Student Name: **Grade:**

Physical Geology 101 Laboratory
Scientific Dating of Rocks Using Absolute Dating and Fossils

I. Introduction & Purpose:

The purpose of this lab is to learn and apply the concepts of absolute dating and fossils 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. Types of Fossils and Their Uses for Determining Rock Age and Environment

Fossils are the remains or traces of ancient life preserved in rock - specifically in sedimentary rocks. Life on earth spans over three billion years, with first 2 1/2 billion years taking place exclusively in the ocean in microbial form. During this mind-numbing amount of time, life has evolved into a myriad number of various species - each time span holding a unique set of organisms. Most of the present day, multicellular phylum on earth got their start around 600 million years ago, and only

A. Knowing and Understanding Fossils and Their Usefulness in Geology

1. **What is a fossil?** Answer. ____

2. **Name the five types of fossils?** 1) __________________ ; 2) ___________________

   3) ____________________ 4) ____________________ & 5) ______________________

3. Classifying Reference Samples According to Fossil Type.
Directions: Classify all 45 fossil samples in the box collection according to their fossil type as listed above. Use microscope for the smaller samples. List the sample numbers in the correct category.

Mold and Cast Fossil Samples #'s ____

Permineralized/Petrified Fossil Sample #'s _______________________________________

Carbonized Fossil Samples #'s ____

Original Form Fossil Sample #'s ____

Trace Fossil Samples #'s ____

Biostratigraphy is based on the Principle of Fossil Succession and the identity of time-constrained rock units called range zones, which contain a unique assemblage of fossilized plant and animal species useful for dating.

3. **Define** the **Principle of Fossil Succession** (from lecture and lab text):

   Answer. ____

____

4. **Fossils used for dating rocks are called ________________ fossils.**

5. **What are the important attributes that makes for a good index fossil?**

1) _______________, 2) ______________, 3) _______________, and 4) _______________

4. Classifying Reference Samples According to Fossil Age.

Directions: Classify all 45 fossil samples in the box collection according to their age as listed in the underside of reference box lid. List the sample numbers in the correct category.

Cenozoic Samples #'s ____

Mesozoic Sample #'s ____

Paleozoic Samples #'s ____

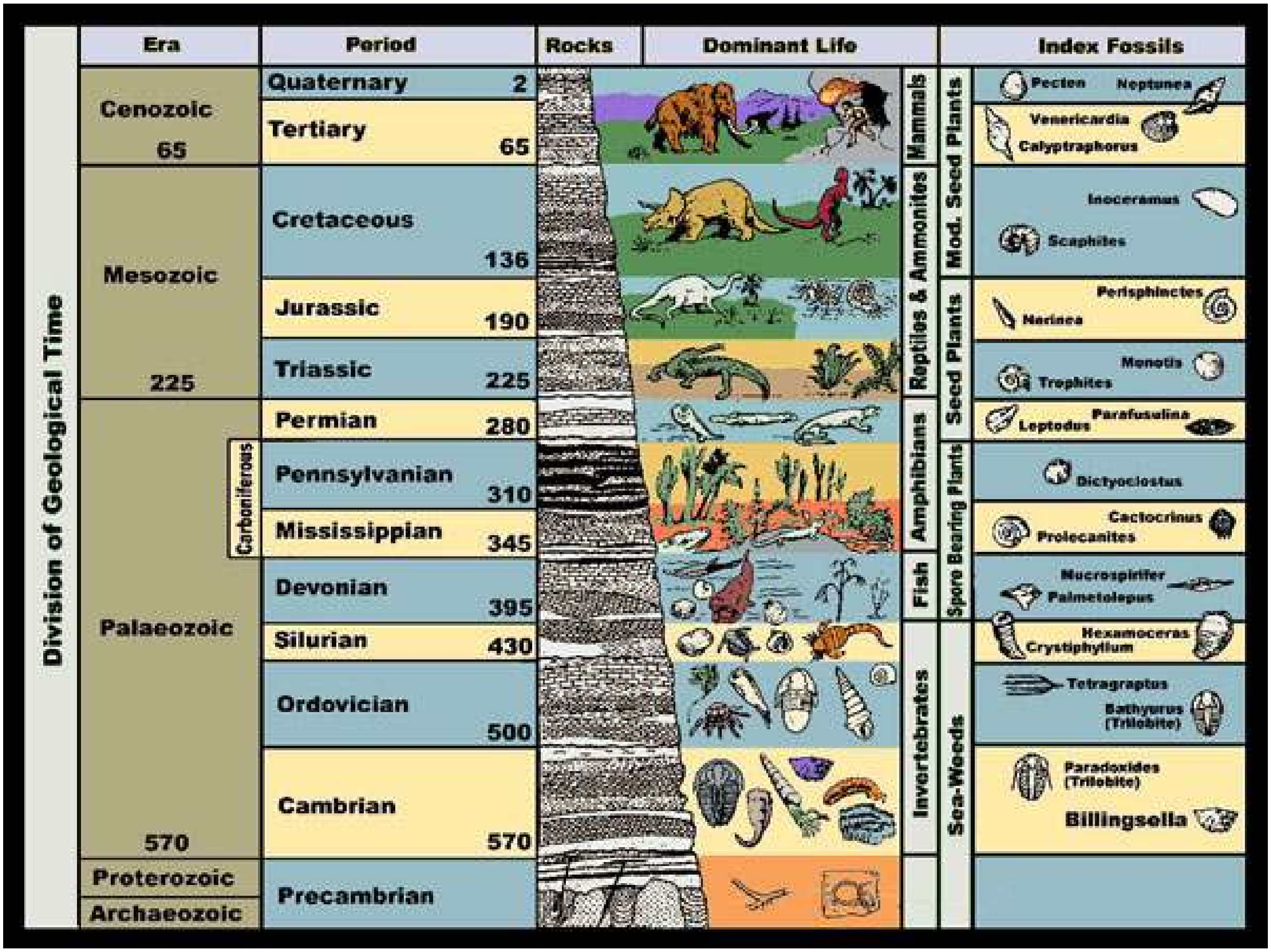
B. The Principle of Fossil Succession and the Geologic Timescale:

The **Geologic Timescale** was developed on the basis of the **Principle of Fossil Succession** and is divided into time eras and periods as defined by unique assemblages of index fossils. The Eras and Periods are separated by major extinction events. **Directions:** 1) Fill in all the spaces with the appropriate timescale names found in the supplied word list. 2) Write down the appropriate ages at the appropriate place for the following: a) Beginning of Earth time, b) Beginning of the Paleozoic Era, c) Beginning of the Mesozoic Era, and d) Beginning of the Cenozoic Era.

2. *Include the following names of Eons, Eras, Periods and Epochs:*
Cambrian, Cenozoic, Cretaceous, Devonian, Eocene, Holocene/Recent, Jurassic, Mesozoic, Miocene, Mississippian, Oligocene, Ordovician, Paleocene, Paleozoic, Pennsylvanian, Permian, Phanerozoic, Pleistocene, Pliocene, Precambrian, Silurian, Triassic

EON	ERA: Place age at the beginning	PERIOD	EPOCH	AGE
		Quaternary		
		Tertiary		

______________________________ ← place term on the line



III. Using Index Fossils to Establish Rock Age

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**

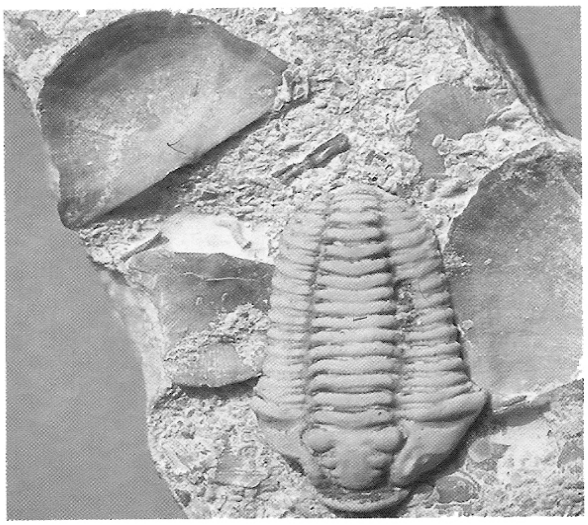


FIGURE 8.14 Fossiliferous rock sample for age analysis.

