Paleontology Lab: Fossils and Geologic Time

Objectives:
- Be able to recognize these common rock types: shale, sandstone, limestone.
- Be able to recognize different kinds of fossils and fossilization processes.
- Be able to understand the differences between **relative dating** and **absolute dating.**
- Understand the evidence on which the geologic time scale was established.
- Understand plate tectonics, sea level changes, and other ways in which the relations of continents to one another have changed over Earth's history

Materials needed for this lab:

Preserved fossils, including smaller specimens in red boxes and also larger specimens housed in drawers in room 322.
Samples of sandstone, limestone, and shale.
Dilute acid (either vinegar or 0.1M HCl) in a dropper bottle.
Maps and wall charts showing the geologic time scale.
Maps and wall charts showing the continents throughout geologic time.

COMMON ROCK TYPES:

Geologists classify all rocks into three major types:
- **Igneous** rocks, melted during their formation (a process that would destroy any fossils)
- **Sedimentary** rocks that accumulate in layers, deposited by wind or water
- **Metamorphic** rocks, subjected to extreme pressures and temperatures that destroy any fossils and also changes crystal structure

Because igneous and metamorphic processes destroy fossils, fossils are only found in sedimentary rocks. The three most common sedimentary rocks are:
- **Sandstone,** formed from sandy sediments (usually SiO_2) of medium grain size
- **Shale,** formed from fine-grained sediments (mud or clay) of any color (usually dark)
- **Limestone,** usually formed as a chemical precipitate ($CaCO_3$) and therefore very fine-grained

EXAMINE specimens of limestone, sandstone, and shale, paying close attention to grain size. You can use a drop of dilute acid to test a corner of the specimen for the carbonate minerals present in limestone; sandstone and shale will show no reaction. Please note that color is only of interest at a particular locality; it usually reflects local chemical impurities present at the time of deposition.

DATING METHODS:

Relative dating, the method most often used, is also the older method. It is based on two principles:
- **Law of superposition:** any sequence of sediments is deposited with the newer sediments laid down on top of the older ones; therefore, in a sequence of sedimentary rocks, the older rock layers will be on the bottom and the newer ones on the top. (Overturned sequences are rare and usually easy to detect.)
- **Correlation by fossils:** rock formations with comparable fossil contents (fossil **assemblages** with many species of several different kinds) are generally of the same age, even if they occur far apart. Rock type (lithology) is **not** a reliable indicator of age.

Starting in the late 1700s, geologists and paleontologists from several countries used these principles to reason that various fossil-bearing deposits were comparable in age to those near the British town of Devon, so they were all called Devonian. Other scientists found fossil-bearing deposits comparable in age to those of the Roman province of Cambria (modern Wales), so they were all called Cambrian. Most of the time periods in the geologic time scale were named in this way. Also, in a few places, rocks of one time period were deposited above rocks of an older time period, so scientists used the law of superposition to determine that Cambrian rocks were older than Ordovician, that Ordovician rocks were older than Silurian, that Silurian were older than Devonian, and so on. The complete sequence is shown on the geological time scale (see the various wall charts).

Notice that relative dating, though it can be very precise, only gives ages in a sequence (and in fine subdivisions within that sequence), but not numerically in years. Devonian fossil faunas can be located in a sequence (younger than Cambrian and Silurian, but older than Mississippian or Cretaceous), but assigning a number to this time period requires absolute, not relative, dating methods.

Absolute dating, giving numerical ages in years, was first developed around 1895 and is based on rates of radioactive decay. The equation for radioactive decay is

$$X / X_0 = (½)^{T/H}$$

which can be rearranged as

$$\ln X - \ln X_0 = (T/H) \ln(½)$$

or as

$$\ln X_0 - \ln X = (T/H) \ln 2$$

where

X = amount of radioisotope now
X_0 = original amount of radioisotope
T = elapsed time
H = half-life of the radioisotope

One problem with this method is that most radioisotopes occur in igneous rocks, but are rare in fossils or in sedimentary rocks. Therefore, if an igneous formation can be inserted into a sedimentary sequence by relative dating methods, then the absolute of age of the igneous rock can be used to assign a date to part of the sedimentary sequence. This is the way that absolute numerical dates have been assigned to the named geological time periods.

