Student Name(s): **Grade:**

Physical Geology 101 Lab #7
Scientific Dating of Rocks, Fossils, and Geologic Events

PRE-LAB SECTION – To be completed prior to Lab Meeting #7

I. Introduction & Purpose:

The purpose of this lab is to learn and apply the concepts of relative and absolute dating to rocks, fossils and geologic events. The history and concepts of stratigraphy, the use of fossils for relative dating, and the techniques of radiometric dating will be discussed. You will learn about the geologic timescale, how to determine relative and absolute time, and the techniques used by geologists to date events in Earth history. You will also get some practice in using the principles and techniques.

II. Knowing and Understanding the Six Principles of Stratigraphy:

A. **List and Define** the six basic laws of physical stratigraphy (see page 152 in your lab manual):

Stratigraphic Law Definition

1) ______________________ ____

2) ______________________ ____

3) ______________________ ____

4) ______________________ ____

5) ______________________ ____

6) ______________________ ____

B. **Unconformities** represent gaps in the time-rock record where non-deposition and/or erosion were occurring over a significant period of time in between periods of deposition. They typically appear as obvious irregularity surfaces between two sets or groups of rock units, termed formations. Note that an unconformity can also record other geologic events such as tilting, folding, faulting, intrusion, and uplift. Therefore, unconformities provide important rock-dating information.

List and define the three kinds of stratigraphic unconformities (examine Figure. 8.1, page 153):

Type of Unconformity Definition

1) ______________________ ____

2) ______________________ ____

3) ______________________ ____

III. Knowing and Understanding the Principle of Fossil Succession:

A. **Define** this very important stratigraphic rock-dating principle (from lecture and lab text):

Answer. ____

____

B. **Biostratigraphy** is based on the identity of **time-constrained** rock units called **range zones**, which contain unique **index fossils. Question:** What makes index fossils useful for dating rocks?

Answer. ____

____

IV. Principles of Radiometric Absolute Dating

A. How do we determine the age of a rock?

1. Relative Dating - "A is older than B" → Use the Principles of Stratigraphy

2. Absolute Dating - Quantify the date in years → Use the Principles of Radiometric Dating

B. Principles of Radiometric Dating

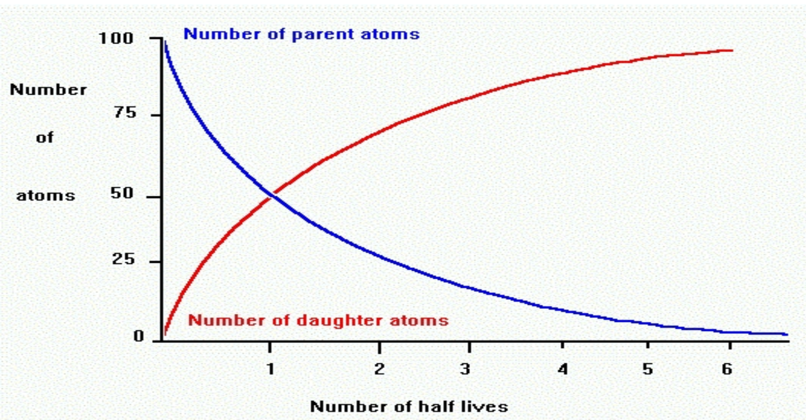
Naturally-occurring radioactive materials break down into other materials at known rates. This is known as **radioactive decay**. Radioactive parent elements decay to stable daughter elements. Henri Becquerel discovered radioactivity in 1896. In 1905, Rutherford and Boltwood used the principle of radioactive decay to measure the age of rocks and minerals (using Uranium decaying to produce Helium. In 1907, Boltwood dated a sample of urnanite based on uranium/lead ratios. Amazingly, this was all done before *isotopes* were known, and before the decay rates were known accurately. The invention of the MASS SPECTROMETER after World War I (post-1918) led to the discovery of more than 200 isotopes. Many radioactive elements can be used as geologic clocks. Each radioactive element decays at its own nearly constant rate. Once this rate is known, geologists can estimate the length of time over which decay has been occurring by *measuring the amount of radioactive parent element and the amount of stable daughter elements*.

