ERTH16 **Name ______________________**
Homework 1 **Due: 4/20/07**

RELATIVE DATING:

From the lectures, you have already been introduced to three major principles used in assigning relative ages to sedimentary rock formations (formation = a distinctive body of rock that serves as a convenient unit for mapping). These are:

Principle of Original Horizontality: Sediments are generally deposited in more or less flat-lying layers. If the orientation of the strata deviates significantly from horizontal, some deformation can be inferred.
Principle of Lateral Continuity: Sediments form laterally continuous layers which extend until the sediment supply is exhausted or some obstruction is reached. Sedimentary rocks therefore generally form continuous layers on the scale of the depositional basin. This latter scale can vary, however: a basin might be as wide as an ocean or as narrow as a river channel.
Principle of Superposition: In a sequence of sedimentary rocks that has not been overturned, younger sediments will lie above older sediments.

Some of these principles apply to other types of rocks as well. For example, lava flows obey these same rules although the scales of lateral continuity may be quite small and flows may cool on slopes that deviate by up to ~10-20° from horizontal. In addition, three other principles apply in special cases:

Principle of Cross-Cutting Relationships: A younger feature (generally, an igneous intrusion) cuts across older features or bodies of rock. A related concept is that the age of deformation (faulting or folding) must be younger than any of the rock units that are affected by this deformation. When hot magma intrudes into pre-existing rocks (called the *country rock*), the intrusion heats its immediate surroundings, producing a zone of contact metamorphic rock. This contact metamorphosed rock is called a contact metamorphic aureole or halo, which may also help delineate cross-cutting relationships.
Principle of Inclusion: Fragments of a rock unit (*xenoliths* meaning foreign rock) which are included in another (host) rock unit must be older than the host rock. This may occur in sedimentary environments, where pieces of pre-existing rock can be ripped up and included in younger sediments. Alternatively, when igneous rocks are intruded, fragments of the country rock may be incorporated into the intrusion.
Principle of Faunal Succession: Groups of fossil plants and animals occur in the geologic record (in sediments) in a definite and determinable order. These groups can be associated with particular periods of geologic time.

Geologic time is continuous. However, the record of geologic time in any sequence of rocks will be discontinuous. Such gaps in time in the rock-forming process are called *unconformities*. From the lectures and your reading you should already be familiar with the three types of unconformities:

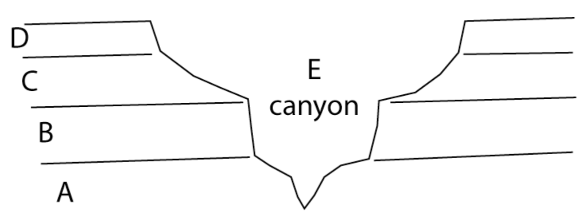
Angular uncomformity: Tilted sediments overlain by flat lying sediments. Since we know that sedimentary layers are originally horizontal, the lower tilted sediments must have been subjected to some deformation (tilting), followed by erosion to create a horizontal surface and then deposition of the younger, flat-lying sediments above.

Nonconformity: Plutonic igneous or metamorphic rocks overlain by sedimentary rocks (flat-lying). This type of unconformity implies: 1) formation of the older igneous or metamorphic rocks, 2) uplift and erosion to create a flat surface across these igneous/metamorphic rocks, and 3) deposition of younger sediments (usually accompanied by subsidence).

Disconformity: Older sedimentary rocks are overlain by younger sedimentary rocks with no obvious structural discordance between the two (i.e., layering is parallel in both) but a significant time gap between the two sedimentary sequences. This type of unconformity implies: 1) uplift and erosion to remove some of the older sedimentary sequence, and 2) deposition of the younger sediments.

Though no firm rule is possible, these different types of unconformities may represent quite different amounts of missing time. For example, the exposure and planing off of plutonic igneous rocks or metamorphic rocks that were originally deep in the Earth necessarily requires a substantial amount of time for uplift and erosion. In contrast, a disconformity may represent a much smaller interval of erosion or nondeposition of sediments.

