# Connecticut Geology: How the Past Shapes the Present

## Peabody Fellows in Earth Science

Published by the Peabody Fellows Program
Peabody Museum of Natural History, Yale University
New Haven, Connecticut, USA

This curriculum unit is made possible through a generous contribution from the National Science Foundation, through a grant from the Geosciences Directorate (GEO 0807864) to Principal Investigators Jay J. Ague and Jane Pickering.

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# Connecticut Geology: How the Past Shapes the Present

## Introduction

***Connecticut Geology: How the Past Shapes the Present*** is a unit covering Earth science concepts as they relate to the geology of Connecticut. The impetus for creating this unit came about as part of the re-design of the Hall of Minerals, Earth & Space at the Yale Peabody Museum of Natural History. We gratefully acknowledge the support of the National Science Foundation for making this unit possible through a grant from the Geosciences Directorate (GEO 0807864).

This program is intended to be a 3-week unit and is geared for the grade 7 Connecticut Science Framework, Grade-level Expectations and CMT Correlation. However, these activities can be adapted for a high school Earth science course and well as a 6th grade science course.

The Peabody Fellows Program of the Yale Peabody Museum of Natural History seeks to educate students by encouraging them to experience the diversity of the natural world, fostering a positive attitude toward scientific inquiry, and promoting the incorporation of science and scientific inquiry methods in the classroom. It works closely with selected teachers to develop science curriculum units aligned with state and national science standards. The program has evolved into a respected resource for professional development that helps teachers show children new ways to view their environment, strengthen their observational and investigative skills, and instill a respect for biodiversity and Earth's history. It provides teachers with access to the educational resources of the Yale Peabody Museum to enhance the learning experience in their classrooms.

The Yale Peabody Fellows Earth Science Program is indebted to the following resource developers who provided assistance with this guide:

Vincent Carbone, Jonathon Craig, Marjorie Drucker,Dorothy Gillespie and Erika Schielke

Also, thanks to Jay Ague, Yale Professor of Geology and Geophysics and Curator-in-Charge of Mineralogy; Barbara Christoff; Zaneli Gomez-Ocampo; David Heiser, Head of Education and Outreach, Yale Peabody Museum; Armand Morgan; Senior Museum Instructor, Yale Peabody Museum; Jan Nelmes; Jane Pickering, Assistant Director for Public Programs, Yale Peabody Museum; and all of the teachers who attended the 2009 GeoScience Summer Institutes, for their valuable help and feedback.

Jim Sirch, Project Director

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# SECTION 1 GEOLOGIC TIME

Understanding geologic time is critical to the study of rocks. How did they form? How did they get here? How old are they? Why is the landscape of Connecticut the way it is today? Students can have an especially difficult time grasping the vast expanse of geologic time.

Geologic time is determined by the ages of rock layers. These ages may be determined by several methods: by radiometric dating, which uses rates of decay of radioactive elements found in the minerals that rocks are made of (including deposits of volcanic ash); by stratigraphy, using rates of deposition and sedimentation to determine how old one layer is relative to another; and by index fossils, which are common representative life forms that existed over narrow time intervals and can be compared from sites around the globe.

The oldest rocks currently known are about 4 billion years old, and the oldest crystal found to date is 4.4 billion years old. The oldest fossils that have been discovered are roughly 3.5 billion years old. Earth itself formed about 4.6 billion years ago, leaving about a billion years of very inhospitable time (the Hadean Eon) for which we have no fossil record. As a crust formed and water condensed and formed the oceans, life could begin. Earth scientists continue to study the ancient rocks of our planet, and may yet discover evidence for life even older than 3.5 billion years.

## ACTIVITY 1 Geologic Time Scale

National Science Standard, Grades 5-8, Content Standard D, Earth’s History

CT Science Standard 7.3 Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #10: Observe and report on the geological events that are responsible for having shaped Connecticut’s landscape.

Objective: students will determine relative time scales of Earth’s history and correlate them with Connecticut geologic events

Vocabulary: eon, era, period, terrane, proto-North America, Iapetos, Avalonia, Precambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, Tertiary, Quarternary

Materials needed:

Part A: tape, Earth Timeline PowerPoint from the Yale Peabody Museum website (http://peabody.yale.edu/teachers/curricula-connecticut-geology-guide)

You will also want an up-to-date copy of the geologic time scale, which can be found on the Geological Society of America website (www.geosociety.org). Here is the 2009 version: http://www.geosociety.org/science/timescale/timescl.pdf

Part B: clothesline, laminated CT Timeline cards – available as a separate pdf file from the Yale Peabody Museum website, designed to print double-sided (http://peabody.yale.edu/teachers/curricula-connecticut-geology-guide)

Teacher Background: Students will begin to familiarize themselves with the names of the time periods as well as the specific geologic history of Connecticut. They will develop a better understanding of these terms and Connecticut's geologic history after exploring plate tectonics.

Procedure:

**Part A**

1. Discuss the meaning of one million and show "counting by ones".

How long will it take for you to count to a million when counting by ones?

11.5 Days

How long will it take for you to count to 100 million?

1,150 days or a little over 3 years

How long will it take for you to count to 1 billion?

11,500 days or 31.9 years

2. Find a hallway where you can tape the pictures from the Earth Timeline PowerPoint document on the wall. The total length is 45 steps. Notice the number of steps in parentheses on each picture.

3. Give each student two sheets. Have them walk the appropriate steps and tape up the pictures.

## Part B

1. Break students into 5 groups and give each group a piece of clothesline, clothes pins and CT Timeline cards. Make sure students do not look inside cards.

2. Have students try to estimate when each event occurred and put them in the relative position on the clothesline.

3. Have groups discuss their cards' positions and change position of the cards as needed after opening cards to see dates.

*Below are examples of the cards that are copy ready and available as a separate pdf file from the Yale Peabody Museum website (see link above in Materials):*

**4.5 BILLION YEARS AGO**

A MARS-SIZED PLANET HIT EARTH, SENDING DEBRIS INTO ORBIT AROUND EARTH. A FRACTION OF THAT DEBRIS FORMED THE MOON AND THE REST RETURNED TO EARTH.

**1 BILLION YEARS AGO**

AS ANCIENT EUROPE ("BALTICA") AND BRAZIL ("AMAZONIA") COLLIDED WITH PROTO-NORTH AMERICA, SEDIMENTARY AND IGNEOUS ROCKS WERE DEFORMED AND METAMORPHOSED TO PRODUCE THE ROCKS OF THE GRENVILLE MOUNTAINS. THESE ARE THE OLDEST ROCKS FOUND IN CONNECTICUT.

**460 MILLION YEARS AGO**

THE TACONIC MOUNTAINS, PART OF THE APPALACHIAN MOUNTAIN CHAIN, FORMED WHEN VOLCANIC ISLANDS AND OCEAN SEDIMENTS COLLIDED WITH NORTH AMERICA.

**380 MILLION YEARS AGO**

THE ROCKS OF THE APPALACHIAN MOUNTAINS CONTINUED TO FORM AS A CONTINENTAL MASS EARTH SCIENTISTS CALL "AVALONIA" COLLIDED WITH EASTERN NORTH AMERICA.

**350-250 MILLION YEARS AGO**

THE SUPERCONTINENT PANGEA (MEANING "ALL LANDS") WAS FORMED WHEN ALL THE CONTINENTS CAME TOGETHER. DURING THIS TIME, THE APPALACHIAN MOUNTAINS CONTINUED TO FORM. THE MOUNTAINS WERE AS HIGH AS THE HIMALAYAS ARE TODAY, REACHING ELEVATIONS OF 20,000-30,000 FEET ABOVE SEA LEVEL.

**230-210 MILLION YEARS AGO**

THE BREAKUP OF PANGEA STARTED AS THE SUPERCONTINENT BEGAN TO RIFT APART, ULTIMATELY CREATING THE ATLANTIC OCEAN BASIN.

**200 MILLION YEARS AGO**

AS PANGEA CONTINUED TO BREAK UP, SOME SMALLER RIFTS PERPENDICULAR TO THE MAIN RIFT DID NOT OPEN COMPLETELY, PRODUCING FAILED RIFT VALLEYS LIKE CONNECTICUT'S CENTRAL VALLEY (NEWARK TERRANE). THE FAMOUS BROWNSTONES OF CONNECTICUT ARE MADE FROM SEDIMENTS THAT WERE DEPOSITED IN THE RIFT VALLEY. THE FLOOD BASALT LAVAS THAT ERUPTED ALONG THE RIFTS ARE NOW PRESERVED AS TRAPROCK RIDGES. ONE LAVA FLOW WAS ABOUT 200 METERS (OVER 600 FEET) THICK! DINOSAURS ROAMED THE CONNECTICUT VALLEY AND LEFT FOOTPRINTS ALONG THE MUDDY MARGINS OF RIFT VALLEY LAKES. ONE TYPE OF LARGE FOOTPRINT IS NAMED *EUBRONTES* AND IS THE CONNECTICUT STATE FOSSIL.

**65 MILLION YEARS AGO**

A 10-KILOMETER DIAMETER ASTEROID STRUCK EARTH NEAR THE YUCATAN PENINSULA (CHICXULUB CRATER) IN THE GULF OF MEXICO. MANY EARTH SCIENTISTS THINK THAT THE RESULTING CATACLYSMS CAUSED A MASS EXTINCTION THAT WIPED OUT MANY SPECIES, INCLUDING DINOSAURS LIKE *TYRANNOSAURUS REX*.

**25,000 YEARS AGO**

A GLACIER DURING THE WISCONSINAN GLACIAL PERIOD COVERED CONNECTICUT. THE ICE MAY HAVE BEEN SEVERAL KILOMETERS (OVER A MILE) THICK IN PLACES.

**20,000 TO 12,000 YEARS AGO**

THE GLACIERS MELTED, UNCOVERING CONNECTICUT. THE TERMINAL MORAINES THAT WERE LEFT BEHIND FORMED LONG ISLAND, BLOCK ISLAND, MARTHA'S VINEYARD AND NANTUCKET ISLAND.

Extensions: Students can use adding machine tape or rope and mark off some type of scale, i.e., one inch = one million years. Another possibility is to use an entire football field and mark off appropriate scale. Yet another is to use the timescale represented on a clock.

References:

Teacher Friendly Guide to Geology of the Northeast
www.teacherfriendlyguide.org

# SECTION 2 TECTONIC PROCESSES

## Plate Tectonics

Plate tectonics is a scientific theory that provides the best explanation for the large-scale motions of Earth’s surface over geologic time scales, along with associated phenomena such as earthquakes, volcanoes and mountain building.

The lithosphere, made up of the crust and upper mantle, is divided into more than a dozen plates that slowly move across Earth’s surface. A plate can be up to 8,000 kilometers across 150 kilometers thick. An incredible amount of energy is required to move such a large object.

Plates are moving because the layer beneath them, called the asthenosphere, is considered solid but has a quality like the frosting of a cake. Even though frosting is solid, if you push your finger into the frosting you can move it around, or deform it. Equally, if you place a hard piece of plastic on top of the frosting, the plastic just sits there until you apply pressure. Once you apply pressure, you can move the plastic pretty easily over the surface of the frosting. Tectonic plates can likewise slide over the asthenosphere below. The asthenosphere is NOT the same consistency as frosting though – it is basically rock-hard, but under the kinds of heat and pressure found at that depth it behaves like very slowly-moving frosting. The plates ride on top of the asthenosphere and the continents are part of these plates. If a part of the asthenosphere moves in one direction, the plate on top of that portion, with its continent or continents, moves that way also.

Plates can either move away from one another, move toward one another or slide against one another. Divergent plates move away from one another and convergent plates move toward one another. Continental plates are usually thicker but less dense than oceanic plates, properties that tend to govern the behavior of convergent plates. Sometimes plates slide sideways against one another, which is one common source of earthquakes. Plates move very slowly, averaging about 2 centimeters per year or about as fast as your fingernails grow!

## ACTIVITY 2 Global Patterns of Earthquakes and Volcanoes

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 7.3 Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #4: Correlate common geological features/events (deep sea trenches, mountains, earthquakes and volcanoes) with the location of plate boundaries.

Grade Level Expectations #6: Analyze and interpret data about the location, frequency and intensity of earthquakes.

CMT Correlation C20: Explain how the boundaries of tectonic plates can be inferred from the location of earthquakes and volcanoes.

Objective: Students will plot the locations of major earthquakes and volcanoes in relation to plate boundaries. Students will correlate the locations of earthquakes and volcanoes to the type of plate boundaries found nearby.

Procedure:

1. On the large model globe in the *Hall of Minerals, Earth and Space* at the Yale Peabody Museum, locate the following and plot them on your copy of the map of the world:

    - Krakatau volcano, Indonesia
    - Mt. Fuji volcano, Japan
    - Paricutín volcano, Mexico
    - Mt. Etna volcano, Italy
    - Mt. St. Helens volcano, US
    - Alaska earthquake of March 17, 1964
    - Chilean earthquake of May 22, 1960

    If you are not able to visit the Yale Peabody Museum, locate these sites using the internet.

2. Use the interactive Magic Planet in the Hall of Minerals, Earth and Space at the Yale Peabody Museum to learn more about the relationships between plate tectonics, earthquakes, and volcanoes
    a. Watch the video segment to learn about Earth's major plate boundaries. Label each plate boundary on your map as convergent, divergent, or conservative (same as transform)
    b. Watch the "Quakes and Plates" segment to learn more about the relationship between tectonic boundaries and earthquakes
    c. Watch the video segment to learn more about plate boundaries and volcanoes.

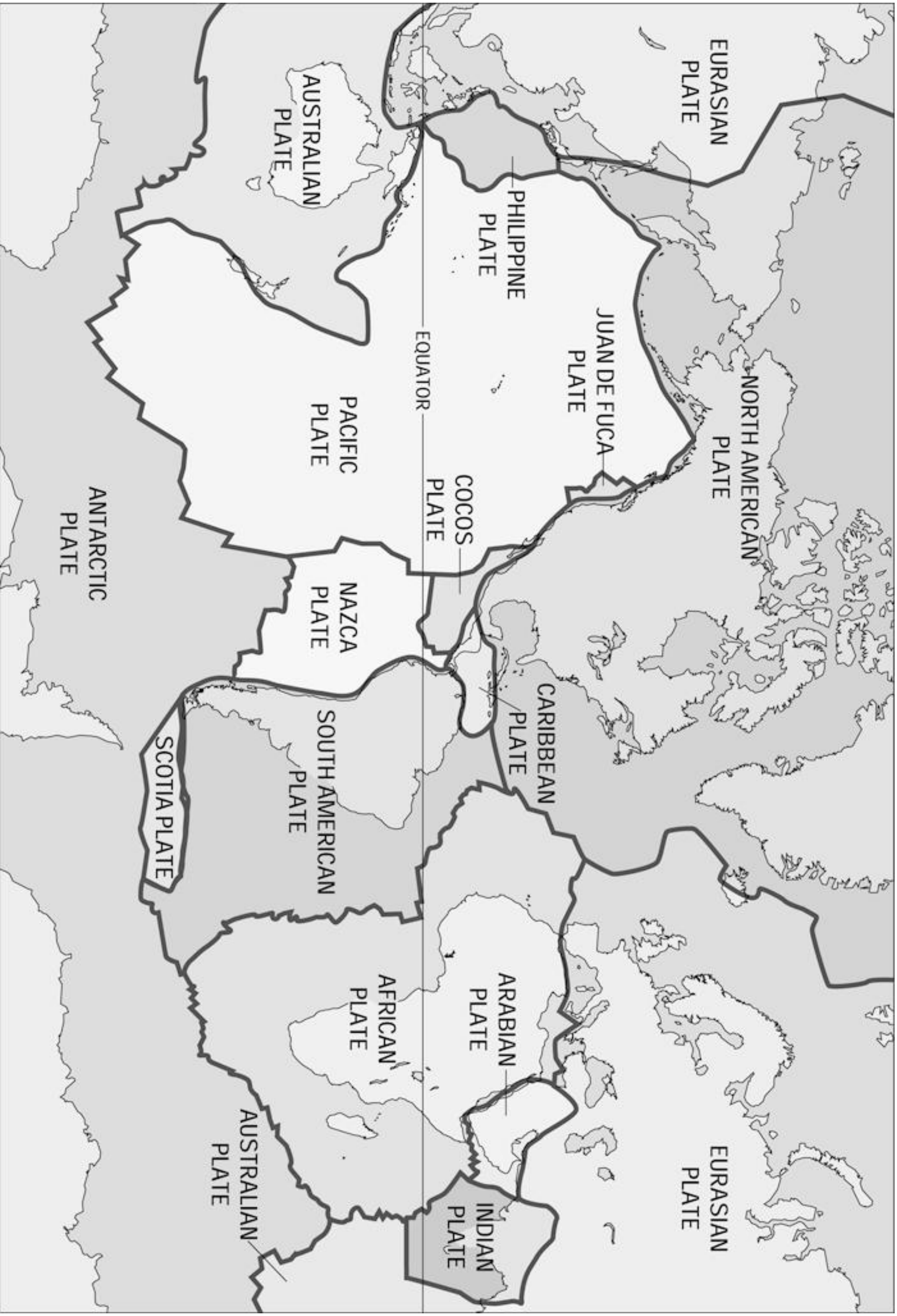
    If you are not able to visit the Yale Peabody Museum, try to locate these features using the internet. As of Summer 2011, the following website was current and scientifically up-to-date: http://www.johomaps.com/world/worldtecton.jpg

3. Observe the locations of the volcanoes that you plotted on your map handout. All of these volcanoes are large explosive volcanoes. Are explosive volcanoes associated with particular types of plate boundaries?

