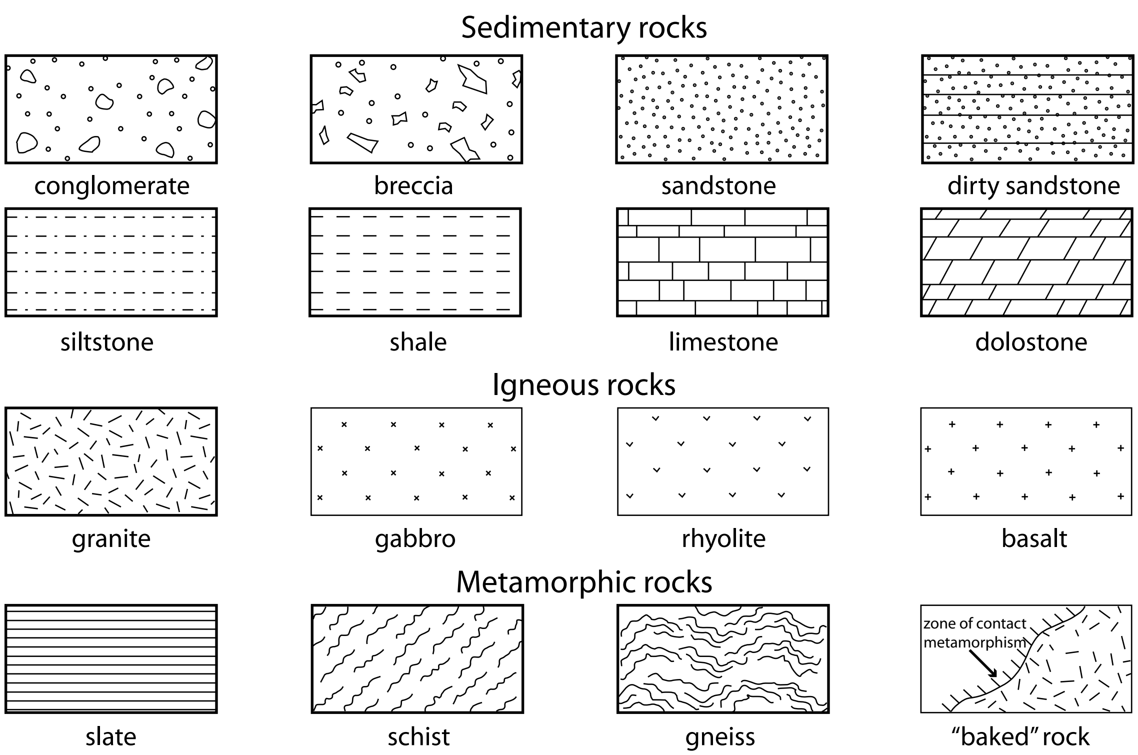
Earth Science - Lab #11
Geologic Time

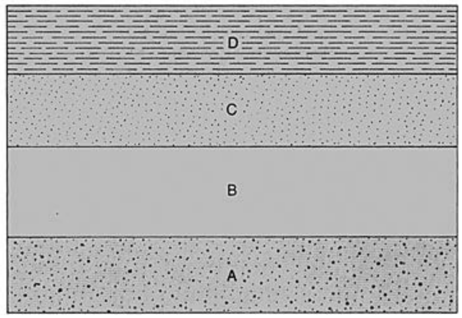
Below are standard geologic symbols for the 3 main categories of rocks. Although these symbols are not universal, they are generally accepted by most geologists who create illustrations of rock outcrops for research and publication.

Sedimentary rocks are created from the hardening (lithification) of sediment:
- Detrital Sediment is derived from eroded pieces of pre-existing rocks.
Nondetrital sediment is derived from eroded hardparts of once living organisms.

Igneous rocks are formed from the cooling of molten rock.
- Slow cooling molten rock below the earth's surface is called magma and upon cooling produces coarse-grained plutonic igneous rocks.
- Fast cooling molten rock at the earth's surface is called lava and upon cooling produces fine-grained volcanic igneous rocks.

Metamorphic rocks are rocks that are altered by intense heat and/or pressure, but no melting occurs.
- At great depths below the earth's surface the intense heat and pressure causes a crushing and an alignment of minerals in the rock to produce foliated (layered) regional metamorphic rocks.
- The intense heat adjacent to a raising magma body may bake the rock in a small region adjacent to the magma body to produce nonfoliated (not layered) contact metamorphic rocks.





Geologic cross section. Rock layer **A** is the oldest layer. Layer **D** is the youngest.

Steno's Principle of Superposition states that in an undisturbed sequence of layers of sediment or of layers of sedimentary rocks the oldest layer is always on the bottom and the layering gets younger as up go up through the exposed section of rock (see diagram above). Geologically speaking, our earth is a very dynamic planet, with many processes present that can 'disturb' the layers and alter their original horizontal layering. These processes can be roughly categorized as: unconformities, faults, folds, tilting, and igneous intrusions.

