GEOLOGY 25 - LECTURE 1-C

DEEP TIME

(Textbook: Chapter 3 (p. 48-50), Chapter 1 (p. 24-29)

Geologic Time (aka "Deep Time")

Geologic time is so vast and incomprehensible that it is commonly referred to as "**Deep Time**," spanning 4.6 billion years of Earth history.

Geologists know these dates within a reasonable degree of precision. The evidence for the age of geologic and evolutionary events is contained in the rocks that form Earth's crust.

Key events in the history of Earth . . . . (We're not going to go over these events in detail and you don't need to memorize the specifics. But be sure to read through this list as it relates to the Grand Canyon.)

4.6 b.y.a. (billion years ago) - birth of the solar system and Earth, based on the radiometric dating of certain meteorites (don't confuse this date with the Big Bang – that was 13.8 b.y. ago)

4.0 b.y. - oldest rocks recognized on Earth

3.5 b.y. - oldest recognizable fossils of single-celled bacteria (beginnings of life)

2.0 b.y. - ***oldest rocks in lowermost Grand Canyon***

1.5 b.y. - oldest recognizable single-celled organisms with nuclei

1.0 b.y. - origin of sexual reproduction

700 m.y.a. (million years ago) - first multi-celled animals

540 m.y. - first animals with hard shells living in the shallow oceans that covered much of the western U.S.

- abrupt appearance of complex, hard-shelled multicellular organisms - called the "Cambrian Explosion"
- 540 m.y. marks the boundary between the **Precambrian Eon** (~88% of all geologic time) and the **Paleozoic Era**

~510 m.y. – ***age of Tapeats sandstone*** *(first sedimentary rock layer above the old 'basement' rocks of the Grand Canyon)*

480 m.y. - first fish (vertebrates)

420 m.y. - first land plants *(invasion of the land begins – prior to this event, the continents were barren expanses of rock and loose sediment)*

380 m.y. - first amphibians

320 m.y. - first reptiles

~270 m.y. – ***age of Kaibab limestone at top of Grand Canyon***

250 m.y. - largest **mass extinction** in Earth history - >90% of species go extinct - this extinction marks the boundary between the **Paleozoic Era** and the **Mesozoic Era** (Age of Reptiles)

230 m.y. - first dinosaurs

210 m.y. - first birds & mammals

66 m.y. - **mass extinction**, including dinosaurs - marks the boundary between the **Mesozoic Era** and the **Cenozoic Era** (Age of Mammals)

5-6 m.y. – tectonic uplift of Colorado Plateau (Colorado River actively begins incising downward, cutting the Grand Canyon)
5-6 m.y. - early hominids (precursors to modern humans)
2 m.y. - Ice Ages begin (and are currently active - we're now in a temporary warm interglacial episode)
300,000 yrs ago - first appearance of *Homo sapiens*
~10,000 yrs ago – beginnings of agriculture and 'civilization'

Eras of time that we need to know for this class: *please memorize these*
Precambrian - 4.6 b.y. to 540 m.y.
Paleozoic - 540 to 250 m.y.
Mesozoic - 250 to 66 m.y.
Cenozoic - 66 m.y. to present

The Precambrian occupies the first 88% of Earth history
- microbes (like bacteria) have dominated the history of life on Earth, with higher organisms appearing relatively late in the planet's lifespan
- recorded human history occupies the last 0.000001% of Earth history

Geologists know these ages within a very reasonable range, using two fundamental methods: "relative" age-dating & "numerical" age-dating

Relative dating

- places rocks into relative positions (i.e., oldest to youngest, with no numerical dates attached). "older than" & "younger than", with no actual dates

Fundamental principles of relative age dating

1) **superposition** - layers of rock at the bottom of a stack are oldest, while layers at the top are youngest. https://en.wikipedia.org/wiki/Law_of_superposition

2) **lateral continuity** – layers of sediment were originally laterally continuous over wide areas before they were buried, compacted and cemented into rock. Later in time, the buried stack of layered rock was uplifted by geologic forces and exposed to the atmosphere where the layers were dissected by erosion. Exposures of the layers (e.g., on mountainsides or within canyons) permits geoscientists to map their original lateral continuity across broad regions. Mapping out exposures of a specific formation across a broad region permits the visualization of the lateral extent of layers of rock and enables the creation of paleogeographic maps.
Recognizing the lateral extent of formations of sedimentary rock allows for the "correlation" of layers over far distances, especially when the layers are fossiliferous. Allows for relative age dating of layers across continents.

https://en.wikipedia.org/wiki/Principle_of_lateral_continuity

3) **faunal succession**
https://en.wikipedia.org/wiki/Principle_of_faunal_succession

- based on progressive evolutionary change; sedimentary rocks contain fossils that are the tangible record of the evolution of species. Faunal succession dictates that rocks with older fossils pass upward into rocks with younger fossils.

