EOSC 110
INTRODUCTION TO GEOSCIENCES
UNIVERSITY OF SAN DIEGO
LABORATORY READER
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GEOLOGIC TIME EXERCISE

Group Members: ____Recorder Initials:______

Learning Objectives

- Explore major events through Earth's history.
- Appreciate the magnitude of geologic time.
- Become familiar with the geologic time scale

Pre-Lab Resources

- An EXCELLENT video on the history of life and the geo-timescale: Will help you progress through this lab with a much better understanding (~12 min.)
    - https://www.youtube.com/watch?v=rWp5ZpJAIAE

ACTIVITY #1 – Becoming familiar with the time scale

Study the geologic timescale and its divisions. Check out how the geologic timescale is divided into different units/segments of time. The four columns - eons, eras, periods, and epochs – are organized according to nested levels of time, going from left to right, with eons the broadest chunks of time, and epochs the smallest. Time runs from **bottom to top – oldest to youngest**, respectively. The eons, eras, periods, and epochs each have a number of uniquely named time segments. For example, the Era column includes the Paleozoic, Mesozoic, and Cenozoic, and the Mesozoic era includes the Triassic, Jurassic, and Cretaceous periods. **The divisions and subdivisions for eons, eras and periods – post-Archean - are primarily defined by the unique assemblages of various types of fossil species** that are found in the rocks of respective age range, and the **boundaries between the time periods are defined by sharp changes in the types of fossils,** most likely a consequence of massive extinction events. Good examples include the beginning of the Proterozoic eon, the beginning of the Cambrian period, the Permian-Triassic period boundary, and the Cretaceous-Tertiary period boundary.

QUESTIONS: Use the summary above and figures on the following pages to help answer questions.

1) List the four **Eons** on the geologic timescale and their numeric age when they started (millions of years = MY or billions of years = BY)

Eon Name	**Start age** *(millions (MY) or billions (BY) of years ago)*
________________________	___________ MY
________________________	___________ BY
________________________	___________ BY
________________________	___________ BY

2) List the three **Eras** on the geologic timescale and their numeric age when they started (millions of years = MY)

Era Name	**Start age** *(millions (MY) of years ago)*
________________________	___________ MY
________________________	___________ MY
________________________	___________ MY

3) Which of the four time units – eons, eras, periods, or epochs, spans the longest amount of geologic time?

____

4) Which of the four time units span the shortest amount of geologic time? ______________________

5) What is the oldest **Eon** in the geologic timescale? ______________________

6) The **Phanerozoic Eon** represents the time span on Earth with abundant, complex life. Roughly **what percentage of Earth's geologic time does the Phanerozoic Eon take up** on the geological timescale?

__________%

Earth age: ___________ Beginning of the Phanerozoic _________

Hint: *Time span of Phanerozoic* ***/*** *Earth Age* x *100* ***show work:***

7) The **Paleozoic Era** represents the "***Age of Complex Life***". It was time of great changes in the evolution of complex, multi-cellular life with the appearance and rapid development of most invertebrate phyla, land plants, fishes, and ultimately amphibians and reptiles. This Era ended with the Earth's greatest extinction event. How many years did this Era last? __________ MY This Era came to a tragic end at what time? _______ MY ago

8) The **Mesozoic Era** represents the "***Age of the Dinosaur***". How many years of geologic time did the dinosaurs get to reign on Earth before they were suddenly wiped out at the end of the Cretaceous Period? ______ MY

Hint: It spans the time across the entire "middle life" Era. This Era also came to a tragic end at what time?

_______ MY ago

9) The **Cenozoic Era** represents the "***Age of the Mammals***". How many years of geologic time have the mammals been reigning on Earth so far? *Hint: It spans the time across the entire "new life" Era.* __________ MY

10) Which **Era** has the most **Periods**? _________________ What's the most likely reason this Era has the most Periods?

11) The **Quaternary Period** represents the current interglacial interval and when human civilizations arose, referred to as the "*Age of the Humans*". *Homo sapiens* evolved during this period, when did it begin?

____

ACTIVITY #2 – The History of Earth…on paper!

INTRODUCTION:

The Earth has changed dramatically and repeatedly over a history that spans nearly 5 billion years. Such immense spans of time are difficult for most of us to comprehend. They fall outside our range of human experience. We normally deal with much shorter time intervals, like the time of our next class or the number of days until the next exam, or even the number of years until graduation!

It is important for students of the Earth Sciences to expand their sense of time. Extremely slow geologic processes, considered only in terms of human experience, have little meaning. To appreciate the magnitude of geologic time and the history of our incredible planet, you will be creating a timeline of important geologic events scaled to a size more tangible and familiar.

INSTRUCTIONS:

1. Construct a timeline of Earth's history on a long strip of adding machine tape. The timeline should be done to scale.
    - 1 meter (100 cm) = 1 billion years (1000 million years)
    - 10 cm = 100 million years
    - 1 cm = 10 million years
    - 1mm = 1 million years
    - There are ten 100 million years in one billion years, or 100 cm in 1 meter.
    - There are ten 10 million years in 100 million years.

a) **Measure out a strip of adding machine tape 5 meters long**. A meter stick will be provided in lab.

b) Refer to the **Geologic time scales** in this exercise. Dates might vary slightly.

c) Select one end of the tape to represent **today**. . Beginning at that end, **mark off and write each billion years** (1 billion, 2 billion, etc.) at 1 meter increments.

d) Draw a **bold line and label** (in color) to **show the beginning of Earth at 4.6 billion yrs. ago.** *To help you get started: 4.6 billion yrs**. Go to the 5 billion mark and plot 4.6 billion: 5 - 4.6 = .4 billion = 400 million = 40 cm. Measure 40 cm "up, or towards today, from 5 billion", draw a line and label "Beginning of Earth"***

e) **Draw** a bold line and **label** (in color) to **show the beginning of the three eras** **(Paleozoic, Mesozoic, Cenozoic**). *To help you get started: 542 Million yr. ago from today would be (50 cm+ 4cm + 2mm) from the "today" end of the paper roll.*

f) **Mark off and write numbers** at 10 cm increments **ONLY WHEN NECCESARY** (plotting boundaries or events)

g) **Starting with the oldest event** (Event #1), mark off all of the important events in Earth's history shown in the list on the next page. In each case you should **write the date and event directly on the timeline.**

h) Come up with your own Earth shattering event (do some research), plot the event on your time scale, and present to the class.

Event #	Date in years before present	Event
1	4.56 billion	Earth forms
2	4.1 billion	Oldest rock
3	3.9 billion	Oldest evidence of a continent
4	3.8 billion	First evidence of life
5	3.5 billion	First fossils (algae and bacteria)
6	1.8 billion	Free oxygen in atmosphere
7	1.1 billion	First fossil of a complex organism (a worm)
8	540 million	First abundant life found in the rock record
9	460 million	First fish
10	440 million	First land plants
11	410 million	First land animals
12	250 million	Largest mass extinction occurs
13	247 million	First dinosaurs
14	240 million	First mammals
15	220 million	Breakup of super-continent Pangaea begins
16	145 million	First flowering plants
17	65 million	Dinosaurs and other animals go extinct
18	1.8 million	First primate in genus Homo
19	40,000	First Homo *sapiens*
20	13,000	Humans first inhabit North America
21	10,000	End of last Ice Age
22	500	European rediscovery of the Americas
23	?	Your birthday

(Please note that some of these ages may differ slightly from those given in your text or that you found in another source. These dates change, but the general order and rough position stay constant.)

LABORATORY REFLECTION: Write a short reflection about your experience in doing the activities in lab today. Include the following: 1) The purpose of the lab 2) What you learned from this laboratory 3) What was interesting 4) The problems and challenges you encountered.

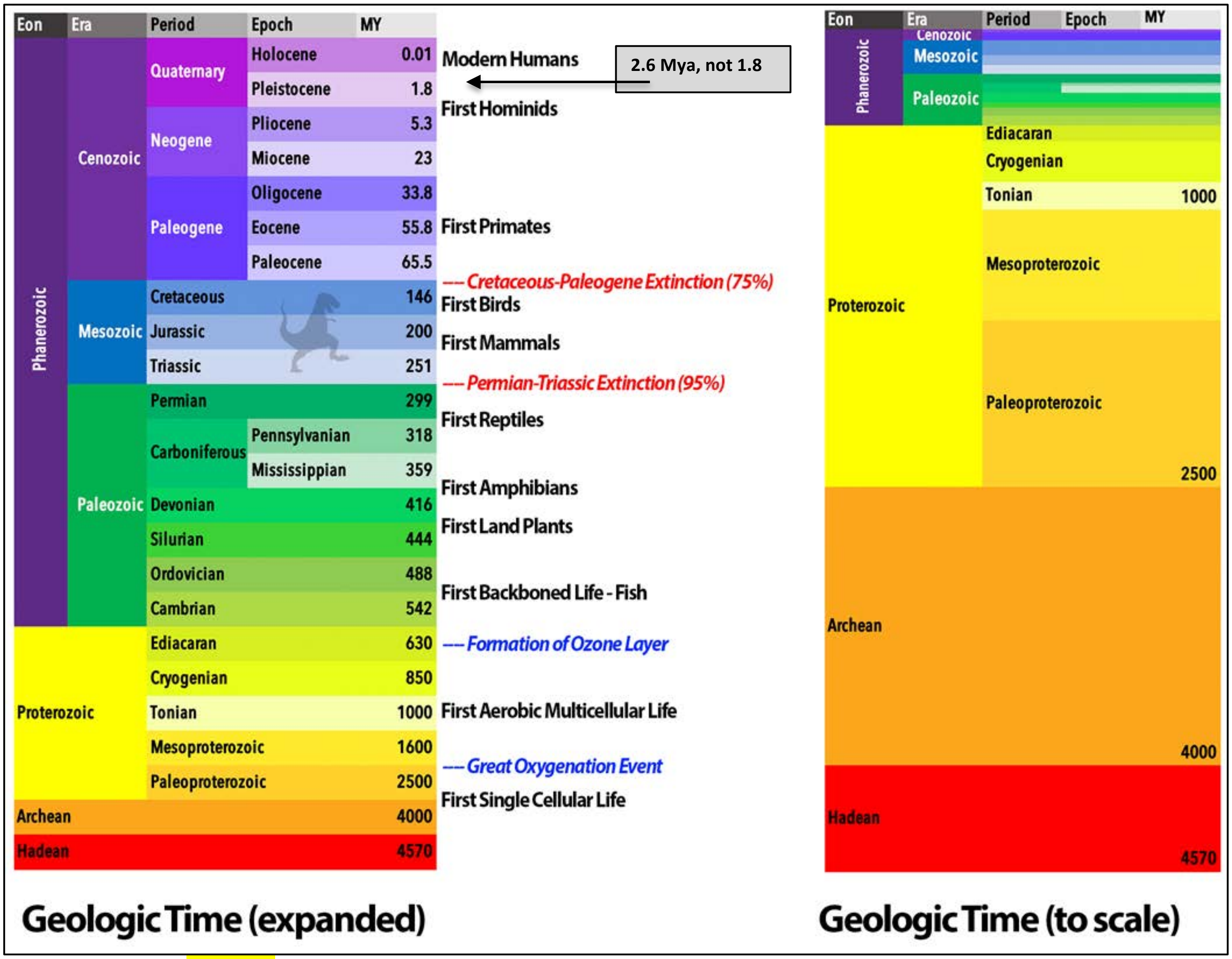


Figure 1 – Geological Timescale (Ga = billions of years; Ma = millions of years)

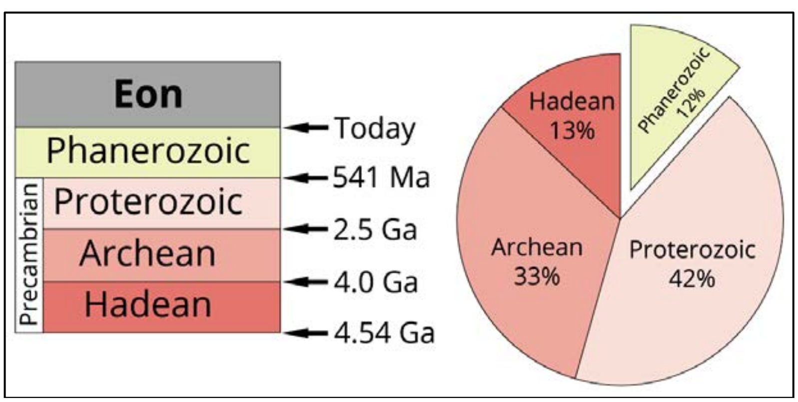


Figure 2: The Eon Time Divisions of the Geologic Timescale.

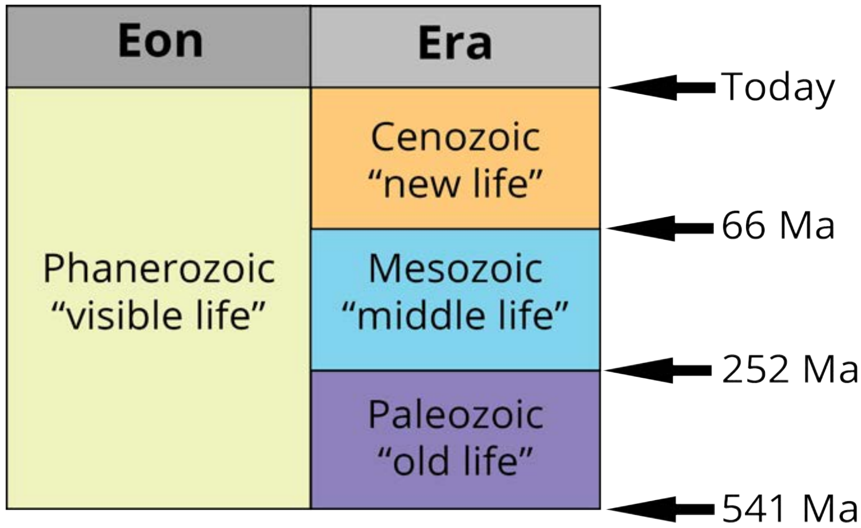


Figure 3: The Era Time Divisions of the Geologic Timescale
Image by Jonathan R. Hendricks. Creative Commons License This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

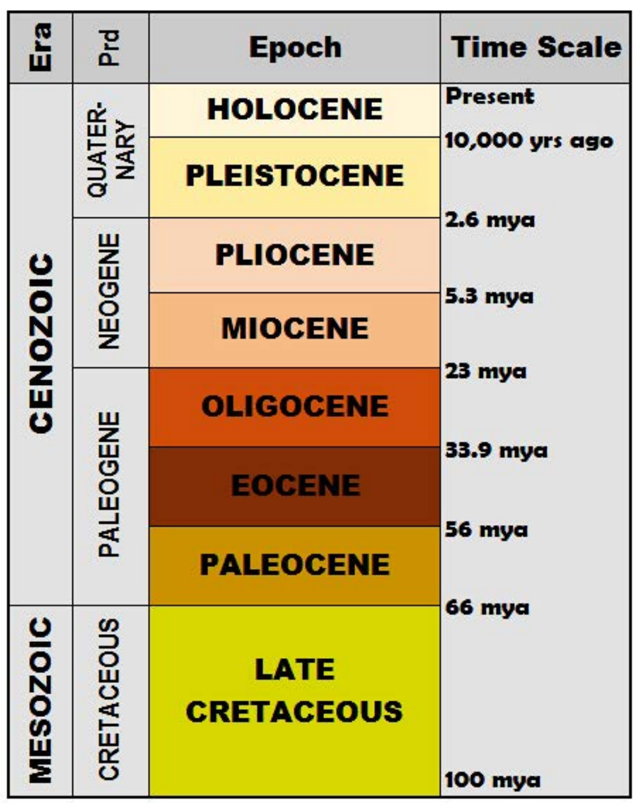


Figure 4: The Epochs of the Cenozoic Era

https://floridadep.gov/fgs/fgs/media/house-graphics-dep-data-portal-screenshot-icon

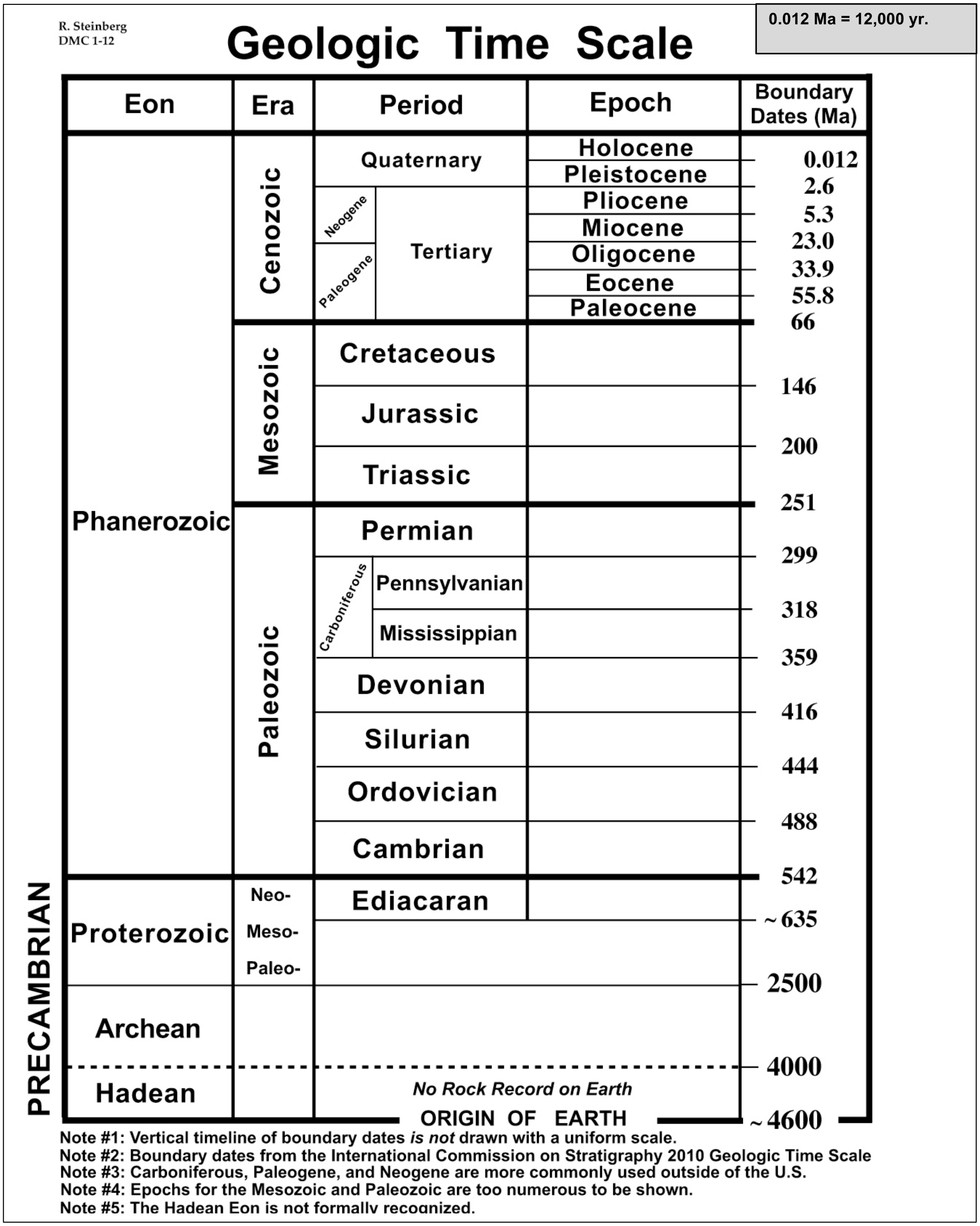


Figure 5: **Timescale.**

by Roger Steinberg, Department of Natural Sciences, Del Mar College
https://serc.carleton.edu/NAGTWorkshops/time/visualizations_teachtips/60786.html

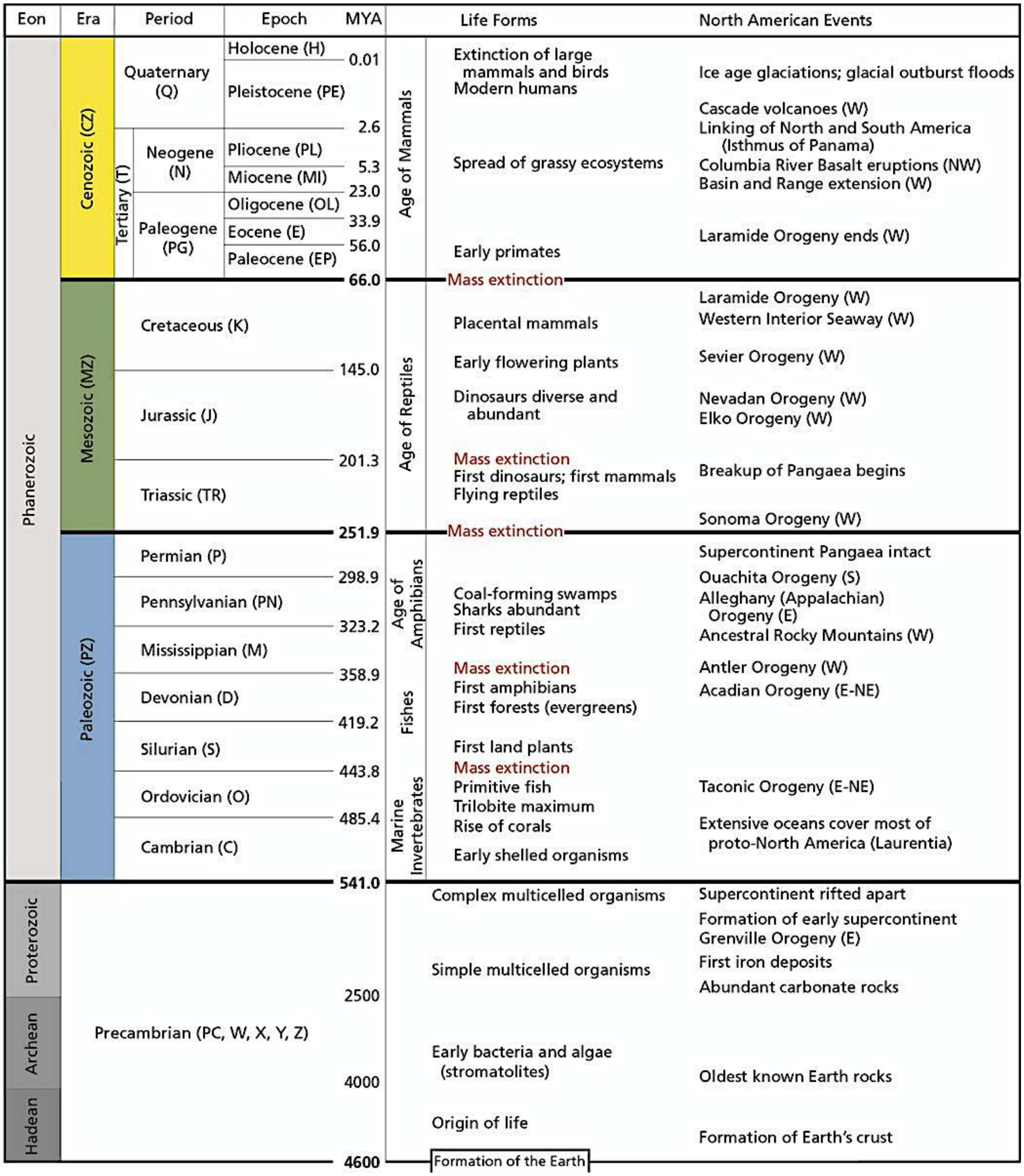


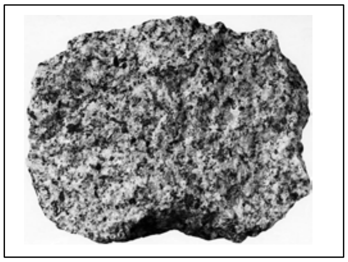
Figure 6: Geologic time scale showing the geologic eons, eras, periods, epochs, and associated dates in millions of years ago (MYA). The time scale also shows the onset of major evolutionary and tectonic events affecting the North American continent. *From the National Park Service*

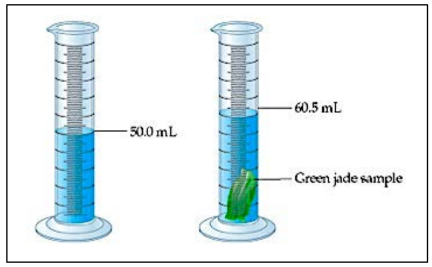
ROCK DENSITY EXPERIMENT

Learning Objectives

Hypothesize differences in density between rock samples
Experimentally determine densities of rock samples

Activity – Ocean crust vs. Continental crust





We can classify silicate minerals and the rocks they form into two broad categories – *felsic* and *mafic*. These categories are based o the chemical composition of the minerals, which influences the color and density of the minerals and rocks. As silicates, both felsic and mafic minerals contain silica (Si) and oxygen (O). Felsic minerals and rocks are more abundant in silica and oxygen, and are also rich in aluminum (Al), sodium (Na) and potassium (K), which makes them light in color. Mafic minerals and rocks are rich in magnesium (Mg) and iron (Fe), which makes them dark in color. In addition to the color differences, there are also density differences between felsic and mafic rocks. **Oceanic crust** and **continental crust** are composed of different types of rocks, the density of which influences the different ways crust interacts in plate tectonics.

We will create a hypothesis linking what we know about the composition of felsic and mafic rocks with the two types of continental crust. Our hypothesis will have two parts:

HYPOTHESIZE: Given a light *(felsic)* and a dark *(mafic)* rock sample:

1. Which is denser.
2. Which represents ocean crust and which continental crust**.**

Here are a few items that are helpful to remember when thinking about your hypothesis:

- *Density = mass/volume*
- *A hypothesis is a tentative, testable, answer to a scientific question.*

Write your hypothesis:

1)

2)

Conduct the following experiment to test your hypothesis

Read through these instructions before you start your experiment.

Determining the density of a rock sample. To determine the density, you will use the displacement method to measure the volume of light and dark samples. Measure water displaced using the plastic graduated cylinders. Each tick mark on the cylinders represents **5 cm^3** (same as 5 mL) of volume. ***Make sure this is correct, you might have a different size cylinder***. It is important to read the water level to the nearest **1 cm^3** (nearest 1 mL), which means estimating as best you can between each tick mark. *Do this as accurately as you can; this is the largest source of error in this part of the lab.*

Directions: Follow steps below to complete the data tables for the three samples of light rock and dark rock.

- Fill the plastic cylinder to 300 mL level. Tap the cylinder to get out air bubbles.
- Start with the light samples.
- Weigh the first sample and record the **mass** in grams for "Sample 1."
- Read the water level to the nearest 1 cm^3 (nearest 1 mL) and record it in the table under "start level" for "Sample 1".
- Tilt the cylinder to ~ 45-degree angle and gently slide the sample in so that it slips into the water without splashing.
- Gently tap the cylinder to get out air bubbles.
- Read the water level to the nearest 1 cm^3 and record it in the table under "end level" for "Sample 1."
- Calculate the **volume** of the sample (in cm^3) by subtracting the start level from the end level.
- Calculate the **density** of the sample (g/cm^3) by dividing the weight (in g) by the volume (in cm^3).
- **Without removing the water or rocks from the cylinder**, repeat above steps for the rest of the light samples. *Note: the "start level" for each successive sample will be the same as the "end level" of the previous sample.*
- Calculate the average density of the **three samples of light rock**. By taking the average of three separate density measurements, we will hopefully cancel out some measurement errors and obtain a more accurate value for the density.
- **Repeat this procedure using the 3 dark samples**. Start with a new cylinder of water. While some students are completing the table for the light rock, the others in the group can start measuring the dark samples.

Light Rock Data Table

Sample number	Mass (g)	Start level (cm^3)	End level (cm^3)	Volume (cm^3)	Density (g/cm^3)
Sample 1					
Sample 2					
Sample 3					

Average density of the **light** samples = mass/volume = _______________ g/cm^3

Dark Rock Data Table

Sample number	Mass (g)	Start level (cm^3)	End level (cm^3)	Volume (cm^3)	Density (g/cm^3)
Sample 1					
Sample 2					
Sample 3					

Average density of **dark** samples = mass/volume = _______________ g/cm^3

Data ANALYSIS:

1. Which rock has the greatest density? ________________________

2. Which sample represents ocean crust? ________________ Why?

3. Which sample represents continental crust? ________________ Why?

4. Do the results support or refute your hypothesis? Why?

…

MINERAL PRELAB EXERCISE

Refer to free online <u>lab manuals on Bb</u> inside the "Lab Folder"
p. 119-126 in the **Weise online lab** manual
p. 140-168 in the Galileo online lab manual

Answer the following on scantron form:

1. Which of the following <u>does not</u> fit the description of a mineral?
   a) inorganic
   b) specific chemical formula
   c) lacking crystalline structure
   d) naturally occurring
   e) both c and d

2. Which mineral group is considered to be the major rock forming mineral group, and the most common mineral group?
   a) silicates b) carbonates c) sulfates d) oxides e) halides

3. This mineral has excellent cleavage in one direction, a hardness of 2 to 2.5, is colorless (sometimes yellow-brown), and has OH in the silicate structure. *(look at the mineral charts in online manuals, see Bb)*
   a) halite b) gypsum c) muscovite mica d) serpentine e) quartz

4. All of the following are useful physical properties except ________________.
   a) streak b) size c) hardness d) luster e) cleavage

5. Corundum is the mineral name for __________________________. (need to google this)
   a) sapphire
   b) diamond d) ruby
   c) emerald e) both a and d

6. Which 2 minerals are not classified as silicates?
   a) pyroxene and olivine d) quartz and k-feldspar
   b) halite and gypsum e) muscovite and hornblende
   c) plagioclase and biotite

7. Which of the following is <u>not</u> characteristic of olivine? *(look at the mineral charts)*
   a) green color
   b) hardness of 6.5 to 7
   c) prominent cleavage
   d) nonmetallic

8. The 2 directions of cleavage for hornblende meet at _______ angles. *(look at the mineral charts)*
   a) 90 degree
   b) 30 and 60 degree
   c) 45 degree
   d) 120 and 60 degree

9. The hardness for calcite is _______ *(look at the mineral charts in online manuals)*

   a) 3 b) 2 c) 5 d) 6 e) 7

MINERALS

Learning Objectives

- Identify common minerals based on their physical properties.
- Explain the significance of the silicate minerals.

Helpful Resources:

- **p. 119-126** in the **Weise online lab** manual
- **p. 140-168** in the **Galileo online lab** manual
- Mineral chapter in the manual on your table
- Execellent video on cleavage: **https://www.youtube.com/watch?v=dZ1u-zJxyVo**
- Notes from ppt lecture

Mineral Identification

- **Use** the **mineral identification charts** to correctly identify the minerals listed below. Make sure you have the correct sample number next to each mineral below and next to your description on the worksheets.
- **Use worksheets** to write **mineral ID** number and **properties of each mineral.**

The minerals we're going to be identifying today fall into two categories: silicate minerals and non-silicate minerals. **Silicate minerals** have **SiO_2** as a fundamental component of their composition. Silicates are the most abundant mineral type in the crust, and the list of silicate minerals we're exploring are the minerals that most commonly comprise our igneous rocks. **Non-silicate minerals** have more varied compositions, and have a wider variety of formation environments. Many of the non-silicate minerals are economically valuable ores.

IDENTIFY THESE SAMPLES WHICH ARE IN THE BOXES ON THE LAB TABLES

SILICATE MINERAL LIST: **Note: **bolded** minerals are part of Mohs hardness scale*

- **Quartz**
- **K-feldspar** [two varieties: Orthoclase (white) and Microcline (pink)]
- Plagioclase Feldspar [two samples – look for striations to identify plagioclase]
- Muscovite Mica
- Biotite Mica
- Hornblende (amphibole mineral group)
- Augite (pyroxene mineral group)
- Olivine
- Tourmaline

- **NON-SILICATE MINERAL LIST:**
  - **Calcite**
  - **Gypsum**
  - **Halite**

Use worksheet to record mineral ID number and properties of each rock. SEE CLASSIFICATION CHARTS IN MANUALS to help identify samples correctly.

MINERALS WORKSHEET:

Sample #	Name of Mineral	Silicate or non-silicate	Luster	Hardness	Cleavage/Fracture (# planes and angles)	Other properties to remember

IGNEOUS AND SEDIMENTARY ROCKS PRELAB EXERCISE

Refer to free online lab manuals on Bb in the "Lab folder"

Igneous Rocks:

- **p. 137-142** in the **Weise online lab** manual
- **p. 177-190** in the **Galileo online lab** manual

Sedimentary Rocks:

- **p. 149-153** in the **Weise online lab** manual
- **p. 227-233** in the **Galileo online lab** manual

ANSWER THE FOLLOWING ON SCANTRON FORM:

1. When there are 2 different sizes of crystals (minerals) caused by different cooling rates; the larger minerals are called phenocrysts. What is the texture?

a) aphanitic
b) phaneritic
c) coarse-grained
d) porphyritic

Match the numbered word to the letter definition (#2-6)

2. Mafic	a) term used for light colored igneous rocks, or minerals, high in silica, potassium and sodium
3. Granite	b) a mineral high in Fe (Iron) and Mg (magnesium) that is found in peridotite
4. Felsic	c) dark, glassy-textured rock or volcanic glass
5. Obsidian	d) term used for dark colored igneous rocks, or minerals, high in Fe (Iron) and Mg (magnesium)
6. Olivine	e) large minerals, felsic, intrusive igneous rock

Match the intrusive igneous rocks to their extrusive equivalents (#7-10):

7. Granite	a) Basalt
8. Diorite	b) Rhyolite
9. Gabbro	c) extrusive equivalent rare
10. Peridotite	d) Andesite

11. The igneous rocks you matched in #7 to 10 have the same chemical composition, but the textures (size of minerals) are different. The intrusive rocks are composed of large, or visible, minerals and the extrusive are made of much smaller minerals. In lab, you will learn some of the terms used to describe igneous textures. For now, what controls the size of the minerals found in igneous rocks?

a) cooling rate (fast or slow cool)
b) where the molten rock solidifies and crystallizes (below the surface in the crust, or on the surface)
c) chemical composition of surrounding rock (country rock)
d) the amount of silica in the molten rock
e) both a and b

12. _______ **does not** play a role in the formation of sedimentary rocks (see rock cycle on p. 103)?

a) weathering
b) transportation d) melting
c) compaction e) deposition

Match the numbered word to the letter definition (13-17)

13. limestone a) this detrital (clastic) sedimentary rock is made of angular-shaped gravel-sized sediment

14. shale b) classified as an evaporite

15. sandstone c) a detrital sedimentary rock composed of mud (clay)-sized particles

16. breccia d) made of calcium carbonate ($CaCO_3$), classified as a biochemical sedimentary rock when has a marine organic origin.

17. gypsum e) the sediment found in this detrital rock ranges from 1/16 to 2 mm in diameter

18. All of the following are classified as detrital sedimentary rocks except ________.
a) conglomerate
b) sandstone d) coal
c) siltstone e) shale

19. Chalk is classified as a __1___ sedimentary rock and has an abundance of ___2____
a) 1. chemical 2. fossils
b) 1. biochemical 2. microscopic shells
c) 1. detrital 2. rock fragments
d) 1. detrital 2. feldspar
e) 1. biochemical 2. coral fragments

20. The following rocks are classified as fine to very fine-grained <u>detrital</u> sedimentary rocks ___
a) shale, and siltstone
b) conglomerate, breccia, and quartz sandstone
c) rock gypsum and chert
d) micrite and chalk

IGNEOUS ROCKS

Learning Objectives

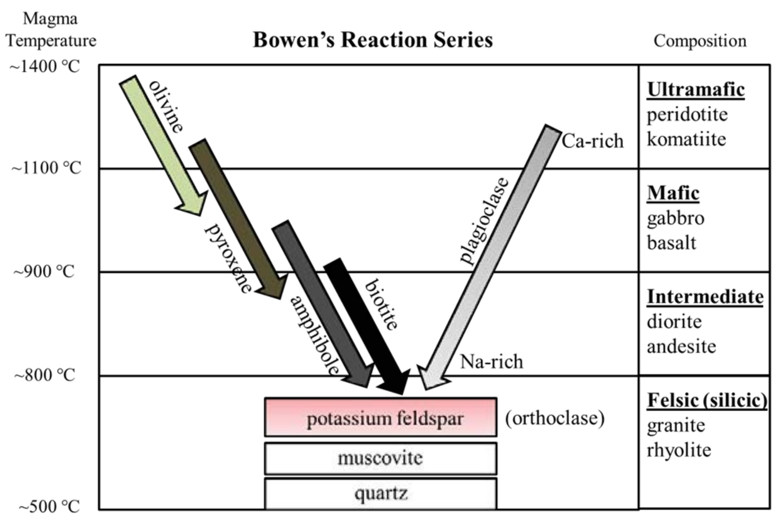
- Classify common igneous rocks based on their mineral composition, texture, and color index
- Classify common sedimentary rocks and develop a general understanding of sediment grain size
- Classify common metamorphic rocks. Be able to distinguish foliated and nonfoliated metamorphic rocks

Helpful Resources:

- **p. 137-142** in the **Weise online lab** manual
- **p. 177-190** in the **Galileo online lab** manual
- Igneous Rocks chapter in the manual on your table
- Notes from ppt lecture and **information below**

Igneous rocks form from molten material. There are a few important categories for igneous rocks – their **texture**, **mineral composition**, and **color index**. These all give us clues to the environment in which the igneous rocks formed. Our two broad categories for igneous rock texture are: **intrusive** and **extrusive**. Intrusive rocks cool slowly deep within the crust, allowing the minerals to grow into big sizes that are distinguishable by the naked eye. Extrusive rocks are extruded at the surface and cool quickly, so the minerals are too small to see individual grains without the aid of a microscope. The color index (usually) helps us identify the category of minerals present in the igneous rocks. Dark colored igneous rocks are **mafic**, light colored igneous rocks are **felsic**, and some are a balanced mix of light and dark and are **intermediate**. Mafic rocks are abundant in minerals rich in magnesium (Mg) and iron (Fe), which makes them dark in color. Felsic rocks are made of minerals more abundant in silica and oxygen, and that are also rich in aluminum (Al), sodium (Na) and potassium (K), which makes them light in color.

As a magma cools, minerals start forming – minerals like olivine and calcium-rich plagioclase have high melting temperatures and are the first to solidify. As the magma temperature continues to drop, minerals with lower melting temperatures form. Each mineral that forms changes the composition of the remaining magma. High temperature mafic minerals (e.g. olivine, pyroxene) are rich in iron and magnesium. By the time temperatures have cooled to start forming the felsic minerals (e.g. quartz, K-felspar), the remaining magma is depleted in the mafic elements, so those minerals and rocks are light in color and richer in silicon, oxygen, and other lighter elements. The mineral formation from a cooling magma follows a predictable pattern called **Bowen's Reaction Series**.



Bowen's Reaction Series *(Image credit: Karen Tefend; license CC BY-SA 3.0)*

The progression of mineral crystallization as magma temperatures drop from ~1400 °C to ~500 °C. Note the corresponding names for igneous rock composition (underlined and bolded) and some example rock types within each compositional group.

HELPFUL STEPS IN IGNEOUS ROCK IDENTIFICATION:

Determine the <u>color:</u> indicates <u>mineral composition</u>

a) Felsic (light) → Granite or Granodiorite and Rhyolite
b) Intermediate → Diorite and Andesite
c) Mafic (dark) → Gabbro and Basalt
d) Ultramafic (dark w/ green) → Peridotite

Determine the <u>texture</u>: indicates cooling history = <u>Intrusive or Extrusive</u>

a) <u>Phaneritic</u> (coarse-grain) = large minerals → <u>Intrusive</u>
b) <u>Aphanitic</u> (fine-grain) = small minerals, too small to identify with the naked eye→ <u>Extrusive (volcanic)</u>
c) <u>Porphyritic</u> = matrix of small minerals with larger minerals (called phenocrysts)→ <u>Extrusive</u>
(Most of the samples in lab are porphyritic)
d) <u>Vesicular</u> = holes from trapped gas → <u>Extrusive (volcanic)</u>
e) <u>Glassy</u> = obsidian (look for conchoidal fracture)→ <u>Extrusive (volcanic)</u>

IDENTIFY THESE SAMPLES WHICH ARE IN THE BOXES ON THE LAB TABLES

- **<u>INTRUSIVE IGNEOUS ROCK LIST:</u>**
  - Granite [two samples with different #s]
  - Granite Pegmatite *(look up texture!)*
  - Granodiorite
  - Diorite
  - Gabbro
  - Peridotite
- **<u>EXTRUSIVE IGNEOUS ROCK LIST:</u>**
  - Rhyolite [two samples, same #]
  - Andesite [two samples, same #]
  - Basalt
  - Obsidian
  - Pumice

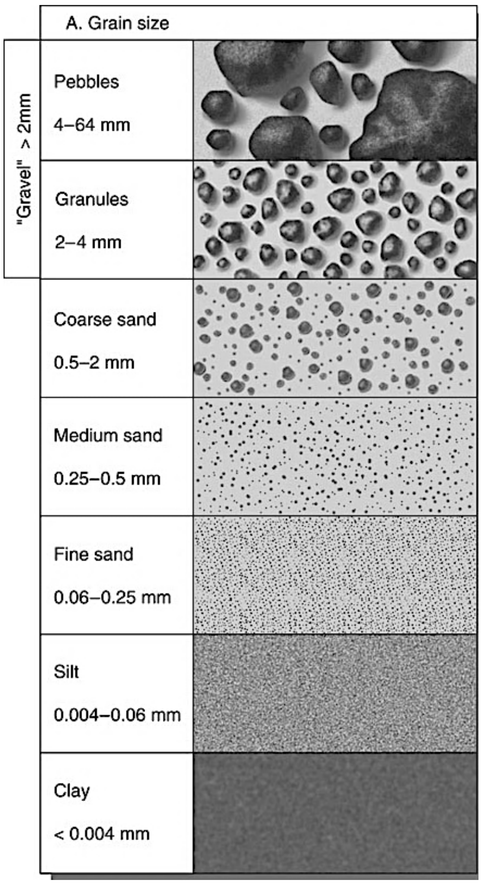
Use <u>worksheets</u> to write rock ID number and properties of each rock. <u>See classification charts in manual on table and in online manuals</u> to help identify samples correctly.

Igneous Rock Worksheet

Sample #	Rock Name	Texture	Felsic, Intermediate, or Mafic	Dominant Minerals (2 to 3) *See classification charts in manuals*	Intrusive or Extrusive

SEDIMENTS – A PRECURSOR TO SEDIMENTARY ROCKS

Many types of sedimentary rocks fall under the category of **detrital** sedimentary rocks, which means rocks formed through the physical breakdown of pre-existing rocks. Detrital sedimentary rocks are the most abundant rock type in the San Diego area. **We classify these types of rocks based on the grain size**. The following brief exercise will help with differentiating between sand, silt, and clay.



Identify the trays of sediment on the table **before proceeding with sedimentary rock identification**.

SEDIMENT CLASSIFICATION:
Match the sediment classification (a-e) to the sediment sample tray number

Tray 1 ______________________________ **a) Coarse sand**

Tray 2 ______________________________ **b) Medium sand**

Tray 3 ______________________________ **c) Fine sand**

Tray 4 ______________________________ **d) Silt**

Tray 5 ______________________________ **e) Clay**

SEDIMENTARY ROCKS

Helpful Resources:

- **p. 149-153** in the **Weise online lab** manual
- **p. 227-233** in the **Galileo online lab** manual
- Sedimentary rock chapter in the **manual on your table**
- Notes from ppt lecture

Sedimentary rocks are formed through the weathering – physical or chemical – of pre-existing rocks. We classify sedimentary rocks into two classes: **detrital** and **chemical** sedimentary rocks. Detrital sedimentary rocks are made up of sediments that have been compacted and/or cemented together so that they form a solid cohesive mass. We usually name these rocks to be reflective of the sizes of the **clasts** (or particles) that comprise the rocks. Chemical sedimentary rocks are formed through the chemical weathering of parent rocks and have precipitated out of solution to form a solid rock. Sometimes this precipitation process includes living organisms that precipitate the minerals as part of their hard parts (e.g. shells, tests, skeletons), so we can also the rocks that include this material **biochemical** sedimentary rocks.

IDENTIFY THESE SAMPLES WHICH ARE IN THE BOXES ON THE LAB TABLES

- **DETRITAL SEDIMENTARY ROCK LIST:**
  - Conglomerate
  - Breccia
  - Quartz sandstone [two samples, same #]
  - Mudstones (silt and/or clay)
    - Siltstone
    - Shale [two samples with different #s]

- **CHEMICAL/BIOCHEMICAL SEDIMENTARY ROCK LIST:**
  - Fossil limestone
  - Chalk
  - Crystalline limestone (Micrite)
  - Chert
  - Rock Gypsum

*Use worksheets to write **rock ID** number and **properties of each rock. See classification charts in manual on table and in online manuals.***

Sedimentary Rock Worksheet

Sample #	Rock Name	Texture/Grain Size (coarse, medium, fine)	Composition (rock fragments, clay, quartz, $CaCO_3$, etc.)	Classification (detrital, chemical, or biochemical)	Comments

METAMORPHIC ROCKS

Helpful Resources:

- **p. 163-169** in the **Weise online lab** manual
- **p. 261-271** in the **Galileo online lab** manual
- Metamorphic rock chapter in the **manual on your table**
- Notes from ppt lecture

The word **metamorphic** comes from the Greek word *meta* meaning "trans" and *morphē* meaning "form". Metamorphic rocks are rocks that have been literally transformed, or metamorphosed. Pre-existing rocks are exposed to pressure and/or heat, causing the mineral structure of the rock to morph into a new form. It's important to note that the heat required to form a metamorphic rock is lower than the melting temperature of the minerals, so the rock is not melting and reforming, but the heat causes some mobility in ions that can allow some mineral grains to grow or even transform into different minerals entirely. The pressures that metamorphose rocks come in two varieties – uniform and directional. Uniform pressure is pressure that is equal in all directions – the pressure water exerts on your body as you swim is an example of a uniform pressure. Directional pressure comes from specific directions – compressional stress acting on a rock is an example of a source of directional pressure. These different kinds of pressures set up the two primary categories of metamorphic rocks: **foliated** and **nonfoliated**. Foliated metamorphic rocks form under directional pressure. Foliated comes from the Latin word *folium* meaning "a leaf", and is used to describe the leaf-like texture of the rocks. The foliated texture comes from the minerals aligning under the directional pressure – the direction of the leaf-texture is perpendicular to the direction of the pressure. Nonfoliated metamorphic rocks indicate metamorphosis from a uniform pressure and/or heat.

The names we give to our metamorphic rocks sometimes is reflective of the parent rock - marble, quartzite, and slate all have identifiable parent rock types. But sometimes the change is so great that it is impossible to identify the parent rock, so the names are based on texture, rather than composition.

IDENTIFY THESE SAMPLES WHICH ARE IN THE BOXES ON THE LAB TABLES

- **FOLIATED METAMORPHIC ROCKS:**
  - Gneiss [possibly two sample #s]
  - Schist
  - Slate
- **NONFOLIATED METAMORPHIC ROCK LIST:**
  - Marble
  - Quartzite

***Use worksheets** to write **rock ID** number and **properties of each rock. See classification charts in manuals as well as the classification tables** on. **p. 271 in the Galileo manual and p. 169 in the Weise manual** to correctly identify and describe the samples correctly.*

Metamorphic Rock Worksheet

Sample #	Rock Name	Texture (foliated or nonfoliated)	Protolith or Parent Rock	Composition or dominant minerals	Comments

TAKE-HOME EXERCISE: Unit Conversion

NAME __________________________

Helpful Resources

- Unit conversion help: http://serc.carleton.edu/mathyouneed/units/index.html
- Measurement Uncertainty: https://courses.lumenlearning.com/boundless-chemistry/chapter/measurement-uncertainty/
- Unit Conversion: https://courses.lumenlearning.com/boundless-chemistry/chapter/dimensional-analysis/
- Conversion chart on the next page

Math for Geoscience

In science, we measure all kinds of properties to learn about the world around us, which means, sometimes, we'll need to do calculations with those measurements to understand what they tell us. A common misconception is that some people are "good at math" and some people "just aren't", but the GOOD NEWS is that **math is a skill that we can practice and get better at!** Just like you can work out to build muscles or practice a new hobby, you can practice working out your math muscles! In this exercise, we'll practice working on some different kinds of common calculations that you'll encounter as a geoscientist.

Directions: Do the calculations in each of the four sections of this assignment. **To receive full credit, show your work.**

Why are we doing this?

This may seem like a pointless (evil?) math exercise, but some serious mishaps have happened because of errors converting between units – particularly between the Metric System and the US Customary System. Take to your favorite internet search engine and find out the details about the two following incidents

1. **Internet search #1**
    a. What happened to the Mars orbiter on 9/23/1999?
    b. What unit(s) caused the problem?
    c. How much did it cost to build the Mars orbiter?
2. **Internet search #2**
    a. What happened to an Air Canada flight 143 on 7/23/1983?
    b. What unit(s) caused the problem?
3. What do these two incidents teach us about why we should pay attention to units?

UNIT CONVERSION PROBLEMS

Unit Conversion Calculation: **SHOW <u>ALL</u> WORK HERE**

<u>Example:</u> 2.5 miles = __4.0__ kilometers

<u>Work:</u> 2.5 ~~miles~~ x 1.6 $\frac{\text{kilometers}}{\text{~~miles~~}}$ = 4.0 kilometers

(miles cancel)

4. 10.0 miles = ________ kilometers

5. 1.0 foot = _______ meters

6. 16 kilometers = _______ meters

7. 25 meters = _______ centimeters (cm)

8. 1.3 liters (L) = _______ milliliters (ml) or cubic centimeters (cm^3)

9. 25.4 mL = _______ cm^3

10. 120 pounds = _______ kilograms (kg)

11. 2 ounces = _______ grams

12. **Velocity = distance/time**. An object travels 280 miles in 4 hours, the velocity of the object: ________ **km/hr**

SHOW YOUR WORK:

Orders of Magnitude and Scientific Notation

An order of magnitude is a class in a system of classification determined by size, each class being a number of times (usually ten) greater or smaller than the one before.

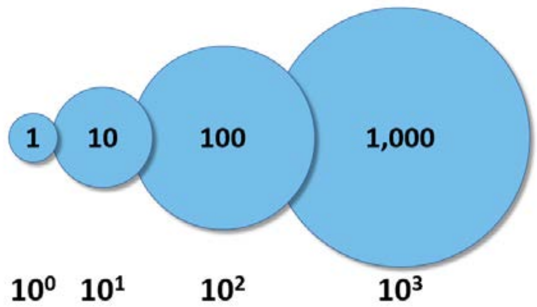


Figure 1 – orders of magnitude

Image Credit: EOSC, USD

It's easy to lose track of zeros and decimal places in very large numbers and very small numbers – so we can use the orders of magnitude to help make them easier to read, understand, and do math with.
Scientific notation is the system that we use, which uses the form $m \times 10^n$ where *m* is an integer whose absolute value is at least 1 but less than 10 and *n* is a coefficient representing the order of magnitude.

For example:

- The diameter of the Earth is 13,000,000 meters = 1.3 x $\mathbf{10^7}$ meters
- The diameter of a gold atom is 0.000000000144 meters = 1.44 x $\mathbf{10^{-10}}$ meters

13. Write one billion (1,000,000,000) in scientific notation. ______________________________________

14. Write 276,000,000 in scientific notation. ____

15. Write 0.00000000602 in scientific notation. ______________________________________

16. Convert 100,000,000 cm to km, give answer in scientific notation _________________ **km**
(100 cm = 1 m; 1000 m = 1 km)
Show your work:

UNITS AND THEIR APPLICATION TO GEOSCIENCE PROBLEMS

Mauna Loa Volcano on the Big Island of Hawaii
Credit: J.D. Griggs, USGS. Public domain.

17) Mauna Loa is one of the **largest volcanoes on Earth** today and sits on the seafloor in the middle of the North Pacific Ocean basin. Classified as a "shield" volcano, the edifice **rises to 13,677 feet above sea level** and constitutes half of the Big Island's area. Its dome is **75 miles long and 64 miles wide**. This hot spot volcano sits over a deep mantle plume and has been active for over 1 million years now since its inception on the deep seafloor.

Work:

a) What is the volcano's **height** (elevation) in meters? _______________ m

b) What is the volcano's **length** (how long) in kilometers? _______________ km

c) What is the volcano's **width** (how wide) in kilometers? _______________ km

Mount Everest in Tibet
Credit: I, Luca Galuzzi, CC BY-SA 2.5 via Wikimedia Commons

18) Mount Everest is the **tallest mountain on Earth** today (absolute elevation**)**, and quite massive. Located in the Himalayan Range of Northern India, Nepal and Tibet. **Everest** has an estimated **weight** of 357 trillion pounds! Although this **weight does** include the rocks, it doesn't include the **weight** of ice and snow at the summit

Note: 1 US ton = 2000 lb or 907.19 kg

a) **How much does Everest weigh** in kilograms? _________________kg

Work:

Lava flowing down flank of Mauna Loa on the Big Island of Hawaii
Credit: USGS photo by D. Peterson

19) Hawaiian lava is very hot and mafic in composition, and it can flow at remarkably fast rates. Measured advance rates on the Island of Hawai'i are as **fast** as 5.8 mi per hour for an 'a'ā **flow** erupted from Mauna Loa in 1950, which **is** slightly slower than typical human jogging **speed**. Pāhoehoe **lava flows** typically move more slowly, less than a few hundred feet (or yards) per hour or day. What is the lava flow velocity in **meters per hour** and **meters per second**?

Mauna Loa lava flow rates = 5.8 mi/hr = ________________km/hr = _______________m/s

Work:

Mathematical Conversions

To convert:	To:	Multiply by:	
kilometers (km)	meters (m)	1000 m/km	**LENGTHS AND DISTANCES**
	centimeters (cm)	100,000 cm/km	
	miles (mi)	0.6214 mi/km	
	feet (ft)	3280.83 ft/km	
meters (m)	centimeters (cm)	100 cm/m	
	millimeters (mm)	1000 mm/m	
	feet (ft)	3.2808 ft/m	
	yards (yd)	1.0936 yd/m	
	inches (in.)	39.37 in./m	
	kilometers (km)	0.001 km/m	
	miles (mi)	0.0006214 mi/m	
centimeters (cm)	meters (m)	0.01 m/cm	
	millimeters (mm)	10 mm/cm	
	feet (ft)	0.0328 ft/cm	
	inches (in.)	0.3937 in./cm	
	micrometers (μm)*	10,000 μm/cm	
millimeters (mm)	meters (m)	0.001 m/mm	
	centimeters (cm)	0.1 cm/mm	
	inches (in.)	0.03937 in./mm	
	micrometers (μm)*	1000 μm/mm	
	nanometers (nm)	1,000,000 nm/mm	
micrometers (μm)*	millimeters (mm)	0.001 mm/μm	
nanometers (nm)	millimeters (mm)	0.000001 mm/nm	
miles (mi)	kilometers (km)	1.609 km/mi	
	feet (ft)	5280 ft/mi	
	meters (m)	1609.34 m/mi	
feet (ft)	centimeters (cm)	30.48 cm/ft	
	meters (m)	0.3048 m/ft	
	inches (in.)	12 in./ft	
	miles (mi)	0.000189 mi/ft	
inches (in.)	centimeters (cm)	2.54 cm/in.	
	millimeters (mm)	25.4 mm/in.	
	micrometers (μm)*	25,400 μm/in.	
square miles (mi2)	acres (a)	640 acres/mi^2	**AREAS**
	square km (km^2)	2.589988 km^2/m	
square km (km2)	square miles (mi^2)	0.3861 mi^2/km^2	
acres	square miles (mi^2)	0.001563 mi^2/acr	
	square km (km^2)	0.00405 km^2/acr	
gallons (gal)	liters (L)	3.78 L/gal	**VOLUMES**
fluid ounces (oz)	milliliters (mL)	30 mL/fluid oz	
milliliters (mL)	liters (L)	0.001 L/mL	
	cubic centimeters (cm^3)	1.000 cm^3/mL	
liters (L)	milliliters (mL)	1000 mL/L	
	cubic centimeters (cm^3)	1000 cm^3/mL	Correction: 1000cm^3/L
	gallons (gal)	0.2646 gal/L	
	quarts (qt)	1.0582 qt/L	
	pints (pt)	2.1164 pt/L	
grams (g)	kilograms (kg)	0.001 kg/g	**WEIGHTS AND MASSES**
	pounds avdp. (lb)	0.002205 lb/g	
ounces avdp (oz)	grams (g)	28.35 g/oz	
ounces troy (ozt)	grams (g)	31.10 g/ozt	
pounds avdp. (lb)	kilograms (kg)	0.4536 kg/lb	
kilograms (kg)	pounds avdp. (lb)	2.2046 lb/kg	

To convert from degrees Fahrenheit (°F) to degrees Celsius (°C), subtract 32 degrees and then divide by 1.8 To convert from degrees Celsius (°C) to degrees Fahrenheit (°F), multiply by 1.8 and then add 32 degrees.

*Formerly called microns (μ)

From Pearson: AGI & NAGT Lab Manual in Physical Geology 10th ed.

PLATE TECTONICS

Group Members: ____Recorder Initials:______

PART I: ISOSTASY (OR ISOSTACY)

Introduction: Why does the Earth have continental areas and oceanic areas? Rephrasing the question a bit, why does the Earth's surface divide into two distinct regions of elevation: the **continents** (average elevation about 0.5 miles above sea level), and the **ocean basins** (average elevation about 2.3 miles below sea level)? The answer relates to the fact that Earth's surface is made up of two different types of crust: the **continental crust** and the **oceanic crust**. These two types of crust differ in both their **thickness** and **density**. In this lab, you will see how these two properties control the elevation of the continents versus the ocean basins.

Relationship between Volume, Mass, & Density

- **Density** is a measure of mass per unit volume.
- **Water:** a gallon (a unit of volume) weighs about 8.33 pounds (a unit of mass). Therefore, the **density** of water is 8.33 pounds per gallon.
- We can use any measurement of mass and/or volume to express **density of water**:
    - 62.4 pounds per cubic foot (62.4 lbs/ft^3)
    - Kilogram per liter (1.0 kg/L)
    - 1 gram per cubic centimeter **(1.0 gm/cm^3)** = 1.0 gram per milliliter **(1.0 gm/mL).**
- In this exercise, we will use the standard Metric System unit for density, **grams per cubic centimeter (gm/cm^3).**
- To measure the **density** of something in **gm/cm^3**, we need to measure both its **mass in grams** and its **volume in cubic centimeters**.
    - Measuring **mass** is easy; we just weigh the object on a scale.
    - We will measure volume by the first method. If the container that the wood blocks are floating in was graduated, then the 2^{nd} method would be an alternative.
        - by linear dimensions
        - by water displacement

QUESTION 1: Heft the pieces of oak and redwood in your two hands. Which one feels denser (heavier for a given amount)?

____

Determine the density of oak and redwood.

1) Weigh the blocks to the nearest gram.
2) Use a ruler to measure, in centimeters, the length, width and height of the blocks.

OAK: **Weight:** ____________ **Length:** ___________ **Width:** ___________ **Height:** ____________

Volume by ruler: cubic cm (cm^3) (length x width x height): ___________________ *include units*

Density (linear): (weight / volume): _________________ gm/cm^3 (round to nearest 0.01)

Show work:

REDWOOD: **Weight:** __________ **Length:** __________ **Width:** _________ **Height:** __________

Volume by ruler: cubic cm (cm^3) (length x width x height): __________________ *include units*

Density (linear): (weight / volume): _______________ gm/cm^3 (round to nearest 0.01)

Show work:

QUESTION 2: The density of water is 1.0 gm/cm^3. Comparing the density of water to the density of Oak and redwood, **predict** what proportion (percent) of your blocks will stick up out of the water when the pieces of wood are floating.

OAK: _________ % of the block will be underwater, and __________ % will stick out of the water.

REDWOOD: _________ % of the block will be underwater, and ________ % will stick out of the water.

QUESTION 3: Take the pieces of redwood and oak and float them in water. Do your predictions in #2 above fit with what you see?

Draw below a simple side view sketch of the two blocks across the waterline, labeling each block and showing how different proportions stick above the water. (Note: Keep this observation in mind when you do the final part of the lab.)

OAK **REDWOOD**

____ **water line**

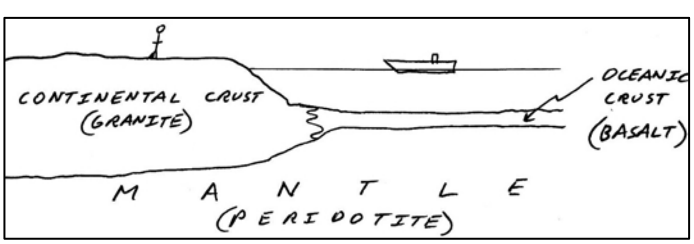
QUESTION 4: Think about what you saw with the blocks of oak and redwood floating. What effect did the difference in density between the two types of wood have on how high each one floated?

ISOSTATIC EQUILIBRIUM OF THE EARTH'S CRUST

In this part of the lab, we will see how differences in the density and thickness of rock control the elevations of the Earth's crust. We'll also see how the crust adjusts when loads of weight are added or taken away.

The Earth is made up of two kinds of crust: continental crust and oceanic crust. **Continental crust**, which is mostly **granite** and rocks of similar density, makes up the continents. **Oceanic crust** is mostly the rock **basalt**, which makes up the floors of the ocean basins. Both types of crust lie on the Earth's **mantle**, which is mostly the rock **peridotite**. The illustration below shows that the continental crust and the oceanic crust have different thicknesses. Continental crust averages about 35 km thick (more underneath mountains), while oceanic crust averages about 5 km thick. The two types of crust, and the underlying mantle, also differ in their density. Most Earth rocks range in density from about 2.6 to about 3.3 gm/cm^3 -- even small differences in density can have important effects.

The geologist Clarence Dutton proposed decades ago that the Earth's two types of crust "float" buoyantly on the mantle, much in the way that an iceberg or a block of wood floats buoyantly in water. He called this condition **isostasy** (Greek for "equal standing"). When the crust floats in a balanced, stable manner in the mantle beneath, we have a condition called **isostatic equilibrium**. This turns out to be a very useful concept, as you will see.



Density of the continental crust (granite): 2.7 gm/cm^3

Density of the oceanic crust (basalt): 3.0 gm/cm^3

Density of the upper mantle (peridotite): 3.3 gm/cm^3

QUESTION 5: What is the connection between wood floating in water and the crust (either type) floating in the mantle? Use specific values of density for wood, water, crust, and mantle in your answer.

QUESTION 6: Imagine a thick block of wood and a thin block of wood, **both with a density** of 0.5 gm/cm^3 floating in water next to each other. Would the tops be at the same level? Why or why not?

Draw below, an accurate side view sketch showing how these two blocks would look floating next to each other. Note: "accurate" here means that you need to consider the density of the wood relative to water.

thick block of wood   **thin** block of wood

____ **water line**

QUESTION 7: Geologists know that the continental crust is much thicker underneath mountain ranges than it is in low areas. Thinking about your answers above, explain why.

PART 2 – EARTHQUAKES, VOLCANISM, AND PLATE TECTONICS

Preview: In this portion of the lab you will explore how the vast majority of the earth's earthquakes and active volcanoes are closely tied to plate boundaries, and the dynamic nature of these boundaries in terms of plate interactions (movement).

Plate interactions give rise to three very important tectonic processes**:** **1)** ocean crust formation and seafloor spreading at divergent boundaries, **2)** ocean crust being destroyed by subduction at oceanic convergent boundaries; and **3)** crustal strike-slip faulting/shearing where plates slide/grind past each other at transform boundaries. Ultimately, most earthquakes and volcanism are caused by these tectonic processes.

Some Helpful Animations:

- Overview of three plate boundaries
  - https://mediaplayer.pearsoncmg.com/assets/FDCWGCDD_fASmPKmRShIyvOqUCeQskWU
- Divergent plate boundary
  - https://mediaplayer.pearsoncmg.com/assets/lTg4rv5_xUXtvoA6JlpklhR0VUWmPTD4
- Subduction at oceanic convergent boundaries
  - https://mediaplayer.pearsoncmg.com/assets/0vpJLiuHydOxO_aZzlAXJfUK8RUNsEIX
- Transform boundaries
  - https://mediaplayer.pearsoncmg.com/assets/zx_YmKtda90vW78ClsCsmD2HUPqiQoHR

The **websites below** have **interactive maps** in which you can overlay one data set over another in order to see the spatial relations between the two or more different worldwide geologic/geographic phenomena.

- Plates on the Move
  - https://www.amnh.org/explore/ology/earth/plates-on-the-move2
- Plates and Plate Boundaries
  - https://divediscover.whoi.edu/plate-tectonics/plate-boundaries/
- Earthquakes, Volcanism and Plate Boundaries
  - http://d3tt741pwxqwm0.cloudfront.net/WGBH/conv16/conv16-int-tectonic/index.html
- Moving plates and stress (very helpful)
  - https://www.youtube.com/watch?v=hdzencI_xkE

In this section you will compare the distribution of earthquakes and active volcanoes to plate boundaries and plate boundary processes. You will use a set of five world maps on the table. SEE MAPS ON THE LAB TABLE

DIRECTIONS: Below are sets of questions addressing the relationship between earthquakes, volcanism, age of the seafloor, surface elevation and depth to plate boundaries.

Geography of the Ocean Floor:

Compare the **Geography Map** and the **Seafloor age Map (Geochronology)**. Look for the **youngest ocean crust** in all three ocean basins.

QUESTIONS

1. Do these regions correlate with shallow or deeper ocean floor?_____________________________
2. Which ocean floor plate tectonic feature is found here (all ocean basins)?_____________________________
3. What type of plate boundary is here?____________________________

Worldwide Earthquake Distribution

Earthquakes occur all over the Earth on a daily basis. The distribution of earthquakes worldwide is far from random, but instead, is mostly concentrated along narrow curvilinear regions. Most earthquakes occur in the shallow crust, but some occur much deeper in some places. In this section, you will explore the global pattern of earthquakes and their proximity to plate boundaries. You will also analyze shallow versus deep earthquakes, and why deep earthquakes are only found in association with convergent boundaries.

DIRECTIONS: Below are a set of questions concerning worldwide earthquake distribution and their relations to plate boundaries and plate processes. Study the **World Earthquake Map (Seismology)** and then compare it to the **Plate Boundary Map (your map).**

QUESTIONS

SHALLOW EARTHQUAKES (SHEQ): SEE Earthquake MAP

1. How well do the shallow earthquakes (red color dots) locate ***divergent plate boundaries*** (i.e. places where plates separate, such as at mid-ocean ridges)? What major plate tectonic process (rifting **or** collision) occurs at these places?

-
- rifting or collision

2. How well do the shallow earthquakes locate ***convergent plate boundaries,*** (i.e. subduction zones at ocean trenches, or continental collision zones)? What major plate tectonics process occurs at these places? (rifting **or** collision/subduction)

-
- rifting **or** collision/subduction

3. How well do the shallow earthquakes locate ***transform plate boundaries***, such as the San Andreas fault? What major plate tectonics process occurs at transform boundaries?

-
-

4. Notice that the **zones of earthquakes** narrowly delineate plate boundaries in most areas of the map. But for some plate boundaries, the earthquakes are <u>spread out over a broader area.</u> Which type of plate boundary is characterized by *the **broadest zones*** of earthquakes? *Hint: Look in the area where the African Plate and Indo-Australian Plate are colliding with the Eurasian Plate – from Spain to India **and** where you see deeper EQ*

Circle two options below.

spreading center ***transform fault*** ***subduction zone*** ***continental collision zone (cont.-cont.)***

DEEP EARTHQUAKES: SEE Earthquake MAP

5. What type of plate *boundary—divergent, convergent,* or *transform—has* <u>deep</u> earthquakes? (green and blue dots on the earthquake map) ___________________________

6. What major process of plate tectonics is responsible for making deep earthquakes? ______________

By convention, the "teeth" symbols on lines that trace subduction zones (**see Earthquake map**) <u>point in the direction that the plate is slanting downward</u> as it subducts. (For example, if the teeth point east, it means that the subducting plate is slanting down towards the east from where it enters the trench.)

Arrow is pointing in direction of plate movement

7. How does the direction that the plate slants relate to **why deep earthquakes do not correlate with shallow earthquakes?** In other words, **why do the deep quakes occur parallel to, but not exactly overlapping with the shallow quakes?** Include in your answer a **<u>simple cross-section of a subduction zone</u>** with the upper and lower plate with down going slab.

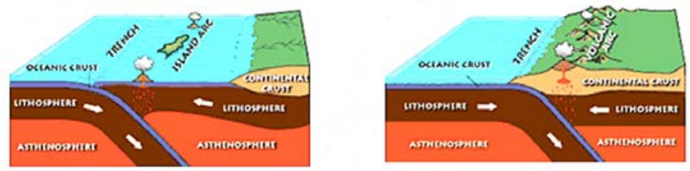
***Answer*:____**

<u>ON YOUR CROSS SECTION</u> <u>place</u> and <u>LABEL</u> the following: 1) With a bold dot: <u>SHEQ</u> *(BOTH focus and epicenter),* **2) With a bold dot: <u>DEQ</u>** *(BOTH focus and epicenter)*. **After completing the next section on volcanoes, add the following 3) <u>Arc</u>** (draw a volcano) **, 4) Melting at depth below arc , say "<u>melting</u>". Point with an arrow the rock that is melting.**

Draw and understand this! You might have to do it again.

Worldwide Volcano Distribution

Volcanism occurs all over the Earth. However, just like earthquakes, the distribution of active volcanoes worldwide is far from random, but instead, is mostly concentrated along narrow curvilinear regions – mostly concentrated around the edges and centers of the ocean basins, especially the Pacific Ocean basin – just like the earthquakes. Most of the active volcanoes on Earth are found around the edge of the Pacific Ocean basin – these are termed **arc volcanoes** and form either a chain of volcanic islands (island arcs), or as a mountain volcanic chain along the margin of a continents (continental margin arcs). In this section, you will explore the global pattern of active arc volcanism and their proximity to convergent plate boundaries. You will also analyze why active arc volcanism is closely associated with deep earthquakes, and why both are only found at oceanic convergent boundaries.



Island arc formed by oceanic-oceanic subduction

Volcanic arc formed by oceanic-continental subduction

DIRECTIONS: Study the **Volcano Map** and compare it to the **Earthquake Map (Seismology)**. Then compare it to your **Plate Boundary Map.**.

QUESTIONS

1. In general, how well do the Earth's active volcanoes locate plate boundaries? ***Please note:*** *the map shows too many volcanoes in CA. CA is a transform plate boundary, however, there are volcanoes associated with Basin and Range rifting to the east and subduction in the very northern region of CA close to the state border*

very well pretty good okay not very well

2. Which of the three types of plate boundaries is mostly absent of active volcanoes? Why might that be?

- ____________________________
- **Why?**

3. Do the volcanoes show the MOR (mid ocean ridge) distribution well, like you see with the shallow earthquakes?
Hint: the Volcanology Map focuses on arc and hotspot volcanoes, ***not*** *submarine volcanism.*

very well pretty good okay not very well

4. Are "arc" volcanoes more closely associated with the shallow earthquakes or with the deep earthquakes, in terms of shared location? Explain the connection between the two phenomena in terms of plate tectonic processes. In other words, **what tectonic process is responsible for arc volcanoes and deep earthquakes**? *Hint: Your explanation should refer back to your cross-section sketch for the deep earthquake question* ***#7***

- Arc volcanoes are more closely related to: **a)** shallow earthquakes **b)** deep earthquakes
- Tectonic process: _______________________________
- Are the majority of the shallow earthquakes located on the trench side or of the arc? **Yes or No**

5. The term "Pacific Ring of Fire" reflects what type of spectacular geologic activity found around the edge of the Pacific Ocean basin? Why isn't there a "RING OF FIRE" (strato volcanoes) all around the Atlantic Ocean or Indian Ocean basins?

_____________________________ is NOT occurring

Part 3 – Tectonic Plate Motion and Processes

Measuring and Evaluating Plate Motion

Geologists use several methods to establish plate velocities, which includes both speed and direction. One method is to analyze hot spot traces. Another method analyzes the age-dated paleomagnetic strip patterns imbedded in the deep seafloor crust. Yet another method looks at the offset along transform faults. In all three cases, the **two pieces of data that need to be collected to calculated plate motion are: 1) distance between two points on Earth's surface and 2) the age difference of the crustal rocks at the two points.**

To determine a plate's rate of motion you divide the distance (kilometers) by time/age (years). However, plate motion units expressed in centimeters per year, so you will need to convert kilometers to centimeters (10^5 cm per km) to get a final velocity in centimeters per year.

Formula: Velocity = Distance/Time (km's/year)

Conversion Factor: 1 km = 100,000 cm = 1 x 10^5 cm

1) Using Hot Spots to Measure Plate Motion

Example: The Hawaiian Hot Spot and Pacific Plate Motion

The Earth has a number of active volcanic regions termed "hot spots". Most of these locations are intra-plate sites of mantle-derived magma eruptions – mostly basaltic – that typically form chains of volcanoes over time as the result of the overlying plate sliding over the mantle-rooted hot spot. A world-class example is the Pacific plate moving over the Hawaiian hot spot in the center of the North Pacific Ocean basin. The Hawaiian Islands are the direct result of this hot spot/plate interaction.

Resources to learn more about Hot Spots:

- **Reading:** http://sci.sdsu.edu/how_volcanoes_work/intraplvolc_page.html
- **Video:** https://www.youtube.com/watch?v=AhSaE0omw9o

Now to determine the velocity at which the Pacific plate is riding over the Hawaiian hot spot (assuming that the mantle hot spot is moving itself), you need to pick two Hawaiian Islands, determine the distance between the two, and know their difference in geologic age (see **Figure 2**).

Note that the **direction of plate motion** is always **toward the older** volcanic centers (islands).

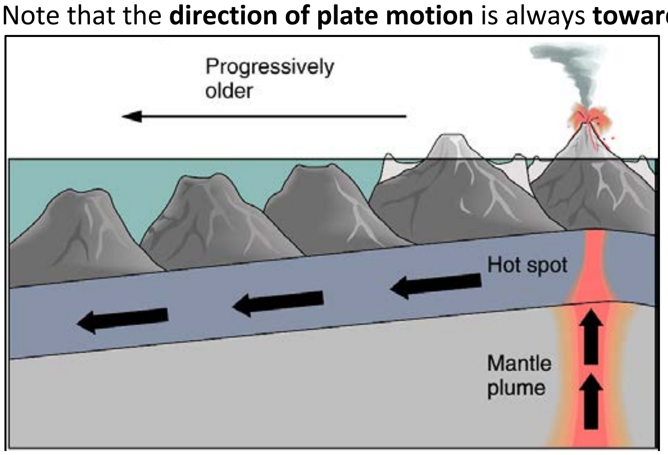


FIGURE 1 – **HAWAIIAN ISLANDS**

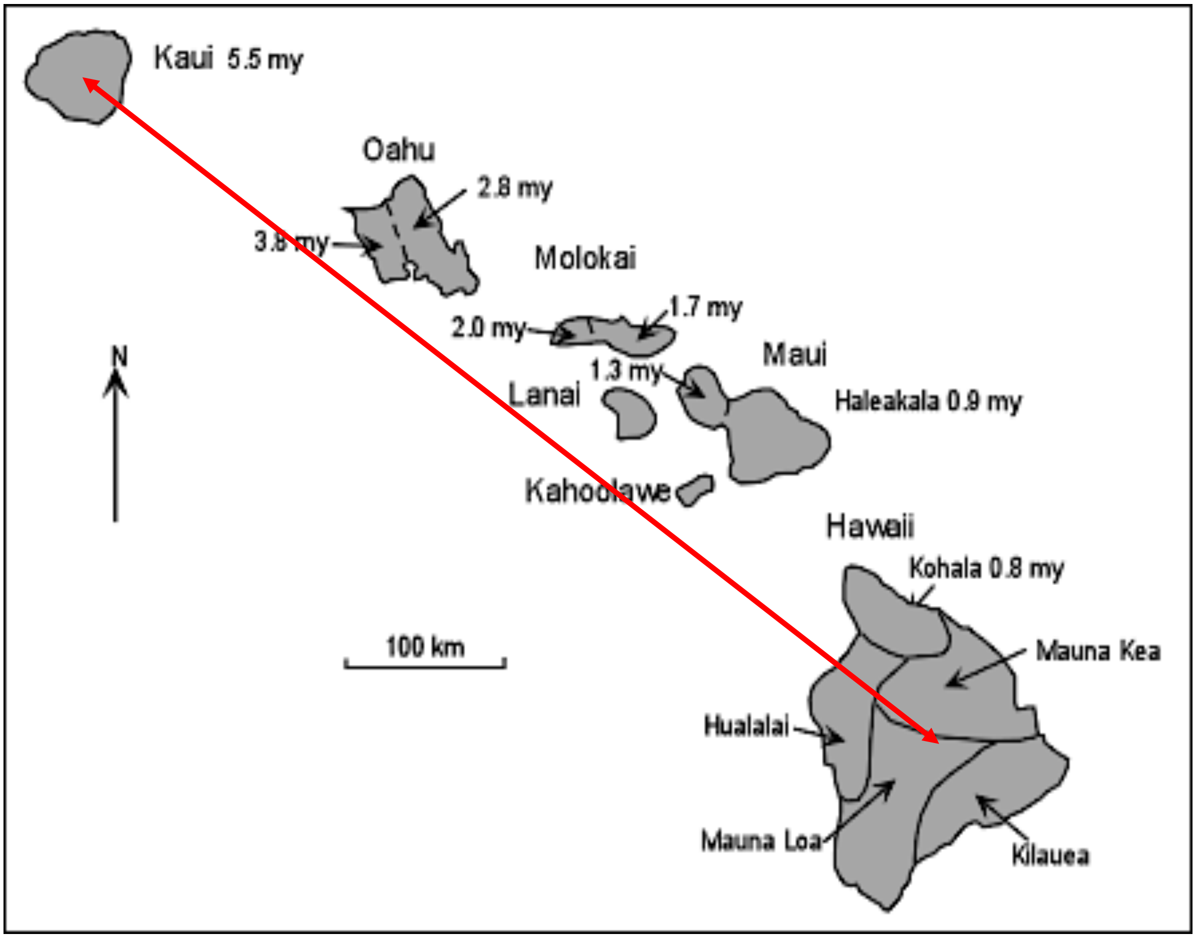


FIGURE 2 – **HAWAIIAN ISLANDS and AGES**

DIRECTIONS: you will use the island of Kauai and the Big Island to determine the average speed and direction of plate motion of the Pacific plate over the hot spot for the last five million years. You have two maps of the Hawaiian Islands hot spot island and seamount chains that you will use to answer the following questions.

SEE FIGURES IN SHEET COVERS ON THE TABLE: Do your measuring using images on the table

1. Which Hawaiian island in Figure 1 is the OLDEST – Kaua'i or the Big Island? ________________________

2. What is the calculated *average speed* for the Pacific plate for the time period between the formations of the islands of Kaua'i and the Big Island of Hawai'i? Note: For the calculation, **assign the Big Island with an age of "zero".** Measure distances from the center of each island (see **Figure 1**).

$$\boldsymbol{Velocity} = \frac{Distance\ between\ the\ islands\ (km)}{Age\ difference\ (yrs)} \times \frac{100{,}000\ cm}{1\ km}$$

Work:

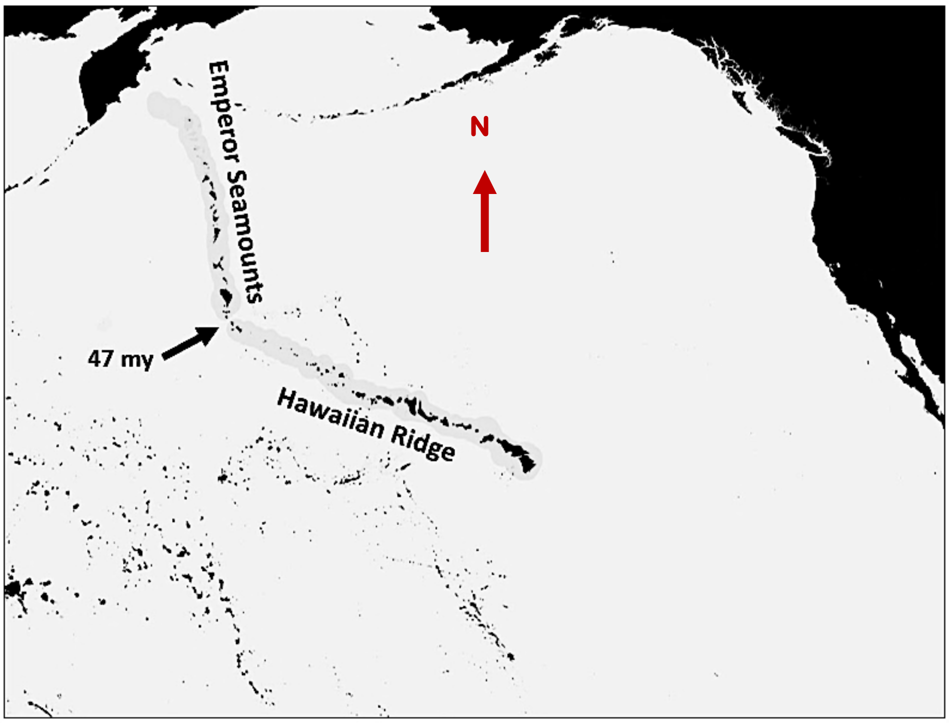
Answer: _________ cm/year

3. What is the interpreted **plate motion direction** for the Pacific plate for the time period between the formation of Kauai and the Big Island of Hawaii? (see **Figure 1 above**). Based on the hot spot method, the Pacific Plate was moving **toward** which direction

(circle answer) **N** **NE** **E** **SE** **S** **SW** **W** **NW**

THE EMPEROR SEAMOUNT CHAIN was formed by the same hot spot that is currently forming the Hawaiian Island chain (labeled as the Hawaiian Ridge on **Figure 3**). We will compare the **Emperor Seamount chain** and the **Hawaiian Island chain** with respect to their geographic extent and proximity to each other in the North Pacific basin, and their most likely (hot spot) volcanic origin.
Based on your analysis of these volcanic chains and their relation to the Hawaiian hot spot, answer the following questions:

4. Which **chain** is older – the Emperor Seamount Chain or the Hawaiian Island Chain (labeled as Hawaiian Ridge on **Figure 3**)? **EXPLAIN HOW YOU KNOW.**



<u>FIGURE 3</u> – PACIFIC SEAMOUNT HOT SPOT CHAINS
Data source: GEBCO Compilation Group (2020) GEBCO 2020 Grid (doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9)

5. <u>On **Figure 3**</u> **ABOVE,** make the following markings:
   a. **<u>Circle the youngest feature</u>** being created by the hot spot responsible for the Hawaiian Islands and the Emperor Seamounts
   b. **<u>Draw an X marking the oldest feature</u>** created by the hot spot responsible for the Hawaiian Islands and the Emperor Seamounts
   c. **<u>Draw an arrow showing the path of the Pacific Plate</u>** as it moved over the hot spot responsible for the Hawaiian Islands and the Emperor Seamounts

6. **When the <u>Emperor Seamount</u> volcanic chain was being formed,** the plate was moving **toward** which direction?
   (circle answer) **<u>N</u>** **<u>NE</u>** **<u>E</u>** **<u>SE</u>** **<u>S</u>** **<u>SW</u>** **<u>W</u>** **<u>NW</u>**

7. The Hawaiian hotspot mantle plume has already started forming the next Hawaiian island. Since it hasn't grown big enough to reach above sea level, we call these formations "seamounts". **Do some internet sleuthing to discover the name of the new Hawaiian seamount. ______________________________**

8. The Hawaiian hotspot is only one of several hot spots across the globe. Do some internet sleuthing - what are some other places with hotspot features? List at least two.

1) **2)**

2) Using Mid-Ocean Spreading Centers to Measure Plate Motion

The Pacific and Juan de Fuca plates meet each other at the Juan de Fuca Ridge (letter B) – an oceanic spreading center off the coast of the Pacific Northwest. (See **Figure 4 below**) The **Juan de Fuca Ridge** forms the boundary between the **Pacific plate to the southwest** and the **Juan de Fuca plate to northeast**. Further east, the Juan de Fuca plate meets the North American plate, which coincides with the western edge of the North American continent. **MUST SEE** this **HELPFUL** video for a brief explanation of this region's plate tectonics.
https://www.youtube.com/watch?v=tRQmq3t866w

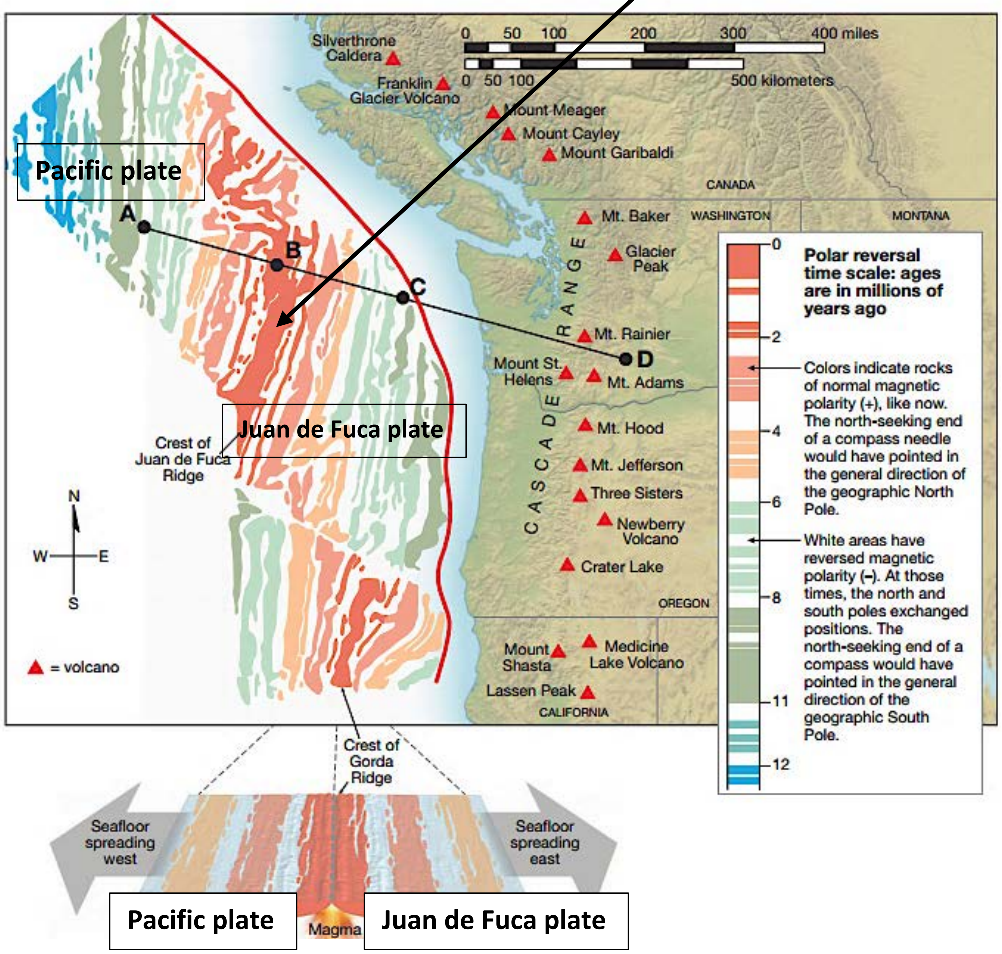


FIGURE 4 – JUAN DE FUCA RIDGE AND CASCADE VOLCANOES

ON THE FIGURE ABOVE LABEL the 1) MOR and 2) TRENCH:

1) the **MOR**, which is a ___________________________plate boundary

2) the **Trench**, which is a ___________________________plate boundary

SEE FIGURES IN SHEET COVERS ON THE TABLE: **Do your measuring using images on the table**

1. What is the interpreted plate motion **direction for the Pacific plate**, based on the orientation and age sequence of the paleo-magnetic seafloor stripes? ***Hint**: draw a line perpendicular to the magnetic anomalies*

   (circle answer) **N** **NE** **E** **SE** **S** **SW** **W** **NW**

2. What is the calculated **average velocity for the Pacific plate for the last 8 million years** (in relation to the spreading ridge), based on the absolute age-dated paleo-magnetic seafloor anomalies between 0 and 8 million years? **Measure the distance from the spreading center** (mid ocean ridge) **toward the NW on the Pacific Plate** (from "B" to "A" on Figure 3). Note: The **spreading ridge (MOR) has an age of "zero" (see B)** and **"A"** (boundary between light and dark green) is **8 million years.**

$$\boldsymbol{Velocity} = \frac{Distance\ between\ the\ magnetic\ stripes\ (km)}{Age\ difference\ between\ stripes\ (yrs)} \times \frac{100{,}000\ cm}{1\ km}$$

Work: **Answer:** _________ cm/year

3. What is the interpreted plate motion direction for the **Juan de Fuca plate,** based on the age pattern and geographic orientation of the magnetic seafloor anomalies (and spreading ridge)? ***Hint**: draw a line perpendicular to the magnetic anomalies*

   (circle answer) **N** **NE** **E** **SE** **S** **SW** **W** **NW**

4. What is the calculated average **velocity for the Juan de Fuca plate for the last 8 million years** (in relation to the spreading ridge), based on the absolute age-dated paleo-magnetic seafloor anomalies between 0 and 8 million years? **Measure the distance from the spreading center toward the SE on the Juan de Fuca plate** (from "B" to "C" on Figure 3). Note: The spreading ridge has an age of "zero" and "C" (boundary between light and dark green) is **8 million years.**

$$\boldsymbol{Velocity} = \frac{Distance\ between\ the\ magnetic\ stripes\ (km)}{Age\ difference\ between\ stripes\ (yrs)} \times \frac{100{,}000\ cm}{1\ km}$$

Work: **Answer:** _________ cm/year

5. Note in **Figure 4** that there are **no paleo-magnetic seafloor anomalies older than 8 million years on the Juan de Fuca Plate**, whereas, paleo-magnetic anomalies west of the spreading center on the Pacific plate are up to 14 million years old and older beyond the map. Assuming that both plates have been growing equally on both sides of the JDF spreading center, then **what happened to the seafloor on Juan de Fuca Plate that was older than 8 million years?** *Hint: Check type of plate boundary between Juan de Fuca and North American Plates.*

3) Using Transform Fault Offset to Measure Plate Motion

Example: ***The San Andreas Transform Fault***

Lateral offset between plates that meet at a transform boundary is a direct measure of the relative motion between those two adjoining plates. If there are recognizable datable geologic offset markers found at a transform boundary, then the average speed of lateral plate motion offset can be established. The Pacific and North American plates meet each other along the San Andreas Fault – a world famous continental transform plate boundary. (See **Figure 5**) Here the two giant plates grind past each other in opposite directions.

- **Check out this video on the San Andreas Fault:** https://www.youtube.com/watch?v=tIuk2blBzHs

When a datable geologic feature – like a lava flow - forms across the San Andreas Fault, that feature will be eventually split into two opposing pieces, and systematically be carried further and further apart from each other (offset) by subsequent lateral "strike-slip" fault movements (earthquakes).

- **Geologic offset along the San Andreas Fault**: https://www.youtube.com/watch?v=TCzst8X2wOY

So, you can calculate the average rate of fault offset (transform speed between the two plates) for the time period from the age of the offset marker to present day by dividing the distance between the two offset pieces by the age of the offset feature (marker). **There are two possible transform motion directions**: ***right-lateral* and *left-lateral*.** (See **Figure 6**)

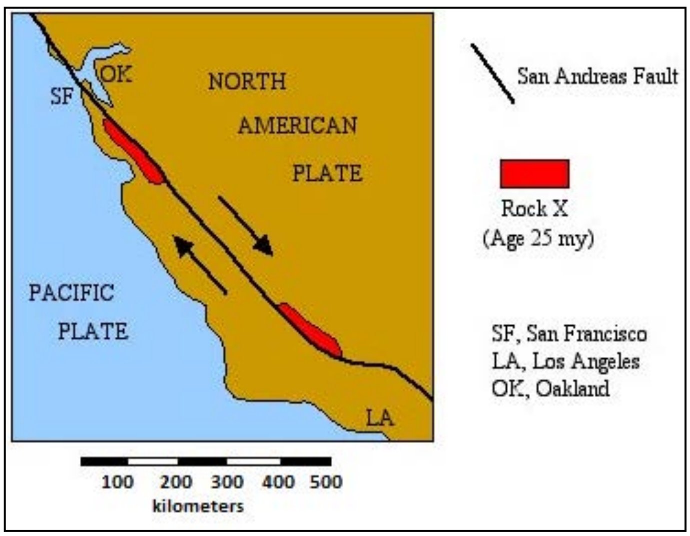


FIGURE 5. San Andreas Fault Offset Marker

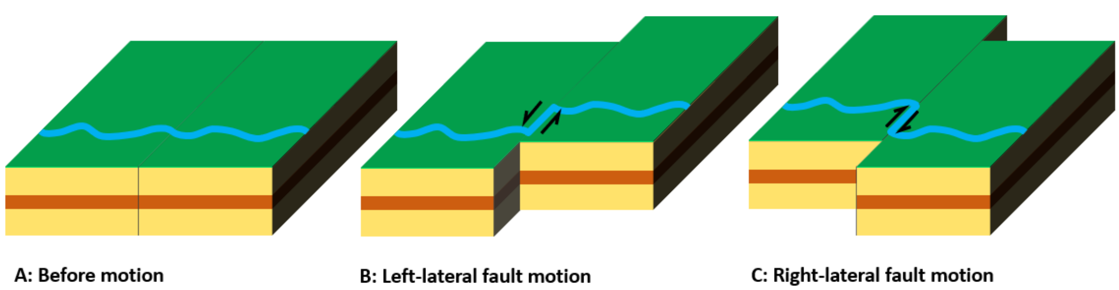


FIGURE 6. Fault Motion

6A: before motion occurs, **6B:** left-lateral fault motion, **6C:** right-lateral fault motion

SEE FIGURES IN SHEET COVERS ON THE TABLE: Do your measuring using images on the table

1. What is the **calculated average rate of transform motion between the Pacific and North American plates along the San Andreas Fault over the past 25 million years?** Use the offset (broken-apart/displaced) Miocene-age (25 million years old (my)) volcanic bodies as the offset marker (Rock "X" info on **Figure 5**)

   Note: Measure from center points of each red body for the distance.

$$\boldsymbol{Velocity} = \frac{Distance\ between\ the\ offset\ volcanics\ (km)}{Time\ since\ the\ offset\ rocks\ were\ together\ (yrs)} \times \frac{100{,}000\ cm}{1\ km}$$

Work: **Answer:** _________ cm/year

2. What is the interpreted relative transform plate offset motion between the Pacific and North American plates using the noted 25 my Miocene volcanic body (Rock X) as an offset marker (shown in **Figure 5**)

   In other words, **is the San Andreas Fault a *right-lateral* or *left-lateral* transform fault?** How do you know?

3. Which direction is San Diego going, plate wise? Northwest or Southeast? ____________________

4. If the San Andreas Fault continues to move at the same calculated rate, how long will it take before San Diego, CA and Oakland CA are neighboring cities?

   Note: San Diego and Oakland are 750 km apart

$$\boldsymbol{Time}\ (\boldsymbol{yr}) = \frac{Distance\ between\ the\ cities\ (km)}{Velocity\ (km/yrs)}$$

DONE WITH THE PLATE TECTONIC LAB!

TOPOGRAPHIC MAP PRELAB EXERCISE

Refer to free online lab manuals on Bb in the "Lab folder"

- **p. 19-22, 47-49** in the **Weise online lab** manual
- **p. 41-49** in the **Galileo online lab** manual

Answer the following on scantron form:

Match the numbered word to the letter definition (1-5)

1. Fractional scale	a. difference in elevation between 2 points on a map
2. Bar scale	b. townships and ranges
3. Topographic profile	c. 1 unit on the map represents 24,000 units of same units on Earth's surface or ratio scale
4. Public land survey	d. used to measure distance on a map
5. Relief	e. allows a "side-view" perspective

Study the rules for contour lines. Answer the true/false questions (6-9).

6. Every point on a contour line represents the exact same elevation.
7. Contour lines always cross one another on the map.
8. The farther apart the contour lines are on the map, the steeper the slope.
9. Contour lines form a V pattern when crossing streams that points downstream.

Match the numbered word to the letter definition (10-14)

10. Latitude	a. can be traced through England, Africa, and the south Atlantic
11. Longitude	b. shortest distance between 2 places on Earth
12. Prime Meridian	c. east-west distance on Earth,
13. Great Circle	d. north-south distance, measured as an angle from the center of Earth
14. The Equator	e. 0° 00' 00''

15. What is the correct **latitude for San Diego**?
    a) 32° 45' N
    b) 117° 08' W
    c) 30° 30' N
    d) 116° 45' W
    e) 35° 32' 45'' N

16. What is **UTM zone for San Diego**?
    a) 5
    b) 11
    c) 16
    d) 32
    e) 116

TOPOGRAPHIC MAP EXERCISE

Group Members: ____Recorder Initials:______

LEARNING OBJECTIVES

Develop basic topographic map skills: measure distances with map scales, interpret contour lines, and determine the latitude and longitude of a location on a map

HELPFUL RESOURCES:

- **p. 19-22, 47-49** in the **Weise online lab** manual
- **p. 41-49** in the **Galileo online lab** manual
- Topographic map chapter in the **manual on your table**
- Notes from ppt lecture
- YouTube tutorial videos covering the **basics** of a simplified topographic map
  - https://www.youtube.com/watch?v=bENEygui4jo
  - https://www.youtube.com/watch?v=wjQZGB0LYYo
  - http://www.ghosttowns.com/topotmaps.html
- San Diego Topographic maps**:** http://www.efghmaps.com/SAN_DIEGO/index.html
- YouTube tutorial videos on **relief and gradient**
  - http://serc.carleton.edu/mathyouneed/slope/index.html
  - http://serc.carleton.edu/mathyouneed/slope/slopes.html
  - https://www.youtube.com/watch?v=semOKPvmoso
- YouTube tutorial videos on the **Rule of Vs**
  - https://www.youtube.com/watch?v=XZTMyBMiIQo
  - https://www.youtube.com/watch?v=RNLXXHA8iBE

The World in Three Dimensions

Through the following parts of this lab, we will be exploring the ways that we communicate the three-dimensional world into a two-dimensional map. **Latitude and longitudes** make up a network of reference lines on the globe, these are incorporated into two-dimensional maps, transferring location information from 3D to 2D. We can also communicate information about elevation through map notations called **contour lines**, which are lines representing constant elevation.

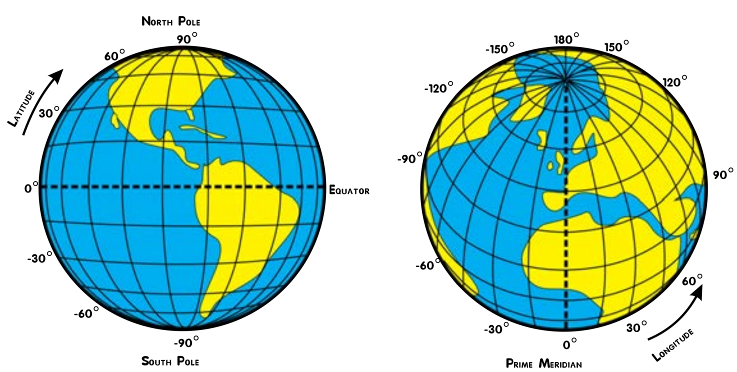


Figure 1: *Latitude (left) and longitude (right).*

Image credit: Public Domain

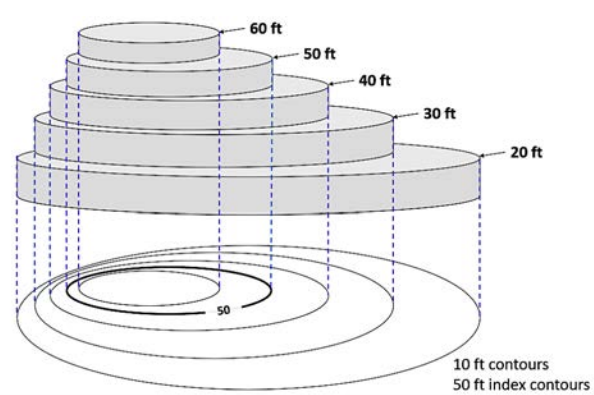


Figure 2: *Layer cake (top) with contours (bottom)*

Image credit: EOSC, USD

YOSEMITE TOPOGRAPHIC MAP

Section A: Topographic Fundamentals and Features

1. In what years was this map published or revised? _______________, _________________

2. What type of map projection was used to create this map? _________________________

Coordinate Systems

3. Write **latitude & longitude coordinates** the two corners of this map? ***(include hemisphere letter)***

	NE Corner	SW Corner
Latitude:	________________	_________________
Longitude:	________________	_________________

4. Latitude & longitude interval (arc distance) **tick marks**, along edges of the map, are ________ minutes apart.

UTM: *see manual on desk*

5. Which **UTM zone** is this map area located in? ______________________

6. What are the **UTM** coordinates for each of the two corners of this map? *(include units & E or N)*

	NW Corner	SE Corner
Easting:	_________________	_________________
Northing:	_________________	_________________

Map Scale

7. What is the ratio scale of this map? ______________________________

8. What is the verbal scale of this map? ____

Review ratio scale:

9. One inch on this map equals exactly _______________ inches of real ground distance.

10. One centimeter on this map equals ________________ kilometers of real ground distance.
Hint*: use the ratio scale and* ***show work***

11. Roughly, how many square miles of real ground does this map cover (Including Legend area)? _______________

show work:

Magnetic Declination

12. What is the magnetic declination? _____________(use **degrees**) East or West declination? ______

13. The declination is based on what year? _______________

Map Features and Symbols

14. Name the topographic map that continues to the NE of this map? _________________

15. What do red dashed or solid lines represent? ______________________________ [Hint: **Related to PLS**]

16. What do associated red numbers indicate? __________________________________ [Hint: **Related to PLS]**

17. Difference between the black dashed and solid double lines?

18. What type of symbols represents buildings on the map? ________________________

Section B: Location, Bearing, and Distance

Establishing Location

19. **Interpolate the best approximate** latitude and longitude for these locations *(include hemisphere letter)*:

	Half Dome	El Capitan (the top)
Latitude:	________________________	________________________
Longitude:	________________________	________________________

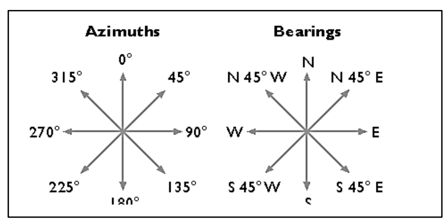
Establishing Bearing and Distance

20. Determine the bearing and distance **from Half Dome to Clouds Rest**.

Quadrant bearing: _________________

Azimuth bearing: _________________

Distance (miles): _________________



21. Determine bearing & distance **from Glacier Point** (triangular BM, 7214') **to Bridalveil Falls**, where Creek crosses 4800' contour.

Quadrant bearing: _________________

Azimuth bearing: _________________

Distance (miles): ________________

Section C: Contours and Surface Relief

22. What is the contour interval of the map? ______________

23. What is the contour interval between the dark/thicker contour lines (Index)? _____________

24. What is the highest measured elevation (benchmark, in feet) on this map? _________________

25. What is the lowest measured elevation (benchmark, in feet) on this map?(see Merced River) _______________

26. What is the total relief of this area? (Difference between highest and lowest elevations?) ____________________

show work:

27. Tightly-spaced contour lines represent what type of geographic feature? ______________

28. Broadly-spaced contour lines represent what type of geographic features? _____________

29. Sets of contour lines that form "V"-shaped patterns pointing to lower elevations represent what sort of general **geographic feature**? (hint: either stream channels or ridge lines) **Answer**:______________________

30. Sets of contour lines that form "V"-shaped patterns that point to higher elevations represent what sort of general **geographic feature**? (hint: stream channels or ridge lines?) **Answer:______________________**

31. **Imagine you are hiking across El Capitan Meadow in Yosemite Valley** and then the next day across **Tenaya Creek,** right below Watkins Pinnacles. **Describe the general shape of each area** as you look up the steep "walls" of granite on each side. Essentially you are thinking about a profile.

- Which is "V" shape and which is "U" shape?
- Which erosional agent is primarily responsible for the shaping of these two sections of Yosemite Valley? **Choose** between water, ice, and wind.
- Briefly explain your choice.

Tenaya Creek Profile: U or V shape ______ Erosion agent: _____________ Why: ________________________

El Capitan Meadow Profile: U or V shape _____ Erosion agent: _____________ Why: _____________________

Geographic Features

31. Which direction does the Merced River Flow through Yosemite (see overall direction)? East or West?

Answer:____________________. Determined by: ______________________, or _________________

32. What special name is used in Yosemite Valley for high promontories that form **flat-topped** "bulls-eye" contour patterns? (hint: rhymes with "home") **Answer:**____________________

Go to Yosemite Valley virtually.. ☺

- **Half Dome**: https://earth.google.com/web/@37.74593833,-119.53319351,2690.54516454a,4205.12446046d,35y,-167.09132146h,44.99997986t,0r/data=ClgaVhJQCiUweDgwOTZmM2VhYmRiMWMwYTM6MHhhM2E1NDQyY2MyZWM3YTY0Ga-6xEd630JAITeQie8f4l3AKhVlYWxmIERvbWUsIENhbGlmb3JuaWEYAiAB
- **El Capitan** : https://earth.google.com/web/search/El+Capitan+peak+/@37.72363935,-119.64249415,1208.19066642a,7618.54217768d,35y,161.50828629h,45.04325593t,0r/data=CnsaURJLCiUweDgwOTZlZGQ4MjRkYjhmYmQ6MHg1N2FkY2M3NjJmYjNkNDAzGaJCdXPx3UJAIRJCrKPP6F3AKhBFbCBDYXBpdGFuIHBlYWsgGAIgASImCiQJoFRrOyzgQkARC0qHIlDVQkAZQmNVV-LfXcAhpSWKXvDmXcA
- **Valley and Cathedral Peaks:** https://earth.google.com/web/search/Cathedral+Rocks+peak/@37.7226496,-119.63468679,1202.77491928a,9706.37291117d,35y,91.25582384h,45.03492883t,0r/data=CigiJgokCT_2Vt7n3UJAEZ522jSG2UJAGZTqUboV513AIWvzMz3R6l3A

Section D: GRADIENT AND VERTICAL EXAGGERATION

PLEASE MAKE SURE YOU UNDERSTAND THE DIFFERENCE BETWEEN VE AND GRADIENT

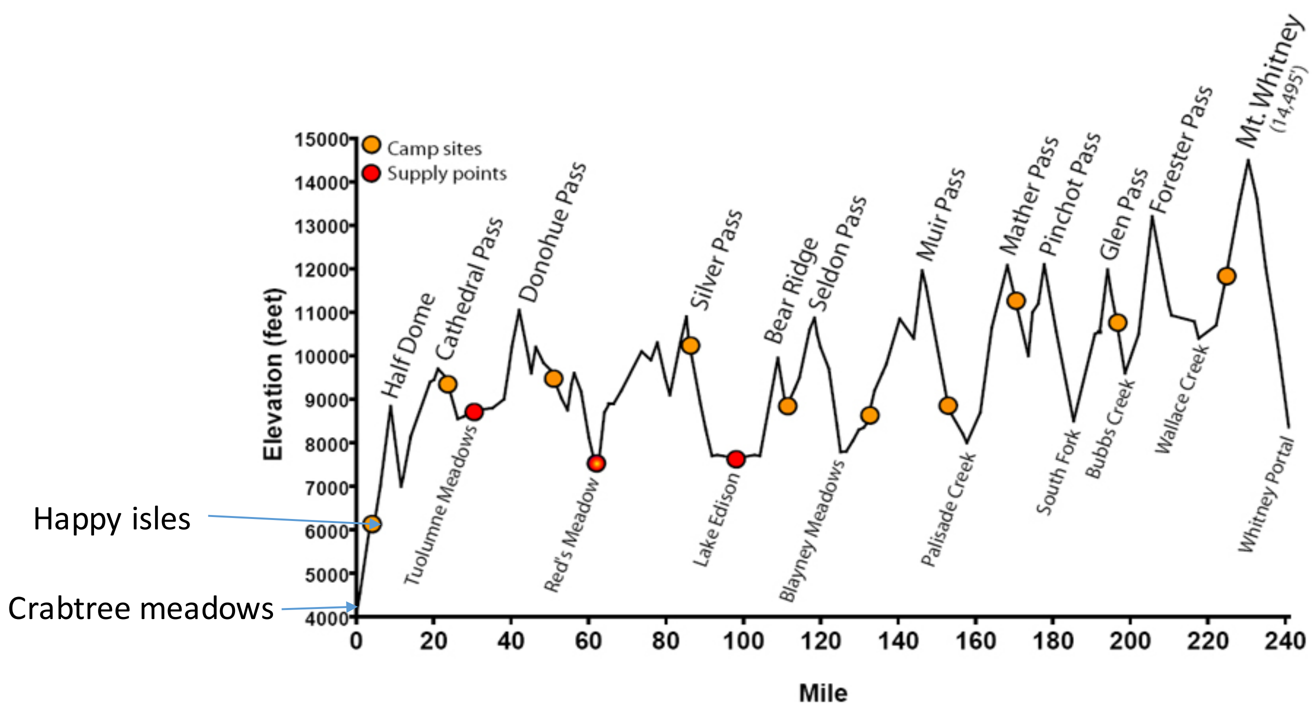


Figure 1: Elevation profile of the John Muir Trail (source: http://hikeforcancer.tripod.com/jmt.html)

1) You are planning to backpack the 200+ mile **John Muir Trail**, which passes through Yosemite, Kings Canyon, and Sequoia National Parks (lucky you!). Using the topographic profile above, **answer the following questions** to help plan your trip. *Show ALL work to receive full credit.* ***Pay attention to the units used on each axis***

a. What is the **vertical scale** of the topographic profile? **1 inch = _______________**

b. What is the **horizontal scale** of the topographic profile? **1 inch = _______________**

c. Calculate the **vertical exaggeration** of the topographic profile.

Show work:

d. Why is it important to know the vertical exaggeration of the profile when planning your hike?

e. What is the **gradient** from Whitney Portal to Mt. Whitney (peak)? *Give your answer in both ft/mile and %.* **Show work:**

_______________ ft/mi

________________ % slope

f. What is the **gradient** from Crabtree Meadows to Mt. Whitney (peak)? *Give your answer in both ft/mile and %.* **Show work:**

_______________ ft/mi

________________ % slope

HELP WITH SLOPE!

Convert gradient to % slope:

- start with: Gradient = 60ft /mile
- change miles to feet, so feet cancel
- 60ft / 5280ft = .01 (5280ft = 1 mile)
- .01 x 100= 1% slope

HELPFUL GRADIENT WEBSITES:

1) http://serc.carleton.edu/mathyouneed/slope/index.html

2) http://serc.carleton.edu/mathyouneed/slope/slopes.html

3) https://www.youtube.com/watch?v=semOKPvmoso

HELP WITH VE

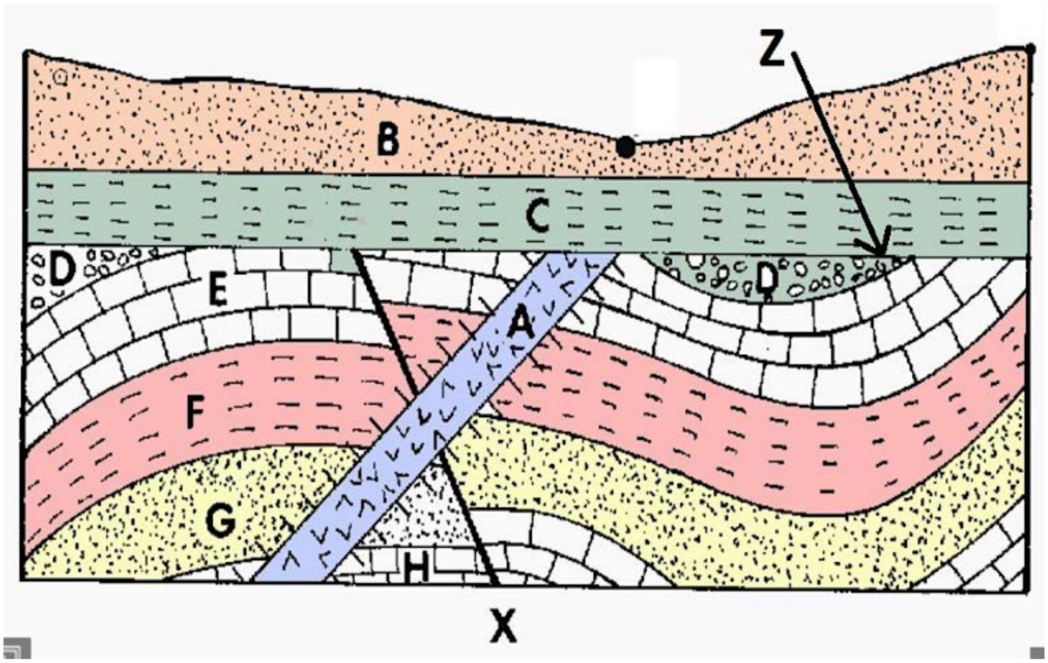
- http://academic.brooklyn.cuny.edu/geology/leveson/core/linksa/vertexag.html

RELATIVE DATING EXERCISE

HELPFUL RESOURCES:

- **p. 177-181** in the **Weise online lab** manual
- **p. 3-8** in the **Galileo online lab** manual
- Topographic map chapter in the **manual on your table**
- Notes from ppt lecture

PRACTICE CLASS EXERCISE *(color version in the Reader on Bb and shown during lab discussion)*:



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

"Z" is which type of unconformity? ______________________

Group Members: ____ Recorder Initials:______

INSTRUCTIONS

- Determine the relative ages for the rock bodies and other geologic features/events, including, tilting, uplift, faulting, and erosional unconformities. **SEE FIGURES ON LAB TABLES**
- 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.
- Determine and name (**by type)** all the lettered unconformities found in each cross-section.

Geologic cross section #1

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

Grand Canyon cross section #2

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

Geologic Cross section #1

Type of Unconformity

R _____________________________

S ______________ and ________________

O _____________________________

P_______________________________

Grand Canyon section #2

Type of Unconformity

R ________________ and ___________________

S _______________________________

Geologic cross section #3

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

Geologic cross section #3
Type of Unconformity

N ______________________________

Z ______________________________ (between D and J)

O ________________________and ________________

C ______________________________

Geologic cross section #4

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

Geologic cross section #4
Type of Unconformity **(omit CC and Q)**

Y ______________________

XX ___________________

W ____________________

U ____________________ and _______________

P ____________________

PRE-LAB EXERCISE_TOURMALINE BEACH FIELD TRIP

SEE TOURMALINE BEACH FIELD TRIP INFORMATION ON BLACKBOARD, **and the geologic time scale in the Reader**

Answer the following on this page and turn in with the rest of the exercise.

1. During your field trip you will walk north along the beach, then observe the layers of sedimentary rocks as you walk south, back to the cars in the parking lot. <u>Where are the oldest rocks located at Tourmaline Beach?</u>
   a) the south end of the beach
   b) the rocks are all the same age
   c) the north end of the beach

2. The <u>oldest</u> sedimentary rocks exposed at Tourmaline Beach are _________________ in age.
   a) Mesozoic c) Paleozoic
   b) Cenozoic d) Holocene

3. The rocks you will see at your first stop are called the Mt. Soledad Formation. The Mt. Soledad Formation is Eocene in age and composed of ________________________.
   a) fossiliferous limestone
   b) siltstone
   c) sandstone and siltstone
   d) conglomerate and sandstone
   e) siltstone and claystone

4. The next formation you will observe, and describe, as you walk along the beach is mostly mudstone (like claystone) and siltstone. What is the name of this formation?
   a) Friars Formation
   b) Del Mar Formation d) Scripps Formation
   c) Linda Vista Formation e) Cabrillo Formation

5. The next, younger, sedimentary rock layer is called the San Diego formation, these rocks are mostly sandstone that is poorly cemented and _________________________.
   a) fossils are abundant.
   b) is interpreted to be a river deposit.
   c) is interpreted to be a deep marine in origin.
   d) includes dinosaur bones.

6. The Mt. Soledad and Scripps Formations are Eocene in age, this epoch starts at ______ and ends at ____________. (Ma = millions of yrs ago)
   a) 54.8 Ma 33.7 Ma
   b) 5.3 Ma 1.8 Ma
   c) 65.5 Ma 54.8 Ma
   d) 1.8 Ma 11,000 yr

7. <u>We</u> are living in the __________________ period.
   a) Jurassic
   b) Devonian d) Quaternary
   c) Tertiary e) Cambria

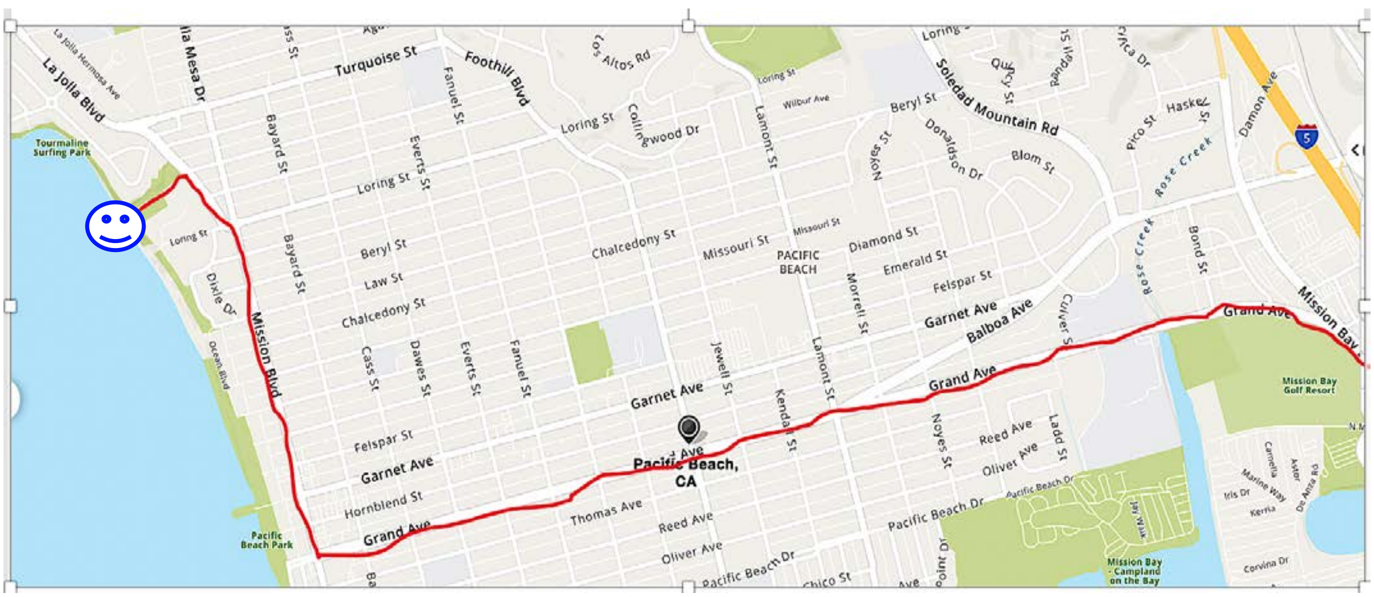
TOURMALINE BEACH FIELD TRIP

*please be there by **3:00PM** if you are driving yourself, the class will meet by the restrooms.*

BRING THESE FOLLOWING READER PAGES WITH YOU. There will be a supplemental handout with figures to go with this exercise

DRIVING INSTRUCTIONS:

- Interstate **5 North** to **Grand/Garnet exit. Stay in left lane.**
- From left lane, turn **<u>left on to Grand</u>** *(less traffic than going down Garnet)*
- Follow **Grand to Mission Blvd**
- **Turn right** on to Mission Blvd.
- **<u>Fork to LEFT from Mission Blvd at Loring</u> on to La Jolla Blvd**
- **<u>Turn left</u> from La Jolla Blvd on to <u>Tourmaline St</u>.**
- Go down the steep hill into the parking lot at Tourmaline Surfing Park
- **<u>Lock vehicles</u>** and put all **items out of site** on floor or trunk



TOURMALINE BEACH EXERCISE

Introduction & Purpose: The coastal geology of San Diego County is beautifully exposed in bluffs of Tourmaline Surf Park. **Sedimentary rocks of Cenozoic ages** were deposited there within various types of coastal marine depositional settings over time. Several unconformities and an ancient fault are also exposed there. The purpose of this lab is to observe, describe, sketch, photograph, and interpret various geologic features in the sea cliff at Tourmaline Surf Park.

Directions:

- **Answer the fieldtrip questionnaire.**
- **Complete the stratigraphic section for Tourmaline Beach** on the stratigraphic section blank provided.
- Fill in the section with the proper geologic symbol for the rock type represented for each interval of rock type observed. See the table of rock symbols for the correct symbol used to indicate the various rock types.
- Give the formation name and age that would appear on a geologic map for that unit.
- **WRITE A BRIEF DESCRIPTION OF EACH FORMATION ON THE DIAGRAM** in the space adjacent to the specific rock unit. This description should include:
  - The range of rock types in the formation (For example, conglomerate with lenses of silty sandstone.)
  - A standard geologic description of the rock type. (For example, if the rock is a conglomerate with silty sandstone matrix: estimate the size range of clasts and matrix material, describe the composition of the clasts and matrix material, the roundness or angularity of the clasts, the sorting of the clasts.)
  - Other observations: fossils observed, unusual minerals, sedimentary structures, the presence of graded bedding or cross bedding or other features that tell something about the depositional environment.

I. LOWER SECTION ROCKS AT THE NORTH END OF BEACH: CABRILLO AND MT. SOLEDAD FORMATION

The Mt Soledad Fm. is exposed in the cliff and is early **Tertiary Period/Eocene Epoch** in age (**52 million years**).

1) What specific rock type(s) make up the Mt Soledad Formation? (Hint: two types; one being coarse-grained detrital sedimentary rock containing large rounded rock fragments):

Rock types :________________________________ and ____________________________________

2) Estimate the rock fragment sizes within the Mt Soledad Formation (consider the pebbles and cobbles clasts, AND finer-grained matrix):

- Avg Clast size: ________cm

3) Name the **three major rock types that make up the cobbles** in the Mt Soledad Formation.

1) 2) 3)

4) The Mt Soledad Formation contains a unique set of cobbles, called **"Poway" clasts**, which have an exotic origin. List the rock type and age for the "Poway" clasts.

Rock Type: ______________________ **Age:**______________

5) Briefly explain where these exotic clasts came from, and how they ended up in this formation in coastal San Diego. Please be thorough with your answer.

- **Origin:**

- **Transport to SD:**

6) What was the most likely depositional environment for the Mt Soledad Fm? ________________________

7) Did sea level **Rise or Fall** after the Mt Soledad Formation was deposited? _______________.

8) LABEL and DESCRIBE the Mt Soledad Formation on your Stratigraphic Column Worksheet.

II. OBSERVATIONS AND ANALYSIS OF THE TOURMALINE FAULT

There is a fault that cuts and offsets the Mt Soledad and Scripps Formations here. Make observations and take measurements of the fault:

1) **Estimated dip angle________ and dip direction _______**
2) **Offset Motion: Hanging Wall moved Up or Down** _________
3) **What type is fault is it**? __________ **What type of stress**

III. OBSERVATIONS AND ANALYSIS OF THE SCRIPPS FORMATION:

Here we observe the **Scripps Formation unconformably overlying the Mt Soledad Formation**. Note that the entire section of rocks here are tilted (dipping) to the south. **This tilting is due to the growth of Mt. Soledad** a few miles to the northeast. Mt. Soledad is being pushed up along a compressional bend in the Rose Canyon Fault Zone. Therefore, as we head south we will be walking "up-section" through the whole sequence, where the Mt Soledad Formation will eventually pass under the beach, giving way to the overlying Scripps Fm.

The Scripps Formation is also Eocene age (approx. 46 million years old) and formed in the middle to lower sections of an offshore sea submarine canyon.

1) Note the **contact between the underlying Mt Soledad Fm and the overlying Scripps Fm**.

Is this contact considered **an unconformity**? If so, which type? ______________________________________

2) What specific rock types make up the **Scripps Formation**?

Answer: ______________________________ and _________________________________

3) What's the special name for the package of numerous, thin layers in the Scripps Fm?

Answer: ____

4) How do these layers form? ____

5) What type of depositional environment do these layers support?

____

6) Estimate the dip angle (tilt angle with respect to the horizontal) of the Scripps Formation. Are these rocks **dipping toward the north or south?**

Dip angle: ______________

7) As you continue walking north along the base of the sea cliff, notice how "messed up" (folded, swirled, etc.) the Scripps Formation is in some spots. These irregular swirls are the result of underwater mass movement events (slides, slumps, etc.) that occurred in this rock unit as it was being formed. **Did this deformation occur when the Scripps Formation was still soft sediment or after it hardened into a rock?**

Answer: ____

8) **Now, walk down the beach along the base of the sea cliff**. Keep walking south until you notice a series of cris - crossing fractures filled with a **very soft, clear mineral.** This mineral was precipitated inside cracks in the rock by groundwater. What mineral is this? Hint: it's very soft and it doesn't fizz in hydrochloric acid.

Answer: ______________________

9) Did sea level **Rise or Fall** after the Scripps Fm. was deposited? Can you explain why?

10) LABEL and DESCRIBE the Scripps Formation on your Stratigraphic Column Worksheet.

IV. UPPER SECTION STOPS - SOUTHERN END OF TOURMALINE BEACH: SAN DIEGO FORMATION:

Before you reach the parking lot, higher up on the sea cliff, is a layer of conglomerate that overlies the Scripps Formation. This rock layer forms the base of the **Pliocene San Diego Formation (less than 3 million years old).** Observe the south-dipping contact between the underlying Eocene Scripps Formation and the overlying Pliocene San Diego Formation.

1) Type of unconformity bounds the Scripps and San Diego Fms? ______________________________

2) What span of **time** does this unconformity comprise? _________ my

3) What specific **rock types** make up the **San Diego Formation**? There are three.

Answer: _______________________, ________________________, and ______________________________

4) Further down the beach, south of the parking lot, you'll notice that the sandstone exposed in the sea cliff contains numerous fossils within the San Diego Formation. Identify and record all the different **fossils** you observe. Note: at a minimum, you should be able to find at least two different types of fossils. Look carefully! You'll see 'em!

Fossil #1: ________________________________ **Fossil #2** ____________________________

5) Evidence in the San Diego Fm indicates that the sediments in this formation were deposited in a rather quiet warm shallow bay environment?

-
-

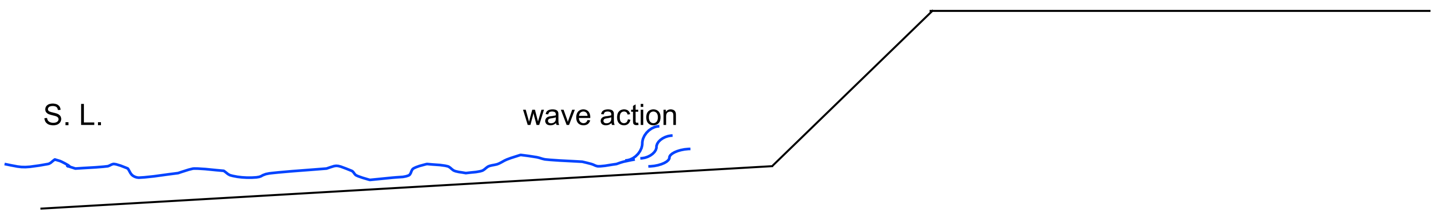
LABEL and DESCRIBE the San Diego Formation on your Stratigraphic Column Worksheet

V. Based on field observations at Tourmaline Surfing Park and the introductory comments, answer the following:

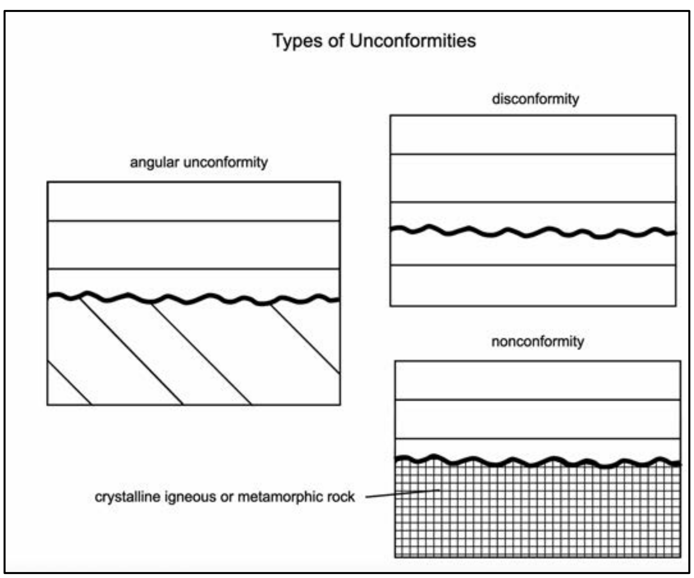
Question 1: On the diagram below label the following: **a)** sea cliff**, b)** abrasion platform, **c)** marine terrace

Question 2: Name two geological processes that will create a marine terrace (a former abrasion platform).

-
-

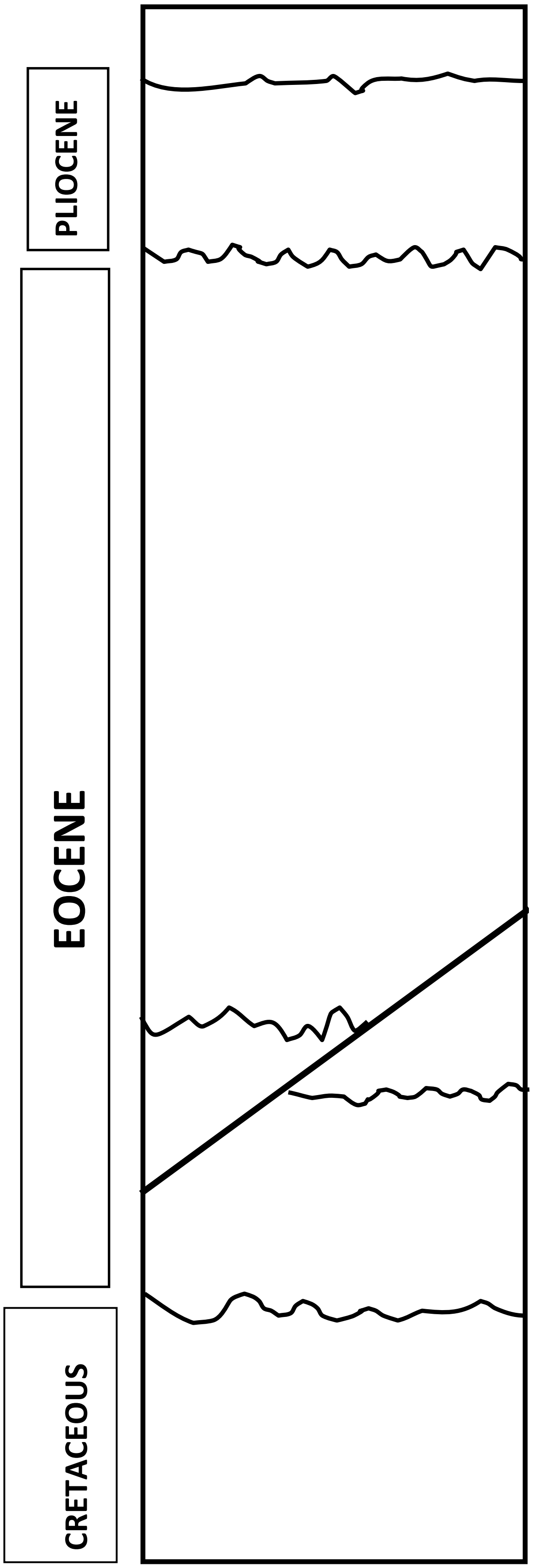


Three Types of Unconformities



Tourmaline Beach Stratigraphic Column   MAKE SURE THIS IS COMPLETE

Field Notes:



UNCONFORMITY: _______________

UNCONFORMITY: ________________

FAULT: Strike: _______ Dip: _____ Type : _____________

UNCONFORMITY: ________________

UNCONFORMITY: ________________

STRUCTURE AND GEOLOGIC MAPS

LEARNING OBJECTIVES:

To learn and apply the concepts of structural geology to reading and interpreting geologic structures including tilted beds, folds, and faults on maps and geologic cross-sections

HELPFUL RESOURCES:

- **p. 61-69** in the **Weise online lab** manual
- **p. 286-303** in the **Galileo online lab** manual
- Geologic Structures and Maps chapter in the **manual on your table**
- Notes from ppt lecture

INTRODUCTION:

Structural geology is the study of how geologic rock units are initially arranged and later deformed. Changing spatial relations between geologic units and the stress and strain that occur during deformation events are key aspects in understanding geologic structures. The purpose of this lab is to both.

The terms and concepts of geologic structures, the application of structural geology to mountain building events, and the techniques used to interpret geologic structures will be presented and discussed. The three types of graphic representations of geologic structures: 1) geologic maps, 2) geologic cross sections, and 3) block diagrams will also be highlighted and discussed.

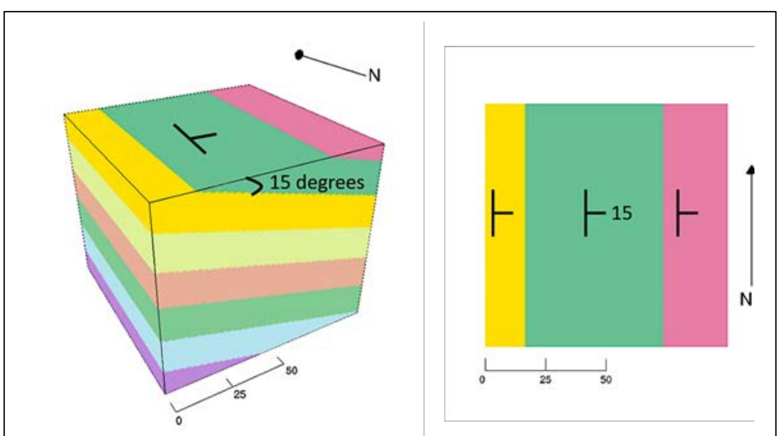
MEASURING THE ATTITUDE OF ROCK UNITS

Attitude is the spatial orientation of planar rock structures. Two aspects of attitude are needed to constrain a rock unit or surface orientation in three-dimensional space: **1) Strike and 2) Dip**. **Strike** is the compass bearing of a line formed by the intersection of a horizontal plane and the (inclined) plane of the layered rock feature. Strike can be expressed as either a quadrant, or an azimuth bearing.

Dip is the angle between the horizontal plane and the planar rock unit or feature. **Dip** direction is always down the inclined plane and is perpendicular to the strike. Strike and dip are drawn on geologic maps as a "T-like" symbol – the long segment is the strike; the short segment the dip. A number nest to the short segment represents the dip angle. In the field, geologists measure attitude with a compass (strike) and an inclinometer (dip).

RULES OF STRIKE AND DIP

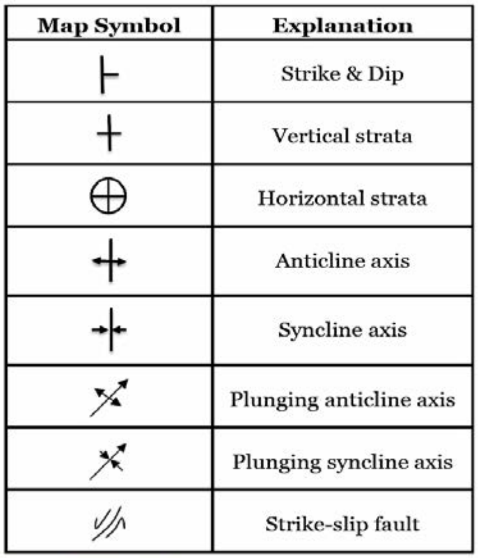
- **Strike** is always **parallel to the bedding direction at that location**.
- The **dip** is **always drawn perpendicular to strike in map view**. It may be drawn at an angle to show perspective in a 3D block diagram.
- **The dip CAN be labelled with the dip angle, or only the direction can be indicated.** The **dip always shows which way layers are tilting into the Eart**h.
- Special symbols are used for **horizontal beds** and **vertical beds (see table below)**.



Notes:

GEOLOGIC MAP SYMBOLS

Geologic symbols are used on geology maps to indicate one or more characteristics of the rock formation at the point on the map that they (the symbols) are placed. Some commonly used map symbols are found in **Figure 12.31 on page 301** (you will refer to these symbols for interpreting and making geologic maps, cross sections, and block diagrams). Map symbols indicate 1) attitude (e.g. strike and dip of either, bedding or foliation), 2) formation contacts, 3) fault lines (rock type, location, and planar orientation), 4) fold axes (type, location, and their limb orientations), and 5) rock formation information (type, name, and age). You will need to be able to recognize and interpret these symbols while working on geologic maps and diagrams.

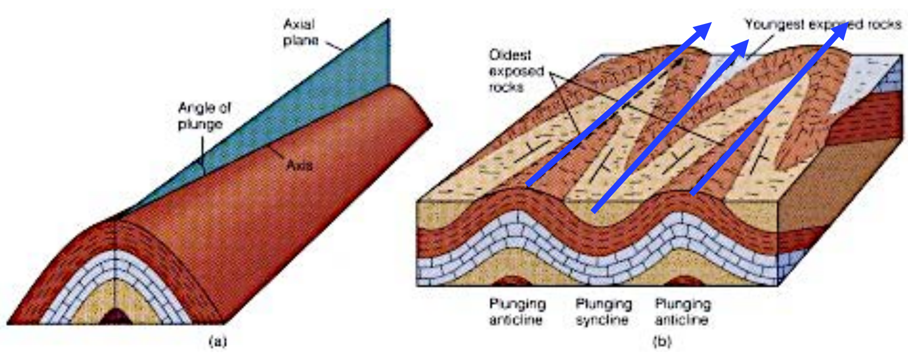


Map Symbol	Explanation
	Strike & Dip
	Vertical strata
	Horizontal strata
	Anticline axis
	Syncline axis
	Plunging anticline axis
	Plunging syncline axis
	Strike-slip fault

Figure 12.31 | Guide to common map symbols.
Author: Randa Harris
Source: Original Work

Major Types of Geologic Structures

Mappable rock units are called **formations**. Locations where rock formations are exposed at the earth's surface are called **outcrops**. Undisturbed rock formations such as sedimentary beds and lava flows are typically horizontal and planar in spatial orientation. However, shifting tectonic plates produce a variety of stresses in the crust that will, over time, cause crustal deformation such as uplift, tilting, erosion, faulting, and folding of formations. Faults and folds exposed at the earth's surface in outcrops have unique structural characteristics that can be recorded, mapped, identified, categorized, and analyzed.



Plunging Folds

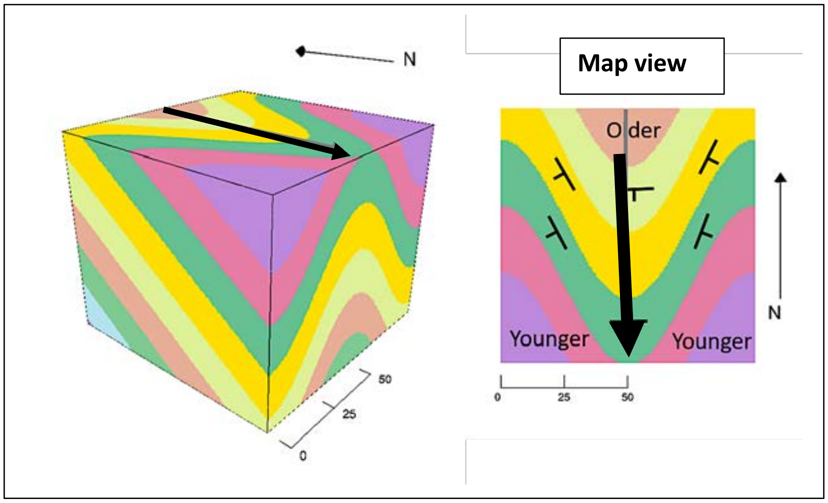
From: https://blank005.tripod.com/geology/deformation.html

PLUNGING FOLDS:

HELPFUL WEBSITES:

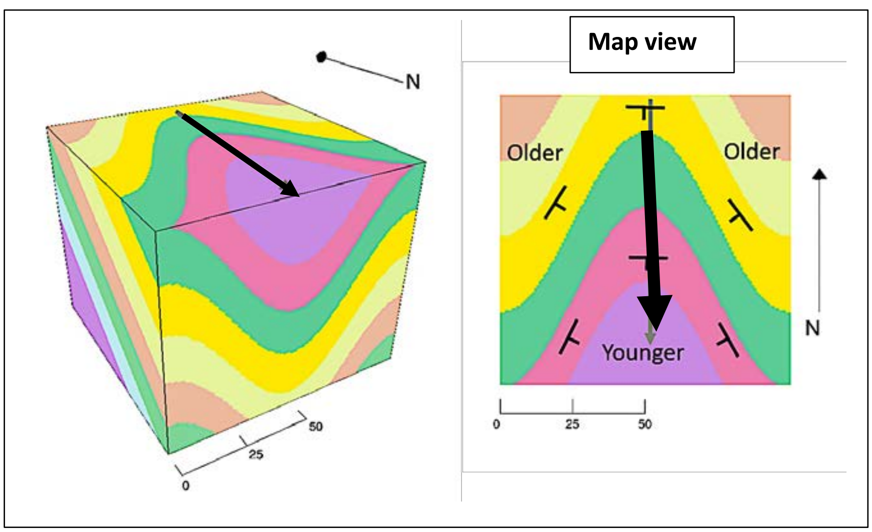
- https://www.arcgis.com/apps/Cascade/index.html?appid=49f5589733904f1798b92c1d5b1cd23a
- https://viva.pressbooks.pub/physicalgeologylab/chapter/plunging-folds/ (3D perspective)

PLUNGING ANTICLINE: *take notes*



Notes:

PLUNGING SYNCLINE: *take notes*



Notes:

STRUCTURE AND GEOLOGIC MAPS EXERCISE

Group Members: ____Recorder Initials:______

INTRODUCTION

A geologic map is a scaled-down, two-dimensional abstract representation of the surface geology, structure, and relief of a geographic region of Earth or other terrestrial planet. A geologic map typically includes most of the information found on a topographic map but most importantly also includes color-coded regions and symbols that denote rock units, ages, contacts, and other structural information. All of the geologic color-coding and symbols are explained in the legend on a geologic map, including topographic and cardinal-point compass information.

READING AND INTERPRETING A GEOLOGY MAP

Directions: First do a general examination of the entire geologic map of the **DEVIL'S FENCE QUADRANGLE.** Carefully examine the various rock units represented by the colored regions and related map symbols on the map that portray the surface geology of this area in the Rocky Mountains. Note their shape, aerial extent, and the larger structural patterns formed by spatially- associated outcropping rock units. Use the "Explanation" part of the map to decipher the rock units, in terms of formation name, **age**, and lithology. Also use the explanation to the left of the map to decipher the structural relations of the various formations, including strike and dip, folding, faulting and **age ranges** of formations. Finally, answer the following questions, based on your analysis of the Devil's Fence Quadrangle.

GEOLOGIC MAP EXERCISE 1: DEVIL'S FENCE QUADRANGLE

GEOGRAPHIC AND TOPOGRAPHIC QUESTIONS (include all appropriate unit abbreviations)

1) What state is this region located in? ____________________

2) What is the magnetic declination for this region? ____________________

3) What is the map and verbal scale for this map? ____

4) What is the contour interval of this map? ___________________

5) How many square miles does this map cover? _______________________

6) What is the total vertical relief for this area? __________________

7) What ***topographic*** feature (hill, ridge, valley, etc.) does Devil's Fence correspond with? ___________________

8) What ***geological*** feature (syncline, anticline, fault, etc.) is the Devil's Fence area? ________________________

GEOLOGIC QUESTIONS: …SEE The legend on the map

9a) List the major rock types in this area, as listed in the map legend. **Include at least six:**

. ____________, __________, ______________, ___________, ____________, and _____________.

9b) What is the total range in age for the various rock types found on the map? ___________ MY's

10) How old is the Colorado Formation? __________ Ma Locate this unit on the map.

11) This rock unit forms the center of what general type of deformational geologic structure, such as a fold or fault? (hint: notice the upside down "V" shaped pattern of rocks) _________________.

12) If you wrote down "fold", is it a syncline or an anticline? ______________________

13) What information did you use to tell whether it was a syncline or an anticline? _______________

____

14) Is it a horizontal or plunging fold? __________ . How could you tell? _____________________

15) Determine the strike of fold axis _____ If plunging, then which direction is the fold plunging? ____

16) How old is the Grayson Shale? __________ ma Locate this unit on the map.

17) This rock unit forms the center of what general type of deformational geologic structure, such as a fold or fault? (hint: notice the upside down "V" shaped pattern of rocks) _________________.

18) If you wrote down "fold", is it a syncline or an anticline? ______________________

19) What information did you use to tell whether it was a syncline or an anticline? _______________

____

20) Is it a horizontal or plunging fold? __________ . How could you tell? _____________________

21) Determine the strike of fold axis _______ If plunging, which direction is the fold plunging? ______

22) How many distinct folds are shown on this geologic map? *Hint: Way more than two!* ______

23) The deviatoric stresses that caused the folding come from which two compass directions? _________

24) When did the folding event occur? *(hint: look for youngest bed folded)*

Deviatoric stress: ¦dēv·ē·ə¦tör·ik ʼstres) (geology) A condition in which the stress components operating at a point in a body are not the same in every direction. Also known as differential stress.

GEOLOGIC MAP EXERCISE 2: LA JOLLA QUADRANGLE

1. What is the name and age of Ta?_______________________________________

2. What is the name and age of Kcs?______________________________________

3. What is the name and age of Qln?______________________________________

4. What is the regional (average) elevation of mesas that are capped by Qln? ____________________

5. What is the elevation of Mt. Soledad where Ta and Kcs outcrop (more than one location)? ___________

6. Mission Valley and San Clemente Canyons are generally east-west trending valleys that dissect the mesas. Are there two valleys stream erosion valleys or are they fault-controlled?

7. Interstate 5 runs north-south along Rose Canyon, east of Mission Bay, separating Mt Soledad from the mesas to the east. Parts of Tecolote Canyon (north of USD) trend parallel to Rose Canyon. Are the I-5 valley and Tecolote Canyon normal stream erosion or fault-controlled valleys?

8. Use the C-C' cross section to determine the type of fold that is observed in Pacific Beach. _______________
see bottom of map

10. Use the B-B' cross section to determine the type of fold associated with Mt. Soledad. ________________
see bottom of map

11. Follow the trace of the Rose Canyon Fault Zone from Mission Valley along I-5 to La Jolla Cove, where it goes offshore. What are the three primary faults that comprise the Rose Canyon Fault Zone?

-
-
-

12. Compare cross sections B-B' to C-C'. State whether the Pacific Beach Syncline is plunging or horizontal. If plunging, give the compass direction (N or S) and **evidence to support** your answer. ***see bottom of map***

13. What is the age, rock type and formation name of rocks on which USD is built? Give the same information about the rocks that outcrop on the sloping hills around USD.

- USD:
- Sloping Hills:

14. An inactive branch of the Old Town Fault (part of the Rose Canyon Fault Zone) cuts through Marion Way and under Camino Hall.

a. What is the approximate strike and dip of this fault? ____

b. In what rock formation is it visible on the surface? ____

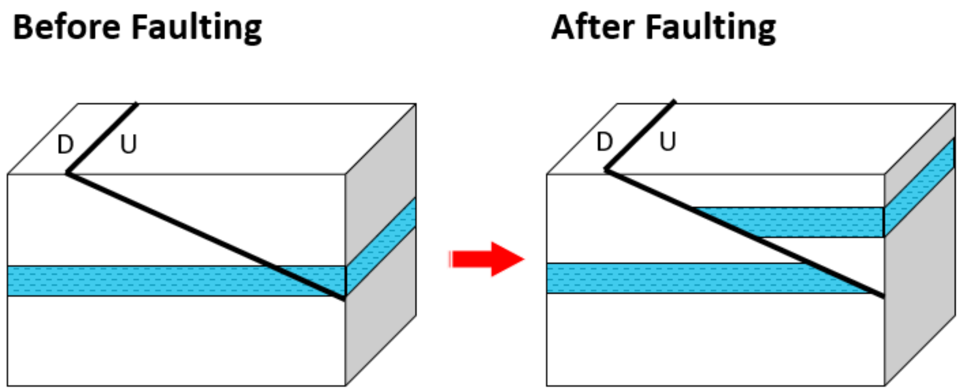
FAULTS

LEARNING OBJECTIVES

- Identify the different types of faults and their components
- Illustrate three dimensional models of fault motion
- Assess fault motion relative to the different types of stress

FAULT DIAGRAMS

Complete the fault diagrams to represent the relationship between the hanging wall and foot wall after faulting. The "U" indicates the block that has moved up in the fault motion, and the "D" indicates the block that has moved down in the fault motion.



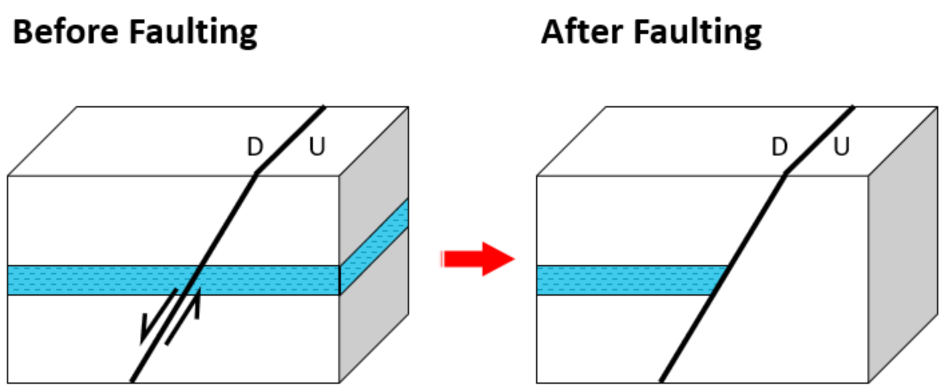
1.

a. DRAW arrows on either side of the fault line representing the motion of the fault

b. LABEL the Hanging Wall and Foot Wall

c. What type of fault is represented here? ________________________

d. What type of tectonic stress is responsible for this type of fault? ________________________



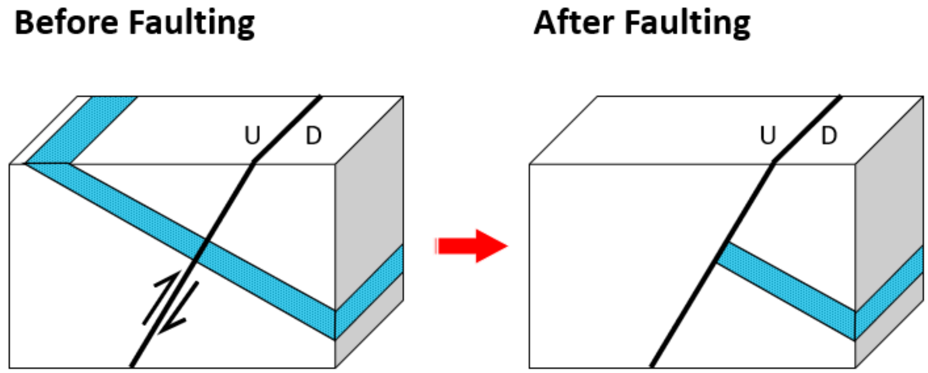
2.

a. **FINISH the blank sides** of the cube (front and right sides)

b. LABEL the Hanging Wall and Foot Wall

c. What type of fault is represented here? ________________________

d. What type of tectonic stress is responsible for this type of fault? ________________________



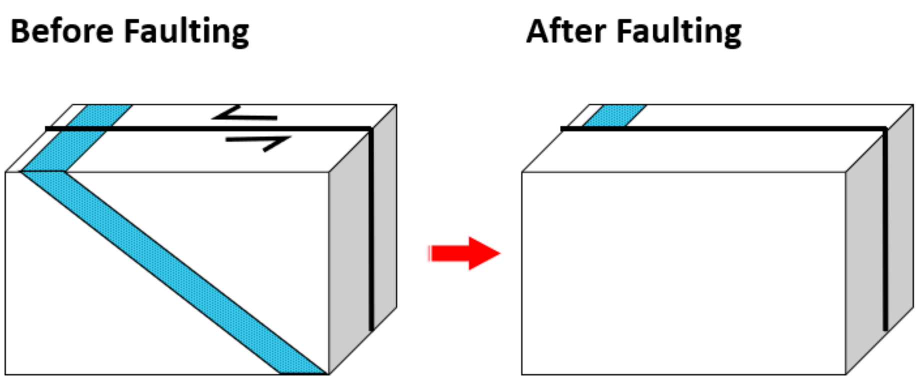
3.

a. **FINISH the blank sides** of the cube (front and top sides)

b. LABEL the Hanging Wall and Foot Wall

c. What type of fault is represented here? ________________________

d. What type of tectonic stress is responsible for this type of fault? ________________________



4.

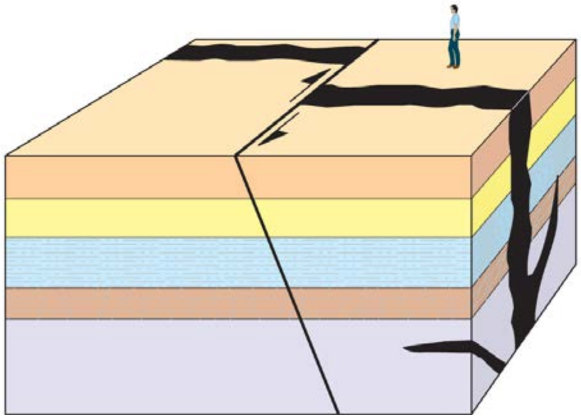
a. **FINISH the blank sides** of the cube (front, right, and top sides)

b. What type of fault is represented here? _________________ _________________

c. What type of tectonic stress is responsible for this type of fault? _______________________

d. Why would it be inappropriate to have a “U” and “D” notation on this sketch?

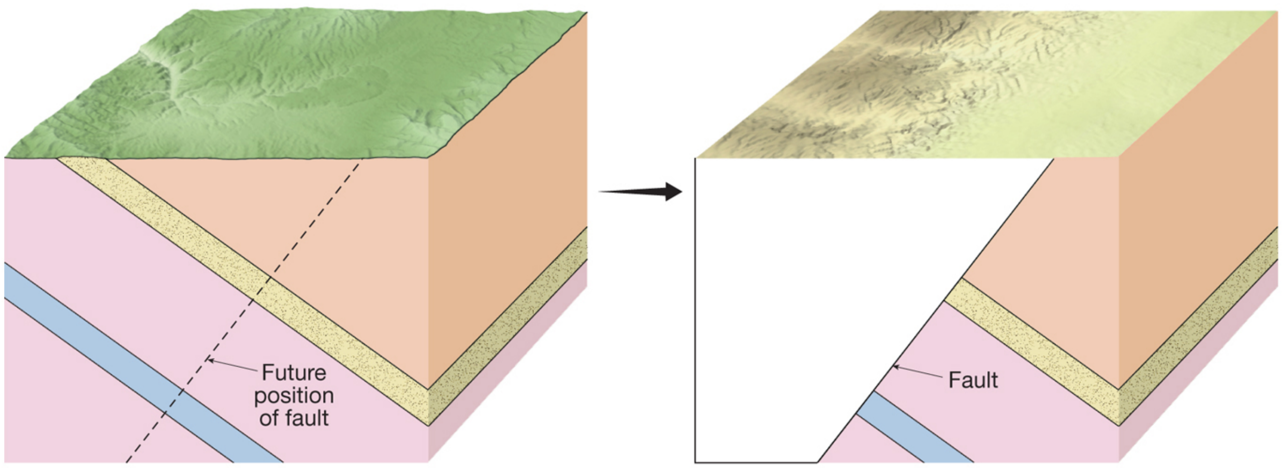
5.



What type of fault is represented here? ____________________ ____________________

Hint: be specific in your name – it should indicate the direction of motion

6.



A. Before faulting

B. Eroded reverse fault

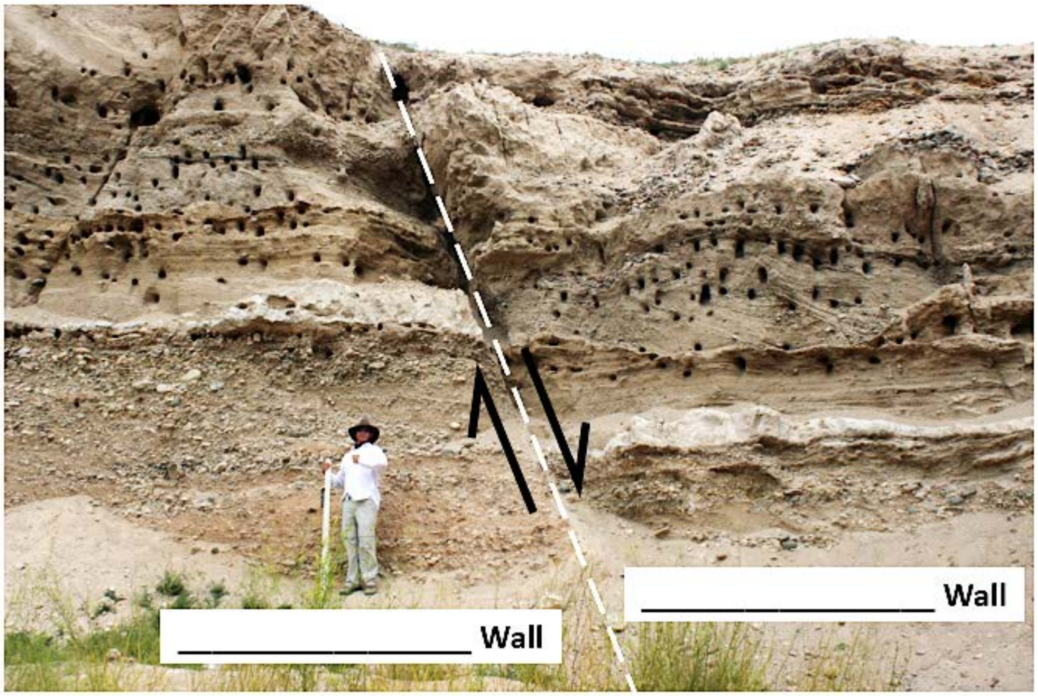
For this **REVERSE FAULT**:

a. DRAW arrows on either side of the fault line representing the motion of the fault on the "before faulting" sketch (A)

b. LABEL the hanging wall and foot wall on the "before faulting" sketch (A)

c. **FINISH the left side of the "eroded reverse fault"** sketch (B)

d. What type of tectonic stress is responsible for this type of fault? ________________________



7. Photo Credit: Michael C. Rygel via Wikimedia Common

a. LABEL the Hanging Wall and Foot Wall

b. What type of fault is represented here? ______________________

c. What type of tectonic stress is responsible for this type of fault? ______________________

d. DRAW a sketch view of the fault and the sedimentary layers from this image

TECTONIC STRESS, FAULTS, AND PLATE BOUNDARIES

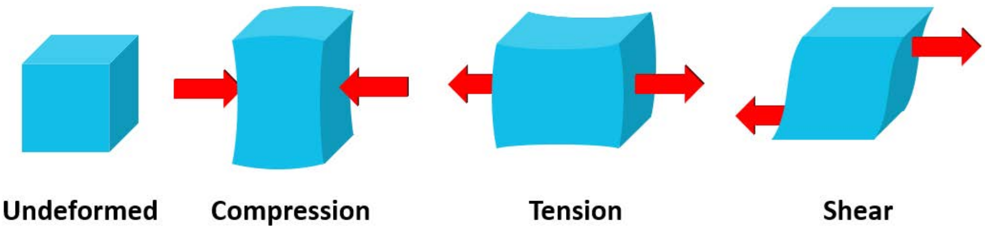
Directions: Complete Columns “B”, “C”, ”D” and “E” below.

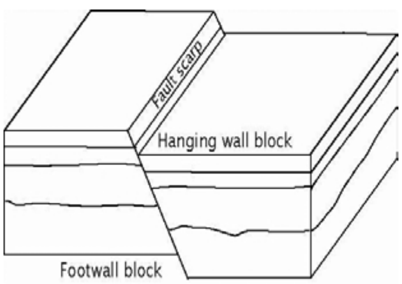
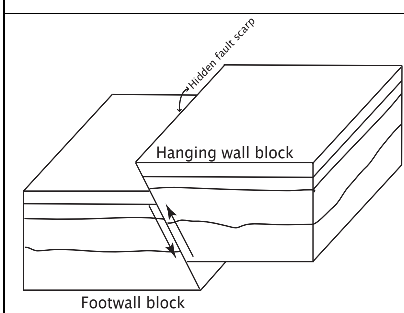
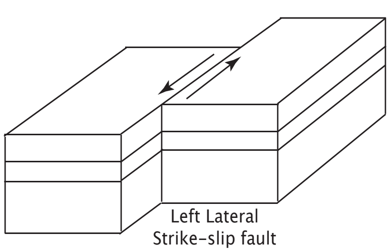
Column A: Block diagrams illustrate three types of crustal faulting.

Column B: Give names of major fault types (see column “A”).

Column C: General type of crustal deformation (stress) associated with type of faulting.

Column D: The type of plate boundary associated with columns “A through “D”.

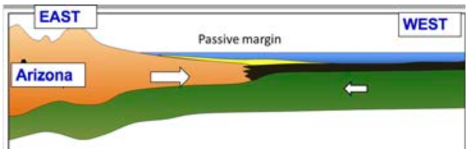


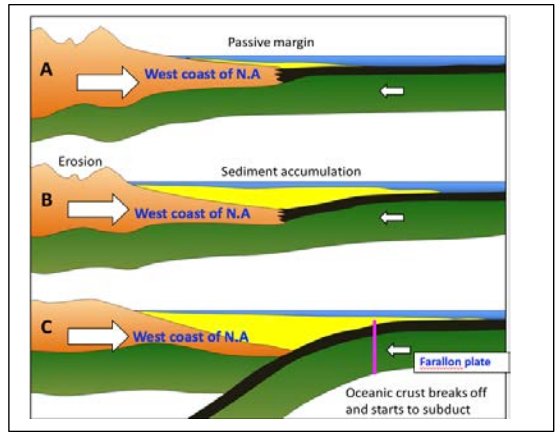
Column A	**Column B**	**Column C**	**Column D**
Block Diagrams	**Fault Type** • Normal • Reverse • Transform	**Stress Type** • Compression • Tension • Shear	**Plate Boundary Type** • Convergent • Divergent • Transform
			
			
			

PRE-FIELD TRIP EXERCISE

EOSC110 LECTURE NOTES_WEEKEND MOUNTAIN-DESERT FIELD TRIP
DO NOT HAVE TO TURN THIS IN. FOR REVIEW LATER

1) Passive Margin:



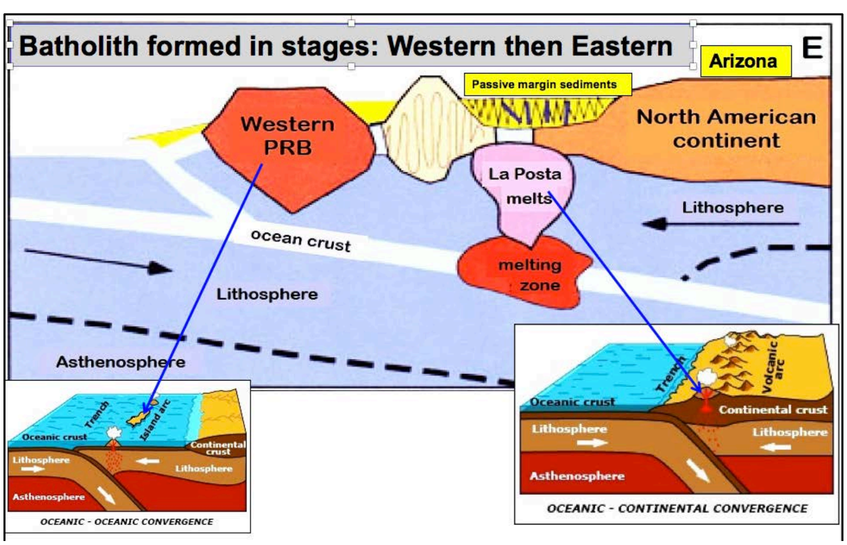


Why did passive margin change to subduction? ________________________________

2) Subduction Plate Boundary:

- **Western PRB:**
  - _______ **subduction angle:**
  - _______ **age** *(older or younger):*
  - _______ **arc** *(island or continental):*
- **Eastern PRB:**
  - _______**subduction angle:**
  - _______ **age** *(older or younger)*:
  - _______ **arc** *(island or continental)*:

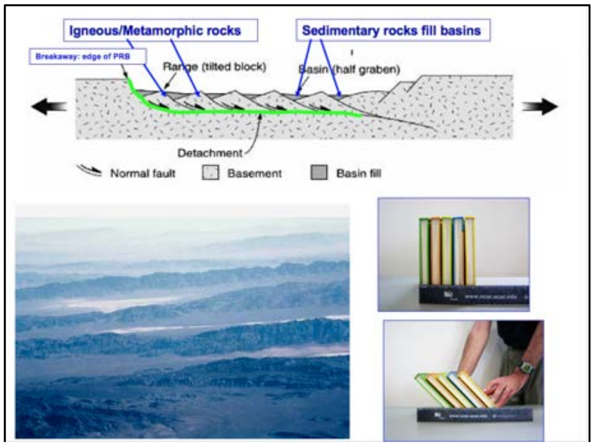
Why did the subduction angle go from steep to shallow?

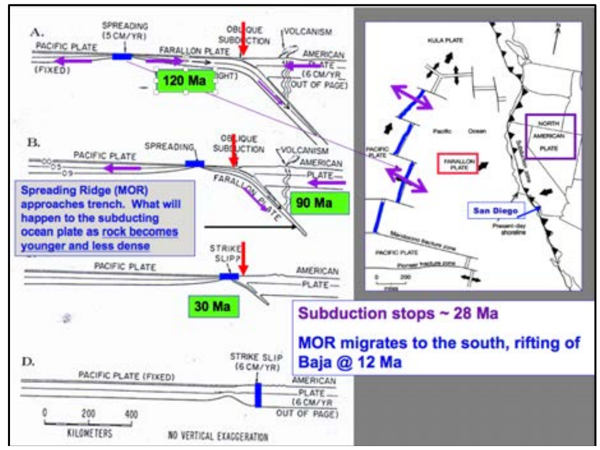


3) **Extension:**

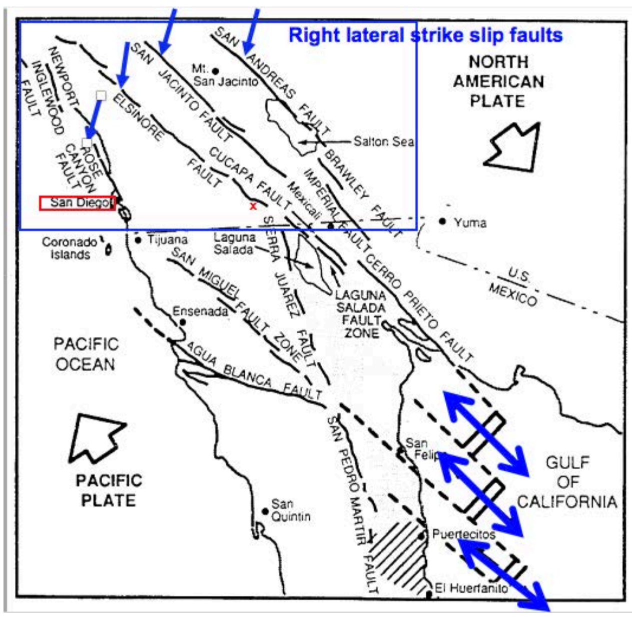
- **Why did subduction stop and tensional stress start?**

- **Type of faults:** ________________________________

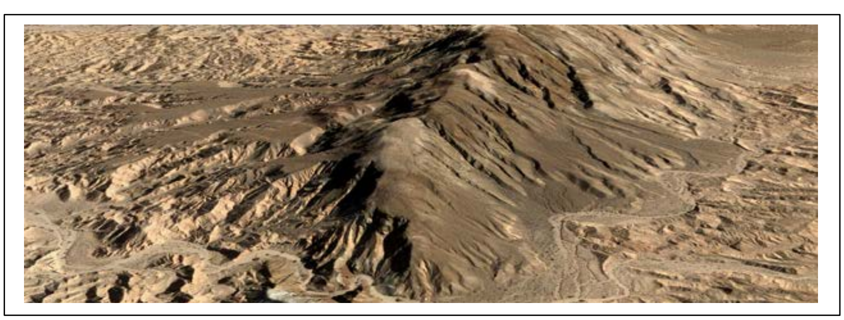




4) **Transform Plate Boundary: Strike slip faulting**



Transform stage: Uplift of ____________**Mountains** due to left bend in RL strike slip ________**Fault**



EOSC110 VIRTUAL PRE-FIELD TRIP_ Prep for weekend field trip

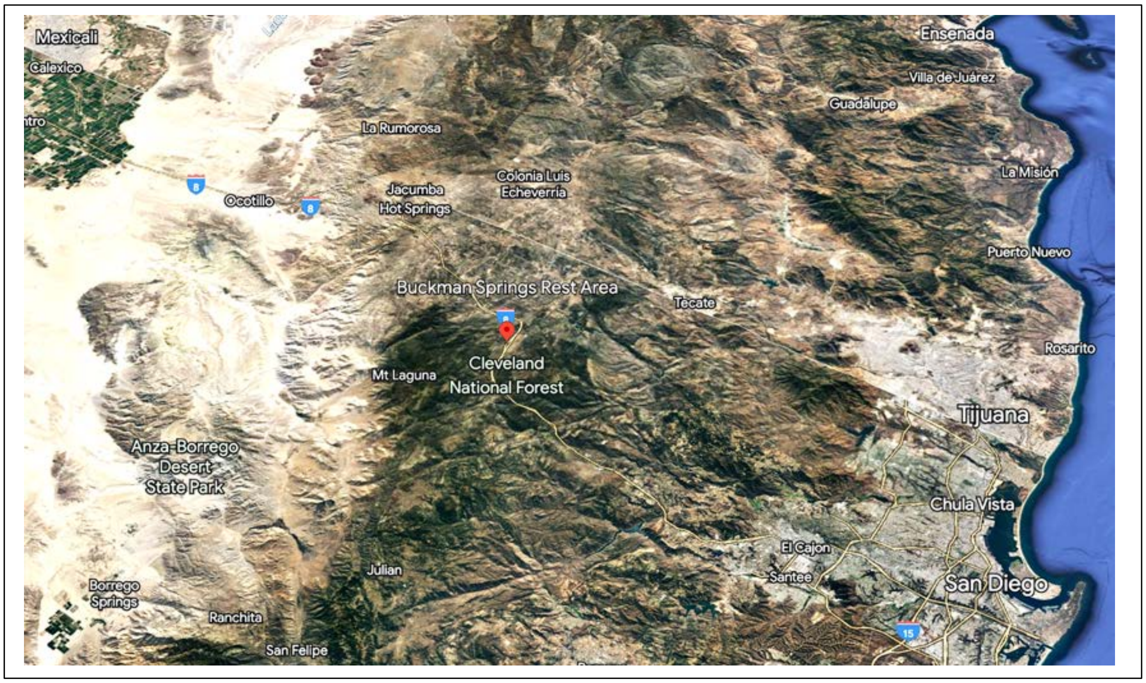
SEE FILE ON BB TO ACCESS GOOGLE EARTH LINKS BELOW

STOP 1- BUCKMAN SPRINGS DISCUSSION: Google Earth link: Buckman Springs rest area

1) Zoom out so you can see the ocean. Now you can see the "bigger picture" and stop 1 location in the PRB (Peninsular Ranges Batholith): **Buckman Springs regional perspective**

2) Is this rest stop in the middle of the PRB? ______________________

Label below, 1) coastal plain, 2) PRB, 3) Desert, 4) WEST *(on the side)*, 5) EAST *(on the side)*



STOP 2 – LA POSTA PLUTON: Google Earth link: La Posta Pluton

2) Are you in the eastern or western PRB? _______________________

Zoom out and pan around, by now you should be able to see the extent of the PRB in relation to the ocean and desert

STOP 3- DESERT OVERLOOK AT DESERT VIEW TOWER: PRB AND SALTON TROUGH:
Google Earth link: Desert View Tower "view"

3) What type of weathering do you see here? _______________________________(just covered this in the pre-field lecture)

4) Zoom out and turn the compass so you are facing North. Look for the Salton Sea, now pan around (looking east and west). Looking at the desert (called the Salton Tough), do you see any indication of a "**Basin and Range" (mountain-valley)** topography________? What type of fault is responsible for this topography? _____________

5) Look for the **Coyote Mountains** (see screenshot below). This is our next stop, in Canyon Sin Nombre!

STOP 4- CANYON SIN NOMBRE: ELSINORE FAULT AND COYOTE MOUNTAINS

Google Earth link: Canyon Sin Nombre (CSN)

- We will park at the entrance to the canyon after a short bumpy ride off the main road. Plan on spending ~ 2 hours leisurely walking through
- Zoom in and look for a very **felsic dike intrusion** in the reddish rock (we call basement rock on the field trip) **Pegmatite Dike**

On the 2-day fieldtrip, we discuss the San Jacinto fault on day 2: Can you draw lines on the figure below and show the 2 strands that make up this fault?

Google Earth link: 2 fault segments that make up the San Jacinto Fault zone

FOSSILS

Group Members: ____Recorder Initials:______

Important Information: During the lab final, you will be asked to identify fossils and determine the age (to the Era) of a fossil assemblage. You will be required to identify fossils using the following common names or taxonomic classifications (common names are given in quotation marks).

You should also know the geologic range of the following groups.

- P. Cnideria:
  - C. Anthozoa
  - O. Rugosa (Rugose or horn corals)
  - O. Tabulata (Tabulate corals)
- P. Brachiopoda:
- P. Mollusca:
  - C. Gastropoda
  - C. Bivalvia (Pelecypoda)
  - C. Cephalopoda, "Ammonites", "Nautiloids"
- P. Arthropoda:
  - C. Trilobita (Trilobites)
- P. Echinodermata:
  - C. Echinoidea
  - C. Crinoidea (Crinoids)

FOSSIL AGE ASSEMBLAGES OF GEOLOGICAL ERAS

<u>Paleozoic – 542 to 251 Ma</u>

Phylim Arthropoda, Class Trilobita "Trilobites"
Phylum Echinodermata, Class Crinoidea, "Crinoids"
Phylum Cnidaria, Class Anthozoa, Order Rugosa "horn corals"
Phylum Cnidaria, Class Anthozoa, Order Tabulata "tabulate corals"
Phylum Brachiopoda, "Brachiopods"
Phylum Mollusca, Class Cephalopoda, "nautiloids", *(simple sutures)*

<u>Mesozoic – 251 to 66 Ma</u>

Phylum Mollusca, Class Cephalopoda, "ammonites"
Phylum Mollusca, Class Cephalopoda, "belemnites" *(internal skeleton)*
Phylum Mollusca, Class Cephalopoda, Order "Ammonoid", Genus *Baculites, (straight with complex sutures)*

<u>Cenozoic – 66 Ma to present</u>

Phylum Mollusca, Class Bivalvia
Phylum Echinodermata, Class Echinoidia (sea urchins)
Phylum Mollusca, Class Gastropoda, "fancy", "armoured" gastropods

At each station, **observe and sketch the examples** of the fossils you see. Compare them to the pictures in your **handout** and look for the features that are common for each group. During the lab final, you will be asked to identify fossils and determine the age (to the Era) of a fossil assemblage. You will also be required to give the mode of fossilization.

PART 1: MODES OF FOSSILIZATION (pages 143-145)

STATION 1.1: TRACE FOSSILS

A trace fossil provides evidence of animal behavior in the past and may not comprise the remains of ancient organisms.

Examine the examples of the following types of trace fossils and make a guess of what organism produced them:

A: Burrows

B: Worm tubes

C: Boring into a hard rock by a clam.

D: Tracks

STATION 1.2: MODES OF FOSSILIZATION: PRESERVATION WITHOUT ALTERATION.

A: Hard parts. Parts of the original aragonite shell are preserved in these fossils. Eventually, aragonite, a calcium carbonate mineral that commonly is found in molluscs, will recrystallize to the mineral calcite. But here, these fossils show the original aragonitic shell material.

B. Soft parts. This fossil insect from the Eocene has been preserved in fossilized tree sap, or amber. Amber preservation though very rare provides much of the information we know about delicate insects. The bubbles in the amber preserve a sample of fossilized air from the Eocene. Geochemists have studied ancient atmospheres by analyzing fossil air bubbles in Amber. **Examine this fossil with magnifying lens and list any insects you recognize.**

-
-
-

STATION 1.3: MODES OF FOSSILIZATION: CARBONIZATION

A. The mode of fossilization shown at this station is carbonization. **What is carbonization?**

B. These two samples show well preserved carbonized fossils from the Eocene Green River formation. The Eocene Green River Formation is a fossil-rich deposit in Wyoming and Utah and Colorado which was once an ancient lake.

1. Can you identify fossils preserved in the Green River Formation?

C. This sample, which is also from the Green River Formation contains water beetles.

2. Explain why fossil insects are rare?

STATION 1.4: MODES OF FOSSILIZATION: PERMINERALIZATION

Permineralization or petrification is represented at this station.

3. What is permineralization or petrification?

4. What types of fossils shown at this station?

STATION 1.5: MODES OF FOSSILIZATION: RECRYSTALLIZATION, REPLACEMENT, VOID-FILLING CEMENT

At this station are examples recrystallization and replacement.

A. **Recrystallization.** The fossil shells at this station were originally aragonite. However, over time their aragonitic shells recrystallized to calcite. Because the minerals recrystallized on a molecular level, the details of the original shell shape are preserved.

B. This ammonite was originally had an aragonitic shell. The shell was dissolved away by percolating ground waters and pyrite filled in the empty void in the sedimentary rock. This process is called **Replacement.** Replacement by pyrite is often called **Pyritization.**

C. Minerals such as calcite, (as seen here) or chert, often crystallize in the empty pore spaces of fossils to fill the void. This is called **'Void-Filling Cement".** Here we see calcite void-filling cement filling up the chambers of a fossil ammonite. You can see the crystal faces of the void-filling calcite filling the pores. **Draw a diagram** of the sample and draw an arrow indicating the "void-filling calcite".

STATION 1.6: MODES OF FOSSILIZATION: IMPRESSIONS (MOLDS AND CASTS)

A. This is your chance to go back to kindergarten and play with play dough again. Using these shells and the play dough, Make the following (see Fig. 4.1):

   i. Internal mold

   ii. External mold

B. Here are some <u>internal molds</u>.

STATION 1.7: PRACTICE QUIZ: MODES OF FOSSILIZATION. **Do this after the other stations**

A. Identify the Modes of fossilization shown here.

A.

B.

C.

D.

E.

F.

PART 2: PALEOZOIC FOSSILS

From http://www.ucmp.berkeley.edu/cambrian/cambrian.php
The Paleozoic is bracketed by two of the most important events in the history of animal life. At its beginning, multicell animals underwent a dramatic explosion in diversity, and almost all living animal phyla appeared within a few millions of years. At the other end of the Paleozoic, the largest mass extinction in history wiped out approximately 90% of all marine animal species.

Two great animal faunas dominated the seas during the Paleozoic. The "Cambrian fauna" typified the Cambrian oceans; although members of most phyla were present during the Cambrian, the seas were dominated by **trilobites,** inarticulate **brachiopods**, monoplacophoran molluscs, hyolithids, "small shelly fossils" of uncertain systematic position, and archaeocyathids. Although all of these except the archaeocyathids survived past the Cambrian, their diversity declined after the Ordovician. **Later Paleozoic seas were dominated by crinoid and blastoid echinoderms, articulate brachiopods**, graptolites, **and tabulate and rugose corals.**

The Permian extinction, 251.4 million years ago, devastated the marine biota: tabulate and rugose corals, blastoid echinoderms, graptolites, the trilobites, and most crinoids died out. One lineage of crinoids survived, but never again would they dominate the marine environment.

STATION 2.1. PHYLUM CNIDERIA, CLASS ANTHOZOA, "CORALS" (p. 167 Fig. 4.17)

Corals are in the Phylum Cnidaria. Corals are like sea-anemones that secrete a hard skeletal cup in which they sit. The Class Anthozoa includes three orders of corals which commonly occur in the fossil record. The orders are the Order Tabulata (tabulate corals) (Ordovician to Permian) and the Order Rugosa (rugose or horn corals) were common fossils in the Ordovician to Permian period of the Paleozoic.

A. Fossils marked here represent the **tabulate corals**. There corals are exclusively colonial. They have prominent tabula and are missing septa. Compare these to the pictures in the handout **(p. 167 Fig. 4.17)** to see if you can identify the **"chain coral"** ***Halysites*** (see handout) and the **"honeycomb coral"** ***Favosites****.*

Draw examples:

"chain coral" ***Halysites***

"honeycomb coral" ***Favosites***

B. These rugose corals (commonly called "horn corals") are characterized by prominent septae and a horn-like shape. Unlike tabulate corals, these corals can be solitary or colonial. Compare these fossils to the pictures in Fig. 4.17 p. 167.

Draw an example:

rugose corals "horn corals"

STATION 2.2: PHYLUM BRACHIOPODA "BRACHIOPODS" (p. 171-174 Fig. 4.19 and 4.20)

A) Although members of the Phylum Brachiopoda or brachiopods are still around, their taxonomic diversity has decreased greatly since the Paleozoic and most genera are extinct. Examine the diversity diagram in **Figure 4.19 p. 171 (bottom right**) of the handout. During what geologic Period(s) were brachiopods most diverse?

____

B) Observe these specimens at this station and compare them to the pictures in **Figures 4.19 and 4.20**. Draw a diagram of **one specimen** at this station.

1) **Draw the side view** labeling the pedicle valve & brachial valve.

2) **Draw a view from the top ("map view") of one of the valves** with a line of symmetry running through the center of the valve. Are the left and right sides of each valve mirror images? ________________________

a. Try to match one specimen at this station to one of the brachiopods depicted **in Fig. 4.20 p. 172**.

STATION 2.3: PHYLUM ARTHROPODA, CLASS TRILOBITA, TRILOBITES (p. 183 Fig. 4.28)

A) The fossils at this station part of an extinct class of Arthopods (insects, crustaceans, etc.) called the Class Trilobita, or "trilobites". Trilobites got their name because their segmented bodies can be divided into three lobes. Like many other arthropods, these fossils molted their exoskeleton many times in their life. The exoskeleton would break open along the facial suture and the animal would molt the old skeleton and grow a new one (see Figure 4.28g on the handout). This phenomenon made their fossil record even better.

1) Draw a sketch of a specimen and label the cephalon, thorax and pygidium, the eye and glabella (see Fig. 4.28 c, g on p.183).

2) Examine the diversity through time diagram in the upper right-hand corner of Fig. 4.28. During what geologic period did trilobites reach their maximum diversity?

____

3) Here are several trilobite reproductions (fake fossils). Try to match at least two of the reproductions to pictures in Figure 4.28.

STATION 2.4: PHYLUM ECHINODERMATA, CLASS CRINOIDEA, "CRINOIDS" (p. 185 Fig. 4.29)

A) The phylum Echinodermata includes sea stars, sea cucumbers, and sea urchins. Stalked, sessile (attached) echinoderms, such as crinoids (Class Crinoidea) lived attached to the sea-floor by a stalk. Although a few species of modern crinoids (sea lilies) inhabit generally deep-water or sheltered environments, they are uncommon in the modern ocean. However, during some periods of the Paleozoic, a great diversity of stalked crinoids covered the floor of shallow seas. The stalk (or column) consisted of stacked poker chip-like calcite plates (columnals) with a hole in the center. Sometimes the stalks and holes show five fold symmetry and sometimes they are round. Draw a sketch of one of the crinoid replicas at this station and label the crown and stem (column).

Sketch: label the crown and stem (column) p. 185 Fig. 4.29

B) During what **geologic period** of the Paleozoic were crinoids most diverse? ________________________

C) Commonly, their stalks (columns) would break apart into individual columnals (poker chips) which littered the Mississippian and Pennsylvanian sea floor. Crinoid columnals are common constituents of these shallow-water limestones of late Paleozoic age. These crinoid columnal-rich limestones are called "encrinoidal" limestones. Examine these stalks, columnals, and encrinoidal limestones.

PART 3: MESOZOIC FOSSILS

From: http://www.fossilmuseum.net/Paleobiology/Mesozoic_Paleobiology.htm

Mesozoic means "middle animals," and is the time during which the world fauna changed drastically from that which had been seen in the Paleozoic. Dinosaurs, which are perhaps the most popular organisms of the Mesozoic, evolved in the Triassic, but were not very diverse until the Jurassic. Except for birds, dinosaurs became extinct at the end of the Cretaceous.

The Permian-Triassic (P/T) Extinction Event marked the end of the Permian Period of the Paleozoic Era, and the start of the Triassic Period of the Mesozoic Era. **The P/T extinction decimated the brachiopods, corals, echinoderms, mollusks, and other invertebrates. The last surviving trilobite also did not survive**. The P/T event set the stage for adaptative radiation in both land and environments. **While crinoids** were the most abundant group of echinoderms from the early Ordovician to the late Paleozoic, they **nearly went extinct** during the Permian-Triassic extinction.

Other invertebrates, notably the **bivalves, ammonoids, and brachiopods recovered to dominate the marine environment, and the squid-like Belemites appeared and became abundant. New groups of echinoderms appeared as well. Baculites, a straight-shelled ammonite, flourished in the seas**. The Cretaceous also saw the first radiation of marine diatoms in the oceans.

STATION 3.1: PHYLUM MOLLUSCA, CLASS CEPHALOPODA, "Ammonites" & "Nautiloids" (Fig. 4.25, 4.26 p.179-180).
http://www.ucmp.berkeley.edu/taxa/inverts/mollusca/cephalopoda.php

The class Cephalopoda includes the nautilus, octopus, squid and cuttlefish. Shelled cephalopods called "ammonites" and "nautiloids" (related to the modern nautilus) filled many ecological nitches and are common fossils during the Mesozoic. They went extinct at the end of the Mesozoic at the same time as the dinosaurs. Examine **the illustrations of the Mesozoic cephalopods** in **figures 4.25 and 4.26 p. 179-180.**

A) Examine this shell of a **modern *Nautilus*** and compare it the image in the upper left corner of Fig. 4.25. Nautiloids are characterized by a chambered shell with gas-filled chambers used to control their buoyancy.

B) These are uncoiled (orthoconic) nautiloids like those in Fig. 4.25 c, d, and e. They moved vertically in the water column by adjusting their buoyancy by filling chambers in their shell with gas. Individual chambers are separated from one another by walls called septa. Compare the orthoconic nautiloids to the modern shell of the *Nautilus*. These can be placed in the Paleozoic Era.

C) Ammonites evolved septa of **increasing complexity throughout the Mesozoic**. The pattern resulting from the intersection of the septa with the outer shell wall is called the suture pattern. Observe the wide variety of shapes, coiling patterns, and sizes of the ammonites. Compare the specimen to the pictures in Figure 4.26. Although the Ammonites ruled the Mesozoic ocean, they went extinct at the Cretaceous/Tertiary boundary, 65 million years ago.

D) ***Baculite*s** is an uncoiled (straight) ammonite (Fig. 4.25 f). Examine these samples and **sketch the suture patterns.** Are they complex or simple? Compare the uncoiled ammonite *Baculites* to the orthoconic nautiloids.

Sketch of suture pattern:

E) These cigar-shaped fossils (belemnoids) were the internal skeletons of squid like organisms that roamed the Cretaceous seas.

STATION 3.2: CLASS VERTEBRATA, CLASS REPTILIA, "Dinosaurs".
While the ammonites ruled the seas during the Mesozoic, these organisms ruled the land.

PART 4: CENOZOIC FOSSILS

The following is from: Earth through Time, 8th ed. by Harold L. Levin

The invertebrate faunas of the Cenozoic have a modern appearance. Once-successful groups of invertebrates such as the ammonites and rudist bivalves went extinct at the end of the Cretaceous. The shells of Cenozoic molluscs look like those found on beaches today. The Cenozoic molluscs are dominated by bivalves (clams) and gastropods (snails). Cephalopods are also present, however, not as widespread and abundant as during previous periods when the ammonoids were still present. Modern cephalopods include the chambered *Nautilus*, as well as other forms without a shell (or with a reduced shell) such as squid, octopus, and cuttlefish. Echinoderms are also present in the Cenozoic, particularly free-moving types (as opposed to the attached crinoids of the Paleozoic). Echinoderms include the echinoids (sea urchins, sand dollars, sea biscuits), and the starfish. Modern crustaceans (such as crabs, shrimp, lobsters, barnacles) became well established in the seas during the Cenozoic**. No new major invertebrate groups appeared in the Cenozoic.**

Dominant invertebrates of the Cenozoic include:

- Sponges
- Scleractinian corals - modern reef corals (Phylum Cnidaria)
- Bryozoans
- Brachiopods (both articulates and inarticulates)
- **Molluscs**
    a. **Bivalves**
    b. **Gastropods**
    c. Cephalopods
- Arthropods
    a. Crustaceans
    b. Insects (on land)
- **Echinoderms**
    a. **Starfish**
    b. **Echinoids (sea urchins sand dollars, and sea biscuits)**

STATION 4.1 PHYLUM MOLLUSCA, CLASS GASTROPODA "SNAILS" (p. 177-178, Fig. 4.23)

A) The Class Gastropoda or "gastropods" include snails and slugs. Though gastropods have been found throughout all the eras of the Phanerozoic, in the Cenozoic they evolved a more ornamented shell with high spires, and a siphonal canal. Examine the images in Fig. 4.23 for examples of gastropods typical of the Cenozoic Era. By contrast, the more simple ancient gastropods (archaeogastropods) that were found in the Paleozoic are shown in Fig. 4.24.

STATION 4.2: PHYLUM MOLLUSCA, CLASS BIVALVIA, "CLAMS" (p. 174-175, Fig. 4.21, 4.22)

A) Examine the diversity diagram in 4.21. When did the bivalves (Class Bivalvia) reach their maximum diversity?

B) **Sketch the inside of one of these shells and label the muscle scars (adductors), pallial line, and teeth and sockets**. The pallial sinus is an indentation in the pallial line. Deep burrowing types have a larger pallial sinus than shallow-burrowing or non-burrowing types. Did this specimen burrow in the sediments or live on the surface of the ocean floor?

Sketch:

C) How do bivalves (clams) differ from brachiopods (Station 2.2) in appearance?
Look at symmetry of shell

Sketch: <u>Brachiopod symmetry</u> <u>Bivalve symmetry</u>

D) Compare these specimens you see at this station to the images in Figure 4.22 p. 175.

STATION 4.3: PHYLUM ECHINODERMATA, CLASS ECHINOIDIA (Fig. 4.30)

These sea urchins, sand dollars, and heart urchins (Class Echinoidea) inhabit epifaunal (on the substrate), semi-infaunal (partially buried in the substrate), and infaunal (buried) habitats, respectively. Whereas the sea-urchins maintain their five-fold symmetry, the sand dollars and heart urchins have evolved secondary bilateral symmetry. This secondary bilateral symmetry appears to be adapted to a life of burrowing, where it is advantageous for the organism to have a more elongated rather than round shape. Echinoids reached their maximum taxonomic diversity in the Cenozoic.

Sketch 2 samples:

STATION 5: FOSSIL ASSEMBLAGES

Each of the stations includes a group of fossils that could have been found during one of the eras of geologic time. For each fossil assemblage, identify each fossil as specifically as possible and determine the geologic ERA represented by the assemblage.

PART A QUIZ:

ERA: ____________________________

A)

B)

C)

D)

E)

F)

PART B QUIZ: Place each fossil with the correct Era (you decide where to place A through F).

ERA: ____________________________ **ERA:__________________________**

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Please return fossil manual. This will be available on Bb for review.

HOPE YOU ENJOYED THE LAB!

Thanks for a fun semester!