Part 1 - Determining Relative Ages of Rock Layers

In this example, you will determine the relative age sequence of a series of rock formations by applying two basic principles used by earth scientists:

- **Principle of superposition**: Younger sedimentary rocks are deposited on top of older sedimentary rocks.
- **Principle of cross-cutting relations**: Any geologic feature is younger than anything else that it cuts across.

After you have decided how to establish the relative age of each rock unit, list the rock names under the diagram, from most recent at the top of the list to oldest at the bottom. Note that there are a total of seven rock units, listed here alphabetically: Basalt intrusion (dike), Granite, Limestone, Pegmatite intrusion, Sandstone, Shale & Siltstone with volcanic ash (considered a single layer), Slate. Hint: Use this as a check list to assess all the rock units.

<table>
<thead>
<tr>
<th>Most recent rock formed</th>
<th>Name of rock formation</th>
<th>Radiometric age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basalt intrusion (dike)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pegmatite intrusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shale &amp; Siltstone with volcanic ash</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slate</td>
<td></td>
</tr>
</tbody>
</table>

List the rocks from oldest to most recently formed:

- Slate
- Shale & Siltstone
- Sandstone
- Pegmatite intrusion
- Limestone
- Granite
- Basalt intrusion (dike)
Part 2 - Determining Radiometric (numerical) Ages of Rock Layers

Some elements have forms (called isotopes) with unstable atomic nuclei that have a tendency to change, or decay. For example, U-235 is an unstable isotope of uranium that has 92 protons and 143 neutrons in the nucleus of each atom. Through a series of changes within the nucleus, it emits several particles, ending up with 82 protons and 125 neutrons. This is a stable condition, and there are no more changes in the atomic nucleus. A nucleus with 82 protons forms the element lead (chemical symbol Pb). The protons (82) and neutrons (125) total 207. This particular form or isotope of lead is called Pb-207. U-235 is the parent isotope of Pb-207, which is the daughter isotope. Many rocks contain small amounts of unstable isotopes and the daughter isotopes into which they decay. Where the amounts of parent and daughter isotopes can be accurately measured, the parent to daughter ratio can be used to determine how old the rock is.

The diagram below illustrates this basic concept. The parent isotope is the original unstable or radioactive isotope. The decay product is the daughter isotope. A half-life is the time required for one half of the parent isotope to decay. For one half-life, one half of the original parent has decayed to daughter; the ratio is thus 1:1 parent to daughter. After two half-lives, one half of the remaining parent has decayed; the parent to daughter ratio is now 1:3. Note that the amount of time that passes for each half life is unique for each parent-daughter pair. Note from the decay curve shown below that the decay process is both an ongoing process and is logarithmic, not linear.
The following graph shows the radioactive decay curve for Uranium-235 to Lead-207. Each box on the vertical scale represents a change of 5%. Each box on the horizontal scale represents a change of 100 years. Use the percent change for each parent:daughter pair to determine the age of the sample.

In the sample geologic diagram given on the first page of this hand-out, there are four rock units with appropriate mineral compositions for radiometric dating. A geochemical laboratory would be able to determine the parent:daughter ratio of the U-235:Pb-207 atoms and thus the age of the rock materials. With the information provided in the chart below, use the decay curve above to determine the age of each sample given and complete the chart. Note that the rock units are listed alphabetically, not numerically. Once you have determined the age for each rock unit, write the ages beside the names of the rocks in the spaces provided on the given diagram on the first page of this hand-out.

<table>
<thead>
<tr>
<th>Rock Name</th>
<th>Parent:Daughter ratio</th>
<th>Fraction</th>
<th>Percent</th>
<th>Age (millions of years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>7:3</td>
<td>7/10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granite</td>
<td>1:3</td>
<td>1/4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pegmatite</td>
<td>1:1</td>
<td>1/2</td>
<td>50%</td>
<td>700</td>
</tr>
<tr>
<td>Volcanic ash</td>
<td>47:3</td>
<td>47/50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hint:** You have been given the parent:daughter ratio of U-235:Pb-207 atoms and the corresponding fraction value. You must calculate the corresponding percent value. Next, apply the percent value on the decay curve given above to determine the age. The pegmatite has been completed as an example for you.
Part 3 - Application of Radiometric Dating

1) As discussed in class, in order for radiometric dating to work correctly it must be a “closed system”. What does this mean? What can happen if the system is not closed?

**From the information provided in Part 2, answer the following questions about the decay process.**

2) Which element is the parent element? Is this element stable or unstable?

3) Which element is the daughter element? Is this element stable or unstable?

4) If you had a rock that only had 50% Uranium -235 atoms, what happened to the other 50% of the atoms?

5) Define the term “half-life.”

6) What percent value is used to determine the half-life of Uranium-235?

   Using this value, what is the half-life value of Uranium-235 in millions of years?

7) Using the decay curve diagram, if you knew that 10 out of 100 Uranium-235 atoms had decayed to Lead-207 atoms, what percentage of the parent isotope still remains?

   How old would this sample be?

8) You analyze a rock that has only 10% of the parent isotope remaining; using the decay curve diagram, what is the age of this rock sample?
Use the diagram on the first page of this hand-out to help you answer the following questions about the fossils.

Three sets of fossil evidence are provided as part of the geologic history of these rock units:

- The slate contains the fossil remains of microscopic single-celled fossils (acritarchs and bacteria).
- The limestone contains fossil Trilobites (similar to modern day horseshoe crabs).
- The shale/siltstone layer contains *Triceratops* dinosaur fossils.

9) Using your completed diagram on the first page of this hand-out, what is the possible age range for the rock unit that contains the acritarch and bacteria fossils?

10) Using your completed diagram on the first page of this hand-out, what is the possible age range for the rock unit that contains the trilobite fossils?

11) Compared to the fossils discussed in the two previous questions, one may be very precise regarding the age of the *Triceratops* fossils. What is this age and why can one be so precise?