An unconformity is a surface of erosion or nondeposition in rocks. Most rocks found at the earth's surface are sedimentary and, hence, are deposited by water. If exposed at the surface forces of nature tend to physically and chemically breakdown and remove the rocks. An unconformity means that rock is literally missing due to it's removal by these 'erosional' processes. The upper 3 diagrams on page 3 illustrate the common types of unconformities. A disconformity is an erosional surface between horizontal layers of sedimentary rock. A common scenario for creating disconformities is sea-level fluctuations. A river deposits sediment at its mouth into the ocean. If sea level were to drop the upper layers of this sediment would be removed by erosion. A raising of sea level would allow continued deposition of sediment onto the erosional surface; the disconformity. An angular unconformity forms between layers of sedimentary rock that are not horizontal. Angular unconformities occur when previously deposited layers of rock are uplifted by tilting or bending, exposing the upper portion to weathering. A disconformity is an unconformity that occurs between vastly different rock types, ie. between sedimentary and igneous rocks, sedimentary and metamorphic rocks, or igneous and metamorphic rocks.

A fault is a break in rock along which movement has taken place. The surface along which the two sides of a fault may move is called the fault plane. The side of the fault that the fault plane is tilted toward is called the hanging wall. The side of the fault opposite the hanging wall is called the footwall. Faults are identified based on the relative movement of the hanging wall and the footwall (page 3, middle 3 diagrams). If the hanging wall moves down relative to the footwall this is called a normal fault. If the hanging wall moves up relative to the footwall then it is called a reverse fault. Sideways movement of the hanging wall or footwall creates a strike slip fault.

A fold is a bending or warping of rock. An arching or upwarping of rock that contains the oldest rock in its center is called an anticline. A downwarping of rock that contains the youngest rock in its center is called a syncline. Anticlines and synclines are considered to be symmetrical if their two sides, or limbs) tilt at the same angle. If their limbs do not tilt at the same angle there are known as asymmetrical anticlines or asymmetrical synclines.

As a general rule, molten rock (or magma) is less dense than the solid rock surrounding it so that were magma forms it begins to raise toward the surface. This raising is sometimes called magmatic intrusion, since the molten mass tends to fracture the surrounding rock and then intrude into the openings.

Magma that cools below the surface does so in descrete bodies known as plutons. If the main magma body (also known as the magma chamber) cools as a single pluton it is called a batholith. Small plutons formed when magma fills the cracks in between rocks are called dikes. If magma moves inbetween layers of sedimentary rock it forms a pluton called a sill (see diagram, top of page 4).

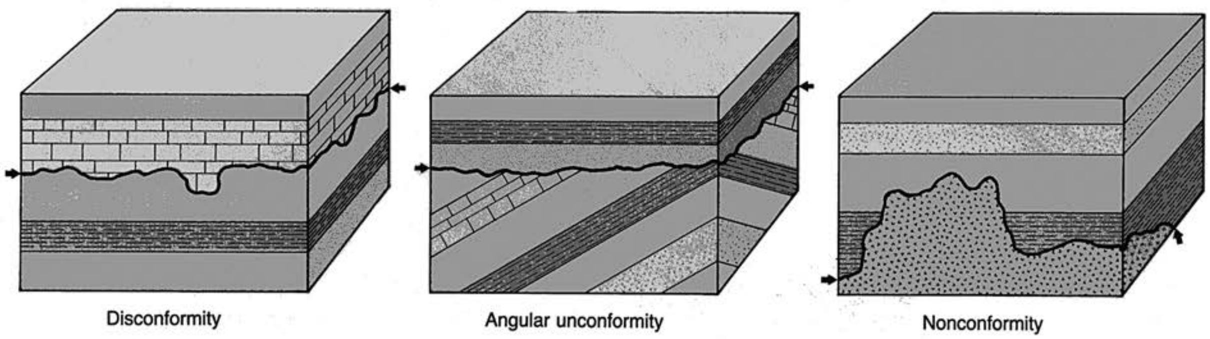


FIGURE A Unconformities. Schematic block diagrams illustrating three common types of unconformities. Arrows point to the unconformity surfaces.

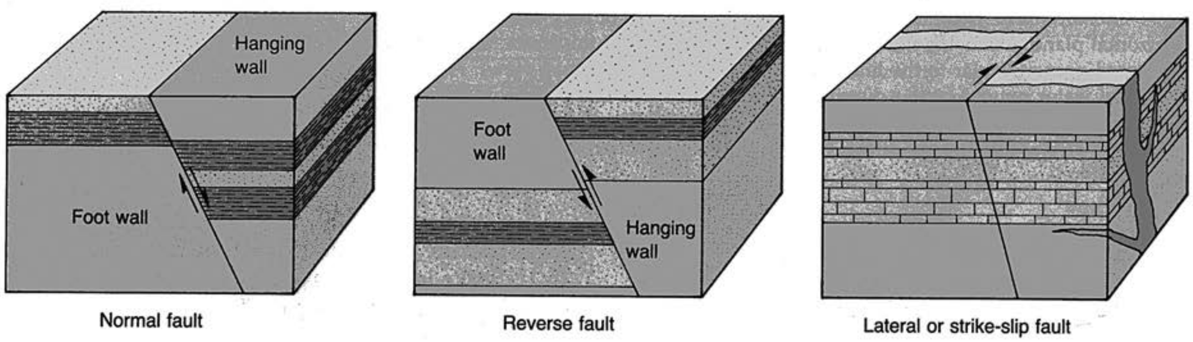


FIGURE B Faults. Schematic block diagrams illustrating three common types of faults.