1. The sketch below shows a sequence of sedimentary rocks into which a canyon has been carved.



a) What is the relative age of sediments A, B, C, D and canyon (E)?

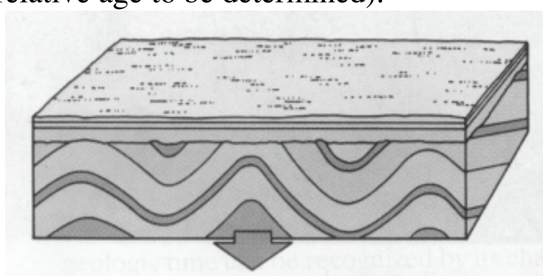
b) What principles did you use to establish this sequence of events?

c) What might account for the difference in slope between units B (which forms cliffs) and C (which is a slope former)?

2. Sketch a cross section that would result from the following series of geologic events: 1) deposition of sediments, 2) mountain building and metamorphism, 3) uplift and erosion, 4) subsidence and 5) deposition of sediments.

a) What type of unconformity is represented?

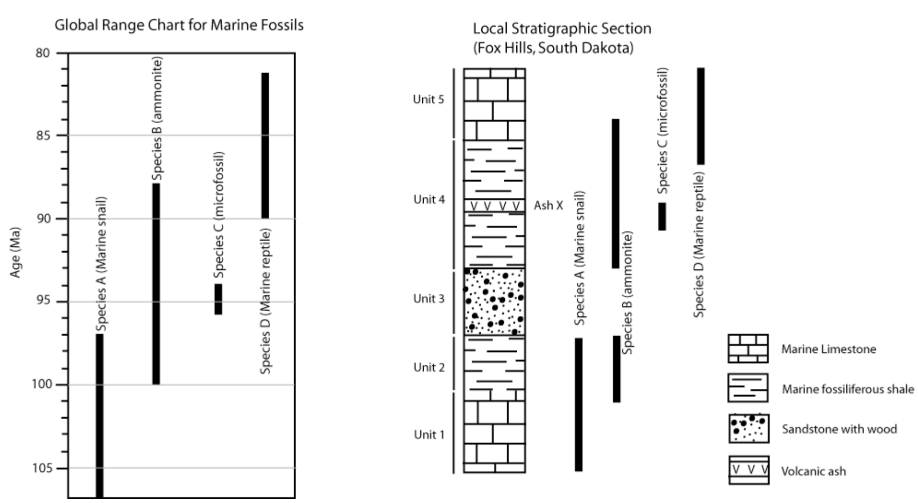
3. The diagram below depicts a sequence of sedimentary rocks (all of which contain fossils that allow their relative age to be determined).



a) How would you go about determining the relative age of the folding?

b) What principles of relative age dating did you apply in this case?

4. The diagram below depicts the age range for a number of fossil groups that occur in a sedimentary sequence (shown at right). The sedimentary sequence also contains an ash layer that records an explosive volcanic eruption and the settling of the ash out of air. Such ashes often contain material that can be used for radiometric dating (to establish the absolute age).



a) What is the approximate age of Ash X in the Fox Hills section based upon the fossil ranges?

b) What range of ages is most likely for Unit 2 in the Fox Hills?

c) Why might fossil B not occur in Unit 3? (hint: look at the types of sediments)

d) How does relative sea level change between the various units? Please explain your reasoning.

5. The diagram below depicts a more complicated series of geologic events involving igneous (unit P), metamorphic (unit F) and sedimentary rocks (remaining units) as well as folding (G) and faulting (K). Unconformities are indicated by wavy lines.

