Lab 1: Geologic Time and Biostratigraphy

As you saw in your previous geology classes, rocks and structures are dated in either relative or absolute terms. **Absolute dates** are determined primarily through the use of radiometric dating techniques. **Relative dating** involves the use of basic stratigraphic concepts to figure out the relative sequence of events that occurred to a particular rock layer or structure.

Basic stratigraphic principles and concepts:

Principle of Original Horizontality: Sedimentary rocks are originally deposited as horizontal layers. Strata that are not horizontal must have been disturbed at some point in the past by movements of the crust.

Principle of Superposition: In an undisturbed sedimentary sequence or sequence of inter-bedded sediments and extrusive igneous rocks, the oldest beds are at the base and the youngest beds at the top of the sequence.

Principle of Cross-Cutting Relationships: Geologic structures (e.g. faults and folds), intrusive rock bodies, and erosional surfaces are younger than the beds and structures which they cut or effect.

Principle of Inclusion: A body of rock that contains inclusions (i.e. unmelted rock fragments) of pre-existing rocks is younger than the rock from which the inclusions were derived.

Principle of Faunal Succession: Fossil organisms succeed one another in a definite and recognizable order. The relative ages of rocks can then be determined by their fossil content.

Unconformities: Unconformities are intervals of time during which deposition ceased, erosion removed previously formed rock, and then deposition resumed. There are three types of unconformities.

- Disconformity: Erosional or non-depositional surface between older and younger beds that are effectively parallel to one another.
- Angular unconformity: An erosional surface on previously folded or tilted strata over which younger rocks have been deposited.
- Nonconformity: An erosional surface cut into intrusive igneous or metamorphic rocks, overlain by younger *sedimentary* strata.

In the early days of geology, these principles were among the only means of determining the sequence of events observed in geologic sections throughout the world. Eventually, a **geologic time scale** was developed. This arranged the geologic record of the Earth into a standard sequence of units in relative age order. The boundaries were originally based on significant changes in lithology and fossil content. The geologic time scale is given below. You are responsible for knowing the Eons, Eras, Periods, and Epochs given, as well as the absolute dates given on the right hand side of the scale.

As stated above, fossils were used extensively to set up the geologic time scale. Places in the geologic record where large numbers of fossil forms disappeared, or where entirely different assemblages of organisms suddenly appeared in rocks were used to set the boundaries of various divisions of geologic time. A fine example of this is the boundary between the Cretaceous (K) and Tertiary (T). In marine rocks it was observed that many species of marine organisms went extinct at this time, to be replaced by new, very different species. In terrestrially deposited rocks, non-avian dinosaurs disappeared from the geologic record. This shift in fossil forms was observed in rocks world-wide, and made an obvious choice for setting up a geologic time boundary.

Absolute dating

Absolute dates are calculated from the decay of radioactive isotopes found in certain rock types. The ability to accurately measure radioactive decay rates has only existed since the latter part of the 20th Century. Absolute dating provides us with an actual numerical value for the age of rock units. For instance, in the example above, the sudden disappearance of a large number of species prompted early geologists to create the division between the Cretaceous and Tertiary Periods in the Geologic Time Scale. However, the absolute age of the extinction event at the boundary remained uncertain until the advent of radiometric dating techniques. We now set the K/T boundary at 65 ± 3 million years ago. You may occasionally see a geologic date given followed by "Ma" or "Ga". This is the abbreviation for "millions of years ago" (Ma) and "billions of years ago" (Ga).

Some definitions which you've probably seen before, but may need a reminder:

Isotope – a variety of an element with a different atomic weight. (For example: carbon 12 is the most common variety of carbon, but there are also carbon 13 and carbon 14)

Daughter isotope – the new element created when unstable, radioactive atoms release radioactive particles, changing their atomic number.

Half-life – the amount of time required for one half of a given sample of a radioactive element to decay into its daughter isotope.

Radiometric dating is possible because radioactive isotopes decay at measurable and constant rates. As magma or lava cools, mineral crystals begin to form. The crystals incorporate atoms from their surroundings, some of which are unstable isotopes of various elements. Once the crystal has formed, the radioactive material in it begins to break down into daughter isotopes. Given knowledge of the length of the half-life of a particular isotope, measuring the ratios between the amount of remaining parent and daughter isotopes will yield the time that has elapsed since the mineral crystal formed.

There are limitations on the usefulness of radiometric dating. First, readings become inaccurate if the sample being tested is younger than 1/10 of a half life, or if it is much older than ten times a half life. This is because our current technology is unable to detect the incredibly small amounts necessary for greater accuracy. Second, a real handicap is the fact that radiometric dating cannot be used to directly date sedimentary rocks.