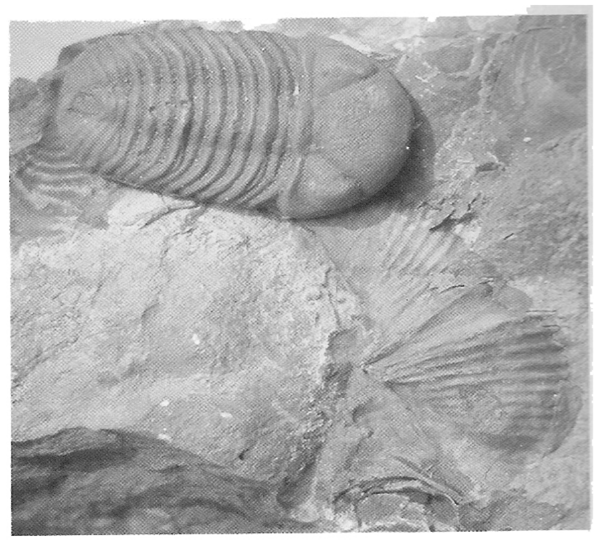


FIGURE 8.15 Fossiliferous rock sample for age analysis.

Question: Which other stratigraphic principle is fundamental to the logic of using fossils (principle of Fossil Succession) for dating?

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 Principles and Techniques of Radiometric Dating

B. Principles of Radiometric Dating

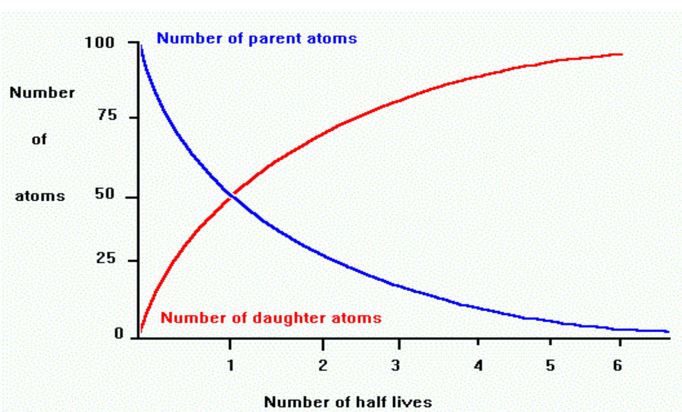
Naturally-occurring radioactive materials break down into other materials at known rates. This is known as **radioactive decay**. Radioactive parent elements decay to stable daughter elements. Henri Becquerel discovered radioactivity in 1896. In 1905, Rutherford and Boltwood used the principle of radioactive 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*.

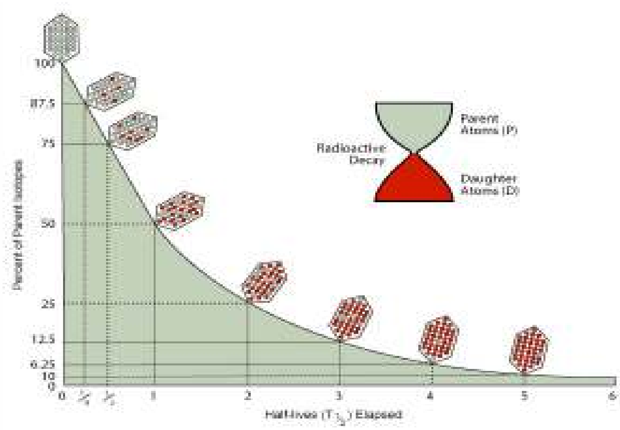
Examples: Radioactive parent isotopes and their stable daughter products

Radioactive Parent	Stable Daughter	Half-life Constant	Suitable Minerals
Potassium 40	Argon 40	1.3 billion years	K-spar, hornblende, biotite, muscovite
Rubidium 87	Strontium 87	47 billion	Feldspars, hornblende, biotite, muscovite
Thorium 232	Lead 208	14 billion years	Zircon, monazite, titanite, apatite
Uranium 235	Lead 207	713 million years	Zircon, monazite,. sphene, apatite
Uranium 238	Lead 206	4.5 billion years	Zircon, monazite,. sphene, apatite
Carbon 14	Nitrogen 14	5730 years	Organics

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 the two illustrations below) 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

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

D. Discuss in a few sentences why the above parent-daughter radio-isotopic abundances in the minerals that form a granite rock can be used to correctly establish the formation age of the granite rock (also true for most other igneous rocks). Also discuss why the isotopic abundances in the minerals making up most sedimentary rocks (like a silici-clastic sandstone) cannot be used to establish the formation age of the sedimentary rock - like sandstone, or other detrital/clastic sedimentary rocks. **Hint:** Is the age of the minerals that make up igneous and sedimentary rocks the same age as the formation age of the rock itself? For example, are the minerals that make up the sand in a sandstone the same age as when the sand cemented together to form the sandstone?

