Student Name: ______________________________ **Grade:** ____

Physical Geology 101 Laboratory
Relative and Absolute Dating of Rocks and Geologic Events

Introduction: Geologists have multiple means of unraveling Earth's history by using a number of geologic dating methods. Geologic dating methods can be classified into two general types: absolute and relative. Geologists use relative dating methods to order a stratigraphic sequence of rocks into its proper temporal order of formation – from the first rock-forming event to the last one – mainly by applying a set of stratigraphic principles. Geologists can also determine an absolute numeric age for a rock-forming event by using radio-isotopic techniques that analyze the chemistry of mineral and rock for radioactive parent-daughter isotopes ratios as a sort of internal geological stopwatch.

This lab is designed to introduce the student to these dating methods and to will get practice in using the stratigraphic principles and the radio-isotopic dating technique to date rock bodies and rock structures in both a relative timeframe, and absolutely.

Purpose: The purpose of this lab is to explore and learn about the concepts of absolute and relative geologic dating. The student will learn the principles of stratigraphy and the radio-isotopic dating technique, and apply that knowledge toward the relative and absolute dating of rocks, fossils and geologic events.

Lab Activity Overview: This lab has four parts:

Part I - Explore the stratigraphic principles and their use in relative dating of vertical sequences of rocks and crustal structures, fossil succession. Learn how each principle has its advantages and limitations in dating rocks and geologic events.

Part II - Apply your newly learned relative rock dating skills to date stratigraphic cross-sections.

Part III – Explore the world of index fossils and how to use fossil assemblages to date rocks.

Part IV - Apply newly learned radio-isotopic rock-dating skills to absolute date stratigraphic cross sections.

Part I. Knowing and Understanding the Six Principles of Stratigraphy:

A. **Give a brief definition for** the seven basic laws of stratigraphy (page 152 in your lab manual):

Stratigraphic Law — Definition

1) **Superposition** ____

____

2) **Cross-Cutting** ____

____

3) **Inclusion** ____

____

4) **Lateral Continuity** ____

____

5) **Original Horizontality** ____

____

6) **Fossil Succession** ____

____

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) ________________________	____

Questions:

1) How would you tell the difference between a *disconformity* and an *angular unconformity*?

2) How would you tell the difference between a *nonconformity* with either a *disconformity* or *angular unconformity?*

Part II. Determining Relative Ages of Rocks and Geologic Events Using Strat Principles

There two basic strategies for determining the age of a rock or geologic event: Figuring out the relative age or temporal order or determine the rock's absolute or numeric age. Relative age dating is primarily done using stratigraphic principles. Absolute dating is primarily done by using radio-isotopic techniques. Relative dating can be done by anyone with a grasp of the principles, and is cost-free. Absolute dating is done by geochronologists who use very expensive equipment that requires much painstaking time and effort.

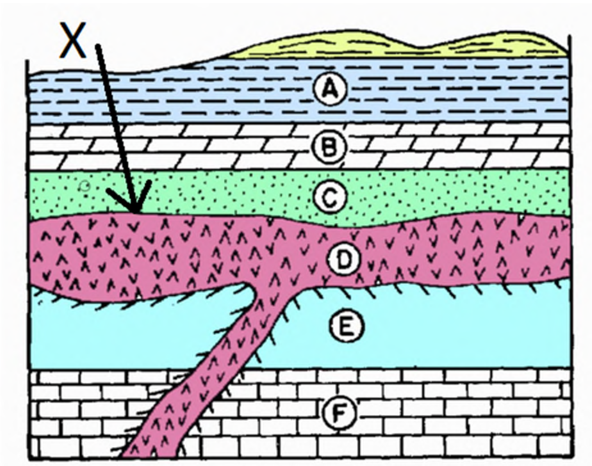
1. **Relative Dating** = Temporal order = "A is older than B" → Use the Principles of Stratigraphy
2. **Absolute Dating** = Numeric dates → Use Principles and Techniques of Radiometric Dating

NOTE: Part II of this lab will cover the basics of relative dating, with focus on the stratigraphic principles.

