SEA FLOOR
&
CONTINENTAL DRIFT

Lesson Plan

A CURRICULUM IN MARINE SCIENCES

FOR GRADES 4 - 8

UNIVERSITY OF CALIFORNIA, LOS ANGELES
MARINE SCIENCE CENTER

revised for UCLA OceanGLOBE, 4/04

SEA FLOOR & CONTINENTAL DRIFT LESSONS

Introduction to the Sea Floor and Continental Drift

Oceanographers discovered the shape of the ocean floor by measuring the depth of the ocean in many places. Early tools included lead weights, lowered on marked ropes or cables to the ocean floor. From such depth readings, scientists gradually built a picture of the ocean floor they could not see. These methods were very slow and eventually were replaced by sonar systems which bounced sound waves off the bottom. Today, sophisticated side-scan sonar and satellite data are fed into computers, giving even more detailed pictures of the ocean floor. Maps catalog and display a wealth of information. On land, topographic maps provide images of the shape of the land. At sea, bathymetric maps provide images of the bottom of the oceans. Turning three-dimensional objects like mountains or guyots into accurate two-dimensional representations on a map is a complicated process involving many steps.

All models of the ocean floor show features with vertical exaggeration, taller and steeper than they actually are. This occurs for a very practical reason. If the model or sketch were prepared to exact scale, it would need to be very large. The Pacific Ocean is 6,000 miles wide in some places, but never more than about 6 miles deep. If you made a model of the Pacific Ocean basin accurate with regard to scale, and the deepest portion of the model were one foot deep, then the entire model would have to be 1,000 feet wide, more than 3 football fields wide. Obviously this is not a good way to illustrate the shape of the Pacific. Instead, we exaggerate the vertical axis in order to reduce the model to a workable size.

The theory of plate tectonics and continental drift hypothesizes that the continents are in relative motion. Thus the positions and shapes of the continents we see today were not the same in the past. The internal structure of the earth is, in part, composed of the core, mantle and two types of crust: continental crust and oceanic crust. The continental crust is less dense than the oceanic crust, so it floats higher in the mantle. It is also thicker and, therefore, extends deeper into the mantle. The crusts float on the mantle much like an ice cube floats in a glass of water. The earth’s core is thought to be comprised primarily of very dense nickel and iron compounds in a molten state. Radioactive decay reactions occurring deep in the core produce intense heat. The heat causes convection currents to form in the more “plastic” mantle. As mantle material is heated, its density decreases and it moves toward the crust. In some places, where the crust is thin, some of the mantle material seeps through and, as it cools, creates new crust. The Mid-Atlantic Ridge was formed in this manner. Sometimes this new crust rises above the water’s surface to form islands. Once it reaches the crust, the mantle material moves laterally beneath the crust. In this manner, it is thought to drag the plates along with it. Cooling of these convection currents results in a downward movement of material under some regions of the continental crust and oceanic crusts. As parts of the oceanic crust move downward under the continental and other oceanic crusts, deep ocean trenches are formed. As the oceanic crust moves downward under the continental crust, remelting of the crust occurs, producing new mantle. In these areas, molten rock is often found rising through the oceanic crust to create volcanic islands. The Philippines, the Marshalls, and Fiji are examples of Pacific volcanic arcs. The Azores are examples of Atlantic volcanic arcs. Hawaii is an example of “hot spot” islands, islands that are formed by volcanic activity due to an outpouring of rising magma through a hole in the plate. For reasons that are not yet clear, “the hot spot” does not change location but the oceanic plate above it moves over time, and new islands are formed over the hot spot, creating an island chain.

As early as 1650, writers commented on the similarities of the coastlines of eastern South America and western Africa, but the idea that continents could change shape or location was unbelievable at that time. Even as late as the 1940's few scientists took the idea of continental drift seriously. No one had been able to explain HOW the continents could move. So where did this theory of drifting continents come from? What gave anyone the idea that certain parts of continents might have been joined to other continents? From the 1700's through the early 1900's scientists had attempted to explain the formation of the earth, its oceans, and its land masses. Three scientists, James Hutton (geologist), Alfred Wegener and Alexander du Toit proposed, somewhat independently, what is today the prevailing theory of how our continents and oceans came to be. This theory is called "the Theory of Plate Tectonics and Continental Drift." In Hutton's time, the thought of drifting continents was considered biblical blasphemy. In Wegener's time, 200 years later, it was just considered ludicrous, because no one could explain how the continents moved. It wasn't until the symmetry of seafloor magnetic anomalies and the midocean ridge spreading zones were discovered on the ocean floor in the 1960's that the continental drift idea was accepted as scientific fact. Continental drift was then unified with the theory of plate tectonics (plate movement) to explain how the Earth's crust is composed of sections, or "plates". These plates move on currents in the mantle below, and carry the continents with them

Sea Floor and Continental Drift

Concepts Related to the California Science Standards

Grade Six:
Plate Tectonics and Earth's Structure

1. Plate tectonics accounts for important features of Earth's surface and major geologic events.

2. Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment.

Grade Seven:
Earth and Life History (Earth Science)

4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept: f. *Students know* how movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographic connections, have affected the past and present distribution of organisms.

Grades Nine through Twelve: Earth Science
Dynamic Earth Processes

3. Plate tectonics operating over geologic time has changed the patterns of land, sea, and mountains on Earth's surface.

All Grades:
Investigation and Experimentation

Record data by using appropriate graphic representations (including charts, graphs, and labeled diagrams) and make inferences based on those data.

Draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion.

Write a report of an investigation that includes conducting tests, collecting data or examining evidence, and drawing conclusions.

Concepts Related to the National Science Standards

1- The floor of the ocean is composed of hills, plains, ridges, trenches and seamounts.

2- Oceanographers have developed methods for mapping the ocean floor, illustrating what cannot be seen.

3- Geologists and oceanographers use maps of the sea floor as tools for research and applied science (technology).

4- land masses on Earth are slowly changing shape as a result of moving for millions of year.

5- Continual convection currents move the earth's crust, resulting in the formation of islands and deep oceanic trenches.

6- Core drilling has produced information regarding the movement and density of the oceanic and continental crust.

Vocabulary

Abyssal Hill	Low, rounded submarine hill less than 1000 m high.
Abyssal Plain	Flat sections of the deep ocean floor.
Atoll	Seamount ringed with coral reefs.
Bathymetric	Measurement of depths of the oceans; also the data derived from such measurement, especially as compiled in a topographic map.
Bay	Partly enclosed body of water open to the sea or a lake.
Continental Drift	Theory proposed by Alfred Wegener in 1912 to explain the similarity of coastlines of Africa and South America and the similarity of 9fossils and rock formations found on both continents. Not taken seriously until mechanism for moving continents could be explained in the 1960's.
Continental Shelf	Submerged margin of the continents.
Continental Slope	Steep slope separating the continental shelf from the deep ocean basin.
Contour Line	Line joining points of equal elevation or depth on a surface or the representation of such a line on a map.
Convection Current	Pattern of movement in unevenly heated fluids.
Guyot	Flat topped volcano which has subsided beneath the water's surface.
Island	Relatively small land area surrounded by water.
Pangaea	The single supercontinent that began to break up 200 million years ago.
Plate tectonics	Theory that explains the way continents move over time: large pieces of the earth's crust, called "plates," move over the mantle below. Continents are located on the crustal plates and move with them. Although various theories have been proposed, the forces driving the movement of plates are unknown.
Rift valley	Trough formed by faulting where plates move apart, as in the midocean ridge.
Seamount	Underwater volcano which has not reached the water's surface.
Sounding	Measurement of depth of water beneath a ship.
Subduction Zone	Area where one crustal plate slips beneath another.
Trench	Long, narrow, deep depression in the seafloor associated with a subduction zone.
Volcanic Island Arc	Series of volcanic islands found along a subduction zone.