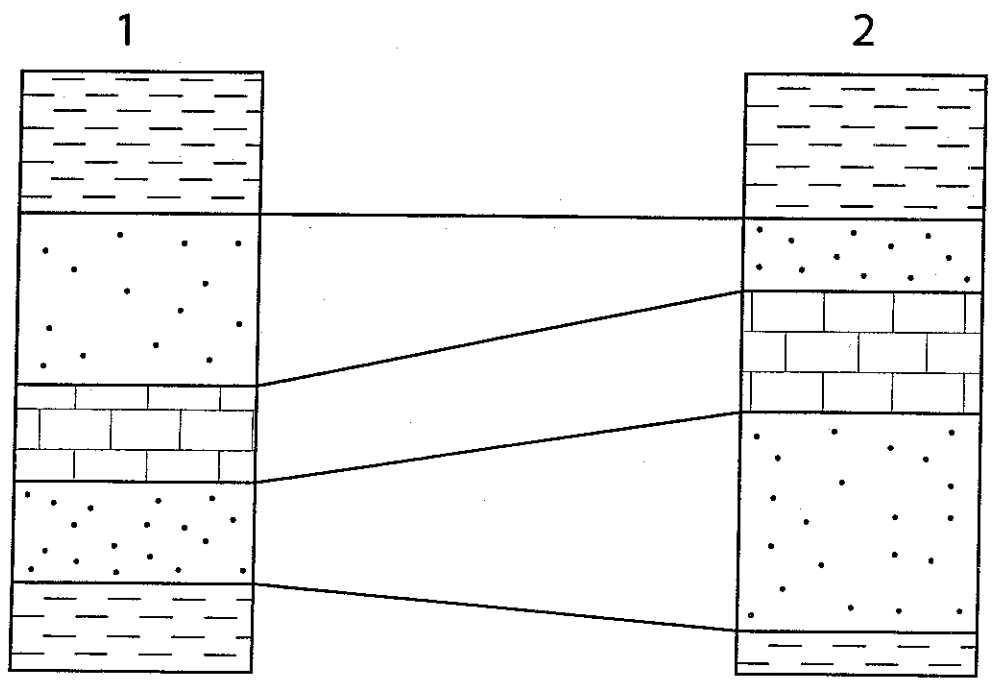
WHY?

Biostratigraphy

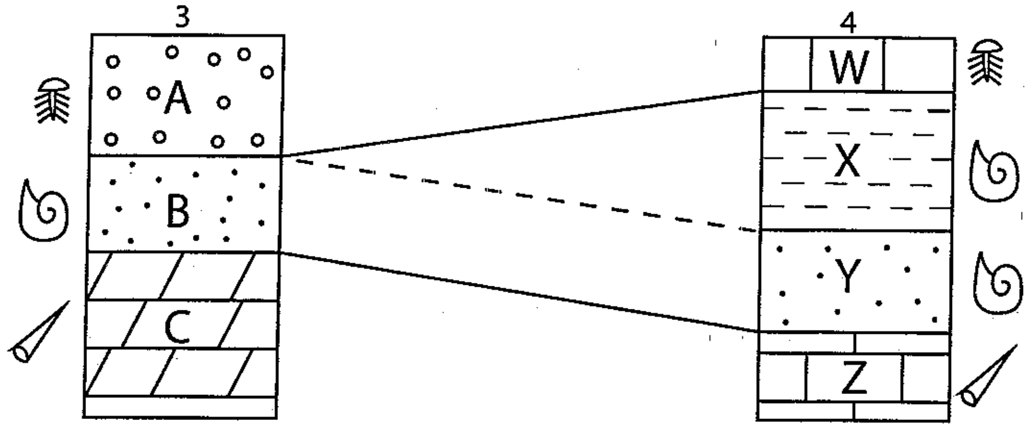
Biostratigraphy is the correlation of geographically separate rock sequences using fossils in conjunction with lithology. A few basic concepts are necessary to perform this task. First, realize that each species has its own, unique, geologic range. This range corresponds to the time when the species was actually alive. Ideally, the rocks in which fossils of a species are contained should have been deposited at the actual time the species existed. Next, keep in mind the Principle of Faunal Succession. Species appear in the geologic record, persist for some length of time, then disappear, and are replaced by something new. This succession is most easily observed in marine rocks and can be traced over large geographic areas, even world-wide. Finally, one must assume that the same species cannot evolve twice. Extinction is forever. Unrelated organisms may look similar, but this is usually due to convergence upon a similar lifestyle or environmental need.