Examples: Radioactive parent isotopes and their stable daughter products

Radioactive Parent	Stable Daughter
Potassium 40	Argon 40
Rubidium 87	Strontium 87
Thorium 232	Lead 208
Uranium 235	Lead 207
Uranium 238	Lead 206
Carbon 14	Nitrogen 14

In the above table, note that the number is the **mass number** (the total number of protons plus neutrons). Note that the mass number may vary for an element, because of a differing number of neutrons. Elements with various numbers of neutrons are called **isotopes** of that element. Each radioactive isotope has its own unique **half-life**. A half-life is the **time it takes for half of the parent radioactive element to decay** to a daughter product.

Radioactive decay occurs at a constant exponential or geometric rate. The **rate of decay** is proportional to the **number of parent atoms** present.



The proportion of parent to daughter tells us the number of half-lives, which we can use to find the age in years. For example, if there are equal amounts of parent and daughter, then one half-life has passed. If there is three times as much daughter as parent, then two half-lives have passed. (see graph, above) Radioactive decay occurs by releasing particles and energy. Uranium decays producing subatomic particles, energy, and lead.

C. Minerals That You Can Date Isotopically to Get Rock Age

Many of the common rock-forming minerals contain radioactive isotope parent-daughter pairs, which can used for absolute dating. Igneous rocks are, by far, the superior rock for isotopic dating because the vast majority of minerals in an igneous rock are formed at the time the magma cooled, hence the isotopic age closely matches the rock-forming age. The following minerals are some of the most useful for the three most common types of isotopic-pair radiometric dating systems:

Potassium 40 (parent) – **Argon 40** (daughter) are found in:

- ✓ Potassium feldspar (orthoclase)
- ✓ Muscovite
- ✓ Amphibole
- ✓ Glauconite (greensand; found in some sedimentary rocks; rare)

Rubidium 87 (parent) – **Strontium 87** (daughter) are found in:

- ✓ Feldspar (orthoclase)
- ✓ Muscovite
- ✓ Hornblende
- ✓ Biotite

Uranium 235 and 238 (parents) – **Lead 207 and 206** (daughters, respectively) are found in:

- ✓ Zircon
- ✓ Urananite
- ✓ Monazite
- ✓ Apatite
- ✓ Sphene

Question 1) Discuss in a few sentences whether or not you think that radioactive isotopes would tell the age of sedimentary rocks (the actual age of the depositional event leading to rock formation). **Hint:** When were the minerals that make up a sedimentary rock (for example, the minerals that make up the sand in sandstone) created? Same time as when the sediments deposited?

____

____

____

____

Question 2) Discuss in a few sentences whether or not you think that radioactive isotopes would tell the age of metamorphic rocks (the actual age of the metamorphism event). **Hint:** When the minerals that make up the parent rock recrystallize or neocrystallize into minerals that become the metamorphic rock (for example, the minerals in a shale that change to become a schist), does the isotopic "clock" in those minerals get completely reset from their original pre-metamorphic rock age to its new metamorphic age (time of metamorphism)? Parent mineral age or metamorphic mineral age?

____

____

____

____

GEO-DATING LAB – THE IN-LAB SECTION

I. Determining Relative Ages of Rocks and Geologic Events Based on Stratigraphic Order
Directions: Complete the analysis and evaluation of the geologic cross sections **in Figures 8.9 and 8.10,** and the geologic cross sections in **Figures 8.11 and 8.12** (included in the handout). For each geologic cross section, do the following:

1. Determine the relative ages for the rock bodies and other geologic features/events, including tilting, uplift, faulting, and erosional unconformities.

