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A Sneak Peek at the New Edition of the ***AGI/NAGT Lab Manual in Physical Geology*** with the Author-Editor

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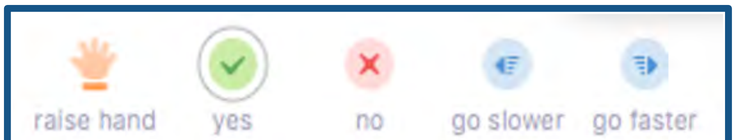

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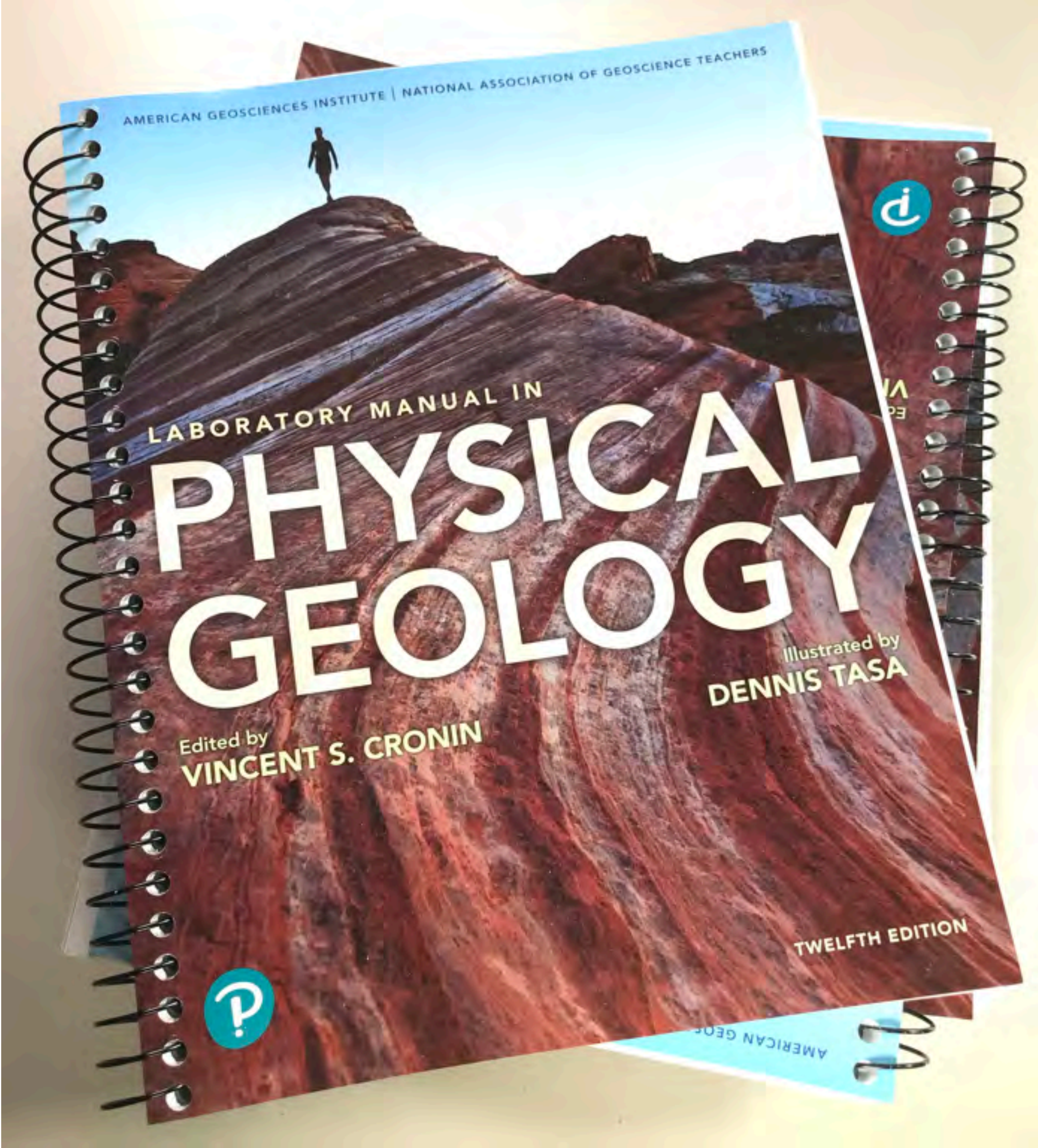

The ***AGI/NAGT Laboratory Manual in Physical Geology, 12th Edition*** is now in print and available for adoption!

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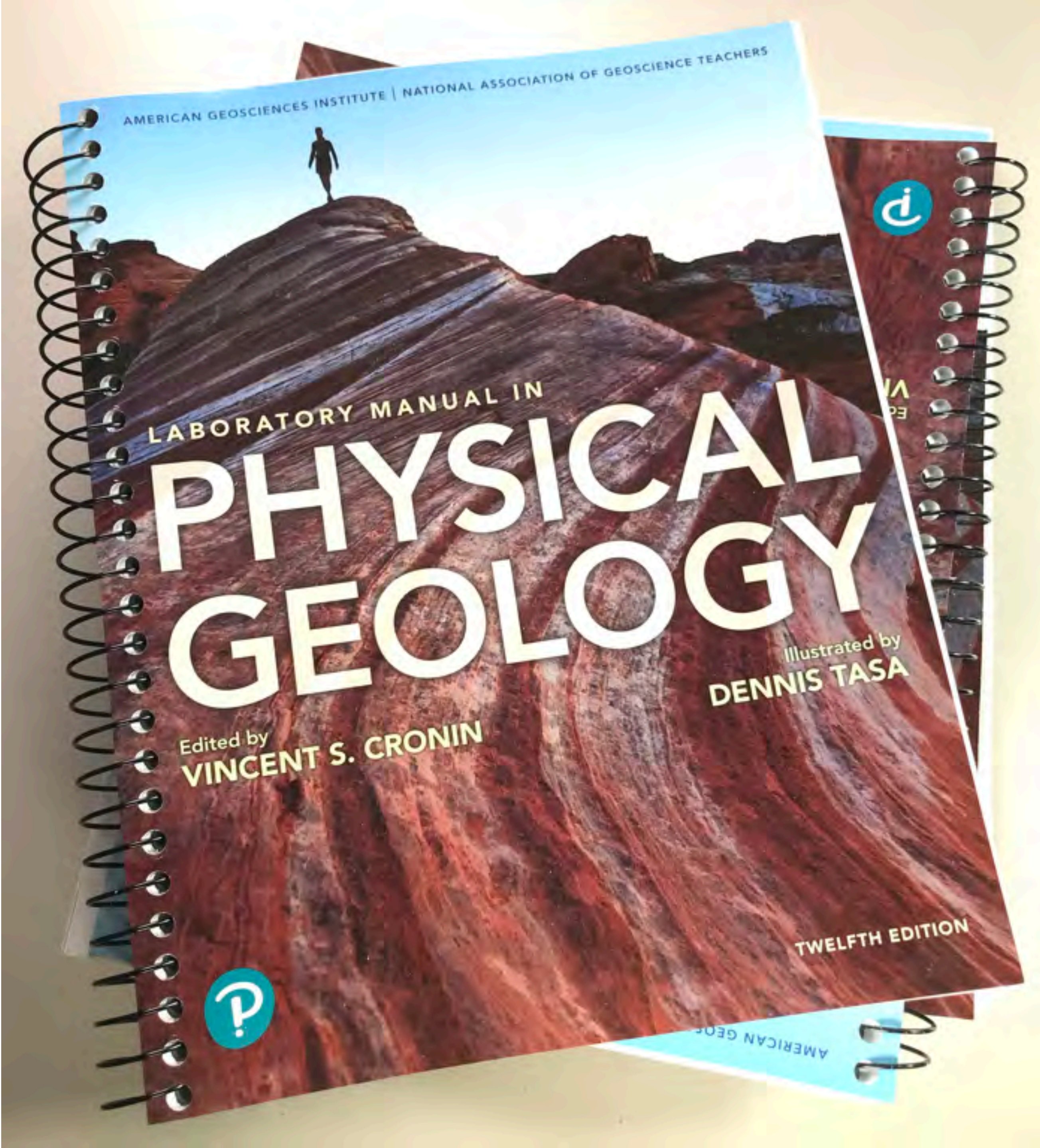

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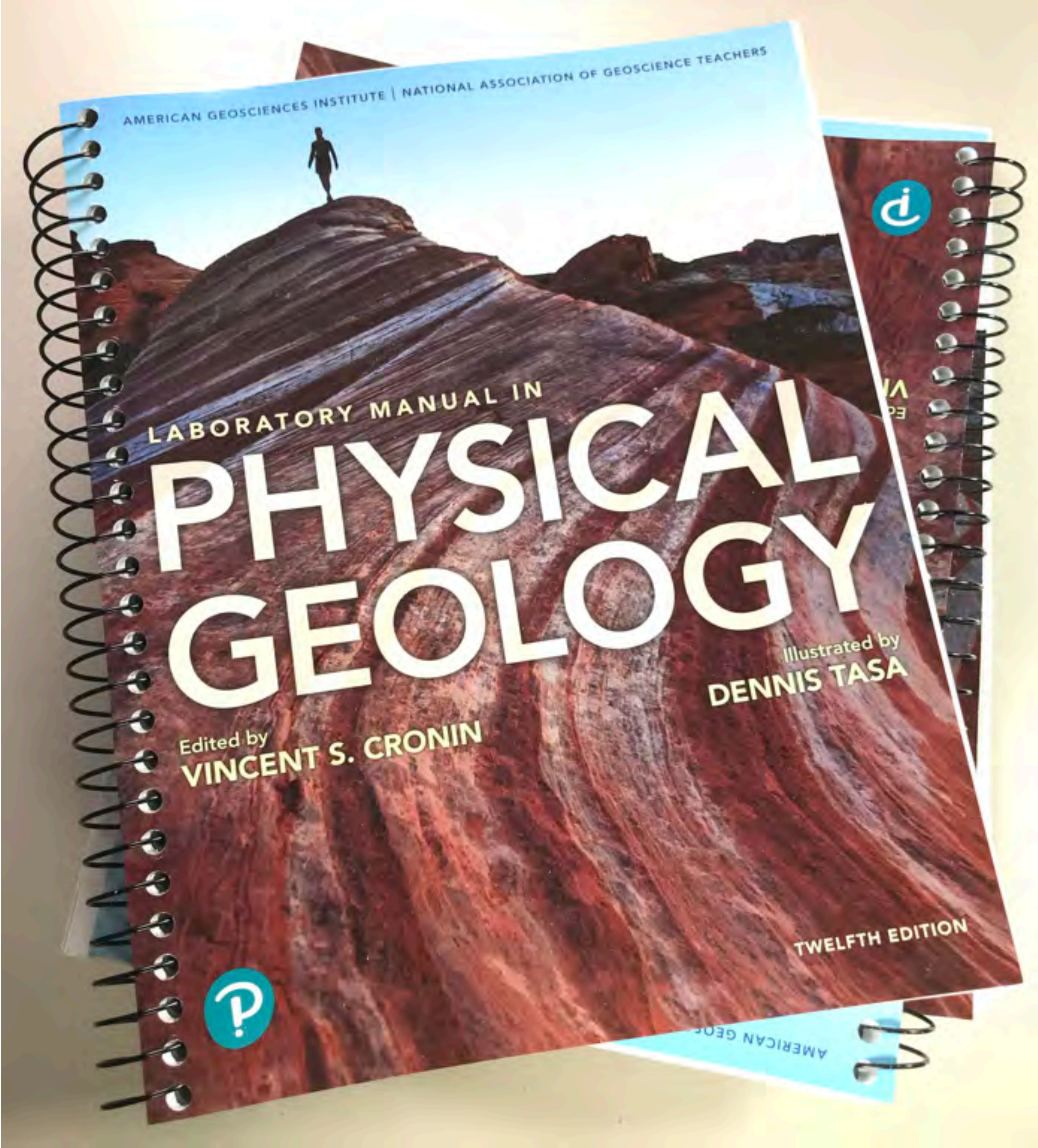

Available in ***Spiral-bound paper***, as an ***eText***, and as a ***custom lab book*** in which you choose the chapters you want to use.

The ***Instructor's Manual*** is available for the 12th edition, containing answers, hints, links, and references for the lab manual content.

Mastering Geology

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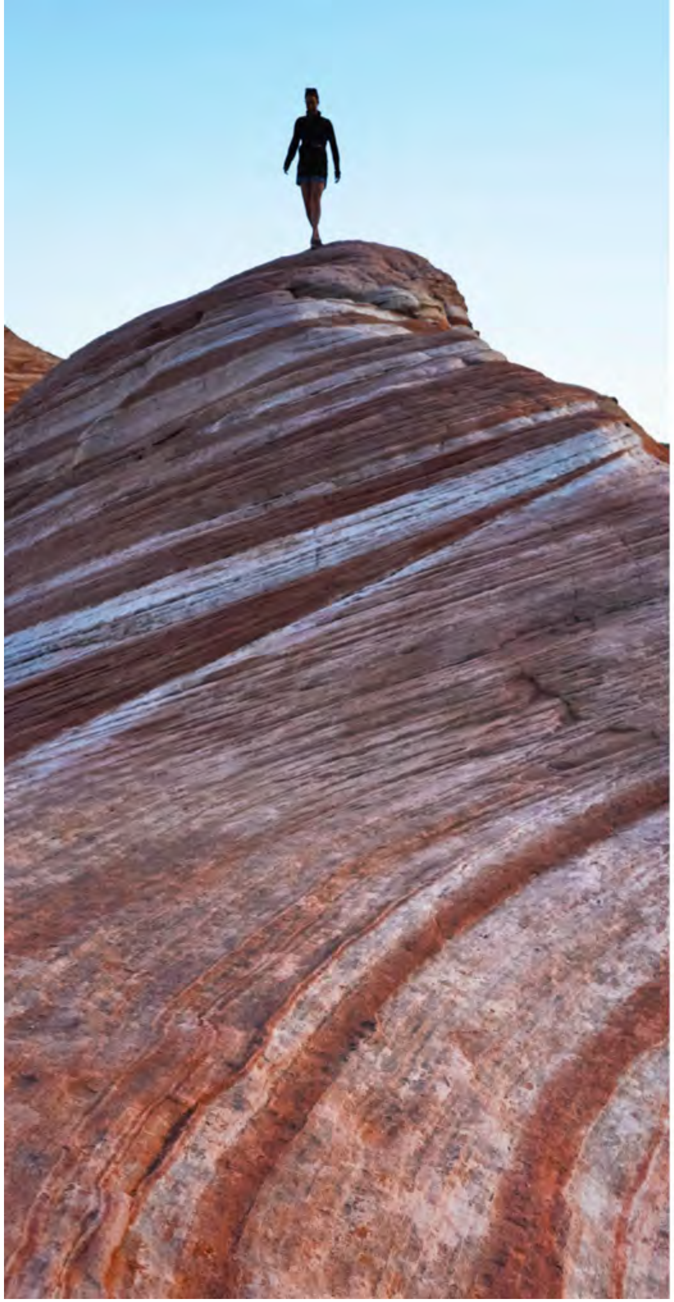

Laboratory Manual in

PHYSICAL GEOLOGY

TWELFTH EDITION

PRODUCED UNDER THE AUSPICES OF THE

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AND THE

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This Laboratory Manual is unique.

- It was created and is maintained by the geosciences community as a community educational resource

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- It was created and is maintained by the geosciences community as a community educational resource
- Proceeds from its sale provide financial support for the work of NAGT and AGI, benefitting the entire geoscience community

"the best laboratory investigations written by geology teachers"

Robert Ridky

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Laboratory 9

Topographic Maps

Contributing Authors

Charles G. Higgins • *University of California*
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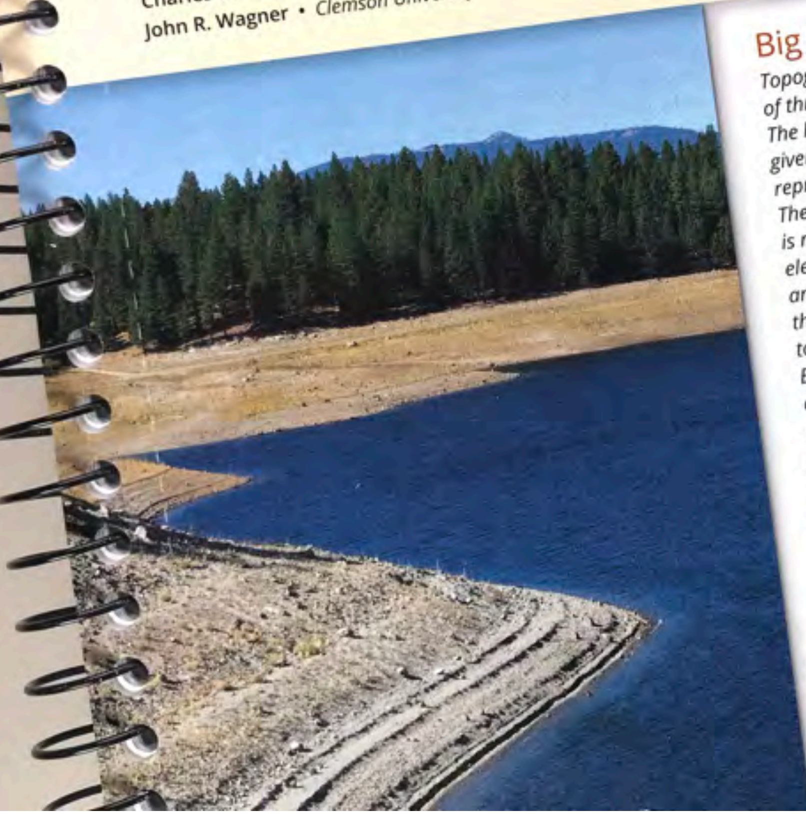
James R. Wilson • *Weber State University*



Big IDEAS

Topographic maps are two-dimensional representations of three-dimensional landscapes viewed from above. The horizontal positions of landscape features are given relative to a coordinate reference frame and are represented at consistent scale throughout the map. The third dimension, the elevation of the ground surface, is represented with contours that join points of equal elevation relative to sea level. The three-dimensional and quantitative aspect of topographic maps make them valuable to geologists and other people who want to know the shapes, elevations, and spatial scales of Earth's surface. They can be used in combination with orthoimages—aerial photographs that have been adjusted to the same scale as the map—in the study of Earth's surface processes and landforms.

Lab ACTIVITIES

9.1 Map and Google Earth Inquiry (p. 253)
9.2 Map Locations, Distances, Directions, and Symbols (p. 255)
9.3 Topographic Map Construction (p. 257)
9.4 Topographic Map and Orthoimage Interpretation (p. 258)
9.5 Relief and Gradient (Slope) Analysis (p. 261)
9.6 Topographic Profile Construction (p. 263)

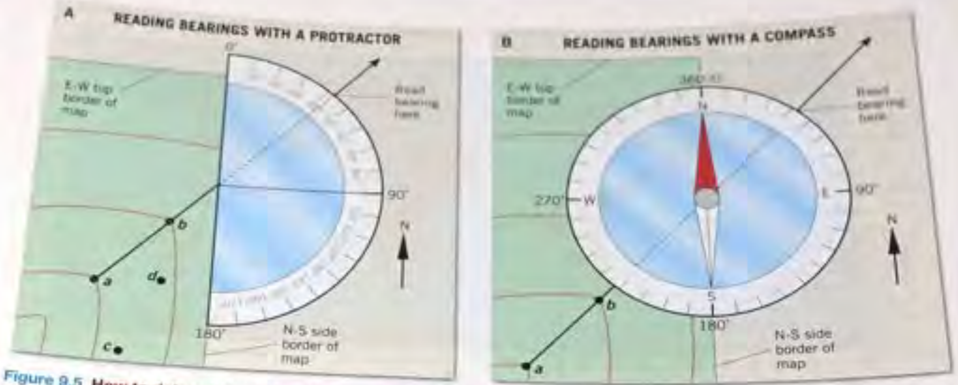


Figure 9.5 How to determine the bearing between two points on a map. **A.** Bearing from point ***a*** through ***b*** on a map. ***b*** is determined using a protractor. Center the protractor where a north–south meridian near the points intersects the line from ***a*** through ***b***. Align the protractor with the *meridian*. Measure the azimuth clockwise from north to the line from ***a*** to ***b***. In this case, the bearing is ~43°. The range of possible bearing azimuths is from 0 to 360°. **B.** You can use a compass as a protractor. Align the north–south axis of the compass ring with the meridian, and place the center pivot of the compass at the intersection of the bearing line and the meridian.

GPS—Global Positioning System

The Global Positioning System (GPS) is a technology that allows us to locate points on Earth with great accuracy. GPS has become woven into the fabric of our lives and is used for everything from keeping track of where people, cars, and even pets are located to its scientific use in geodesy—the science of measuring changes in Earth's size and shape and the position of points on its surface over time. The GPS technology operated by the U.S. government is based on a constellation of about 30 satellites whose orbits are designed so that a minimum of 6 satellites will be above the horizon at any point on Earth at any time. We access the GPS system through small GPS receivers—either handheld receivers like those used by hikers or receiver circuitry that is built into common products such as smartphones and navigation systems in cars.

The accuracy of a GPS location depends on several variables, but is generally in the range of about ±3 to 9 meters for consumer GPS receivers. The GPS systems used by surveyors and geoscientists can have uncertainties that are much less than 1 meter, but achieving that kind of accuracy is significantly more difficult and costly.

UTM—Universal Transverse Mercator System

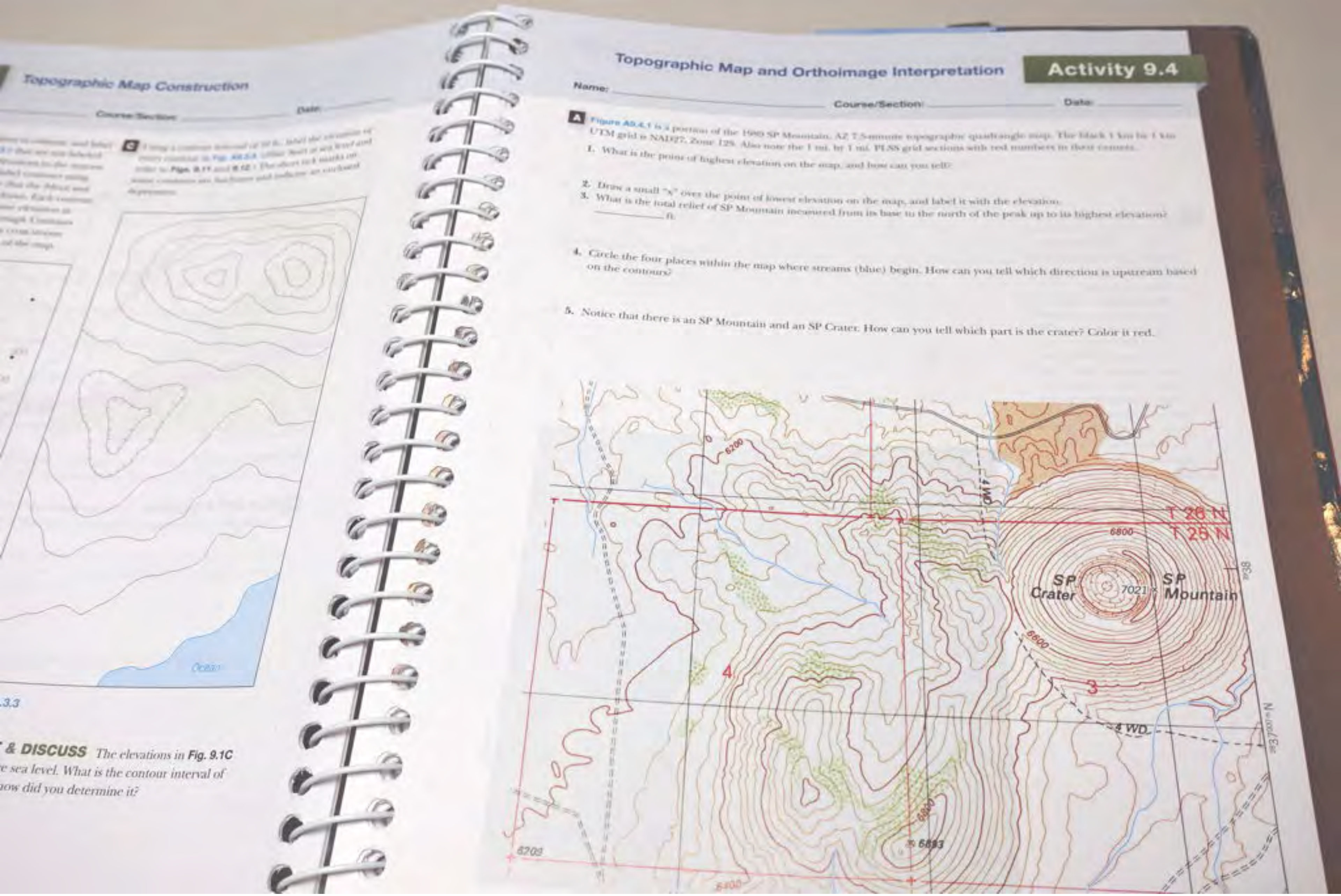
The U.S. National Imagery and Mapping Agency (NIMA) adapted and improved ... is the **Universal Transverse Mercator (UTM)** coordinate system. Unlike the latitude–longitude grid that is spherical and measured in degrees, minutes, seconds, the UTM grid is rectangular and measured in meters. The full specification of a location in the UTM system requires four elements: zone, latitude band (or hemisphere), easting, and northing.

UTM Zones and Latitude Bands

The UTM grid (top of Fig. 9.6) is based on 60 north–south **zones**, which are strips of longitude with a width of 6°. The zones are consecutively numbered from Zone 01 (between 180° and 174° west longitude) at the left margin of the grid to Zone 60 (between 174° and 180° east longitude) at the east margin of the grid. Each zone has a north–south **central meridian** that is perpendicular to the equator (**Fig. 9.6**). A version of UTM based on the Military Grid Reference System (MGRS) divides the zones into east–west segments called **latitude bands** that are identified by different letters (**Fig. 9.6**). Latitude bands are lettered consecutively from C (between 80° and 72° south latitude) through X (between 72° and 84° north latitude) and are 8° long except for band X, which is 12° long. Letters I and O are not used because they could be confused with numbers 1 and 0.

Easting and Northing

Points located al...