4. Observe the locations of the earthquakes that you plotted on your map handout. Are earthquakes associated with a particular type of plate boundary?

5. You plotted only two earthquakes on your map. What are the potential problems of drawing conclusions for question #4 based on only two data points?

6. Look at the map of global earthquake activity above the seismograph. If you are not at the Yale Peabody Museum, see: http://www.iris.edu/seismon/ Compare patterns of earthquake activity to the types of plate boundaries. Are earthquakes associated with a particular type of plate boundary? Is this different from your answer to question #4 above? If so, how?



Tectonic map courtesy USGS

Plot on your map:

- Krakatau volcano, Indonesia
- Mt. Fuji Volcano, Japan
- Paricutín volcano, Mexico
- Mt. Etna volcano, Italy
- Mt. St. Helens volcano, United States
- Alaska earthquake of March 17, 1964
- Chilean earthquake of May 22, 1960

## ACTIVITY 3 A Convection Cell

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 7.3 Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #2: Explain how Earth's internal energy is transferred to move tectonic plates.

Grade Level Expectations #4: Correlate common geological features/events (deep sea trenches, mountains, earthquakes, volcanoes) with the location of plate boundaries.

Objective: To observe how material moves within a convection cell, making a model of a convection cell and investigating it as a force that drives plate tectonics.

Background

Geologists have known since the early 1960s that Earth's lithosphere (the crust and upper mantle) is broken up into more than a dozen plates that move very slowly. They move about 2 centimeters per year, or about as fast as your fingernails grow! The lithosphere sits on top of the asthenosphere – part of Earth's mantle that is mostly solid rock but, under enough heat or pressure or both, behaves like the frosting of a cake, which is solid when undisturbed but can be deformed or made to "flow" by pushing it with your finger.

These plates are massive chunks of Earth's surface (up to 8,000 kilometers across and 150 kilometers thick). We know that the motion of these plates is responsible for mountains and oceans, earthquakes and volcanoes. But geologists are still trying to figure out exactly what makes these plates move around. There appear to be a few different forces involved, and in this activity we are going to investigate one of the most important – convection.

Materials

For each class

- Rectangular plastic tubs filled ¾ way up with room temperature water
- A kettle of hot water, enough to fill one cup for each group
- Paper towels to handle water spills

- Food coloring (red)
- Small containers to hold food coloring
- Tray of blue, dyed ice cubes
- Rubber gloves to handle ice cubes
- Basin for collecting used water

For each group

- A tray
- A small cup containing red food coloring
- A pipette or medicine dropper
- Towels for cleaning the pipette
- Spoons to handle blue, dyed ice cubes
- 5 sturdy 10 oz. hot cups – 4 to hold up bin, one for hot water
- Two sheets of white paper
- Data sheets for each student (teacher to supply)

## Procedure

### Setup

1. Place supplies on the table for each group.
2. Place four hot cups upside down, forming a rectangle. The fifth cup will be placed right side up amid the other three, as shown in Figure 1.

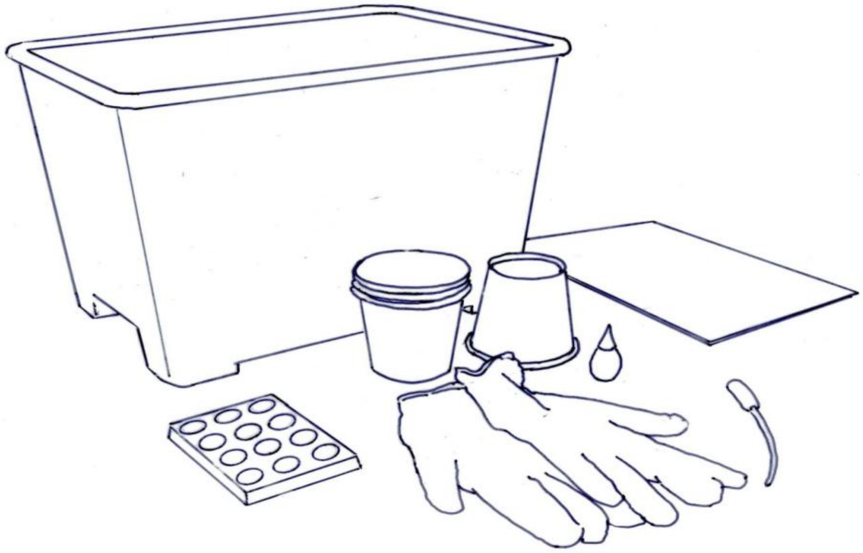


Figure 1

3. Add enough room-temperature water to the clear plastic tub so that it is approximately 2/3 full.
4. Place the bin on top of the four upside-down cups.
5. Leave the tubs alone for several minutes. There should be no ripples in the water when you begin.
6. Fill a cup with hot water almost to the top and carefully place it centered and underneath the tub. It is advisable for the teacher to come to groups and give each group the hot water in a cup.
7. Make predictions as to what will happen when 1-2 drops of red food coloring are placed on the bottom center, in the water and above the hot cup below it. Be careful as food coloring can stain clothing.
8. Have one person fill a pipette and place a few, small drops of red food coloring in the bottom center of the water (Figure 2). <u>Slowly</u> release the drop. Observe the water for about two minutes, viewing both from the top and from the sides. To help your observations, hold a piece of white paper behind the tub. Record your observations on the Data Sheet. In the space provided, draw what you see happening to the distribution of the food coloring. Use arrows to show the direction of movement.

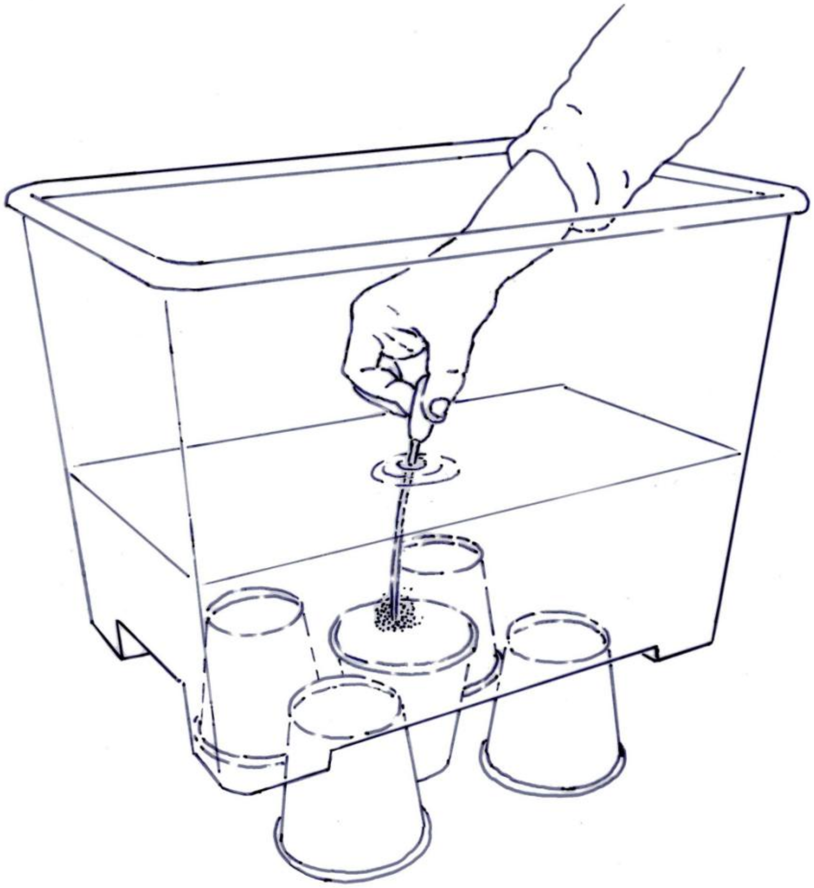


Figure 2

9. Make a prediction as to what will happen when blue, dyed ice cubes are added to the water on one side of the tub.
10. Add 2-3 blue, dyed ice cubes to the water on one side of the tub, as shown in Figure 3. To help your observations, hold a piece of white paper behind the tub. Record your observations on a data sheet. In the space provided, draw what you see happening to the food coloring. Use arrows to show the direction of movement.

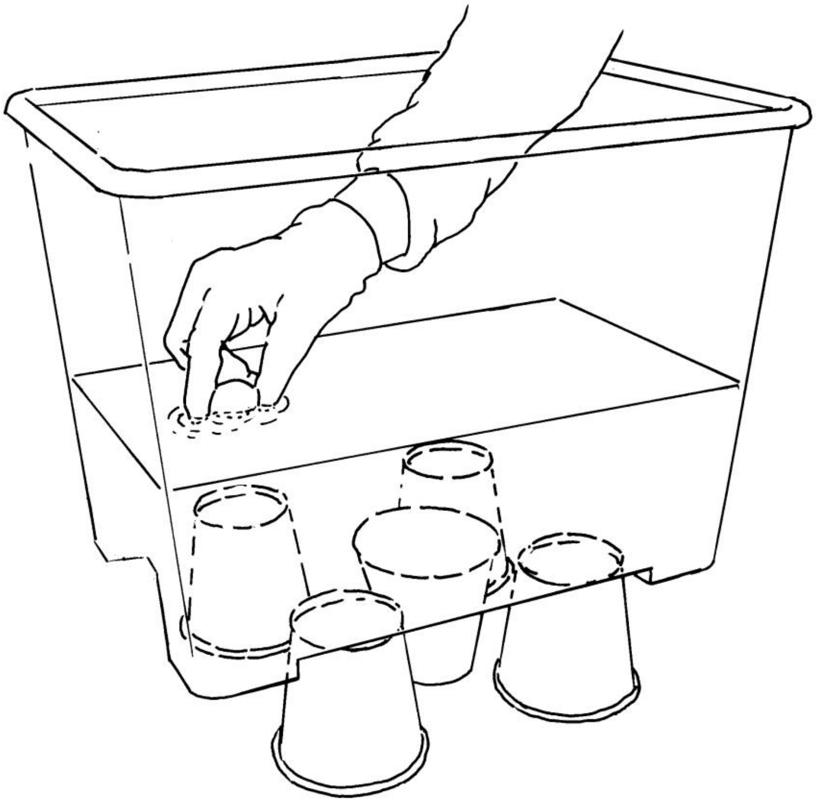


Figure 3

Questions/Conclusions

This activity models one of the mechanisms geologists think is one of the drivers of plate tectonics. In this model, what does the water represent? What does the hot water in the cup represent? In this model there is not anything that represents tectonic plates. To include them, what might be added and where should they be placed?

The currents in the water cause the food coloring to move at a rate of two to three centimeters or more per minute. Compare this rate to the actual rate estimated for tectonic plate motion.

## What Happened?

Discuss with your students what happened. In convection, heat moves from one place to another. Hot things rise and cold things sink. Heating a pan of water produces a simple convection cell. When heated from underneath, the water molecules near the heat source bounce around more quickly and become less packed together, and hence become less dense than the cooler, slower moving and more tightly-packed water molecules around them. This less dense water rises upward away from the heat source and, as it does so, it begins to cool. By cooling, it increases in density and sinks. But why does something that is less dense move up, and something that is more dense move down? Imagine a one-gallon bucket of cold water, and imagine all of the many trillions of $H_2O$ molecules floating around in that gallon bucket. Molecules in cold stuff move around slowly, so those $H_2O$ molecules are all floating around very slowly, occasionally bouncing off each other but not bouncing back very far when they do. This allows for the molecules to be packed fairly close together. Now imagine the exact same size bucket of hot water. Because the water is hot, those molecules are moving around fast, and when they collide they bounce back much farther. Each hot water molecule therefore requires a little more space than a cold water molecule, so they can’t be packed as closely together. And therefore, you can simply fit more cold water molecules in your one-gallon bucket than hot water molecules. More cold water molecules in the bucket means that a gallon of cold water weighs more than a gallon of hot water. It follows that heavier, cold water will sink in a tub of warmer water, and lighter, hot water will rise when it is surrounded by cooler water.

The same phenomenon occurs in hot-air balloons. It’s not helium that carries them up into the sky! It’s just hot air! Hot air balloon pilots use a large engine to heat up the air inside the balloon. As it heats up, the molecules move faster, bounce off each other farther, and push some air molecules out of the balloon, leaving air inside the balloon that is less dense than the surrounding air, and therefore lighter.

The cycle of heating and rising, cooling and sinking establishes convection currents in the water. The combined system of currents is called a convection cell.

Make sure students understand that convection happens in water, but it also takes place in the rock of the mantle. The mantle is mostly solid rock, but because of the heat and pressure deep within Earth, the material in the mantle can slowly flow. When additional heat is supplied from below, convection cells may develop. Remind them to think of it as super-thick and VERY slowly moving cake frosting.

Figure 4 shows a cross section through Earth and the various layers referred to throughout this curriculum.

EARTH CROSS SECTION

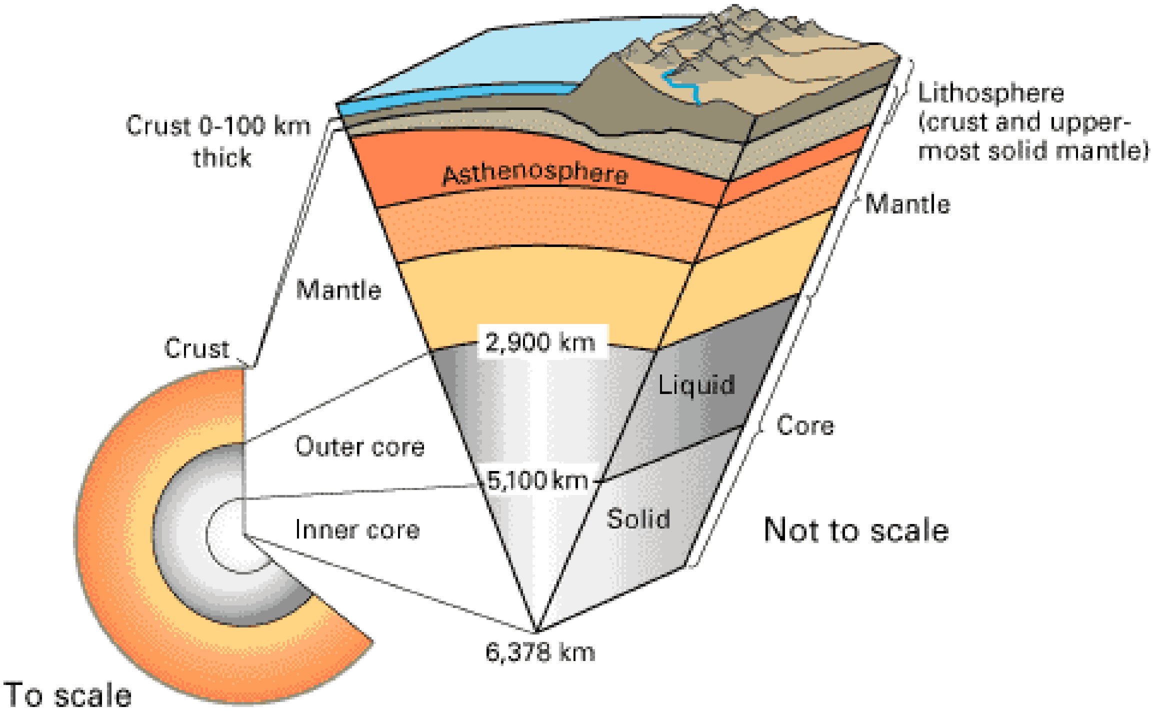


Figure 4

Image used by permission © USGS, http://pubs.usgs.gov/gip/dynamic/inside.html

A good visual that illustrates convection cells in the mantle is this link:

http://www.absorblearning.com/media/item.action?quick=12p

## What Else is Going On?

This section reprinted with permission from:

http://www.windows2universe.org/earth/interior/how_plates_move.html

Windows To The Universe. 2010. How Do Plates Move? National Earth Science Teachers Association.