Directions: Complete the analysis and evaluation of the six geologic cross below. 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.

NOTE: The first two geologic cross-sections ("I" and "II") below will be solved together in lab in order to practice using the principles to solve geologic cross sections, and to show you how the spreadsheet should look correctly completed.



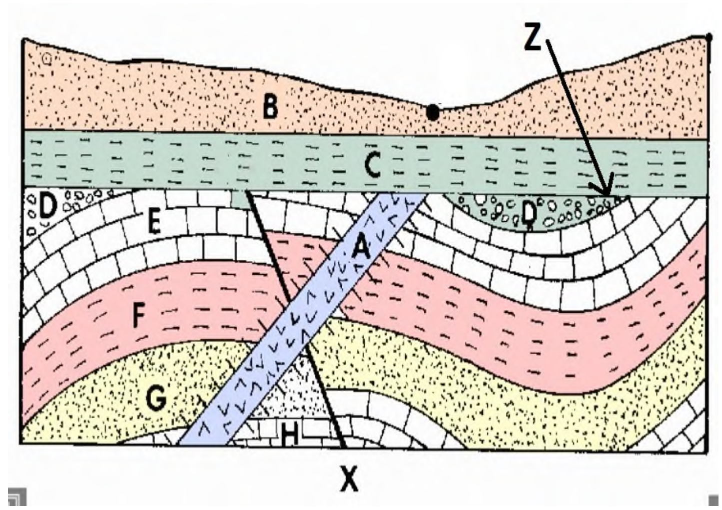
Geologic Cross Section "I"

Unit "D" is an intrusion; "X" is an unconformity;
All others are sedimentary layers

Age Sequence	Stratigraphic Law
(Youngest) ___ (sed layer)	_ _
_ _ (sed layer)	_ _
_ _ (sed layer)	_ _
_ _ (unconformity)	_ _
_ _ (intrusion/lava flow)	_ _
_ _ (sed layer)	_ _
(Oldest) _ _ (sed layer)	_ _

Question: "X" is which type of unconformity?

Answer: ___________________________



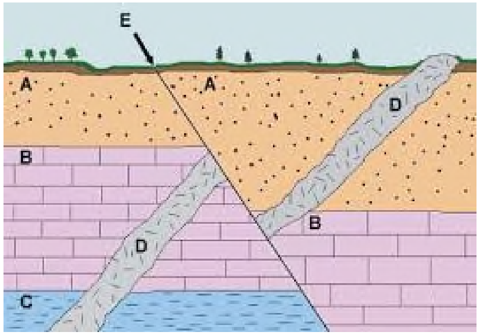
Geologic Cross Section "II"

Unit "A" is an intrusion; "X" is a fault; "Z" is an unconformity;
All others are sedimentary layers

Age Sequence	Stratigraphic Law
(Youngest) _ _ (sed layer)	_ _
_ _ (sed layer)	_ _
_ _ (unconformity)	_ _
_ _ (intrusion)	_ _
_ _ (fault)	_ _ (first post-folding)
_ _ (sed layer)	_ _ (last pre-folding)
_ _ (sed layer)	_ _
_ _ (sed layer)	_ _
_ _ (sed layer)	_ _
(Oldest) _ _ (sed layer)	_ _

Question: "Z" is which type of unconformity?

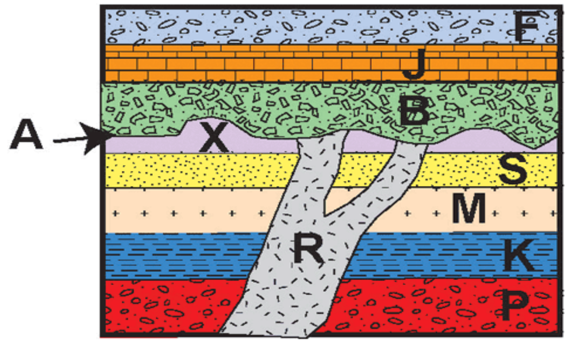
Answer: _________________________________



Geologic Cross Section "III"

Unit "D" is an intrusion; "E" is a fault;