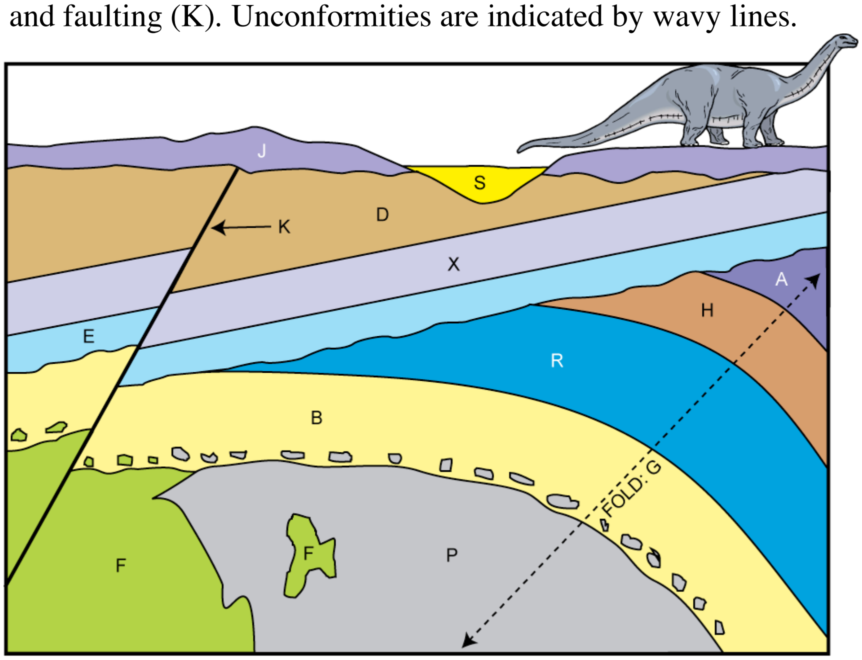


Figure 3 (Modified from Bushee and Singh, 1986)

a) What principle requires that Unit P is younger than Unit F?

b) What is the relative age of Unit B compared to Units F and P? What principle did you use to determine this?

c) Using the principles of relative time, list the ages of the labeled features from oldest to youngest. In your list of relative ages, include also the relative position of any unconformities (specifying what type of unconformity it is).

Introduction to the three types of rocks

Many of the observations used to establish the relative timing of geological events require some knowledge of the three types of rocks: igneous, metamorphic and sedimentary. In order to provide a brief practical overview of these rock types, a few representative examples of each type will be on display in the York 3030.

Igneous rocks are formed from the cooling and crystallization of silicate melts (generally at temperatures of 700°C to 1200°C). These processes lead to a texture of interlocking grains that differentiate igneous rocks from sedimentary ones. Slow cooling, generally beneath the surface of the earth, allows growth of larger crystals than when lavas (magma) is erupted at the surface and cools more quickly. To first order, one can differentiate *intrusive* (*plutonic*) rocks where individual crystals are large enough to be recognized with the naked eye from *extrusive* (e.g., lava flows) rocks where the majority of crystals are typically too small to easily recognize. Note that in either intrusive or extrusive rocks there may be a range of grain sizes, so the primary distinction is based on the grain size that characterizes the majority of the rock.

Sedimentary rocks are composed of discrete grains cemented (e.g. by calcite which precipitates between the grain spaces) together. In *clastic* sedimentary rocks, the discrete particles are mineral or rock fragments that have been eroded and redeposited from a fluid medium such as water or wind. In contrast, the most common *chemical* sedimentary rocks are typically composed of shell material (generally composed of aragonite or calcite, which you will recall are polymorphs of CaCO3) and finer grained carbonate mud. A hallmark of sedimentary rocks is the presence of layering or stratification, though this may not always be obvious in hand sample sized pieces.

Metamorphic rocks are formed when pre-existing rocks (which could be igneous, sedimentary or metamorphic) are exposed to temperature and pressure conditions that differ from those under which the rocks originally formed. Though these temperatures can be high (generally ~100°-600°C) they are not so high as to melt the rock. Rather, the original assemblage of minerals undergoes changes in the solid state to a new assemblage of minerals appropriate for the temperature and pressure conditions of metamorphism. These changes can include the growth of new minerals, the alignment of minerals (particular of platy minerals such as mica) into planes, and the deformation of pre-existing minerals or rock fragments.