Name________________________________

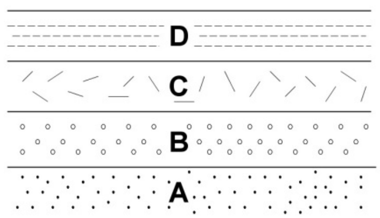
89.325 – Geology for Engineers
Geologic Time

I. Introduction

There are two types of geologic time, *relative* and *absolute*. In the case of ***relative time*** geologic events are arranged in their order of occurrence. No attempt is made to determine the actual time at which they occurred. For example, in a sequence of flat lying rocks, shale is on top of sandstone. The shale, therefore, must by younger (deposited after the sandstone), but how much younger is not known. In the case of ***absolute time*** the actual age of the geologic event is determined. This is usually done using a radiometric-dating technique.

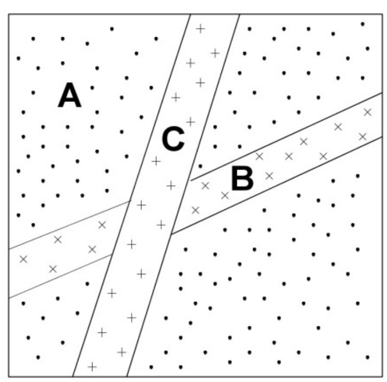
II. Relative Geologic Age

In this section several techniques are considered for determining the *relative age* of geologic events. For example, four sedimentary rocks are piled-up in the following order



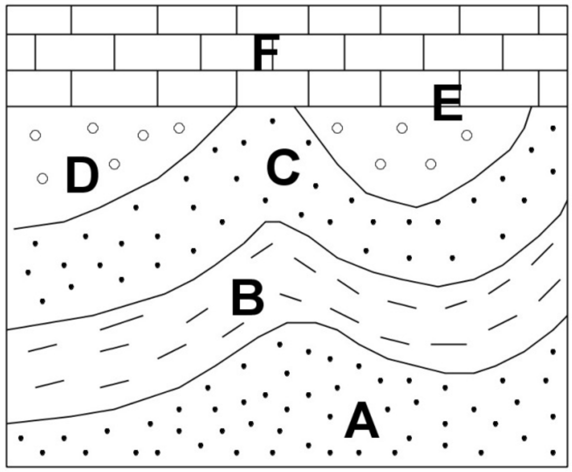
A must have been deposited first and is the oldest. *D* must have been deposited last and is the youngest. This is an example of a general geologic law known as the ***Law of Superposition***. This law states that ***in any pile of sedimentary strata that has not been disturbed by folding or overturning since accumulation, the youngest stratum is at the top and the oldest is at the base***.

As a second example consider a sandstone that has been cut by two dikes (igneous intrusions that are tabular in shape).



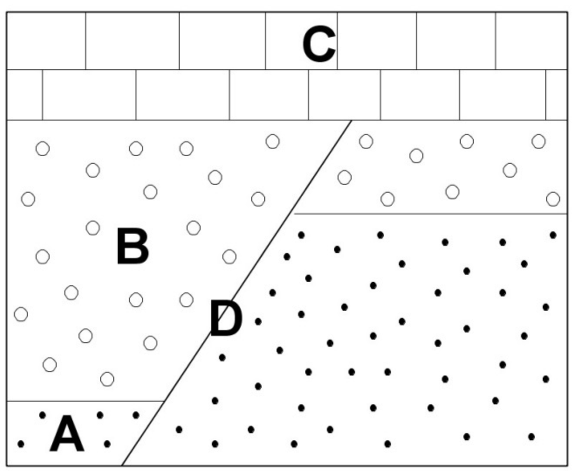
The sandstone, A, is the oldest rock since it is intruded by both dikes. Dike B must be older than dike C since it is cut by dike C. The sequence of events, therefore, is deposition of sandstone A followed by intrusion of dike B and then dike C.

