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GEOL 104 Dinosaurs: A Natural History
Geology Assignment

DUE: Mon. Sept. 17

Part I: Environments of Deposition

Geologists can use various clues in sedimentary rocks to interpret their **environment of deposition**: that is, the type of conditions that were present when they were laid down.

Some aspects of the environment of deposition are revealed by the type of sedimentary rock. **Carbonate rocks** are composed of calcium carbonate, like limestone (including chalk): these form primarily form in saltwater (marine) environments or along their shores (the white beaches of the Caribbean, for instance, or possible future limestones). **Coal**, compressed plant material that was buried so fast it did not have time to decay, indicates the presence of swamps. **Evaporites** (rock salts) show an environment that was very arid; the quick evaporation of the salty lake or sea water results in accumulations of evaporite deposits. On the other hand, **detrital** sedimentary rocks (breccias, conglomerates, sandstones, siltstones, and mudstones) can form in a variety of environments, so we need additional information.

Another aspect of the environment recorded in the sedimentary rocks is the **energy of the environment**: that is, how fast the water (or wind) was moving. Essentially, the higher the energy, the larger the size of the particles of sediment. Slow moving water can only move extremely fine (small) particle sizes: silt, clay, and mud. This slow moving water might be the still water of lake or lagoon or the slowly moving water of a river at flood stage that has overflowed its banks. Moderately quick moving water (or fast moving wind) can move sand. Only the fastest moving water can move gravel: these conditions are found in mountain streams or the strongest (and deepest) parts of the channels of rivers.

Detrital sedimentary rocks are classified mostly on the size of the largest particle, and thus reflect the energy of the environment:

- **Breccias** and **conglomerates** have gravel-sized particles, and represent the highest energy. These are further distinguished by how continuous the flow of the water was:
    - **Breccias** have angular particles, and so were not transported for very long and probably only moved once (for example, an avalanche)
    - **Conglomerates** have rounded particles, and were transported more continuously (for example, in a river)
- **Sandstones** represent moderately fast water or wind. This could be in stream systems, in desert winds, at the beach, and so forth.
- **Siltstones** represent more slowly moving water and wind: as sandstone above, but with slower speed.

- **Mudstones** generally represent water that is still or moving only very slowly: the middles of lakes, lagoons, deeper water, etc. (One special case is on floodplains: when a river overflows its banks, it deposits lots of mud over everything.)

Note that the energy of environment can affect the type of fossils preserved. Higher energy often means that the animal bodies will get buried faster, and so have a greater chance of being fossilized. However, higher energy **also** means that the bodies (especially of small animals) will tend to be torn apart and the edges of the fossils will be **rounded** by rolling. In contrast, large bodied animals are unlikely to be buried quickly enough in low energy environments to be fossilized (an exception is a river at flood stage: there is so much mud available that dinosaurs (or today, even houses!) can be buried). However, if a smaller animal falls to the bottom of a low energy environment that is **anoxic** (low in oxygen) there will be no decay organisms like worms to disturb the body: this can often produce extremely well preserved fossils.

One set of clues comes from types of layering or **bedding** within the sedimentary **strata** (layers). **Laminations** (very thin layers) indicate environments where the water is very still (and anoxic): lagoons, the interiors of lakes, and the like. In contrast, **cross-bedded** layers and **ripple marks** indicate that there was some form of higher energy environment: the channels of streams and rivers, desert sand dunes, the shores of lakes and rivers. In the case of the shores of lakes and rivers the ripple marks will be symmetrical around their crest, indicating that they are **bi-directional** (produced by water moving to-and-fro, as the water laps onto shore and drains back again). In contrast, in any given layer of a stream channel or sand dune deposit, the ripples will be **unidirectional**, indicating a single direction of the current. Because winds keep on shifting in deserts and on sandy beaches, though, these unidirectional cross-beds will often show dramatic shifts in the direction of the current: these are called **trough cross-beds**.

Bedding and ripple marks are just two types of **sedimentary structure**. There are others that also give clues to the environment of deposition. For example, **mud cracks** can only form in spots which were wet but were then exposed to the air and sunlight (so that they could dry out): if you find mud cracks in rocks, you know that the environment had to have been occasionally exposed to air. Similarly **raindrop marks** also imply ground that is wet but exposed to air, at least during that rainfall. **Tracks** of terrestrial animals (like dinosaurs) would indicate that the ground was soft but was either exposed to air or in very shallow water (obviously if the water was too deep, the feet of the animals wouldn't touch bottom!).