Scientists once thought that Earth's plates just surfed on top of the mantle's giant convection cells, but now scientists believe that plates help themselves move instead of just surfing along. Just like convection cells, plates have warmer, thinner parts that are more likely to rise, and colder, denser parts that are more likely to sink.

New parts of a plate rise because they are warm and the plate is thin. As hot magma rises to the surface at spreading ridges and forms new crust, the new crust pushes the rest of a plate out of its way. This is called ridge push.

Old parts of a plate are likely to sink down into the mantle at subduction zones because they are colder and thicker than the warm mantle material underneath them. This is called slab pull.

## ACTIVITY 4   Snack Tectonics

National Science Standard, Grades 5-8, Content Standard D, Earth's History; Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 7.3   Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #2: Explain how Earth's internal energy is transferred to move tectonic plates.

Grade Level Expectations #4: Correlate common geological features/events (deep sea trenches, mountains, earthquakes, volcanoes) with the location of plate boundaries.

This activity and accompanying images are used with permission from the National Earth Science Teachers Association (NESTA). Their Windows to the Universe website is full of educational activities for Earth science teachers:

http://www.windows2universe.org

Objectives: Students create a tasty model that illustrates plate tectonic motions. Students learn how Earth's tectonic plates (lithosphere) ride atop the slow flowing asthenosphere layer. Students understand how plates interact at their boundaries.

Source: A Classic Classroom activity adapted by the Windows Team. Recommended by Karen Manning.

Time: 15 minutes prep time and 20-30 minutes class time

National Standards Addressed:

- 5-8:Content Standard A: Science as Inquiry
- 5-8: Content Standard D: Structure of the Earth System

**MATERIALS:**

For each student:

- One large graham cracker broken in half (i.e., two square graham crackers)
- Two 3-inch squares (approx.) of fruit roll up
- Cup of water
- Frosting

- Sheet of wax paper
- Plastic knife or spoon
- Directions overheads

**DIRECTIONS:**

1. Make the model
    a. Give each student about a square foot of wax paper and a large dollop of frosting. Instruct students to spread frosting into a layer about half a cm thick.
    b. Tell students that the frosting in this model represents the asthenosphere, the viscous layer on which Earth's plates ride. The plates in this model are represented by fruit roll up (oceanic crust which is thin and dense) and graham crackers (continental crust which is thick but less dense).
2. Divergent plate boundary
    a. Instruct students to place the two squares of fruit roll up (oceanic plates) onto the frosting right next to each other.
    b. Press down slowly on the fruit roll ups (because they are dense and will sink a bit into the asthenosphere) as you slowly push them apart about half a cm.
    c. Notice how the frosting is exposed and pushed up where the plates are separated? This is analogous to how magma comes to the surface where real plates are moving apart at divergent plate boundaries. Most divergent plates' boundaries are located within oceanic crust. When plates begin to pull apart at continents, rift valleys are made, like the Great Rift Valley in Africa, which can become the bottom of the sea floor if the plates continue to pull apart.
3. Continental-oceanic collision
    a. Instruct students to remove one of the fruit roll ups from the frosting. (They can eat it if they wish!)
    b. Tell students to place one of the graham cracker halves **lightly** onto the frosting asthenosphere next to the remaining fruit roll up piece. The graham cracker represents continental crust, which is thicker and less dense than oceanic crust (fruit roll up). It floats high on the asthenosphere so don't push it down.
    c. Gently push the continent (graham cracker) towards the ocean plate (fruit roll up) until the two overlap and the graham cracker is on top. The oceanic plate is subducted below the continental one.
4. Continent-continent collision
    a. Tell students that they will next model what happens when two continents collide. Have them remove both the cracker and fruit roll up from the frosting asthenosphere. (Students can eat or discard the fruit roll up.)

    b. Place one edge of both crackers into the glass of water for just a few seconds.
    c. Place the crackers onto the frosting with wet edges next to each other.
    d. Slowly push the graham crackers towards each other.
    e. Notice how the wet edges crumple? This is how mountains are made at convergent plate boundaries! When continents move towards each other there is nowhere for the rock to go but up!
5. Transform plate boundaries
    a. Pick the two crackers up off the frosting and turn them around so that two dry edges are next to each other.
    b. Push one cracker past the other to simulate a transform plate boundary like the San Andreas Fault!
6. Final step: eat all remaining model materials (except, of course, wax paper and plastic utensils!)

## ASSESSMENT

Have students draw what each situation looks like in cross section (by looking at the edge of their model).

## BACKGROUND INFORMATION:

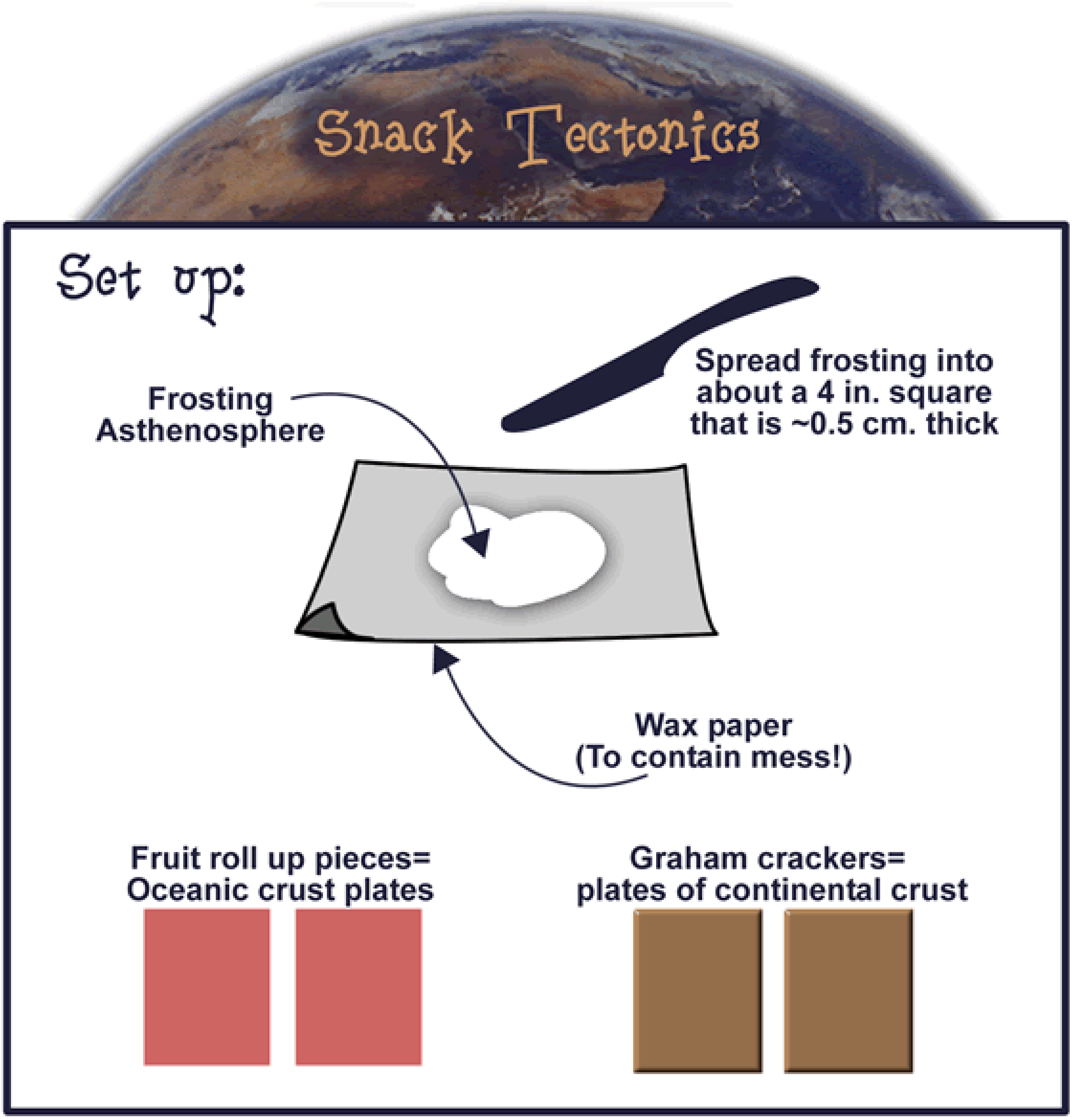
The main force that shapes our planet’s surface over long amounts of time is the movement of Earth's outer layer by the process of plate tectonics.
Earth’s rigid outer layer, called the lithosphere, is made of plates that fit together like a jigsaw puzzle. These plates are made of rock, but the rock is, in general, less dense than the layer underneath- the asthenosphere. The density difference allows the plates to "float" on top of the asthenosphere. In this activity, the asthenosphere is represented by the frosting. However, plates are not all the same. Plates made of continental crust are thicker but less dense than plates made of ocean crust, which are denser but thinner. In this activity, ocean plates are represented by fruit roll ups and continental crust is represented by graham crackers.

Movements deep within Earth, which carry heat from the hot interior to the cooler surface, cause the plates to move very slowly on the surface, about 5 centimeters per year on average. There are several different hypotheses to explain exactly how these motions allow plates to move.

Interesting things happen at the edges of plates. At divergent plate boundaries, rift valleys and spreading ridges form as plates pull away from each other. At convergent plate boundaries, where plates are coming together, subduction zones form when an oceanic plate and a continental plate collide and mountains build when two continental plates collide. Large faults form when plates slide past each other making Earth tremble with earthquakes.

## Snack Tectonics Student Instruction Overheads

You can print each of these directions onto overhead transparency. Then show the overheads in sequence to provide students with directions for developing their tasty models of plate tectonics!



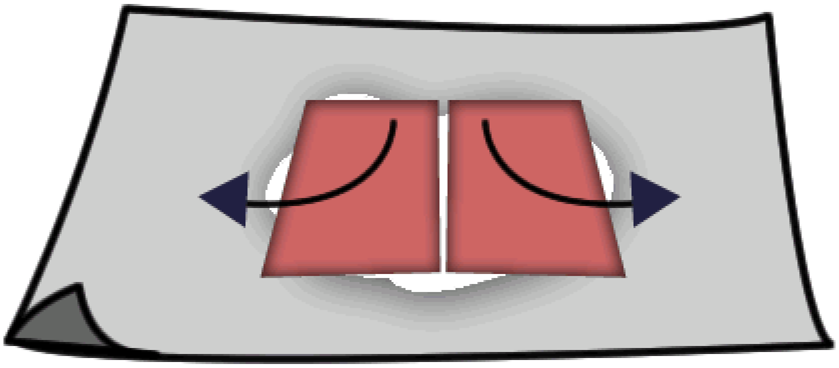
Windows to the Universe, Copyright UCAR 2004

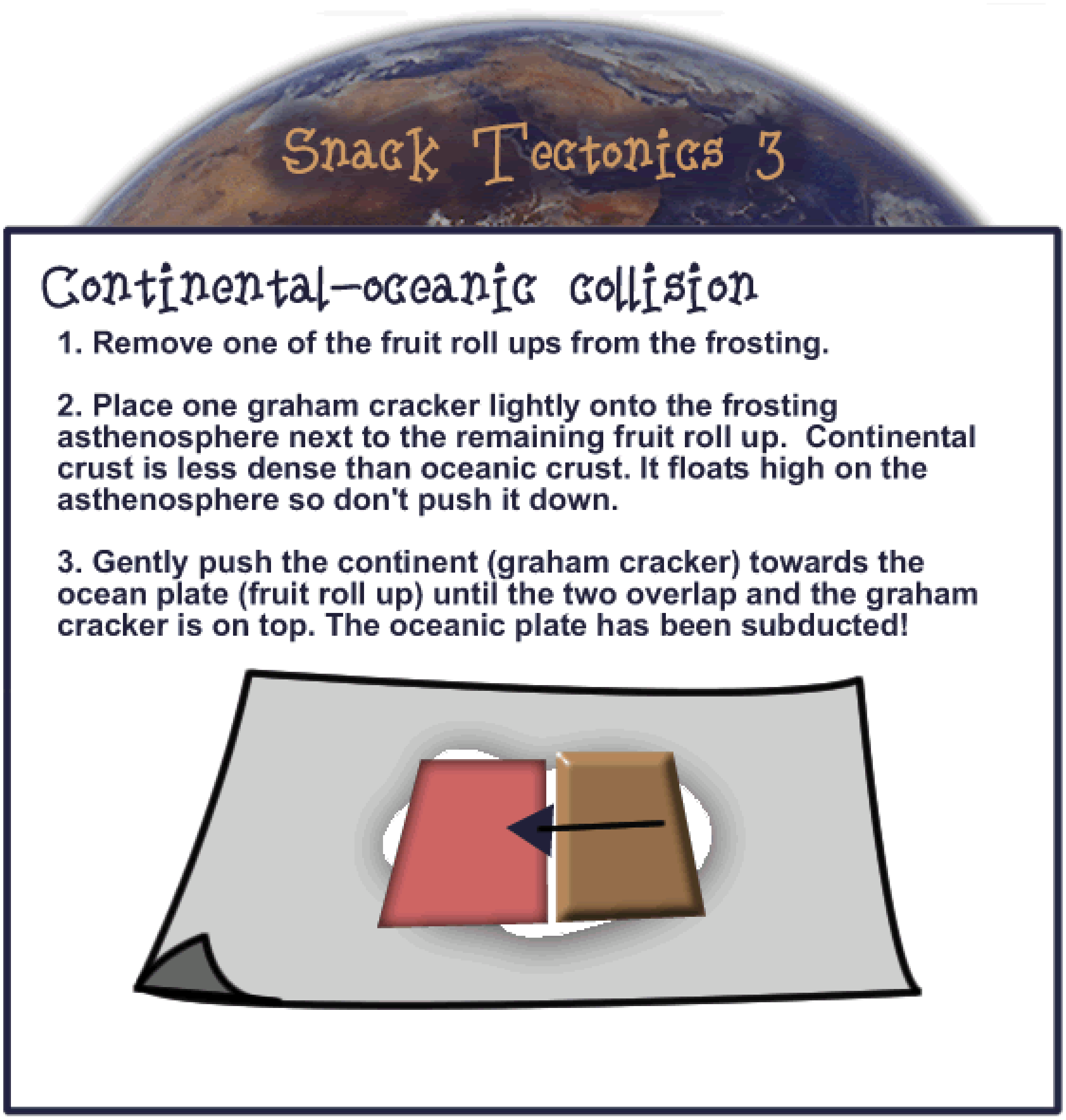
# Snack Tectonics 2

## Divergent plate boundary

1. Place the two plates of oceanic crust (fruit roll up pieces) side by side lightly on the frosting asthenosphere.

2. Press down slowly on the oceanic plates (because they are dense and will sink a bit into the asthenosphere) as you slowly push them apart about half a cm.





# Snack Tectonics 3

## Continental-oceanic collision

1. Remove one of the fruit roll ups from the frosting.

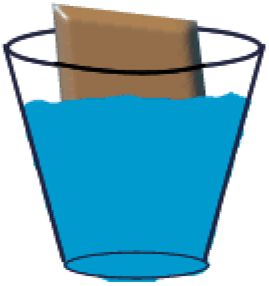
2. Place one graham cracker lightly onto the frosting asthenosphere next to the remaining fruit roll up. Continental crust is less dense than oceanic crust. It floats high on the asthenosphere so don't push it down.

3. Gently push the continent (graham cracker) towards the ocean plate (fruit roll up) until the two overlap and the graham cracker is on top. The oceanic plate has been subducted!

# Snack Tectonics 4

## Continent–continent collision

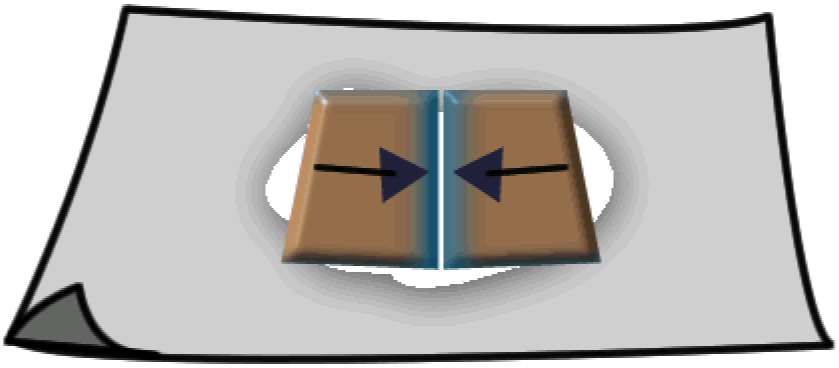
1. Remove both the cracker and fruit roll up from the frosting asthenosphere.

