**I. Geologic time**

**A= sandstone**

**B= conglomerate**

**C= shale**

**D= limestone**

**E= marble**

**F= granite**

**G= shonkinite**

**Absolute Dating** – actual age of something (radioactive decay)

vs

**Relative Dating** – determining which rock, fossil or, event came first.

(geologic sequencing)

**II. Relative Dating**

**Law of Uniformitarianism** – all the geological forces and process that happen today happened the same way in the distant past.

\*\* Road cuts are great case-studies to examine the geologic history of the Earth through relative dating.

**Geologic cross sections/diagrams**

\*\* Each layer is coded with a specific symbol to represent the type of rock. \*\*

**Eight Rules of Geologic Layering**

**Rule # 1:** Sedimentary rock forms as sediments deposit on the bottom of a body of water.

* Sedimentary rock layers were likely under water at one time during their formation.

**Rule #2:** Weathering and erosion of rock layers occurs on the surface (not under water).

* Rocks are uplifted through geological forces

**Rule #3: (Law of Superposition)**

Layers of the rock towards the bottom of the layer are older than layers at the top.

\*\* Because of the rough edge we can assume that this diagram represents a cross-section that has not been under water for some time, and that geologic forces of uplift and weathering and erosion created the uneven edge.

**Rule #4:** **(Law of Original Horizontality)**

Sedimentary layers are deposited horizontally. Deformation: folding, faulting, and tilting.

* **Different types of deformation**

1. **Fault** – causes layers to mismatch (layers are tilted)

2. **Tilting** – plate tectonic movement

**Rule #5:** Igneous intrusions are younger than the rock it effects or the rock it metamorphoses.

 (dikes, sills, batholiths, laccoliths)

**Rule #6:** Faults are younger than the rocks they cut through.

**Rule #7:** **Unconformities.** Uplift, weathering and erosion, and subsidence (sinking back under water) forms **unconformities**.

* Unconformity represents a missing part of the rock record.
* Example: book with pages ripped out

**Rule #8:** **(Law of Inclusions)** Inclusions must be older than the layer they are in.

**Absolute Dating –** any method of measuring the age of an object or event in years

**Recall the structure of an atom:**

* All atoms of the same element have the same # of protons and different # neutrons
* Neutron = proton + neutron
* 99.9% of an atom’s mass is in its nucleus.
* Mass of an atom (mass #) = the number of protons + number of neutrons.
* Atomic number = number of protons

**Isotopes** = element with a different number of neutrons.

Example: C-12 (6 protons 6 neutron) C-14 (6 protons 8 neutrons)

**Radioactivity** = when nuclei spontaneously break apart

**2 Types of decay**

1. **Beta decay** – when an atom loses an electron and a neutron decays to form a proton
2. **Alpha decay** – two protons and two neutrons emitted from the nucleus
	* Mass number reduced by 4 units and atomic number reduced by 2.

Carbon-14 Nitrogen-14

***Parent material***– unstable radioactive isotope of an element

***Daughter products***– isotope resulting from the decay of a parent isotope

Carbon-14 Nitrogen-14

**Radiometric Dating** – rates of decay for isotopes are predictable and consistent under the physical conditions that exist on Earth’s outer layers.

1. Radioactive Isotope = unstable isotope that decays at a fixed rate from the time of formation of sample.

**Half-life** – time required for one half of the nuclei in a sample to decay.

**Carbon-14 has a half-life of 5730 years**

|  |  |  |  |
| --- | --- | --- | --- |
| Half-life | Parent-Daughter ratio | Amount of parent remaining | C-14 half-life years |
| 0 | 1:0 | 1/0 = 100%  | 0 |
| 1 | 1:1 | 1/2 = 50%  | 5,730 |
| 2 | 1:3 | 1/4 = 25%  | 11,460 |
| 3 | 1:7 | 1/8 = 12.5%  | 17,190 |
| 4 | 1:15 | 1/16 = 6.25%  | 22,920 |



**Different elements have different half-lives.**

Uranium-lead dating. The dating method is usually performed on the mineral [**zircon**](https://en.wikipedia.org/wiki/Zircon).

* The mineral incorporates [uranium](https://en.wikipedia.org/wiki/Uranium) and [thorium](https://en.wikipedia.org/wiki/Thorium) [atoms](https://en.wikipedia.org/wiki/Atom) into its [crystal structure](https://en.wikipedia.org/wiki/Crystal_structure)
* Strongly rejects [lead](https://en.wikipedia.org/wiki/Lead)
* Entire lead content of the zircon is [radiogenic](https://en.wikipedia.org/wiki/Radiogenic) ([radioactive decay](https://en.wikipedia.org/wiki/Radioactive_decay))
* Ratio of lead to uranium in the mineral can be used to determine its age.

|  |  |  |  |
| --- | --- | --- | --- |
| Radioactive Isotope | Daughter Isotope | Half-life (years) | Effective dating range (years) |
| Rubidium-87 | Strontium-87 | 48.8 billion | 10 million – 4.6 billion |
| Urainium-238 | Lead-206 | 4.5 billion | 10 million – 4.6 billion |
| Potassium-40 | Argon-40 | 1.3 billion | 50,000 – 4.6 billion |
| Carbon-14 | Nitrogen-14 | 5730 | 100 – 75,000 |

Example Problems:

1. When it cooled a sample of basalt contained 200 grams of Potasium-40. In present day, the sample contains 1/4 of the original amount. How much time has passed since the granite was formed?
	* Answer: 1/1 = 1 half-life, 1/2 = 2 half-lives, 1/4 = 3 half lives
	* 3 x 1.3 billion = 3.9 billion years

2. What fraction of Uranium-238 would remain after 9.0 billion years?

a. 1/2 b. 1/4 c. 1/8 d. 1/3

Answer: Half-life = 4.5, 4.5 x 2 = 9, after 2 half-lives ¼ of parent material remains.

**Geologic time** is divided into four major time intervals: **Eon, Era, Period, Epoch**.

Most of geologic time **(88%)** consists of the first three Eons known as the **Precambrian time**.

* Precambrian: 4.6 bya – 540 mya (approx. 4 billion years in length!)

The rest of geologic time is represented by the Phanerozoic Eon (Greek = *visible life*)

* 540 mya – Present (540 million years)

The Phanerozoic Eon is divided into three Eras.

1. Paleozoic Era “Old Life”
2. Mesozoic Era “Middle Life”
3. Cenozoic Era “ New Life”

From this point the geologic time scale is dived into Periods and Epochs.

Geologic intervals at this level are separated by major events that characterize life on Earth.

In the 540 million years of life on Earth there have been 5 great mass extinction events.

1. End Ordovician, 444 million years ago, 86% of species lost
2. Late Devonian, 375 million years ago, 75% of species lost
3. End Permian, 251 million years ago, 96% of species lost
4. End Triassic, 200 million years ago, 80% of species lost
5. End Cretaceous, 66 million years ago, 76% of all species lost

**Visualizing Geologic Time**

|  |  |  |
| --- | --- | --- |
|  | Millions of Years Ago | Number of meters |
| Origin of Earth | 4.6  | 91.5 |
| First life (single-celled/prokaryotic) | 3500 | 69.6 |
| Multicellular plants and animals | 700 | 13.9 |
| Ordovician extinction86% life lost | 444 | 8.9 |
| First land life (plants and insects) | 425  | 8.5  |
| Late Devonian75% species lost | 375 | 7.5 |
| Trees appearCarboniferous period | 350 | 7 |
| End Permian “GREAT DYING”96% of species lost | 251 | 5 |
| First Dinosaurs | 225 | 4.5 |
| First Mammals  | 220 | 4.4 |
| End Triassic80% species lost | 200 | 4 |
| Flowers become dominant  | 125 | 2.5 (250 cm) |
| End CretaceousExtinction of Dinosaurs76% of all species lost  | 65 | 1.3 (130 cm) |
| *Homo Erectus*  | 1.2 | 0.02 (2 cm) |
| First Use of Fire by Man | 500,000 years ago | 0.01 (1 cm) |
| *Homo sapiens* | 300,000 years ago | 0.006 (6 mm) |
| Modern man (*Homo sapiens*) | 100,000 years ago | 0.002 (2 mm) |
| Sixth Extinction | NOW! | 0 |