Activity #1 - Ocean Floor Model

Concept # 1

#1 The floor of the ocean is composed of hills, plains, ridges, trenches, and seamounts.

Objective:

Students construct a simulated model of the ocean floor in a shoebox. The shoebox model can be used for a sonar mapping lesson in Activity #2.

Materials:

- salt (1 part)
- flour (2 parts)
- food coloring (2-3 drops)
- warm water (1 part)
- bowl
- spoon
- cardboard shoe box (with lid)

Procedures: (See illustrations)

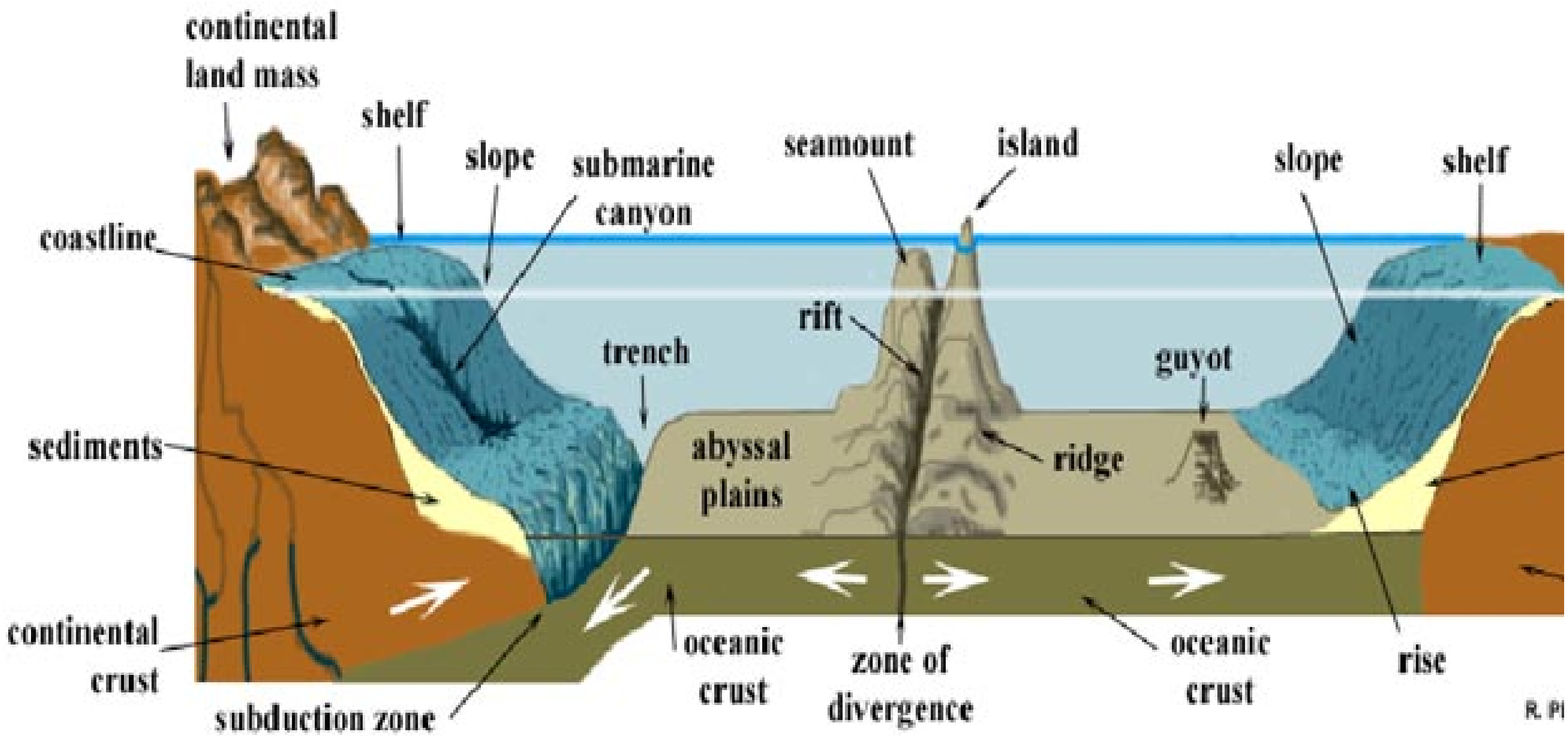
1. Place water and food coloring in a bowl, add salt and mix, add flour and continue to mix to form dough.
2. Divide students into groups of 4-6.
3. Each group draws out a plan for their ocean floor which includes abyssal plains and hills, an atoll, a bay, continental shelf and slope, guyot, island, rift valley, seamount, trench, mid-ocean range, submarine canyon, subduction zone.
4. After a plan is completed students obtain dough mixture from the teacher. Students then shape the ocean floor with the dough on the bottom of the cardboard box.
5. The dough will dry in 3-5 days. Have students label the ocean features and write a definition for each feature.

Evaluation:

- Which feature forms most of the ocean floor? (abyssal plain)
- Where would you find the best fishing zone according to the features of the ocean makeup? (continental shelf)
- Where is new ocean floor created? (mid-ocean ridge)
- How old is the ocean floor? Explain.

Activity #1 - Ocean Floor Model

Typical Ocean Floor Features



Activity # 1 - Ocean Floor Model

Labels for ocean floor map

abyssal hills	abyssal hills
abyssal plains	abyssal plains
atoll	atoll
bay	bay
continental shelf	continental shelf
continental slope	continental slope
contour	contour
guyot	guyot
island	island
island arc	island arc
rift valley	rift valley
seamount	seamount
subduction zone	subduction zone
submarine canyon	submarine canyon
trench	trench
mid-ocean range	mid-ocean range

Activity #2 - Sonar Mapping

Concept # 2

#2 Oceanographers have developed methods for mapping the ocean floor, illustrating what cannot be seen.

Objective:

Students may use their shoe box sea floor mdel from Activiy #1, or may use cardboard layering inside a shoebox, to simulate a section of the ocean floor. Then the students probe the ocean floor to simulate sonar echoes. They graph this data to get a visual picture of the ocean floor.

Materials:

- corrugated cardboard
- scissors
- glue
- chop stick
- shoebox
- papping guide grid
- pen
- tape
- stiff paper (card stock)
- data sheet
- graph sheets
- bathymetric map
- metric ruler

Procedures:

1. Students are grouped in pairs. Each pair obtains a shoebox, cardboard, glue, and scissors.
2. Students glue layers of cardboard to the bottom of the box to create ocean floor height variations. The variations will be measured at 1cm heights so the cardboard layers must be thick enough to show height differences.
3. Students tape a mapping guide grid to the box lid labeled Rows A-G and 1-13.
4. At the intersection of each row and line a hole is poked with the tip of the scissors. The hole should be big enough for the probe (chop stick).
5. The probe is marked and labeled from one end (the bottom) every cm from 1 to 8 cm with a pen.
6. After the box has dried, the lid is put on, and students probe the ocean floor through the holes and record their findings on a data sheet.

Graphing Alternative 1 - making a 3D paper model

7. Numbers (depths) on the data sheet are then plotted on graph sheets, one sheet for each row.
8. After plotting each row, color the area below the line connecting the data points (this represents changes in ocean floor depths).
9. Students cut out the graph above the line and discard.
10. Glue the cut out sheet onto the stiff cardstock in the order of the rows.
11. When finished, open the box and compare your model to the original ocean floor.

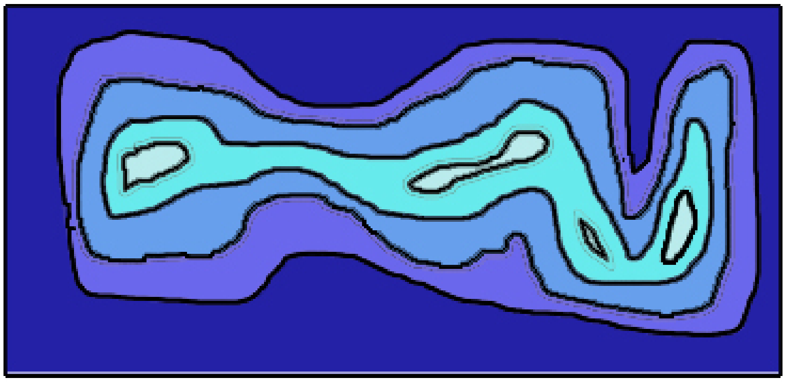
Graphing Alternative 2 - making a contour map

7. Use the numbers on the data sheet to create a contour map (see Activity #3). Plot a contour line for each centimeter of depth. Plot the first contour line by connecting all the 1 cm soundings on the data sheet. Plot the next contour line by connecting all the 2's, and so forth.
8. Color in your depth contours by using light blue, then darker and darker shades of blue indicating deeper depths.
9. When finished, open the box and compare your model to the original ocean floor.

Evaluation:

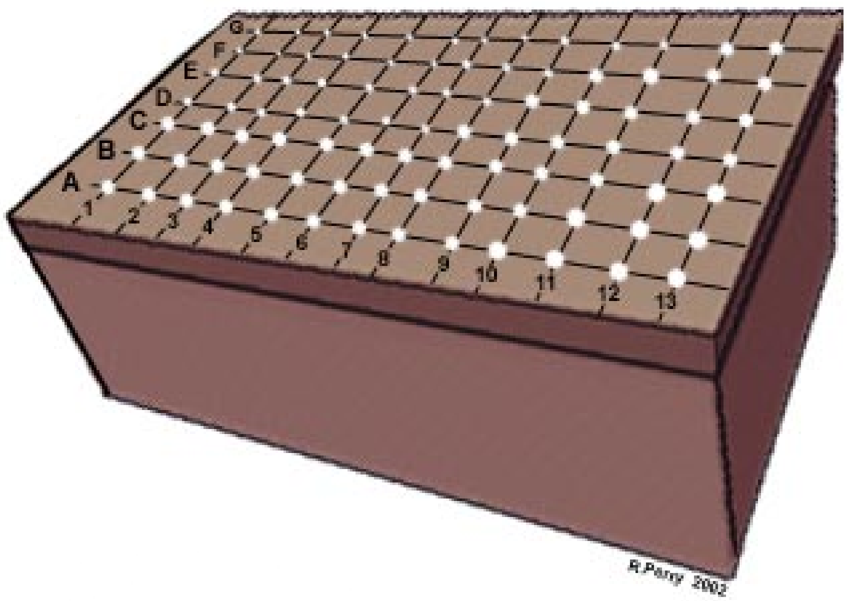
- Does the cut out model and/or contour map look like your ocean floor shoebox model? Explain.
- Were any features missed? Why?
- Do you think oceanographers have similar problems during their investigations?
- How could you have improved the accuracy of your results?

Activity #2 - Sonar Mapping



Inside of shoebox, looking down at cardboard strips representing ocean floor contours.

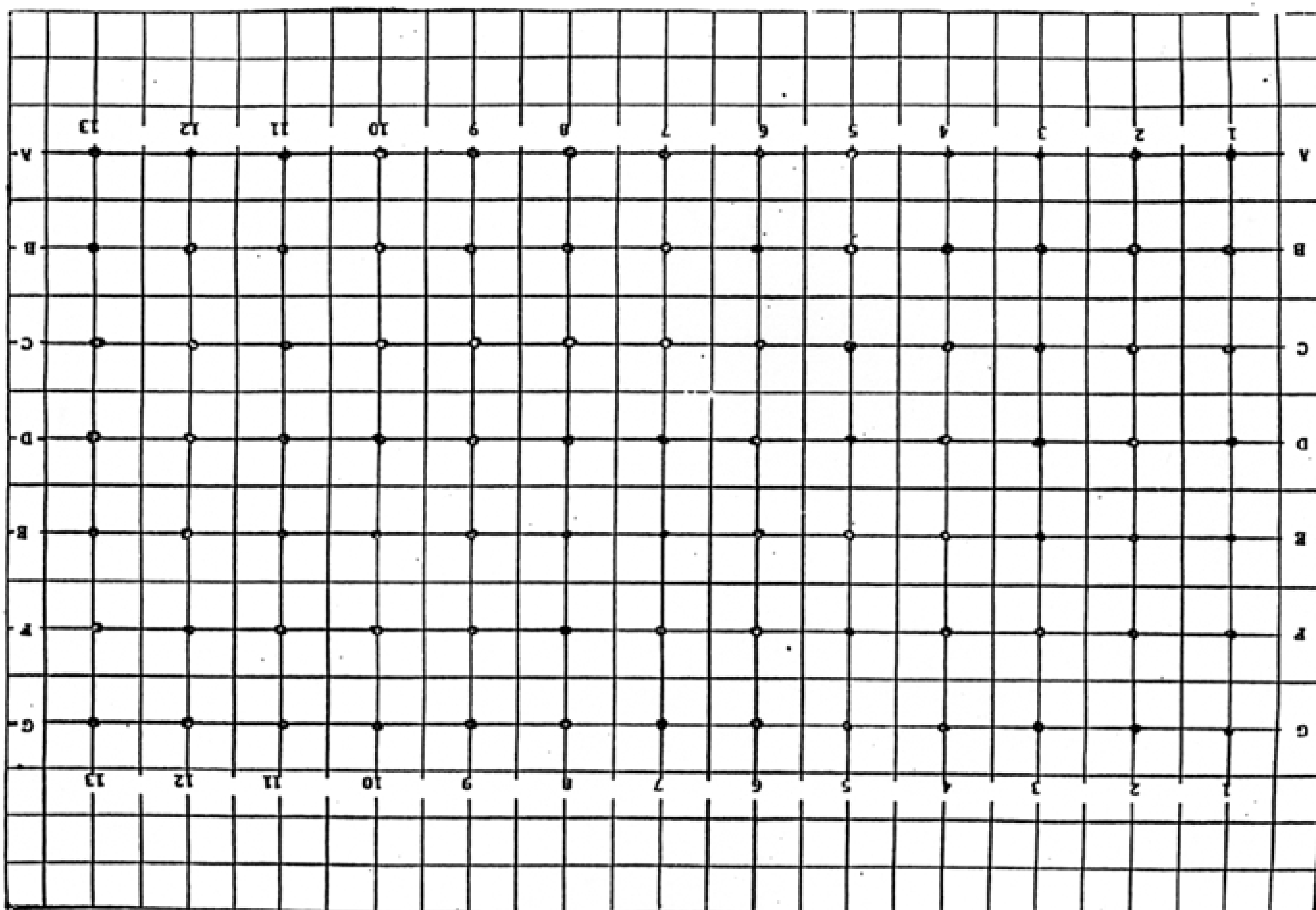
Shoebox with mapping guide on top of lid. Ocean floor model is inside. Holes are poked at grid intersections.



Graphs of data, cut-out and glued in order of the rows.

Activity #2 - Sonar Mapping

Mapping Guide for Box Top



Activity #2 - Sonar Mapping

Data Chart

	1	2	3	4	5	6	7	8	9	10	11	12	13
A													
B													
C													
D													
E													
F													
G													

Activity #2 - Sonar Mapping

Graph Paper - One Graph per Row of Data

Activity #3 - Bathymetric Mapping

Concepts # 1, 2

#1 The floor of the ocean is composed of hills, plains, ridges, trenches, and seamounts.
#2 Oceanographers have developed methods for mapping the ocean floor, illustrating what cannot be seen.

Objective:

Students will draw contour lines based on NOAA soundings on a nautical chart. They will color the contours and glue label tags for topographic features.

Materials:

- nautical chart 1 with soundings in fathoms (1 fm = 6 ft) for student activity
- nautical chart 2 with contour lines (for reference)
- nautical chart 3 with shaded contours (for reference)
- nautical chart 4 with topographic labels (for reference)
- nautical chart 5 - actual NOAA chart of same region
- label tags for topographic features
- scissors
- colored pencils, water colors or crayon
- pencil
- bonus activity map (see last evaluation item)

Procedures:

1. On nautical chart 1 use a PENCIL to draw contour lines for the following depths (in fathoms): 50, 250, 500, 750, 1000, 1250, 1500, 1750 and 2000. Draw the 50 fathom line by keeping all the soundings less than 50 on one side of your line and all the soundings larger than 50 on the other side. Do the same thing at 250 fathoms and every 250 fathoms as you go deeper. Remember that contour lines do not cross each other. When done your teacher may want you to check your contours with chart 2.

2. After you have finished drawing your contour lines, color in each contour by using light blue for the first depth contour (around the land and islands), then darker and darker blue colors, until you end up using black for the deepest contour (bottom left corner). When done your teacher may want you to check your contours with chart 3.

3. Finally, cut out the label tags for the topographic features you have drawn and colored in. Glue them in place to identify the basins, banks and submarine canyons on your chart. When done your teacher may want you to check your contours with chart 4.

Evaluation:

- How might the geologic formations shown on your map have been formed ? (along fault lines; some crustal blocks sink to form basins, other are uplifted to form mountains, islands or banks.)
- Where is the continental shelf? slope? abyssal plains? (The continental shelf here is not flat, it is interrupted by islands, basins and banks. The shelf runs to the Patton Escarpement, which is the continental slope. The abyssal plains are in the lower left corner).
- Suppose you are the captain of a fishing boat. You hear a report of good fishing near San Miguel Island and sail to the area. GIve at least two reasons for studying a nautical chart with bathymetric information before fishing? (To keep from running aground and to keep from getting your fishing gear caught on the bottom.)
- How is the map you drew similar to the nautical chart drawn by professionals? (soundings are the same; some contour lines are barely visible beneath the other data)
- How can you account for the differences? (nautical charts show other important navigational information such as the shipping lanes for large commercial vessels, the LORAN grid for older navigational units, the details of every lighthouse, buoy and other markers, areas for military testing, dumping and other information)
- Students complete map 3 for homework. If the map is done correctly a dolphin fish will appear.

Activity #3 - Bathymetric Mapping

Label Tags for Topographic Features

Cut out each tag as close to the lettering as you can.
Try NOT to leave too much white space around the edges of the label.

Santa Barbara Basin

Santa
Cruz
Basin

Santa Rosa - Cortes Ridge

Patton Escarpement

Tanner
Basin

Tanner
Bank

Santa Monica Basin

San
Pedro
Basin

Lasuen
Bank

Osborn
Bank

Santa Catalina Basin

San Nicolas Basin

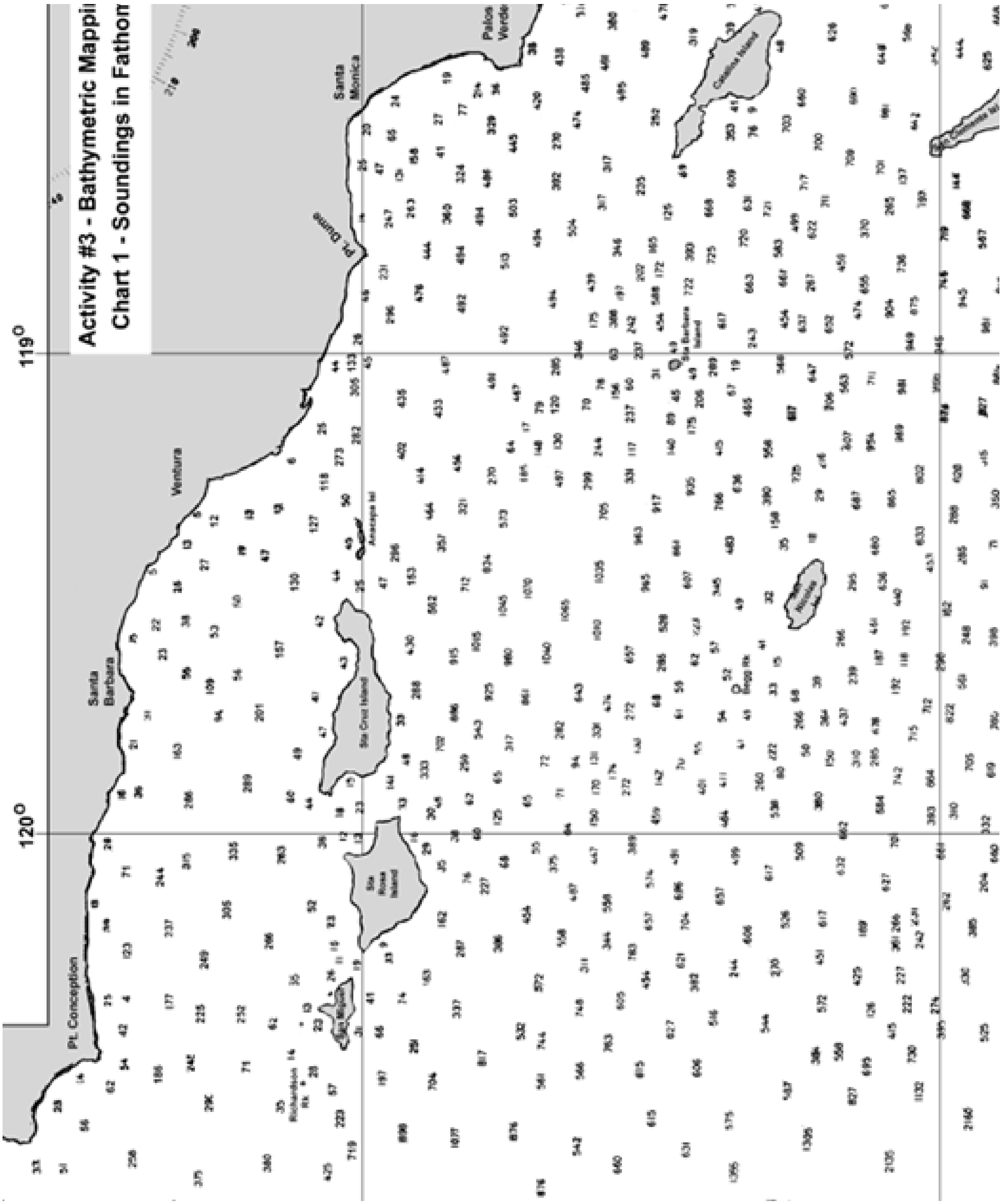
San
Fernando
Basin

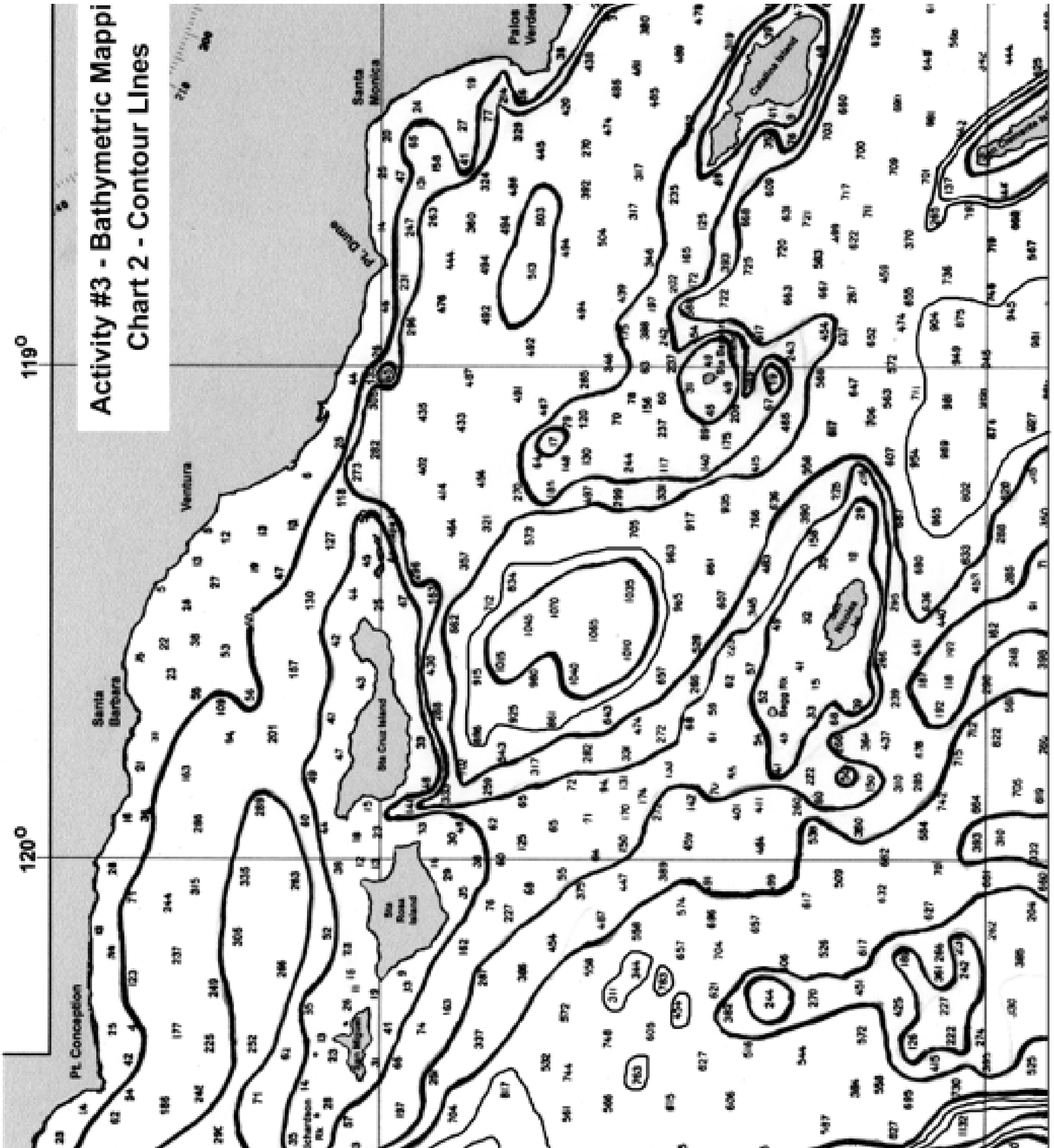
Los
Angeles
Basin

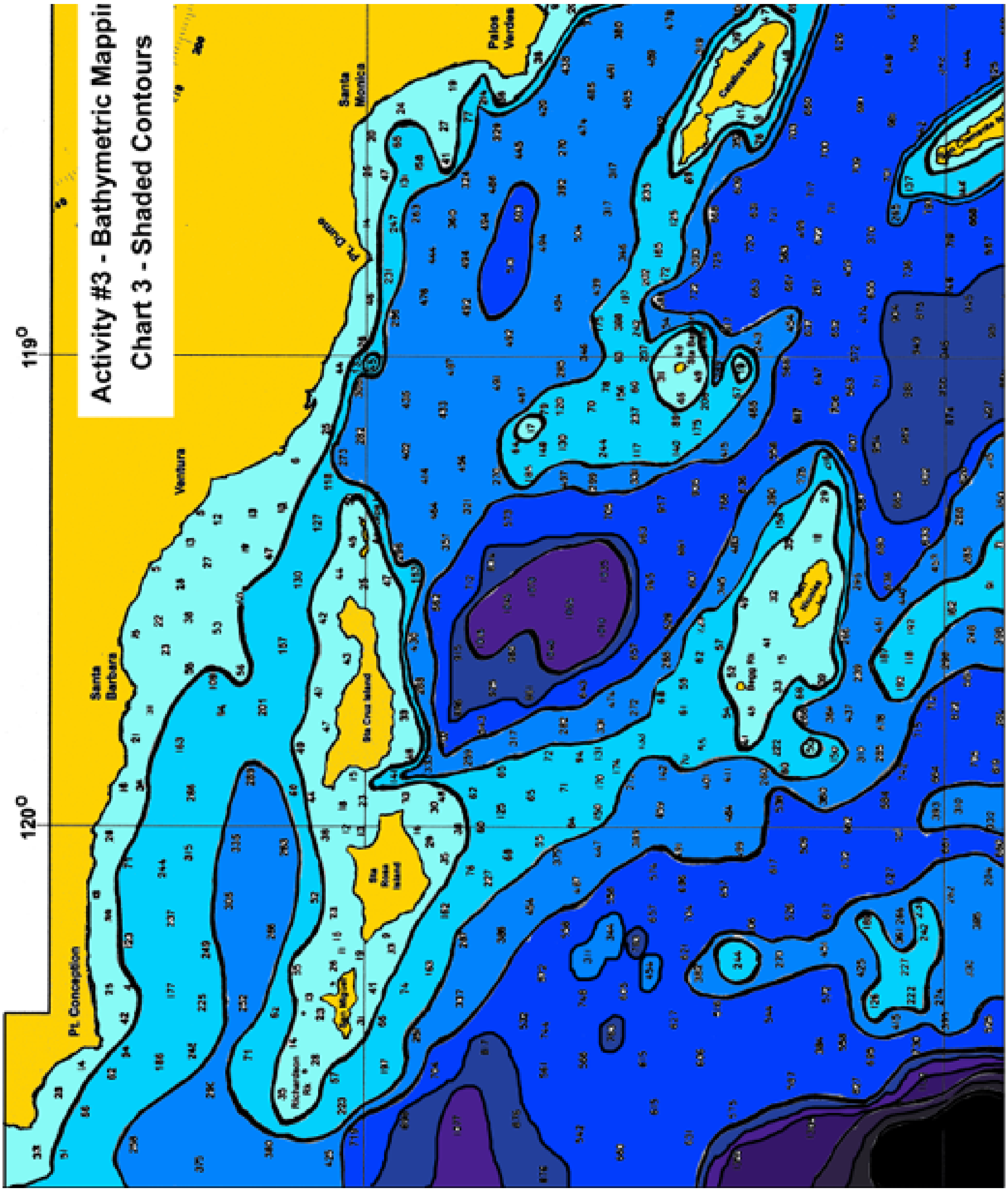
Sant Cruz Canyon

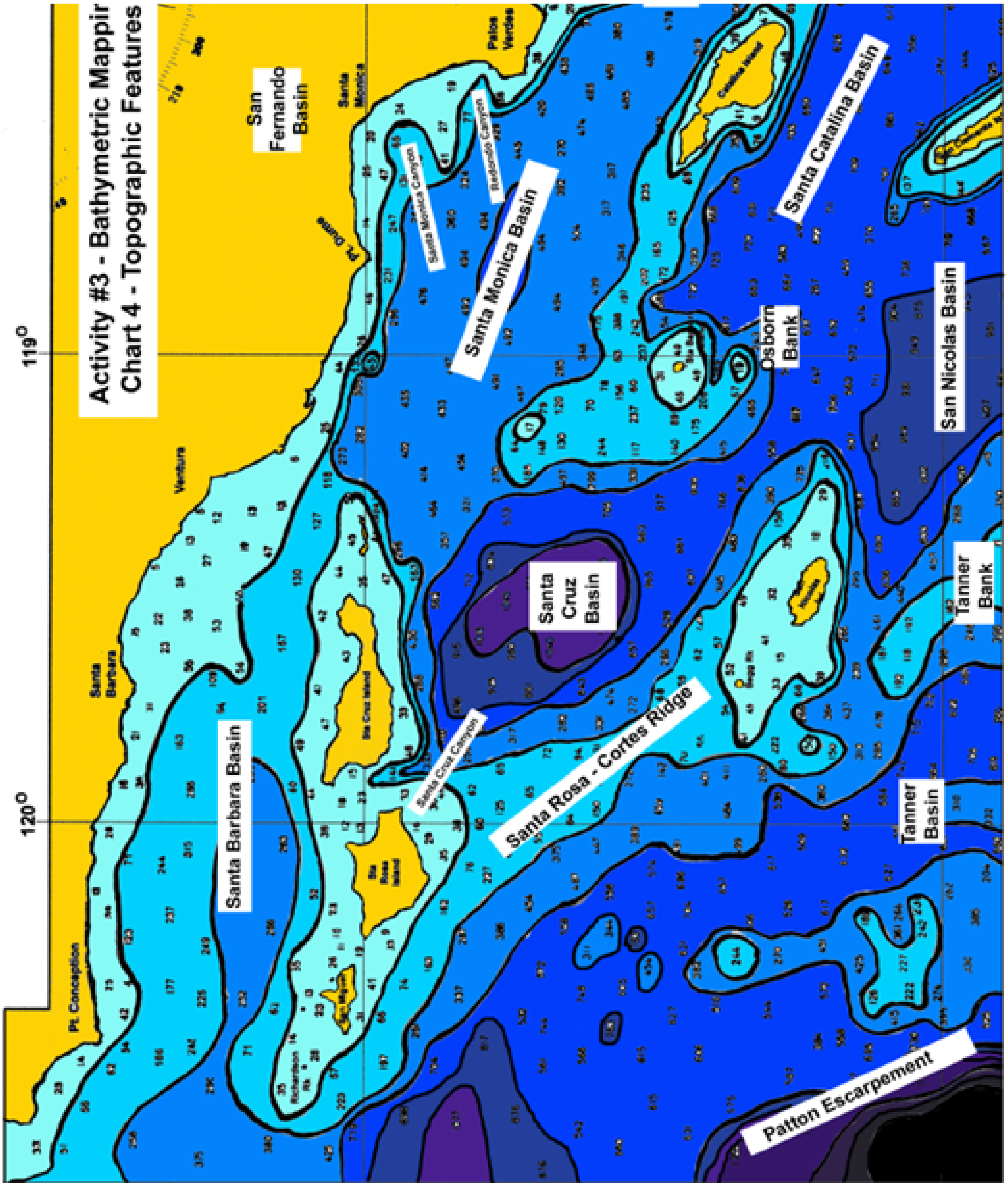
Santa Monica Canyon

Redondo Canyon

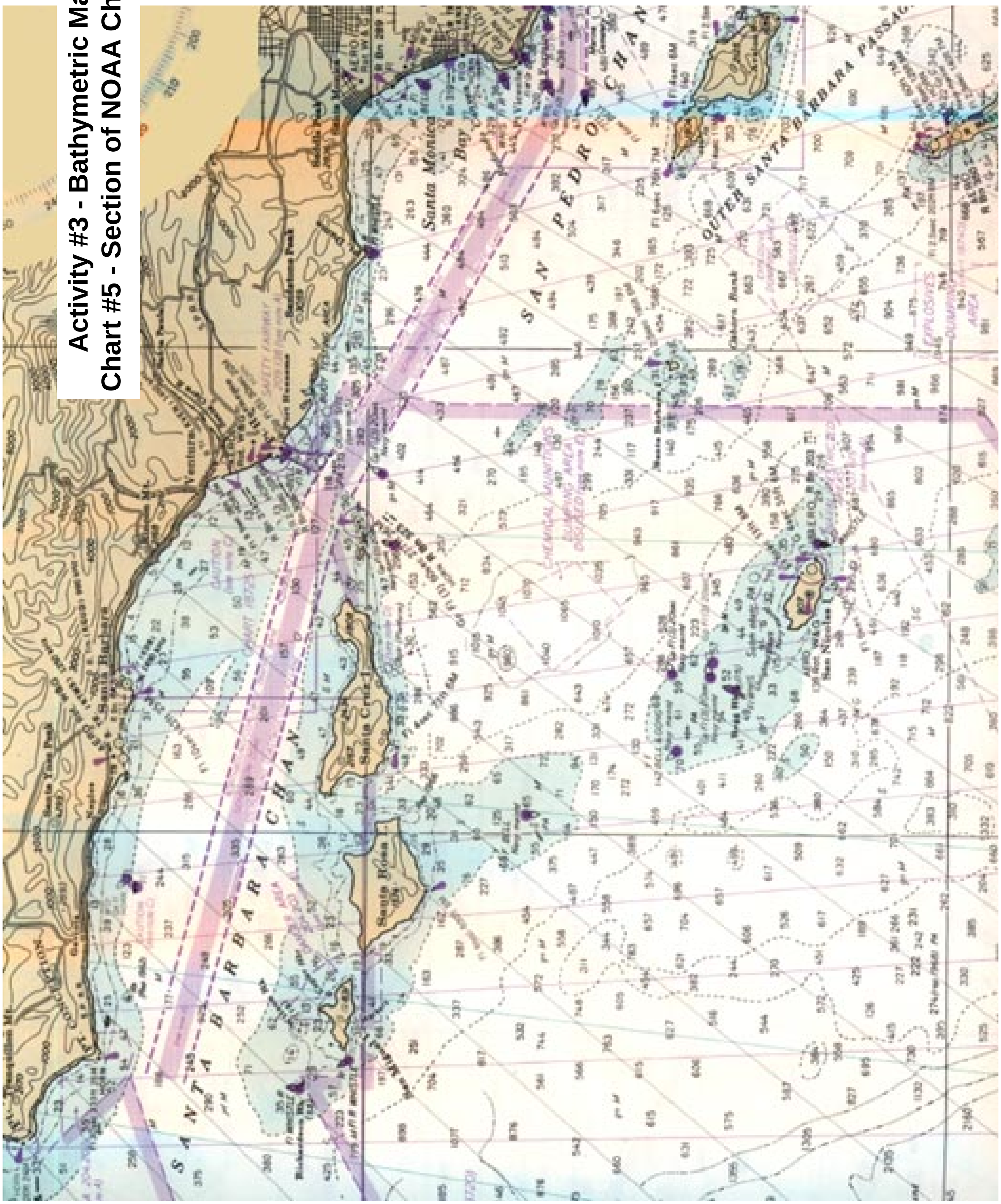

Activity #3 - Bathymetric Mappi
Chart 1 - Soundings in Fathor
119°
120°
Pt. Conception
Santa Barbara
Ventura
Santa Monica
Palos Verde
Pt. Dume
Anacapa Isl
Sta Cruz Island
Sta Rosa Island
Catalina Island


Activity #3 - Bathymetric Mappi
Chart 2 - Contour LInes
120°
119°
Pt. Conception
Santa Barbara
Ventura
Santa Monica
Palos Verdes
Pt. Dume
Sta Cruz Island
Sta Rosa Island
Richardson Rk.


Activity #3 - Bathymetric Mappi
Chart 3 - Shaded Contours
119°
120°
Pt. Conception
Santa Barbara
Ventura
Santa Monica
Palos Verdes
Sta Cruz Island
Sta Rosa Island


Activity #3 - Bathymetric Mappir
Chart 4 - Topographic Features
119°
120°
San Fernando Basin
Santa Monica
Palos Verdes
Pt. Dume
Ventura
Santa Barbara
Pt. Conception
Santa Barbara Basin
Santa Monica Canyon
Redondo Canyon
Santa Monica Basin
Santa Catalina Basin
Osborn Bank
San Nicolas Basin
Santa Cruz Basin
Santa Cruz Canyon
Santa Rosa - Cortes Ridge
Tanner Bank
Tanner Basin
Patton Escarpement

Activity #3 - Bathymetric Mapping
Chart #5 - Section of NOAA Chart 18022



Activity #3 - Bathymetric Mapping

Bonus Activity Map

Activity #4 - Pangaea Puzzle Pieces

Concept # 4

#4 Land masses on Earth are slowly changing shape as a result of moving for millions of years.

Objective:

Students in groups of 2-3 examine 10 pieces of evidence for the Pangaea theory and use them to reconstruct the supercontinent.

Materials:

- large piece of paper (a large 18” blue cirlcle would be ideal, but any paper will do)
- scissors
- glue
- wall world map as reference
- Pangaea pieces
- evidence sheet

Procedures:

1. The teacher discusses the history of plate tectonics and continental drift.
2. Students are divided into groups of 2-3.
3. The students label each continent on their Pangaea Pieces.
4. Cut out the continents.
5. Try to reunite the Pangaea puzzle pieces based on the clues.
6. Glue your finished Pangaea puzzle in place on a large sheet of paper.

Evaluation:

- There are some very prolific diamond mines in South Africa. What do you suppose the chances are that one could find diamonds in South America?
- The coal deposits mined in Pennsylvania were formed from plants that grow in tropical climates. What does this suggest about where Pennsylvania was once located? What does this suggest about the locations of North and South America?
- The fit between Africa and South America along their coastlines is not exact. How might the fit be better?
- The dotted line you cut along the northern edge of India is where the Himalayan mountains are located. How do you think those mountains were formed?
- How would you evaluate the evidence in terms of your fit: Where was the evidence good and where was it bad?
- Does the evidence suffice, in your opinion, to support the theory of Continental Drift? Explain your answer.

Extension:

- Based on the direction and speed of crustal plate movements over the past 250 million years, put together a second world map showing the oceans and continents as they should appear 250 million years in the future.

Activity #4 - Pangaea Puzzle Pieces

Evidence or "Clues"

1. The paleomagnetic stipes or iron crystal patterns in the rocks of northern Brazil and central Africa are mirror images of each other.

2. There is evidence of glacier activity on both sides of the Atlantic Ocean along the Equator.

3. *Glossopteris* is a genus of extinct seed fern (a Pteriosperm) whose fossils are found throughout India, South America, southern Africa, Australia, and Antarctica.

4. *Mesosaurus* was one of the first aquatic reptiles. Fossils have been found in South Africa and South America.

5. The age of the rocks in Europe and north America are the same, and get progressively older as you move inland from the ocean.

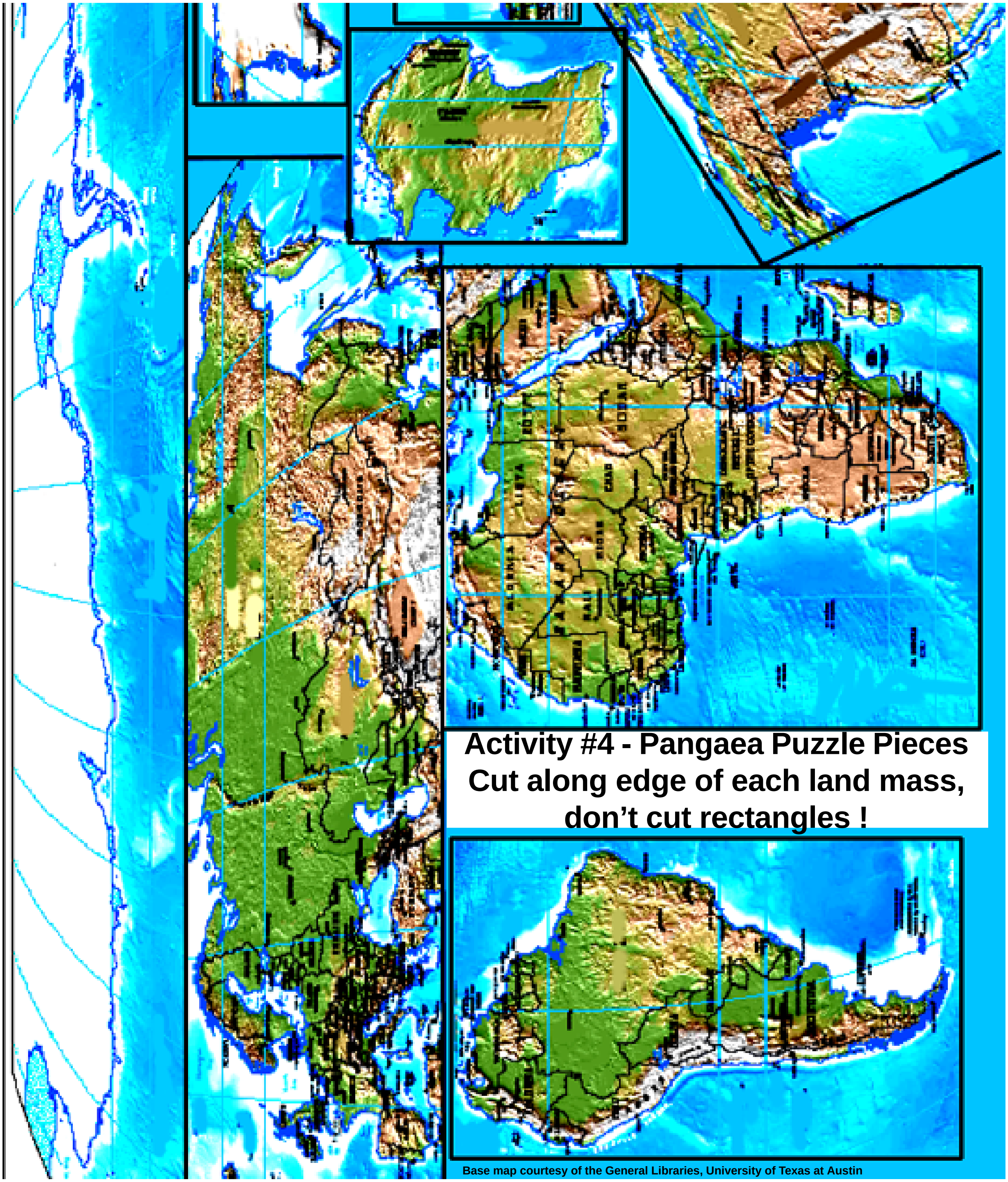
6. Fossils of Lystrosaurus, a mammal-like reptile, are known from Antarctica, India, and Africa.

7. Mountains in Greenland and Norway are almost identical in their geological structure.

8. The locations of earthquakes and volcanoes are not random. The occur along the margins of the crustal plates.

9. The mountains of Scotland and the Appalachian mountains of north Americal are almost identical in their geological structure.

10. The geological structure of southern Senegal and the Amazon Basin are almost identical.



Activity #4 - Pangaea Puzzle Pieces
Cut along edge of each land mass, don't cut rectangles !

Base map courtesy of the General Libraries, University of Texas at Austin

Activity #5 - Seafloor Block Model

Concepts # 1, 3, 5, 6

#1 The floor of the ocean is composed of hills, plains, ridges, trenches, and seamounts.
#3 Geologists and oceanographers use maps of the sea floor as tools for research and applied science (technology).
#5 Continual convection currents move the earth's crust, resulting in the formation of islands and deep oceanic trenches.
#6 Core drilling has produced information regarding the movement and density of the oceanic and continental crusts.

Objective:

Students construct a 3-D block model of the ocean floor to study fundamental earth processes.

Materials:

- block model sheet (cardstock isn't necessary, but can be used as an option if available)
- label tags sheet
- colored pencils or fine tipped felt markers
- scissors
- glue

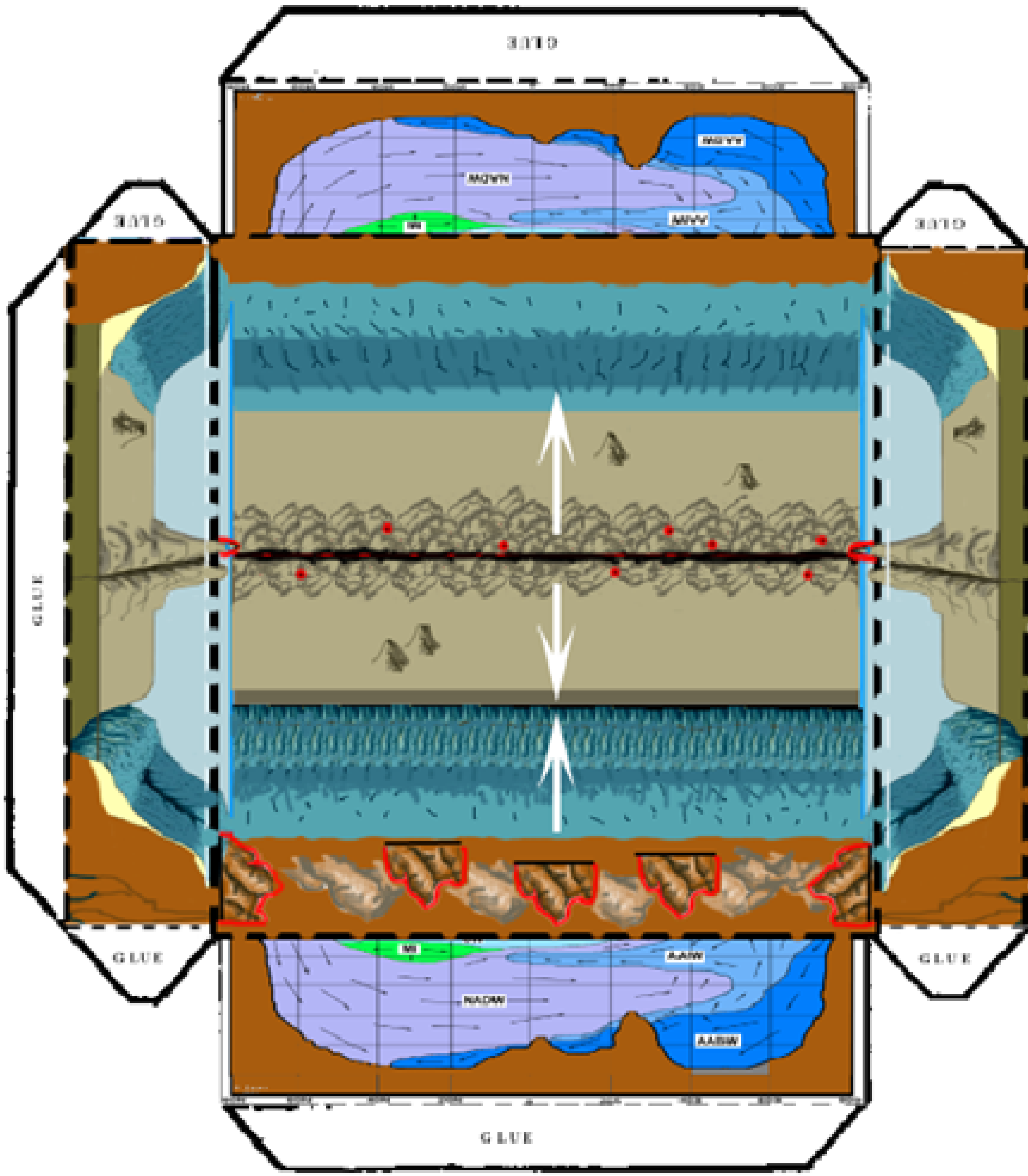
Procedures:

1. Cut out the block model from the sheet by cutting on the solid lines.
2. For extra fun cut out the mountains and islands and fold them up above the sea level. (see photo)
3. Make folds on the dashed lines.
4. After fitting your block model together to see how it will look, use your colored pens or pencils to color-in your model. Be creative, but use the same color patten on the top and along the sides.
5. Glue the model together using the flaps that say "glue."
6. Cut the label tags carefully, as close to the letters and words as possible. (Don't leave much white space around the borders).
7. Glue the label tags on the top and along the sides. Draw neat arrow from each label tag pointing to the correct feature.

Evaluation:

- Which crust, the oceanic or the continental, is thicker? (continental)
- Which type of crust floats higher above the mantle? (continental; the top of the continental crust is higher than the top of the oceanic crust, like an ice cube floating in water.)
- Which type of crust must, therefore, be less dense? (continental)
- Use arrows to draw in convection currents beneath the surface of the mid-ocean ridge.
- Place an "x" at the point(s) where the oceanic crust remelted to form the mantle.
- If the amount of crust remains the same, new crust must be formed to replace the crust that is remelted. Where is the new crust formed? (New crust is formed at the mid-ocean ridges of the deep ocean basin)
- Circle the path of molten rock from the mantle to the top of an oceanic volcano.
- The Pacific Ocean has many volcanic islands. There are also volcanic islands in the Atlantic Ocean. Name an island group that is an example of a volcanic island arc. (The Azores, Philippines, Marshall Islands, Tuamoto Islands, Fiji islands)
- What is thought to cause deep-ocean trenches? (Where plates collide, one dives under the other.)
- What does the theory of plate tectonics and continental drift say about the positions of the continents? (Hypothesizes that the continents are in relative motion and are not in the same positions as in the past. The continents are always changing.)
- Write a paragraph describing and explaining what the box demonstrates about earth processes. Use the terms found on the label tags in the paragraph.

Activity # 5 - Seafl
Block Model



DIRECTIONS:

-- Cut out object on solid black lines.
-- For fun, cut and fold up mountain
(top 2 corners and islands on midc
-- Fold on dotted lines to make a box
-- Glue tabs as marked.
-- Cut out label tags and glue them o
and sides.

name______________________

Activity #5 - Seafloor Block Model

Label Tags

HINT: Try to cut each label tag as close to the letters and words as you can. (Don't leave a lot of white space around the edges of each tag). Don't worry if you end up with extra tags !

ABYSSAL
PLAINS

RIFT

SEAMOUNT

ISLAND

TRENCH

TRENCH

ABYSSAL
PLAINS

RIFT

RIDGE

RIDGE

SLOPE

SLOPE

SLOPE

SLOPE

SHELF

SHELF

SHELF

SHELF

CONTINENTAL
CRUST

CONTINENTAL
CRUST

OCEANIC
CRUST

OCEANIC
CRUST

LAND
MASS

LAND
MASS

GUYOT

GUYOT

ABYSSAL
PLAINS

RISE

RISE

Activity #5 - Seafloor Block Model

View of Completed Model