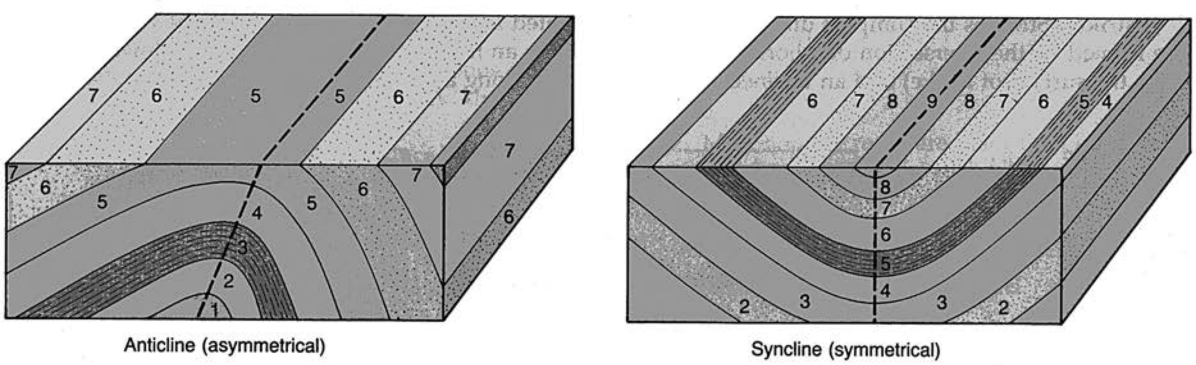
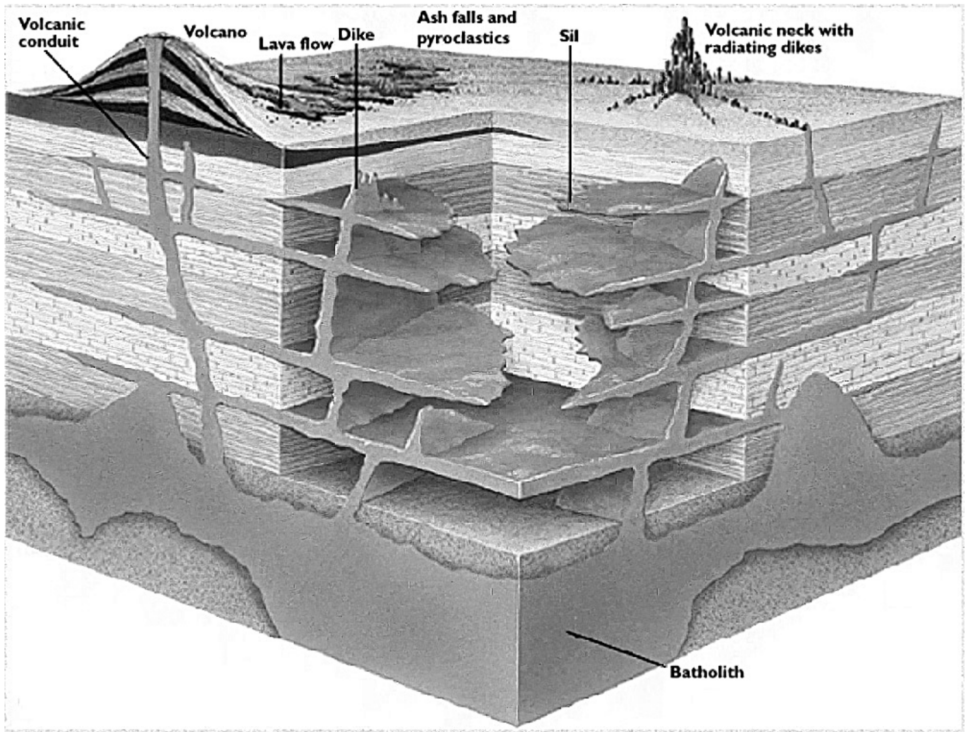
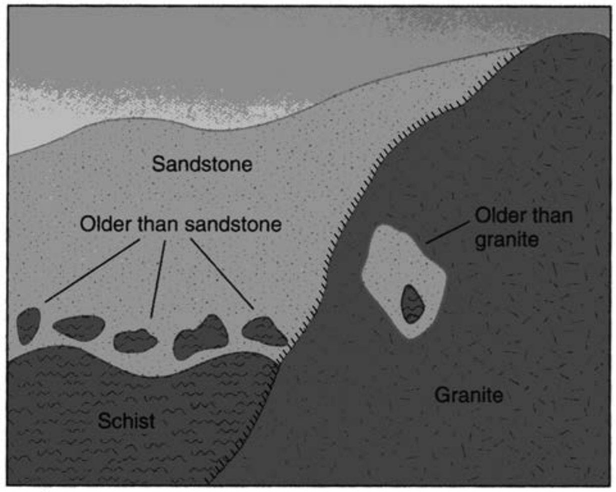


FIGURE C Folds. Schematic block diagrams illustrating two common types of folds. Numbers indicate ages of the rock units, from **1** (oldest, deposited first) to **7** or **9** (youngest, deposited last). Heavy dashed lines indicate edges of axial planes of the folds.