2. List the sequence of geologic events (each one is labeled with a letter) in chronologic order by writing down the letters from oldest (bottom of list) to youngest (top of list) in the column of blanks. For each dated event you must also indicate which stratigraphic law was used to place the event in its proper time slot. Use the following initials for the stratigraphic laws: **SP** = superposition, **IN** = inclusions; **CC** = cross-cutting, **UN** = unconformity.

3. Determine and name (**by type)** all the lettered unconformities found in each cross-section.

Fig. 8.9 (Geologic cross section#1)

Age Sequence	Stratigraphic Law
(Youngest) ______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
(Oldest) ______	______

Fig. 8.10 (Grand Canyon cross section)

Age Sequence	Stratigraphic Law
(Youngest) ____	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
(Oldest) ______	______

Type of Unconformities – Fig 8.9

R ______________________________

S ______________________________

O ______________________________

P______________________________

Type of Unconformity – Fig 8.10

R _________________________________

S _________________________________

.**Figure 8.11** (Geologic cross section#3)

Age Sequence	**Stratigraphic Law**
(Youngest) ______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
(Oldest) ______	______

Fig. 8.12 (Geologic cross section#4)

Age Sequence	**Stratigraphic Law**
(Youngest) ______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
(Oldest) ______	______

Types of Unconformities in Fig 8.11

-

N ________________________

O ________________________

C ________________________

Types of Unconformities in Fig. 8.12

1 ____________________

2 ____________________

3 ____________________

4 ____________________

5 ____________________

II. Using Fossils to Determine Age Relationships

Directions: Refer to Figures **8.14** and **8.15**. Use the chart in Figure **8.13** and the geologic time scale to help you determine the ***relative age*** and the ***absolute age*** of the sample in each figure. ***Note***: If, **for example**, you identified your fossils as *dinosaurs* (relative age Early Triassic through Cretaceous Periods, absolute age ca. 240–66 Ma) and *mammals* (Jurassic through Quaternary Periods, absolute age ca 208–66 Ma) **from Fig. 8.13**, the concurrent or ***Overlapping Age Range,*** or **Resolved Age,** of the two groups of organisms is Jurassic through Cretaceous, which equates to a numeric age range of 208 Ma to 66 Ma. Therefore, the ***resolved age*** of rock is the age range in which **both** fossil species were simultaneously alive.

Question 4. Page 158 —Figure 8.14: Fossiliferous Rock Sample for Age Analysis

Index Fossils Present **Age Range: (in million years ago = mya)**

1. ______________________________ _________ mya to ________ mya

2. ______________________________ _________ mya to ________ mya

***Resolved* age of sample: _________ mya to ________ mya**

Question 5. Page 135—Figure 8.15: Fossiliferous Rock Sample for Age Analysis

Index Fossils Present **Age Range: (in million years ago = mya)**

1. ______________________________ _________ mya to ________ mya

2. ______________________________ _________ mya to ________ mya

***Resolved* age of sample: _________ mya to ________ mya**

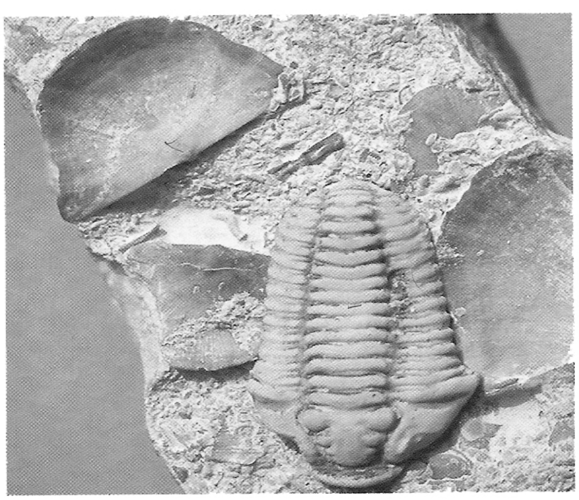


FIGURE 8.14 Fossiliferous rock sample for age analysis.