Index fossils are fossils that have a short temporal (time) range, but a wide geographic distribution. They are also abundant, are facies independent (appear in a wide range of lithologies or paleoenvironmental settings), and have a distinctive morphology. Index fossils are extremely useful in biostratigraphic work. Many planktonic (free floating, marine) organisms make good index fossils. Other widely used index fossils are ammonites (shelled, squid-like creatures) and ostracods (tiny, shelled crustaceans) and graptolites.

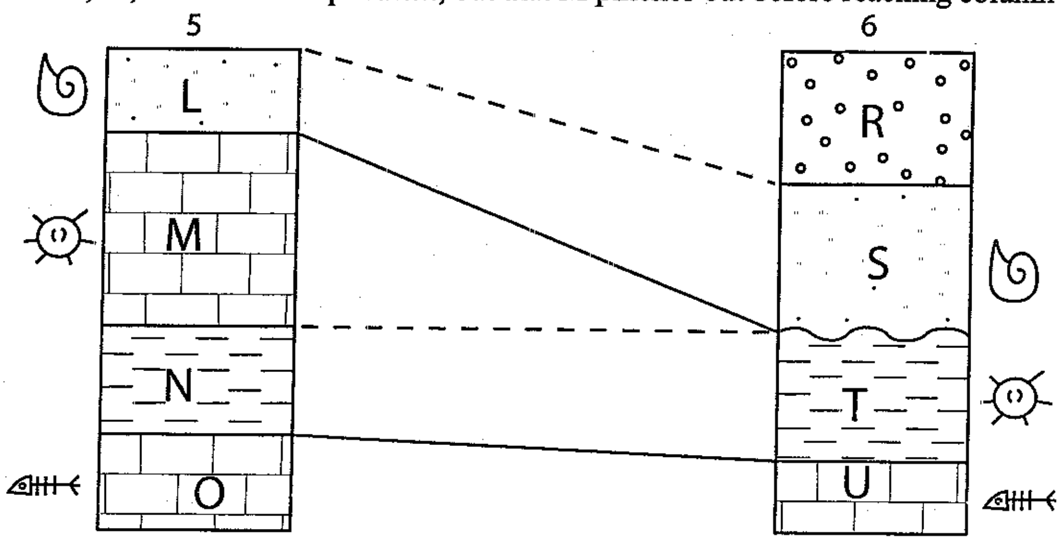
It is relatively easy to correlate beds that retain the same lithology from one geographic locality to another. Take a look at the figure below. In section 1, a limestone layer is sandwiched between two sandstone layers. In section 2, taken several miles away, the limestone layer is also sandwiched between two sandstone layers. The correlation of these beds is quite simple. To graphically depict correlation between sections, simply draw a solid line from the **contacts** (boundaries) of units believed to be equivalent.



Now look at the two stratigraphic columns below (3 and 4). In these sections there is only one bed in each that appears to be lithologically equivalent, bed B and bed Y. Based on lithology alone, the surrounding layers cannot be determined to be equivalent. This is where fossils come in handy. Notice the presence of identical fossil species in layers A and W. Even though the lithology is not the same, they contain the same fossils, indicating they were laid down at the same time. Solid lines are drawn to their contacts. These lines indicate equal points in time, and are called **isochrons**. The same goes for units C and Z. When contacts are inferred, dashed lines are drawn. This occurs when a unit is at the top or bottom of a section and you cannot determine the true point of contact. It also applies to beds or units that do not have equivalents in other sections. Take a look at unit X. It does not share lithology with any units in column 1. It does share fossils with B. This suggests that it is equal in age to B, but that whatever environment deposited layer X did not reach geographically as far as column 1.



Another case of correlating units is seen in columns 5 and 6. Notice that L and S share litholgies and fossils. They are equivalent. The dashed line from the top of L to S is because L is the top unit in the section, and its upper boundary is not definite. Look at M and N and their equivalence with T. In this case, M and T share fossils, but N lacks fossils altogether. N and T share lithologies. Layers O and U are equivalent in both lithology and fossils. This means that in all likelihood, M, N and T are equivalent, but that M pinches out before reaching column 6.