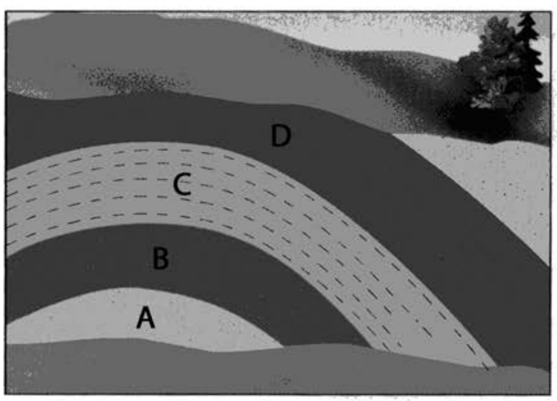
Plutonic and volcanic igneous bodies.

Besides the Principle of Superposition, there are two other rules that aid in placing rocks in their proper relative geologic time sequence. The Rule of Crosscutting relationships states that “younger geologic features always cuts across older geologic features. Folds, faults, igneous intrusions, unconformities, etc. always cut across older rock. In the case of igneous rocks, a pluton is younger if it not only cuts across older rock, but it will also bake it to form a contact aureole (symbolizes by little lines drown along the igneous contact). The Principle of Inclusions states that inclusions in rock are always older than the rock that contains them. A magma body may break up rock that it intrudes. If it incorporated this rock and does not melt it these inclusions (called xenoliths) are older than the plutionic rock that contains them. Likewise, any rock that is exposed to the surface my begin to erode and may begin to break up into large pieces. If these pieces (called clasts) are incorporated in younger, overlying sedimentary rock, than the clasts are, again, always older than the sedimentary rocks that contain them

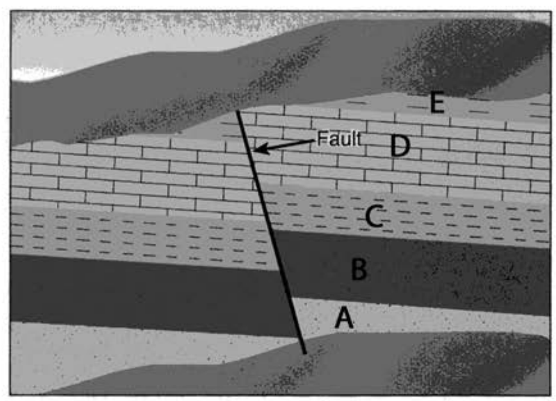


Principle of Inclusions. This cross section shows boulders of schist at the base of a sandstone; the boulders must be older than the sandstone containing them. Similarly, the xenolith of sandstone in the granite must be older than the granite.