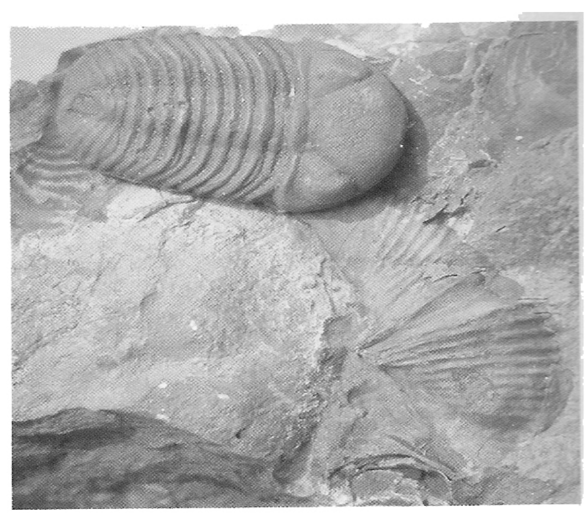


FIGURE 8.15 Fossiliferous rock sample for age analysis.

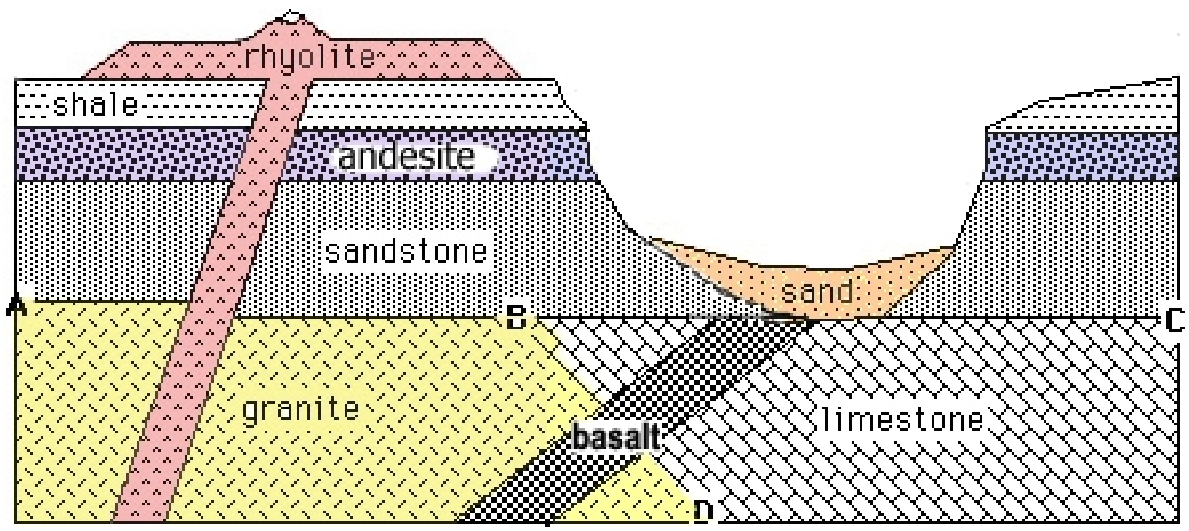
Question: Which stratigraphic principle is fundamental to the logic of using fossils for dating?

Answer: ____

III. Determining "Absolute" Dates of Rocks by Radiometric Dating

Directions: Below is geologic cross section consisting of sedimentary and igneous rock layers. There is a rhyolite lava surface flow, an andesite lava flow, a basalt dike, and a granite intrusion. The solidified rhyolite lava flow and granite intrusion both have zircon mineral crystals, which contain Uranium-235. The andesite lava flow and basalt dike both have abundant amphibole, which contain Potassium-40.

A mass-spectrometer analysis was used to count the isotopic ratios of the uranium-235 (U-235) and lead-207 (Pb-207) from the zircons of both the rhyolite and the granite, and it was used to count the isotopic ratios of potassium-40 (K-40) and argon-40 (Ar-40) in both the andesite and basalt.



