NAME____________________

89.215 - FORENSIC GEOLOGY
GEOLOGIC TIME AND GEOLOGIC MAPS

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 as shown on Figure 1. *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***. While this may seem to be a simple observation, this principle of superposition (or stratigraphic succession) is the basis of the geologic column which lists rock units in their relative order of formation.

As a second example, Figure 2 shows 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*.

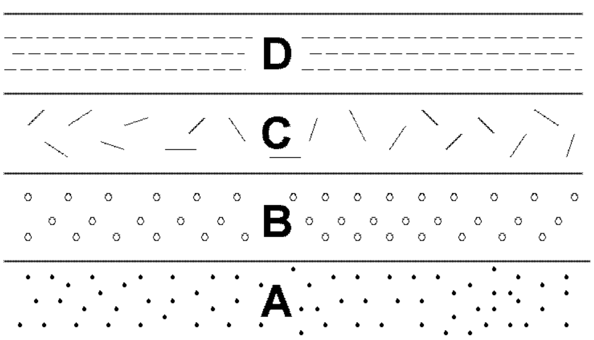

Figure 1. Example of superposition. Layer A was deposited first, layer D was deposited last.

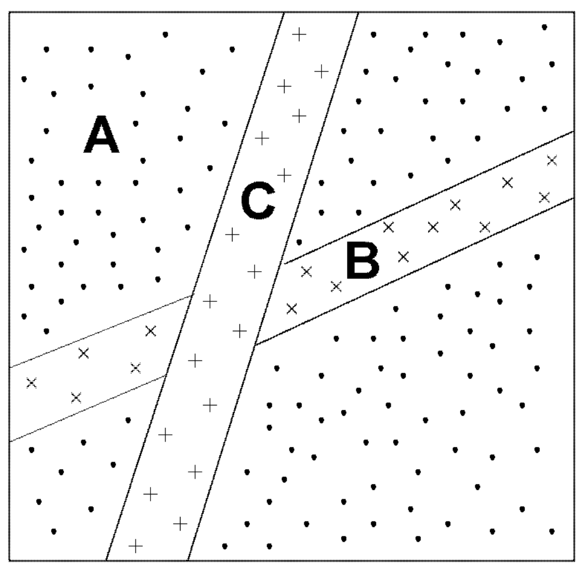

Figure 2. Two dikes cutting a sandstone. Dike B is intruded before dike C.

As a third example (Figure 3), a sequence of sediments is 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. The erosion surface, E, is an example of an unconformity. An ***unconformity represents a break in the geologic record either due to erosion of previous material or a period of nondeposition***. In this case surface E is referred to as an angular unconformity because the underlying rocks (A to D) are at an angle with respect to the overlying rocks (F).

As a final example (Figure 4), 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.

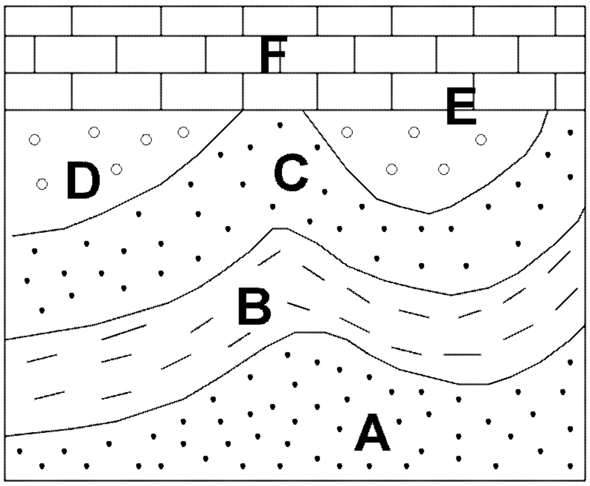

Figure 3. Sedimentary units A to D are deposited, lithified, and folded. After the folding the rocks are eroded and at some later time marine limestone is deposited.