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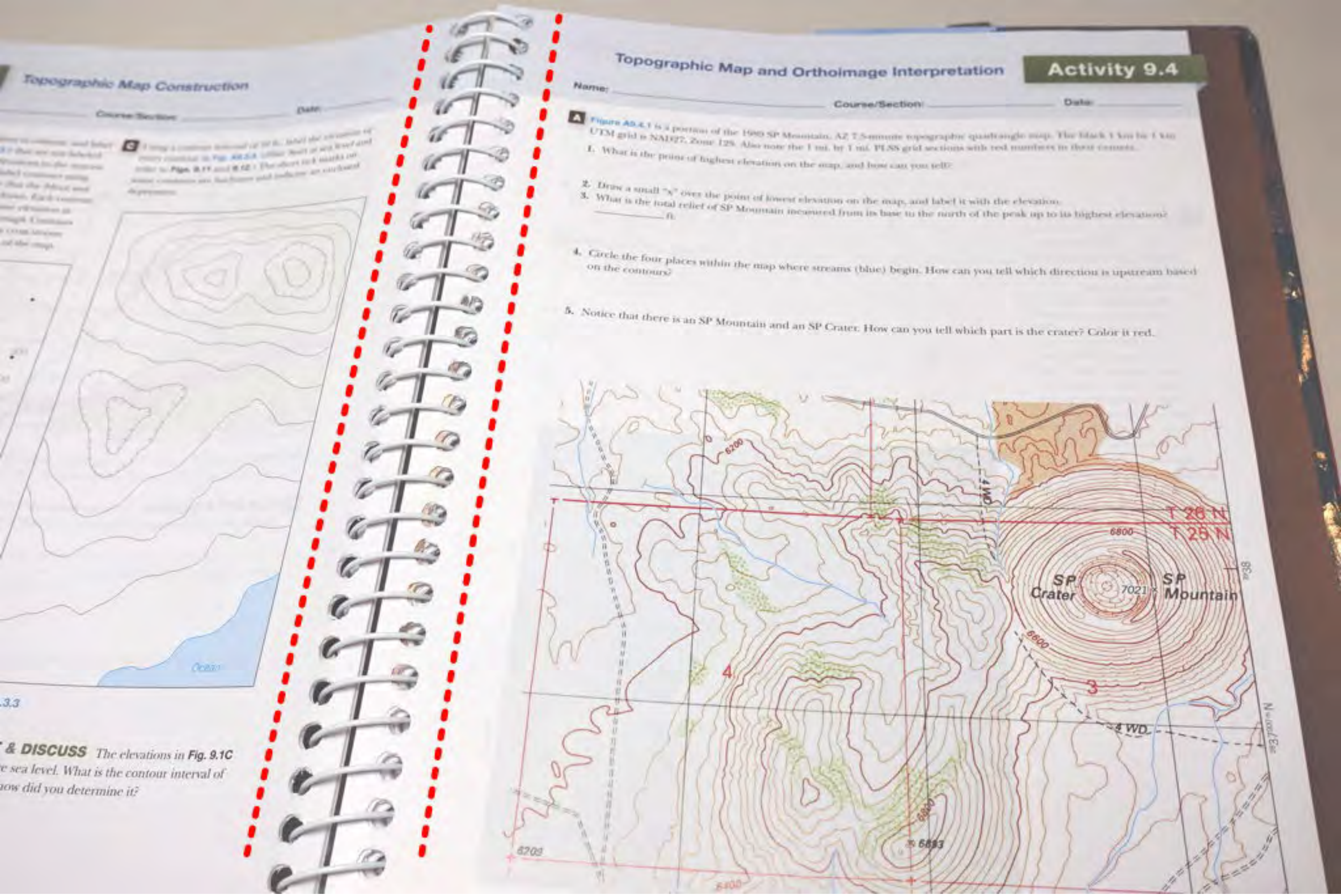
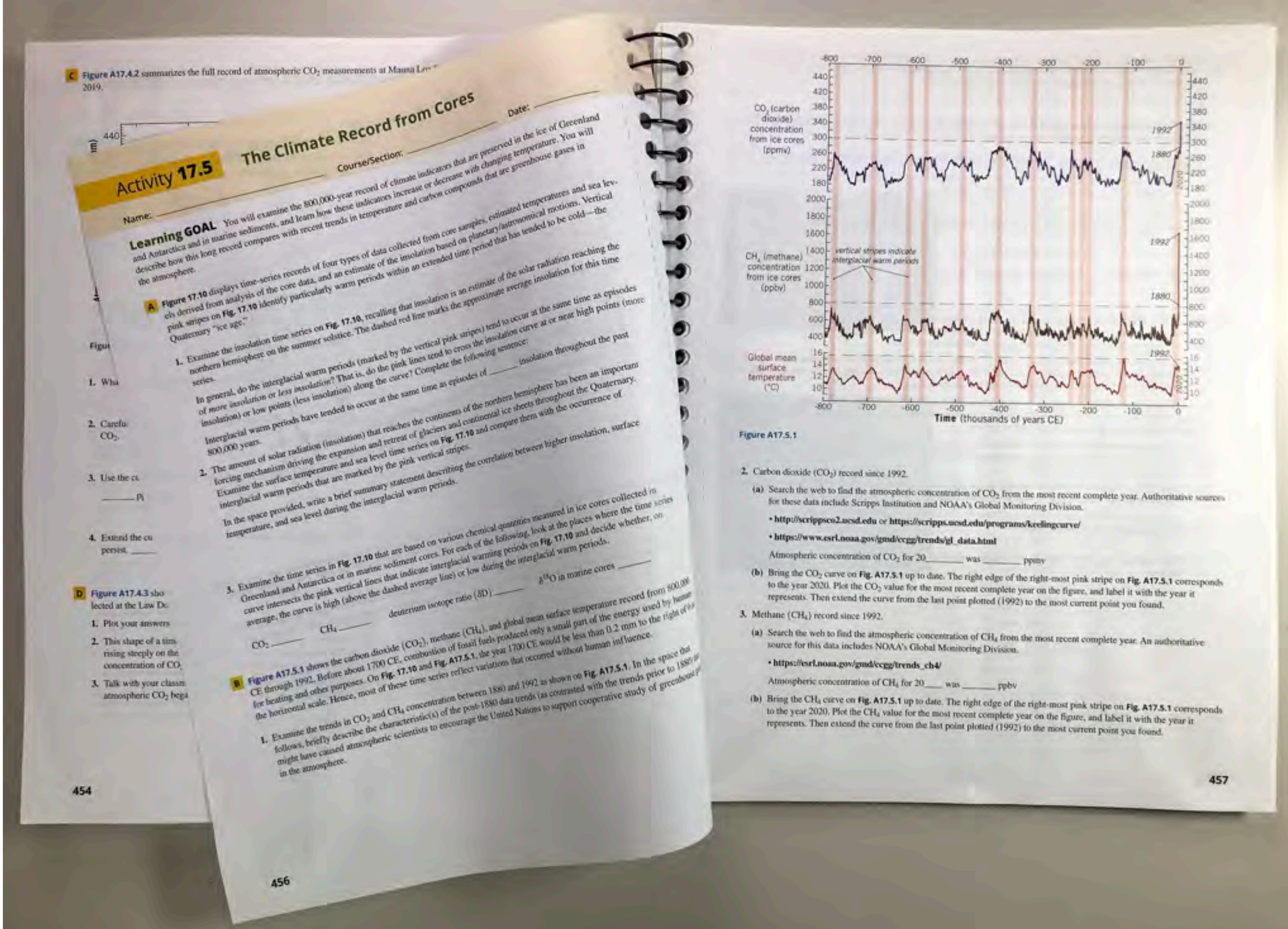

Topographic Map Construction
Course/Section:
Date:
Ocean
& DISCUSS The elevations in Fig. 9.1C
sea level. What is the contour interval of
how did you determine it?
Topographic Map and Orthoimage Interpretation
Activity 9.4
Name:
Course/Section:
Date:
1. What is the point of highest elevation on the map, and how can you tell?
2. Draw a small "x" over the point of lowest elevation on the map, and label it with the elevation.
3. What is the total relief of SP Mountain measured from its base to the north of the peak up to its highest elevation?
ft.
4. Circle the four places within the map where streams (blue) begin. How can you tell which direction is upstream based on the contours?
5. Notice that there is an SP Mountain and an SP Crater. How can you tell which part is the crater? Color it red.
T 26 N
T 25 N
6800
SP Crater
7021
SP Mountain
6600
6200
4
3
4 WD.
6893



17 chapters (laboratories)

105 lab activities

Students collaborating with a customized version of the Lab Manual.

What's New in the 12th Edition?

- New Lab: ***Earth's Dynamic Climate*** with 6 activities and 4 new lab videos
-
-
-
-
-

What's New in the 12th Edition?

- New Lab: ***Earth's Dynamic Climate*** with 6 activities and 4 new lab videos
- Growing emphasis on Earth systems

Earth System Science

Geoscientists think about Earth as a system. Earth system science is the study of the connections and interactions between the major parts of the planet, also known as Earth's *spheres*: the **geosphere**, **atmosphere**, **hydrosphere**, **cryosphere**, and **biosphere**. Studies of these components over the past few decades have revealed that we live in a far more dynamic and complex world than we previously imagined. The goal of Earth system science is to understand how the planet works and answer questions about global change—past, present, and future. Clearly, any attempt to construct a model of something as large, old, and complex as Earth faces some serious challenges. To achieve this goal, we must narrow our field of view, carefully sample often-widespread phenomena, and make generalizations about how the Earth system functions. Despite limitations, such studies have provided deeper insights into the interconnected nature of Earth's major systems.

Building Better Models

Geoscientists are now able to model major global **interactions**, from the effects of atmospheric winds on the circulation of the oceans, the role of thermal convection on worldwide volcanism, and the effects of mountain building and uplift on climate to the transfer of carbon through Earth's biosphere and other systems. Such integrated studies increasingly reveal that humankind is not an independent variable in the Earth system. We play an increasingly significant role, and our quest for natural resources affects systems as diverse as the rock cycle and global ecology. Humans are also affected by global change, from short-term natural hazards such as earthquakes, volcanoes, and tsunamis to processes like El Niño and changes in global climate. Looking ahead, the exponential growth in data gathering networks and computer processing power has set the stage for us to improve upon our predictions of what Earth's future and ours might hold.

Global Connections

By looking at Earth as a system you will discover numerous connections between topics in this lab manual. Our approach will be to begin with small steps and focus on organization or **structure** in systems. The structure of the geosphere, or rocky part of the planet, is probably already familiar. Earth's core, mantle, and crust form concentric layers differentiated by their physical properties. To go a step further and seek understanding about how Earth systems work, we must find out about key **processes**. Processes cause systems to change in some way. More specifically, we want to consider the flow or **transfer of energy and matter** into, within, and out of systems. To return to our geosphere example, Earth's largest reservoir of heat is found at great depth in the core and mantle rocks.

What's New in the 12th Edition?

- New Lab: ***Earth's Dynamic Climate*** with 6 activities and 4 new lab videos
- Growing emphasis on Earth systems
- 17 new or significantly revised lab activities
-
-
-

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- 17 new or significantly revised lab activities
- Over 100 new photographs including many high-res specimen photos constructed using focus stacking.
-
-

High-resolution photograph in the Lab Manual 12th edition created using focus stacking

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High-resolution photograph in the Lab Manual 12th edition created using focus stacking

High-resolution photograph in the Lab Manual 12th edition created using focus stacking

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- 17 new or significantly revised lab activities
- Over 100 new photographs including many high-res specimen photos constructed using focus stacking.
- About 150 new or revised graphics by Dennis Tasa
- Learning goals stated for each lab activity

New activity in the 12th Edition

Plate Motion from Different Frames of Reference

Activity 2.1

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will be able to recognize the direction of motion of one plate as observed from another plate across a mid-ocean ridge, given the trends of two axial rifts and the ridge-ridge transform fault between them. You will also use vector arrows to represent plate motion in a reference frame that is external to the plates—a "no-net-rotation" or *NNR* reference frame—and estimate the position of this ridge-fault-ridge system ~2 million years (Myr) in the future.

Important Reminder: We can only measure a velocity or a displacement (the movement from an initial location to a different location) relative to some reference frame. Before we describe a velocity or a displacement, it's important to ask the question "velocity relative to what?"

A **Motion of Plates Relative to Each Other Across a Shared Boundary.** Figure A2.1.1 is a sketch map of the Atlantis Transform Fault and adjacent axial rifts along the northern Mid-Atlantic Ridge. The parallel red lines between points 1 and 2 and points 3 and 4 represent axial rifts along the ridge, and the bold black line is the transform fault along which the two plates move past each other.

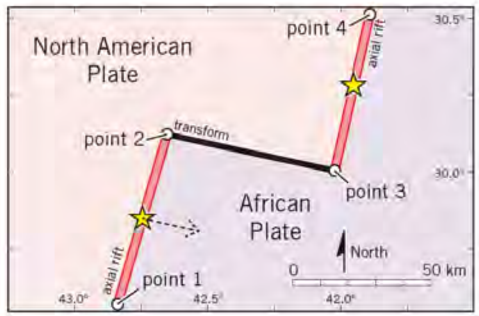


Figure A2.1.1 ▲

1. Starting at the yellow star along the axial rift between points 1 and 2, draw a vector arrow on the African Plate that is approximately parallel to the transform fault, pointing toward the interior of the African Plate. (The vector arrow is started for you.) Starting at the same yellow star, draw a vector arrow in the opposite direction on the North American Plate, pointing toward the interior of the North American Plate. These arrows indicate the sense of divergent plate motion across the ridge as the two plates spread apart. Do the same at the yellow star between points 3 and 4 along the ridge axis. (See **Fig. 2.1B–C** for guidance.)

2. Using the arrows you just drew as a guide, draw one arrow on each side of the transform fault, parallel to the fault line, to indicate the sense of relative plate motion across the fault.

3. As viewed from point 2, point 3 is located toward the east southeast (azimuth ~102°). Viewed in the opposite direction, point 2 is toward the west-northwest (~282°) as seen from point 3. In what general direction is the African Plate moving relative to the North American Plate?

Direction: ______________________________

This blank space is the cut-out area for Fig. A2.1.3 on the next page.

B **Plate Motion in an External Reference Frame**

1. Carefully use scissors to cut along the dashed line in Fig. A2.1.3, making separate maps of the North American and African Plates near the Atlantis Transform Fault.

2. Place the two halves of the cut-out map on Fig. A2.1.2 so that points 1, 2, 3 and 4 are all aligned. The result is what the boundary looks like today.

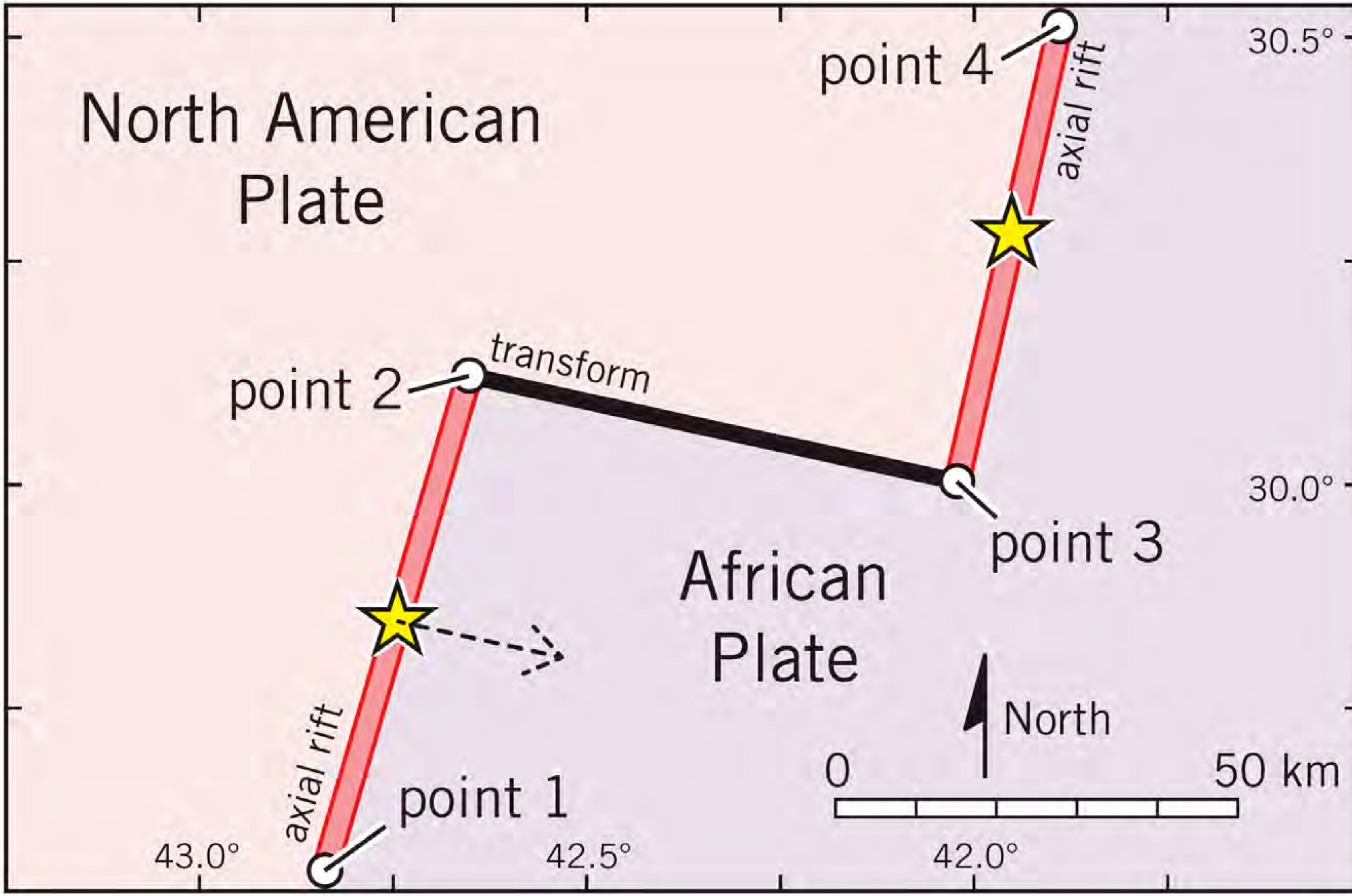
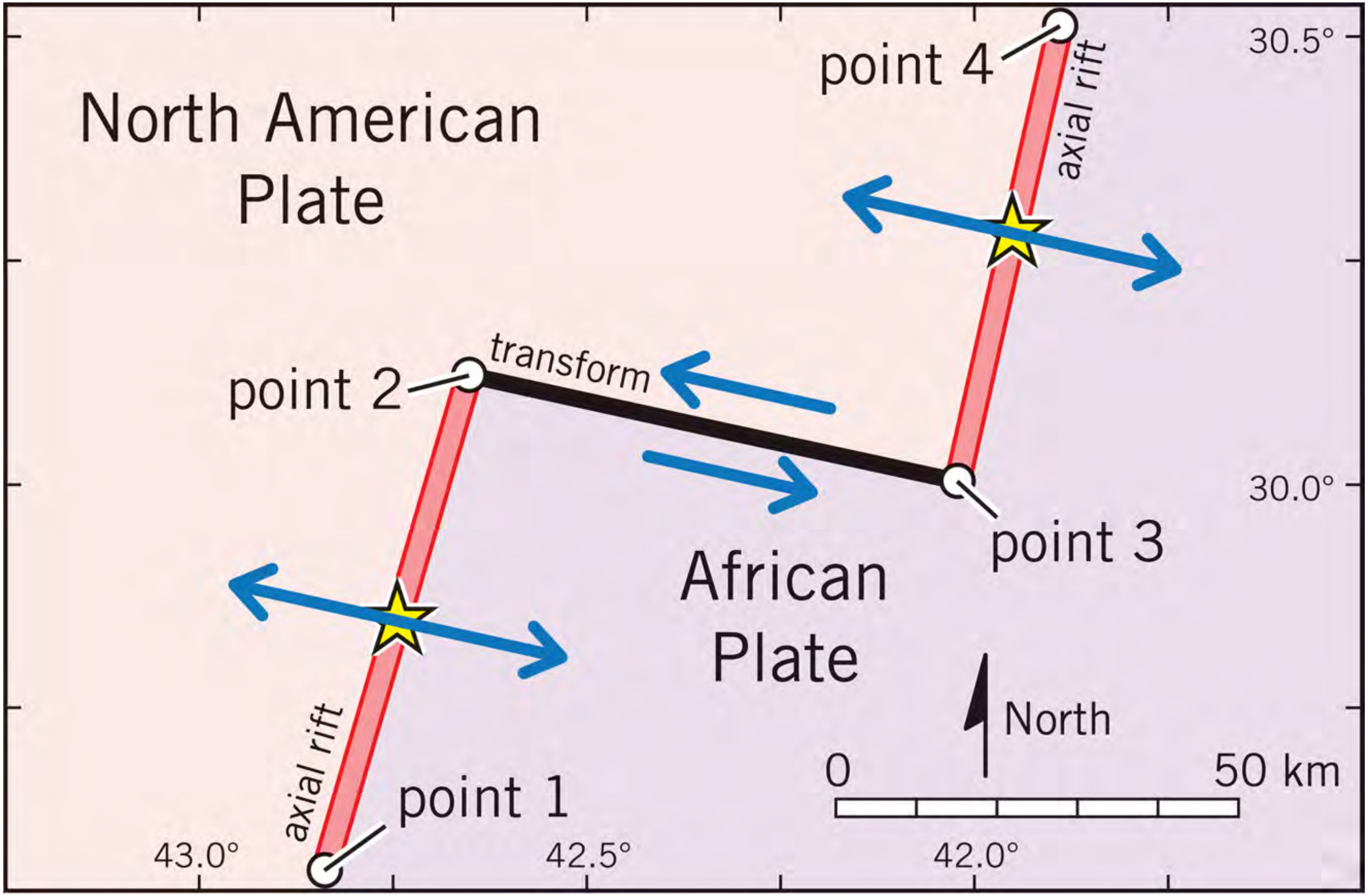

North American Plate
point 4
axial rift
30.5°
point 2
transform
30.0°
point 3
African Plate
North
axial rift
point 1
0
50 km
43.0°
42.5°
42.0°

Figure A2.1.1 ▲



North American Plate
African Plate
point 1
point 2
point 3
point 4
axial rift
axial rift
transform
North
0
50 km
30.5°
30.0°
43.0°
42.5°
42.0°

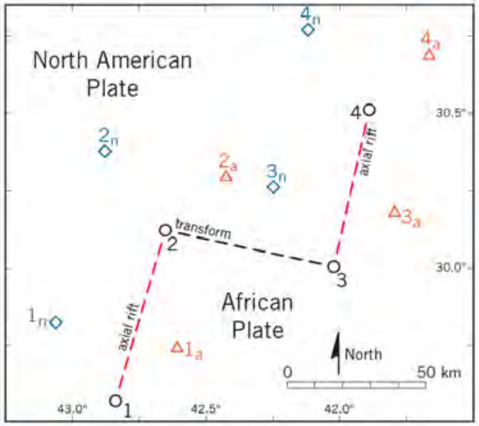


Figure A2.1.2 ▲

3. Move the two cut-out maps so that points 1 and 4 on the North American Plate coincide with points 1_n and 4_n on **Fig. A2.1.2** and points 1 and 4 on the African Plate coincide with points 1_a and 4_a.

4. Use a pencil to trace the $1_n - 2_n - 3_n - 4_n$ boundary on **Fig. A2.1.2** and do the same for the $1_a - 2_a - 3_a - 4_a$ boundary. Those traced lines mark where the oceanic crust along today's plate boundary will likely be after 2 Myr, as observed in a NNR reference frame external to the plates.

5. Using the lines you just drew, assume that the ridge will be located halfway between 1_n and 1_a and halfway between 2_n and 2_a after 2 Myr of spreading. Carefully draw that ridge axis on **Fig. A2.1.2** and do the same halfway between points $3_n - 3_a$ and $4_n - 4_a$.

6. Complete the picture by drawing the transform fault between the ridge ends.

7. You have now made a prediction for where the section of the Mid-Atlantic Ridge around the Atlantis Transform Fault will be located about 2 Myr from today relative to the NNR reference frame.

C Plate Motion in Different but Related Reference Frames

1. Draw a vector arrow on **Fig. A2.1.2** from point 1 to 1_n. This vector is an estimate of the direction of average motion of that point along the North American Plate boundary in the next 2 Myr, as observed in the NNR reference frame. Now, draw a vector arrow from point 1 to 1_a, indicating the direction of average motion of the African Plate at that point in the next 2 Myr relative to the NNR frame. Do the same for points 2, 3, and 4.

cut-out this area only

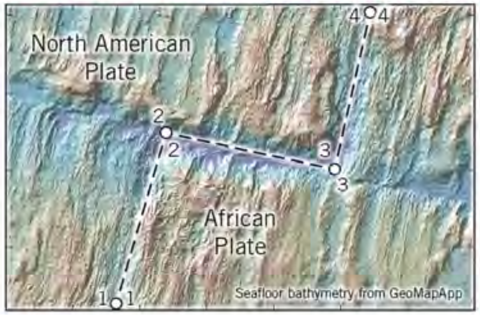


Figure A2.1.3 ▲

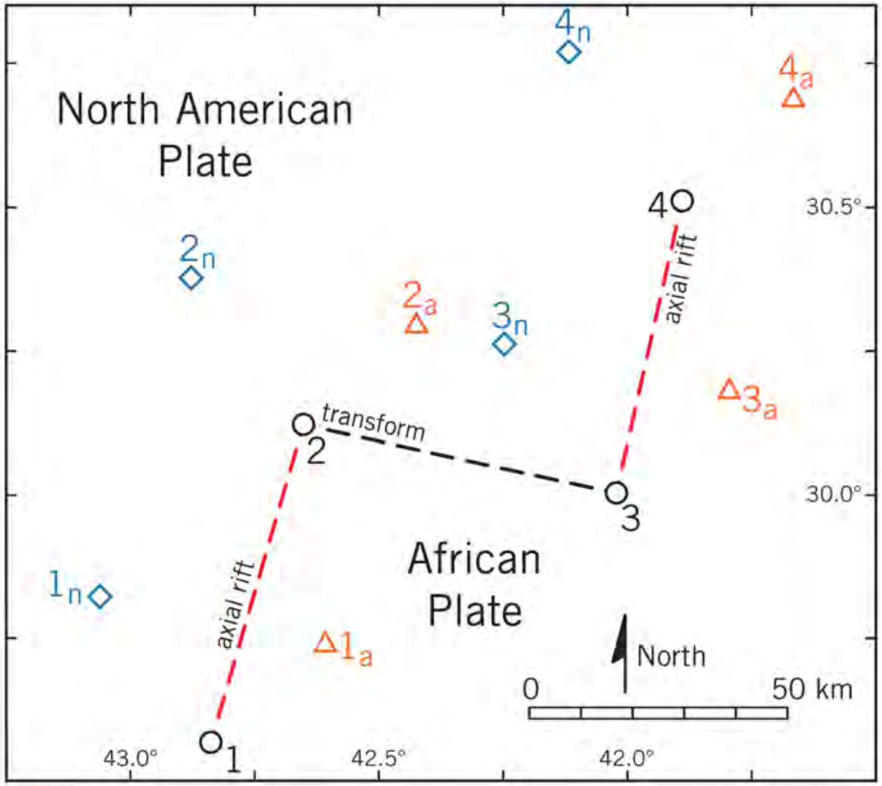
2. Draw an arrow on **Fig. A2.1.2** from point 1_n to point 1_a. This vector is an estimate of the average motion of point 1 on the African Plate as observed from the North American Plate. Do the same for points 2, 3, and 4.

3. Use the map scale to estimate the distance the African Plate will move in the next 2 Myr along the Atlantis Transform Fault, as observed from the North American Plate. (*Hint*: Measure the $2_n - 2_a$ or $3_n - 3_a$ distances.)

   Answer: __________ km

4. Approximately what will be the width of new crust developed along the Mid-Atlantic Ridge between Africa and North America near the Atlantis transform fault during the next 2 Myr? (*Hint*: Think about your answer to the previous question.)