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



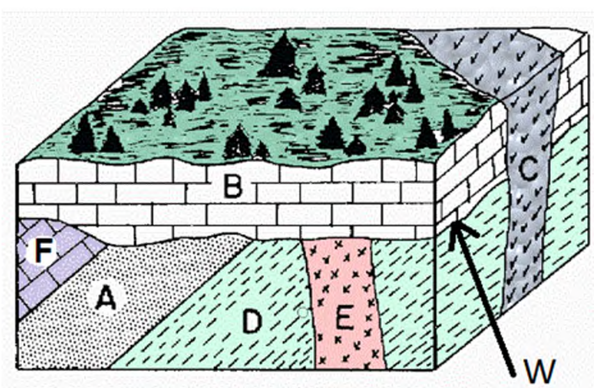
Geologic Cross Section "IV"

Unit "R" is an intrusion; "A" is an unconformity;

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

Question: "A" is which type of unconformity?

Answer: ______________________________



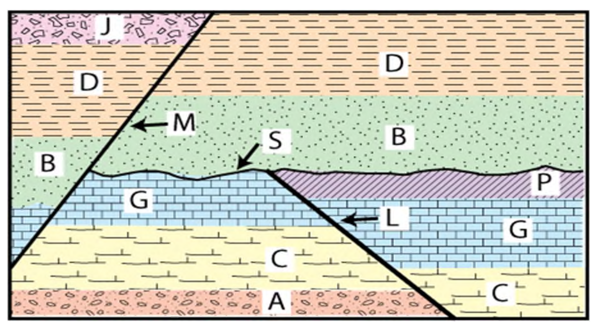
Geologic Cross Section "E"

Units "C" and "E" are intrusions; "W" is an unconformity;

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

Question: "W" is which type of unconformity?

Answer: ______________________________

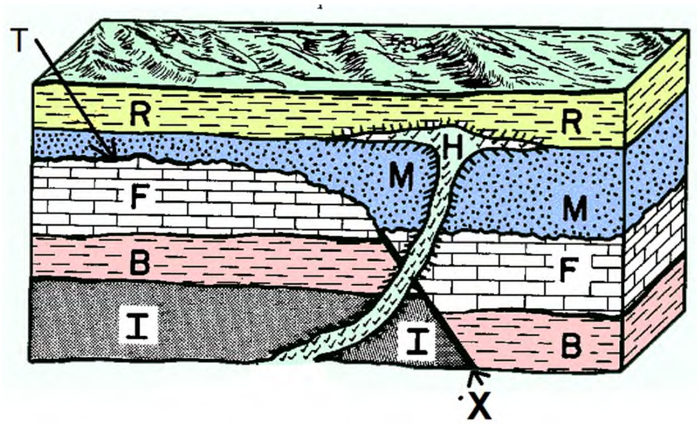


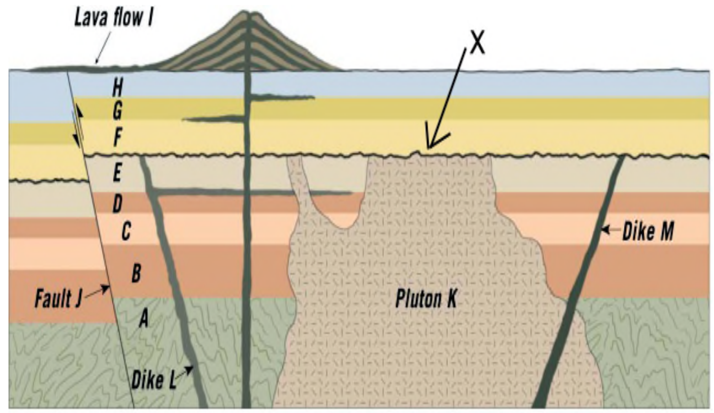
Geologic Cross Section "F"

"L" and M" are faults; "S" is an unconformity;

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

Question: "S" is which type of unconformity? Answer: ______________________________





Geologic Cross Section "VII"

"H" is an intrusion; "X" is a fault; "T" is an unconformity

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

Question: "T" is which type of unconformity?