Each fossil (and the sedimentary rock in which they are found) is diagnostic of a particular range of geologic time.

Fossils are only preserved in sedimentary rocks (since plants and animals lived in depositional environments where sediment accumulates)

- It doesn't matter whether a succession of fossils are found in Australia, Siberia or Nevada – **the order of the fossils will always be the same**. Note that there are no dates associated with the fossils because we can only use them to tell whether one fossil is 'younger than' or 'older than' another.

Major boundaries of the geologic time scale are based on global evolutionary events such as major 'explosions' of new fauna and mass extinctions

At this point you can determine the **relative** chronology of events that formed the Grand Canyon:

1) Formation of complex rocks of the 'basement' within an ancient mountain range (now long lost to erosion)
2) Deposition of loose sediment in depositional environments near sea level during a series of transgression and regressions of the shoreline related to changes in sea level
3) Burial, compaction, and cementation into rock
4) The rocks of the entire Colorado Plateau were uplifted by tectonic forces to a high elevation. (*more on tectonic uplift soon.)*
5) Uplift enabled the Colorado River and its tributaries to incise downward into the rock, carving the landscape of the Grand Canyon that we see today.

- "**uplift**" is a general term that simply implies the creation of highlands from a region that was once much lower in elevation. It's synonymous with "mountain-building." We'll discuss "uplift" in greater detail in time.

Numerical (radiometric) dating (sometimes referred to as "absolute" dating)

https://en.wikipedia.org/wiki/Absolute_dating

As opposed to relative dating, numerical dating places specific ages on individual rocks.

- uses the naturally occurring breakdown of radioactive elements within minerals to determine an absolute numerical date for that mineral. Procedure called **radiometric dating**.
- method works best on minerals that crystallize from a molten magma or lava (**igneous rocks**) (Rocks composed of minerals that crystallize from a molten magma are called igneous rocks)
- all rocks are composed of minerals. Rocks are simply aggregates of minerals.

- when molten rock cools, either under the ground as magma or above the ground as lava, minerals crystallize from the liquid. Certain minerals (such as zircon) commonly incorporate radioactive elements like uranium, thorium or potassium into their atomic structure. Once the mineral solidifies, those radioactive elements begin to spontaneously decay to other elements at a very precise rate. (e.g., U atoms spontaneously change to Pb atoms over time)
- the mineral crystal (e.g., zircon) is the specific object that is dated in an instrument called a mass spectrometer, thus determining the time at which the mineral (and thus the rock) first crystallized from the magma or lava.

In the interests of time, we're going to skip the concept of the 'half-life' of radioactive elements and other details of radiometric dating. Trust that geologists use the fundamental principles of chemistry and physics, combined with sophisticated mathematics, to measure and calculate the age of many rocks.

Numerical age-dates have been determined for tens of thousands of rocks around the world. They become even more useful when they can be integrated with rocks that have only been dated by relative age-dating techniques.

Let's combine the relative chronology of events that formed the Grand Canyon with radiometric dates that have been determined from layers of volcanic ash within the sedimentary layers of the Grand Canyon for a more precise sequence of events:

1) Formation of complex rocks of the 'basement' within a Precambrian mountain range (~2 b.y.a.)
2) Deposition of loose sediment in depositional environments near sea level during a series of transgression and regressions of the shoreline related to changes in sea level (500-250 m.y.a. – Paleozoic)
3) Burial, compaction, and cementation into rock (Mesozoic)
4) The rocks of the entire Colorado Plateau were uplifted by tectonic forces to a high elevation. (Cenozoic)
5) Uplift enabled the Colorado River and its tributaries to incise downward into the rock, carving the landscape of the Grand Canyon that we see today. (5 – 6 m.y.a. – late Cenozoic)

By careful observation and collection from thousands of rock exposures around the world, geologists have integrated relative ages of rock with numerical dates to produce the geologic time scale. Most people take the geologic time scale for granted, but it is truly a monumental achievement as it is essentially a calendar of Earth history. The geologic time scale is constantly being modified, updated and refined as new data are discovered and as the instrumentation evolves to higher and higher degrees of resolution.

I've created a folder in Files called "Hikes and Articles on Visiting National Parks" where I've placed all sorts of information on hiking trails, places to say, articles on visiting parks with your dog, how to become a NP ranger, and how to get an internship at a NP. I'll allude to it occasionally where relevant.

A comprehensive place to begin regarding popular trails in Grand Canyon NP is at https://www.planetware.com/arizona/top-rated-hiking-trails-at-the-grand-canyon-us-az-230.htm

These websites provide an extra source of information beyond the notes, images and textbook. Use them if you decided not to buy the textbook.

National Park Service – principles of determining Geologic Time
https://www.nps.gov/subjects/geology/geotime.htm

National Park Service geologic time scale
https://www.nps.gov/subjects/geology/time-scale.htm