Problem 1.
A limestone containing fossils of the dinosaur *Hadrosaurus* is cut by an igneous dike judged to be of comparable age. If a rock sample from the dike contains 2.1521×10^{-3} moles of ^{238}**U** (half-life = 4.471×10^{9} years) and an additional 3.0245×10^{-5} moles of ^{206}**Pb** (derived from the radioactive decay of ^{238}**U**), find (a) the total amount of ^{238}**U** originally present, (b) the age of the *Hadrosaurus* fossil, and (c) the geological time period to which this age belongs.

Problem 2.
A fossil shark's tooth is embedded in a shale judged by geologists to be close in age to a nearby lava flow. One sample of this lava contains 4.5845×10^{-4} moles of ^{40}**K** and an additional 1.0568×10^{-4} moles of ^{40}**Ar**, derived from the radioactive decay of the ^{40}**K** (half-life = 1.27×10^{9} years). Assuming that all the **Ar** trapped in the rock accumulated since the lava was molten, and that none has escaped, find (a) the total amount of ^{40}**K** originally present, (b) the age of the shark's tooth, and (c) the geological time period to which this age belongs.

GEOLOGIC TIME SCALE

Study the wall charts of the geologic time scale, and discuss with other students the evidence on which the time scale is based. Also discuss: if you were to find a new fossil fauna, how would you determine its relative age? Could you always determine its absolute age? If so, how?

TYPES OF FOSSIL PRESERVATION

- **Fossils containing original material:**
  - **Unaltered remains.** *Example*: frozen mammoths
  - **Compressions:** Flattened and dehydrated, but unaltered otherwise, with cellular details often preserved.
- **Replacement fossils** (with original material largely replaced):
  - **Permineralization:** Gradual *addition* of minerals by ground water, preserving many internal details. The organic material remains, but minerals are added. Many bones are preserved in this manner.
    - **Petrifaction:** A common type of permineralization in which the added mineral is either silica (SiO_2) or calcite ($CaCO_3$)
  - **Impregnation or embedding:** Similar to permineralization, except that the embedding material surrounds the fossil as well as filling in any interstitial spaces.
  - **Carbonization:** Volatile compounds lost, leaving carbonized skeleton only.
  - **Mineralization:** Complete replacement of original material by minerals.
- **Casts and molds:** Impressions in fine-grained sediments, preserving only surface shapes.
  - **Casts** are solid objects. *Example*: **endocasts** of brains
  - **Molds** are hollow, "negative" surfaces. *Example*: Impressions of dinosaur skin
- **Trace fossils:** Tracks, trails, and other traces of activity. *Examples*:
  - Organic material derived from biological activity:
    - **Amber** (fossil tree sap or resin)
    - **Coprolites** (fossil dung)
  - Inorganic material indicating the "work" of an organism:
    - **Tracks and trails** of worms, etc.
    - **Footprints** (e.g., of dinosaurs or early humans) in fine-grained sediments
    - **Burrows and tubes** (if filled with sediment different from surrounding material)
    - **Castings:** sand or other sediment, often with some organic matter added, that has passed through the body of a detritus feeder and been discarded.

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FOSSIL TYPES AND FOSSILIZATION

Study the chart above, then examine the various fossil specimens available. For each fossil you examine, determine if you think the fine, delicate parts and cellular details were preserved. Make a chart on your own paper, showing headings similar to the following, and then fill in as much information as you can:

Major taxon (phylum or class)	Genus (if provided)	Body part (e.g., whole, skull, teeth, leaf, shell)	Method of preservation	Geologic period	Comments

PLATE TECTONICS, SEA LEVELS, AND THE CONTINENTS THROUGH TIME

Study the various **maps** showing continental relations at various times in past geologic ages.

1. How far back are the modern shapes of continents still recognizable?
2. Which continents (and major islands) were isolated, and which were connected by land bridges?
3. Which continents have moved, relative to other continents? What mechanisms are thought to be responsible for these movements? What evidence do we have for these movements and mechanisms?