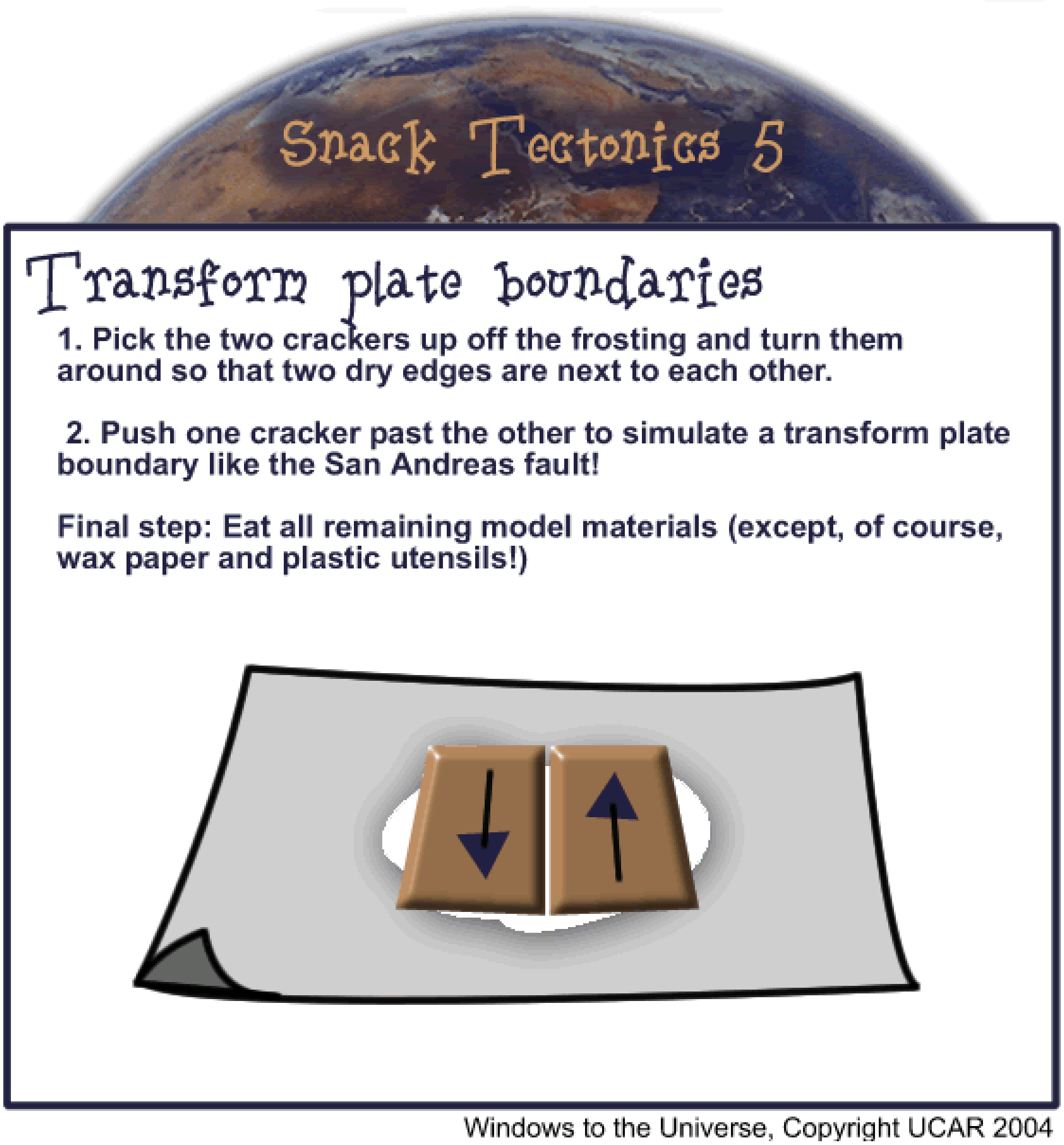


2. Place one edge of both crackers into the glass of water for just a few seconds.

3. Place the crackers onto the frosting with wet edges next to each other.

4. Slowly push the graham crackers towards each other.





# Snack Tectonics 5

## Transform plate boundaries

1. Pick the two crackers up off the frosting and turn them around so that two dry edges are next to each other.

2. Push one cracker past the other to simulate a transform plate boundary like the San Andreas fault!

Final step: Eat all remaining model materials (except, of course, wax paper and plastic utensils!)

## Activity 5 Gelatin Volcanoes

This activity used with permission from Hawaii Space Grant Consortium (1996)

http://www.spacegrant.hawaii.edu/class_acts/GelVolTe.html

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 7.3 Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #4: Correlate common geological features/events (deep sea trenches, mountains, earthquakes, volcanoes) with the location of plate boundaries.

Objective: Students will understand how and why magma moves inside volcanoes.

Background

***Magma*** is molten rock, including crystals and dissolved gases, found at depth in a planetary interior. When magma ***erupts*** onto the surface, the volcanic products make distinctive landforms including lava plains and ***volcanoes***, depending on the details of the eruption. One of the most interesting things to consider about magma is how it moves up from underground reservoirs, called magma chambers, to erupt as ***lava*** on planetary surfaces. Does it travel in natural tubes or pipes? Or along fractures? This experiment strikingly reveals the answer.

Magma leaves underground reservoirs through fractures in the surrounding rock. The fractures are either pre-existing or are created by the erupting magma. An active ***dike*** is a body of magma moving through a sheet-like, vertical or nearly vertical fracture.

An important aspect of magma flow not dealt with in the gelatin activity is the heat lost during eruption. Magma, ascending as a dike begins to cool and solidify and the flow may become localized in the dike. Such localized eruption of magma over a long period of time produces a volcano.

Stresses in the planet affect the orientation of dikes. Dikes open (widen) in the direction of least resistance. They propagate (grow longer and taller) perpendicular to the direction of opening.

Hawaiian shield volcanoes are characterized by concentrated regions of dike injections from the mantle, called mantle plumes. A series of experiments using gelatin models was conducted by researchers in 1972 to explain the growth and orientation of Hawaiian mantle plumes. The "Gelatin Volcanoes" classroom activity was inspired by this work.

CT Connection: Contrast extrusive rock formed from lava that cooled on the surface, such as the “Hanging Hills” of Meriden with intrusive rock which formed from magma underground, such as at Sleeping Giant and East Rock Park.

Activity Background

Gelatin, molded in bowls or bread pans, is used as transparent models of volcanic landforms. Colored water is used as the dike-forming magma. In this activity, dikes tend to propagate radially from the center of bowl-shaped casts of gelatin because the resistance to opening is the same in every direction. Dikes tend to parallel the long-axis of ridge-shaped (bread pan) casts of gelatin because the narrow dimension provides less resistance to opening than the long dimension. The dike opens in the narrow dimension and we see propagation in the long dimension. With a slow, steady injection rate, the colored water creates a dike and generally erupts from the flanks or ends of the gelatin casts.

Edge-on, a dike appears as a line. When the gelatin cast is sliced through with a knife, dikes appear as red lines in the vertical, cut edges.

Hawai’i Space Grant Consortium

## Teacher Preparation

Follow the directions listed on the student sheet (below) for preparing the gelatin. Gelatin requires at least three hours of refrigeration to set. Use a warm water bath to free the gelatin from the bowl without getting water on the gelatin itself.

Unflavored gelatin is ideal for this experiment because of its transparency. Sweetened gelatin desserts also work. If you prefer the dessert variety, then use a flavor that is easy to see through, such as lemon. Another alternative is agar. Agar hardens at room temperature, eliminating the need for refrigeration, but it must be made so it is easy to see through.

Two-liter (or two-quart) capacity bowls work very well because the diameter allows enough space for multiple dike injections. This size is large enough for demonstration purposes. Smaller bowls, down to the size of margarine containers, have also been used successfully.

## Teacher Tips

Make sure a drip tray is placed under the gelatin to catch the colored water that drains out of the fractures. They will remain visible.

Wear protective gloves to keep stains off hands.

The colored water should not be injected too fast. Rapid injection drives the fluid straight up and creates an eruption but ruins the simulation of dike formation.

When slicing the gelatin, choose a direction perpendicular to a dike to show its "line" shape on edge.

**Student Sheet: Gelatin Volcanoes** Name________________________

Objective: To understand how and why magma moves inside volcanoes.

Materials:

- Unflavored gelatin, 28 gm (one-ounce) box containing four packages
- Spoon
- Bowls or bread pans, either one 2-liter (or 2-quart) capacity, or smaller sizes
- Red food coloring, to mix with water in a glass to make "magma"
- Syringe for injecting magma, best to use a plastic variety found at pet stores for feeding birds
- Peg board, 40 x 60 cm, with 5-mm-diameter holes spaced 2.5 cm apart. Or you can use a large, disposable aluminum pan that you've punched holes into.
- Two bricks, 30 cm high
- Large knife to cut through the gelatin model
- Tray, for collecting drips
- Rubber gloves for protecting hands from food coloring

Procedure

1. Prepare gelatin for the volcano model by mixing two cups of cool water with four packages of unflavored gelatin in a large bowl. Stir for 30 seconds. Then add six cups of boiling water and stir until gelatin is dissolved. Transfer mixture to a 2-liter bowl, smaller bowls, or bread pans. Refrigerate gelatin at least three hours or until set.

2. Prepare "magma" by mixing water in a glass with enough red food coloring to make a very dark liquid.

3. Loosen the gelatin by dipping the bowl briefly in a larger bowl of hot water.

4. Transfer the gelatin upside down to the center of the peg board and lift off the bowl. The gelatin cast will settle somewhat after being removed from the bowl. It should resemble a colorless to milky, shimmering volcano. There should be no cracks in the gelatin, but it's OK to proceed if one develops during unmolding.

5. Place the peg board on top of the two bricks.

6. Fill a syringe with red water. Remove air bubbles from the syringe by holding it upright and squirting out a small amount of water. Air tends to fracture the gelatin.

7. Predict what will happen when red water is injected into the gelatin cast. What direction will it go? What shape will it take? Will it erupt through the surface of the gelatin? If so, where?

8. Insert the syringe through a hole in the peg board into the center of the gelatin cast. Inject the red water slowly, at a rate of about 20 cc/minute, and watch carefully.

9. Describe how the experimental results compare with your predictions.

10. Refill and insert the syringe as many times as possible. Compare magma migration each time. Are there differences in the direction the magma takes when the syringe is inserted in different parts of the gelatin cast? Describe and explain what you see.

11. Looking directly down on the gelatin cast, sketch the positions and shapes of the magma bodies. Label your drawing "Map View."

12. Use a sharp knife to cut through the gelatin cast. Separate the pieces and examine the cut surfaces. Note the traces made by the magma bodies; these are similar to what we see in highway road cuts or cliff faces.

13. Sketch the positions and shapes of the magma bodies on a cut face. Label your drawing "Cross-sectional View."

14. Compare what you see in two dimensions on the cut face with what you see in three dimensions looking into the gelatin cast. Which view gives you more information? Why?

15. How and why does magma move through volcanoes?

## Extension

Repeat the experiment with an elongated model such as a bread pan (the original research by Fiske and Jackson used elongate models with triangular cross-sections). Before injecting the magma, try to predict what will happen. What effect does gelatin shape have on magma movement?

## Reference

Fiske R. S. and Jackson, E. D., 1972, Orientation and growth of Hawaiian volcanic rifts: the effect of regional structure and gravitational stresses, *Proc. R. Soc. London, Ser. A, vol. 329*, 299-326.

## ACTIVITY 6 Demonstrating Faulting, Folding, Mountain Building and Subduction – Modeling Using Foam Pads

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 7.3 Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #3: Demonstrate the processes of folding and faulting of the Earth's crust.

CMT Correlation C18: Describe how folded and faulted rock layers provide evidence of gradual up and down motion of the Earth's crust.

Objective – to demonstrate faulting, folding, mountain building and subduction using 3-D models.

Materials: blocks of wood, manila folders, rubber cement, open cell foam pads, 1 inch foam pads, two small tables, razor blade knife, and permanent markers.

See the following website for diagrams and more information about making your own blocks and using them to demonstrate **convergent, divergent and transform plate boundaries** as well as normal and reverse **faults**:

http://web.ics.purdue.edu/~braile/edumod/foammod/foammod.htm

For an excellent 5 minute lecture from IRIS on **faults and folds** using blocks:

http://www.iris.edu/hq/programs/education_and_outreach/videos#F

You can also order nicely designed blocks from science supply companies.

# SECTION 3 GLACIATION, WEATHERING AND EROSION

Continental ice sheets have repeatedly advanced and retreated during the most recent glacial period that began several million years ago. That last glacial advance reached its maximum extent about 25,000 years ago. Connecticut was covered by an ice sheet more than one mile thick!

The ice sheets scoured and rounded the hills as well as moved and deposited material. Other factors caused changes in the land as well. Wind, freezing, rain and the action of plant roots, lichens and microscopic life have caused particles on rocks to loosen through physical and chemical weathering. Chemical weathering is the decomposition of rocks through chemical reactions. Physical weathering is the decomposition of rocks by mechanical processes, such as frost-wedging. Particles are broken down and then transported and deposited through erosion.

## ACTIVITY 7 Investigating How Glacial Features are Formed in Rocks

National Science Standard, Grades 5-8, Content Standard D, Earth's History; Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 7.3 Landforms are the result of constructive and destructive forces over time.

Grade Level Expectations #7: Compare and contrast the major agents of erosion and deposition of sediments: running water, moving ice, wave action, wind and mass movement due to gravity.

Grade Level Expectations #8: Investigate and determine how glaciers form and affect the Earth's surface as they change over time.

CMT Correlation C19: Explain how glaciation, weathering and erosion create and shape valleys and floodplains.

Objectives: Students will explore the effects moving ice has on erosion and deposition of sediments. Students will also investigate and determine how glaciers form and affect Earth's surface as they change over time.

PLEASE NOTE: Permission has not been granted from the National Science Teachers Association (NSTA) to include this activity. This activity, "*Explaining Glaciers Accurately*" can be found in NSTA publication **Science and Children,** May, 2009.

## Extensions

### Kettle Hole Activity

From Jonathon Craig, Talcott Mountain Science Center

Students can explore how a kettle hole forms by assembling a pile of sand and ice cubes in a 13" x 16" aluminum pan. Form the sand into a hill as if it were a moraine and put ice cubes inside and on top.. Leave this for a few hours. The cubes will melt and form kettles in the moraine. Some of the ones near the bottom will have water in them. The rest will show a dry, steep-sided kettle hole. The glacier has left features like this on Cape Cod, Martha's Vineyard, Nantucket and Block Island and a few features around New London. Often large chunks of ice are buried in the outwash as the majority of the ice melts. The steep-sided kettles have a sand bottom and steep banks leaving clear ponds and lakes with a level below the water table. Some of the kettles on Block Island are lined with clay, trapping water. Tides and storm waves have washed some of their sides away leaving only one half of the original depression.

### Glacial Shuffle Activity

Used by permission from the Yosemite Institute.

Using their feet, your group will show how a glacier piles up rocks and debris to make a terminal moraine and lateral moraines. You'll need a sandy or gravely outdoor area without any plants (they would be trampled and mashed by this activity), or this can be done in dry leaves or leaf litter.

Form your group into a single file (or double file) line facing along the gravelly area, each person standing behind the back of the person in front of them. About 15 feet ahead of the first person, drop a stick to mark the end point of the shuffle. One by one (or two by two if double file, and with their feet touching), have each member of the group shuffle straight up to the stick, then jump over it and wait. After everyone has gone, they'll see how their feet have scoured away the gravel in a path leading up to the stick. At the end next to the stick will be a small heap of sand: a terminal moraine. Along the sides of the scuffed path they'll see small parallel ridges: lateral moraines.

## ACTIVITY 8  Delineating a Watershed

This activity is a modified version of the following fact sheet/excerpt from Appendix E of the Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire, 1991. Alan Ammann, PhD and Amanda Lindley Stone.

http://www.nh.nrcs.usda.gov/technical/Publications/Topowatershed.pdf

The modified version is used here with permission from the Natural Resources Conservation Service, a program of the US Department of Agriculture.

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A: Science As Inquiry

CT Science Standard 7.3 - Landforms are the result of the interaction of constructive and destructive forces over time.

Grade Level Expectations #7: Compare and contrast the major agents of erosion and deposition of sediments: running water, moving ice, wave action, wind and mass movement due to gravity.

CMT Correlation C19: Explain how glaciation, weathering and erosion create and shape valleys and floodplains.

Objective:  Students will determine the boundary of a watershed.