Answer: ______________________________

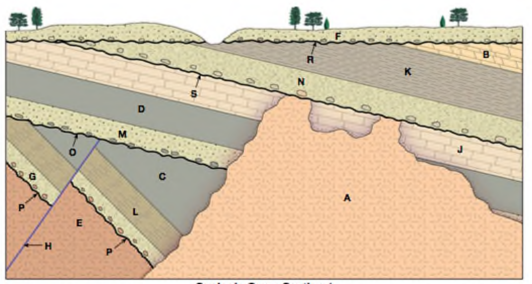
Geologic Cross Section "VIII"

Units "K", "L", and "M" are intrusions; "J" is a fault;
"X" is an unconformity

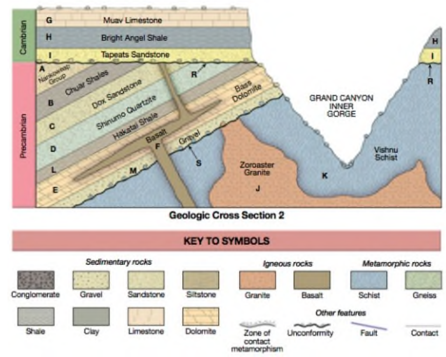
Age Sequence	Stratigraphic Law
(Youngest) _____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
(Oldest) _____	_____

Question: "X" is which type of unconformity?

Answer: ______________________________



Geologic Cross Section 1



Geologic Cross-Section #1

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

Grand Canyon Cross-Section #2

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

Type of Unconformities - X-Section #1

R ______________________________

S ______________________________

O ______________________________

P ______________________________

Type of Unconformities - X-section #2

R _________________________________

S _________________________________

Questions:

1) Which stratigraphic principle did you primarily use for dating the sedimentary layers?

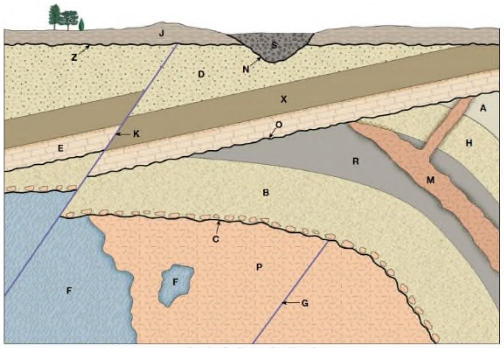
Answer: _________________________________

2) Which stratigraphic principle did you primarily use for dating intrusions and faults?

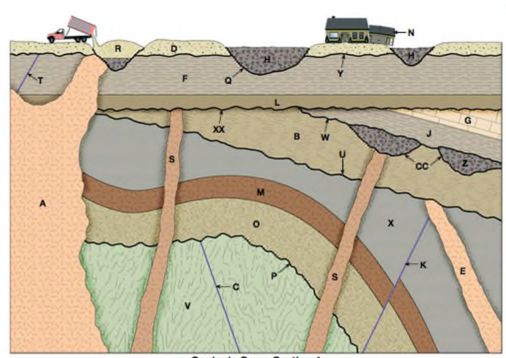
Answer: _________________________________

3) Which other stratigraphic principle did you use for dating rocks directly above and below an unconformity?