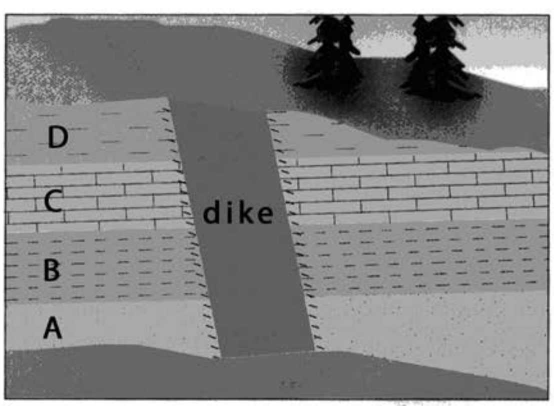
PRACTICE DIAGRAMS



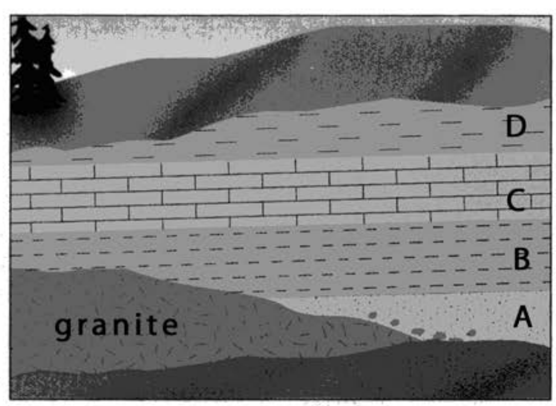
A. Folded rocks



B. Tilted and faulted rocks



C. Igneous dike that intruded older sediments



D. Igneous rock upon which sediments were deposited

MORE PRACTICE DIAGRAMS

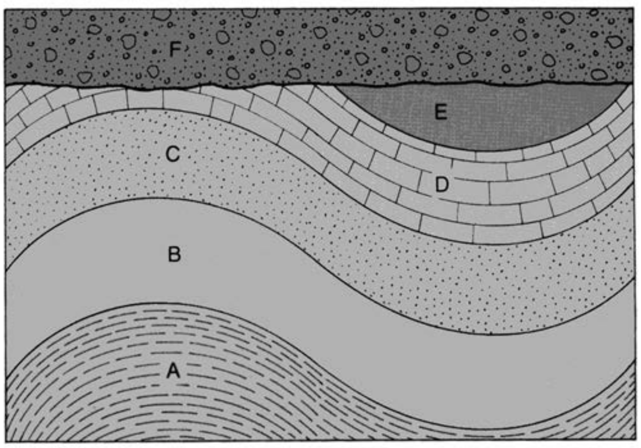


FIGURE A Geologic cross section. Rock layer **A** is the oldest. Layer **F** is the youngest. Folding and erosion occurred after **E,** but before layer **F** was deposited.

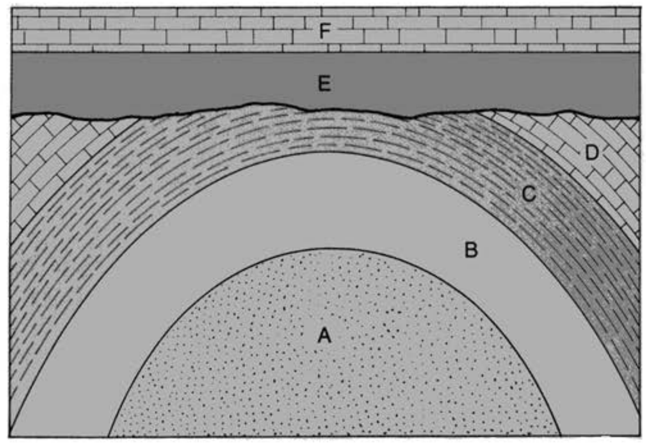


FIGURE B Geologic cross section. Formation **A** is the oldest. Formation **F** is the youngest. Folding and erosion occurred after **D,** but before **E.**

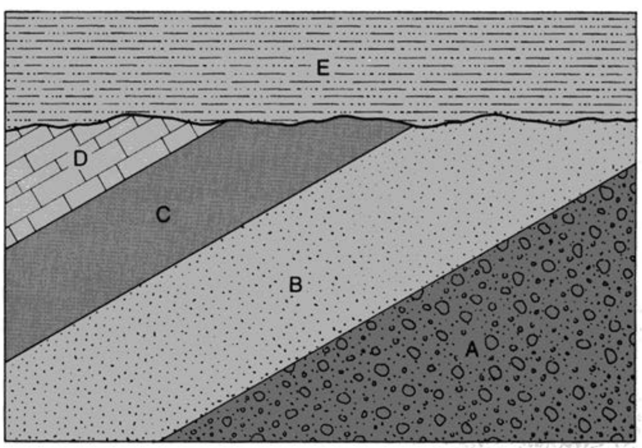


FIGURE C Geologic cross section. Formation **A** is the oldest. Formation **E** is the youngest. Tilting and erosion occurred after **D,** but before **E.**

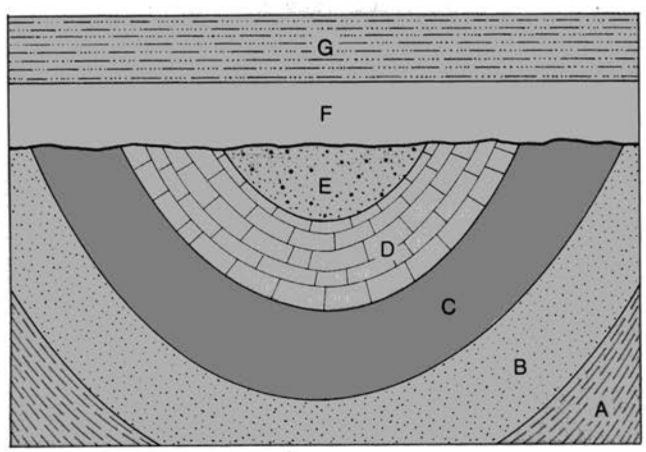
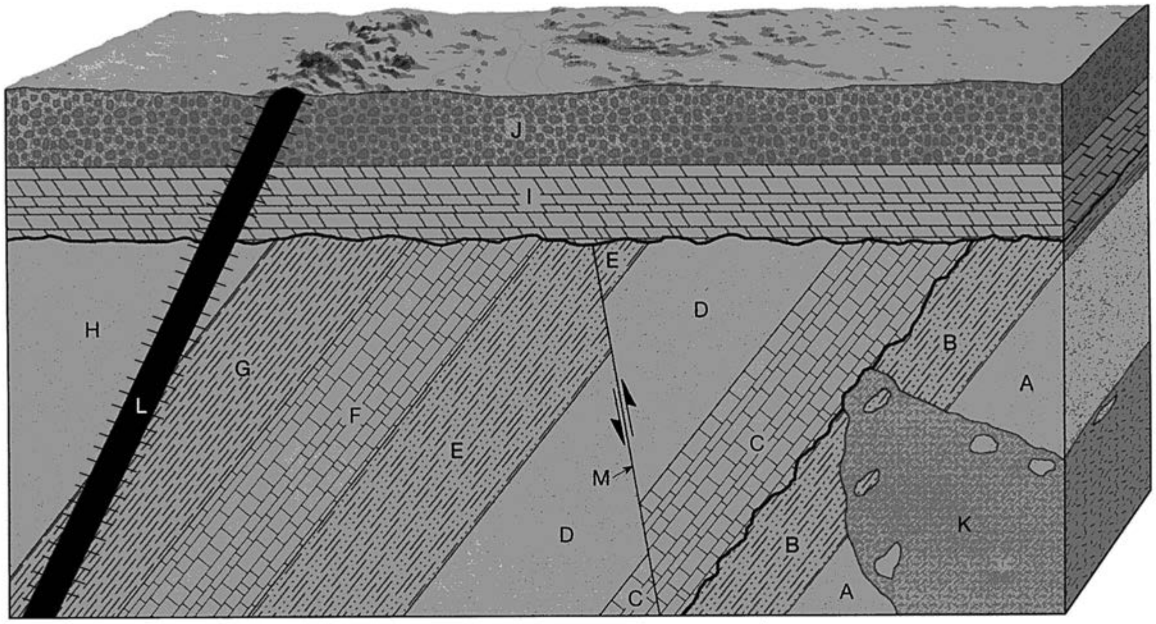