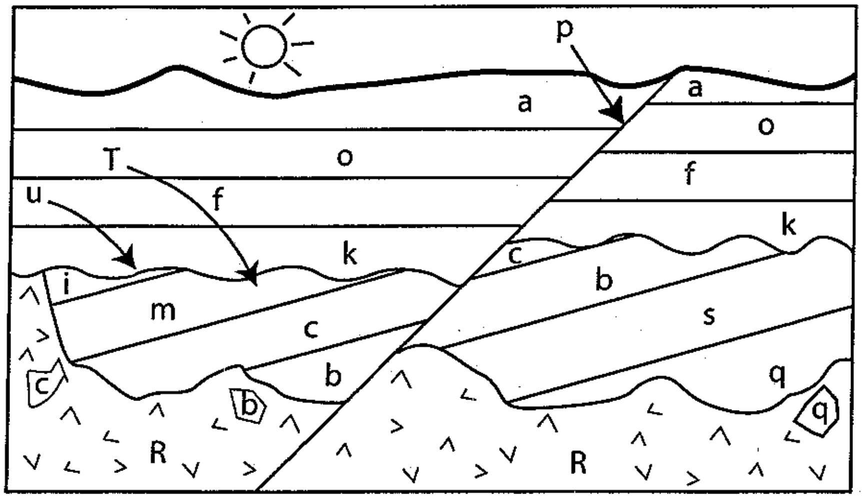


Name:________________________

Lab day& time:__________________

Lab. 1 – Geologic Time and Biostratigraphy Exercises

1. Based on the principles in your handout, give the relative age of the various beds and/or structures labeled in the figure below. Order them with the oldest on the bottom.



youngest

oldest

p = fault, u = unconformity, T = tilt of beds i,m,c,b,s,q, and R.

2. A stratigrapher examining an outcrop of river sediments needs to know the age of the deposits she's working on. She collected six types of fossils, for which paleontologists have already determined the geologic ranges (listed below).

Species A = Eocene through Pleistocene
Species B = Pliocene
Species C = Miocene through Pliocene
Species D = Miocene through Recent
Species E = Pliocene through Pleistocene
Species F = Paleocene through Pleistocene

2A. Plot the geologic range of the six species below:

	Paleocene	Eocene	Oligocene	Miocene	Pliocene	Pleistocene	Holocene
Species A							
Species B							
Species C							
Species D							
Species E							
Species F							

2B. What is the age of the sandstone being examined?

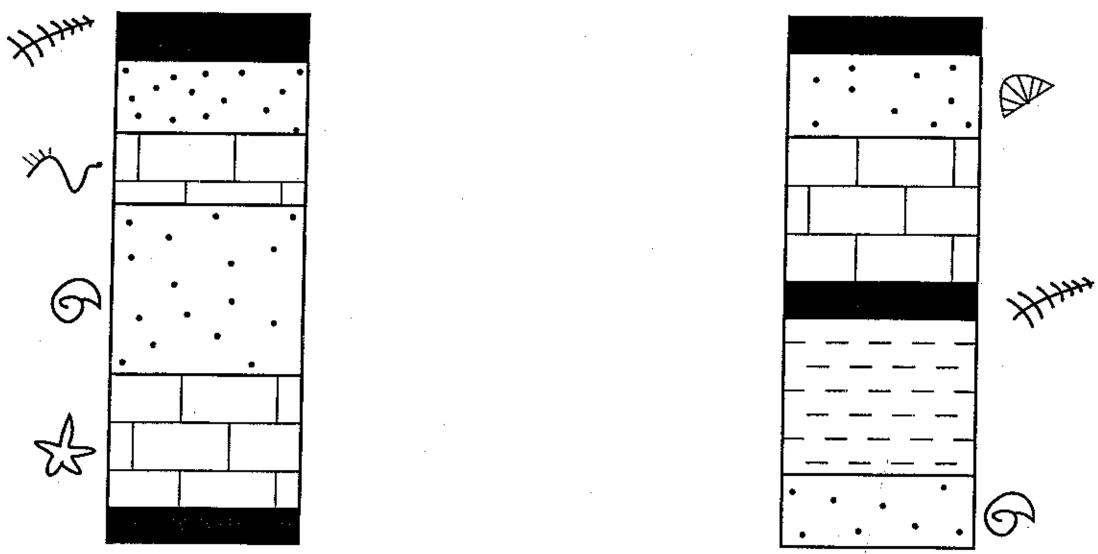
2C. Which species is the best index fossil?

2D. Which species is least useful for determining the relative age of the sandstone?

2E. Later the stratigrapher finds a piece of limestone in the conglomerate. It is heavily waterworn, and paleontologists identify a fossil in it that is Mississippian in age. What is the age of the sandstone now? Why?

3. Stratigraphic correlation.

3A. The diagram below shows two stratigraphic columns, separated by great geographic distance. Use both lithographic and temporal evidence to correlate the beds.



3B. Correlate the geologic units in the stratigraphic columns below. Use temporal and lithologic clues to accomplish this.