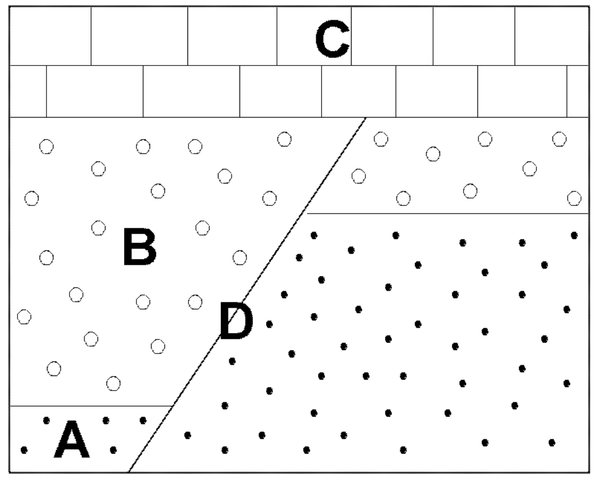

Figure 4. Fault cutting earlier deposited and lithified rock. The fault is eroded prior to deposition of unit C and must therefore be older than C.

Figures 1 to 4 represent what are called sequence of events problems. In studying any geologic area one of the things to know is the order in which the geologic events occurred. This allows us to develop a relative geologic history for the area. A sequence of events problem is found on the next page.

For the geologic cross-section (Fig. 5) determine the relative sequence of occurrence for the rocks or events indicated by the letters.

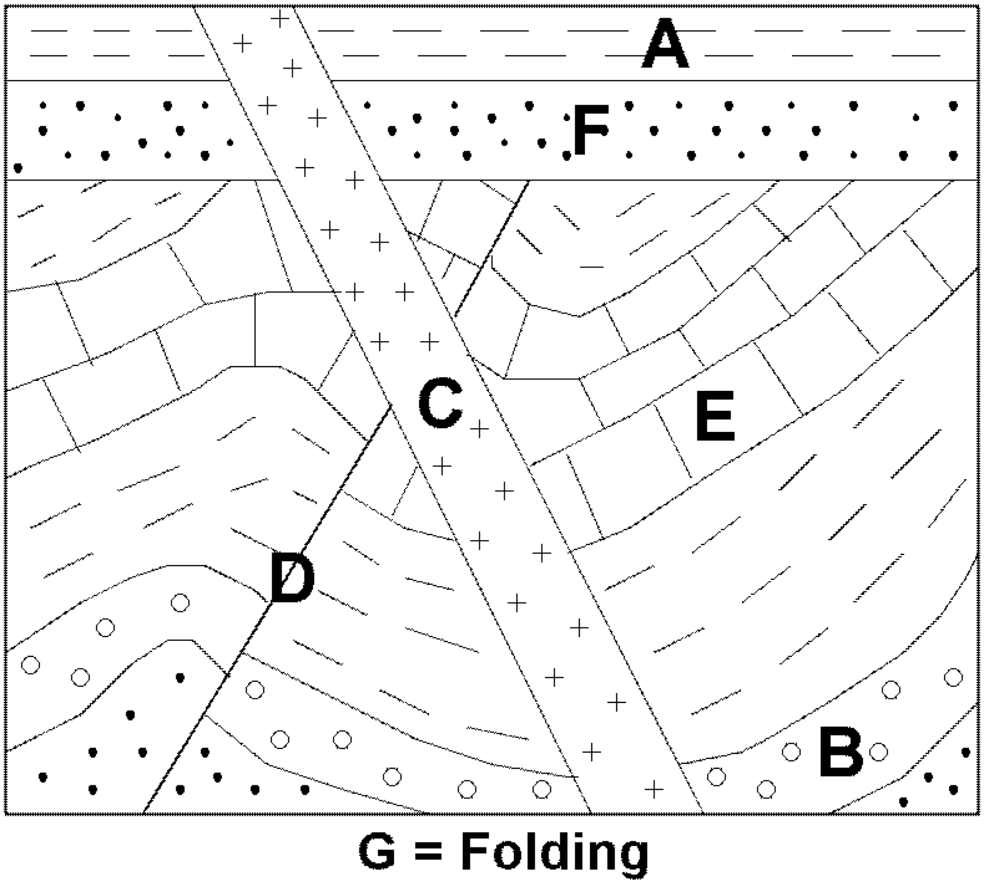

Figure 5. Diagram for sequence of events problem

Enter the sequence of events in order from youngest at the top of the table to oldest at the bottom.

	Rock or Event	Criteria used to determine the relative position
Youngest		
Oldest		

III. Absolute Geologic Age

The time of formation of a rock or mineral can be determined by measuring the amounts of naturally occurring radioactive elements, such as uranium, rubidium or potassium, in the rock or mineral and the amount of their radioactive decay products in the rock or mineral. Since the rate of decay of a radioactive element is not changed by any natural process such methods provide accurate absolute ages.