Answer: _________________________________



Geologic Cross Section 3



Geologic Cross Section 4

Geologic Cross Section #3

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

Types of Unconformities in X-Section #3

Z ______________________________

O ______________________________

C ______________________________

-

Geologic Cross Section #4

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

Types of Unconformities in X-Section #4

Y ______________________________

XX ______________________________

W ______________________________

U ______________________________

P ______________________________

Part III. Index Fossils and Their Usefulness in Geologic Dating

A. 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.

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

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

Answer. ____

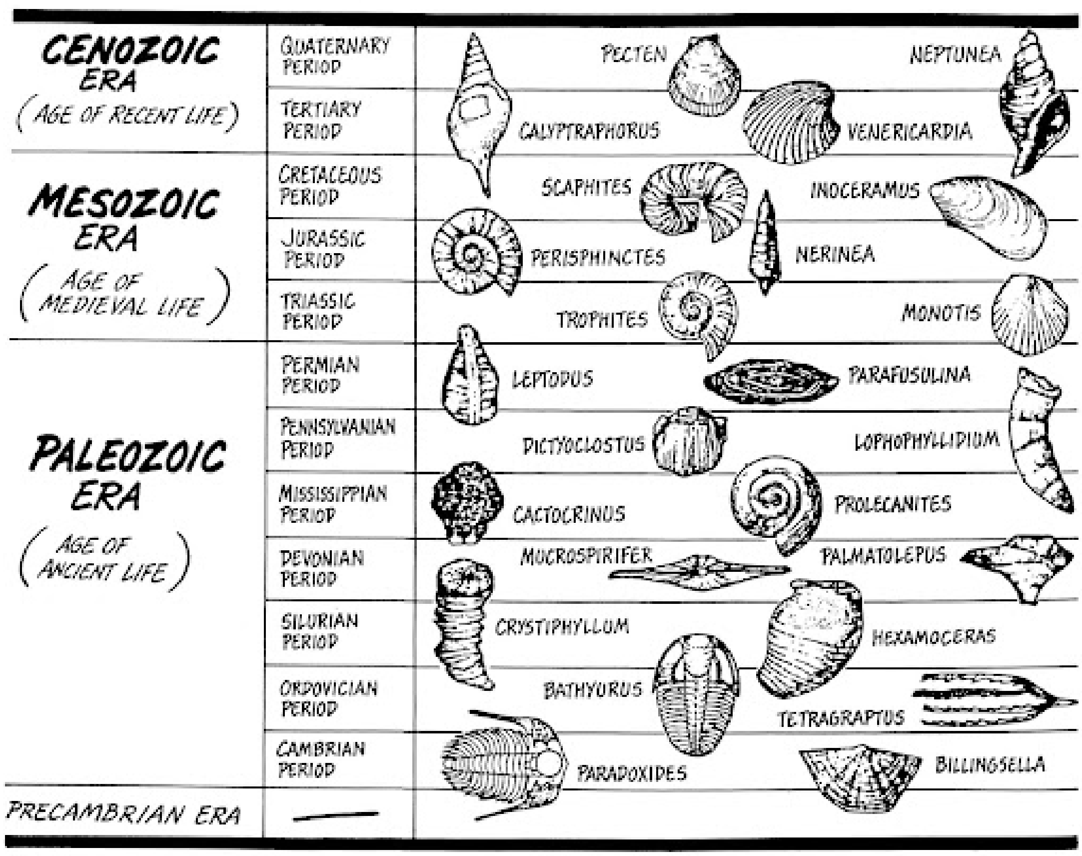
3) **What are *INDEX* fossils used for?** ____

4) **What are the important attributes that makes for a good index fossil?**

1. _______________, 2. _______________, 3. _______________, and 4. _______________

B. Index Fossils of Each Different Era

5) **Directions**: Use the Geologic Timescale diagram below to find and list the names of some of the most common, useful groups of index fossils for each of the three eras.



Cenozoic Examples: *1.* ________________________ *2.* ________________________________

Mesozoic Examples: *1.* __________________________*2.* ______________________________

Paleozoic Examples: *1.* __________________*2.* ___________________*3.* ___________________

C. Dating Rocks Having Multiple Index Fossils – Determining "Resolved Fossil 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 overlap age range in which **both** fossil species were simultaneously alive.