FIGURE D Geologic cross section. Formation **A** is the oldest. Formation **G** is the youngest. Folding and erosion occurred after **E,** but before **F.**

HOMEWORK - Exercise 1



Geologic block diagram of a hypothetical area showing igneous intrusive features (K and L), a fault (M), and sedimentary rocks.

youngest event----> ____

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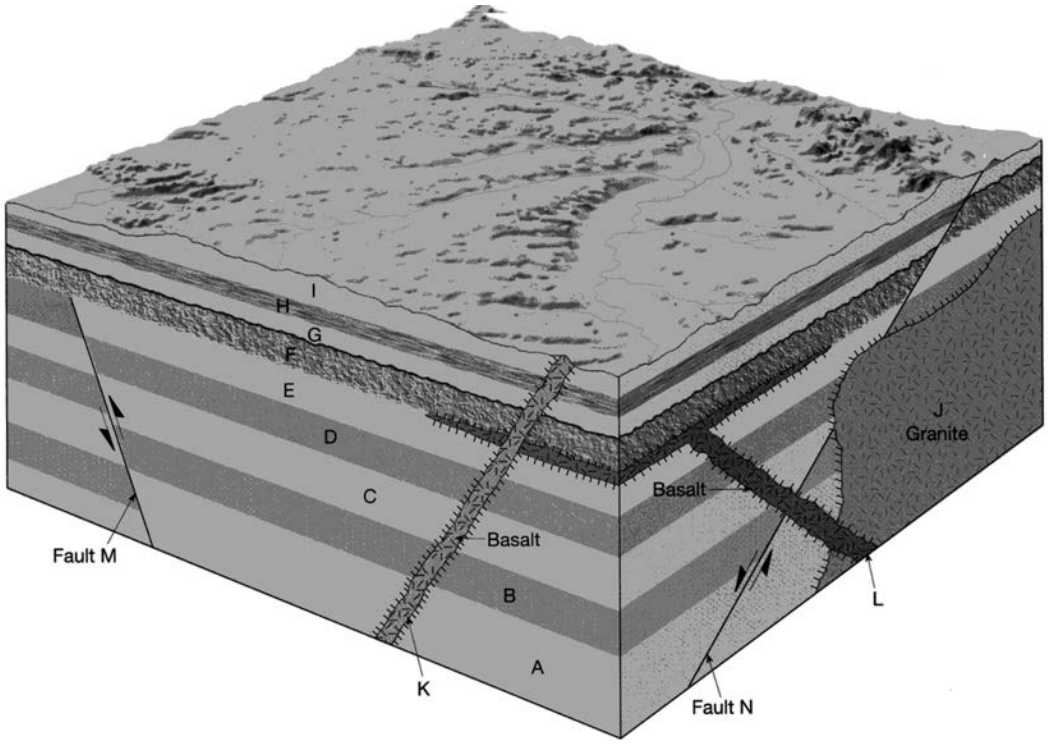
oldest event----> ____

HOMEWORK - Exercise 2



youngest event----> ____

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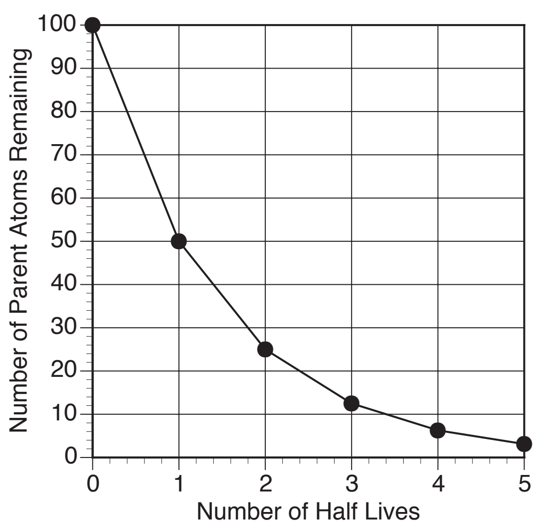
oldest event----> ____