Vocabulary: delineate, watershed, topographic map, elevation, contour line, contour interval, headwaters, mouth, tributary

A watershed is an area of land that drains water to a stream, lake, wetland, ocean or other body of water.  From hills, ridges, and other high points, water flows downhill and collects either at a low point, that lacks an outlet, or in streams which flow into rivers and eventually reach the ocean.

The size of a watershed varies.  Larger waterways, such as the Connecticut River, drain thousands of square miles.  Tributaries to the river drain smaller areas.  As each tributary branches into smaller tributaries, the size of the drainage area decreases.  Local watersheds, which might not even contain permanent streams, can be quite small, covering only a few acres.

Defining the boundaries of a watershed is an important first step in assessing water quality. Larger watersheds have more potential pollution sources than smaller watersheds. Sediment and dissolved materials running off the land can have major impacts upon the quality of surface and ground waters.

Materials: Topographic map showing study area, pencil or marker

Procedure:

1. Have your students go through the Guide to Interpreting Topographic Maps below. Don't assume your students know how to read a topo map. It is definitely worth guiding them through this or another short topo map-reading tutorial before going any further.
2. Divide students into groups and provide each group with a topographic map of the study area. You can use the one included here, or find your own. In Connecticut, the website Connecticut Environmental Conditions Online is an excellent resource for custom-generating your own topo maps of areas of interest: http://www.cteco.uconn.edu/advanced_viewer.htm.
3. Have students examine the map and locate well-known places, such as rivers, town centers, your school and major roads if your map contains them. This will help establish reference points for the watershed.
4. Next, have students locate the stream in question and any nearby topographic high points (hills, ridges, etc.). NOTE: if your students are working with black and white copies of the map, you will probably need to show them a version in color so they can easily see the streams, other water bodies, and other important features given in color.
5. If you prefer that students not delineate on the map itself, provide transparencies and have students cover the stream and surrounding high points with an overlay.
6. Instruct students to draw a circle at the mouth or downstream point of discharge of the stream.
7. Have students trace the course of the stream and all tributaries.
8. Next, have students place an "X" at the tops of hills or other highest topographic points around the stream and its tributaries.
9. Starting at the circle, have students draw a line connecting the "X's" along one side of the stream, crossing to the other side at the highest elevation above the headwaters, and continuing until they get back to the circle. Be sure that contour lines are crossed at right angles. Most watersheds take the shape of a rough oval. See teacher version below on page 41.

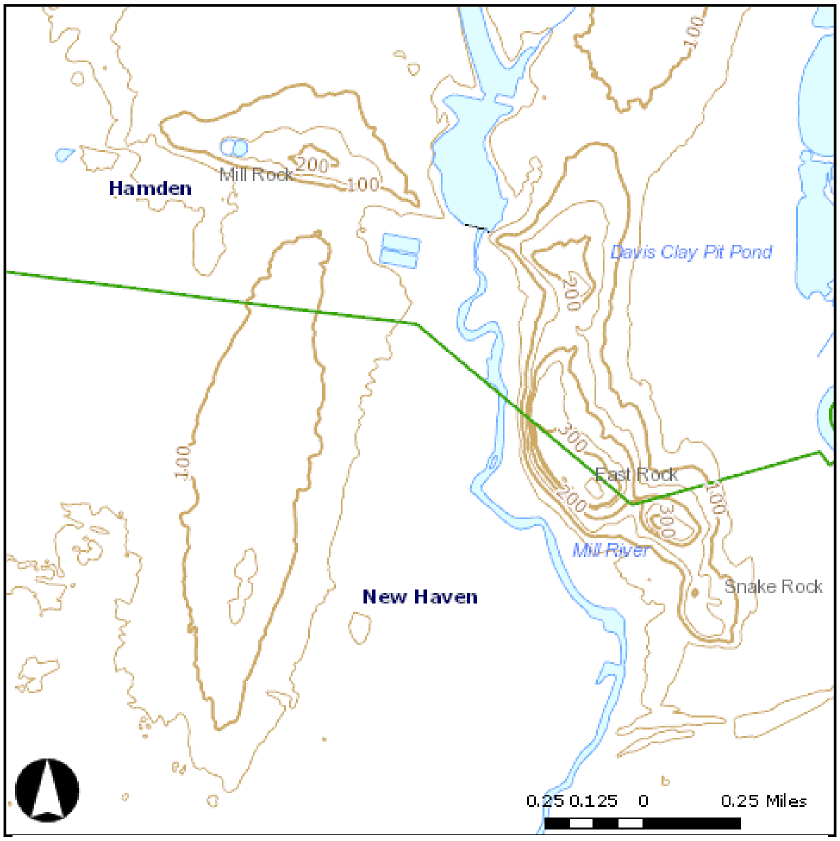
Extensions:

1. Have the students describe land use in the watershed and identify those uses that are nonpolluting or potential pollution sources.
2. Have the students calculate the size of the watershed and compare that to a familiar area, such as a football field or the school parking lot. Area can be calculated using a dot grid.

# Guide to Interpreting Topographic Maps

In order to successfully delineate a watershed boundary, you will need to visualize the landscape as represented by a topographic (topo) map. This is not difficult once the following basic concepts of topographic maps are understood.

As with most maps, topographic maps are drawn as if you were up in the sky looking down towards Earth. They are representations of 3-dimensional surfaces on flat pieces of paper. Each contour line on a topographic map represents an elevation or vertical distance above a reference point, usually sea level, which represents the zero (0) contour line. A contour line is level with respect to the earth's surface just like the floor of your school. All points along any one contour line are at the same elevation. Below is a simple topographic map of the New Haven, Connecticut area around East Rock. The streets and highways are not included in order to give you a view of just the landscape.



Map generated with the Advanced Map Viewer on Connecticut Environmental Conditions Online: http://www.cteco.uconn.edu/advanced_viewer.htm

The difference in elevation between two adjacent contours is called the contour interval. This is typically given in the map legend. It represents the vertical distance you would need to climb or descend from one contour elevation to the next. In this sample map, the contour interval is 50 feet.

The horizontal distance between contours, on the other hand, is determined by the steepness of the landscape and can vary greatly on a given map. On a very gentle hill, two 50 foot contours can be far apart horizontally. On a steep cliff face, like the West face of East Rock in the map above, two 50 foot contours might be almost directly above and below each other, and on the map they would appear to be touching, with no horizontal distance between them. In each case the vertical distance between the contour lines would still be fifty feet.

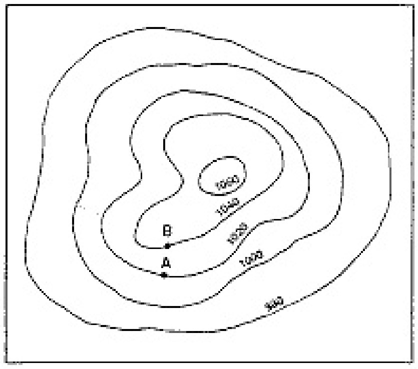


Figure E-1: Isolated Hill

One of the easiest landscapes to visualize on a topographic map is an isolated hill. If this hill is more or less circular the map will show it as a series of more or less concentric circles (Figure E-1). Imagine that a surveyor actually marks these contour lines onto the ground. If two people start walking in opposite directions on the same contour line, beginning at point A, they will eventually meet face to face.

If these same two people start out in opposite directions on different contours, beginning at points A and B respectively, they will pass each other somewhere on the hill and their vertical distance apart would remain 20 feet. Their horizontal distance apart could be great or small depending on the steepness of the hillside where they pass.

A rather more complicated situation is one where two hills are connected by a saddle (Figure E-2). Here each hill is circled by contours but at some point toward the base of the hills, contours begin to circle both hills.

How do contours relate to water flow? A general rule of thumb is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. Water flows from the top of the saddle or ridge, down each side in the same way water flows down each side of a garden wall (See arrows on Figure E-2).

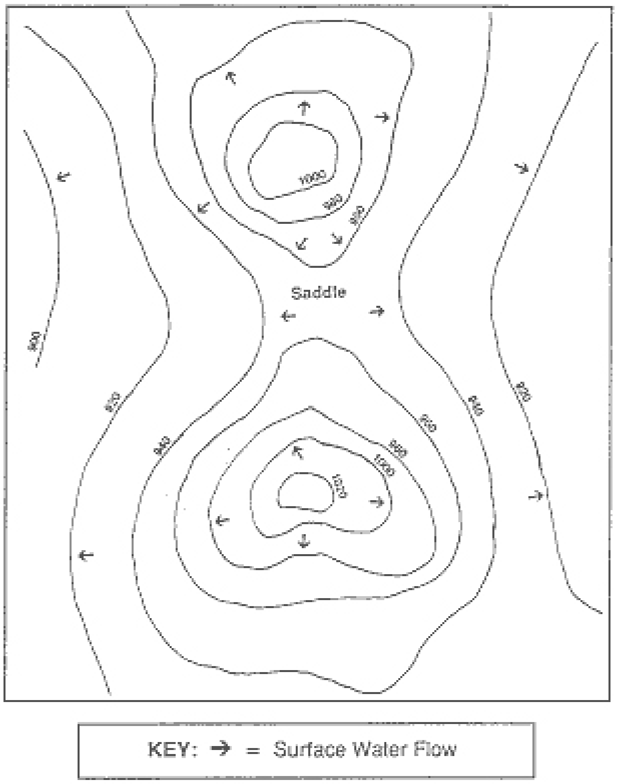


Figure E-2: Saddle

As the water continues downhill it flows into progressively larger watercourses and ultimately into the ocean. Watersheds can be defined at many different scales. That is, the entire drainage area of a major river like the Connecticut River can be considered a watershed, but the drainage areas of each of its tributaries are also watersheds.

Each tributary in turn has tributaries, and each one of these tributaries has a watershed. This subdivision can continue until very small, local watersheds are defined that drain only a few acres, and might not even contain a defined stream.

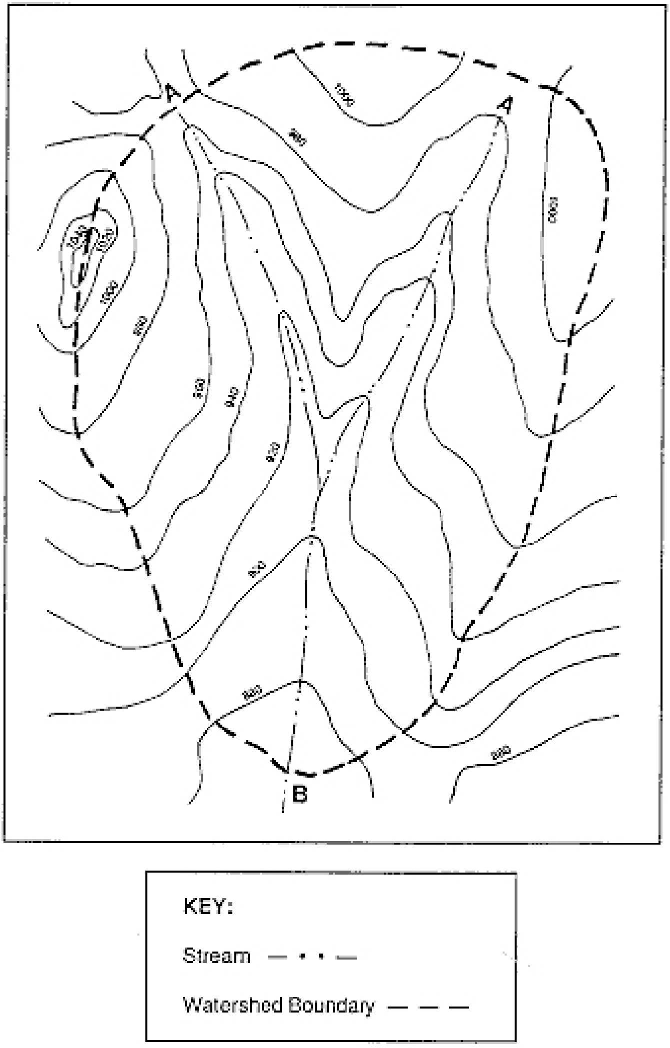
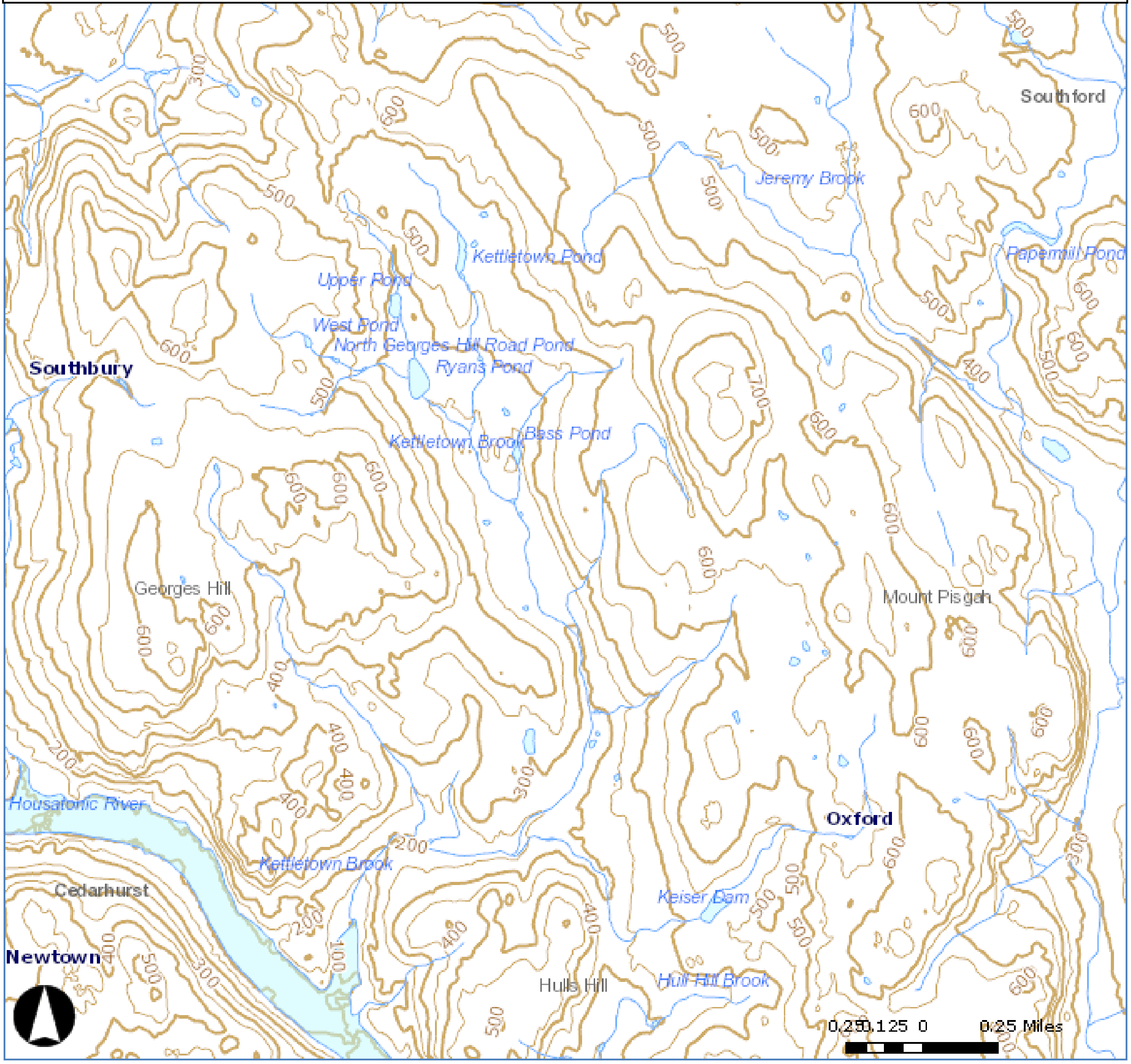


Figure E-3: Idealized Watershed Boundary

Figure E-3 shows a watershed of a small stream. Water always flows downhill perpendicular to the contour lines. As you proceed upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Likewise the valley slopes upward on each side of the stream. A general rule of thumb is that topographic lines always point upstream like the head of an arrow. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape even when there is no stream depicted on the map. In Figure E-3, for example, the direction of stream flow is from points A to point B.

Ultimately, when delineating a watershed you must reach the highest point upstream. This is the head of the watershed, beyond which the land slopes away into another watershed. At each point on the stream the land slopes up on each side to some high point then down into another watershed. When you connect all of these high points around the stream, you have the watershed boundary.

## Kettletown Brook watershed, Southbury/Oxford, Connecticut

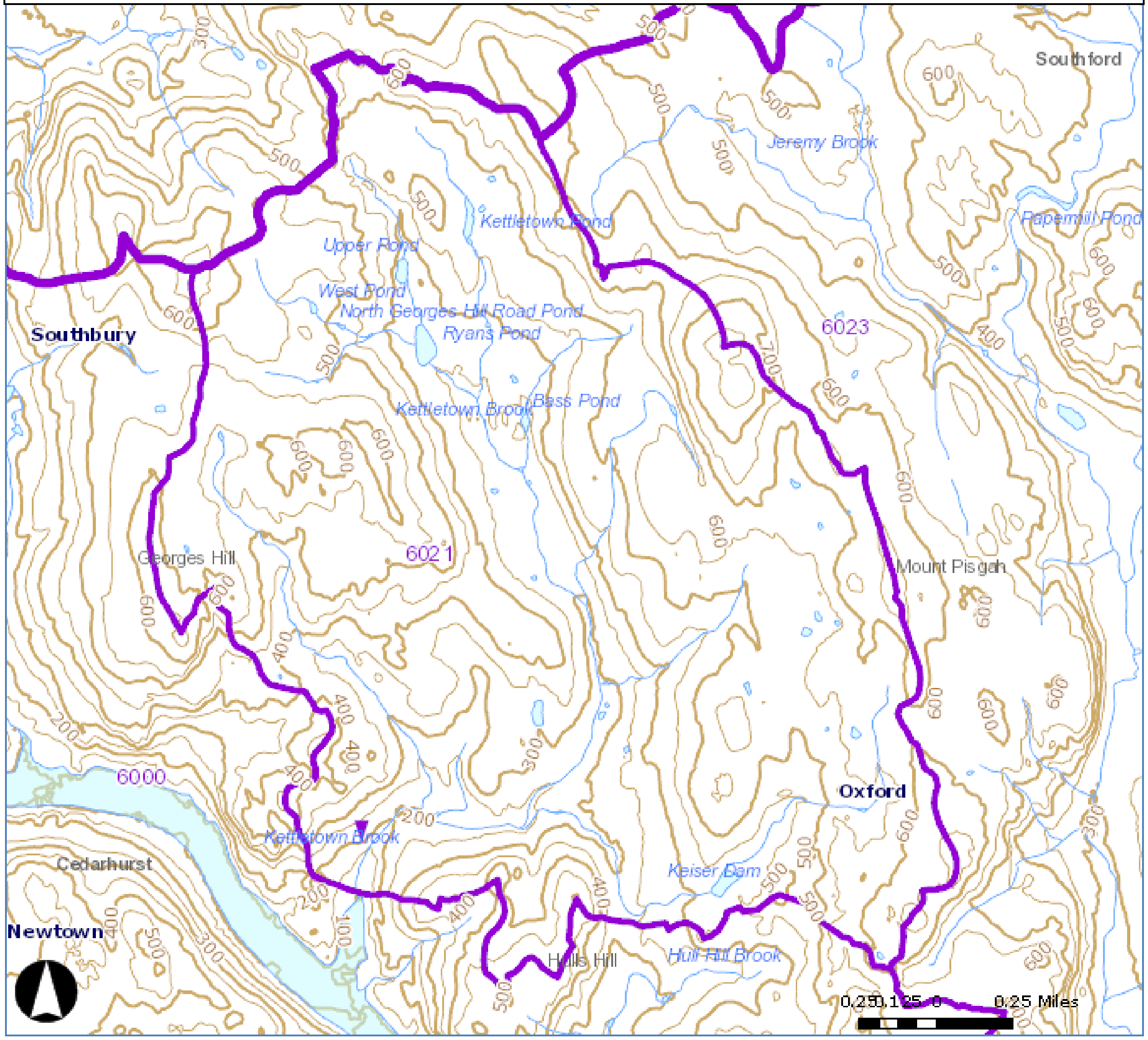


Generated with Advanced Map Viewer on Connecticut Environmental Conditions Online: http://www.cteco.uconn.edu/advanced_viewer.htm

1. Locate the spot where Kettletown Brook empties into the Housatonic River (the mouth) near the southwest corner of the map and draw a circle around it.
2. Starting from there and using a pencil or pen, carefully trace all streams back to their headwaters so that you can see them more clearly on your map.
3. Next, place an “X” at the tops of hills or other highest topographic points surrounding Kettletown Brook and all of its tributaries.
4. Starting at the circle, draw a line connecting the “X’s” until you return to the mouth of Kettletown Brook. Be sure that the line you draw crosses the contour lines at right angles. Most watersheds take the shape of a rough oval.

# Kettletown Brook watershed, Southbury/Oxford, Connecticut

Answer Key



Generated with Advanced Map Viewer on Connecticut Environmental Conditions Online: http://www.cteco.uconn.edu/advanced_viewer.htm

This version of the Kettletown Brook watershed map shows the watershed as defined by the Advanced Map Viewer on Connecticut Environmental Conditions Online. In this case, you can see that there is not one clear “headwaters” but instead a number of small streams that combine to form Kettletown Brook. You can see parts of the boundaries of other adjacent watersheds as well.

Keep in mind this can be done at many different scales – one could zoom out and determine the watershed for the entire Housatonic River (the river in the southwest corner of the map).

## ACTIVITY 9 Reading the Landscape Online

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A: Science As Inquiry

CT Science Standard 7.3 - Landforms are the result of the interaction of constructive and destructive forces over time.

Grade Level Expectations #7: Compare and contrast the major agents of erosion and deposition of sediments: running water, moving ice, wave action, wind and mass movement due to gravity.

CMT Correlation C19: Explain how glaciation, weathering and erosion create and shape valleys and floodplains.

There are a host of online resources that help people visualize Earth's surface, including a few listed below. These can be particularly useful in studying features that highlight erosion and deposition, such as rivers, streams, flood plains, deltas, glacial outflows, etc.

National Geographic Map Machine:
http://maps.nationalgeographic.com/map-machine

- Google Earth type views

The USGS National Map Viewer:
http://viewer.nationalmap.gov/viewer/

- Topo maps (contour lines need to be turned on) and aerial photos of study areas

EarthKam:
http://www.earthkam.ucsd.edu/

- Satellite images of rivers and other geological features

Connecticut Environmental Conditions Online, Advanced Map Viewer:
http://www.cteco.uconn.edu/advanced_viewer.htm

- Custom-generated, GIS-style maps of Connecticut

NOTE: *A copy-ready student worksheet for this activity is available as a separate pdf file from the Yale Peabody Museum website:*
http://peabody.yale.edu/teachers/curricula-connecticut-geology-guide

**Reading the Landscape Online**

Use the National Geographic Map Machine to study river features.

http://maps.nationalgeographic.com/map-machine

Go to the "SATELLITE" view and then enter each of the following places into the Search box (don't enter the text in parentheses). Zoom in or out to observe features along the rivers and streams in each area.

1. Menan Buttes, Idaho (Snake River)
2. Mobile, Alabama (Tensaw River)
3. Grand Teton National Park, Wyoming (Snake River)
4. Ennis, Montana (Cedar Creek)
5. Kent, Connecticut (Housatonic River)

For each of the five places, complete the following:

- Describe the drainage patterns visible.
- List the features you find.
- Find evidence for deposition and erosion on the river. Where is the water eroding the land, and where are sediments being deposited?
- What patterns do you notice?

Teacher Notes

There is a lot to see in these images! The level of detail you can go into will depend on the amount of time you have for this activity. All five areas have different features to study, and all of them are interesting. The first example, Menan Buttes, probably provides the clearest evidence of deposition and erosion. What follows are some notes about interpreting some of the features at some of these sites.

1. Menan Buttes, Idaho (Snake River)

   Have the students zoom in on the section of the river just to the east of the northern butte (where the map machine puts the pushpin) until the scale bar at the bottom right reads 500 yards or 250 yards. Have students try to determine what deposition looks like on a satellite view like this. Close observation will reveal sandy beaches (light-colored, clearly no vegetation) on the inner (convex) shore of every sharp bend in the river. Why? It has to do with “secondary flow” of sand and gravel across the floor of a river or stream from the concave bank towards the convex bank. As for erosion, the majority of the erosion is happening on the outer (concave) shores of the riverbends, although it is more difficult to see this from a satellite image. If you were actually standing there looking at it, you would see a “cut bank” where the exposed soils of the concave banks are more easily eroded and often look like small cliffs, where the vegetation may become so undercut that it falls in!

2. Mobile, Alabama (Tensaw River)

   This provides an excellent example of meandering and braided river channels, including fully formed oxbow lakes. Have students look just north of the city of Mobile. In this case, the whole area is almost flat, and you can see the effect of that on the very spread out river system.

3. Grand Teton National Park, Wyoming (Snake River)

   This shows heavily-braided river channels of the Snake River. Specifically, look about five (5) miles due east of Jenny Lake.

4. Ennis, Montana (Cedar Creek)

   This is an interesting feature known as an alluvial fan. Look east of Ennis and Jeffers, Montana, where Cedar Creek emerges from Beaverhead National Forest and fans out into the flatlands.

5. Kent, Connecticut (Housatonic River)

   You can look at just about any large river in Connecticut and see some similar features. This example is perhaps not the most interesting of the bunch, but it is nice to provide a local example. Have students try to find at least one example of deposition.

## ACTIVITY 10 Stream Table Investigations - A Study in Drainage Patterns and the Evolution of Streams

This activity is from the Exploratorium (San Francisco, CA), who include an expanded range of very useful activities for inquiry:

http://www.exploratorium.edu/IFI/docs/Stream_Table.pdf

National Science Standard, Grades 5-8, Content Standard D, Structure of the Earth

National Science Standard, Grades 5-8, Content Standard A, Science As Inquiry

CT Science Standard 6.4 - Water moving across and through Earth materials carries with it the products of human activities.

CT Science Standard 7.3 - Landforms are the result of the interaction of constructive and destructive forces over time.

Grade Level Expectations #7: Compare and contrast the major agents of erosion and deposition of sediments: running water, moving ice, wave action, wind and mass movement due to gravity.

CMT Correlation C19: Explain how glaciation, weathering and erosion create and shape valleys and floodplains.

Objective: Students will explore factors that affect rates of erosion and deposition due to water.

Materials

A. Stream table (22” x 11”x 2 ½”) with 2 quarts of play sand (use more sand with larger capacity stream tables). There are a variety of sand textures one can use- fine, coarse, and a combination of the two. The types of sand textures one uses depends upon the type of investigations one wants to pursue. Optional- purchase a bag of aquarium gravel to mix with the sand for further investigation.

B. Drip container - 32 oz. with1/8” hole.

C. A ruler or strip of wood that supports the plastic container at one end of the table. Make sure that the hole in the bottom of the drip container can empty water directly onto the sand.

D. Blocks to prop up the stream table

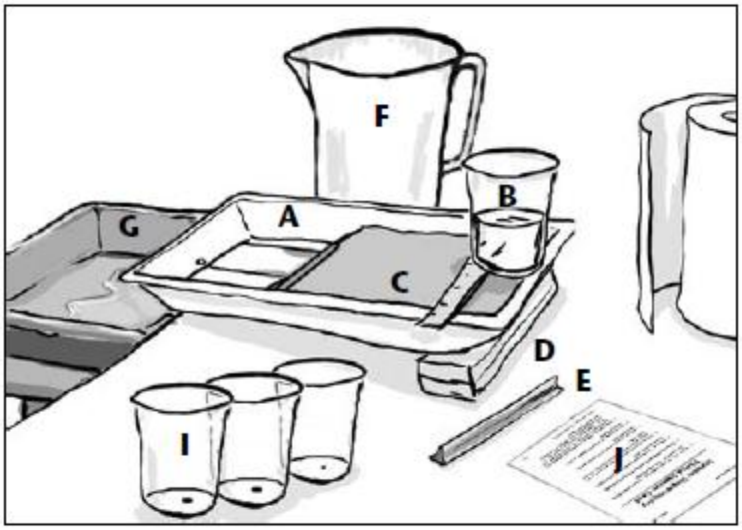
E. A scraper to move and smooth sand

F. A water pitcher

G. A basin to catch water flowing out of the stream table pan

H. (N/A – not pictured on diagram below)

I. Extra drip containers with different size holes (3/16”, 5/16”, and 3/32”)



**Flow setup—note extra drip containers (I) with holes of different sizes**

© The Exploratorium, www.exploratorium.edu

The following activities can be done as demonstrations or as ongoing investigations. The length of the investigations is left to the discretion of the teacher.

**Stream Table**- Post students’ questions and seek their ideas for set up. Test one variable at a time.

Notebooks provide a valuable record of what you did and the evidence you need to support your conclusions. A) Questions; B) Observations; C) Interpretations

The students should focus on the features formed at the head/source, channel, and mouth of the river.

**Suggested tests for watershed investigation**

Part 1- Test slope and flow amounts with play sand- fine sand.
Part 2- Test the slope and flow amounts with coarse sand.
Part 3- Test the slope and flow amounts with a sand and gravel mix.

Potential variables to manipulate and ideas to develop through investigation

1) Keeping the drip container always filled vs. letting the drip container empty out before refilling
2) The effect of slope
3) The effect of particle size on erosion (Main idea: the smaller the particles, the farther they travel).
4) How the amount of flow affected the width of the delta encountered (Main idea: when the flow of a stream increases, more erosion takes place)
5) The effect of different types of sands on channel depth.
6) Objects such as toothpicks or gravel pieces can be effective in channeling the water, increasing the flow (and erosion) in certain places, and decreasing the flow in others.

**Main Ideas about Stream Flow and Erosion**

Erosion occurs when natural materials are removed, or worn away.

Finer particle sizes tend to move farther than coarse particles.

When the flow of a stream increases, more erosion takes place.

Did greater flows…

move more sand?

dig deeper or wider channels?

create longer or wider fans?

*Is there supported evidence of more erosion?*

When the slope of a stream increases, more erosion takes place.

Did greater slope…

move more sand?

dig deeper or wider channels?

create longer or wider fans?

*Is there supported evidence of more erosion?*

## Chaotic Systems

This is a complex idea that has to do with the interaction between the sediments and the flowing water. Some groups may have found that it was hard to get consistent results, no matter how hard they tried to make the starting conditions the same. In fact, seemingly similar starting conditions can lead to very different results. This occurs because of mutual interaction (feedback loops) between two variables that can accentuate an effect in particular ways that result in very different outcomes.

The sediment affects how the water flows, which changes the position of the sediment, which changes where the water flows. This kind of feedback loop can amplify even very small differences. Even imperceptible variations in the initial starting setups can lead to very different results. It may have been hard to get consistent results, no matter how hard you tried to make the starting conditions the same.

**Patterns to notice:**

> Certain landforms frequently occur, such as fans, canyons, and islands. They also may have similar shapes. This happens because water can flow past these shapes without eroding them quickly.
>
> While you cannot predict whether the stream will flow left or right, you can predict, under certain circumstances, it will change.
>
> On places like fans, where many particles are being moved, you may have noticed the stream's path changing from the middle to one side, and then back and forth. This happens because particles carried by the water sometimes drop to the bottom of the streambed, when they build up. Eventually, the water changes course, going around this higher ground, and the process begins again.
>
> These channels keep damming themselves up, changing the direction of the flow, and forming new channels that dam themselves up again. Although you cannot predict which way a stream will go, you can predict that it won't stay on the same path.

## Other ideas to address

The more the soil is saturated, the more erosion occurs.

Impact of humans on the river – human-made dams

## Student Notebook

The students should draw each type of river that was created in their investigation.  Later they can organize their findings on a large piece of white paper so they can analyze their work.

After the students draw their rivers and label their features, the teacher can introduce new vocabulary for the features.

**Student  Notebook**

State the investigation question here:

______________________________________________

Draw/illustrate the rivers that were created in each box. Include labels for different features created.

| **River # 1** | **River # 2** | **River # 3** |
|---|---|---|
| | | |

On a separate piece of white, lined paper, answer the question that you investigated.

**Extension:**

During a unit on environmental science, pollution and ecosystems, students can place drops of food coloring or other dye in specific areas (Monopoly houses can work for factories) near the stream course and see the effects when water runs through.

# SECTION 4 ADDITIONAL RESOURCES

## I. Plate Tectonics

Students can learn about Earth's internal layers, constructive and destructive forces and plate tectonics through a series of free, inquiry-based interactives from the National Science Teachers Association called Science Objects. Included are National and CT Science Standard correlations. They are:

Plate Tectonics: Plates
Plate Tectonics: Plate Interactions
Plate Tectonics: Consequences of Plate Interactions
Plate Tectonics: Layers of the Earth
Plate Tectonics: Lines of Evidence
Earth's Changing Surface: Changing Earth From Within
http://learningcenter.nsta.org

For an excellent overview of the geologic history of Connecticut and the northeast, have students read pages 3-25 of:

**Teacher Friendly Guide to the Geology of the Northeast**
www.teacherfriendlyguide.org

This guide includes the last one billion years of geologic history with a great summary and visuals.

## II. Key Geologic Features of Connecticut

by Jonathon Craig, Talcott Mountain Science Center

Connecticut has a wide variety of geologic features, the result of about one billion years of geologic activity including the welding of ancient continents, rock formations from tropical seas, rifting and lava flows, and features shaped by recent glaciations. A number of resources and sites throughout the state help explain and describe some of these events. The intent of this travelogue is not to describe all of these in detail but rather to inform the reader of the locations of various features throughout the state so that one might visit and find out more.

We will begin in the western hills and proceed to the east. In the northwest corner of Connecticut are our highest mountains. For many people from states with *real mountains,* these are mere hills and are referred to as the foothills of the Berkshires. The highest mountain peak in Connecticut is Bear Mountain, elevation 2,326 feet. However, the highest elevation in Connecticut lies on the face of Mount Frissell at 2,380 feet, although its peak is actually in Massachusetts. The access roads are gravel and not the easiest going but the views from the top are spectacular with vistas into three states. A lake and dam at the top of nearby Mount Riga provided the waterpower for an iron smelter. The stone remnants can be seen just southeast of the lake. Iron was a major industry in the 1700's and 1800's for this region of Connecticut, where more than 40 furnaces turned out tons of iron products. Another furnace under restoration by the State is located in Canaan.

The Beckley Furnace on the Blackberry River was a site chosen by John Adam, a legendary ironmaster from those times. In the Canaan area are several marble quarries, some more than 300 feet deep. Most are not accessible but special permission might be obtained from private owners. Just north of Rte.7A across the border into Massachusetts is a remarkable metamorphic feature jutting out of the pastoral landscape. This is Bartholomew's Cobble, with layers of resistant marble, quartzite, and quartz veining. Here you can imagine being transported in time where once Native Americans sought refuge amongst the crevices in the rock or paddled a birch bark canoe in the meandering, upper Housatonic.

To learn more of the rocks and minerals of the region visit the Connecticut Mining Museum located in Kent, which is on the same site as the Sloan Tool Museum, off Rte. 7. Kent Falls is also worth a visit, where water cascades hundreds of feet down a series of steps in the metamorphic rocks. The Marble Valley continues along the path of the Housatonic south to Redding, where more quarries are located. Other features of the region are the falls at Bull's Bridge and old mines and quarries throughout the area. Roxbury is known for large garnets. Mining is available for a nominal fee at Greene's Farm in Roxbury, southeast of the center of town.

Several flood control dams in the western part of the state have sites for visitors and have dramatic cuts and exposed bedrock features. These include the federally managed Colebrook River Dam and the Thomaston and Black Rock Dams. An exposure of the Meriden formation lies in Southbury and Woodbury with features that mirror the Central Valley.

The Central Valley has several high vantage points (you may refer to *Traprock Ridges of Connecticut* for detailed descriptions and directions to some of these sites). Most notable of these are at Sleeping Giant State Park, a volcanic neck formation in Hamden, and at East and West Rock State Parks in New Haven. These are intrusive formations composed of a fine grained diabase or dolerite, as described on the bedrock geology map of Connecticut. These features formed below the surface, later to be exposed by erosion. They represent some of the earliest igneous activity in the Central Valley. The Metacomet Ridge to the north may be observed from Castle Craig and the Hanging Hills in Meriden, Talcott Mountain State Park in Simsbury and Old Newgate Prison in Granby, where malachite (a copper carbonate mineral) was mined from seams in the basalt and sandstone.

In Southington, south of Lake Compounce and along Roaring Brook, is The Great Unconformity, marking a sharp boundary between Triassic and Ordovician rocks. At Dinosaur State Park in Rocky Hill you can observe dinosaur footprints in the East Berlin formation. The park museum has dioramas of the Mesozoic landscape and examples of local fossils. Devil's Hopyard was named after the potholes formed at the base of Chapman Falls. The legend there is that the Devil burned the holes in the rock with his hooves.

Connecticut is also home to the Yale Peabody Museum of Natural History in New Haven, which houses impressive displays of dinosaurs and other fossils, the world famous *Age of Reptiles* and *Age of Mammals* murals by Rudolph Zallinger, and the Hall of Minerals, Earth and Space.

The State Parks along the coast, especially Hammonasset, Sherwood Island and Bluff Point, give access to glacial features and a variety of rock types. Here you can study the shoreline formation processes where moraine features are eroded by the tides and waves, building long stretches of sandy beaches. Some of these beaches are backed by small dunes. With a hand lens you can distinguish the angular Aeolian sand of the dunes from the rounded grains of the intertidal zone. The slope of rock and cobble beaches can be contrasted against those of fine sand.

In Portland are several abandoned mine sites that contain a variety of minerals, including semi-precious garnets, tourmaline, and beryl. A limited number of permits may be obtained from the State to visit tailings from mines in this area.

To the East are roadcuts through the Avalonian Terrane and glacial formations that can be observed. Horsebarn Hill in Storrs is a classic glacial drumlin. To the north a series of drumlins make up the Woodstock drumlin field.

To obtain specimens, visit local companies that provide building stone or decorative marbles and granite. They may be willing to share broken pieces and provide you with samples from across the country and in some cases from around the world. When collecting, always get permission from the landowner (Federal sites are closed to collecting and State sites require a permit from the State Department of Environmental Protection). Always follow safety precautions with eye protection, adequate footwear, gloves and use the proper equipment.

## III. Connecticut Geologic Sites for Student Field Trips

by Jonathon Craig, Talcott Mountain Science Center

Please see the Yale Peabody Museum website for a pdf of this numbered map:

http://peabody.yale.edu/teachers/curricula-connecticut-geology-guide

There are numerous sites throughout Connecticut that make good places to investigate geology. Many universities and colleges have developed an inventory of places where certain minerals or rock formations can be found, and people with local knowledge and expertise can advise better than this general list of sites. Permission needs to be obtained for private property and permits for State or Municipal sites may be needed to collect specimens. The following is a compilation of sites located in different regions of the state that are readily accessible to classes.

Connecticut is composed of a series of folded and faulted terranes that have formed over hundreds of millions of years, later sculpted by glaciation and adapted for use by civilization. The result is a state very diverse in its topography and rock and mineral resources. Sedimentary, metamorphic and igneous rocks all can be found over a relatively short distance. Using a simplified geologic map of Connecticut, the state can be divided into 5 regions that lie basically northeast to southwest in broad bands. Each region is of a different age and has various rock types. The oldest rocks are located in the west and northwest, where you will also find the highest relief. The southern face of Mt. Frissell **(1)** is the highest point in Connecticut, at 2,380 feet. Its peak is in Massachusetts. Mount Riga State Park has other features, including bare rock faces that expose the metamorphic gneiss and the Riga Furnace at the end of South Pond. Bear Mountain **(2)** is the highest peak at 2,326 feet above sea level. It is hardly a mountain by western standards, yet it belies its once impressive past. The rocks of this region precede the great collision of continents that created Pangaea, with some over a billion years old. The old gneiss formations are interlaced with the marble of the Housatonic Valley. Marble has been and still is quarried from this region for building stone, agricultural lime, slake for the processing of iron, cement, and filler for building products.

Several sites of interest are found throughout this region including historic furnaces and scenic vistas. Beckley Furnace **(3)**, now a State Park, is located in Canaan off Rte 44. It provides a setting for the early iron industry where iron ore, marble (lime) and charcoal were combined to separate pig iron from rock. Iron from this era was used to make cannons for the Revolution, anchors and chain for ships as well as nails, hinges and farm implements to support the colonies. As railroads developed the iron was made into iron wheels for the trains. Slag and bits of refined iron are plentiful around this site with a dump pile of several acres across the river from the furnace. Slag is like glass and can cause cuts and abrasions. The slag piles are of loose material and not safe to climb. Waterpower and railroads provided the catalyst to this industry, which was a significant regional commodity for the colonies.

On Rte. 7 in Kent is the Mineral and Mining Museum **(4),** where specimens of Connecticut minerals are displayed along with historic artifacts of the industrial past. Iron was the mainstay for the western region of the state. More than 40 smelters along the Housatonic and its tributaries produced iron for the colonies and great wealth was made from this industry. The toll this took on the land was another issue. Each smelter required 1,100 acres of forest each year to provide charcoal for its fires. This led to the elimination of large forests in Connecticut and local contamination of air and water. Not much further south on Rte. 7 is Kent Falls **(5)**, where water cascades down a series of steps composed of the Stockbridge Marble and Wallomsac schist. The layers and depth of the marble can be observed as you climb the trail to the top of the falls.

The next region is an area of metamorphic rock, primarily schist, which includes the southwest corner of Connecticut over to Bridgeport and extends north through Waterbury, Torrington and into Massachusetts. Road cuts along many of the major highways expose the rocks of this tumultuous formation as the Iapetos seabeds were wedged into Proto-North America. Schist from these deposits are found on both sides of the Central Valley region and comprise the most common rock type for the State. Hence, it has been designated our State Rock. Mount Tom State Park **(6),** south of Litchfield on Rte. 202, exhibits outcrops of schist and gneiss with glacial scouring and erratics along the trails. Garnets are often found in much of the metamorphic formations with some large specimens typical to Roxbury. This has been chosen as our State Mineral. For a nominal “mining” fee, classes may extract garnets from the schist at Green’s Farm Garnet Mine **(7)**. Also found in Roxbury is the Roxbury Furnace **(8)** and Iron Mine. This is on Land Trust property where visitors can see the large furnace constructed of native gneiss to extract pig iron from the siderite ore, an iron carbonate mineral that was not easily refined. Remains of the slag and minerals that were found in this interesting deposit are scattered around the site. The ore mined here was siderite. An anomaly to this region is the Pomperaug Basin where a miniature version of the Connecticut Valley rocks is replicated. This small rift basin mirrors the sandstone and basalt found further to the east. Platt Farm Preserve (**9**), a park in Southbury, is located along a portion of this basin. These deposits form a layer cake of basalt and sandstone with exposures to the west. Intrusive rocks can also be found throughout this area as magma welled toward the surface and created granites and pegmatite as sills, domes and dikes. These can be observed along stretches of Rte. 8 north of Waterbury but stopping is not allowed.

Old Mine Park in Trumbull **(10)**, north of Rte 25, is the site of the Hubbard Tungsten Mine, where layers of lime and volcanic ash metamorphosed into marble and gneiss. Here, magmatic intrusions formed exotic minerals including the first tungsten deposits found in North America. Also found here were quartz, topaz and a number of other exotic minerals. The 72-acre park features streams, hiking trails, pavilions, picnic tables and historic remnants of the mining and ore processing. Many sites are at the interface of two terranes. Intrusions of magma welled to the surface to provide a variety of minerals. Early entrepreneurs were eager to take advantage of any resource available. Today we have hints of where some of these sites were located, from names like Mine Hill, Lead Mine Brook, Silver Mine Acres, Furnace Brook or Quarry Road. Materials mined included hematite, limonite, Goethite, siderite, galena, nickel, tungsten, cobalt, malachite and pure copper, bismuth, arsenic, quartz, feldspar, mica, barite, and garnet. Many other minerals have been found including gold. However, many a dollar was lost to hucksters who might sprinkle a little gold dust or drill a hole and pour in a barrel of oil to attract unwary investors.

The Central Valley may be a misnomer, for the rift basin's basaltic ridges and diorite intrusions can protrude up to over 800 feet. A number of vantage points provide access to this region that was formed in the early age of dinosaurs. These Triassic/Jurassic layers formed in a climate that was warmer and wetter than our current time. The supercontinent Pangaea rifted apart as Africa pulled away from North America by tectonic forces. Basalt flooded from the cracks in three significant flows: the Hampton, followed by the Holyoke (the thickest) and finally the Talcott flows. The monsoon climate of 200 million years ago caused extensive flooding and erosion, depositing stream and lakebed deposits in the rainy seasons followed by hot, dry conditions of the summer months when waters receded and sediments dried. Connecticut at this time was located between 15 and 18 degrees north of the Equator. The drying deposits contained iron, which effectively rusted when exposed to oxygen, hence the red color of the sandstone beds typical of the Connecticut valley (Connecticut's famous "brownstone").

North to south along the ridge are prominent parks and lookouts that are accessible to classes. In Granby, north of Rte. 20, is the Old Newgate Prison **(11),** where copper was mined from the interface of the basalt and sandstone. The historic site may be toured but no rocks removed. Copper was mined in several locations along the ridges. This resource fueled another industry: brass became a mainstay for the industrial towns along the swift Naugatuck River. Clocks and fine machinery were milled from the copper/tin alloy. Entire towns formed around each industry. For example, Thomaston is named after the Seth Thomas Clock Company.

Talcott Mountain State Park **(12),** off Rte. 185 (see Connecticut DEP description for Penwood State Park) and between Simsbury and Bloomfield, provides access to a hiking trail leading to the Heublein Tower. This grand estate provides an unprecedented view of the center of Connecticut with the Connecticut Valley and Bolton range to the East and the Farmington Valley and Western Highlands and beyond our borders to the West. It is said that King Phillip, chief of the Pequot tribes, stood upon this site watching Simsbury burn at the hands of his warriors. The ridge, primarily comprised of the Holyoke Basalt, extends up into Massachusetts and south to Branford. Significant exposures can be seen as steep steps rising on the western face and sloping gently to the east.

Trap rock has become a major industry for the region, with some of the largest quarries in the United States located in Connecticut. The Hanging Hills of Meriden and Sleeping Giant State Park in Hamden can also be seen from this vantage point. The Hanging Hills can be approached from a hiking trail in Hubbard Park **(13**), west of Meriden off Rte. 695. The trail leads up to Castle Craig, where a 360° vista reveals the dramatic relief created as these ancient lava beds were tilted, broken and eroded over the millennia. Sleeping Giant **(14)** in Hamden along Rte 10 (Whitney Ave.) is a feature not from the lava flows but an intrusive feature where magma solidified just before reaching the surface. This along with East Rock **(15)** and West Rock **(16)** are of a slightly different rock structure than the Basalt. This more crystalline rock is called diabase. Copper was also mined from these rock outcrops and may be found as green oxidized malachite along interfaces with the sandstone. These parks can all be visited to see the view and experience the dramatic impact this violent period had on the environment.

The red sandstone beds contain clues to Triassic/Jurassic life with bits of tree roots, twigs, dinosaur tracks and even fish preserved in some of the layers. To learn more about dinosaurs and the rocks of Connecticut, Dinosaur State Park in Rocky Hill **(17)** and the Yale Peabody Museum of Natural History **(18)** are excellent instructional facilities. Dinosaur State Park features an extensive dinosaur trackway, exhibits, hiking trails and a picnic site. You may also cast your own track replica but you have to bring a bucket and several pounds of plaster. Sandstone was also quarried extensively in Portland for building stone and was used in New Haven, New York and many other cities along the coast. The Portland Quarry has now been turned into a town recreational facility. At Brownstone Park **(19),** much of the quarry is under water, but the exposed ledges show where the stone was cut and loaded on barges for transport down the Connecticut River. It has 40 acres with hiking trails that provide excellent views of the Connecticut River. The Yale Peabody Museum of Natural History in

New Haven features the Great Hall of Dinosaurs, the Hall of Minerals, Earth and Space and numerous other cultural and natural history exhibits.

The Eastern Highlands are similar to the western part of the state, but there are important differences as well. The Central Valley is abruptly ended by the Eastern Border Fault that extends along a series of hills known as the Bolton Range. These hills are remnants of an ancient island arc range of volcanoes. All that's left are their deep foundations. Many mines and quarries were opened to extract the minerals found in this rock. Unfortunately, most have either been covered in or are closed to the public for safety reasons. Gneiss is still quarried for building stone in Glastonbury. The Bolton Range may be observed from Bolton Notch State Park **(20),** north of I-384 in Bolton. Trails and rock outcrops make an interesting field trip destination. Devils Hopyard **(21)** and Gillette Castle **(22)** in East Haddam also show signs of glacial plucking, where boulders are broken away from the underlying rock and deposited downstream of the glacial flow. The metamorphic schist and gneiss also has intrusive pegmatite with large mica and feldspar crystals and some accessory minerals such as black tourmaline and garnets.

The last terrane to the east is what remains of the Avalonian continent that collided with North America during the formation of Pangea. This terrane extends from the Massachusetts and Rhode Island borders down into New London/Groton and along the shore to New Haven Harbor. In North Stonington, a granite intrusion is found at Lantern Hill **(23),** where the quartz has been mined for glass, abrasives and filler for building materials. The view atop this 600 foot outcrop extends from this site to Long Island Sound with a view of five states: Rhode Island, New York, Massachusetts, Vermont and of course Connecticut. It was said to be a lookout for both the Native Americans and the colonists and a signal location for ships. North of New London in Ledyard, near the intersection of Vinegar Hill Rd. and Whalehead Rd., is the Ledyard Glacial Park **(24),** where a ¾ mile trail winds through a series of kettle holes and recessional moraine deposits, including a ravine filled with huge granitic-gneiss boulders deposited as the glacial ice receded. The Mashantucket Pequot Museum **(25)** off Rte. 2, has wonderful displays on Native American life and of the last Ice Age. The Native Americans depended upon the local geology for tools and ceremonial purposes. Quartz, quartzite, chert, flint, basalt, soapstone and beach cobbles were used for points, blades, clubs and agricultural tools. Graphite, galena and iron ores were mixed with animal fat to make black and red pigments.

As a result of the glacial deposits, including Long Island and the various jutting headlands, Connecticut has more than 30 protected harbors that have contributed to the sea trade and whaling industry. These industries brought great wealth to the State. Bluff Point State Park in Stonington **(26),** exhibits both the bedrock features of pink-banded gneiss along the beachhead and glacial deposits further inland. The sand beach is also banded as the waves sift the minerals of different densities with bands of red garnet or black magnetite—the magnetite can be collected with a magnet. Glacial deposits are found all along the coastline and can be studied at Barn Island **(27)** in Stonington. Here, there are views of some of the offshore islands such as Fisher's Island and the terminal moraine of Long Island. Two deposits here make up the highland features, the Ronkonkoma and Harbor Hill moraines. Islands along the shore are partially made up of rocky headlands and recessional moraine deposits of the Wisconsinan Glaciation, which occurred 25,000 to 12,000 years ago.

Hammonasset State Park **(28)** in Madison exhibits two moraine features with the largest feature at Meig's Point. Here, granitic and gneissic boulders are jumbled in a ridge of unsorted till. These features have been subject to erosion and are rapidly diminishing, as people leaving the path destroy the protective vegetation. The glaciers are responsible for providing the plentiful quartz sand and shallow silt-filled bays and marshes that line our coast and contribute to the productive fisheries and recreational resources of our shore. Lighthouse Point Park **(29)** on New Haven Harbor has a beach formed from the ancient Avalonian rock escarpment from 1.2 billion years ago. The weathered granitic-gneiss is eroded by the waves and seasonal temperature change and contains feldspar and quartz. Sherwood Island State Park **(30),** located in Westport, is another site where glacial features can be observed. Rocks along the beach and breakwater reflect the granitic gneiss and grey schist common to the headlands of the region.

The State parks noted in this section all can be found with a geologic description including significant minerals, rock types and geologic features, on the Connecticut DEP website "Geology of Connecticut State Parks" http://www.ct.gov/dep/cwp/view.asp?A=2716&Q=325130. This website provides valuable trail guides, pictures, maps, and notable features for each park. Many other parks listed on this site may also be valuable for local study. Greg McHone has compiled an extensive resource in "*Great Day Trips to Discover the Geology of Connecticut",* Perry Heights Press, 2004.

## References

Kirby, Ed. 1998. *Echoes of Iron in Connecticut's Northwest Corner.* Sharon, CT: Sharon Historical Society.

McHone, Greg. 2004. *Great Day Trips to Discover the Geology of Connecticut*. Wilton, CT: Perry Heights Press.

Connecticut DEP website *Geology of Connecticut State Parks*: http://www.ct.gov/dep/cwp/view.asp?A=2716&Q=325130

**Field Sites**

1 Mt. Frissell, Mt. Riga State Park, Salisbury

2 Bear Mountain, Mt. Riga State Park, Salisbury

3 Beckley Furnace State Park, North Canaan

4 The Connecticut Mining and Mineral Museum, Kent

5 Kent Falls State Park, Kent

6 Mount Tom State Park, Bantam

7 Greens Farm Garnet Mine, Roxbury

8 Roxbury Iron Mine and Furnace, Roxbury Land Trust

9 Platt Farm Preserve, Town of Southbury

10 Old Mine Park, Town of Trumbull

11 Old Newgate Prison State Park, Granby

12 Talcott Mountain State Park, Simsbury

13 Hubbard Park, City of Meriden

14 Sleeping Giant State Park, Hamden

15 East Rock, City of New Haven Parks

16 West Rock Ridge State Park, New Haven

17 Dinosaur State Park, Rocky Hill

18 Yale Peabody Museum, New Haven

19 Brownstone Park, Portland

20 Bolton Notch State Park, Bolton

21 Devils Hopyard State Park, East Haddam

22 Gillette Castle State Park, East Haddam

23 Lantern Hill, North Stonington

24 Ledyard Glacial Park, Town of Ledyard

25 Mashantucket Pequot Museum

26 Bluff Point State Park, Stonington

27 Barn Island State Park, Stonington

28 Hammonasset State Park, Madison

29 Lighthouse Point, City of New Haven

30 Sherwood Island State Park, Westport

## IV. Online Resources and Other References

### Online Resources

Earthquake Frequently Asked Questions and Answers
http://earthquake.usgs.gov/

Earth Science Teacher Online Resource www.geology.com/teacher
A collection of sites with links.

Geological Society of America http://www.geosociety.org/profdev/

IRIS Seismic monitor http://www.iris.edu/hq/

National Earth Science Teachers Association www.nestanet.org
Sponsors Windows to the Universe www.windows2universe.org

National Science Teachers Association www.nsta.org

U.S. Geological Survey www.usgs.gov
Many resources here, including
This Dynamic Earth, a publication of the USGS - the story of plate tectonics.

## Other References

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A MARS-SIZED PLANET HIT EARTH, SENDING DEBRIS INTO ORBIT AROUND EARTH. A FRACTION OF THAT DEBRIS FORMED THE MOON AND THE REST RETURNED TO EARTH.

# 4.5 BILLION YEARS AGO

AS ANCIENT EUROPE (“BALTICA”) AND BRAZIL (“AMAZONIA”) COLLIDED WITH PROTO-NORTH AMERICA, SEDIMENTARY AND IGNEOUS ROCKS WERE DEFORMED AND METAMORPHOSED TO PRODUCE THE ROCKS OF THE GRENVILLE MOUNTAINS. THESE ARE THE OLDEST ROCKS FOUND IN CONNECTICUT.

# 1 BILLION YEARS AGO

THE TACONIC MOUNTAINS, PART OF THE APPALACHIAN MOUNTAIN CHAIN, FORMED WHEN VOLCANIC ISLANDS AND OCEAN SEDIMENTS COLLIDED WITH NORTH AMERICA.

# 460 MILLION YEARS AGO

THE TACONIC MOUNTAINS, PART OF THE APPALACHIAN MOUNTAIN CHAIN, FORMED WHEN VOLCANIC ISLANDS AND OCEAN SEDIMENTS COLLIDED WITH NORTH AMERICA.

# 380 MILLION YEARS AGO

THE ROCKS OF THE APPALACHIAN MOUNTAINS CONTINUED TO FORM AS A CONTINENTAL MASS EARTH SCIENTISTS CALL “AVALONIA” COLLIDED WITH EASTERN NORTH AMERICA.

# 350-250 MILLION YEARS AGO

THE SUPERCONTINENT PANGEA (MEANING "ALL LANDS") WAS FORMED WHEN ALL THE CONTINENTS CAME TOGETHER. DURING THIS TIME, THE APPALACHIAN MOUNTAINS CONTINUED TO FORM. THE MOUNTAINS WERE AS HIGH AS THE HIMALAYAS ARE TODAY, REACHING ELEVATIONS OF 20,000-30,000 FEET ABOVE SEA LEVEL

# 230-210 MILLION YEARS AGO

THE BREAKUP OF PANGEA STARTED AS THE
SUPERCONTINENT BEGAN TO RIFT APART,
ULTIMATELY CREATING THE ATLANTIC
OCEAN BASIN.

# 200 MILLION YEARS AGO

AS PANGEA CONTINUED TO BREAK UP, SOME SMALLER RIFTS PERPENDICULAR TO THE MAIN RIFT DID NOT OPEN COMPLETELY, PRODUCING FAILED RIFT VALLEYS LIKE CONNECTICUT'S CENTRAL VALLEY (NEWARK TERRANE). THE FAMOUS BROWNSTONES OF CONNECTICUT ARE MADE FROM SEDIMENTS THAT WERE DEPOSITED IN THE RIFT VALLEY. THE FLOOD BASALT LAVAS THAT ERUPTED ALONG THE RIFTS ARE NOW PRESERVED AS TRAPROCK RIDGES. ONE LAVA FLOW WAS ABOUT 200 METERS (OVER 600 FEET) THICK! DINOSAURS ROAMED THE CONNECTICUT VALLEY AND LEFT FOOTPRINTS ALONG THE MUDDY MARGINS OF RIFT VALLEY LAKES. ONE TYPE OF LARGE FOOTPRINT IS NAMED EUBRONTES AND IS THE CONNECTICUT STATE FOSSIL.

# 65 MILLION YEARS AGO

A 10-KILOMETER DIAMETER ASTEROID STRUCK EARTH NEAR THE YUCATAN PENINSULA (CHICXULUB CRATER) IN THE GULF OF MEXICO. MANY EARTH SCIENTISTS THINK THAT THE RESULTING CATACLYSMS CAUSED A MASS EXTINCTION THAT WIPED OUT MANY SPECIES, INCLUDING DINOSAURS LIKE *TYRANNOSAURUS REX*.

# 25,000 YEARS AGO

THE GLACIERS MELTED, UNCOVERING CONNECTICUT. THE TERMINAL MORAINES THAT WERE LEFT BEHIND FORMED LONG ISLAND, BLOCK ISLAND, MARTHA'S VINEYARD AND NANTUCKET ISLAND.

# 20,000 TO 12,000 YEARS AGO

**Student Sheet, Reading the Landscape Online**

Use the National Geographic Map Machine to study river features.

http://maps.nationalgeographic.com/map-machine

Go to the “SATELLITE” view and then enter each of the following places into the Search box (don’t enter the text in parentheses). Zoom in or out to observe features along the rivers and streams in each area.

1. Menan Buttes, Idaho (Snake River)

   Describe the drainage patterns visible.

   ______________________________________________________________________

   ___________________________________________________________

   List the features you find.

   ______________________________________________________________________

   ___________________________________________________________

   Find evidence for deposition and erosion on the river. Where is the water eroding the land, and where are sediments being deposited?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   _________________________________________________

   What patterns do you notice?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   _________________________________________________

2. Mobile, Alabama (Tensaw River)

   Describe the drainage patterns visible.

   ______________________________________________________________________

   ___________________________________________________________

   List the features you find.

   ______________________________________________________________________

   ___________________________________________________________

   Find evidence for deposition and erosion on the river. Where is the water eroding the land, and where are sediments being deposited?

   ______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

__________________________________________________

What patterns do you notice?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

__________________________________________________

3. Grand Teton National Park, Wyoming (Snake River)

   Describe the drainage patterns visible.

   ______________________________________________________________________

   ____________________________________________________________

   List the features you find.

   ______________________________________________________________________

   ____________________________________________________________

   Find evidence for deposition and erosion on the river. Where is the water eroding the land, and where are sediments being deposited?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   __________________________________________________

   What patterns do you notice?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   __________________________________________________

4. Ennis, Montana (Cedar Creek)

   Describe the drainage patterns visible.

   ______________________________________________________________________

   ____________________________________________________________

   List the features you find.

   ______________________________________________________________________

   ____________________________________________________________

Find evidence for deposition and erosion on the river. Where is the water eroding the land, and where are sediments being deposited?

What patterns do you notice?

5. Kent, Connecticut (Housatonic River)

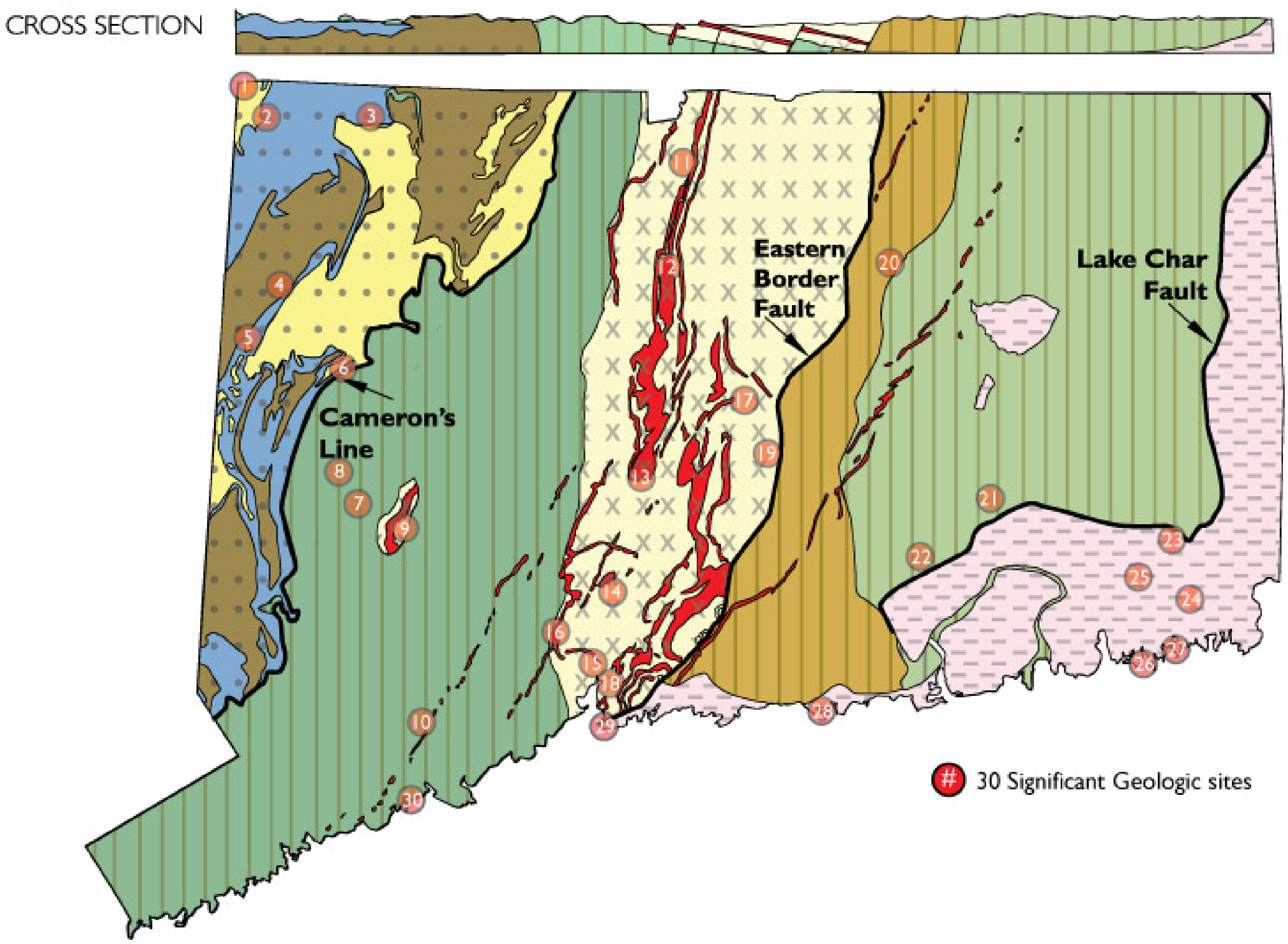
   Describe the drainage patterns visible.

   List the features you find.

   Find evidence for deposition and erosion on the river. Where is the water eroding the land, and where are sediments being deposited?

   What patterns do you notice?

# SIMPLIFIED GEOLOGIC MAP OF CONNECTICUT



● 30 Significant Geologic sites

## Bedrock Legend

**Newark terrane** (190 to 220 million years old)

- 🟥 Trap rock (basalt lava flows and diabase intrusions)
- ⬜ Sedimentary rocks, including brownstone

**Iapetos terrane** (350 to 500? million years old)

- 🟩 🟫 🟩 Schist and gneiss (metamorphosed sedimentary and igneous rocks)

**Proto-North American terrane** (450 to 1,100 million years old)

- 🟨 Schist
- 🟦 Marble and other metamorphosed sedimentary rocks
- 🟫 Gneiss and schist; some rocks over 1 billion years old

**Avalonian terrane** (mostly 600 to 700? million years old)

- ▤ Granite, gneiss, and schist
  Includes some younger granites and metamorphic rocks

## Terrane Legend

- X X Newark terrane
- ▥ Iapetos terrane
- ▤ Avalonian terrane
- · Proto-North American terrane

Modified from the Connecticut Geological & Natural History Survey map: *Generalized Bedrock Geologic Map of Connecticut.*
Based on the *Bedrock Geological Map of Connecticut* by John Rodgers. Department of Environmental Protection 1990.