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In each of the following cases, use the evidence provided to circle the single most likely possible environment of deposition, and give your reasons for your choosing.

1) A limestone with dinosaur tracks, mudcracks, and bidirectional ripple marks. This most likely formed at:

a. a stream channel. b. a desert. c. the seashore. d. bottom of a lake or lagoon.

Reason for choosing?

2) Laminated mudstone containing the articulated skeletons of many small animals. This most likely formed at:

a. a stream channel. b. a desert. c. the seashore. d. bottom of a lake or lagoon.

Reason for choosing?

3) Trough cross-bedded siltstone and sandstones, with the articulated skeletons of some small and medium sized dinosaurs, mammals, and lizards. This most likely formed at:

a. a stream channel. b. a desert. c. the seashore. d. bottom of a lake or lagoon.

Reason for choosing?

4) Conglomerates and sandstones with crossbeds and unidirectional ripple marks; the rocks contain fossils (dinosaur bones and teeth; fish scales; etc.) that have been rounded. This most likely formed at:

a. a stream channel. b. a desert. c. the seashore. d. bottom of a lake or lagoon.

Reason for choosing?

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5) In the same rocks as question 4 you find an articulated skeleton of a large (5 m long) dinosaur). Did the carcass of this dinosaur still have meat on it when it was deposited, or was it most likely already just a bare skeleton?

6) Justify your answer to 5.

<u>Part II. Reconstructing the Sequence of Events in Geologic Cross-Sections</u>

Below is a series of drawings of **geologic cross-sections**: diagrams that represents a vertical slice out of some section of the Earth's crust. Your task is to figure the sequence of events that occurred in this spot: specifically, the

- **deposition** of sedimentary rocks
- **intrusion** of plutonic igneous rocks
- **eruption** of volcanic igneous rocks
- **metamorphism** of… you guessed it, metamorphic rocks
- **erosion** of previously existing rocks
- **folding** (twisting) of previously existing rocks
- **faulting** (breaking) of previously existing rocks
- **tilting** of previously existing rocks
- or any other disruptions of the rocks of this region.

Your answer should be a list, with the **oldest on the bottom** and the **youngest on the top** of the events that occurred at this spot.

Remember to use your basic **Principles of Stratigraphy**. These are:

<u>Steno's Principles</u>

- **Original Horizontality**: When sedimentary rocks are first deposited, they deposit as horizontal sheets (strata); later events may tilt, fold, or otherwise move them from horizontality
- **Superposition**: In undisturbed sedimentary rocks (or volcanic rocks), the **oldest** rocks to be deposited are on the bottom, the next oldest second, all the way up to the youngest rocks

<u>Hutton's Principles</u>

- **Cross-Cutting Relationships**: Any erosional surface, fold, fault, tilt, plutonic intrusion, metamorphic event, or other disturbance which deforms a body of rock must be **younger** than the body of rock that is deformed
- **Inclusions**: (really a special case of the above) Any fragments of rock that are contained in a second body of rock must be from a previously formed (older) body of rock

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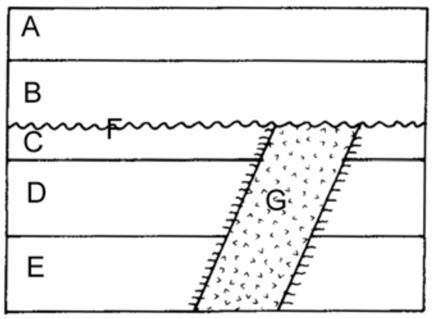
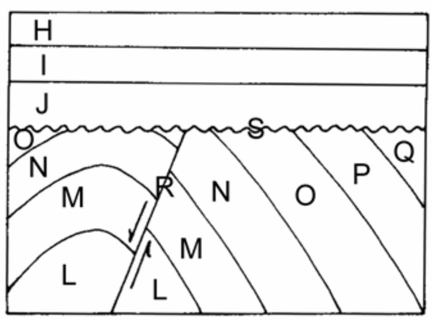
Here is an example. A-E are sedimentary rocks; F (the wavy line) is an erosive surface; G is an intrusive (plutonic) igneous rock. I've listed the sequence of events, with the **oldest on the bottom** and the **youngest on the top**, that would fully explain the cross-section:

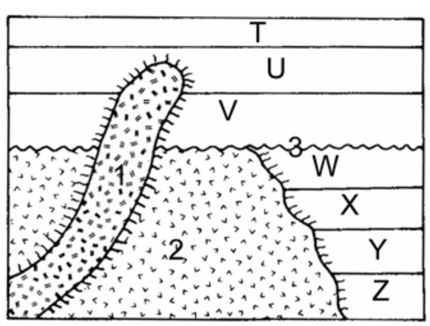


A is deposited (youngest event)
B is deposited
Erosional surface F is formed
G intrudes into C-E
C is deposited
D is deposited
E is deposited (first event)

7) Now it's your turn. H-J and L-Q are sedimentary rocks; R is a fault; S (the wavy line) is an erosive surface; and K (not shown as a letter) represents the folding of the lower rocks. List the sequence of events, with the **oldest on the bottom** and the **youngest on the top**, that would fully explain the cross-section.



8) A third cross-section. T-Z are sedimentary rocks; 1 and 2 are separate intrusive igneous rocks; 3 is an erosive surface. List the sequence of events, with the **oldest on the bottom** and the **youngest on the top**, that would fully explain the cross-section.



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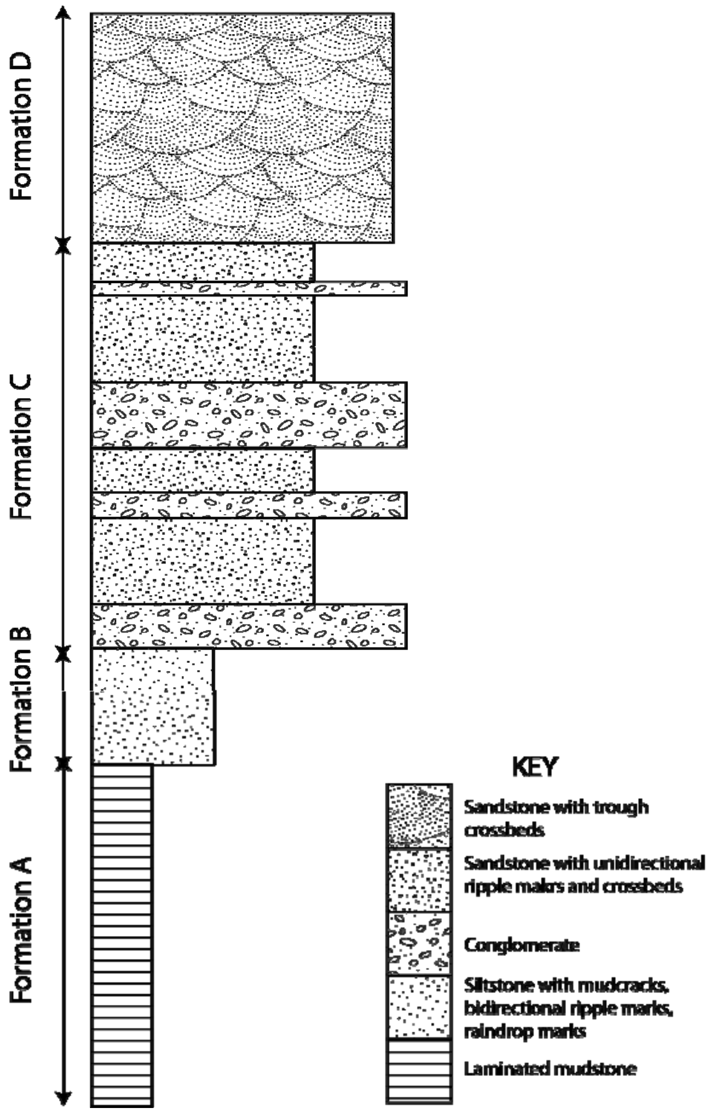
Now let’s combine our information about paleoenvironments and superposition.

Below is a **geologic section**: a representation of the vertical sequence of strata at some region. In this particular case, there is no evidence of a **hiatus** (gap) in the record, so no major missing chunk of time. Each of the four formations was deposited after the other.



Indicate (by letter) which formation represents the following environments:

9) Lakebed? _______________

10) River channels? _______________

11) Desert? _______________

12) Lakeshore? _______________

Extra Credit) The environment of this region was [becoming wetter | becoming drier] over time. (Circle the correct answer).

Part III. Index Fossils

Physical relationships are all well and good for dating relative events at a particular outcrop, but how can one determine if two rocks at **different** outcrops were formed at the same time? One way is to match up the bodies of rock. Since a rock is the record of the environment in which it formed, the rocks formed in a given region at a given time will tend to be of the same type, down to the little details of color, mineralogy, etc. You can trace out these bodies of rocks (called **formations**) over large regions.