   Answer: __________ km



4n
4a
North American
Plate
4
30.5°
2n
2a
3n
axial rift
3a
transform
2
30.0°
3
African
Plate
1n
axial rift
1a
North
0
50 km
1
43.0°
42.5°
42.0°

Figure A2.1.2 ▲

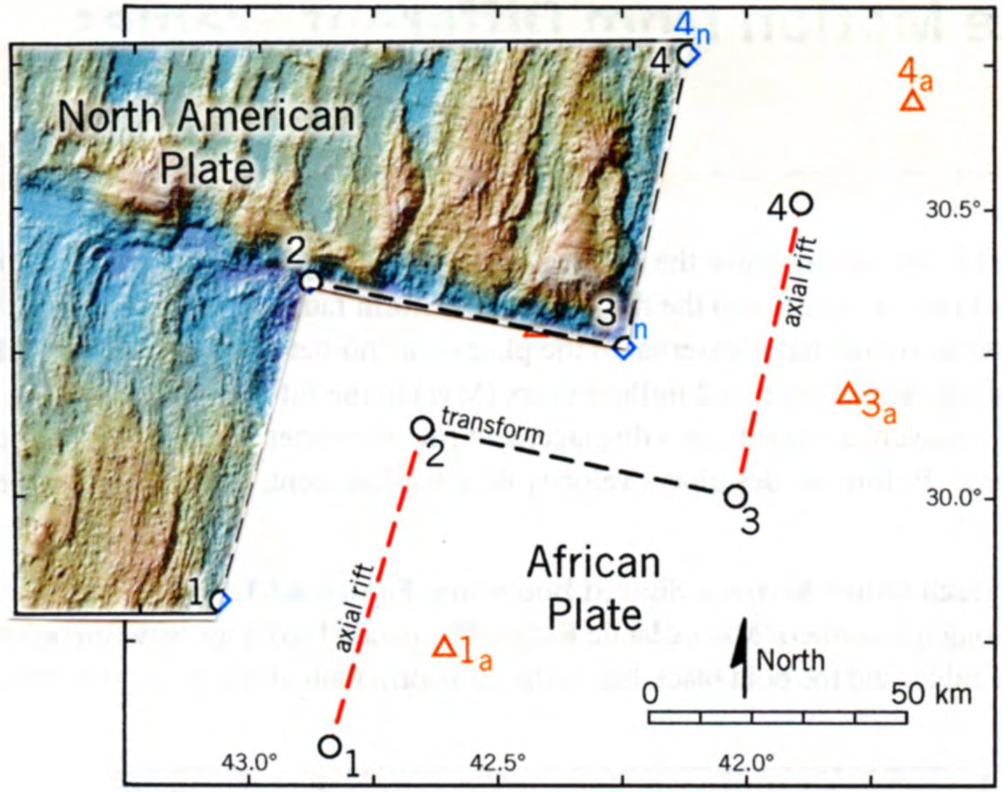
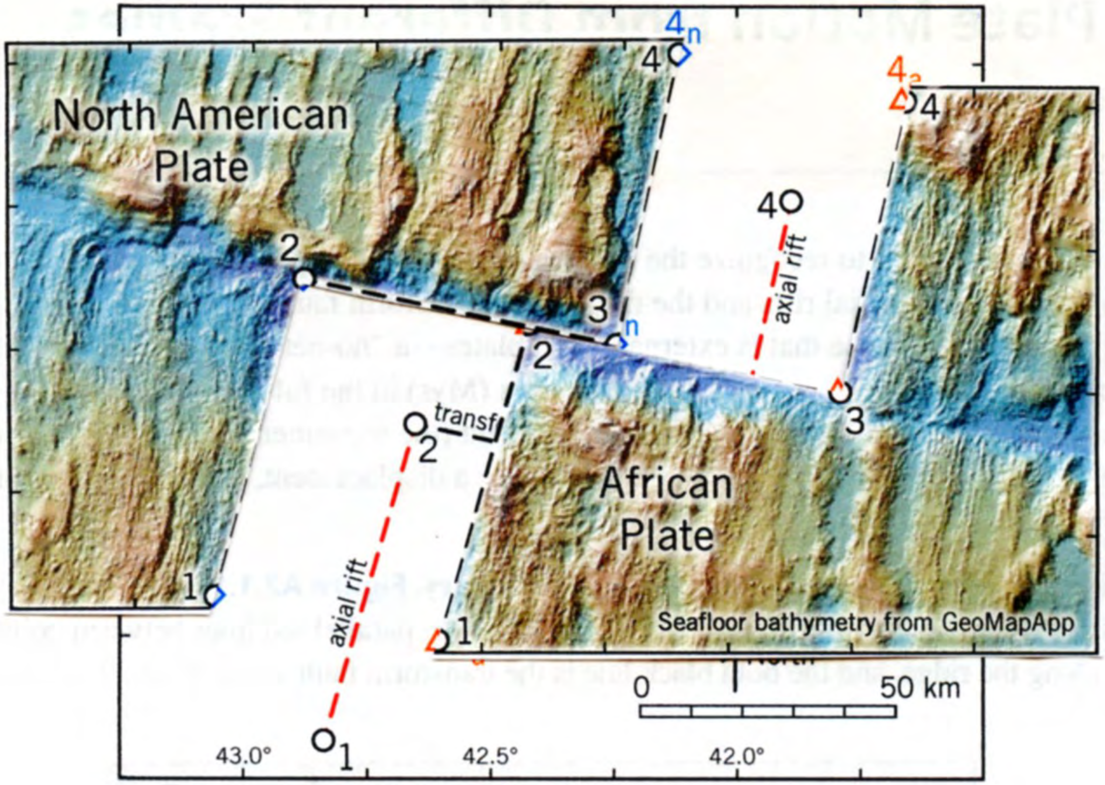
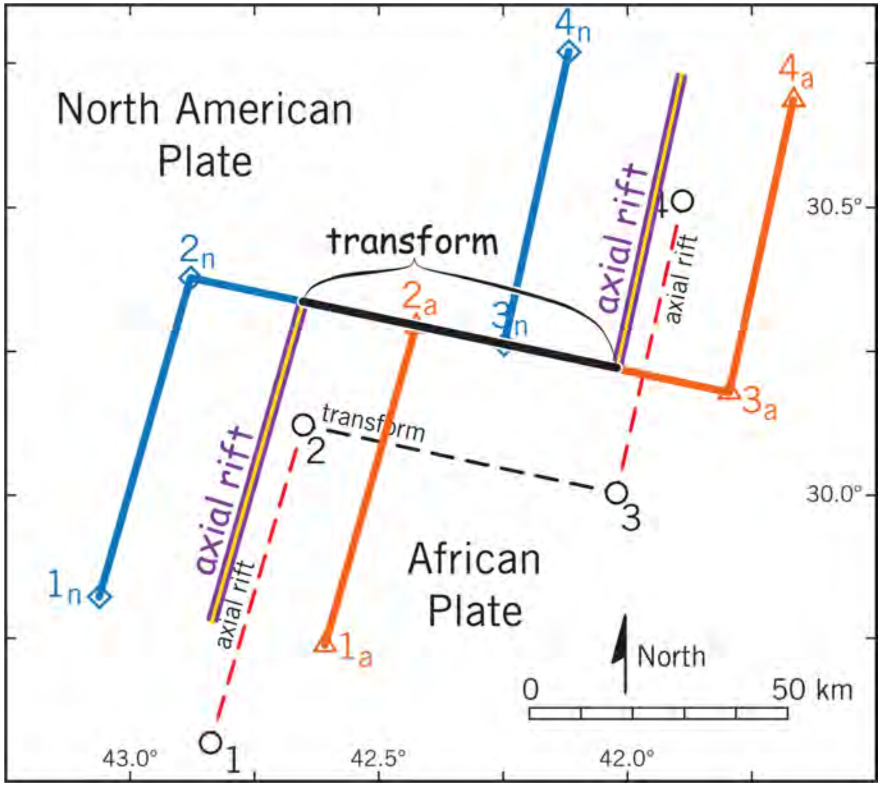

North American Plate
African Plate
transform
axial rift
axial rift
1
2
3
4
1
2
3
4
4n
3n
1a
3a
4a
North
0
50 km
30.5°
30.0°
43.0°
42.5°
42.0°

Figure A2.1.2 ▲

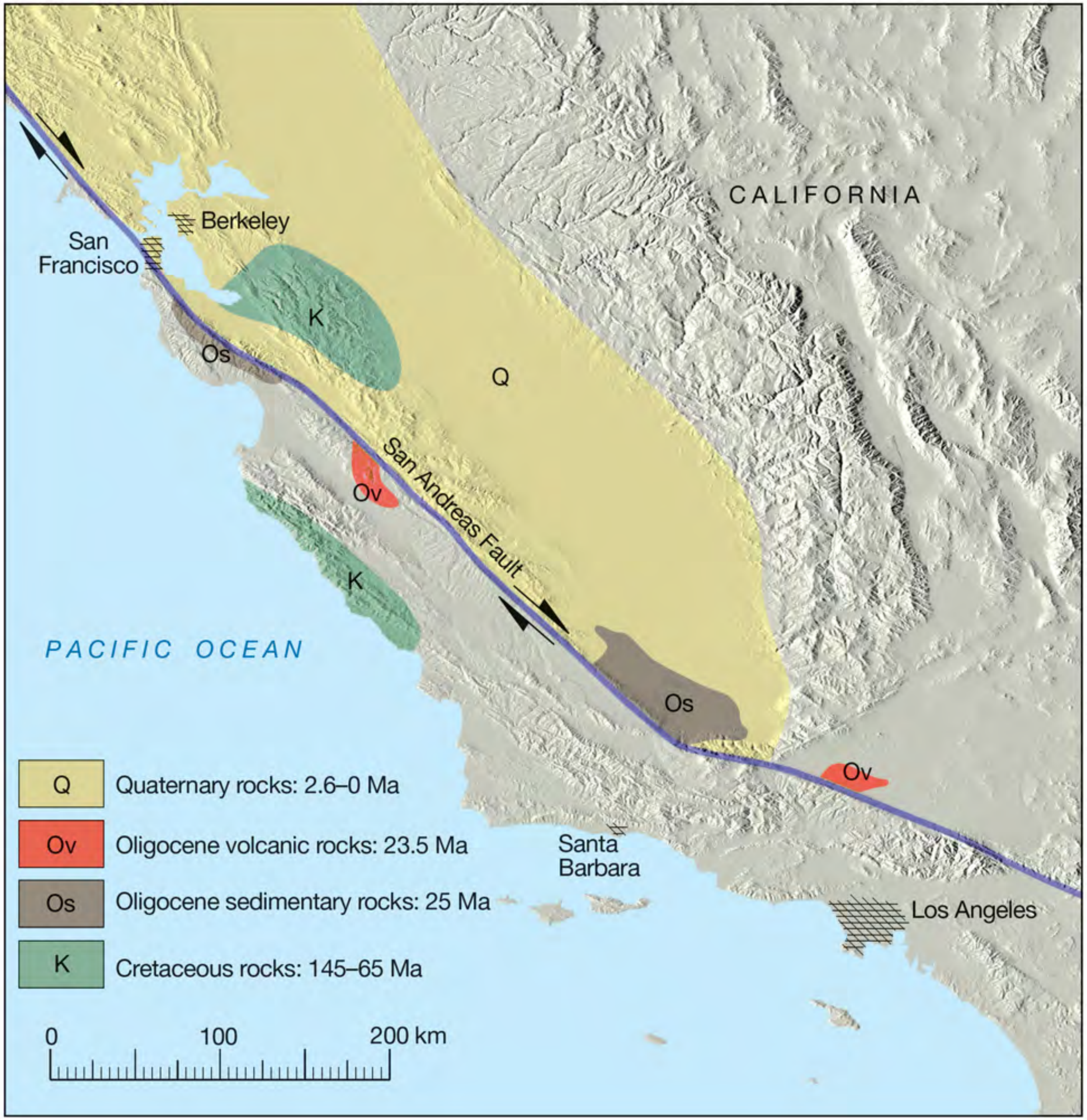


North American Plate
African Plate
axial rift
axial rift
transf
4n
4a
4
4
4
3n
3
3
2
2
2
1
1
1
Seafloor bathymetry from GeoMapApp
0
50 km
43.0°
42.5°
42.0°

Figure A2.1.2 ▲


North American Plate
transform
axial rift
axial rift
axial rift
axial rift
transform
African Plate
North
0
50 km
30.5°
30.0°
43.0°
42.5°
42.0°
1n
2n
3n
4n
1a
2a
3a
4a
1
2
3
4

From the 10th Edition



As revised in the 12th Edition

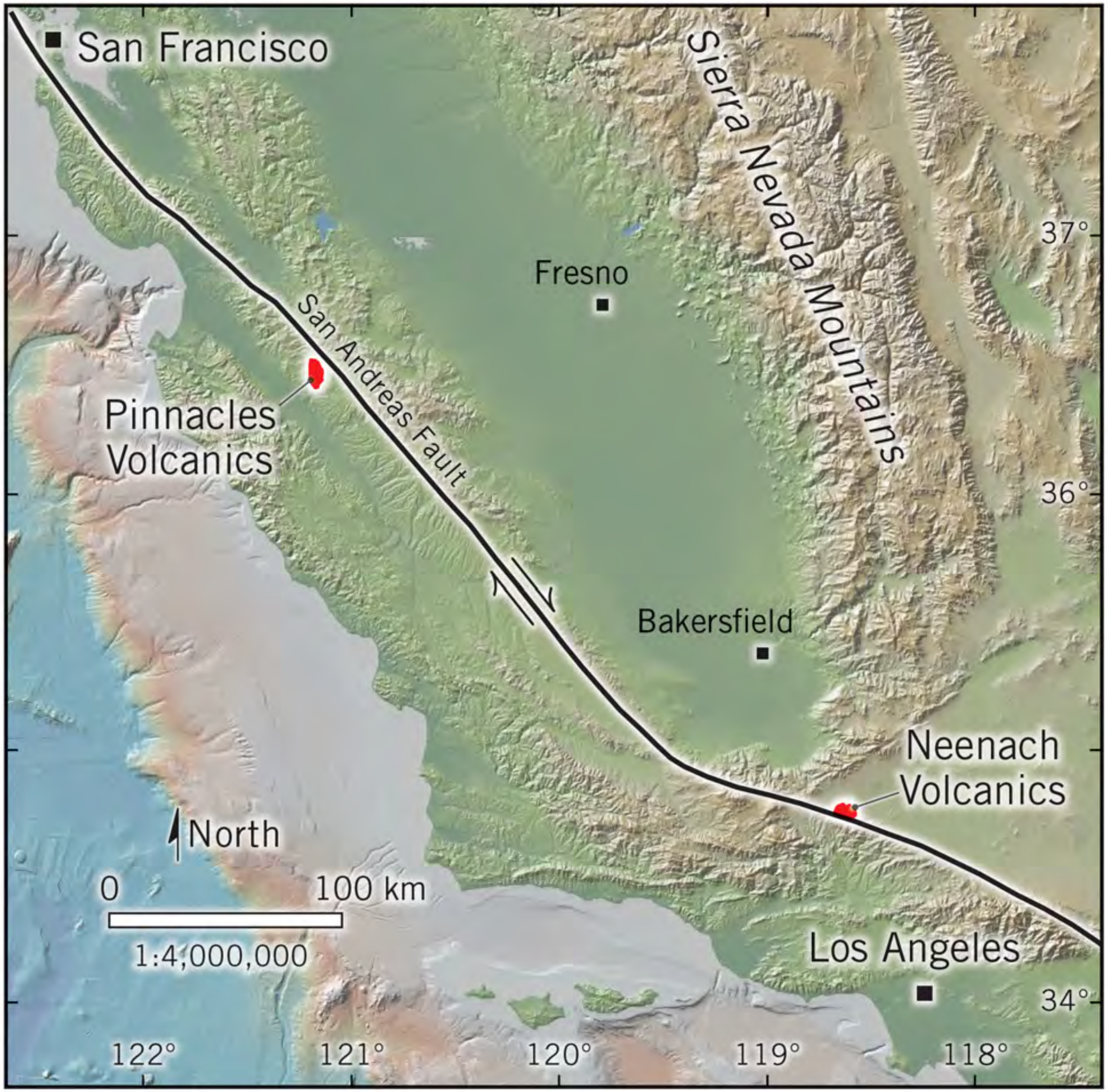
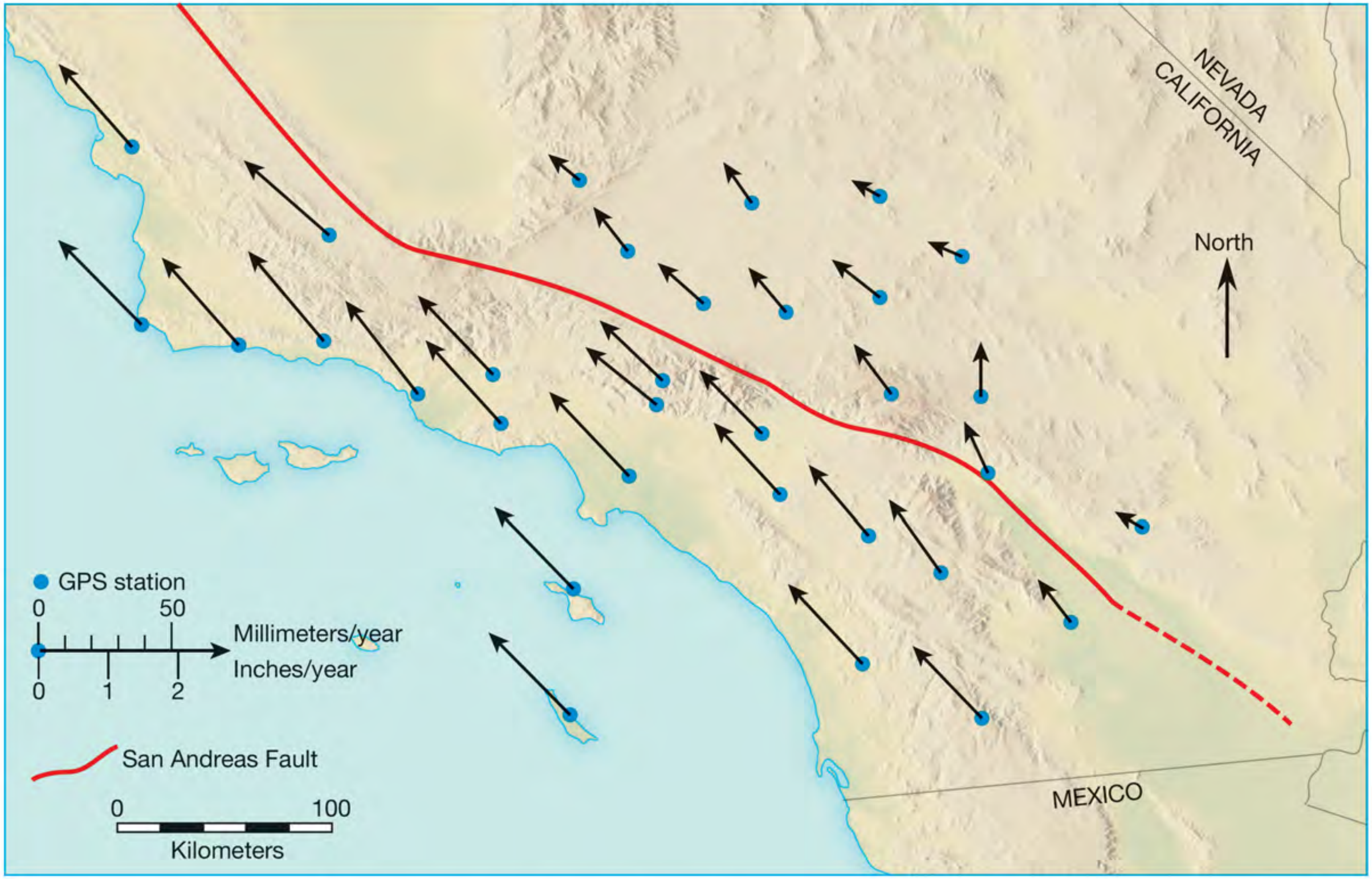


Figure A2.2.1 ▲



B. The above map shows some Global Positioning System (GPS) reference stations and observations from the JPL-NASA GPS Time Series website at **http://sideshow.jpl.nasa.gov/post/series.html**. Length of the arrows indicates **absolute plate motion**, the direction and rate that the plate is moving in mm/yr at the GPS station (which is attached to bedrock of the plate).

From the 10th Edition

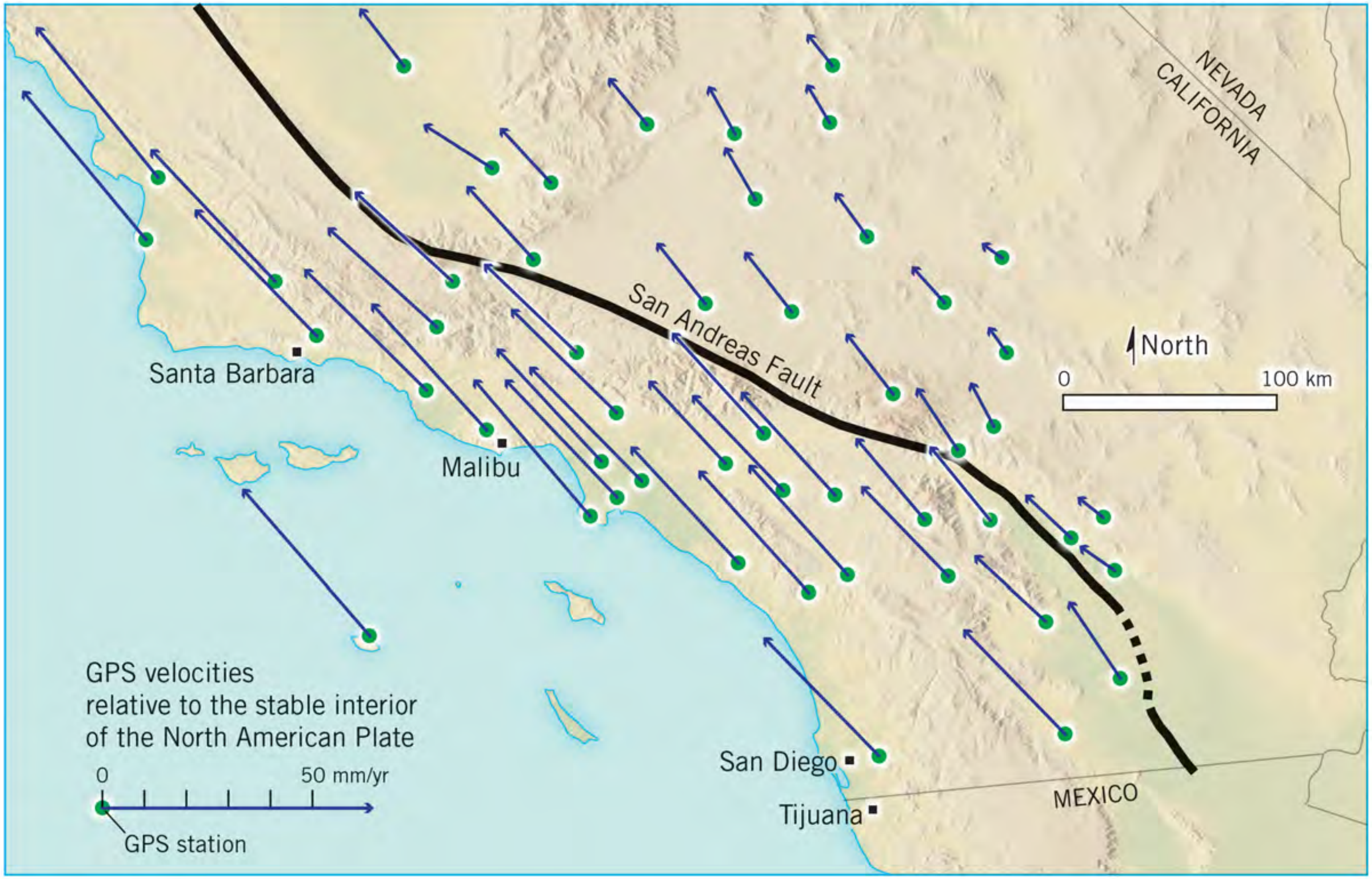


Figure A2.2.2 ▲

1. Velocities measured at several GPS stations in southern California are shown in **Fig. A2.2.2**. The length of the arrow provides the speed of the GPS site, measured in a reference frame called NAM08 that is fixed to the stable interior of the North American Plate—the area east of the Rocky Mountains. Longer arrows indicate faster motion, and an arrow that is 25 mm long on the map represents a speed of 50 mm/yr. The data for this map were derived from UNAVCO's GPS Velocity Viewer (**https://www.unavco.org/software/visualization/GPS-Velocity-Viewer/GPS-Velocity-Viewer.html**) on February 28, 2019.

As revised in the 12th Edition

New/Revised in the Minerals Lab

Mineral Luster, Diaphaneity, Streak, and Color

Activity 3.1

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will gain some practical knowledge and experience with characterizing some optical properties of mineral specimens that will be helpful to you in identifying minerals.

A Determine whether each specimen in **Fig. A3.1.1** displays a *metallic* or *non-metallic* luster. For each non-metallic specimen, decide whether one of the following additional luster terms should also be used: vitreous, silky, or earthy. Write your interpretation for each under its photograph.

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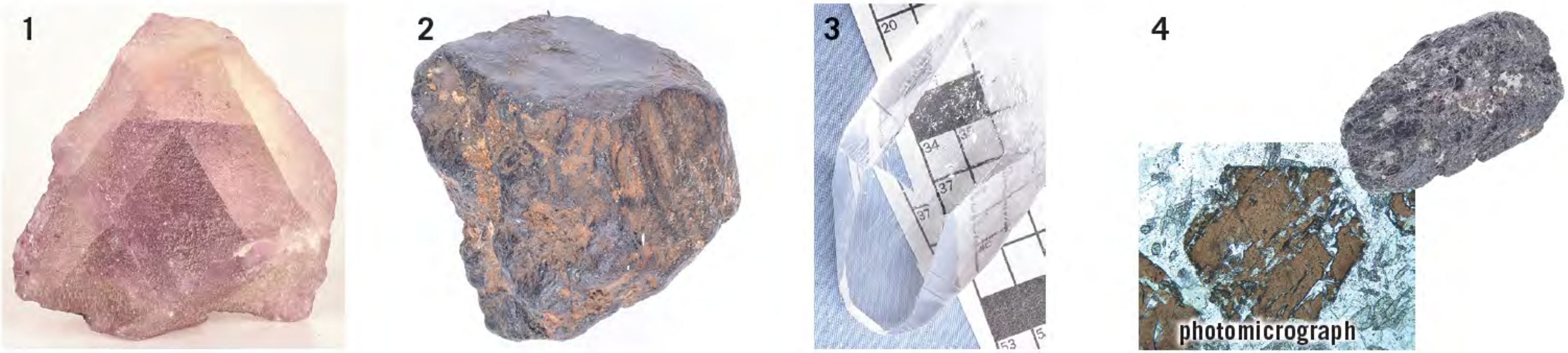
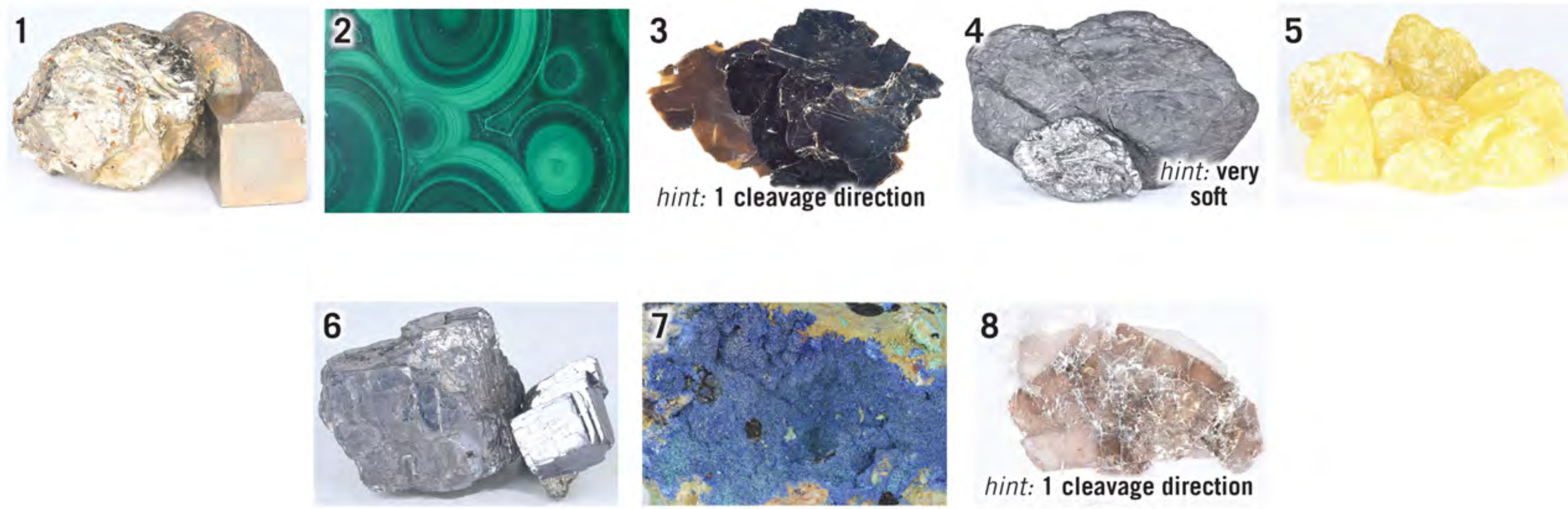
B Four minerals are shown in **Fig. A3.1.2**. Along with specimen 4 is a photo taken using a microscope showing a thin section of the same type of mineral. Light passes through the thin section from below before it passes into the microscope. For each mineral, characterize its diaphaneity as either opaque, translucent, or transparent. Write your interpretation for each under its photograph.