Generally one can only determine radiometric ages for igneous and metamorphic rocks. In the case of igneous rocks we can determine the time at which the magma solidified and for metamorphic rocks we can determine the time of peak metamorphism. Except in rare cases we cannot directly determine a radiometric age for a sedimentary rock. This means that there is often some ambiguity about the age of a sedimentary rock. For example, suppose that for dike B shown in Figure 2 we obtained an age of 250 million years. From this age all that we can conclude about the age of sedimentary rock A is that its older than 250 million years. We know this must be the case because sedimentary rock A has to be there before it is intruded by the magma that formed the dike.

Radiometric dating has numerous applications and has been used to establish the long history of the earth. The best estimate for the age of the earth is 4.5 billion years and the oldest dated materials on earth are zircons from a meta-conglomerate in the Jack Hills of Western Australia. Some of the zircon grains from this meta-conglomerate gave ages of 4.4 billion years, very close to the age of the earth. The instructor's web site has pictures of this area in WA.

IV. The geologic time scale.

The geologic time scale was largely developed in the 19th century. The basic principles used to establish the geologic time scale are the *Law of Superposition* (previously discussed) and the *Law of Faunal Succession*. The ***Law of Faunal Succession*** states that ***species change as a function of time and once a species becomes extinct it does not re-appear in the geologic record***. What geologists (or more correctly, at that time, naturalists) did was to establish the order in which sedimentary rocks were deposited (the stratigraphic sequence). They then used the fossils in these rocks to identify rocks of similar time in other locations. Major divisions in the geologic time scale were based on what appeared to be major changes in conditions at the earth's surface. For example the Mesozoic Era was the "Age of the Reptiles", at least in the popular media an era associated with dinosaurs. This era came to an end with a major change (generally believed to be a large impact event) that led to the extinction of the dinosaurs and the rise of mammals. Hence, the Cenozoic Era is referred to as the "Age of the Mammals". The geologic time scale is based on the sedimentary record, and it is a relative time scale.

Since, in general, we cannot date sedimentary rocks, absolute ages for the geologic time scale are determined by radiometrically dating igneous and metamorphic rocks. How these radiometric ages are then assigned to the sedimentary rocks is a bit of an arcane exercise that we will not discuss here. Suffice it to say that these ages are continually revised and that the absolute geologic ages are subject to change. A recent version of the geologic time scale is shown in Figure 6.

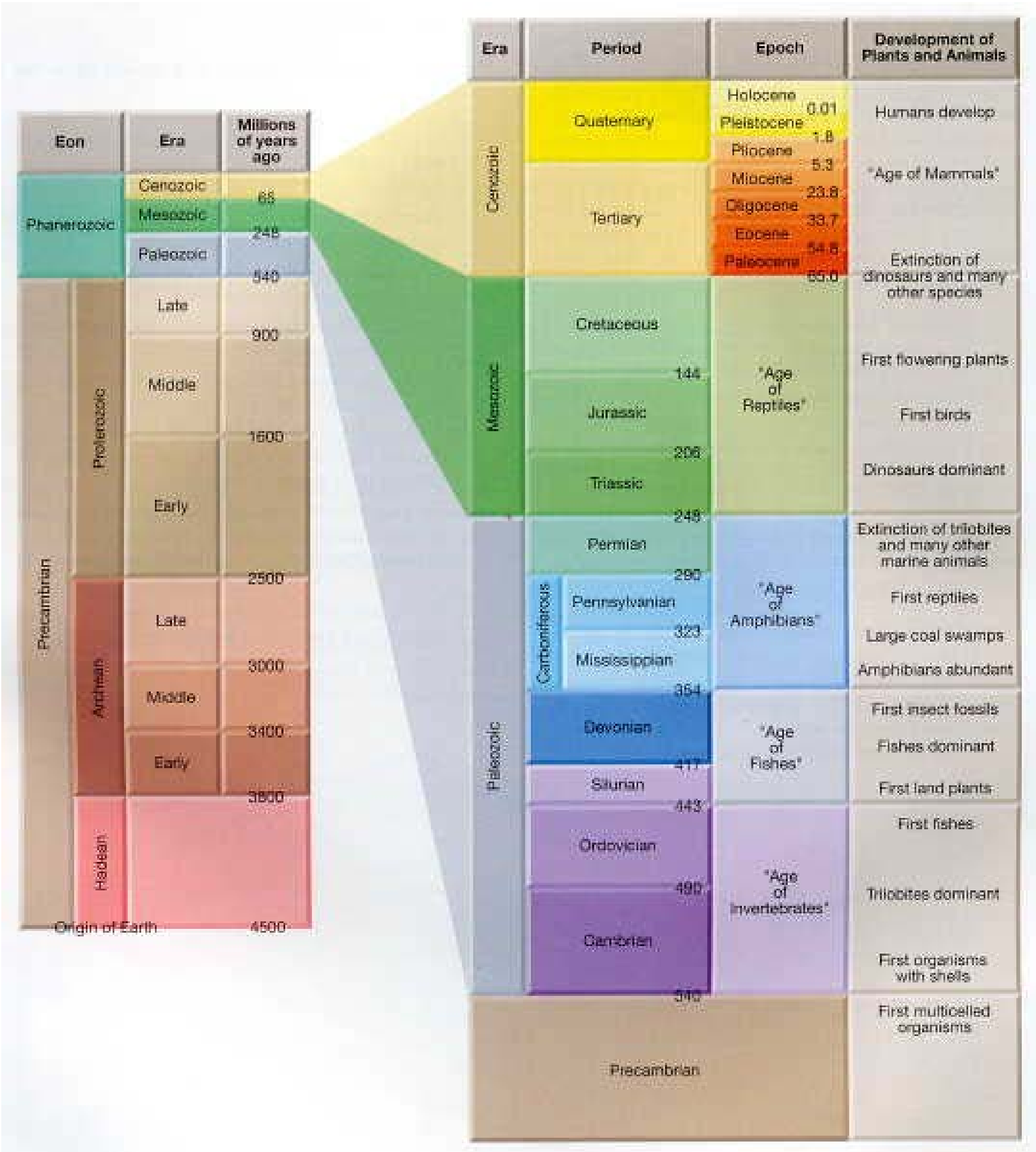

Figure 6. The Geologic Time Scale. From Tarbuck, Lutgens, and Pinzke (2003)

V. Geologic maps

Geologic maps show, for a given area, the types of rocks and their ages. These maps present basic geologic information that can be used in a variety of ways. The most famous geologic map (sometimes referred to as "The Map that changed the world") is William Smith's map of the British Isles (Fig. 7), considered to be the first geological map. The map was published between 1815 and 1817. Smith's work was of such high quality that modern geologic maps of the British Isles still bear a great similarity to his original work.

Figure 7. William Smith's geologic map of the British Isles (1815-1817) - "the map that changed the world". Source: Geological Society of London

All geologic maps have a legend that identifies the types of rock in the area, their sequence, and their relative age. The rocks are grouped together into formations (mapable rock units) that may consist of only one rock type or several similar rock types. These formations are then arranged in stratigraphic order and their geologic ages are shown.

VI. Geologic maps and forensic science

Geologic maps are often used in forensic science to establish the origin of a rock. A common example is the material switch in which rocks are substituted for a valuable commodity. By identifying the type of rock and, in certain cases using fossils its age, one can compare the rock to the lithologies (rock types) that are exposed in the areas where the switch might have taken place. This comparison is done using geologic maps of the areas of interest. Once the location where the switch took place has been identified, further investigation may lead to the perpetrators of the crime.

1. With reference to the *Geologic Map of Southeastern Utah*, what types of rocks (formation names and rock types) occur in the NE corner of the map area?

2. This problem uses the *Geologic Map of the Winnemucca Quadrangle, Nevada* (CSI Las Vegas territory). A body is discovered on Hayden Ranch (SW area of map). A bloody rock is found with the body (specimen provided). Identify the rock. Does this type of rock occur anywhere in the area covered by this geologic map (see the Legend)? The answer is most likely yes. Where in the area does this type of rock occur? Do you think the person was killed at Hayden Ranch or might the crime have taken place somewhere else? Explain.

3. Refer to the *Geologic Map of Washington*. A shipment of engine parts from Korea arrives at the Port of Seattle and the containers are transferred to railroad cars and shipped to Detroit. When the containers arrive in Detroit they are found to contain not engine parts but volcanic rocks. A geologist from the University of Detroit is called to the plant. He's done geologic research on rocks from Washington and his observation of the rocks in the crates suggests that they are Miocene volcanic rocks. Could the replacement of the engine parts with the rocks have occurred in Seattle? If so, what was the likely source of the rocks? One of the dock workers lives in Ellensburg. Is he a possible suspect? Explain.