Absolute Geologic Time

Absolute geologic time studies involve finding a numeric age for a sample or a geologic event. The common approach to obtaining a numeric age requires careful analysis of unstable, radioactive isotopes. All radioactive 'parent' isotopes decay into stable 'daughter' isotopes at a specific rate of time known as the half live. The half life is the amount of time it takes half of the parent to decay to the daughter. As an example, if you start with 100 atoms of radioactive element 'X', how many atoms of 'X' you you have after 5 half lives had passed?

0 half lives	----->	100 atoms of X
1 half life	----->	50 atoms of X
2 half lives	----->	25 atoms of X
3 half lives	----->	12.5 atoms of X
4 half lives	----->	6.25 atoms of X
5 half lives	----->	3.125 atoms of X

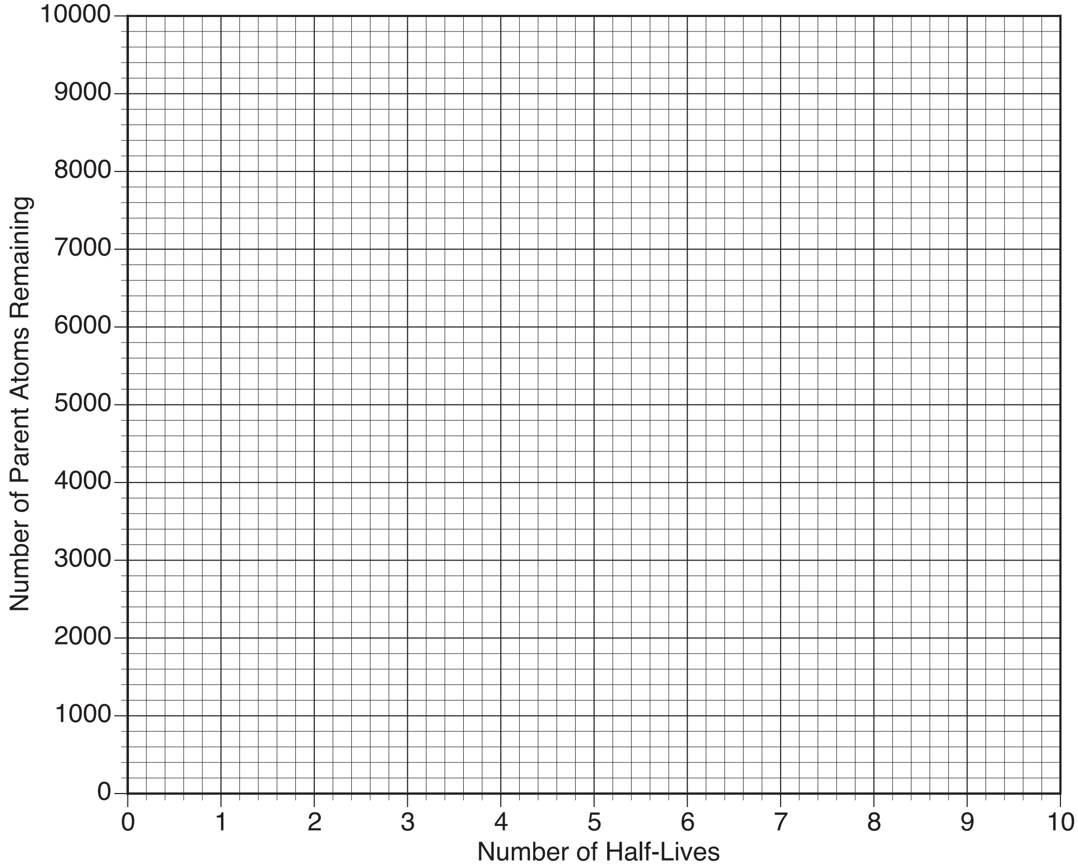
Plotting number of half lives versus number of parent atoms remaining produces a graph known as a Generic Radioactive Decay Curve (see below). It is generic in the sense that it works for all radioactive parent - stable daughter pairs.