C Several mineral specimens are shown in **Fig. A3.1.3** along with their streak across a streak plate. For each, use information from **Fig. 3.22** to form a tentative identification—one or two likely minerals—and write your interpretation for each under its photograph.

Figure A3.1.3 ▲

D The eight specimens shown in **Fig. A3.1.4** commonly occur with a specific color or within a narrow range of colors. For each, use information from **Figs. 3.19–3.22** to form a tentative identification—one or two likely minerals. Write your interpretation for each specimen under its photograph.



E Several specimens of quartz are shown in **Fig. A3.1.5**. Use information from **Fig. 3.22** to identify the variety of quartz depicted, based on the color of each specimen. Write your interpretation for each specimen under its photograph.

Figure A3.1.5 ▲

Mineral Shape   Activity **3.2**

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will examine some minerals that have well-developed faces so that you can determine the mineral form. Other specimens have been broken, and you will examine their cleavage or fracture. Learning to observe these characteristics provides another tool to help you identify minerals.

A Three types of minerals are shown in **Fig. A3.2.1**. Use the information in **Fig. 3.7** to describe whether each mineral displays a *closed* form or a combination of *open* forms. Then specify which form(s) are found in each of the three types of mineral. Write your interpretation under the corresponding photograph(s).

Figure A3.2.1 ▲

B Snowflakes are ice crystals that form in the atmosphere and sometimes fall to Earth's surface. The two photographs of snowflakes in **Fig. A3.2.2** were taken by Kenneth Libbrecht of Caltech and show a symmetric pattern of growth.

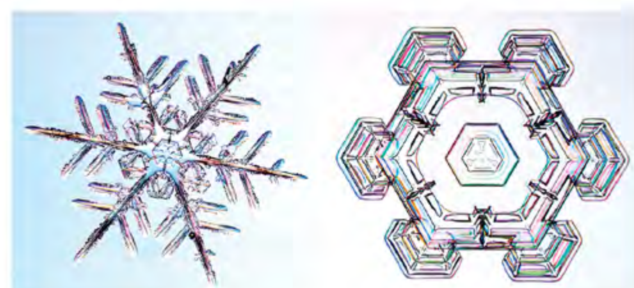


Figure A3.2.2 ▲

1. How many arms does snowflake 1 have? ______________ How many sides does the inner part of snowflake 2 have? ______________. How many arms does snowflake 2 have? ______________

2. There are six crystal families: isometric or cubic, tetragonal, orthorhombic, monoclinic, triclinic, and hexagonal. Using the number of arms on a snowflake as a hint, what crystal system do ice crystals belong to? ____________________ What is the basis for your interpretation?

C Photographs of five mineral specimens that display cleavage are shown in **Fig. A3.2.3**. Dashed lines indicate the orientation of cleavage faces on the sides of most of the specimens, and the type of surface on the front of the specimens is indicated. Use your observations along with **Figs. 3.7** and **3.22** to answer the following two questions for each specimen: How many directions of cleavage does each specimen have, and what mineral might this be? It's OK if your tentative identification includes more than one possibility. Write your responses under the corresponding photograph(s).

Figure A3.2.3 ▲

Mineral & Rock ID Tables

A Flow Chart for Identifying Minerals

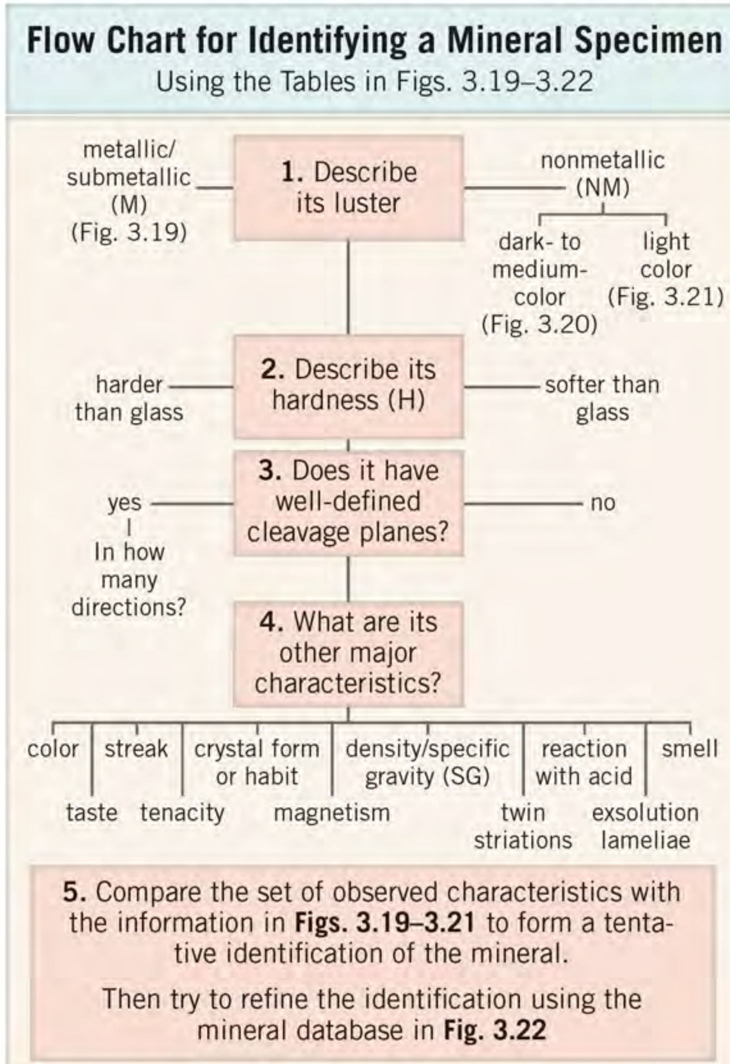


Figure 3.18 **Flow chart for identifying minerals.**

NAGT WEBINARS ON THE CUTTING EDGE PROGRAM

A Field Classification of Igneous Rox

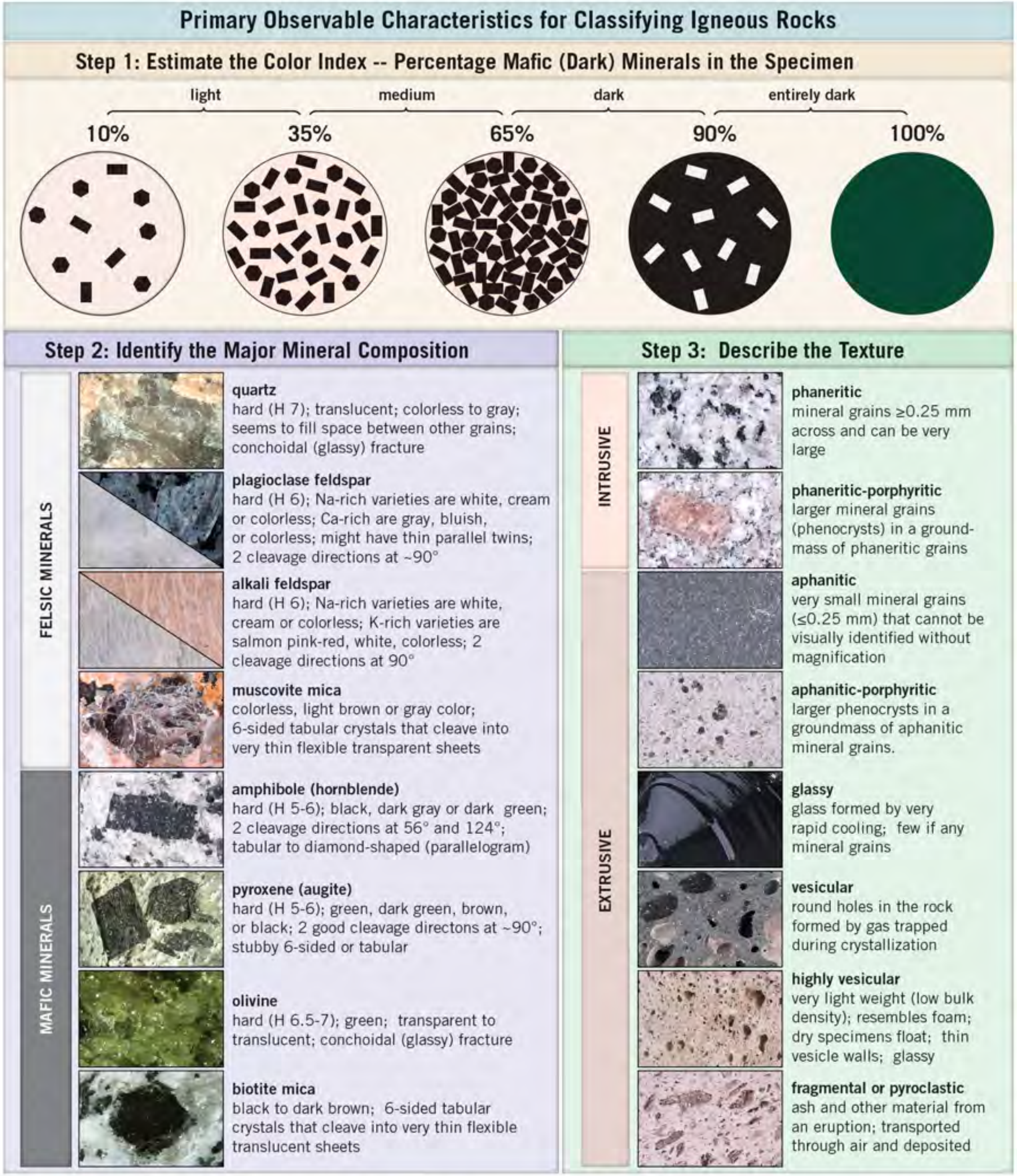


Figure 5.21 Observable characteristics of common igneous rock types. Refer to relevant sections in the text for full discussion of the color index, major minerals, and textures of igneous rocks. These characteristics are used in **Fig. 5.22** to identify selected igneous rock types.

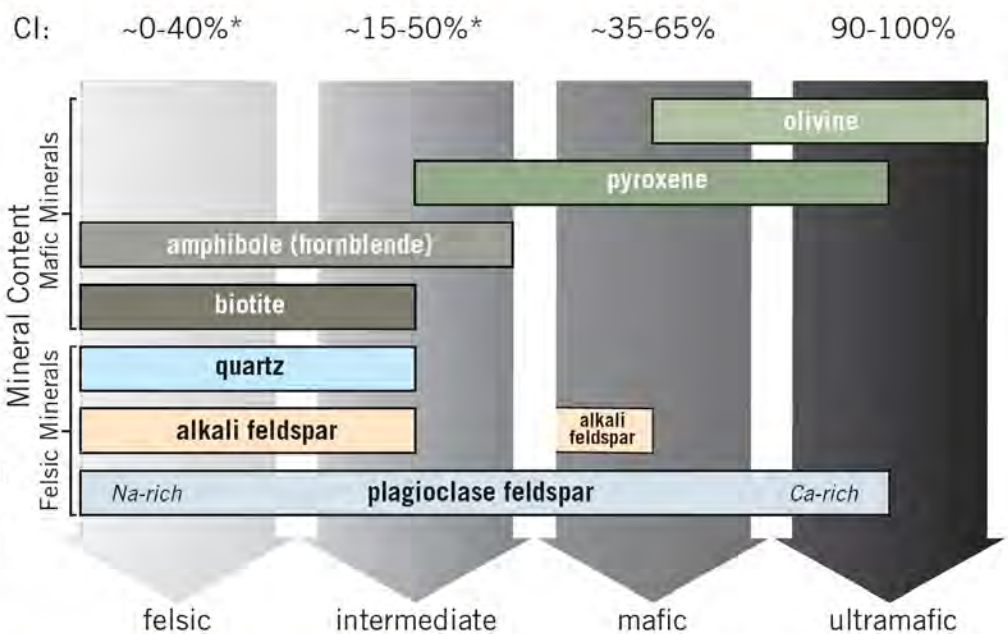
A Field Classification of Igneous Rox

A Field Classification of Igneous Rock in Hand Specimen

1. Color Index (CI). Estimate the % of mafic minerals in the rock specimen.

2. Minerals. Identify the major minerals in the rock. Find the vertical column that includes the same minerals you see in the rock. That column points toward a tentative interpretation in the table below.

(If a particular mineral is present in *some* but not all examples of a given rock type, the rectangle for that mineral extends only part way across the column.)



3. Texture. Identify the texture(s).

4. Interpretation. Select the rock name below, based on data from steps 1-3 and Fig. 5.21. Review the descriptions in the text for further details about each rock type.

Texture		felsic	intermediate	mafic	ultramafic
coarser grained (phaneritic)	INTRUSIVE	**granite**	**diorite**	**gabbro**	**peridotite** Other coarse ultramafic rocks include pyroxenite and hornblendite.
phaneritic-porphyritic	INTRUSIVE	porphyritic granite	porphyritic diorite	porphyritic gabbro	
fine grained (aphanitic)	EXTRUSIVE	**rhyolite**	**andesite**	**basalt**	Extrusive ultramafic rock types like *komatiite* are very uncommon. Most komatiite is billions of years old.
aphanitic-porphyritic	EXTRUSIVE	porphyritic rhyolite	porphyritic andesite	porphyritic basalt	
vesicular to highly vesicular	EXTRUSIVE	**pumice**: extremely vesicular resembling froth or foam		vesicular basalt; **scoria** or cinder	
glassy	EXTRUSIVE	**obsidian**		tachylyte	
fragmental or pyroclastic	EXTRUSIVE	**tuff** (fragments <64 mm across)		pyroclastic breccia (fragments >64 mm across)	

*The CI ranges for the two columns on the left are from IUGS classification for field identification of granitic and dioritic rocks.

Figure 5.22 Igneous rock classification chart. Follow steps 1 through 4 to develop a tentative rock identification, based on observable characteristics summarized in **Fig. 5.21**.

A Field Classification of Sedimentary Rox

A Field Classification of Sedimentary Rocks

A	Observed Characteristics	Name
Organic Solids	Brown to black. Partially decayed plant material, can resemble a soil.	**peat**
Organic Solids	Brown to black. Soft and crumbles easily when dry. Leaves black smudge on fingers.	**lignite (brown coal)**
Organic Solids	Black, sometimes dark brown. Generally dull luster but can have bright, shiny layers. Harder than lignite, softer than anthracite coal. Leaves black smudge on fingers.	**bituminous coal** (Fig. 6.11B)
Organic Solids	Black, sometimes with a brown or blue reflection, semi-metallic luster. Harder than a fingernail but softer than copper or steel.	**anthracite coal** (Fig. 6.11C)

B		Major Mineral Composition	Observable Texture	Distinguishing Characteristics and Comments		Rock Name
Fizzes in dilute hydrochloric acid (HCl)	Carbonate Sedimentary Rocks	calcite or aragonite	clay-silt sized carbonate grains	readily fizzes with acid, variable color (gray, tan, brown), mostly very fine grains	limestone (ls.)	**microcrystalline ls. or micrite**
		calcite or aragonite	very fine; bioclastic	typically white or light gray, soft, generally leaves a white powder on fingers	limestone (ls.)	**chalk**
		calcite or aragonite	intergrown crystals	precipitated mineral grains; typically associated with springs, caves or geysers	limestone (ls.)	**travertine** (Fig. 6.7)
		calcite or aragonite	sand-size	carbonate sandstone; carbonate grains of any type cemented together	limestone (ls.)	**calcarenite**
		calcite or aragonite	sand-size	sand-sized white spheroids (ooids-Fig. 6.6) usually cemented with calcite	limestone (ls.)	**oolitic ls.**
		calcite or aragonite	sand-gravel; bioclastic	shells and shell fragments cemented in a porous mass; looks like shell granola	limestone (ls.)	**coquina** (Fig. 6.5)
		calcite or aragonite	sand-gravel; bioclastic	abundant fossils (bivalves, gastropods, coral, etc.) in a carbonate matrix	limestone (ls.)	**fossiliferous ls.** (Figs. 6.4 & 6.22)
		dolomite	typically very small intergrown crystals	***fizzes in dilute HCl strongly only if powdered;*** usually light colored (tan, gray); small sparkly grains		**dolostone**
Does not react with hydrochloric acid (HCl)	Siliciclastic Sedimentary Rocks	quartz	microscopic grains	hard, scratches glass or steel; wide range of colors; might be precipitated or bioclastic quartz		**chert** (Fig. 6.23)
		clay minerals, quartz ± others	silt & clay-size gr. mostly clay-sized	color varies; might swell when wet; >67% clay-size particles; lacks fissility or obvious fine layering		**claystone**
		clay minerals, quartz ± others	silt & clay-size gr. mostly silt-sized	color varies, tans-grays; >50% silt-size particles; lacks fissility, breaks into blocks or layers		**siltstone** (Fig. 6.20)
		clay minerals, quartz ± others	silt & clay-size	very fine-grained rock that lacks fissility and percentage of clay or silt-size grains is unknown		**mudstone**
		clay minerals, quartz ± others	silt & clay-size	claystone that breaks along roughly planar surfaces spaced close together (has fissility)		**shale** (Fig. 6.21)
		mostly quartz	mostly sand-size grains	quartz sand grains, typically with silica or calcite cement ± clay; range of colors	sandstone (ss.)	**quartz ss.** (Fig. 6.19)
		quartz, clays	mostly sand-size grains	mostly sand-size grains but with a large component of clay-size grains	sandstone (ss.)	**muddy ss.** (argillaceous ss.)
		quartz, feldspar, clays, ± rock fragments	mostly sand-size grains	at least 25% feldspar; color tends toward red-brown-pink; usually poorly cemented	sandstone (ss.)	**arkose ss.** (Fig. 6.13)
		quartz, clays, feldspar, ± rock fragments	mostly sand-size grains	quartz & feldspar grains in a clay matrix, often with dark minerals and rock frags; dark gray-green	sandstone (ss.)	**graywacke**
		fossils in matrix of quartz ± other silicates	mostly sand-size grains	sandstone containing obvious fossils; range of colors possible	sandstone (ss.)	**fossiliferous ss.**
		quartz, rock fragments ± other silicates	mostly sand-size grains	sandstone of any compositional variety containing rock fragments	sandstone (ss.)	**lithic ss.**
		various silicates and rock fragments	mostly gravel-size grains	rounded to subround gravel-size grains surrounded by finer grains		**conglomerate** (Fig. 6.17)
		various silicates and rock fragments	mostly gravel-size grains	angular to subangular gravel-sized grains surrounded by finer grains		**breccia** (Fig. 6.18)
	Other	halite	fine to very coarse mass of crystals	can be clear, white, pink, red; tastes salty; evaporite deposit		**rock salt** (Fig. 6.10A)
	Other	gypsum, anhydrite	fine to very coarse mass of crystals	soft enough to be scratched by a fingernail; evaporite deposit		**rock gyspsum** (Fig. 6.24)

Figure 6.25 A system for classifying sedimentary rock in a hand specimen.

A Field Classification of Metamorphic Rox

METAMORPHIC ROCK ANALYSIS AND CLASSIFICATION

STEP 1: What are the rock's textural characteristics?			Step 2: What are the rock's distinctive features, including composition?	Step 3: Metamorphic rock name		Step 4: What was the likely protolith?	Step 5: What is the rock used for?
IS DEFINITELY FOLIATED	Very-fine-grained	Very fine grained; slaty cleavage	Dull luster; common colors are black, gray, green, red	SLATE* (Fig. 7.7)	INCREASING METAMORPHIC GRADE ↓	mudstone or shale	Roofing slate, table tops, floor tile, and blackboards
	Very-fine- to fine-grained	Fine- or very-fine-grained; phyllitic layering	Breaks along wrinkled or wavy foliation surfaces with silky or shiny luster	PHYLLITE* (Fig. 7.8)		mudstone, shale, or slate	Construction stone, decorative stone, sources of gemstones
	Medium- to coarse grained	Schistocity: preferred orientation of flat (platy) or elongated mineral grains to form foliation surfaces; breaks most easily along foliation surfaces	Blue amphibole (glaucophane) and blue-gray lawsonite	BLUESCHIST	SCHIST* (Fig. 7.9)	mudstone, shale, slate, or phyllite	
			Green chlorite, epidote, or actinolite (green amphibole)	GREENSCHIST			
			Mostly muscovite mica; sparkles in reflected light	MUSCOVITE SCHIST			
			Mostly biotite mica; sparkles in reflected light	BIOTITE SCHIST			
		Gneissic layering of light and dark minerals in foliations	Alternating layers of light and dark mineral grains; might resemble a layered granitic rock	GNEISS* (Figs. 7.10, 7.12)		Many possible protoliths	Construction stone, decorative stone, gemstone source
CAN BE GRANOFELSIC OR FOLIATED	Medium- to coarse-grained; can be foliated or granofelsic; might display compositional banding of light and dark minerals		Mostly visible glossy black amphibole (hornblende) in blade-like crystals	AMPHIBOLITE		basalt, gabbro, other rocks with mafic minerals	Construction stone
	Medium to coarse-grained; can be foliated or granofelsic		Mostly green pyroxene (omphacite) and garnet	ECLOGITE		basalt, gabbro	Titanium ore
	Grain size might be difficult to resolve, except for fibrous minerals; foliated or granofelsic.		Mostly green-white serpentine minerals	SERPENTINITE (Fig. 7.17)		basalt, gabbro, or ultramafic rocks	Decorative stone
	Very fine-grained; commonly granofelsic but can be foliated		Mostly talc, but might have micas, chlorite, other minerals	SOAPSTONE		basalt, gabbro, or ultramafic rocks	Art carvings, electrical insulators, talcum powder
	Coarse- to very-fine-grained; often granofelsic but can be foliated		Mostly calcite or dolomite; calcite fizzes vigorously in HCl, dolomite fizzes weakly unless the rock is ground to a powder.	MARBLE* (Fig. 7.3)		limestone or dolostone	Art carvings, construction stone, decorative stone, source of lime for agriculture
	Medium- to very-fine-grained; typically granofelsic		Mostly quartz	QUARTZITE* (Figs. 7.13, 7.15)		quartz sandstone	Construction stone, decorative stone
	Conglomeratic texture; breaks across the clasts		Rock fragments, typically quartz or calcite	METACONGLOMERATE (Fig. 7.16)		conglomerate	Construction stone, decorative stone
Granofelsic texture, fine-grained			Contact-metamorphic rock	HORNFELS (Fig. 7.18)		any rock type	--
Black, submetallic luster, no visible grains, layering might be indistinct or absent			Organic solid, no diagnostic minerals; scratched by steel blade	ANTHRACITE COAL		bituminous coal	Solid fossil fuel

* Modify rock name by adding names of minerals in order of increasing abundance, for example, garnet muscovite schist is mostly muscovite with some garnet.

Figure 7.19 Five-step chart for metamorphic rock analysis and classification.

Activity 5.6 Estimate Mineral Composition of a Phaneritic Rock by Point Counting

Name: ______________________ Course/Selection: ______________ Date: __________

Learning GOAL You will learn how to use a form of point counting to identify the rock by its composition. This activity also gives you experience with simple counting statistics: the average (mean) and standard deviation.

Geologists sometimes classify rocks using a technique called *point counting* to estimate the relative abundance of different minerals in a rock. We will use a similar method adapted for this lab so that you can experience the basic idea of point counting without having to learn optical mineralogy or how to use a petrographic microscope.

A phaneritic igneous rock is shown in **Fig. A5.6.1A**. The four major minerals in the rock are identified and mapped as different-colored areas in **Fig. A5.6.1B**.

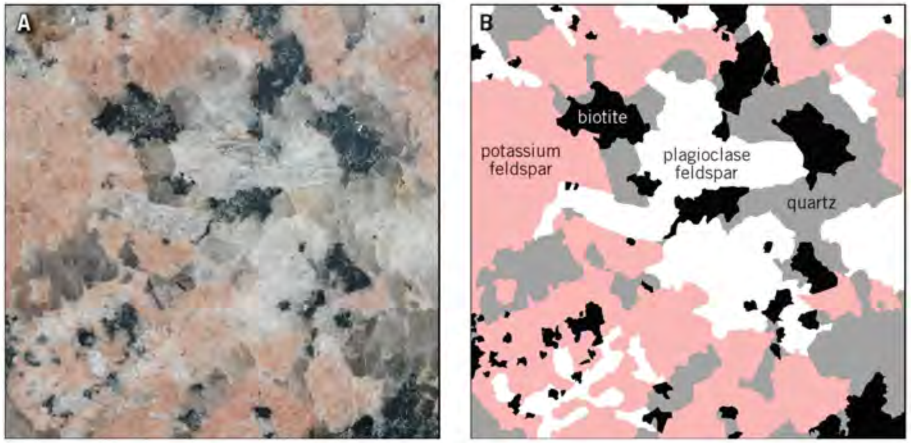


Figure A5.6.1 ▲

The task is to identify the mineral(s) found at each of several points on the rock. We make 25 small holes in a square grid on an opaque sheet, with each hole just large enough so that you can look through it to see what's on the other side. Then we put the grid sheet on top of the mineral map of the igneous rock (**Fig. A5.6.2A**) and repeat this process three times with the grid shifted slightly each time (**Fig. A5.6.2B–D**).

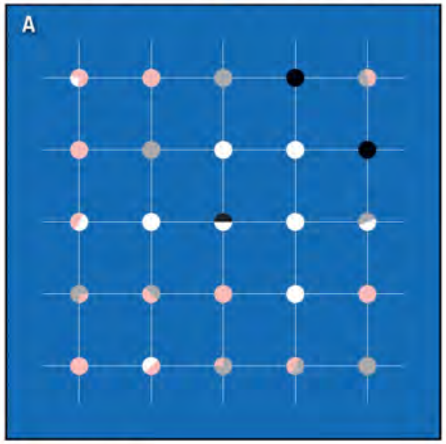


Figure A5.6.2 ▲

Count the number of node points that are filled with each of the four major minerals (that is, with each of the four colors on the map) and use that number to estimate the total volume of each major mineral in the rock. You can see more than one mineral through the hole at some node points, so estimate how much of each mineral fills each hole: 0.25 if a mineral fills a quarter of the hole, 0.5 if a mineral fills half of the hole, and 1.0 if a mineral fills the entire hole. For example, 7.25 circles are filled with white (plagioclase feldspar) in **Fig. A5.6.2A**, so estimate that about $(7.25 \times 4)\%$ or ~29% of the rock is composed of plagioclase feldspar.