6) 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**

***Overlap* age of sample = _________ mya to ________ mya**

7) 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**

***Overlap* age of sample = _________ mya to ________ mya**

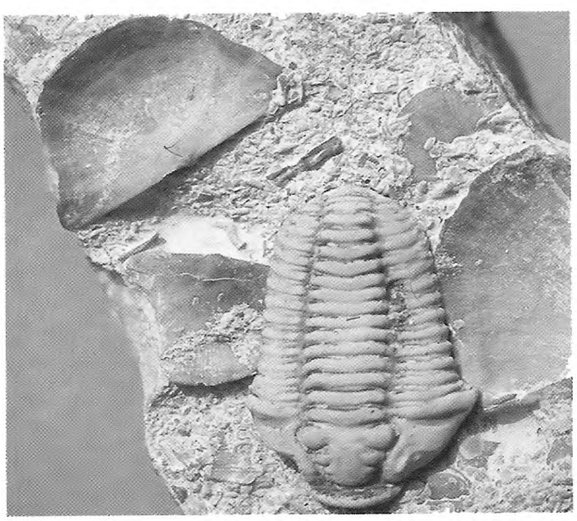


FIGURE 8.14 Fossiliferous rock sample for age analysis.

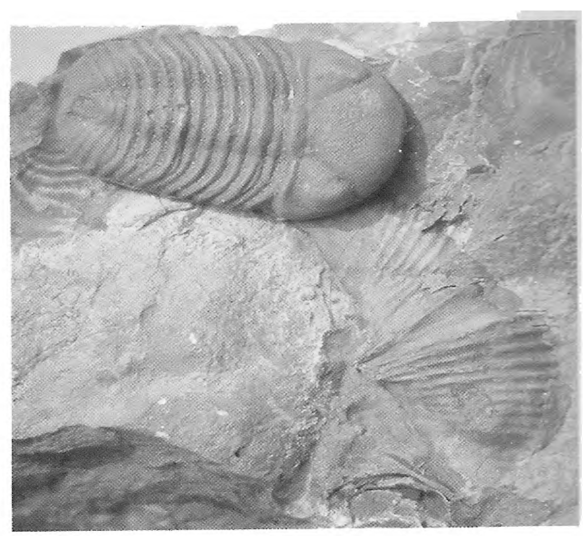


FIGURE 8.15 Fossiliferous rock sample for age analysis.

Question 8) Which other stratigraphic principle is fundamental to the logic of using fossils (principle of Fossil Succession) for dating? Hint: it is one of the two most used stratigraphic principles.

Answer: ____

Part VI. Determining "Absolute" Dates of Rocks Using the Radiometric Technique

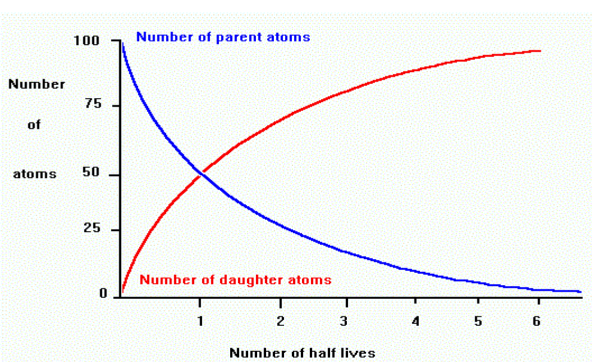
A. Introduction to the Principles of Radiometric Dating: An element with various numbers of neutrons are called ***isotopes*** of that element. Naturally-occurring, unstable radioactive isotopes ultimately break down over time into a stable, "daughter" isotope at an a very constant, precisely-known; this is known as ***radioactive decay***. 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 uraninite 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. Several radioactive-parent/stable-daughter decay pairs are used as geologic clocks. Each radioactive element decays at its own constant rate. Geologists can estimate the length of time over which decay of a specific radioactive parent isotope has been occurring by *measuring the proportional amounts (ratio) of radioactive parent element and stable daughter element*.

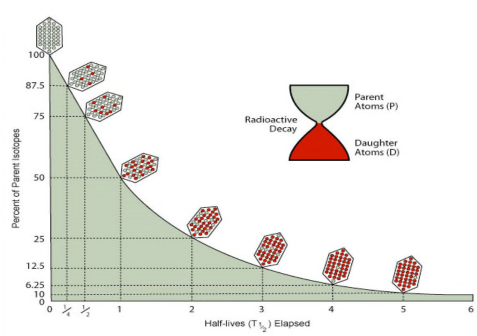
Examples of unstable radioactive parent / stable Daughter pairs and their half-live constants

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 after the isotope name 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. 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)