However, even this has limited application. After all, a rock is a record of the environment in which it formed, but different environments coexist at the same time all over the world. Thus the rocks that formed at any given slice of time will represent all sorts of different environments. How could one **correlate** (match up the ages) of rocks from different regions?

William "Strata" Smith recognized that one aspect of the rock record that did not repeat in vertical series (i.e., through time) was the **sequence of fossils**. Unlike rock type or characteristics, which would come and go depending on local conditions, the species of fossil organisms only appeared in a single sequence through time. This became the key to his contribution to the principles of stratigraphy:

<u>Smith's Principle</u>

- **Fossil Succession**: Any rock containing a particular fossil species was deposited some time between the origin (first appearance) and the extinction (last appearance) of that species.

Fossils used for correlation are called **index fossils**. Not all fossils are equally good as potential index fossils. Evaluate the following cases, and decide whether it would make a **good index fossil** or a **lousy index fossil**, and **why**.

13) *Tullimonstrum gregarium*: A highly distinctive worm-like animal lacking any hard parts and of uncertain relationship to any living group. It is found in great numbers, but is known only from a single location (Mazon Creek) where the unusual sedimentary conditions preserved impressions of its soft tissues.

14) *Demoscaphites bassleri*: An ammonoid (shelled relative of the squid and octopus) with easily preservable shells found in vast numbers. *Demoscaphites* fossils are found in many regions of the world, and preserved in a variety of marine environments. This species lasted only a short time when it was on earth (a few hundreds of thousands of years), and had a distinctive pattern on the shell.

15) *Ozraptor subotaii*: A dinosaur known only from a single fragment (the lower part of a shin bone and upper ankle) from Australia. This fragment is distinctive, but no other parts have ever been found.

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16) *Aquilapollenites*: Fossilized pollen of a flowering plant of uncertain relationship to any particular living group of plant. This pollen is very easily preserved, occurs in vast numbers in rocks formed both on land and in near-shore marine deposits across western North America, eastern North America, Europe, and Asia. *Aquilapollenites* existed for only the last million years or so of the Mesozoic Era (the "Age of Dinosaurs").

Extra Credit) *Amia* (the bowfin fish) is found in rocks deposited in freshwater environments. It is a distinctive fish, and its fossils are found both in North America and eastern Asia. Fossils of *Amia* remain nearly identical throughout the last 95 million years.

Part IV. Radiometric Dating

So far we have only dealt with **relative** dates: the sequence of events rather than the absolute amount of time between events. The latter (which interests a lot of people) is what are called **numerical dates**.

The simplest way to recover numerical time from the geologic record is by means of **radiometric dating**. Put in its simplest form, radiometric dating relies on the following observations:

- Naturally occurring radioactive minerals decay from parent to daughter product at a regular **half-life** (the time it takes half the atoms in the sample to decay from parent to daughter)
- This rate of decay can be observed in the laboratory, by use of chemistry (to determine the number of atoms in a sample) and counting the number of decay events over a period of time. (Actually, there are also other tricks one can do to force the decay to count the total number of radioactive atoms, too)
- The ratio of daughter to parent is calculated (either directly or each against a third mineral) to determine the number of half-lives that have happened since the minerals formed
- The number of half-lives times the duration of one half life yields the estimate of numerical age

Note that certain conditions should be met in order to effectively use radioactive decay:

- The daughter product should only occur as the result of the decay of the particular parent
- Both parent and daughter should not be able to leave or enter the particular crystals of the rock so that the ratios accurately reflect the decay

Consequently, only those rocks whose crystals form from a molten state will be able to yield radiometric ages that reflect the actual age of the rock. In other words, radiometric dates are essentially limited to **igneous rocks**.

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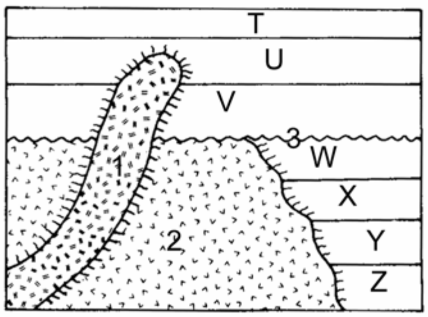
However, using the principles of stratigraphy (including fossil succession and correlation) we can use radiometric dates from igneous units to start to put numerical dates onto a relative time scale. Remember that for sedimentary rocks we will wind up with a range of dates ("between X and Y million years ago" or "older than Z million years ago", etc.).