Point Count, Grid A

Number of nodes filled with the mineral

(________ × 4)% = ______ % potassium feldspar (pink)

(___7.25___ × 4)% = ~29% plagioclase feldspar (white)

(________ × 4)% = ______ % quartz (gray)

(________ × 4)% = ______ % biotite (black)

From the 11th Edition

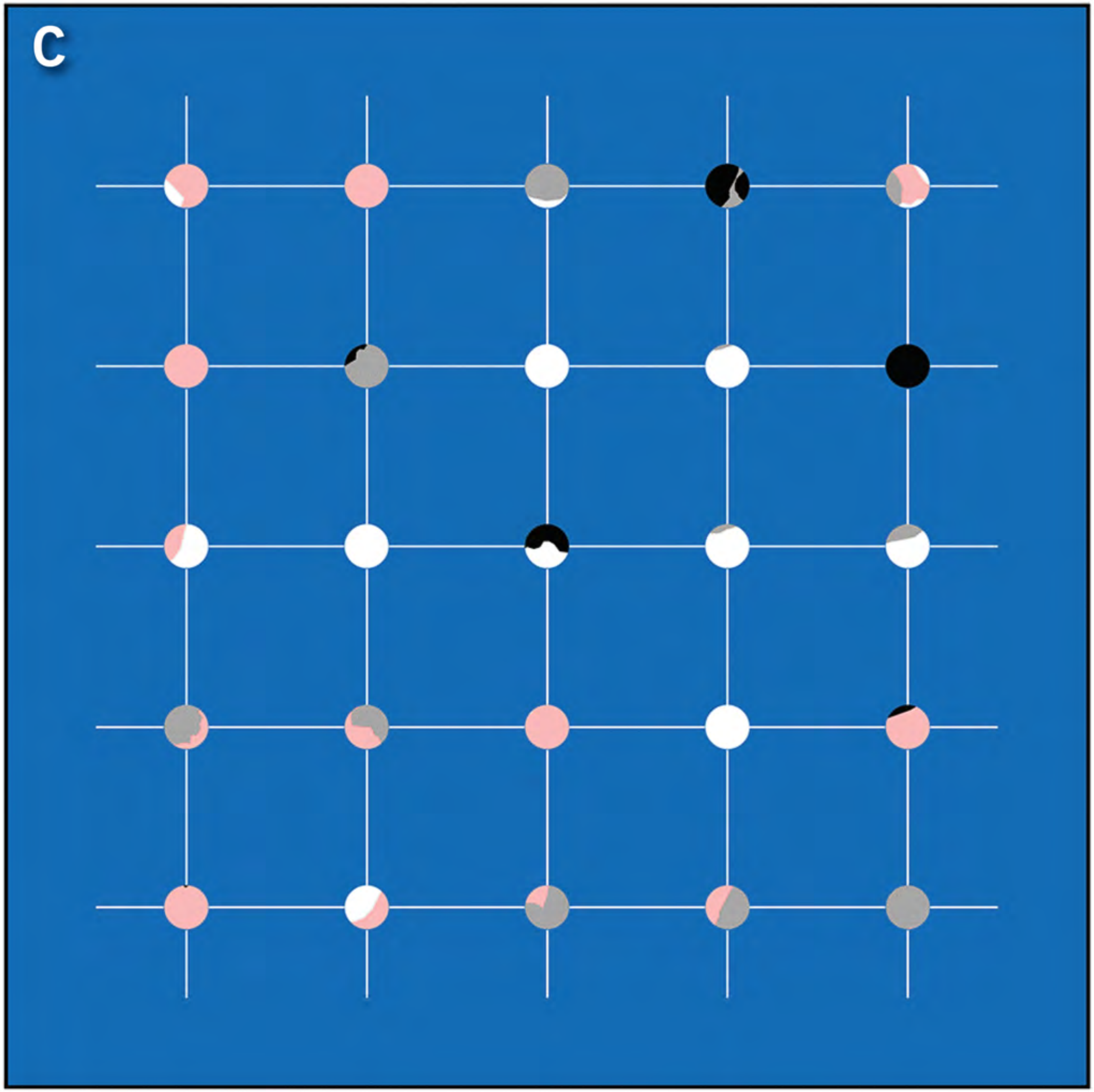


Figure A5.6.2

As revised in the 12th Edition

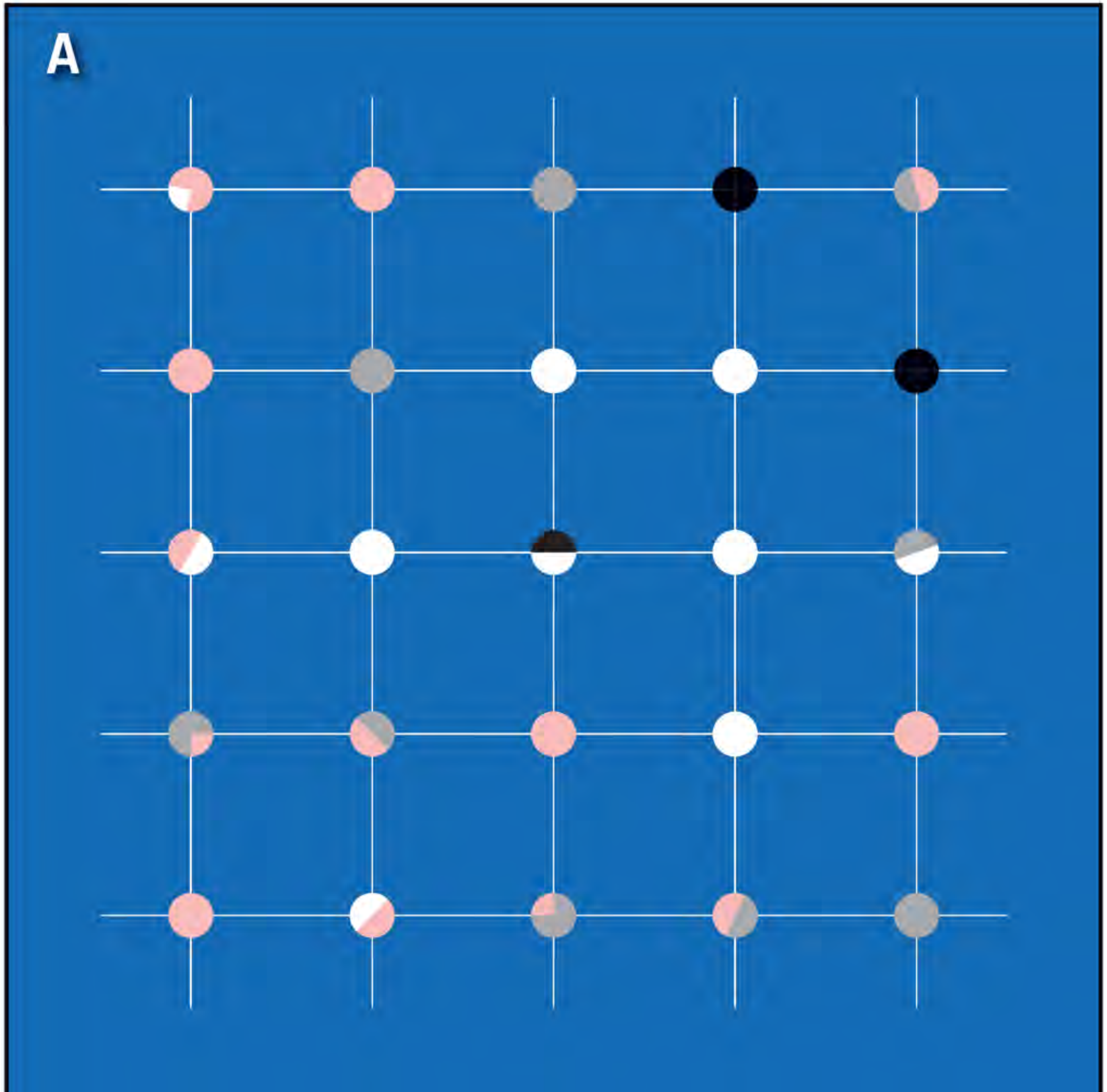


Figure A5.6.2 ▲

New activity in the 12th Edition

Activity 5.8 Tectonic Setting of Some Major Volcanic Rock Types

Name: ______________________ Course/Selection: ______________ Date: __________

Learning GOAL You will discover how different magma types might be related to tectonic setting, given information about active volcanoes in the United States and the adjacent seafloor.

A Color each of the white circles in **Fig. A5.8.1** to indicate the composition of the most felsic major rock type at that volcano (red/pink = rhyolite; gray = andesite; black = basalt), using information about active volcanoes in the United States in **Fig. A5.8.2**.

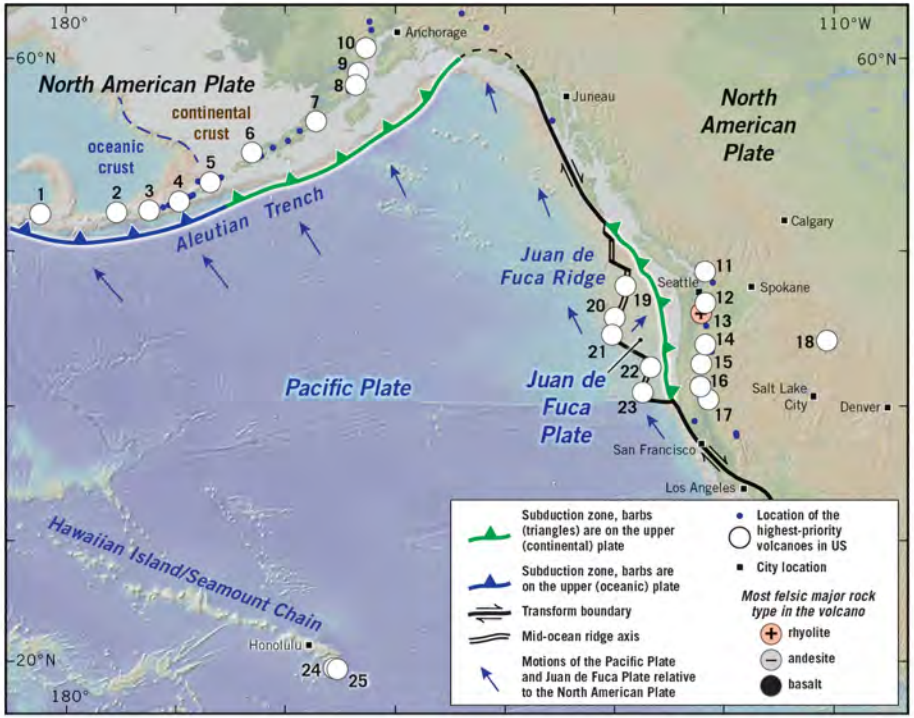


Figure A5.8.1 ▲

Volcano Number	Volcano Name	Volcano Type	Major Rock Type(s)	Volcano Number	Volcano Name	Volcano Type	Major Rock Type(s)
1	Kiska	stratovolcano	andesite	14	Three Sisters	complex	andesite-rhyolite
2	Kasatochi	stratovolcano	basalt-andesite	15	Crater Lake	caldera	basalt-rhyolite
3	Sequam	stratovolcano	basalt-andesite	16	Shasta	stratovolcano	andesite
4	Cleveland	stratovolcano	andesite	17	Lassen	stratovolcano	andesite
5	Makushin	stratovolcano	basalt-andesite	18	Yellowstone	caldera	basalt-rhyolite
6	Amak	stratovolcano	andesite	19	Endeavour Segment	fissure vent(s)	basalt
7	Yantarni	stratovolcano	andesite	20	Axial Seamount	caldera & fissure	basalt
8	Fourpeaked	stratovolcano	andesite	21	Cleft Segment	fissure vent(s)	basalt
9	St. Augustine	dome cluster	andesite	22	N Gorda Segment	fissure vent(s)	basalt
10	Redoubt	stratovolcano	basalt-andesite	23	Escanaba Segment	fissure vent(s)	basalt
11	Baker	stratovolcano	andesite	24	Mauna Loa	shield	basalt
12	Rainier	stratovolcano	andesite	25	Kikauea	shield	basalt
13	St. Helens	stratovolcano	basalt-rhyolite				

Figure A5.8.2 ▲

NAGT WEBINARS ON THE CUTTING EDGE PROGRAM

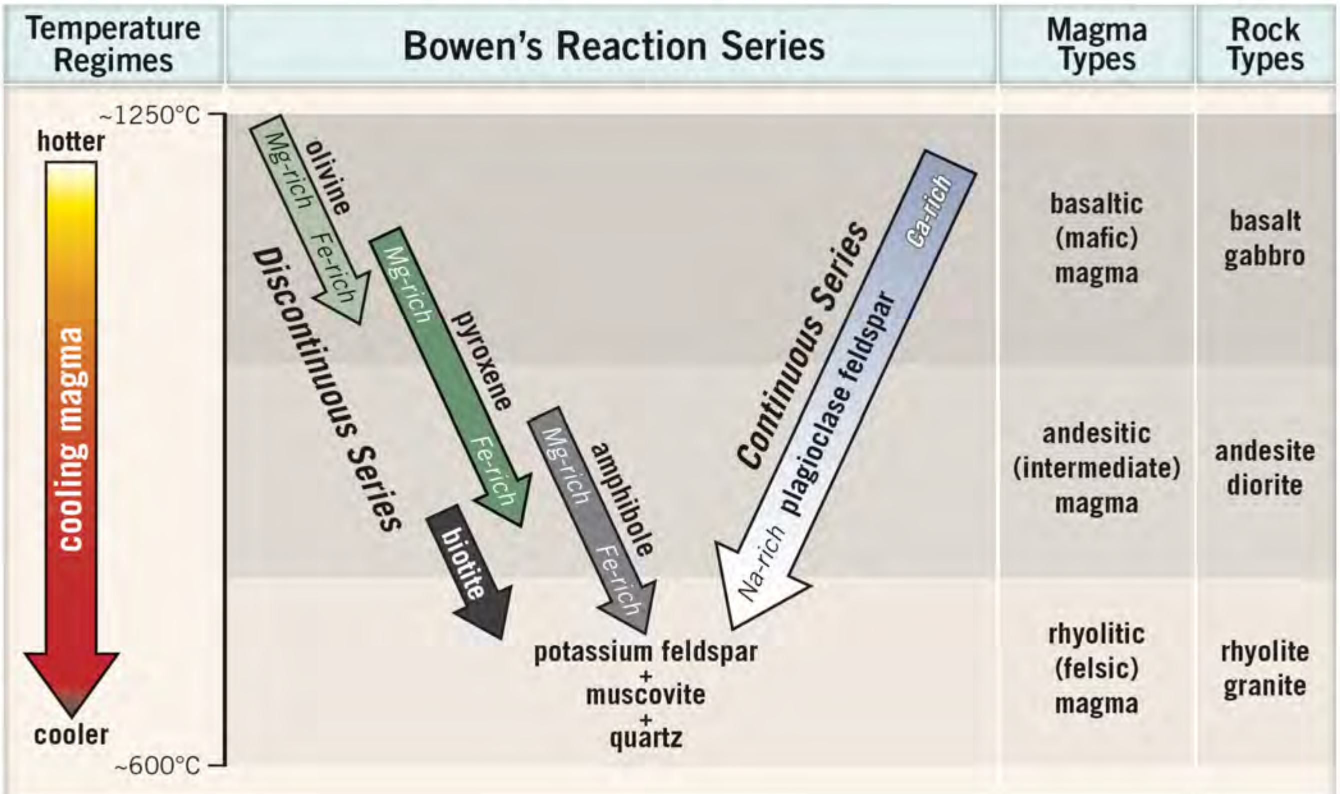


Figure 5.2 Bowen's reaction series. See text for explanation.

Bowen's reaction series as represented in the 12th edition of the Lab Manual

Revised graphic in the 12th Edition

New graphic in the 12th Edition

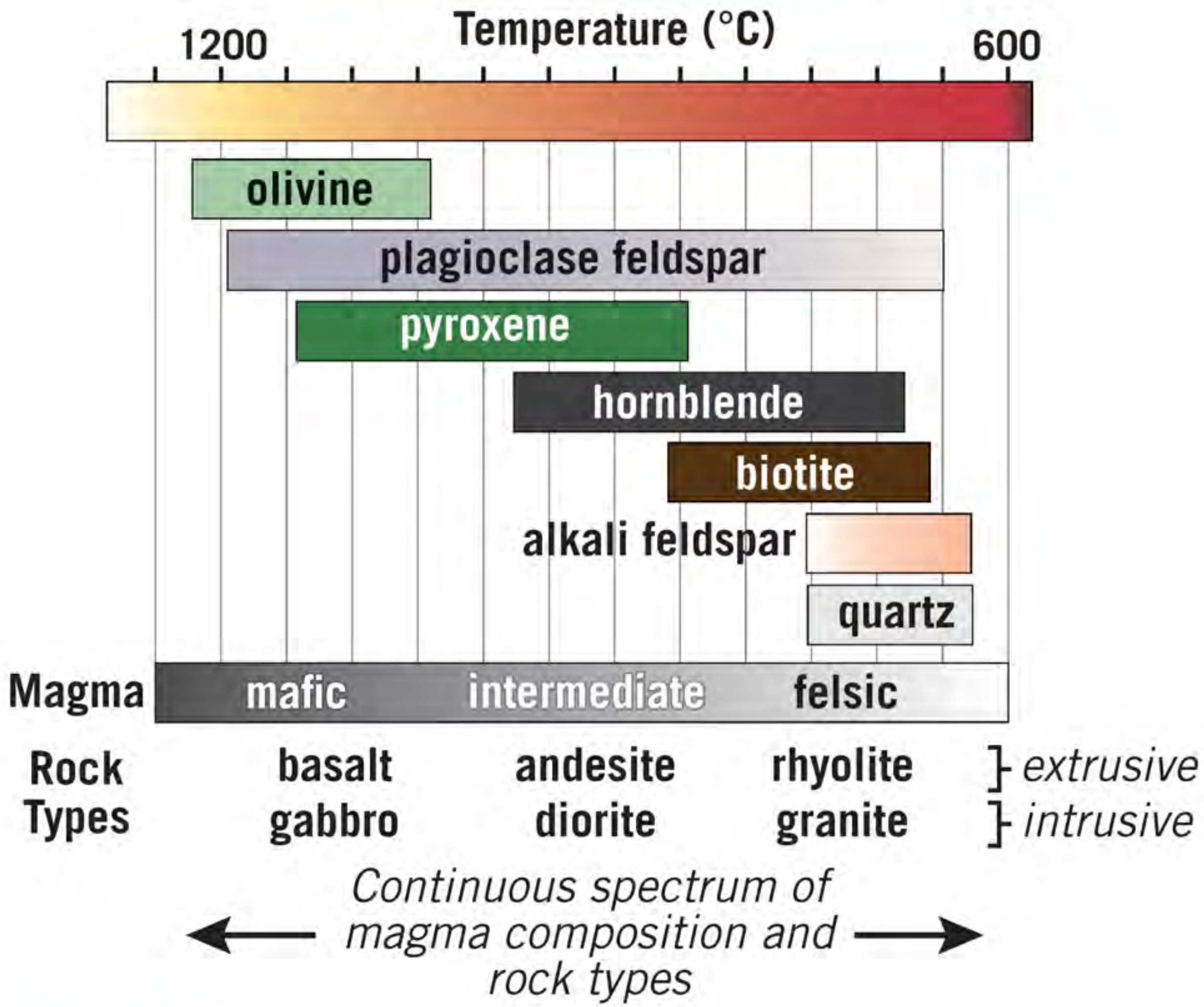


Figure 5.3 Typical order that certain major minerals crystallize from cooling magma. Details of the sequence and type of minerals that crystallize from a particular magma might differ from those shown in this figure. (Adapted from a figure by Allen Glazner)

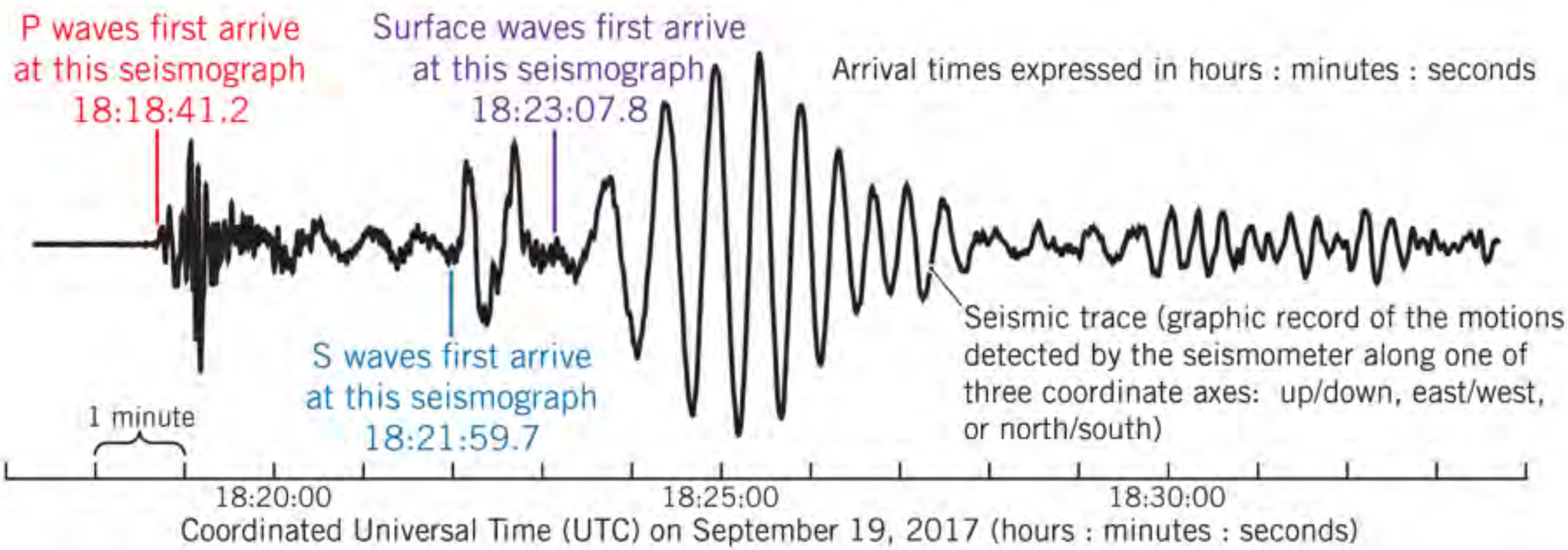
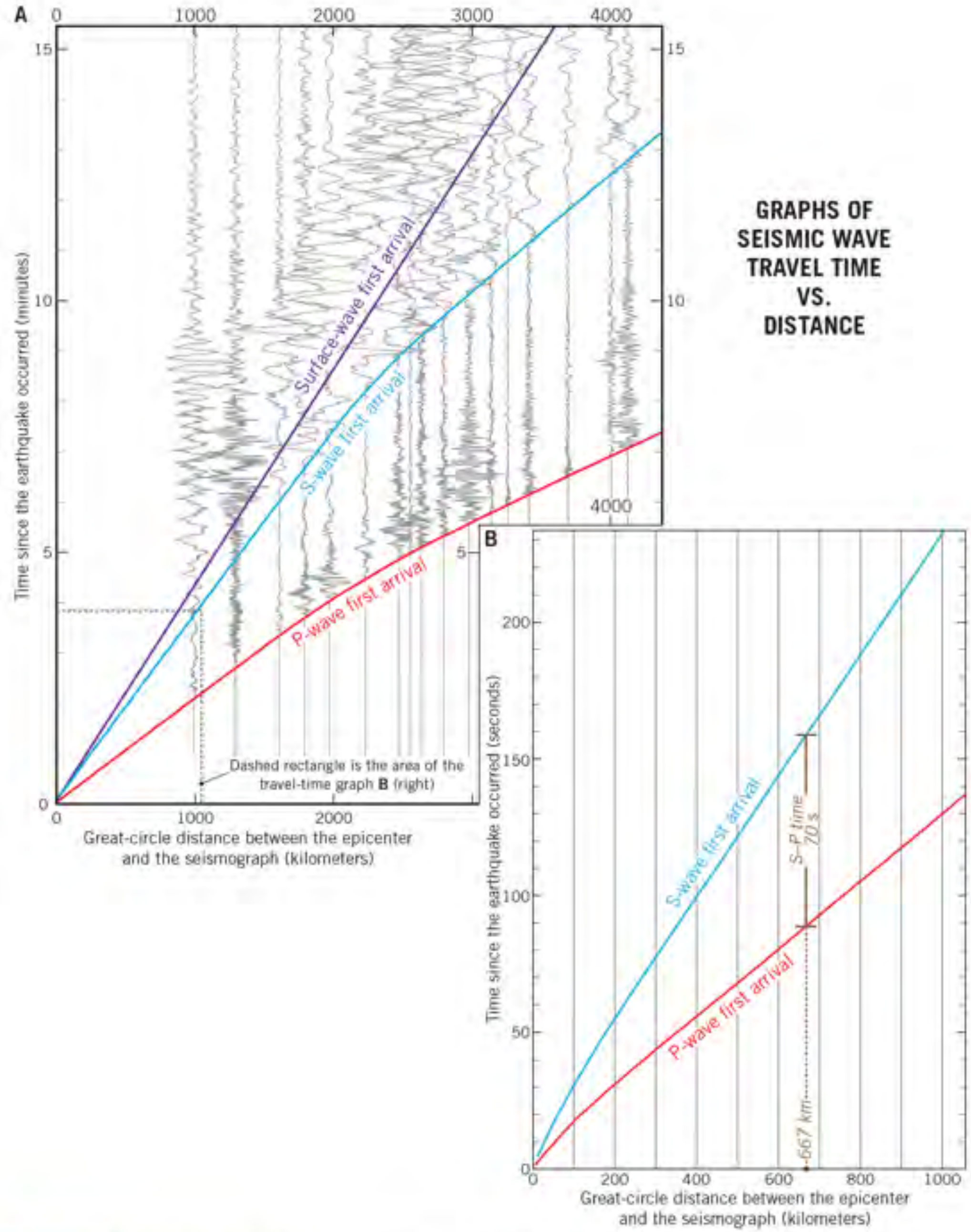


Figure 11.4 Seismogram of an earthquake in Mexico. Example of a seismogram associated with the 2017 Ayutla-Puebla earthquake as recorded at station LRAL at Lakeview Retreat, Alabama. This trace shows the first arrivals of the P-, S-, and surface waves and records the vertical (up-and-down) motion measured by the seismometer during this magnitute-7.1 earthquake. (Digital data for this trace were provided by John Taber at IRIS.)

Revised graphic in the 12th Edition

New graphic in the 12th Edition



GRAPHS OF SEISMIC WAVE TRAVEL TIME VS. DISTANCE

Figure 11.5 Travel-time curves. **A.** Travel-time curves for P-, S-, and surface waves with a set of traces from 17 different seismographs at various distances from the epicenter of the magnitude-7.1 Ayutla-Puebla earthquake of September 19, 2017. The seismograms illustrate how the curves can be derived using empirical data. **B.** Travel-time curves for use within ~1000 km of an epicenter. This graph is used in Activity 11.3. Notice that an S-minus-P time of 70 seconds corresponds to a distance to the epicenter of approximately 667 km.

Revised activity in the 12th Edition

Locate the Epicenter of an Earthquake

Activity 11.3

Name: ____________________ Course/Section: ____________ Date: ________

Learning GOAL You will use a set of seismograms and travel-time curves to locate the epicenter of an earthquake and gather some information about the event from web sources.

A widely felt moderate earthquake occurred on August 23, 2011, and was detected by seismographs at Standing Stone, Pennsylvania (SSPA); Wyandotte Cave, Indiana (WCI); and Waverly, Tennessee (WVT). Seismograms of the vertical component of motion at those three seismograph stations are shown in **Fig. A11.3.1.** Times are expressed in Coordinated Universal Time (UTC). Seismologists express time in hours:minutes:seconds. See if you can use these seismograms and a seismic-wave travel-time curve (**Fig. 11.5**) to locate the epicenter of the earthquake that produced the seismograms.

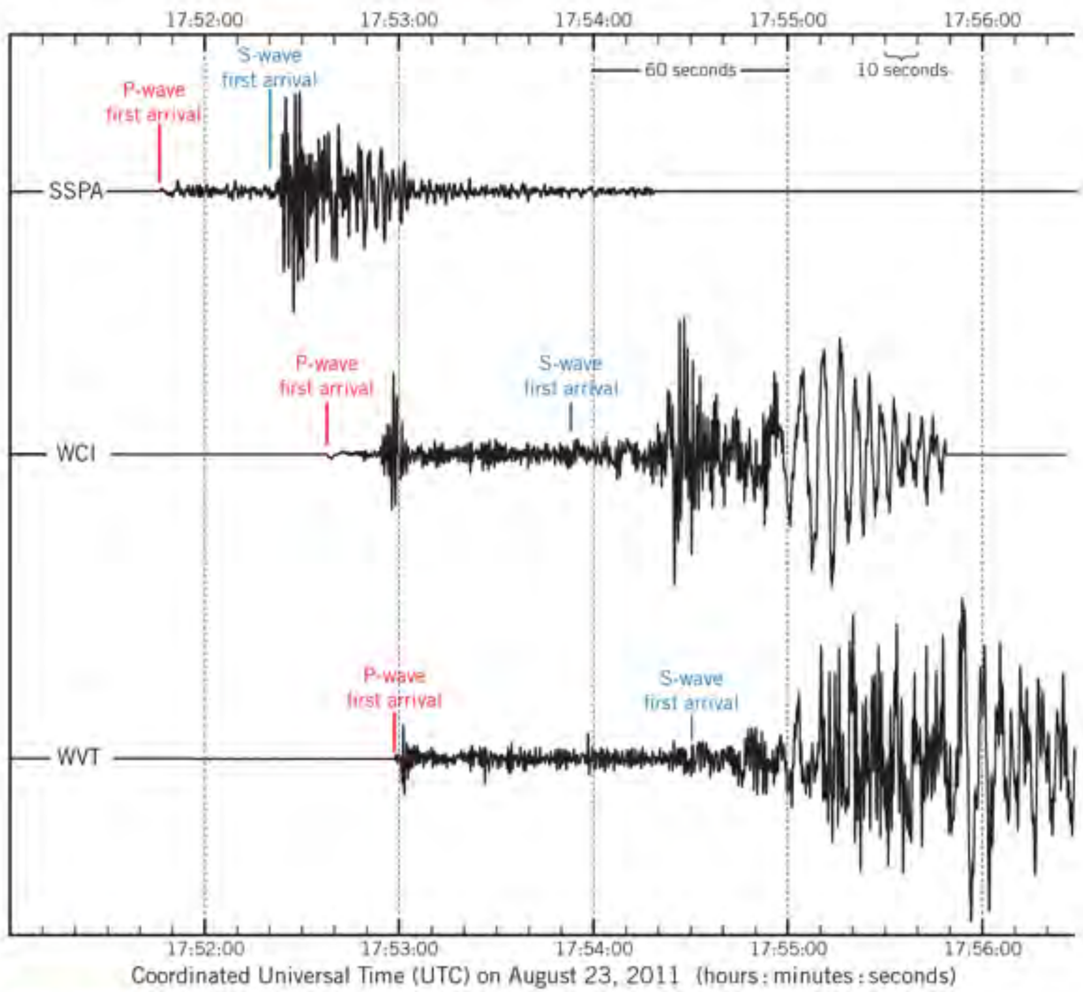


Figure A11.3.1

NAGT WEBINARS ON THE CUTTING EDGE PROGRAM

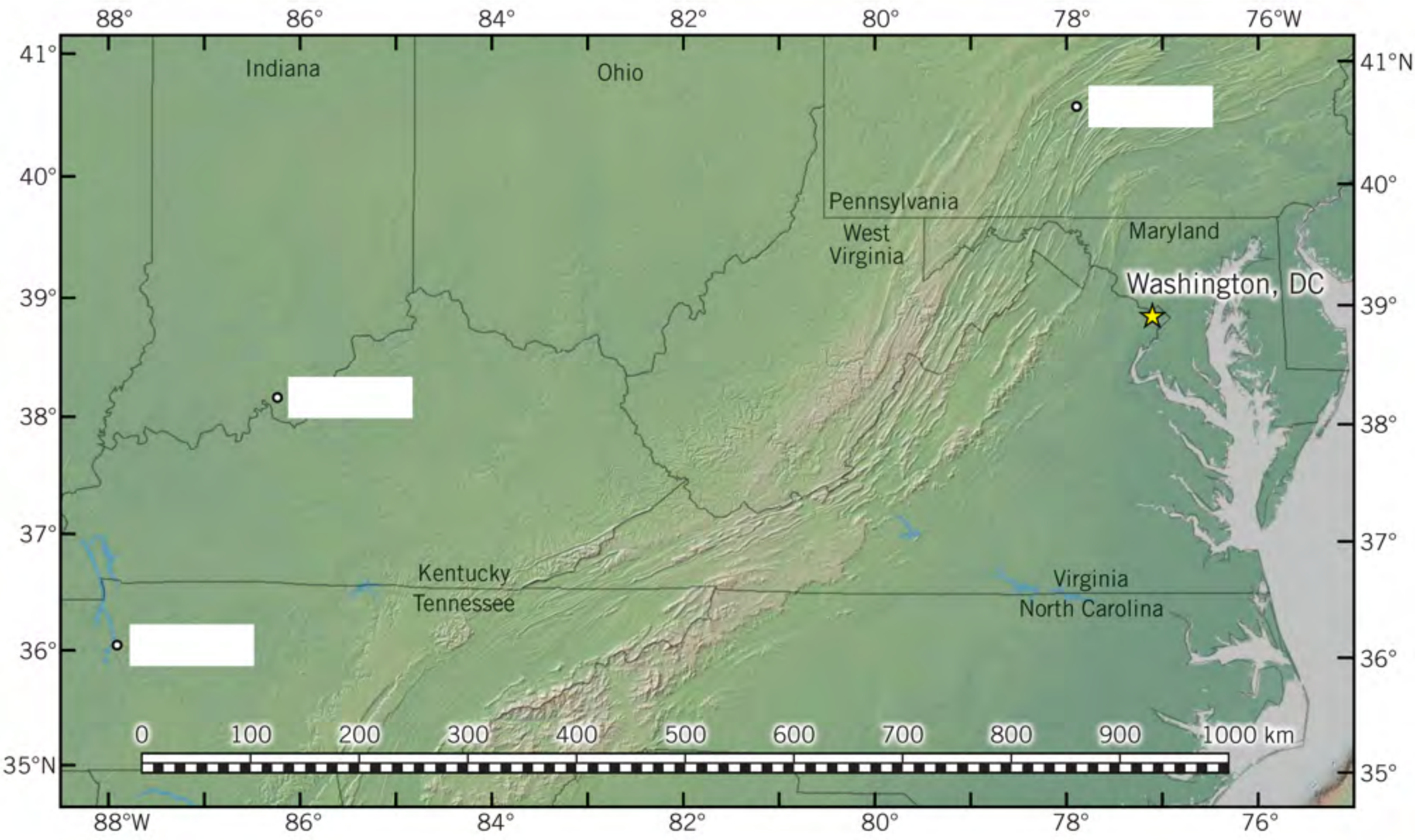


Figure A11.3.2

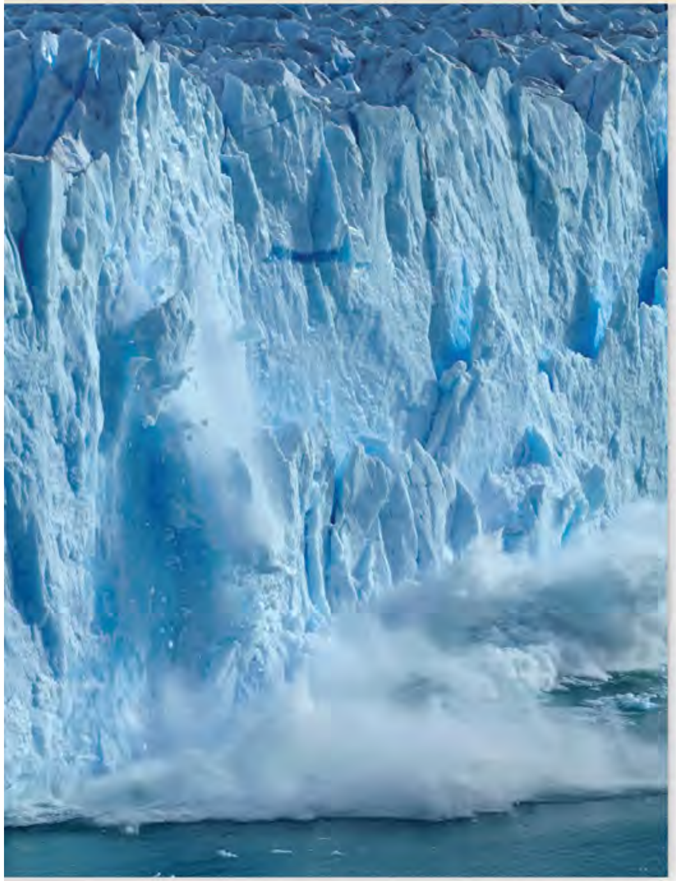
New laboratory in the 12th Edition

Laboratory **17**

Earth's Dynamic Climate

Contributing Author

Mark Carpenter • *American Geosciences Institute*



▲ Ice calving from the terminal face of Perito Moreno Glacier into Lago Argentino, Parque Nacional Los Glaciares, Patagonia, southern Argentina (near 50.467°S, 73.041°W). Photo taken 25 April 2017 by David Wall/Alamy.

Big **IDEAS**

Advances in science and technology over the past century have enabled us to measure changes in the Earth system, providing us with a strong base of reliable information. Superimposed on the natural rhythms of a planet that has been in an "ice age" for the past ~2.6 million years are extraordinary changes in the chemistry and temperature of the atmosphere and oceans that pose significant challenges to human society worldwide, now and for the foreseeable future. With our expanding knowledge of the history of Earth's climate before human involvement, scientists draw data-based interpretations of the contribution of human activities to global environmental change. Geoscience has an extraordinary opportunity to contribute to the health and welfare of both human society and the Earth ecosystem by continuing to provide reliable information and informed advice to a growing global community so that, together, we can navigate toward a more sustainable and just future.

Lab **ACTIVITIES**

17.1 How Does Rising Temperature Affect Sea Level? (p. 445)

17.2 Melting Ice and Rising Sea Level (p. 448)

17.3 Using Tide Gauge Data to Model Sea-Level Change (p. 450)

17.4 Carbon Dioxide in the Atmosphere (p. 453)

17.5 The Climate Record from Cores (p. 456)

17.6 Local Effects of Sea-Level Rise (p. 459)

PEARSON

Pre-Lab Videos: Earth's Dynamic Climate

A new chapter-opening video by Callan Bentley

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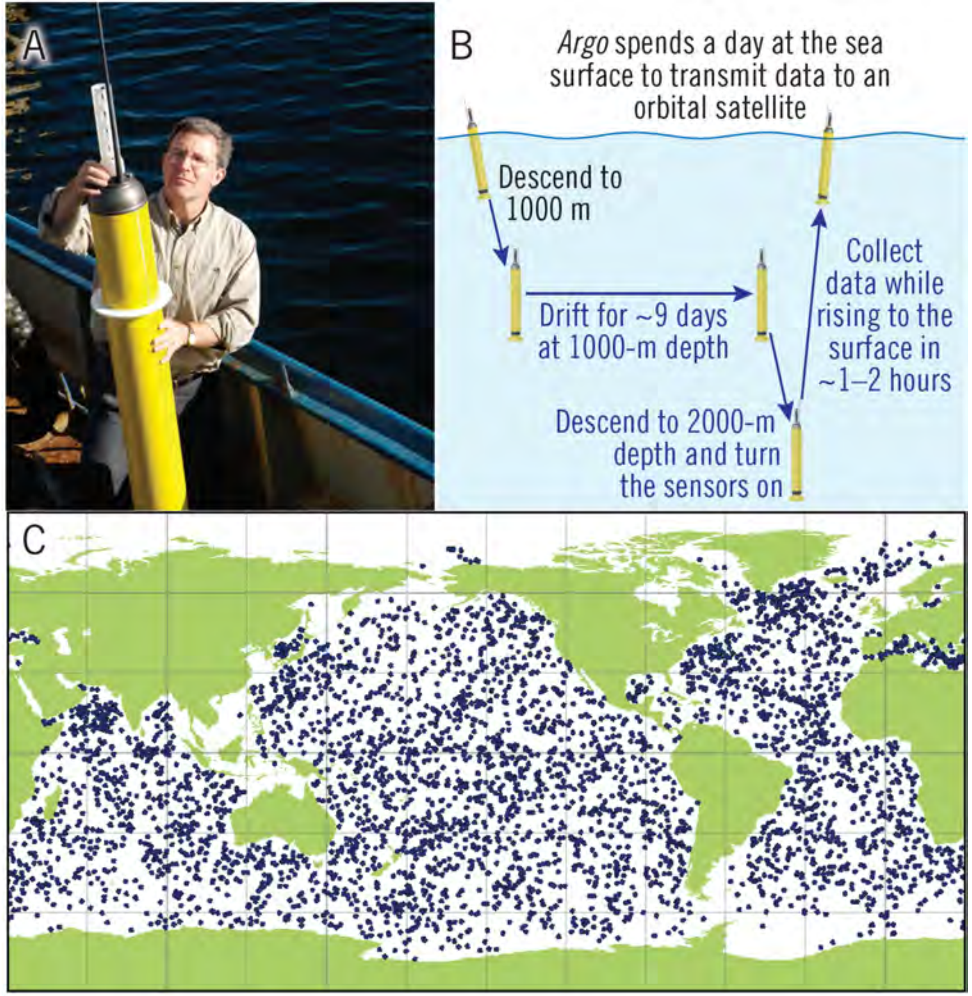

Figure 17.2 ***Argo* robotic float.** **A.** *Argo* robotic float being prepared for deployment. Photo: Allamy. **B.** The ~10-day cycle of *Argo* drifting, sampling, and reporting on the environmental conditions in the upper 2000 m of the oceans. **C.** Location of 3890 *Argo* floats (blue dots) contributed by 25 nations in May 2019. Map: Argo Information Centre.

How we measure changes in ocean temperature and chemistry

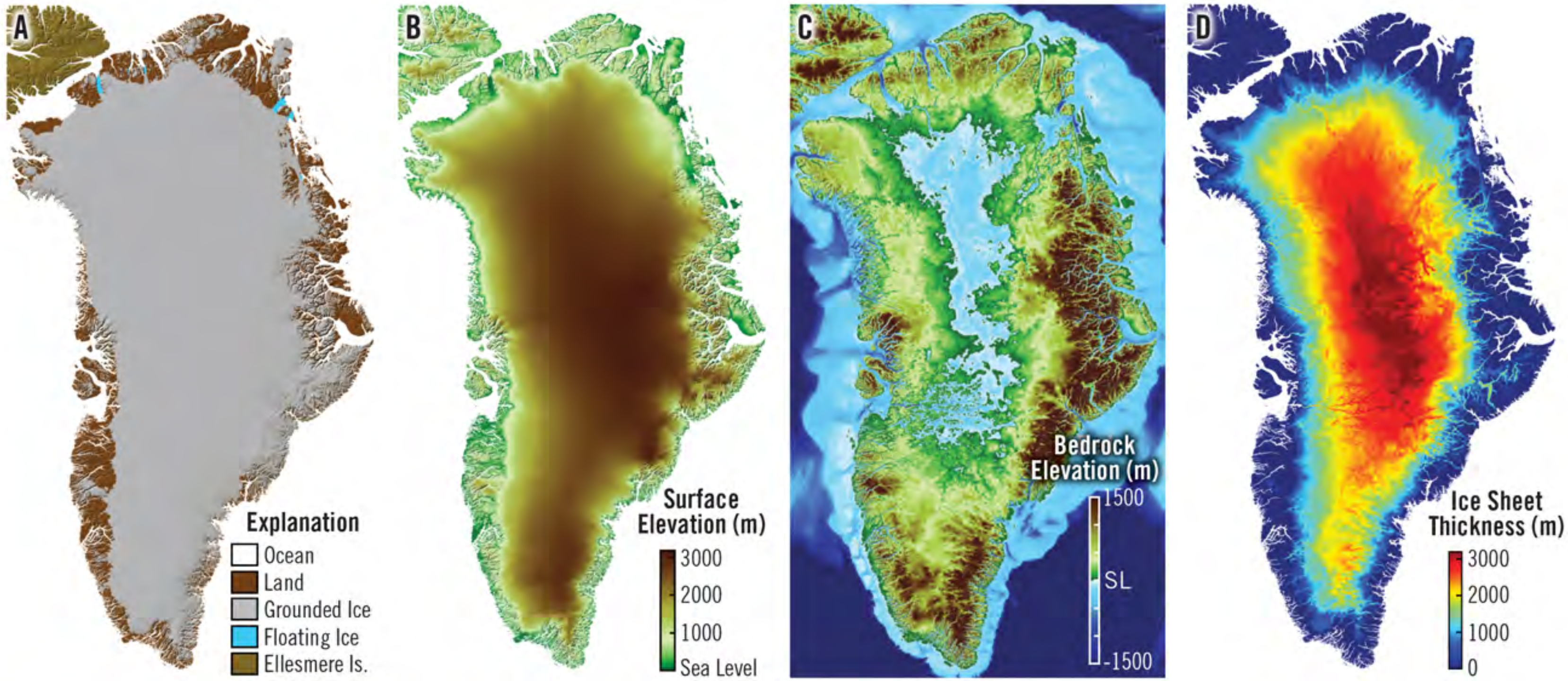

Figure 17.3 Estimating Greenland ice sheet volume. **A.** Extent of the Greenland ice sheet and ice shelves. **B.** Digital elevation model of the upper surface of Greenland, including the top of the ice sheet. **C.** Relief map of the top of the bedrock under the Greenland ice sheet. **D.** Map of the thickness of the ice sheet. Base maps from Morlighem and others (2017).

How we measure changes in the Greenland Ice Sheet

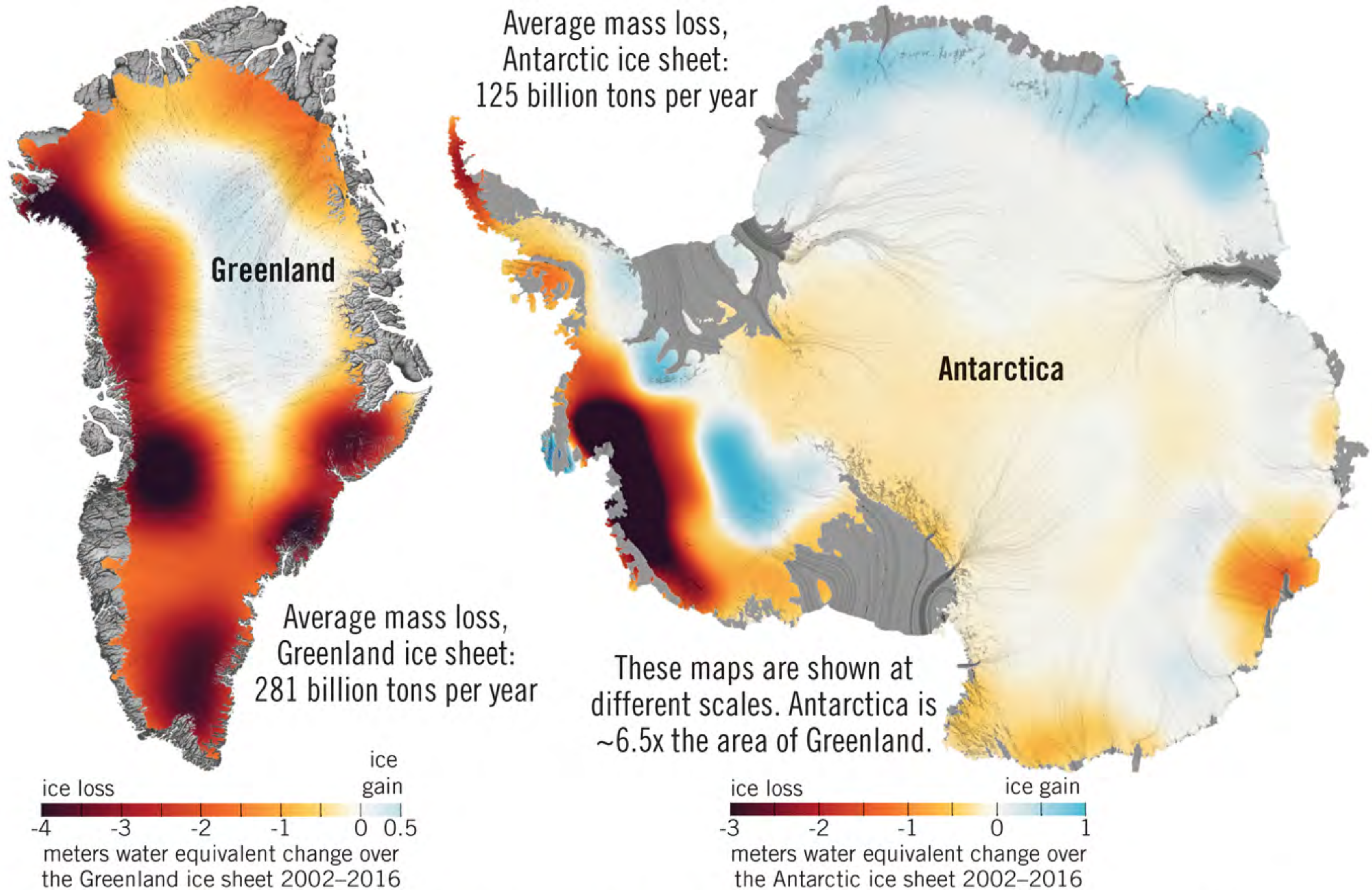

Figure 17.4 Graph of ice mass loss, Greenland and Antarctica. Maps showing changes in ice mass of the Greenland and Antarctic ice sheets between 2002 and 2016, using gravity data from the *GRACE* satellite system. Darker red-brown areas indicate greater ice mass loss. NASA maps.

Measured ice mass change in Greenland and Antarctica

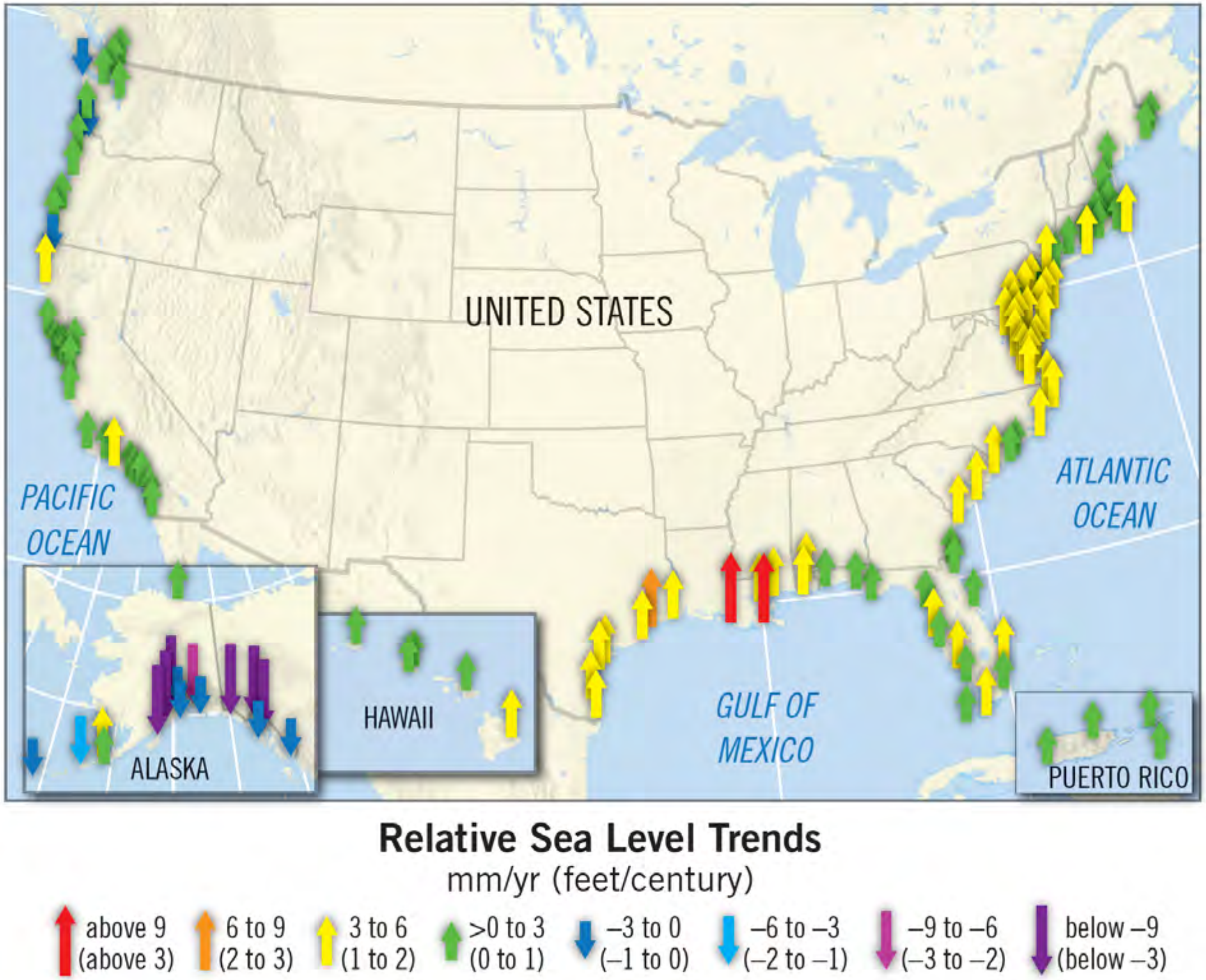

Figure 17.5 Trends in relative sea level. Relative sea level recorded locally at NOAA tide-gauge stations as of August 2018. Based on NOAA Sea Level Trends (**https://www.tidesandcurrents.noaa.gov/sltrends/sltrends.html**).

How we measure relative sea level changes.

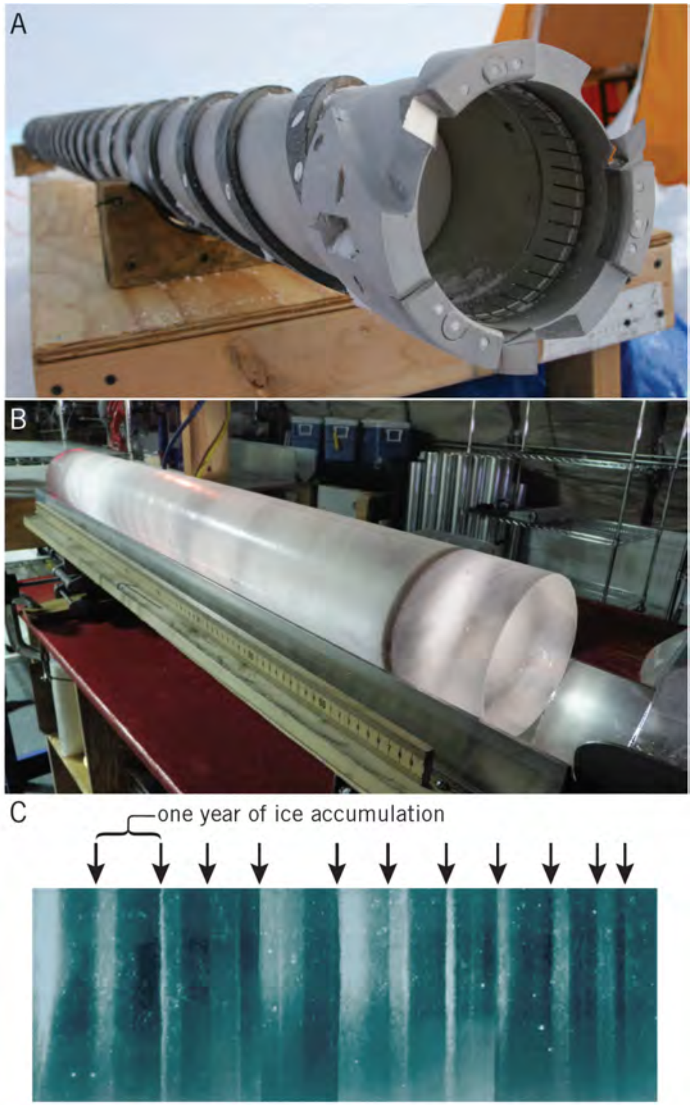

Figure 17.9 Ice core. **A.** Core barrel and bit used to collect ice cores in Antarctica. **B.** Ice core from the West Antarctic Ice Sheet Divide, showing a layer of ash (dark band near the closer end of the core) preserved in the ice from a volcanic eruption ~21,000 years ago. **C.** Short (19 cm) section the GISP2 ice core from Greenland showing annual layers with lighter summer layers sandwiched between darker winter layers. Photos: Steven Profaizer, Heidi Roop, and Anthony Gow, National Science Foundation.

A brief introduction to ice cores

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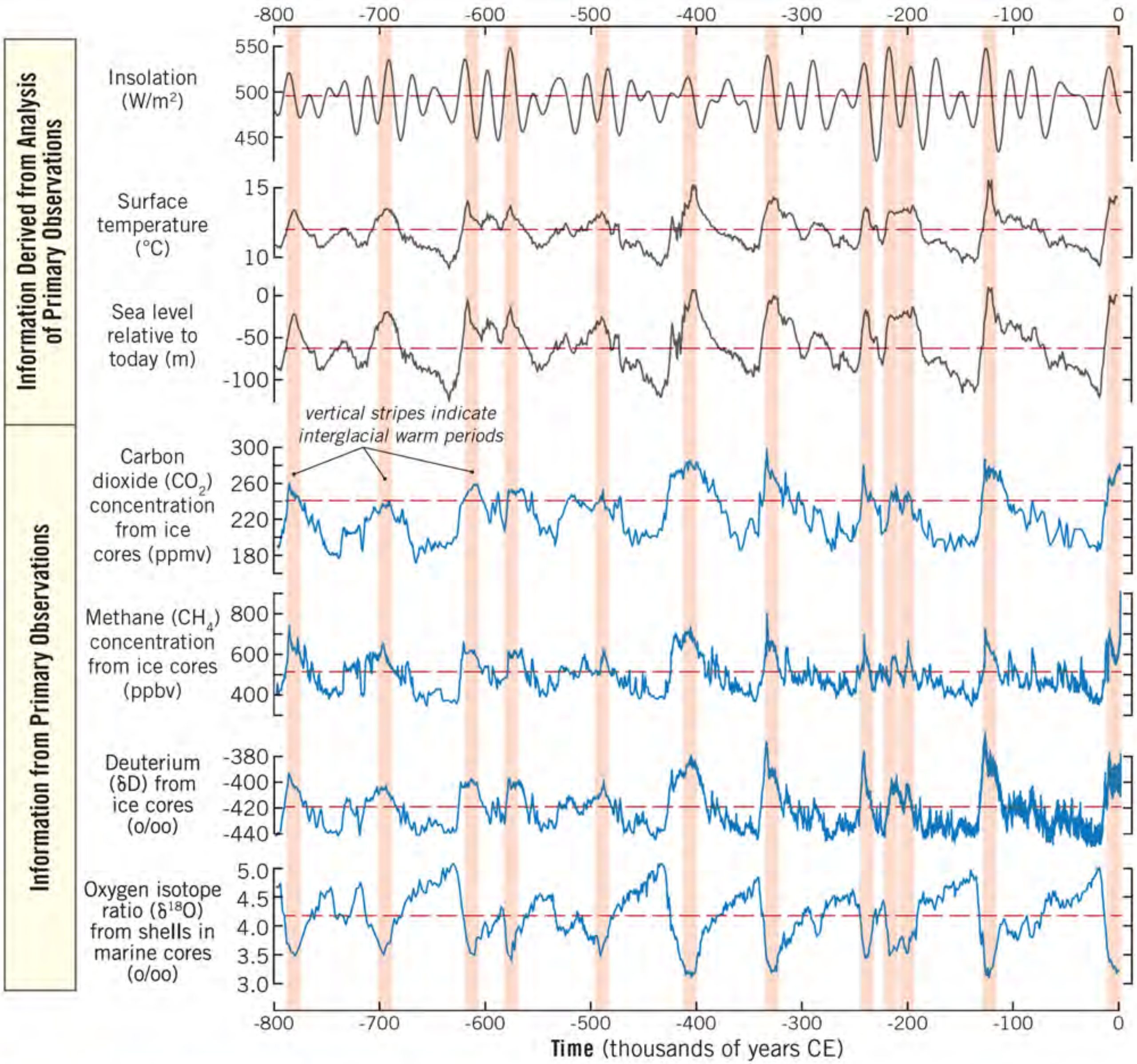

Figure 17.10 **800,000 years of climate record.** Time-series graphs of peer-reviewed published data relevant to the study of climate change over the past 800,000 years.

Record of environmental change from analysis of ice cores

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How Does Rising Temperature Affect Sea Level?

Activity 17.1

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will use observations from an experiment, orbital satellites, and floating robotic sensors to develop a basic understanding of how increasing the temperature of water can change its volume and hence the level of its upper surface in a container (or in an ocean basin).

A What happens to the volume of liquid water when its temperature is raised? To answer this question, either perform the following simple experiment or watch the brief video available at **https://qrgo.page.link/Hd51t**

Figure A17.1.1

You need the following items for the experiment (Fig. A17.1.1): a small glass Erlenmeyer flask, a two-hole rubber stopper sized for the top of the flask, a digital or alcohol thermometer that can be inserted through a hole in the stopper, a glass tube that can be inserted through the other hole in the stopper, a heat source such as a hotplate or a heat lamp, cold tap water (fresh water), and food coloring.

Step 1. Fill the flask to the top with cold water mixed with food coloring so you can easily see the water level.

Step 2. Carefully insert the thermometer and glass tube through the holes in the stopper and place the stopper assembly in the top of the flask. The stopper will displace some water at the top of the flask, and some of that displaced water should move up into the glass tube. If you can't see water in the tube, add drops of water until the water level is visible above the stopper in the tube.

Step 3. Before heating the assembly, mark the initial water level in the tube.

Step 4. Apply heat to the bottom of the flask either by setting the flask on a hotplate or by pointing the heat lamp toward the base of the flask.

Step 5. After a few minutes of heating, observe whether heating causes a change in water volume by seeing whether the water in the tube rises, falls, or remains at a constant level.

New activity in the 12th Edition

Does raising the temperature of water change its volume?

Pearson

2-minute video to support Activity 17.1A

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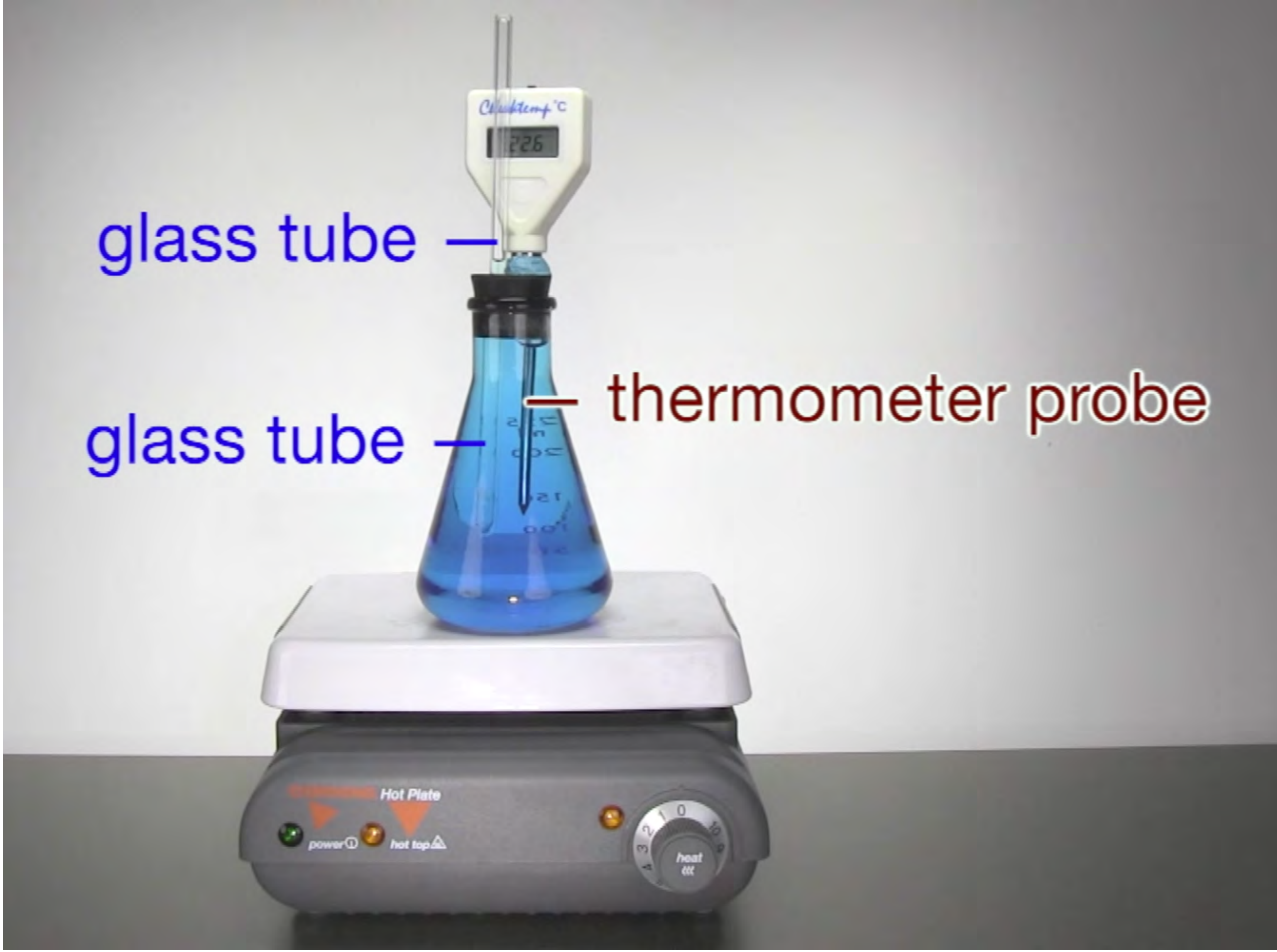

2-minute video to support Activity 17.1A

2-minute video to support Activity 17.1A

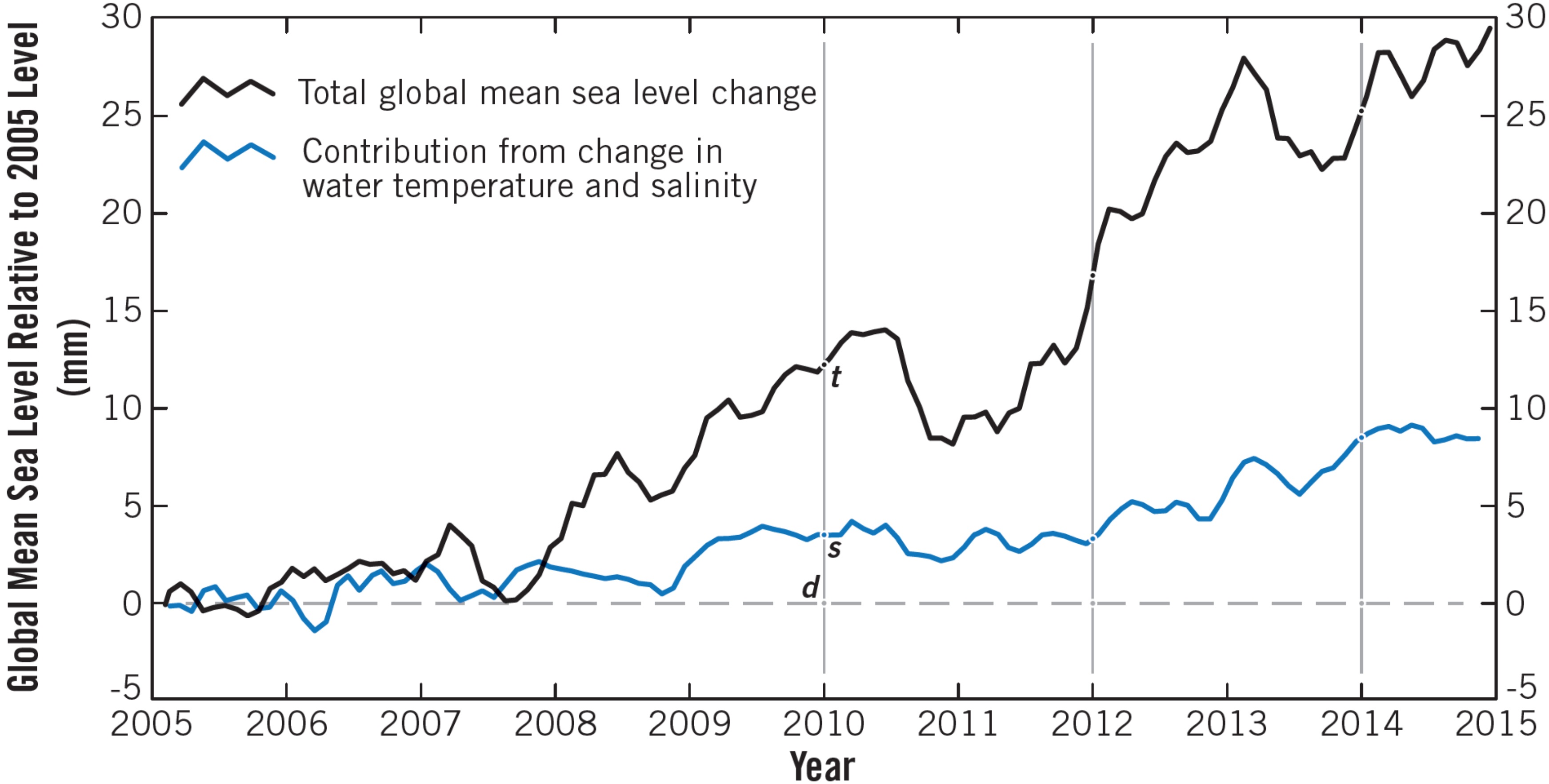

Figure A17.1.2

Activity **17.2** Melting Ice and Rising Sea Level

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will use simple experiments to investigate the effects of melting continental glaciers and ice sheets versus melting ice floating in the ocean. You will consider how this melting affects sea level (if at all). You will use data from orbital satellites to explore these effects on a global scale.

A Does sea level rise, fall, or remain the same when a floating iceberg melts? To investigate this matter, either perform the following simple experiment or watch the brief video available at **https://qrgo.page.link/Mr42z**

To perform the experiment, you need a glass container, some tap water, and ice that has sufficient volume that it might have an obvious effect on the water level in the container (**Fig. A17.2.1A**).

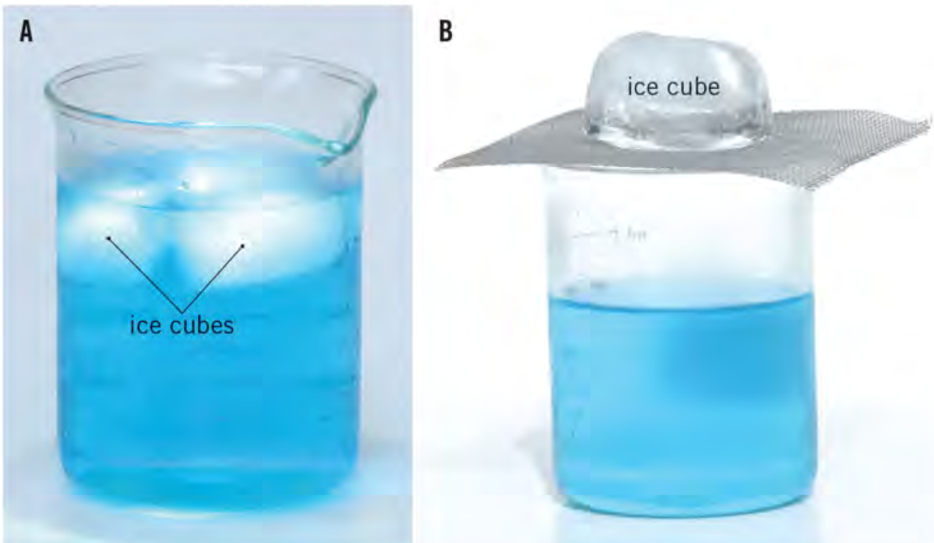

Figure A17.2.1

Step 1. Fill the container about half full of tap water and add the ice. All of the ice should be floating in the water, not touching the bottom of the container.

Step 2. On the side of the glass container, mark the level of the liquid water in the container.

Step 3. When the ice melts completely, observe the level of the liquid water in the container.

1. How did the water level in the container change, if at all, during the experiment?
2. Based on your observations, infer how the melting of floating icebergs might affect global sea level and write a brief statement explaining that inference in the space provided.

New activity in the 12th Edition

Does sea level change when sea ice or a floating iceberg melts?

Pearson

2-minute video to support Activity 17.2A

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2-minute video to support Activity 17.2A

2-minute video to support Activity 17.2A

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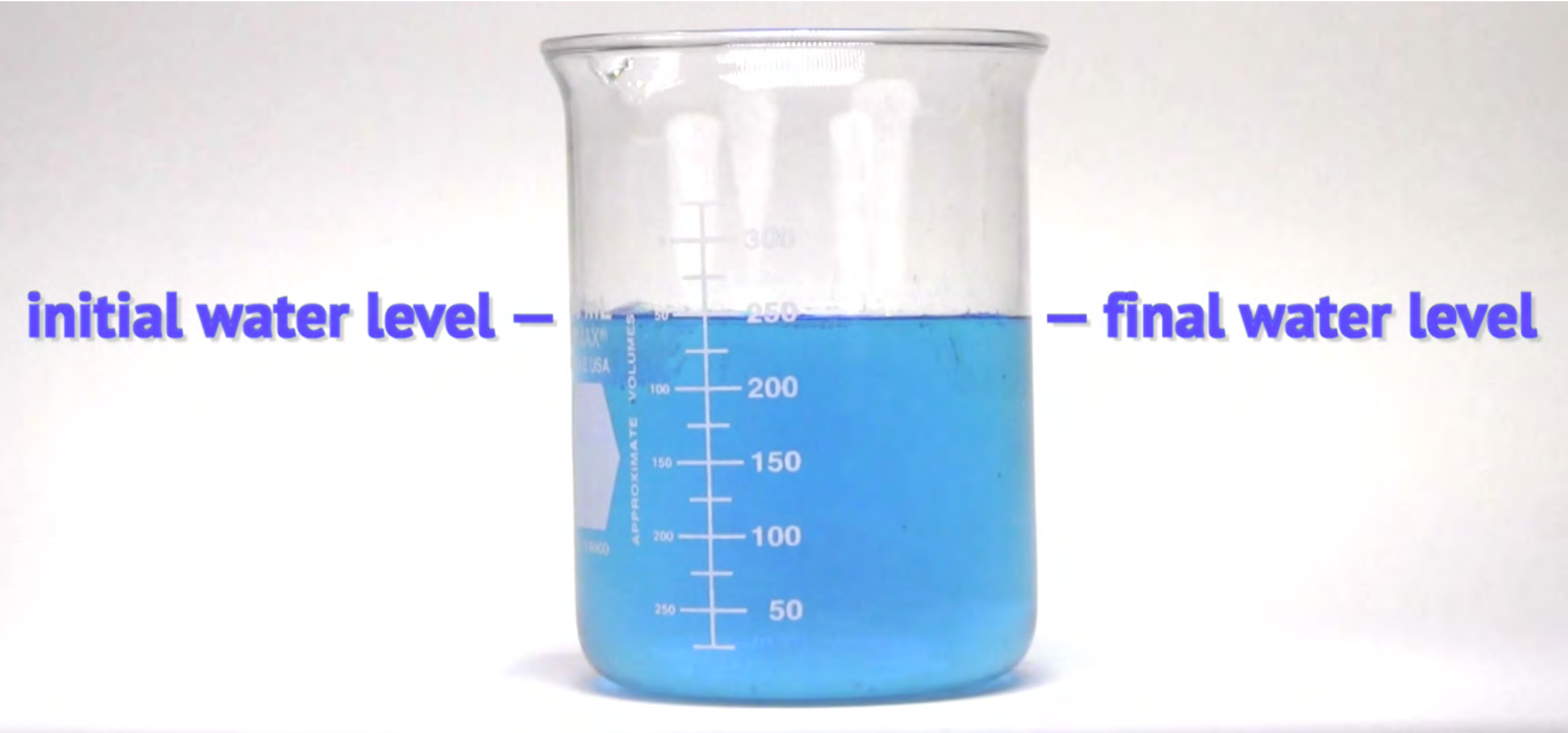

2-minute video to support Activity 17.2A

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Does sea level change when continental ice sheets and glaciers melt?

Pearson

2-minute video to support Activity 17.2B

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2-minute video to support Activity 17.2B

2-minute video to support Activity 17.2B

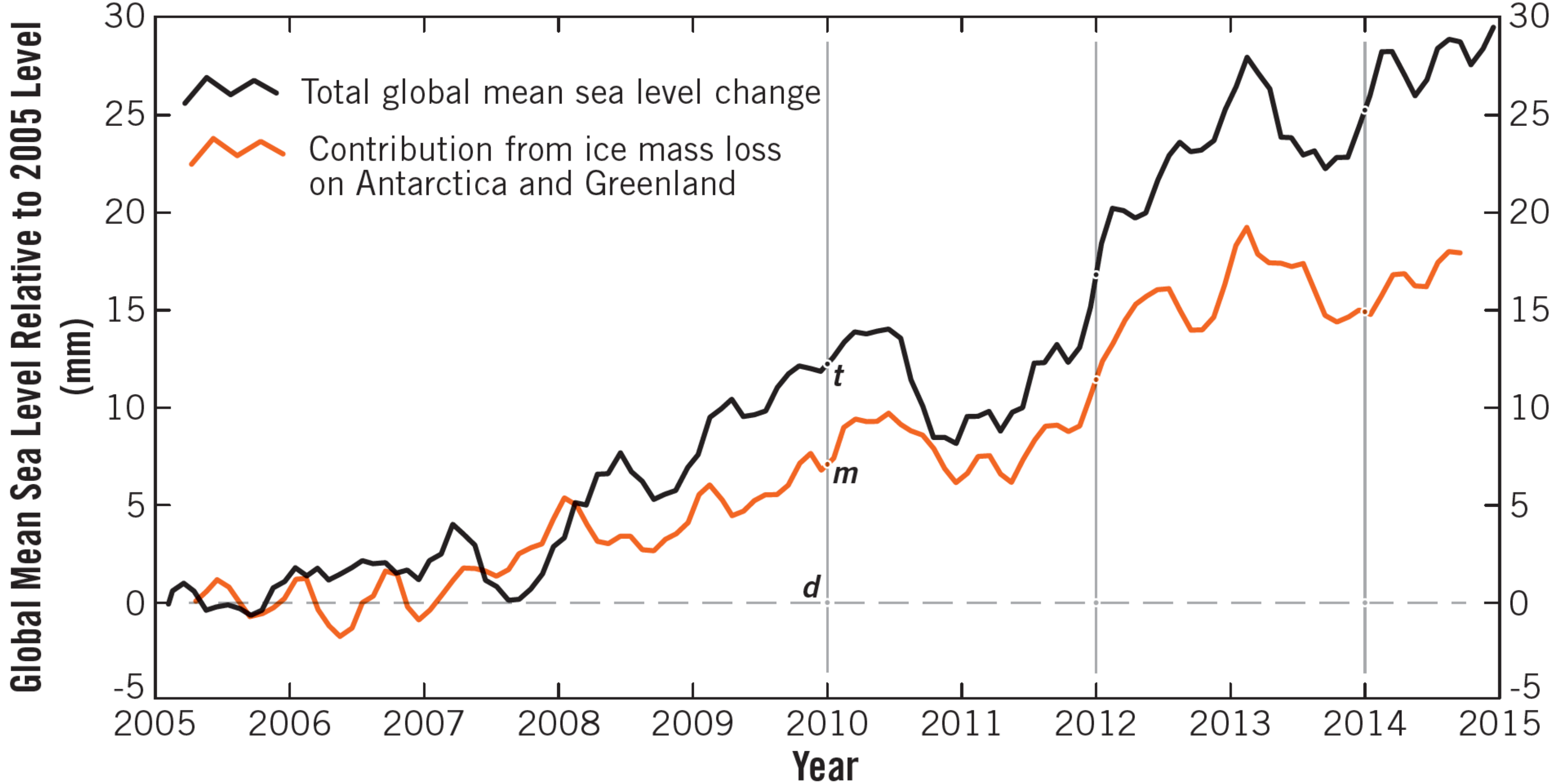

Figure A17.2.2

Activity 17.3 Using Tide Gauge Data to Model Sea-Level Change

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will use information provided by the USGS, NOAA, and other public agencies to model changes in local sea level along the coastlines of the continental United States with scenarios for global mean sea-level change that bracket conditions that are considered to be likely for the next couple of centuries.

A Use a web-enabled device to navigate to **https://js-169-194.jetstream-cloud.org/terriamap**. After this web app loads, use the zoom controls and position the map so that it looks approximately like **Fig. A17.3.1**, with the continental United States centered on the map window and with both the west and east coast tide gauge locations visible. Along the left side of the window is a frame called the *Workbench* in which you can select options for display on the map. A colorful map legend or explanation in the workbench identifies the colors associated with different amounts of local relative sea-level rise (RSL). For example, the range associated with the dark maroon color at the top of the scale in **Fig. A17.3.1** is from 0.51 m up to 2.12 m.

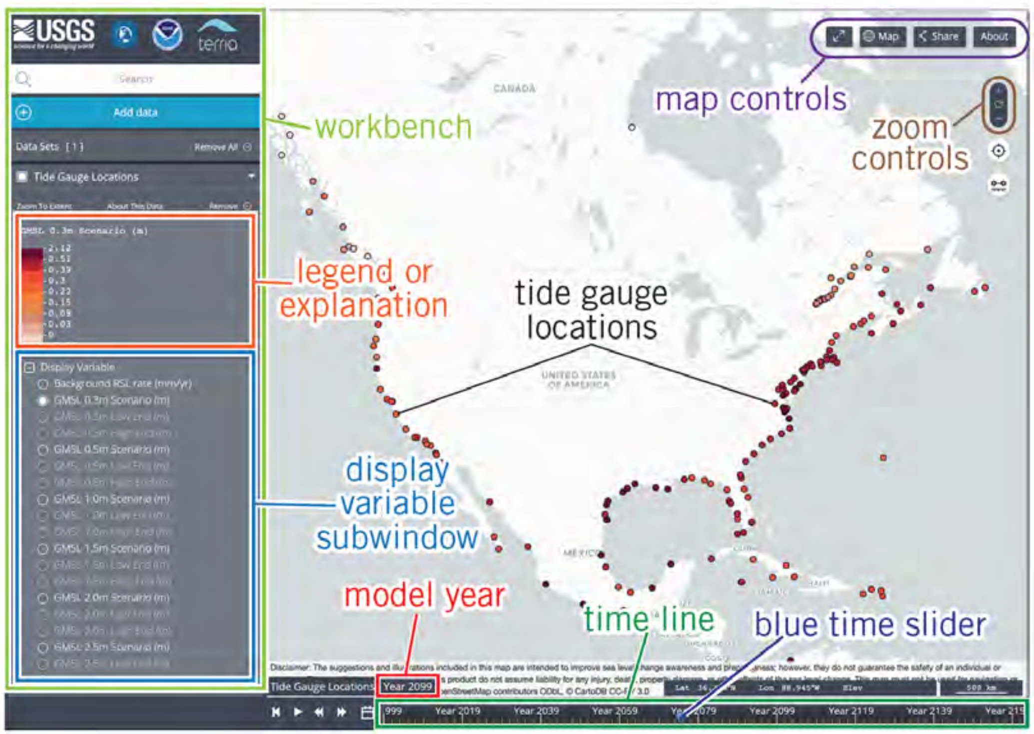

Figure A17.3.1

New activity in the 12th Edition

Carbon Dioxide in the Atmosphere

Activity 17.4

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will become familiar with the record of atmospheric carbon dioxide (CO_2) as measured since 1958 at the Mauna Loa Observatory as well as a longer record from an ice core that extends back about 2000 years and explore the trends evident in these data. How does CO_2 concentration in the atmosphere seem to correlate (if at all) with Earth's surface temperature?

A What is the most recently measured concentration of atmospheric CO_2 at the Mauna Loa Observatory? On the web, navigate to **https://scripps.ucsd.edu/programs/keelingcurve/** to find the latest reading, which is expressed in units of parts per million.

date of latest reading: ______________ CO_2 concentration: __________ ppm

B **Figure A17.4.1** shows a two-year record of atmospheric CO_2 measurements at Mauna Loa Observatory.

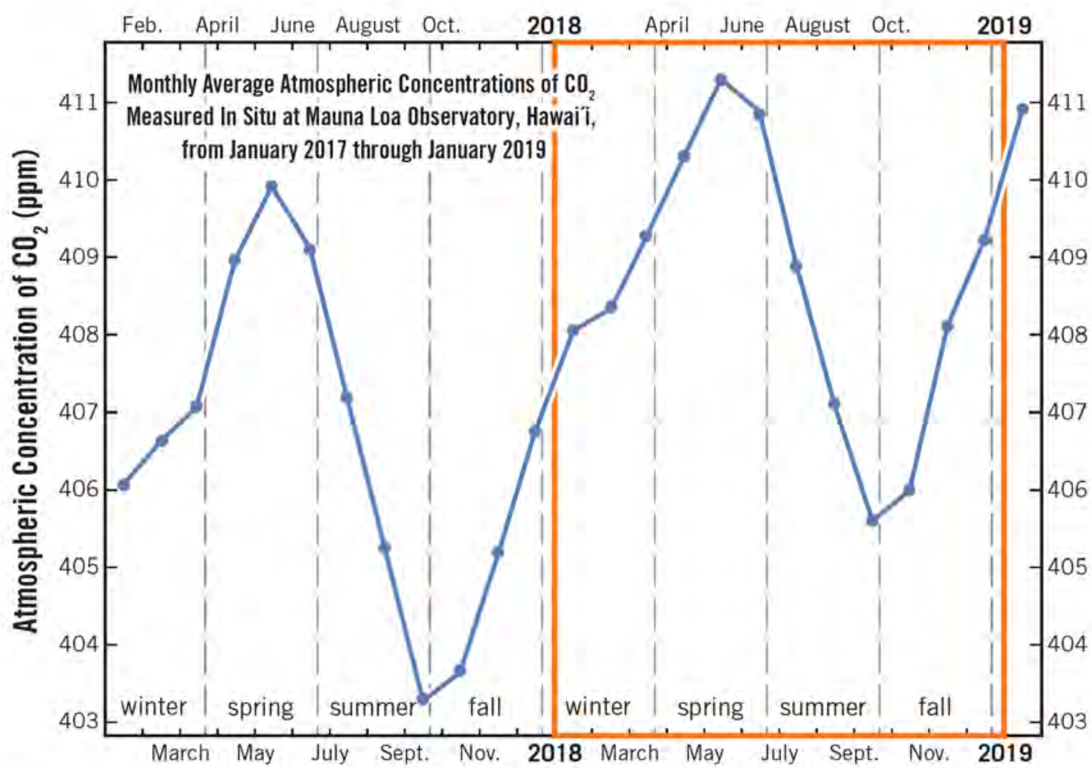

Figure A17.4.1

New activity in the 12th Edition

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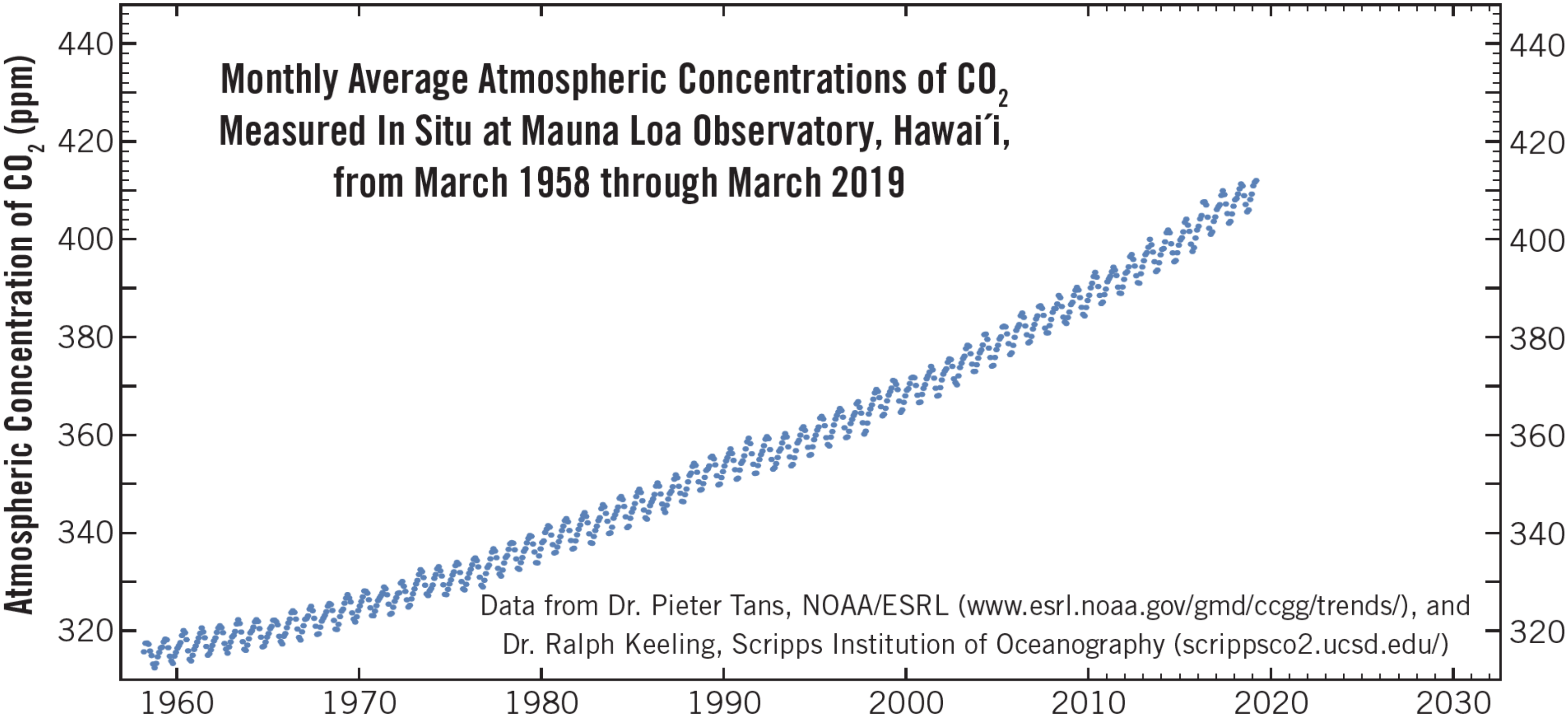


Figure A17.4.2

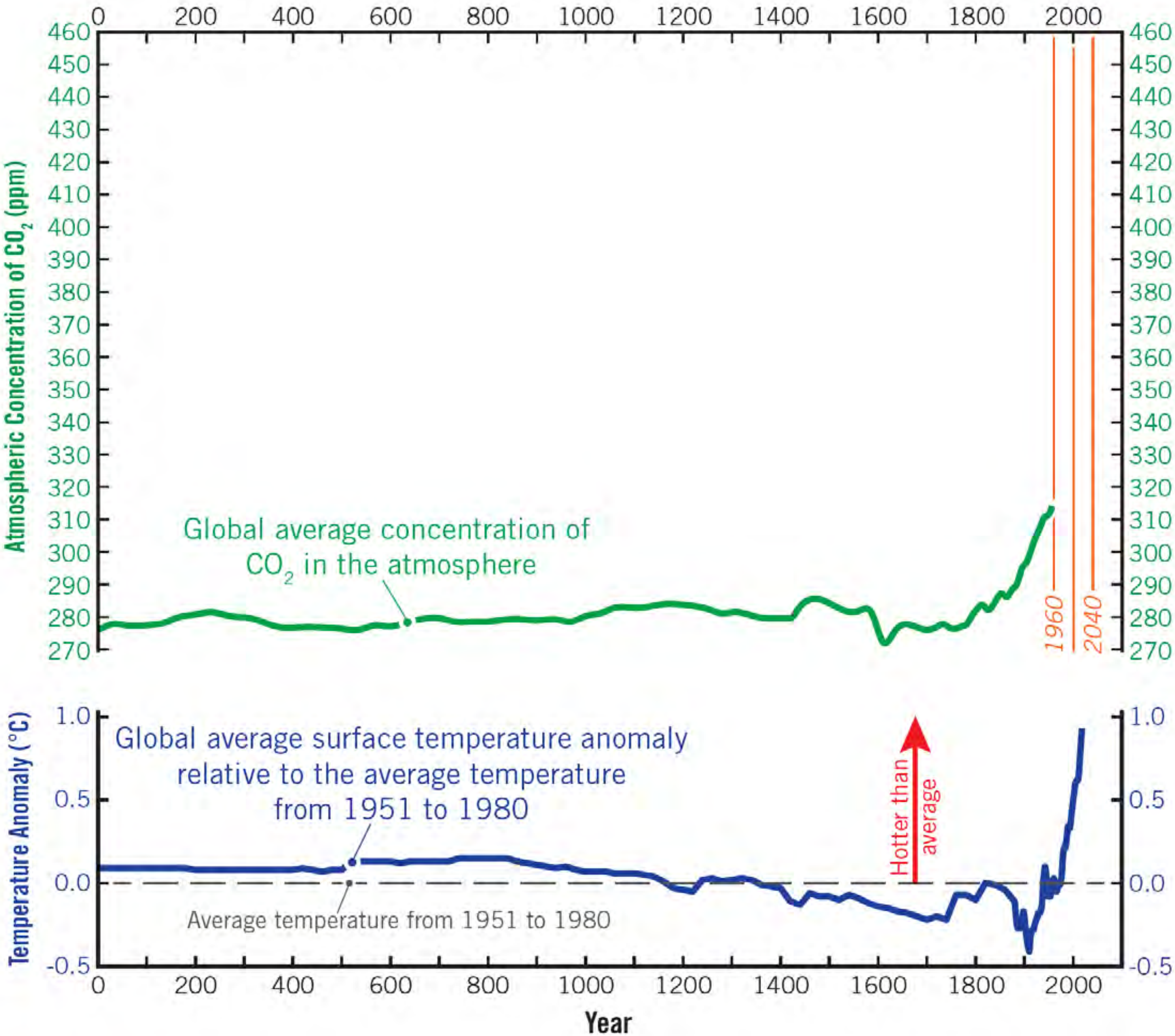


Figure A17.4.3

Activity **17.5** The Climate Record from Cores

Name: ______________________ Course/Section: ______________ Date: __________

Learning GOAL You will examine the 800,000-year record of climate indicators that are preserved in the ice of Greenland and Antarctica and in marine sediments, and learn how these indicators increase or decrease with changing temperature. You will describe how this long record compares with recent trends in temperature and carbon compounds that are greenhouse gases in the atmosphere.

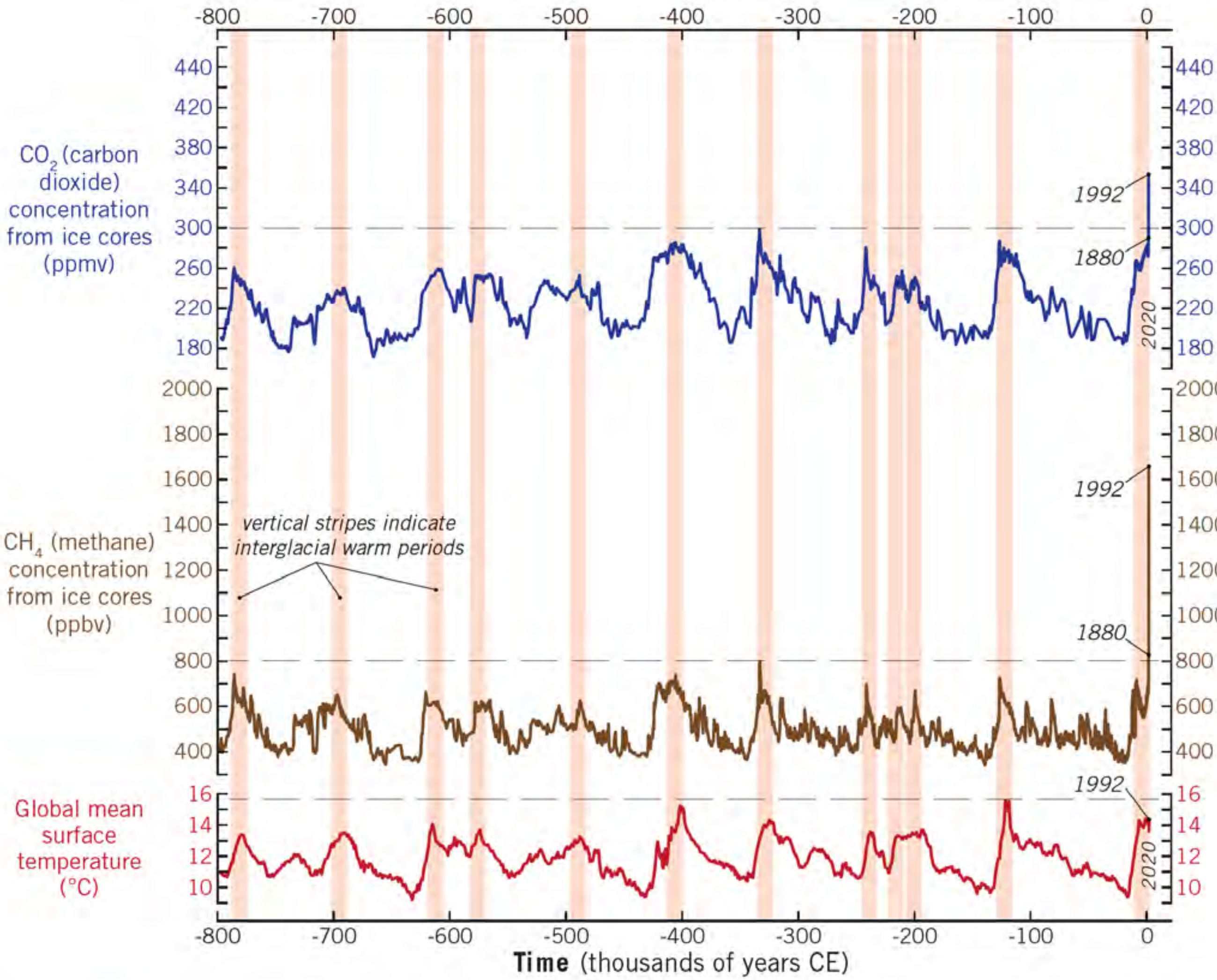


Figure A17.5.1

New activity in the 12th Edition

Local Effects of Sea-Level Rise

Activity **17.6**

Name: ____________________ Course/Section: ______________ Date: __________

Learning GOAL You will learn to use NOAA's *Sea Level Rise Viewer* to investigate how global mean sea level (GMSL) rise will affect coastal communities in the United States, which should help you appreciate the likely impact of sea-level rise worldwide.

Use a web-enabled device (best if larger than a smartphone) to access NOAA's *Sea Level Rise Viewer* at **https://coast.noaa.gov/slr/**. Click on the green button labeled "Get Started," and you should see a window that looks approximately like **Fig. A17.6.1**.

Figure A17.6.1

For each of the following exercises, do the following steps.

Step 1. Type the given place name in the white location input box, and then select (click on) the corresponding place name in the menu that will appear below the location input box. Wait until the new map loads completely.

Step 2. Adjust the map so that its extent includes the area shown in the map provided with each exercise. Any bright green areas on the map are lowlands that are near sea level.

Step 3. Click on the white circle of the "units switch" (see **Fig. A17.6.1**) until the units displayed along the water level slide bar are meters (m).

Step 4. Follow the directions for each of the following exercises.

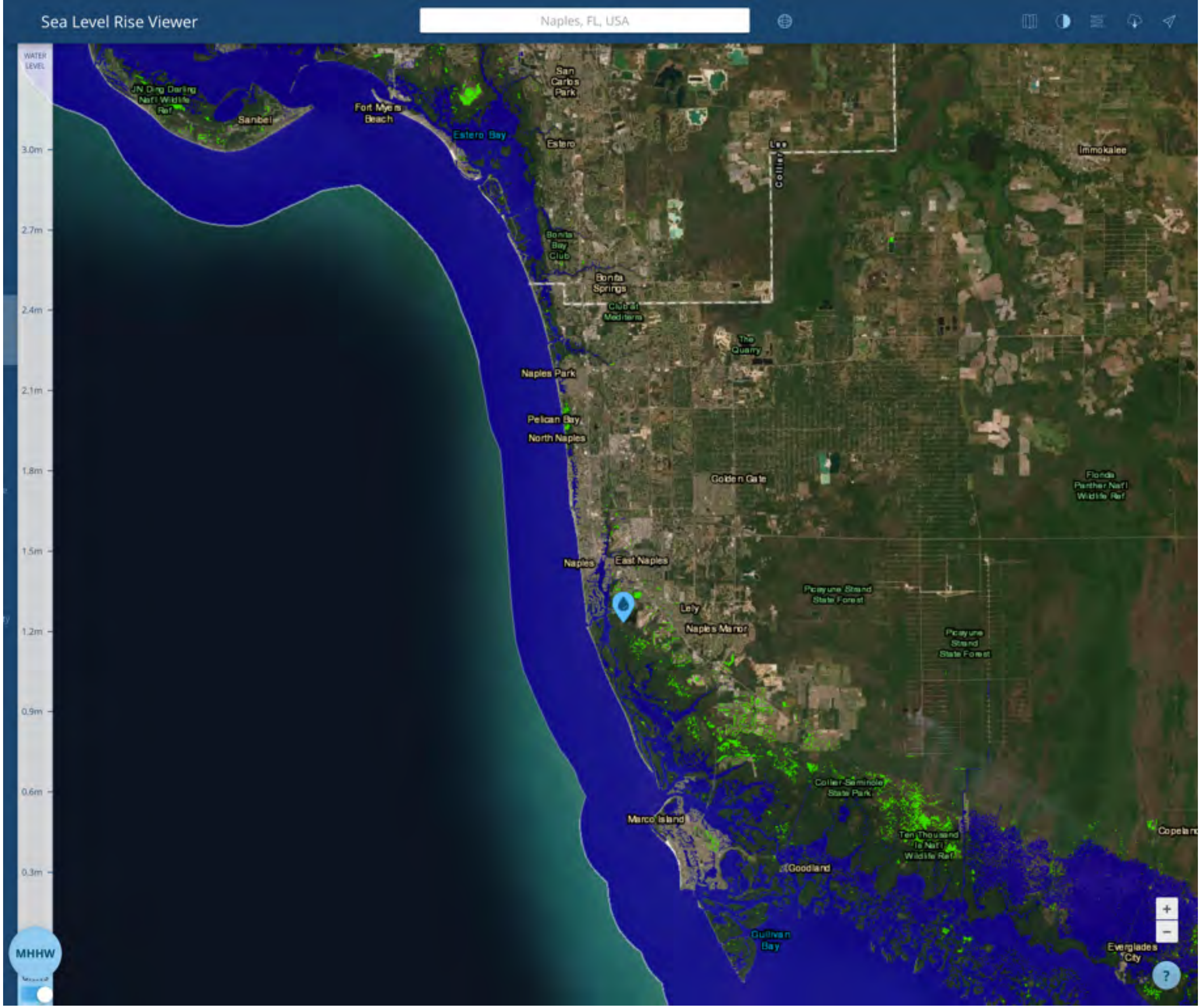
Step 5. After completing an exercise, move to the next exercise (if any) by typing the new place name in the location input box.

Figure A17.6.2

A San Francisco, California

1. Type "San Francisco, CA" in the location input box, and then follow steps 1–3 (described previously).
2. Move the water level slider up to 1.5 m to visualize the coastline after a 1.5-m rise in global mean sea level (GMSL). The "high intermediate" estimate of sea-level rise in this area by the year 2100 is ~1.42 m—close to the 1.5-m step along the slider.
   - **(a)** Use a colored pencil or highlighter to fill in the coastal areas in **Fig. A17.6.2** that will be under water (inundated) if GMSL rises by 1.5 m (~5 ft).
   - **(b)** What is likely to happen to the San Francisco (SFO) and Oakland (OAK) airports after a 1.5-m rise in GMSL?
   - **(c)** The area around Foster City includes homes, businesses, and important transportation infrastructure. What do you think society's response to this perceived threat should be?

New activity in the 12th Edition



Coastline near Naples at current mean sea level.

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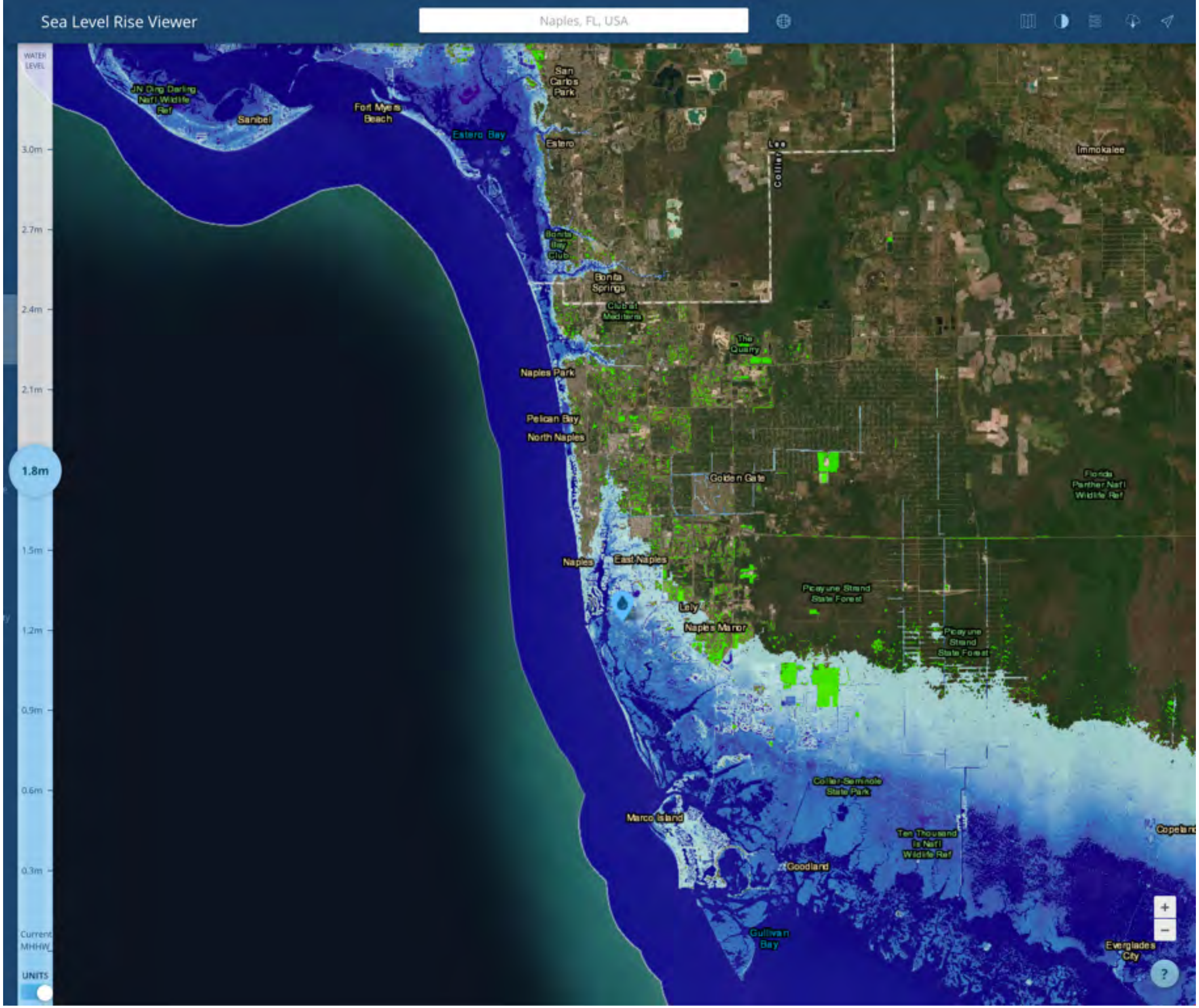

Coastline near Naples at 1.8 m higher mean sea level.

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Summary

- The 12th edition of the AGI/NAGT Laboratory Manual in Physical Geology ***is now in print and available for course adoption.***

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Summary

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- The Lab Manual is supported by an Instructor’s Manual and Mastering Geology

Teachers can request an examination copy of the new 12th edition of the Lab Manual by contacting their Pearson rep.

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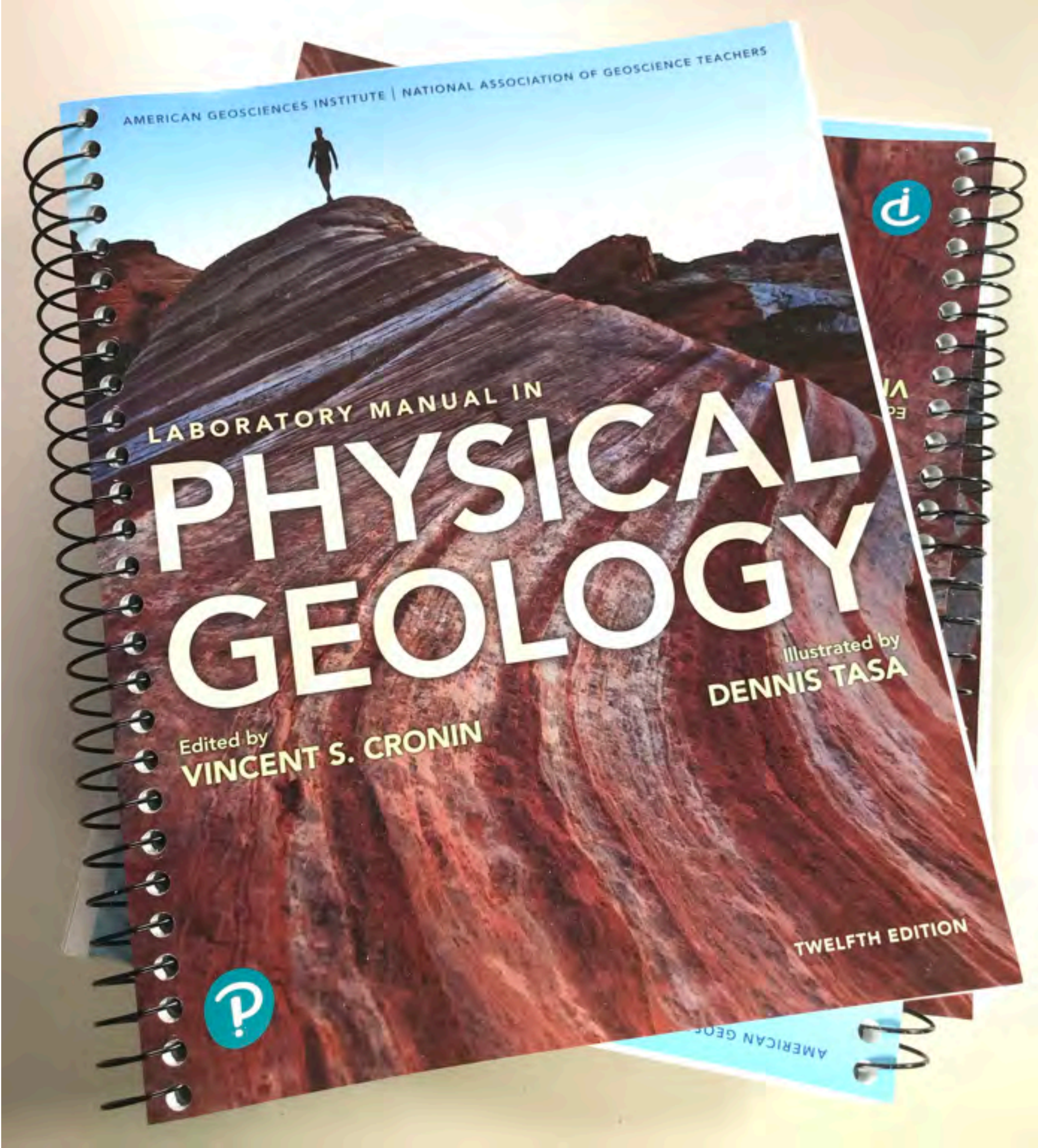
We want to hear from you as you review and use the Lab Manual 12th edition. What are your ideas and suggestions?

Vince_Cronin@baylor.edu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