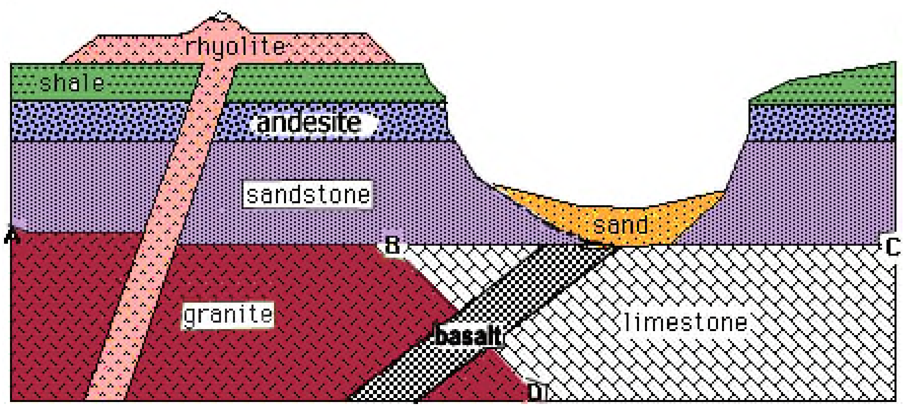
Question 1) How many half-lifes have elapsed if ***HALF*** (1/2) of the original radioactive parent isotope has decayed into its stable daughter isotope? **How about if roughly one quarter (1/4) of the parent decays?**

Answers: 50% parent /50% daughter = _____ half-lifes elapsed

75% parent /25% daughter = _____ half-lifes elapsed

B. Dating Problem Using the Radio-isotopic Technique:

Introduction: Below is geologic cross section consisting of sedimentary and igneous rock layers, and two unconformities. There are four igneous rock units that can be radio-isotopically dated: a rhyolite lava surface flow, an andesite lava flow, a basalt dike, and a granite intrusion. The rhyolite lava flow and granite intrusion both contain *zircon* mineral crystals, which contain Uranium-235. The andesite lava flow and basalt dike both have abundant *amphibole* mineral crystals, which contain Potassium-40. Three sedimentary rock units are sandwiched between the igneous rocks: a limestone, a sandstone, and a shale. Unconformity A-C separates sandstone from the underlying granite and limestone. Unconformity B-D separates limestone from the underlying granite.



Directions: First, use the principles of relative dating to arrange the geologic units in the above cross section into their proper temporal order. Include unconformities B-D and A-C in your list. Second, read below for directions on how to determine the absolute ages for the igneous rock units.

	Relative Age	Determined Absolute Age
Youngest	____________________	
	____________________	________________myo
	____________________	
	____________________	________________myo
	____________________	
	____________________	
	____________________	________________myo
	____________________	
	____________________	
Oldest	____________________	________________myo

Absolute Dating Directions: Calculate the absolute age for each of the four igneous rock units and write the calculated ages in the above age column. Below is the necessary lab data. 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.

The specific parent/daughter system is noted and the measured amounts of both the parent and daughter are listed for each of the four rock units. Use the parent/daughter proportions to determine the number of half-lives for each sample, and then use the age formula (# of half-lives elapsed times the decay constant) to determine the absolute ages. Half-live proportion (%'s) and decay constants are listed in your lab room manual.

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 2) 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 3) 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 4) 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 5) 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 6) 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** = _______

Question7) 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 8) 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 9) 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**

<u>Using the Established Absolute Dates to Place Age Constraints on the Undated Rock Units</u>

Directions: *Use the absolute age information above to answer questions 10 through 14 below.*

Question 10) Tightest ***constrained age*** range of **nonconformity B-D**? _____ **mya to** _____ **mya**

Question 11) Tightest **constrained age** range of **limestone unit**? ______ **mya to** ______ **mya**

Question 12) Tightest ***constrained age*** range of **nonconformity A-C**? ____ **mya to** ____ **mya**

Question 13) Tightest **constrained age** range of **shale unit**? ______ **mya to** ______ **mya**

Question 14) 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 3-point 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.

1) *What was the purpose of this geo-dating 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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