Once the number of half lives is known an age can be determined by multiplying the number of half lives by the amount of time that it takes for each half life to take place. The half lives for several frequently used radioactive isotopes are listed below:

Radioactive Parent	Stable Daughter	Half Life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years
Carbon-14	Nitrogen-14	5730 years

HOMEWORK - Exercise 3



1. Starting out with 10,000 atoms of carbon-14 construct a Generic Radioactive Dacay Curve for eight half lives.

0	half lives	________________	atoms remaining
1	half life	________________	atoms remaining
2	half lives	________________	atoms remaining
3	half lives	________________	atoms remaining
4	half lives	________________	atoms remaining
5	half lives	________________	atoms remaining
6	half lives	________________	atoms remaining
7	half lives	________________	atoms remaining
8	half lives	________________	atoms remaining

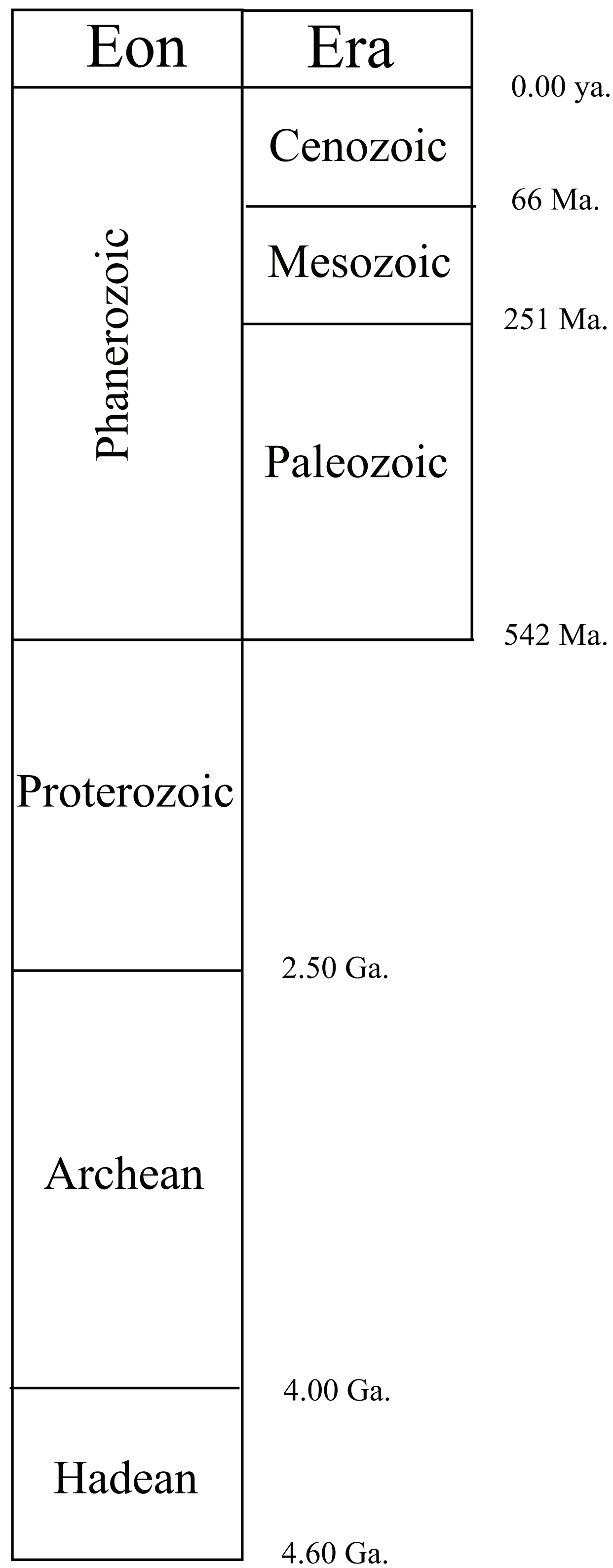
2. How many half lives will have passed if 7500 atoms of carbon-14 remain? How old would the rock be?

3. If, instead of carbon-14, uranium-235 was used and 4000 atoms of uranium were left over, how old would the rock be?

4. Is carbon-dating an effective means of dating very old rocks? Why?

5. Is uranium-lead dating an effective means for dating very young rocks? Why?

A Simplified Geologic Time Scale



6. The Granite K from the first block diagram (page 7) has 40% of its original 235U. Calculate its absolute age. Show your work.

7. The oldest rock in this diagram has a relative age of that is at least as old as which geologic eon/era?
(a) Cenozoic (b) Proterozoic (c) Paleozoic (d) Mesozoic

8. Layer G, a siltstone from the first block diagram (page 7) has the mineral glauconite, which can be dated using Potassium 40. In G, 85% of its original Potassium 40 remains. Calculate its absolute age. (Take great care with measuring the number of half lives. Use a ruler and try to be as precise as possible. Show your work.)

9. Layer G formed during which geologic eon/era?
(a) Archean (b) Proterozoic (c) Paleozoic (d) Mesozoic

10. Dike L from the first block diagram (page 7) is made of basalt. which can be dated using 235U. 90% of its original 235U. Calculate its absolute age. Take great care with measuring the number of half lives. Use a ruler and try to be as precise as possible. Show your work.

11. The youngest rock in this diagram formed during which geologic eon/era?
(a) Archean (b) Proterozoic (c) Paleozoic (d) Mesozoic

12. Examine block diagram 1 again from page 7. There are three packets of layers that are separated by unconformities. Determine as best you can the geologic eon/era of formation from the geologic time scale for these three packets.

Basalt L and Layers J and I ____________________________

Layers C to H ____________________________

Granite K and Layers A and B ____________________________