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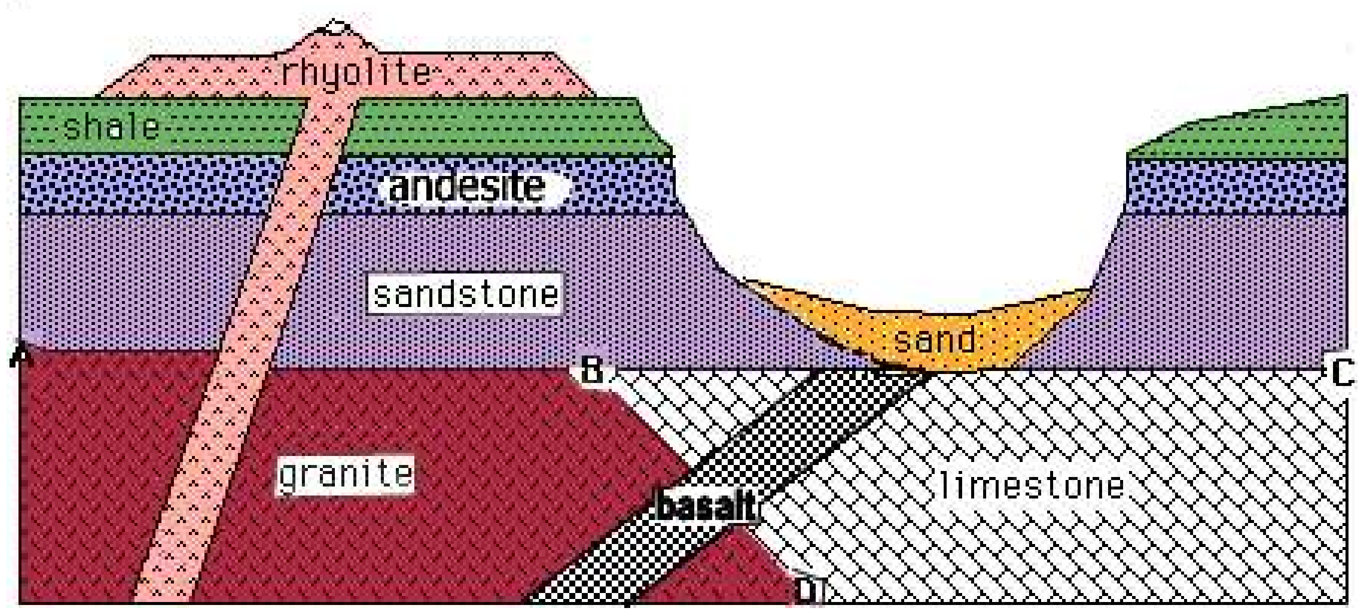
V. Determining "Absolute" Dates of Rocks by Radiometric Dating

Introduction: 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.



Directions: 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.

Absolute Age

Youngest ________________

________________ ______________myo

____

________________ ______________myo

____

____

________________ ______________myo

____

____

Oldest ________________ ______________myo

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

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** ($t_{1/2}$) 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** ($t_{1/2}$) 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**

Stratigraphic Sequence Dating Using Igneous Rock Absolute Ages

Directions: *Use the absolute age information above to answer questions 1 through 5 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. 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?

Question 6. The shale unit contains abundant plant imprints of the tree species **Fagopsis**.

What is the time range of this index fossil? _________ myo to _________myo

Question 7. Does the age range of the plant imprints of the tree species **Fagopsis** in the shale unit do a better job of dating the shale unit than the igneous rocks found above and below the shale?

Yes or No? ________ Explain your answer: ____

____

Question 8. The limestone unit contains abundant shell fossils of the species **Platystrophia**.

What is the time range of this index fossil? _________ myo to _________myo

Question 9. Does the age range of the **Platystrophia** index fossil in the shale unit do a better job of dating the shale unit than the igneous rocks found above and below the limestone? Yes or No?

________ Explain your answer: ____

____

VII. GEO-DATING USING FOSSILS AND RADIO-ISOTOPES AND LABORATORY REFLECTION

Directions: Write a 3-paragraph 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?*

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____

____

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

____

____

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____

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.*

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