As a third example, a sequence of sediments are deposited and then lithified. The resulting sedimentary rocks are deformed (folded), eroded and then covered by an ocean. Subsequent deposition of carbonate shell material leads to the formation of a marine limestone.



The sedimentary sequence A through D (oldest to youngest) must have been deposited first. This sequence was then folded and subsequently eroded (erosion surface E). After erosion, marine limestone F was deposited.

As a final example, consider the case in which a fault developed after formation of a sequence of rocks.



In this case rocks A and B are offset by fault D, so they must have been formed prior to faulting. However rock C is not offset so it must have been formed after faulting occurred.

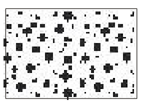
III. Determination of relative ages

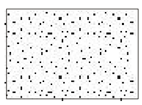
The determination of relative ages is based on the order in which various geologic events occurred. For example, if one layer of sediment overlies another layer of sediment, the overlying layer must be younger. If a magma (which forms igneous rock) intrudes a sequence of rocks, the rocks that were intruded by the magma must be younger. If a fault cuts pre-existing strata it must be younger than the strata. On the following pages you will find several "sequence of events" problems.

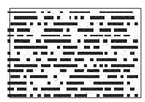
Below is a key to the rock symbols used on the diagrams. Sedimentary rocks are formed at or near the surface by deposition or chemical/organic precipitation. Igneous rocks crystallized from magma (molten rock material) and may form at (extrusive) or below (intrusive) the surface. Metamorphic rocks are usually formed at high pressures and temperatures at significant depths below the surface. Contact metamorphism occurs around an igneous intrusion when the host rocks are heated to high temperatures. Unconformities are breaks in the geologic record (consult your class notes). Faults are fractures along which movement has occurred.

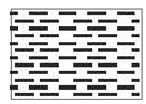
Key to Rock Symbols

Sedimentary Rocks

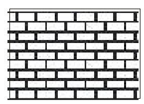

Conglomerate


Sandstone


Siltstone

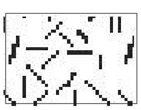

Shale

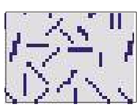

Shale

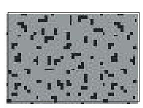

Limestone


Limestone

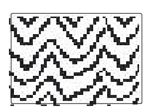
Igneous Rocks

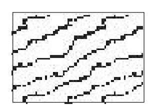

Granite


Granite


Basalt

Metamorphic Rocks

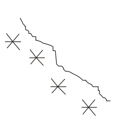

Gneiss


Schist

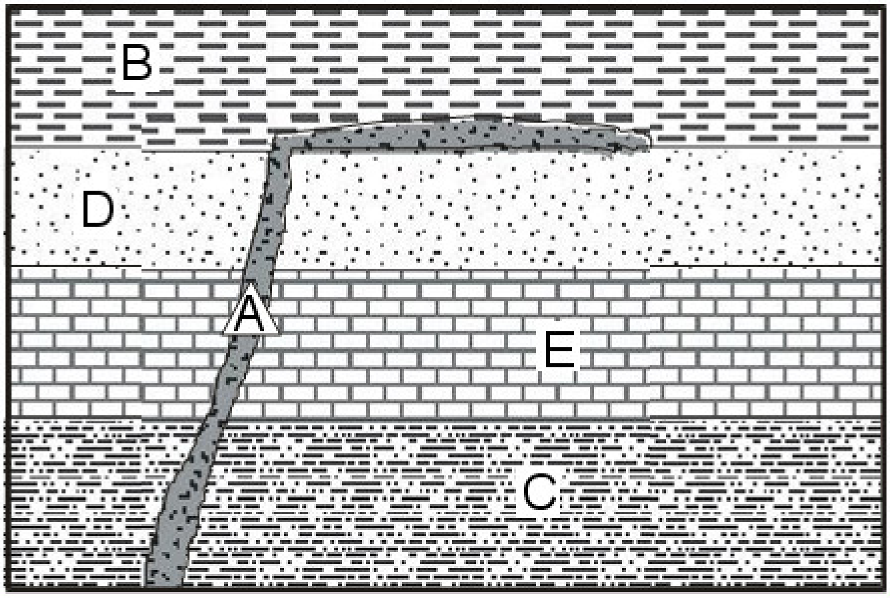
Special Features:


Contact that is an unconformity (layers on either side of it are of differing ages)


Fault


Zone of contact metamorphism

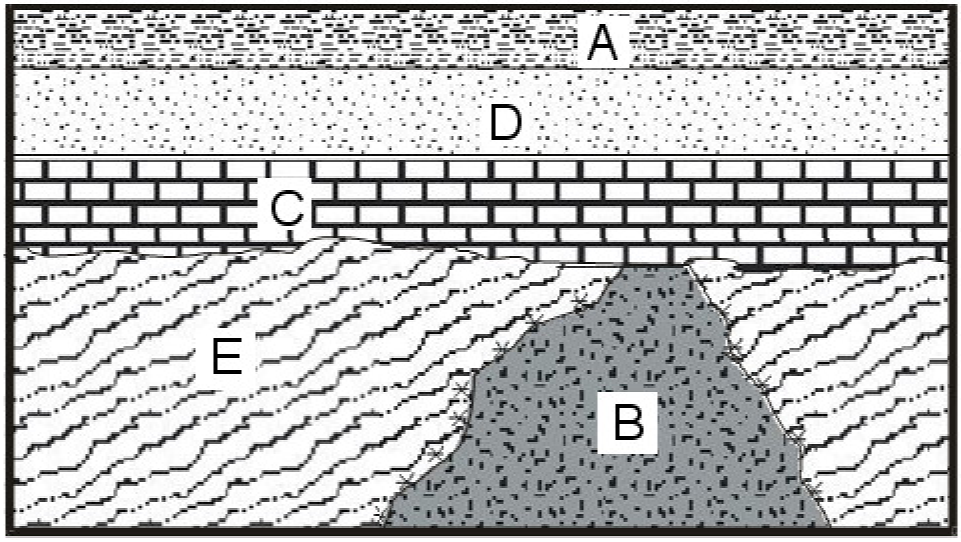
1. Arrange the following geologic events from oldest to youngest.



Relative Age	Event (Letter)	Rock type or geologic feature
Youngest		
Oldest		

Event A can be interpreted in two different ways. What are the two different ways? Explain.

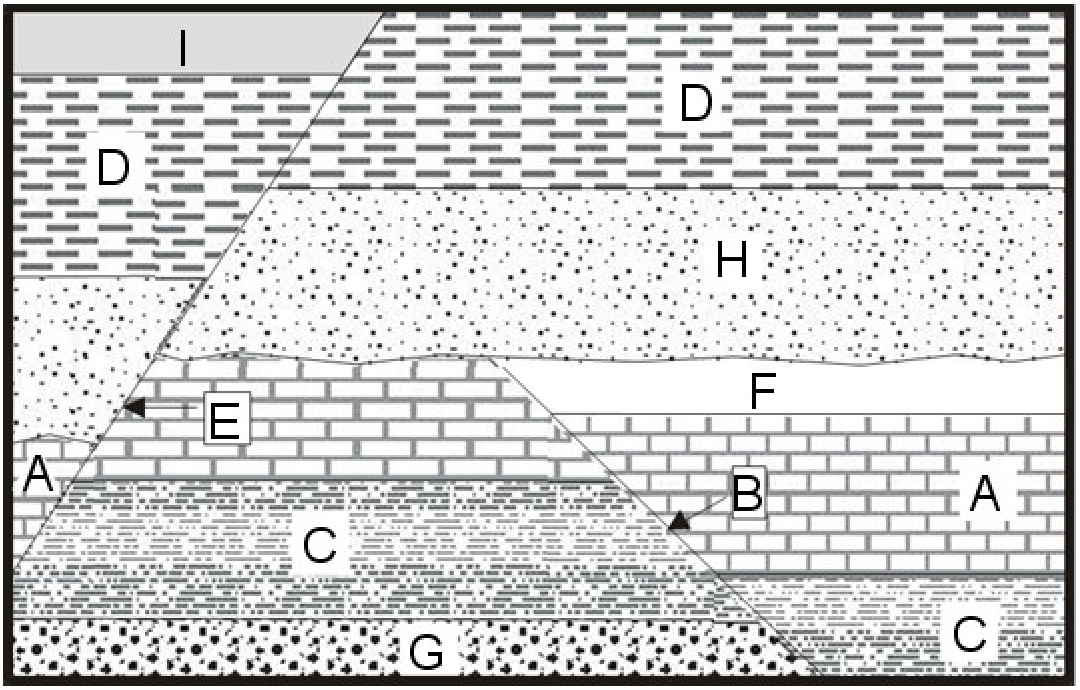
2. Arrange the following geologic events from oldest to youngest.



Relative Age	**Event (Letter)**	**Rock type or geologic feature**
Youngest		
Oldest		

The surface between layer C and layer E (and B) is an unconformity. What is the name of this type of unconformity and why did you give it this name?

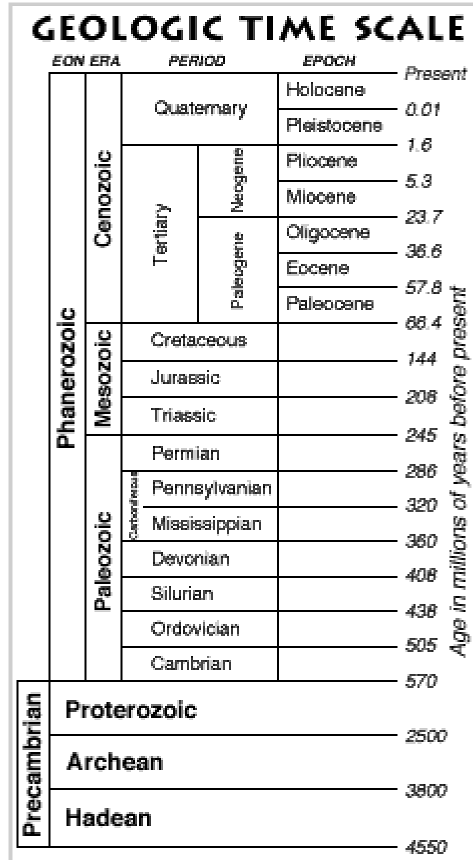
3. Arrange the following geologic events from oldest to youngest.



Relative Age	**Event (Letter)**	**Rock type or geologic feature**
Youngest		
Oldest		

The surface between layer H and layer E (and F) is an unconformity. What is the name of this type of unconformity and why did you give it this name?

IV. Geologic Time Scale



During the past several hundred years geologists have been mapping rock outcrops at the earth's surface. By correlating outcrops from place to place, and using the ***Principle of Superposition***, it has been possible to determine the sequence in which sedimentary rocks were deposited. This information, coupled with the fossil record, led to the development of the ***Geologic Time Scale***. The various subdivisions are based on major changes in the history of the Earth as documented by the geologic record. For example, the transition from the Mesozoic to Cenozoic Era is marked by the extinction of the dinosaurs. The time scale is a relative time scale, e.g. Devonian rocks were deposited before Mississippian rocks. Ages are attached to the various geologic periods using radiometric dating. It is important to note, however, that the geologic time scale is based on the sedimentary record while radioactive dating is applied to igneous and metamorphic rocks. This creates a disconnect between relative geologic time and absolute geologic time. Resolving this disconnect is an active area of geologic research.

V. Geologic Maps

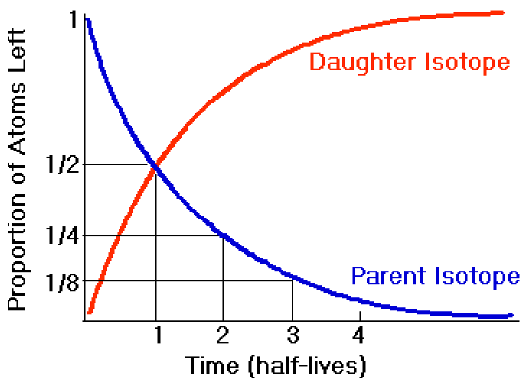
One of the products of mapping rock outcrops is a geologic map. The map shows the rocks that are found at the earth's surface. This type of rock is called a Bedrock Geology Map. There are also Surficial Geology maps (which we will use in another laboratory exercise) that show the unconsolidated material, such as river and glacial deposits, found at the earth's surface.

The geology of a portion of the Grand Canyon is shown on the *Geologic Map of the Bright Angel Quadrangle, Arizona*. Remember that you are looking down on the land surface and the Grand Canyon is a big hole in the ground. The map pattern appears complex but the various geologic layers are flat lying. As the Colorado River and its tributaries cut down through these flat laying layers it exposed the edges of the layers.

4. The geologic column for the various units is shown on the right side of the map. There are a number of unconformities in this sequence. Identify the unconformities. What is the significance of these unconformities in terms of the geologic history of the Grand Canyon area?

VI. Radiometric Dating

Radioactive decay is the spontaneous breakdown of a nucleus. The radioactive isotope is the Parent Isotope and the decay product is the Daughter Isotope. The half-life of a radioactive element is the length of time it takes for 50% of the parent isotope to decay. This is an exponential relationship as illustrated in the graph below. A number of different radioactive isotopes are used to determine geologic ages based on the material and its age. For example, ^{235}U which decays to ^{207}Pb has a half-life on 0.704 billion years. One could not use this system to date material formed in the last several thousand years because only a miniscule amount of ^{207}Pb would have been produced. Rather this dating technique is used to date rocks that are millions of years old. The equation used to calculate a radiometric age is shown below.



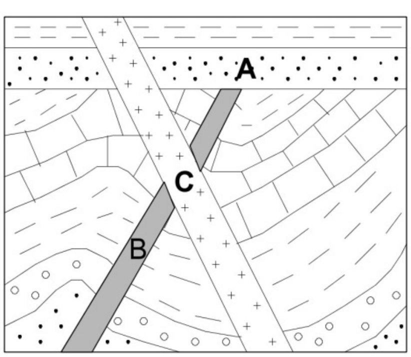
$$t = \frac{1}{\lambda} \ln\left(1 + \frac{D}{P}\right)$$

where t is the age of the rock or mineral specimen,
D is the number of atoms of a daughter product today,
P is the number of atoms of the parent isotope today,
ln is the natural lograithm (logarithm to base e), and
λ is the appropriate decay constant.

(The decay constant for each parent isotope is related to its half-life, $t^{1/2}$ by the following expression: $t^{1/2} = \frac{\ln 2}{\lambda}$

The mineral zircon, which contains trace amounts of U but usually no Pb, is often used to determine the age of igneous rocks. The idea is that the zircon grains crystallized from the magma and therefore are the same age as the rock. With reference to the geologic cross-section below, A is a sandstone (sedimentary rock), B is a basalt dike (tabular igneous intrusion), and C is a diorite dike (tabular igneous intrusion). Zircon grains are separated from the basalt dike and the diorite dike. The number of ^{235}U and ^{207}Pb atoms is determined for a zircon from the basalt dike and a zircon from the diorite dike. The data are shown in the table below. Because we want to calculate the age in millions of years, $\lambda = 9.8458 \times 10^{-4}$ my^{-1}. Ma = 1 million years.

Geologic Unit	^{235}U	^{207}Pb	Age (Ma)
Basalt dike (B)	720	380	
Diorite dike (C)	730	370	



5. The folded rocks must be older than?

6. The age of the sandstone must be between?

7. Geologic time scale age of the sandstone?