Below is the cross-section we saw back in Part II, question 8. Radiometric dating reveals that igneous rock 1 comes from 125 million years ago, and igneous rock 2 comes from 180 million years ago. Use this information to date, as best as you can, the following:



17) Rock W:

18) Erosional event 3:

Extra Credit) How old is Rock T? How can you tell?

Part V. Putting it All Together

The final questions refer to the two simplified cross-sections on the next page, representing a series of four sedimentary formations in each region (one in England, the other in New Mexico). Each block is a different formation. The dinosaur names represent a characteristic dinosaur from each unit; the squiggly line in the New Mexico section is an erosional surface; **A** is a volcanic igneous rock (that is, it was deposited on the surface) radiometrically dated to 200 million years old; **B** is a volcanic igneous rock dated to 150 million years old; and **C** is an intrusive igneous rock dated to 130 million years old. Assume the dinosaurs have all the appropriate characteristics for index fossils.

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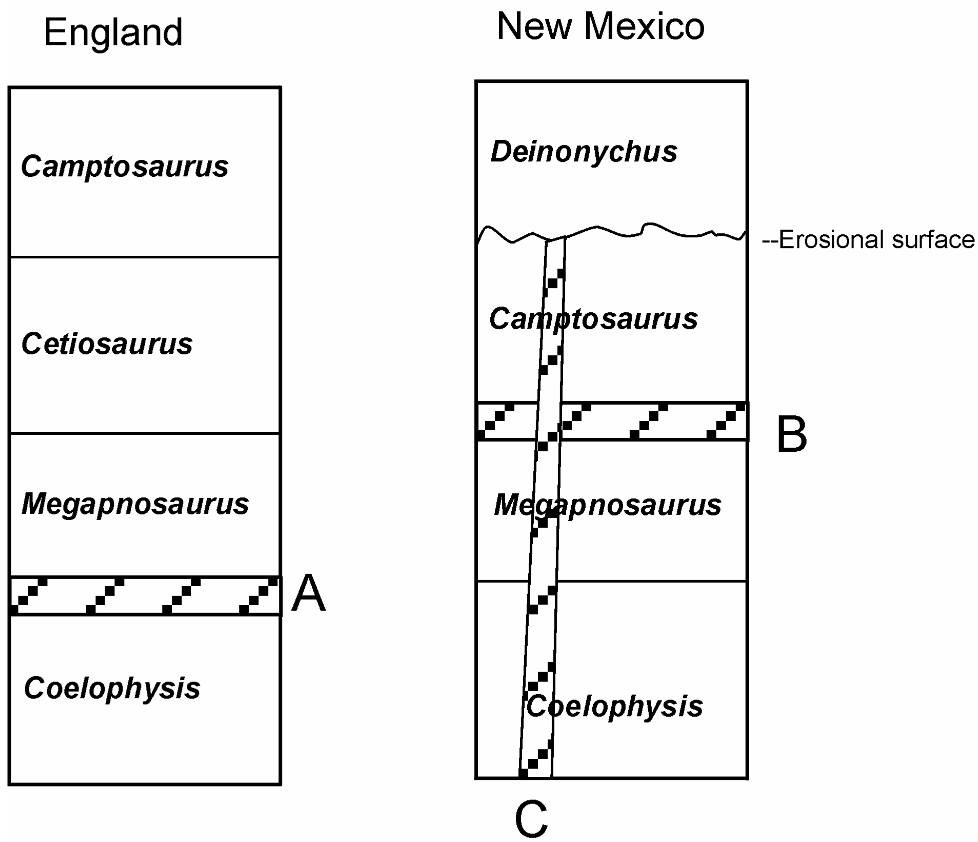

Use the information above to estimate the age of the different dinosaurs, assuming that each dinosaur genus lasted for only a short duration. For questions 19-22, match the letter of the age ranges to the right with the fossil on the left.

19) *Camptosaurus* _______ A. Younger than 130 million years old.

20) *Coelophysis* _______ B. Between 130 and 150 million years old.

21) *Deinonychus* _______ C. Between 150 and 200 million years old.

22) *Megapnosaurus* _______ D. Older than 200 million years old.

23) *Cetiosaurus* is younger than *Megapnosaurus*, but older than *Camptosaurus*. Are there any sedimentary rocks of this age represented in New Mexico? [Yes | No] (Circle the appropriate answer)

24). As best as you can tell, what is the possible age **range** (i.e., from what numerical time to what numerical time) for *Cetiosaurus*?