Part A – Radiometric Analysis of Igneous Rock Units

Directions: *Use the below information to answer questions 1 through 8.*

Rhyolite Lava Flow: Zircon crystals in yielded the following isotopic analyses:

✓ ***98.9%** of the atoms were **Uranium-235** and **1.1%** of the atoms were **Lead-207**.*

Question 1. About how many **half lives** ($t_{½}$) have elapsed since the zircon crystals formed in the ***rhyolitic lava flow***? (time since it became a closed system?) **Number of Half-lives** = ______

Question 2: What is the "absolute" (numeric) age of the zircon crystals and the lava flow? You must show your calculations below for full credit!

Calculation: **Rhyolite Lava Flow Age = _______ mya**

Andesite Lava Flow: Amphibole crystals yielded the following isotopic analyses:

✓ **97.9%** of the atoms were **Potassium-40** and **2.1%** *of the atoms* were **Argon-40**.

Question 1. About how many **half lives** ($t_{½}$) have elapsed since the hornblende crystals formed in the ***andesite lava flow*?** (time since it became a closed system?) **Number of Half-lives** = _____

Question 2. What is the "absolute" (numeric) age of the amphibole crystals and the *andesite flow*? You must show your calculations below for full credit!

Calculation: **Diabase Lava Flow Age = _______ mya**

Basalt Dike: Amphibole crystals yielded the following isotopic analyses:

- ✓ **84.1%** of the atoms were **Potassium-40** and 15.9% *of the atoms* were **Argon-40**.

Question 1. About how many **half lives** ($t_{½}$) have elapsed since the hornblende crystals formed in the ***basalt dike***? (time since it became a closed system?) **Number of Half-lives** = _______

Question 2. What is the "absolute" (numeric) age of the amphibole crystals and the *basalt dike*? You must show your calculations below for full credit!

Calculation: **Basalt Dike Age = _________ mya**

Granite Intrusion: Zircons crystals yielded the following isotopic analyses:

- ✓ ***50%** of the atoms were **Uranium-235** and **50%** of the atoms were **Lead-207***.

Question 1. About how many **half lives** ($t_{½}$) have elapsed since the zircon crystals formed in the ***granite intrusion***? (time since it became a closed system?) **Number of Half-lives** = _______

Question 2: What is the "absolute" (numeric) age of the zircon crystals and the *granite intrusion*? You must show your calculations below for full credit!

Calculation: **Granite Intrusion Age = _______ mya**

Part B – Stratigraphic Sequence Dating Using Igneous Rock Absolute Ages

Directions: *Use the absolute age information above to answer questions 1 through 6 below.*

Question 1. Tightest ***constrained age*** range of **nonconformity B-D**? _____ **mya to** _____ **mya**

Question 2. Tightest **constrained age** range of **limestone unit**? ______ **mya to** ______ **mya**

Question 3. Tightest ***constrained age*** range of **nonconformity A-C**? ____ **mya to** ____ **mya**

Question 4. Tightest **constrained age** range of **shale unit**? ______ **mya to** ______ **mya**

Question 5. Using the principles of relative dating to arrange the geologic units the above cross section, what is the proper age sequence? Include unconformities B-D and A-C in your list.

Youngest _________________

____

____

____

____

____

____

____

____

Oldest _________________

Question 6. Do the absolute ages agree with the relative ages of all the units, based on the stratigraphic principles? Yes or No? _____. If not, what is the best explanation for the discrepancy?

GEO-DATING LABORATORY REFLECTION

Directions: Write a 120 word minimum reflection of the lab activity, explaining its purpose, the methods used, the results obtained, and a brief personal reflection of what you enjoyed and learned about doing this lab (*3 points possible*). Answer the following 3-point question reflection set on a separate sheet of paper:

1) *What was the purpose of this lab? What did you actually discover and learn during this lab?*

2) *What did you enjoy most about this lab? Also, what was challenging or thought-provoking?*

3) *What are your constructive comments about the design and execution of this lab? What's good? What's bad? Offer suggestions for making the lab better.*

Response: