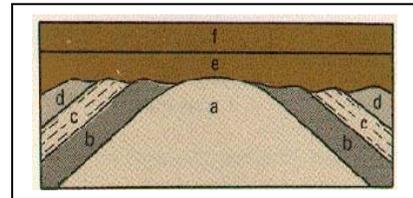
(Steno's Laws)

- 1) **Original horizontality** = sediments are deposited in approx. horizontal beds.
- 2) **Superposition** = upper beds are younger, lower older
- 3) **Cross cutting relationships** = intrusion or fault is younger than the rock it intrudes or offsets.

But... sedimentation is not uniform or continuous

**Unconformity** – time gap in the stratigraphic sequence:

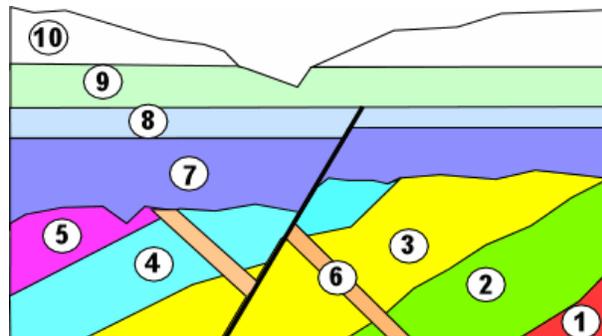
- 1) **angular unconformity**  
layers above and below are not parallel (eroded surface)
- 2) **disconformity**  
gap in time between parallel sedimentary layers (hard to see)
- 3) **nonconformity**  
sediment on erosion surface of metamorphic or igneous rx



## Cross cutting relationships

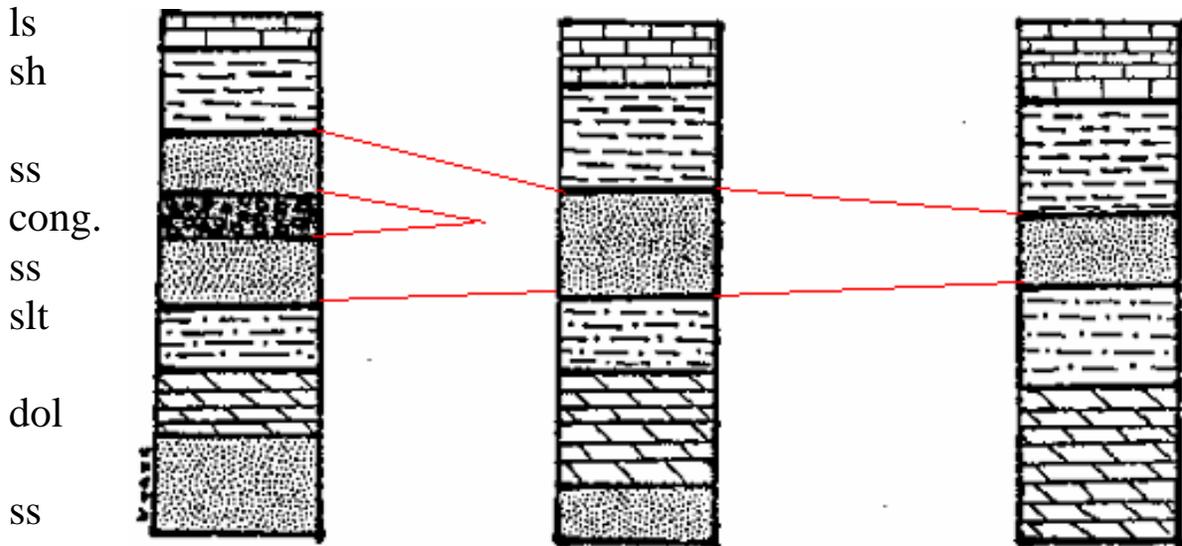
= intrusion or fault is younger than the rock it “cuts” (intrudes or offsets).

Inclusions are older



## Stratigraphic Correlation *Unraveling the story in the rocks.*

Correlation = matching beds from one exposure (area) to another.  
(There can be lateral changes in lithology and thickness.)



Formation = distinctive sequence of layers that can be recognized and mapped. Usu. similar rock type or fossil assemblage.

Process Aided by examining Fossils

**Fossils** = preserved remains of organisms

**Law of Faunal Succession** (Wm. Smith)

= fossils appear and disappear in a definite order.

Index fossils = fossil with wide range but short duration.

- Rock band analogy – Grateful Dead vs. Hanson

**Geologic Time Scale**

- Based on piecing together stratigraphic columns worldwide.
- Big divisions based on change in fossil sequences
  - Cambrian Explosion (other “radiations”)
  - match mass extinctions

**Mass Extinctions** (probably caused by big climate changes)

| End of...  | Marine invert species killed |
|------------|------------------------------|
| Ordovician | 22%                          |
| Devonian   | 21%                          |
| Permian    | 57%                          |
| Triassic   | 20%                          |
| K-T        | 15%                          |

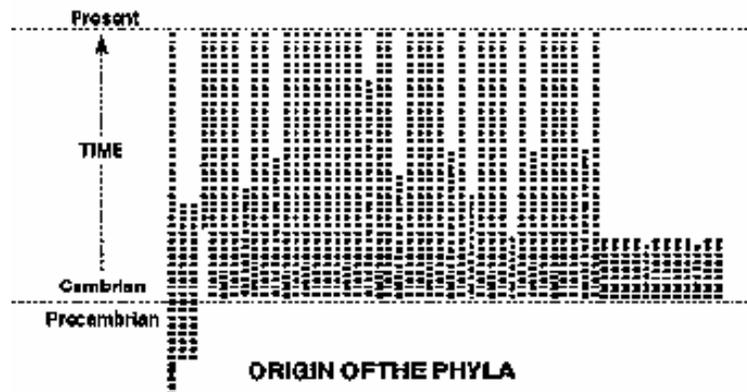
Also smaller mass extinctions at end of: Precambrian, Cambrian, Eocene, Pleistocene.

**Cambrian Explosion** (~542 My ago)

Appearance of all but a few of the major animal groups (phyla) suddenly (over 5 – 10 My period).

Some sponges & worms before.

There is no consensus explanation.



# Absolute Geologic Time

Early attempts to date the earth were

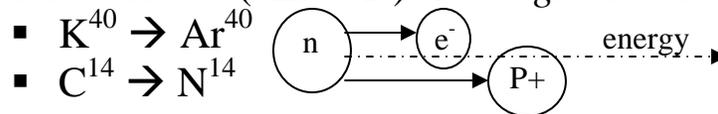
- Salinity of oceans: ~ 100 Ma (didn't account for sedimentation)
- Rate of erosion: ~ 100 Ma (didn't account for tectonics)
- Cooling of the earth: – Kelvin 20-40 My (no radioactivity)

## Radiometric Dating

- Radioactivity (radium) discovered in 1896 (Becquerel & Curie)
- Ernest Rutherford (1905) suggested using it to date rx

Radioactive decay (there are 4 types)

- Some elements have radioactive isotopes (# of neutrons)
- spontaneously decay over time of:
  - *parent element* (unstable) → *daughter element* (stable)



- random for each atom but **average** statistically for large amount (analogy: people live to diff. ages but avg. ~78)
- not affected by T, P, or chemistry (unless contaminated, leaks)
- when igneous or metamorphic rock xlizes the clock starts
- Clock reset at “Curie” point (melting or metamorphism)
- each isotope has a different half-life

**Half-life** = time for half of the parent to decay.

∴ ratio of parent/daughter element yields the age.

1   1/2   1/4   1/8   1/16   1/32   1/62   1/128   1/256

| Parent Isotope   | Daughter          | Half-life | Range          |
|------------------|-------------------|-----------|----------------|
| Rb <sup>87</sup> | Sr <sup>87</sup>  | 47 by     | 10my – 4.6by   |
| U <sup>238</sup> | Pb <sup>206</sup> | 4.5 by    | “              |
| K <sup>40</sup>  | Ar <sup>40</sup>  | 1.3 by    | 50,000 – 4.6by |
| C <sup>14</sup>  | C <sup>14</sup>   | 5730      | 100 – 70,000   |

∴ Can put absolute ages on the geologic time scale