A View of Earth from Above

Activity 1.1

Name: ______________________ **Course/Section:** ______________ **Date:** __________

This activity requires use of Google Earth on a device that has an active connection to the Internet. You will need to be able to search, zoom in and out of the image, and find the apparent altitude at which the Google Earth image is being viewed. You will also need to be able to input a degree symbol (°) for which you can get help from your teacher. It is useful to choose to view the labels for various places and to look at photos that have been posted on Google Earth because of the additional information that sometimes accompanies the photos.

A Four types of map coordinates are provided in **Fig. A1.1.1**: three versions of latitude and longitude and one UTM. For each, input the coordinates into Google Earth using its Search function, press the "Search" button to go to the spot, identify the feature at that location, note where it is (country, continent, or island), and write a brief description in the space provided in the last column. You will probably want to zoom out to view the surroundings after Google Earth finds each location for you.

Coordinate Style	Coordinates Latitude	 Longitude	Google Earth Seach Input	Description—Be sure to zoom out and look around before answering
decimal degrees	27.9881°N	89.9253°E	27.9881, 86.9253	Continent/Island: Country: What did you find there?
degrees–decimal minutes	77°50.680′S	166°40.603′E	−77°50.680′, 166°40.603′	Continent/Island: Country: What did you find there?
degrees–minutes–seconds	63°04′10.2″N	151°00′26.64″W	63°04′10.2″, −151°00′26.64″	Continent/Island: Country: What did you find there?
Universal Transverse Mercator (UTM)	Zone: 31 Latitude Band: U	Easting: 448252mE Northing: 5411935mN	31U 448252 5411935	Continent/Island: Country: What did you find there?

Figure A1.1.1

B Find an interesting place on Earth, and let us know what you found by providing the information requested in **Fig. A1.1.2**. Share your discoveries with other students and your teacher.

Longitude & Latitude	Best-View Altitude (km)	Continent/Island	Description

Figure A1.1.2

C The latitude–longitude coordinates for several interesting sites are provided in **Fig. A1.1.3** in decimal degrees along with the best altitude to view each of the features. Choose a few sites to investigate using Google Earth, and record your results in **Fig. A1.1.4**.

Site #	Latitude, Longitude	Best-View Altitude	Site #	Latitude, Longitude	Best-View Altitude	Site #	Latitude, Longitude	Best-View Altitude
1	40.5230, −112.1510	5–15 km	9	32.2186, 35.5661	10 km	17	−3.0647, 37.3584	10–75 km
2	−21.1492, 14.5775	50 km	10	35.2715, −119.8275	2 km	18	35.2505, −75.5288	1–2000 km
3	19.4726, −155.5918	15–150 km	11	4.1744, 73.5097	2–600 km	19	0.2220, −50.3950	300 km
4	56.3333, −79.5000	150 km	12	−30.5450, 138.7280	25–100 km	20	45.9764, 7.6583	15–25 km
5	21.8462, 54.1514	1–200 km	13	40.8214, 14.4333	2–10 km	21	37.5940, −122.4240	10 km
6	37.7460, −119.5336	5–25 km	14	35.0275, −111.0228	5 km	22	57.2688, −4.4921	50 km
7	36.0999, −112.0994	10–75 km	15	59.0850, −136.0615	5–20 km	23	21.1240, −11.4020	100 km
8	24.9652, −76.4201	75 km	16	29.1200, 25.4300	1–150 km	24	62.7924, −164.1667	95–500 km

Figure A1.1.3

Site #	Continent/ Island	Country (± State)	Description — Be sure to zoom out to the "best-view altitude" and look around before answering.

Figure A1.1.4

D **REFLECT & DISCUSS** Turn off the function in Google Earth that displays national or state borders and place names. Navigate to 54.1291, −7.3064 and examine the area from a eye altitude of ~4 km.

1. Where do you think the national border is in this image?

2. Have Google Earth display the border, and zoom out to a higher elevation. What countries are separated by this border? ______________________ and ______________________. What is your impression of this national border?

3. Now turn off the borders again, navigate to −9.8396, −66.3362, and zoom out to an eye altitude of ~100 km. How does land use differ across the border?

4. Have Google Earth display the border, and determine which countries are separated by the border: ______________________ and ______________________. What natural feature marks the border on the landscape?

Finding Latitude & Longitude or UTM Coordinates of a Point

Activity 1.2

Name: ____________ **Course/Section:** ____________ **Date:** ____________

A Air samples have been collected at the Mauna Loa Observatory (MLO) on the main island of Hawaii since the late 1950s and analyzed to determine the concentration of carbon dioxide (CO_2) in the atmosphere. Located at 3397 m above sea level on the north slope of the Mauna Loa Volcano, this remote sampling site is high enough so that contamination is minimized. The location of MLO is shown by the yellow-filled circle in **Fig. A1.2.1**, which is a map that uses the geographic coordinate system of decimal latitude and longitude. One of the orange lines through the site extends north–south along a meridian—an arc of equal longitude—and the other extends east–west along a parallel—a circle of equal latitude (**Fig. 1.4**).

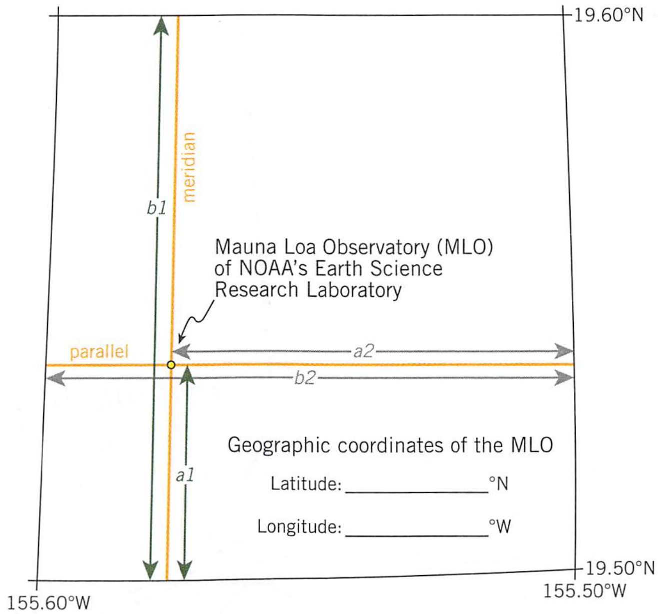


Figure A1.2.1

1. Latitude 19.50°N is the minimum latitude shown on the map. Carefully measure the distance along the orange line from the 19.50°N parallel to the MLO site. We will call that map distance *a1*. *a1* = ____________ cm
2. Measure the total map distance along that same orange line from the 19.50°N parallel through the MLO site to the 19.60° parallel and call that map distance *b1*. *b1* = ____________ cm
3. We know the difference in latitude from the bottom of the map at 19.50°N to the top of the map at 19.60°N and call that distance *d1*. *d1* = ____________ °
4. We would like to know the difference in latitude between 19.50°N and the MLO site and will call this unknown quantity *c1*. The ratio of *a1* to *b1* is the same as the ratio of *c1* to *d1*. Use what you learned about proportions by reading the text earlier in this chapter to find *c1*. *c1* = ____________ °
5. Determine the latitude of the MLO site (19.50°N + *c1*) ____________ °N
6. Just in case you come across this situation again in the (near) future, write a general equation to solve this type of equation directly using the variable names *a*, *b*, *c*, and *d*: *c* = ____________

   Follow the same general procedure to find the longitude of the MLO site.
7. Map the distance from longitude 155.50°W to MLO (*a2*), recognizing that longitude 155.50°W is the minimum longitude shown on the map: *a2* = ________ cm.

8. Map the distance from 155.50°W through MLO to 155.60°W (*b2*): *b2* = __________ cm.

9. The difference in longitude between 155.50°W and 155.60°W (*d2*): *d2* = __________ °

10. Use your general equation from part **A6** to find the value of *c2* (that is, the difference in longitude between 155.50°W and the MLO site). *c2* = __________ °

11. Determine the longitude of the MLO site (155.50°W + *c2*). ___________ °N

B Part of the USGS 7.5-minute topographic quadrangle map of the Lower Geyser Basin, Wyoming (2015), is reproduced in **Fig. A1.2.2**. On the topographic map, put a dot in the center of the blue oval representing the *Grand Prismatic Spring* (**Fig. 1.3**). We are going to build on what you learned in part **A** to find the UTM coordinates of the center of the Grand Prismatic Spring.

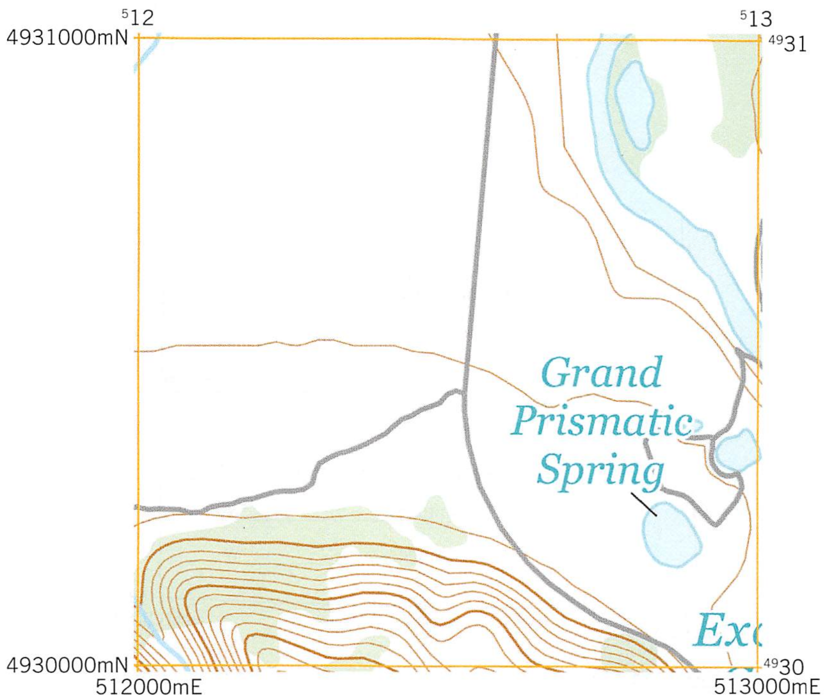


Figure A1.2.2

1. Regarding a first look at the map in **Fig. A1.2.2**
   - **(a)** What is the minimum easting on the map? __________________ mE. What edge of the map is bounded by the minimum easting (top, bottom, left, right)? __________
   - **(b)** What is the minimum northing on the map? __________________ mN. What edge of the map is bounded by the minimum northing (top, bottom, left, right)? __________
   - **(c)** Is the central meridian for this zone to the east (right) or west (left) of this map area? (Refer to **Fig. 1.5** for assistance.) __________

2. The yellow square that surrounds most of the map in **Fig. A1.2.2** represents a horizontal area on the ground at Yellowstone National Park that is 1000 m by 1000 m (1 km × 1 km) in dimension. We can use a side of that square like a bar scale.
   - **(a)** As accurately as you can, measure the length of a side of the yellow square on the map in cm; we'll use the variable name *a3* for this map length. *a3* = __________________ cm
   - **(b)** We will use the variable name *b3* for the ground distance along one of the sides of the yellow square—1 km—but expressed *in the same units* as we used for *a3*. That is, *b3* is the number of cm in 1 km. There are 100 cm in 1 m, and 1000 m in 1 km. *b3* = __________________ cm
   - **(c)** The fractional scale of this map can be found by dividing *b3* by *a3*—we'll call that result *e3*. The fractional scale is 1/*e3* or 1:*e3*. 1/__________ or 1:__________.

     That means that 1 length unit of any sort (cm, for example) on the map represents *e3* length units of the same sort (cm) on the ground.

3. Find the UTM coordinates of the middle of Grand Prismatic Spring.

(a) Measure the map distance from the side that represents the minimum easting of the yellow square (*c3*).
c3 = ____________ cm

(b) Use the fractional scale of the mathematical expression you developed in part **B2(c)** to find the ground distance between the minimum easting and the middle of Grand Prismatic Spring ($d3 = c3 \times e3$). *d3* = ____________ cm

(c) Convert *d3* into meters, and call the result *d3'*. *d3'* = ____________ m

(d) What is the easting of Grand Prismatic Spring (minimum easting +*d3'*)? ____________ mE

Follow the same general procedure to find the northing of Grand Prismatic Spring.

(e) Measure the map distance from the side that represents the minimum northing of the yellow square (*c4*).
c4 = ____________ cm

(f) Use the fractional scale of the mathematical expression you developed in part **B2(c)** to find the ground distance between the minimum northing and the middle of Grand Prismatic Spring ($d4 = c4 \times e3$).
d4 = ____________ cm

(g) Convert *d4* into meters, and call the result *d4'*. *d4'* = ____________ m

(h) What is the northing of Grand Prismatic Spring (minimum northing +*d4'*)? ____________ mN

(i) The UTM coordinates of the middle of Grand Prismatic Spring are
12T ________________ mE ________________ mN

Activity 1.3 Plotting a Point on a Map Using UTM Coordinates

Name: ______________________ **Course/Section:** ______________ **Date:** __________

A Part of the USGS 7.5-minute topographic quadrangle map of Old Faithful, Wyoming (2015), is reproduced in **Fig. A1.3.1**. We are going to plot the location of the active vent of the Old Faithful geyser. As of mid-August 2015, the active vent was located approximately at UTM coordinates 12T 513671 mE 4923032 mN.

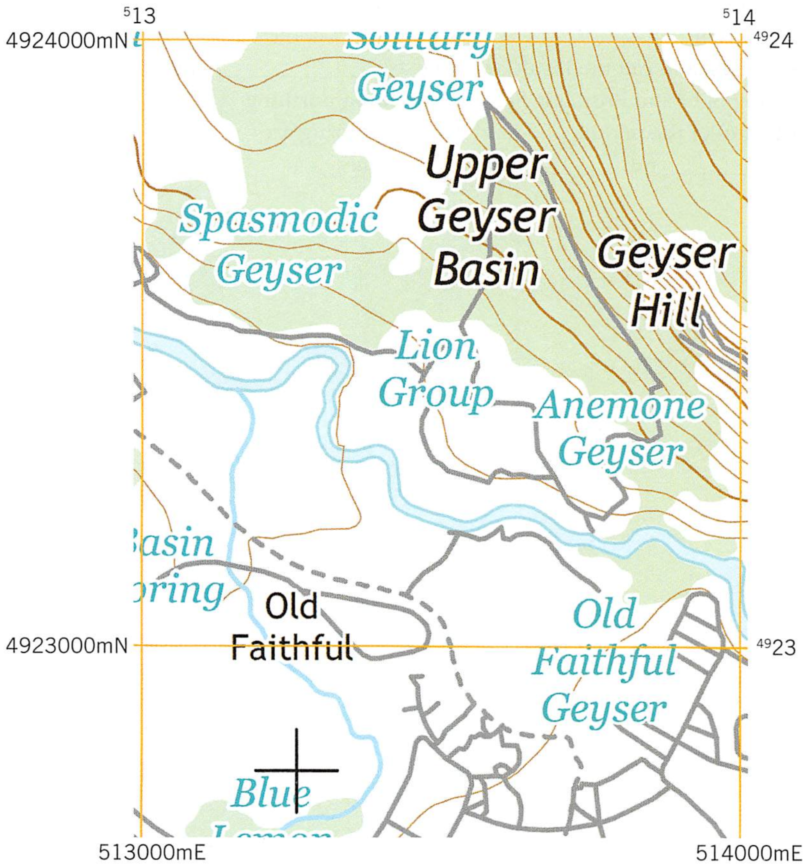


Figure A1.3.1

1. Regarding a first look at the map in **Fig. A1.3.1**
   (a) What is the minimum easting on the map? ________________ mE. What edge of the map is bounded by the minimum easting (top, bottom, left, right)? ________
   (b) What is the minimum northing on the map? ________________ mN. What edge of the map is bounded by the minimum northing (top, bottom, left, right)? ________
   (c) Is the central meridian for this zone to the east (right) or west (left) of this map area? (Refer to **Fig. 1.5** for assistance.) ________

2. The yellow square that surrounds most of the map in **Fig. A1.3.1** represents a horizontal area on the ground that is 1 km by 1 km in dimension, so we can use a side of that square as a bar scale.
   (a) As accurately as you can, measure the length of a side of this square in cm; we'll use the variable name *a5* for this length. *a5* = ________ cm
   (b) We will use the variable name *b5* for the number of cm in 1 km. *b5* = ________ cm
   (c) The fractional scale of this map can be found by dividing *b5* by *a5*—we'll call that result *e5*. The fractional scale is 1/*e5*, or 1:*e5*. 1/________ or 1:________. That means that 1 length unit of any sort (cm, for example) on the map represents *e5* length units of the same sort (cm) on the ground.

3. Plotting the vent location: 12T 513671 mE 4923032 mN.

(a) Based on the UTM coordinates of the vent, how far north of the 4923000 mN line is the vent *on the ground* at Yellowstone National Park? __________ m

(b) Using the fractional scale, how far up from the yellow 4923000 mN line is the vent *on the map*? __________ cm

(c) Draw a line on the map that is that distance above the 4923000 mN line.

(d) Based on the UTM coordinates of the vent, how far east of the 513000 mE line is the vent? __________ m

(e) Using the fractional scale, how far to the right of the yellow 513000 mE line is the vent on the map? __________ cm

(f) Draw a line on the map that is that distance to the right of the 513671 mE line.

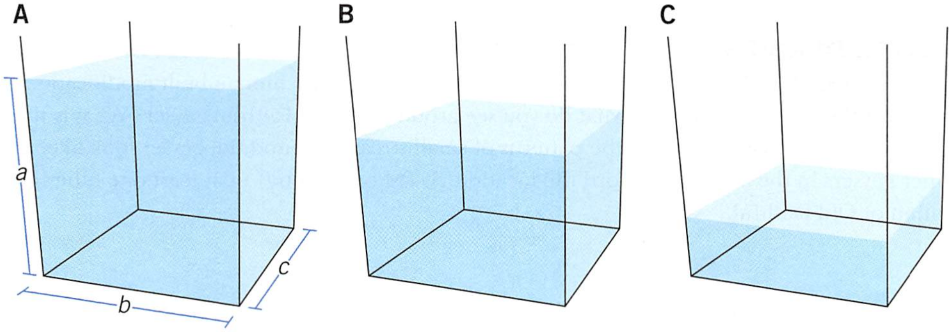
(g) The active vent is located where the two lines you drew intersect. Put a small circle around that point, and add an appropriate label to the map near that point to identify it as the active vent.

B **REFLECT & DISCUSS** Use Google Earth to navigate to the active vent at 12T 513671 4923032 (or latitude 44.46046, longitude −110.82815). Think like a geoscientist and ignore all of the human-built modifications to the landscape. Now, observing just the natural landscape, what do you see around the Old Faithful geyser? What is the color or tone of the material around the geyser? What do the patterns of small streams around the geyser look like? Use your description to find other geysers in the area, and record the location (UTM or lat–long) of at least one other geyser you found using your description of Old Faithful.

Activity 1.4 Floating Blocks and Icebergs

Name: ______________________ **Course/Section:** ______________ **Date:** __________

A Imagine that you have a solid that is square on the top and bottom and either a square or rectangle on all the other sides (i.e., it is a cube or rectangular prism) like the one shown in column A of **Fig. A1.4.1**, whose sides have lengths a, b, and c, and the b and c are of equal length.



	A	B	C
depth (a)	1.0 cm	0.7 cm	______ cm
base dimensions (b, c)	1.0 cm 1.0 cm	1.0 cm 1.0 cm	1.0 cm 1.0 cm
volume (V)	1.0 cm^3	______ cm^3	______ cm^3
density (ρ)	1.0 g/cm^3	1.0 g/cm^3	1.0 g/cm^3
mass (m)	______ g	______ g	0.3 g

Figure A1.4.1

1. Now imagine that you know the volume of the solid (V, measured in cm^3) and the length of two of the three sides, b and c (measured in cm). Explain in words or with an equation how you can calculate the length of the remaining side, a.

2. The relationship between mass, density, and volume is that mass (m, measured in grams, g) is the product of density (ρ, measured in g/cm^3) times volume (cm^3): $m = \rho \times V$. Recall that the Greek letter rho (ρ) is used to represent density.

   (a) If you know mass and density, you can calculate the volume. How?

   (b) If you know volume and density, you can calculate mass. How?

3. Use the relationships you just described to compute the values needed to fill in the blanks in the table in **Fig. A1.4.1**.

4. Imagine a rectangular prism of pure water whose density (ρ) is 1.0 g/cm^3. The base of this imaginary prism is 1 cm on a side, and the remaining side of the prism is the water depth (a) measured in cm. The mass (m) of that prism of water, expressed in grams, is related to the water depth (a) in the following way: the value of a is _____ the value of m.

B One way of restating Archimedes' Principle is that the mass of a block that is floating in a fluid is equal to the mass of the fluid displaced by the block. Imagine that we have a solid block in which all of the sides are 1 cm long—a cube with a volume of 1 cm^3 (**Fig. A1.4.2A**). We set it in a beaker of pure water and find that, when the block and water come to rest, 70% of the block is submerged under water, so a = 0.7 cm and b = 1.0 cm (**Fig. A1.4.2B**).

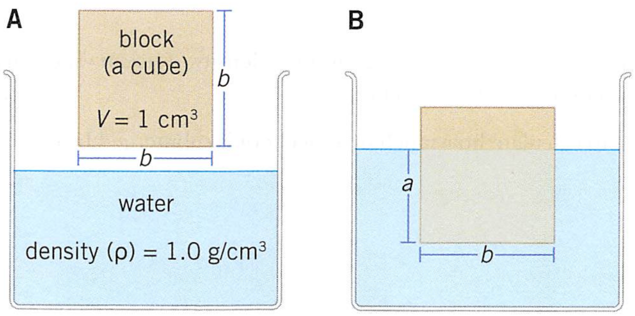


Figure A1.4.2

1. What is the volume of water displaced by the block? _____ cm^3

2. The density of the water (ρ_{water}) is 1.0 g/cm^3, so what is the *mass* of water displaced by the block? Multiply the volume of water by the density of the water. The mass of water displaced by the block is _____ g.

3. Using the previous answer, apply Archimedes' Principle to find the *mass* of the block. The mass of the entire block (m) is _____ g.

4. The block is a cube with a volume of 1 cm^3. Now that you know the mass and the volume of the block, what is the *density* of the block (ρ_{block})? ρ_{block} = _______________ g/cm^3

5. The submerged part of the block is 70% of the total volume of the block. What is the ratio of the density of the block to the density of the water; that is, what is ρ_{block} divided by ρ_{water}? Express your answer as a percentage (e.g., 0.7 = 70%) $\rho_{block}/\rho_{water}$ = _______ %

6. Using words rather than numbers, compare the ratio of the volume of the submerged part of the block ($V_{submerged}$) to the total volume of the block (V_{total}) with the ratio of the density of the block (ρ_{block}) to the density of the water (ρ_{water}). The ratio $V_{submerged}/V_{total}$ is _____ the ratio $\rho_{block}/\rho_{water}$.

C If your teacher has provided a block of wood and a beaker or bowl of water, try the floating-block experiment yourself.

1. Carefully measure the three dimensions of the wood block and record the lengths.

   _____ cm _____ cm _____ cm

2. Determine the volume of the block. V_{block} = ________ cm^3

3. If one is available, use a pan balance to measure the mass (m) of the block. m_{block} = ________ g. Now determine the density of the block (ρ_{block}), which is equal to the volume divided by the mass (V_{block}/m_{block}). ρ_{block} = __________ g/cm^3

4. Gently place the block in water and wait until it comes to rest. Mark the waterline on the block, and measure the distance the block extended below the waterline.

   _____ cm

5. Determine the volume of the block that was submerged. _____ cm^3

6. Calculate the ratio of the volume of the submerged part of the block to the total volume of the block. _____

7. Use Archimedes' Principle to find the density of the block. _____ g/cm^3

8. Compare your answers for parts **C3** and **C7**, and comment on which seems like it might be a more reliable or simpler method to measure the density of the block.

D The density of water ice in icebergs is 0.917 g/cm^3. The average density of ocean water varies with temperature and salinity (saltiness), but we will assume a density of 1.025 g/cm^3.

1. Use Archimedes' Principle to calculate how much of an iceberg is submerged below sea level. Show your work.

2. Use Archimedes' Principle to calculate how much of an iceberg is exposed above sea level. Show your work.

3. Notice the graph paper grid overlay on the picture of an iceberg in **Fig. 1.9B**. Use this grid to determine and record the cross-sectional area of this iceberg that is below sea level and the cross-sectional area that is above sea level by adding together all of the whole boxes and fractions of boxes that overlay the root of the iceberg or the exposed top of the iceberg. Use these data to calculate the percentage of the iceberg that is below sea level and the percentage that is above sea level. How do your results compare to your calculations in steps **D1** and **D2**?

4. What do you think might happen as the top of the iceberg melts?

E **REFLECT & DISCUSS** How much does the melting of an iceberg floating in the ocean contribute to sea level rise. (*Hint*: Does the liquid level change when an ice cube floating in a glass of liquid water melts?)

Summarizing Data and Imagining Crustbergs Floating on the Mantle

Activity 1.5

Name: ______________________ **Course/Section:** ______________ **Date:** __________

A *As exactly as you can,* determine the mass and volume of a small sample of basalt. Use a laboratory balance to measure the sample's mass, and use the water-displacement method with a graduated cylinder to determine the volume (**Fig. 1.8**). Add your data to the basalt density chart (**Fig. A1.5.1**). Calculate the density of your sample of basalt to 10ths of a g/cm^3. Then determine the descriptive statistics for all 10 lines of sample data in the basalt density chart.

BASALT DENSITY CHART

Basalt Sample Number	Sample Mass (g)	Sample Volume (cm^3)	Sample Density (g/cm^3)
1	40.5	13	3.1
2	29.5	10	3.0
3	46.6	15	3.0
4	31.5	10	3.2
5	37.6	12	3.1
6	34.3	11	3.1
7	78.3	25	3.1
8	28.2	9	3.1
9	55.6	18	3.1
10			

Density of basalt

Average or Mean = ______ g/cm^3 Median = ______ g/cm^3 Mode = ______ g/cm^3 Standard Deviation = ______ g/cm^3

Figure A1.5.1

B *As exactly as you can,* determine the mass and volume of a small sample of granite. Follow the same methodology for measuring the granite that you used in the previous section. Add your data to the granite density chart (**Fig. A1.5.2**). Calculate the density of your sample of granite to 10ths of a g/cm^3. Then determine the descriptive statistics for all 10 lines of sample data in the granite density chart.

GRANITE DENSITY CHART

Granite Sample Number	Sample Mass (g)	Sample Volume (cm^3)	Sample Density (g/cm^3)
1	32.1	12	2.7
2	27.8	10	2.8
3	27.6	10	2.8
4	31.1	11	2.8
5	58.6	20	2.9
6	62.1	22	2.8
7	28.8	10	2.9
8	82.8	30	2.8
9	52.2	20	2.6
10			

Density of granite

Average or Mean = ______ g/cm^3 Median = ______ g/cm^3 Mode = ______ g/cm^3 Standard Deviation = ______ g/cm^3

Figure A1.5.2

C Geoscientists who study the propagation of earthquake energy through Earth's interior—seismologists—indicate that the average density of the uppermost upper mantle is around 3.3 g/cm^3. Where it is hot enough, the mantle is able to flow.

1. Seismologists indicate that the average thickness of basaltic ocean crust is about 7 km. As a thought experiment, imagine that a particular bit of solid oceanic crust with the same bulk density that you calculated for basalt is floating in a sea of upper mantle material that has a bulk density of 3.3 g/cm^3 and that is hot enough to flow. (In fact, most of the oceanic crust is on top of a relatively cool, solid part of the upper mantle that does not flow, but let's not spoil the fun with details.) Use what you have learned about Archimedes' Principle, buoyancy, and isostasy to estimate (i.e., to calculate) how high (in km) basalt would float in a viscous, flowing upper mantle. Show your work.

   The upper surface of oceanic crust in this imaginary world would be about _____ km above the level of the upper mantle.

2. Seismologists indicate that the average thickness of granitic continental crust is about 35 kilometers. Make the same kind of calculation you just completed in section **C1**, but this time, use the average density you determined for granite to estimate how high granitic continental crust would float in a viscous, flowing upper mantle. Show your work.

   The upper surface of continental crust in this imaginary world would be about _____ km above the level of the upper mantle.

3. What is the difference (in km) between your answers in **C1** and **C2**?

4. How does this difference between **C1** and **C2** compare to the actual difference between the average height of continents and average depth of oceans on the hypsographic curve (**Fig. 1.11C**)?

D **REFLECT & DISCUSS** Reflect on all of your work in this laboratory so far. Explain why Earth has a bimodal global topography.

E **REFLECT & DISCUSS** How is a mountain like the iceberg in **Fig. 1.9B**?

Unit Conversions, Notation, Rates, and Interpretations of Data

Activity 1.6

Name: ______________________ **Course/Section:** ______________ **Date:** __________

A Make the following unit conversions using the Mathematical Conversions chart on page xx.

1. 10 mi. = ____________ km
2. 1 ft. = ____________ m
3. 16 km = ____________ m
4. 25 m = ____________ cm
5. 25.4 mL = ____________ cm^3
6. 1.3 L = ____________ cm^3

B Write these numbers using scientific notation

1. 6,555,000,000 = ________
2. 0.000001234 = ________

C RATES

1. Our current best estimate is that the western Grand Canyon in Arizona began to be excavated by river erosion about 6 million years ago. The greatest depth of the Grand Canyon is about 1.6 km.

   (a) What is the mean (average) rate that the Grand Canyon has been eroded into the Colorado Plateau during the past 6 million years, expressed in millimeters per year? Show your work below.

   (b) If erosion of the Grand Canyon proceeded at that rate during the most recent century, how much deeper is it today than it was on the day you were born? Show your work.

2. During Earth's very early history, our planet was whacked by meteorites large and small, and eventually grew to its current size. Earth probably went through a period in which it was molten from near the surface to its center. Throughout its history, Earth has been hotter at its center than at its outer surface.

   (a) In caves just below Earth's ground surface in continental crust, the temperature tends to be a constant ~15°C (~59°F). (That's why people use caves for wine storage.) The deepest mine on Earth is currently the Mponeg gold mine just southwest of Johannesburg, South Africa, which reaches just over 4 km below the surface. At the bottom of that mine, the rock temperature reaches 66°C (~151°F). Using the cave temperature to represent the surface temperature of the crust at ~0 km depth, what is the rate at which temperature changes in Earth between 0 and 4 km—the near-surface *geothermal gradient*? ____________°C/km

(b) The temperature at the bottom of the lithosphere in Earth is often inferred to be around 1300°C. If we assume a depth to the base of the lithosphere of 100 km, what is a reasonable estimate for the geothermal gradient between 0 km and ~100 km? _____________°C/km

(c) The center of Earth at an average depth of 6371 km below the surface has a temperature that has been estimated to be approximately 6000°C. What is the average geothermal gradient from Earth's surface to its center? _____________°C/km

(d) Write a brief statement of a hypothesis you think might best explain the variation in the geothermal gradient within Earth.

D SINGLE-LINE GRAPH

The amount of CO_2 in the atmosphere has been monitored at Mauna Loa Observatory, Hawaii, since the late 1950s, initiated by Dave Keeling of the Scripps Institution of Oceanography and continued in cooperation with the U.S. National Oceanic and Atmospheric Administration (NOAA). A selection of data from this ongoing study is presented in **Fig. A1.6.1**, showing how the concentration of CO_2 in ppmv (parts per million volume) has changed per decade since 1959. The source of the data is **http://www.esrl.noaa.gov/gmd/ccgg/trends/**.

1. Round each of the CO_2 concentration values to the nearest integer value, and write the rounded numbers on the lines provided in the table of **Fig. A1.6.1**. To get you started, the first rounded value is 316.

2. Plot the data onto the graph as carefully as you can.

3. Use a ruler to draw a line that follows the trend of the points. To do this, you will need to visually approximate by drawing the line so that it passes through the middle of the points with about as many points above as below the line.

4. What does the slope of the line you drew through the data tell you about the change in the atmospheric concentration of CO_2 as observed at the Mauna Loa Observatory?

Annual Average Concentration of Atmospheric Carbon Dioxide (CO_2) at Mauna Loa Observatory, Hawaii

Year	CO_2 (ppmv)	Rounded to Integer
1959	315.97±0.12	______
1969	324.62±0.12	______
1979	336.78±0.12	______
1989	353.07±0.12	______
1999	368.33±0.12	______
2009	387.37±0.12	______
2015	400.83±0.12	______

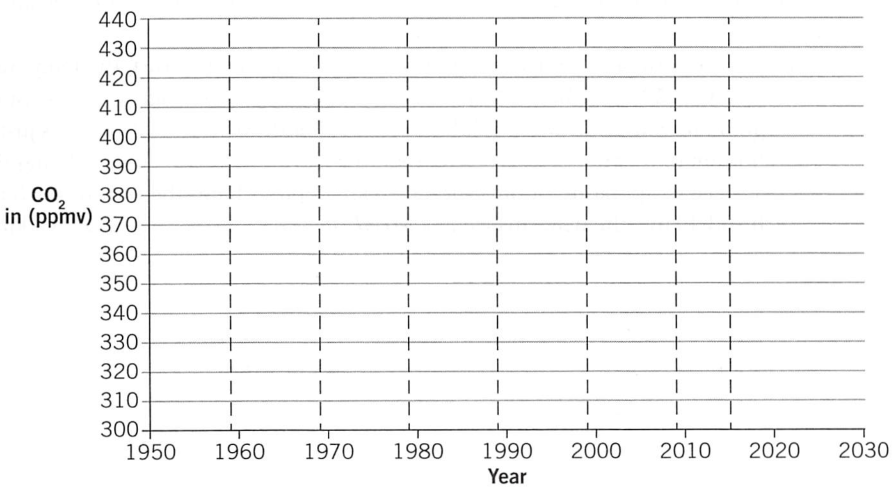


Figure A1.6.1

E BAR GRAPH

We will use a different type of graph to derive additional information from the CO_2 data (**Fig. A1.6.2**).

Average Yearly Rate of Increase in the Concentration of Atmospheric Carbon Dioxide (CO_2) at Mauna Loa Observatory, Hawaii	
Time interval	Rate of increase per year
1959–1969	0.9
1969–1979	
1979–1989	
1989–1999	
1999–2009	

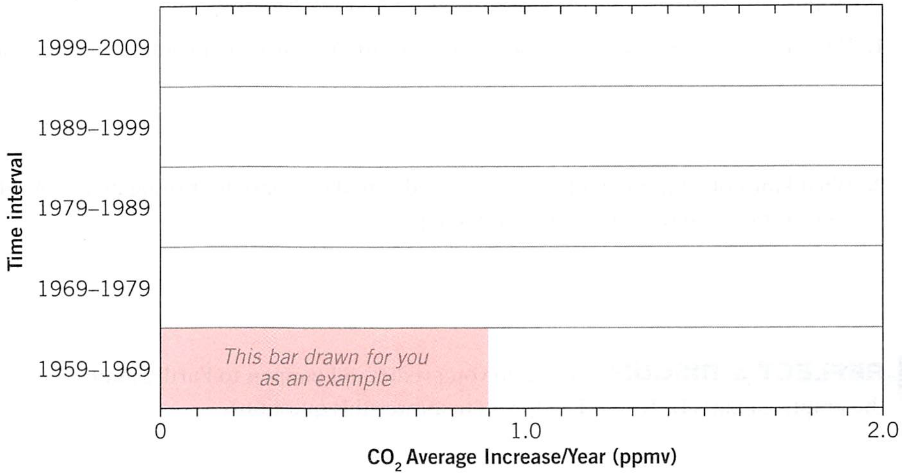


Figure A1.6.2

1. Calculate the average rate of increase in CO_2 concentration per year for the time intervals 1959–1969, 1969–1979, 1979–1989, 1989–1999, and 1999–2009, and write the results in the spaces provided in **Fig. A1.6.2**. The value for 1959–1969 is provided for you as an example.

2. Plot the results as a bar graph. The 1959–1969 bar is plotted for you.

3. Briefly describe how you interpret the information you plotted in the bar graph.

F TWO-LINE GRAPH

Two different datasets are plotted as a function of time in **Fig. A1.6.3**, both obtained by analysis of an ice core from Vostok Station, Antarctica (**https://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/ice-core**). The blue line tracks the change in temperature at Vostok Station relative to the present, and the relative

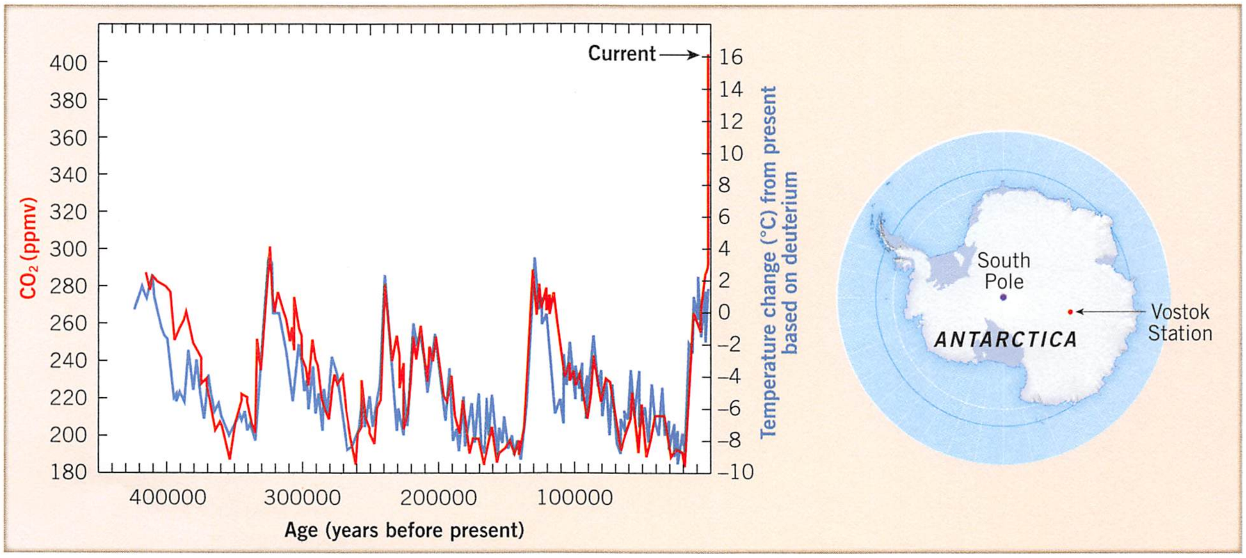


Figure A1.6.3

temperature scale is printed on the right vertical axis of the graph. Positive values indicate warmer than present, and negative values are cooler than present. The red line tracks the concentration of carbon dioxide at Vostok Station, and the corresponding scale is on the left vertical axis. Both plots share the same time scale on the horizontal axis.

1. What relationship between temperature and carbon dioxide concentration is revealed by this graph?

2. What kinds of additional information would you like to have to investigate further the possible correlation between CO_2 concentration in the atmosphere and temperature?

G REFLECT & DISCUSS What do you predict will happen to Earth's atmospheric temperature in the future? How do the graphs in parts **D**, **E**, and **F** help you to answer this question?

Scaling, Density, and Earth's Deep Interior

Activity 1.7

Name: ____________________ **Course/Section:** ______________ **Date:** __________

Earth is a combination of several dynamic systems. To get a feel for the dimensions of some of Earth's primary layers, let's create a scaled image of Earth from outer space to Earth's center and investigate how density plays a role in this structure.

A We are given several distances expressed in km that we need to scale so that we can represent distances within Earth as much smaller distances on our page. Our scale is that 100 mm on the page represents the 6371 km of Earth.

1. We need a scaling factor that we can multiply the "distances from sea level" in km shown in **Fig. A1.7.1** to find the appropriate map distance in mm. Using our skills with proportions, we notice that 100 mm on the map is to 6371 km in Earth as our unknown conversion factor is to 1 km. Using your knowledge of proportions (and referring to the coverage of proportions earlier in the chapter text if necessary), determine the conversion factor: ______________ mm/km

Distance from Sea Level	Layer Name	Average State	Distance from Sea Level on Illustration
~ 100 km			____ mm
	atmosphere	gas	
sea level			0 mm
	continental crust	solid	
~35 km			____ mm
	upper mantle	solid	
410 km			____ mm
	mantle transition zone	solid	
660 km			____ mm
	lower mantle	solid	
2889 km			____ mm
	outer core	liquid	
5154 km			____ mm
	inner core	solid	
6371 km	center of Earth		100 mm

Figure A1.7.1

2. Use that scaling factor to compute the values in the right column of **Fig. A1.7.1**. Two values are provided for you.

3. Use a sharp pencil to carefully mark the "distances from sea level" from the right column of **Fig. A1.7.1** onto the left side of the millimeter scale on **Fig. A1.7.2**.

4. Use a drafting compass to draw concentric quarter-circle arcs from each of the pencil marks you just made on **Fig. A1.7.2**. The sharp pivot end of the compass should be held in the small circle at the 100 mm mark at the center of Earth.

5. Label each of the major layers of Earth's interior on **Fig. A1.7.2A**.

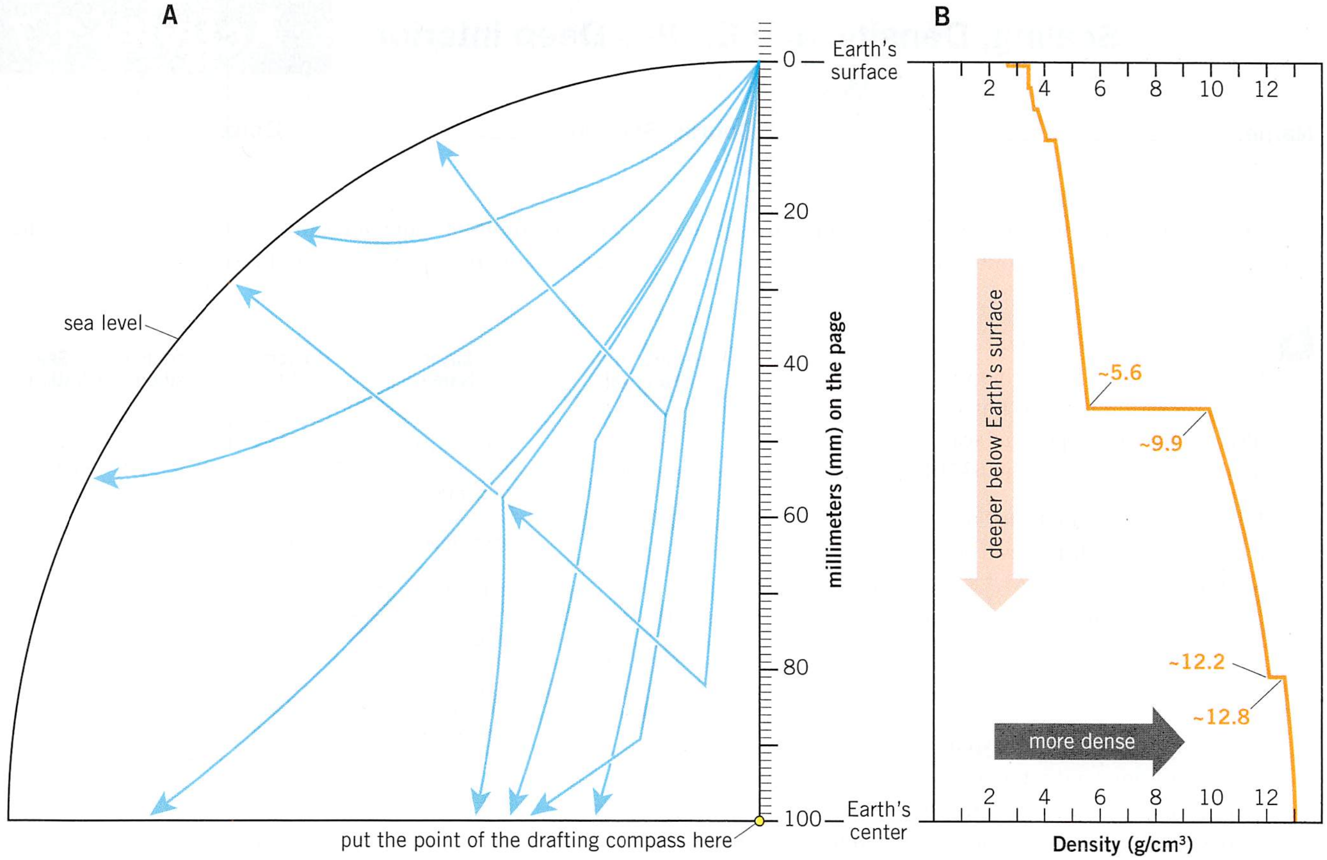


Figure A1.7.2

B Seismologists who study Earth's deep interior by modeling how earthquake energy propagates through Earth's interior have developed ways of recognizing the places where that energy is reflected off of boundaries where the upper layer is less dense than the lower layer. This phenomenon is like the reflection of a beam of light off of a reflective surface. The larger the difference between layer densities across a boundary, the more prominent the reflection of earthquake energy will be.

1. **Figure A1.7.2B** shows a plot of the approximate variation in density with depth in Earth's interior arranged so that its vertical scale is the same as the radius of the section through Earth in **Fig. A1.6.2A**. Circle the largest jump in density in **Fig. A1.7.2B**.
2. At what depth does the largest density jump occur in Earth's interior as depicted in **Fig. A.1.7.2B**? ____________ km
3. Across the boundary between which two layers does this large density jump occur?

   less dense layer: ____________ more dense layer: ____________

C **REFLECT & DISCUSS** Rays indicating the paths of seismic waves through Earth due to a single earthquake that occurred near the top of **Fig. A1.7.2A** are shown in light blue on that figure. Describe how the shapes of the light blue ray paths relate (if at all) to the various boundaries you drew in section **A4** and to the boundaries indicated in the density plot in **Fig. A1.7.2B**.

D **REFLECT & DISCUSS** As Earth was forming in its earliest history and probably when the collision that resulted in the formation of the Moon occurred more than 4 billion years ago, Earth was a blob of molten rock with just a thin solid film on its outer surface. Given your experience with materials of different densities, what can you infer about the relative densities of Earth's atmosphere, ocean, rocky crust and mantle, and iron-rich core?