Real Evidence of a Subducting Plate

By
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TOPIC: Plate Tectonics

GRADE LEVEL: 9 - 12

CONTENT STANDARD: Earth and Space Science

CONTENT OBJECTIVE: To provide students with actual data to interpret

TIME REQUIRED: 90 minutes

Teacher's Guide:

Introduction

The objective of this activity is to allow students to manipulate real data and understand how such data is interpreted and used in support of a theory. The concepts studied are maps, earthquakes, and plate tectonics, particularly a subduction zone plate boundary. The student will learn or be refreshed on using latitude and longitude for mapping purposes. The activity should be used in a unit on plate tectonics so that the student has a basic understanding of plate tectonics, plate boundaries, and types of crust. It is also useful that the class have a discussion abut the different types of evidence used to support the theory of plate tectonics.

Materials (per group)

- 1 box, lightweight, for example 1' x 0.5' x 1'or large shoebox on side
- 22 balls or beads of 3 colors, approx. ¾ diameter (Styrofoam works well)
- Glue and masking tape
- Heavy thread/string
- 2 rulers
- Scissors
- 1 map of area in South America
- Earthquake data table
- 22 paper fasteners or push pins or 1 darning needle

Preparation

Students should work in groups of 2-3, with each group having at least one student with good hand/eye motor skills. Overheads should be prepared to discuss latitude and longitude. The first point should be plotted together. An overhead of the South American map is needed for this.

This activity can be presented after a discussion of plate tectonics and its supporting evidence to reinforce how theories are developed from the available data. After answering the results questions, a more detailed discussion of the three types of plate boundaries will fit nicely, and allow students to answer the conclusion questions. Questions on what causes the trench should thus emphasize the physical manifestations of subduction activity.

This lab can also be used as an introduction to plate tectonics, as a springboard for discussing plates, plate boundaries, data interpretation, etc. Class discussion of the conclusion questions will hopefully kindle the students' interest in the topic.

This activity contains a good hands-on model that allows interaction and cooperation among students. The concept developed is very interesting and, through this modeling, easy to grasp. Seeing actual data (as opposed to fabricated data to make the activity work well) being used is also very exciting, and helps sustain interest and credibility to the theory of plate tectonics.

Running the Activity

The teacher should read through the student directions at this point to understand what they are directed to construct (see Figure T-1). Each group will have to construct the box and determine how to tape the map on correctly. The teacher can have each student plot the station points on their own map, or have it be a group effort. This is easier to do before it is taped to the box. Students should be warned to do one epicenter at a time and label it well with the station numbers to save time searching for it later. It is also possible to have one student locating the epicenter, one making the ball and string, and a third actually constructing the model with the material from the first two students. Students should swap jobs at certain points throughout the lab.

There are several options for making the model itself. Styrofoam balls can be used, and the thread can be pushed through a hole pre-made with a pushpin. A darning needle would work great with this method as well. If you do not wish to use darning needles, another option is to fasten the strings to the top of the box with paper fasteners ("brad clips") - wrap the string around the end of the pin, adjusting for length, push the ends up through the box and flatten the ends on the map. Make the hole with scissors to make it large enough. The strings can also simply be taped to the underside of the top of the box, with students feeling a hole at the epicenters made by a pushpin. In either case, the epicenter can be found by pushing a pin through the top of it and locating the hole on the underside.

A further suggestion is to use different color beads for different magnitudes, OR for different depths (e.g., three colors for shallow, intermediate, and deep quakes). Paper clips can also work – the sky is the limit (or the budget). The map could be copied onto a transparency, a hole cut into the top of the box, and the map placed over the hole so that the student can look down upon the final product. Different colored beads would allow students to see the pattern of where the different levels of earthquakes are located. The map would have to be firmly attached to the box, however, and very light beads would be needed so that the transparency isn't too heavily weighted. Using this method, it would be much easier to use a darning needle to pull the thread through the map.

Students will immediately see the pattern that the balls make if constructed correctly. Questions are geared toward making the connection between the earthquakes and moving rock – and the fact that a belt of earthquakes means large masses of rocks (plates) are moving against each other.

A general sketch of what the final product will look like is provided (figure T-1). The data can also be used to make a cross-section graph by ignoring the latitude data and plotting longitude vs. depth below the surface. This may be more appropriate for higher-level students capable of abstract thinking. Scale is also optional. We believe that a scale with a vertical exaggeration of 2 works well, but it is possible to have no vertical exaggeration. An exaggeration of 4 makes the slope of the lower plate appear much too steep. A graph of the data at actual vertical scale is shown in figure T-2.

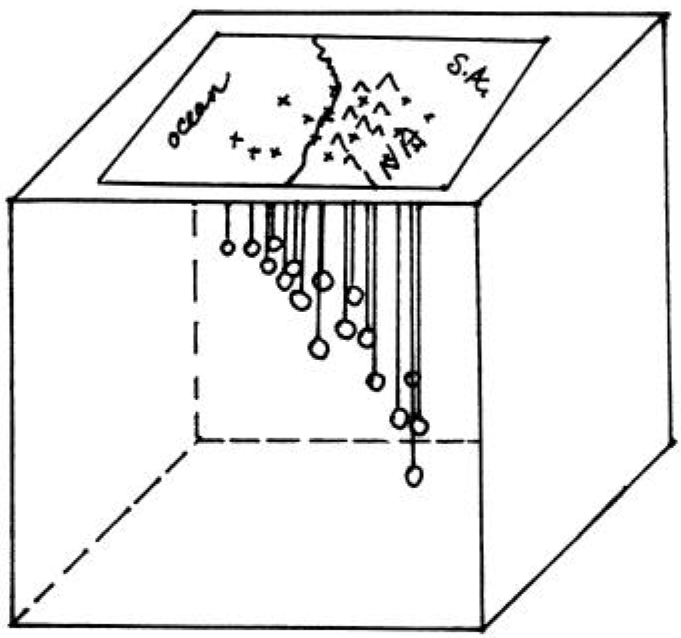

Figure T-1. Sketch of final box model using Styrofoam balls.

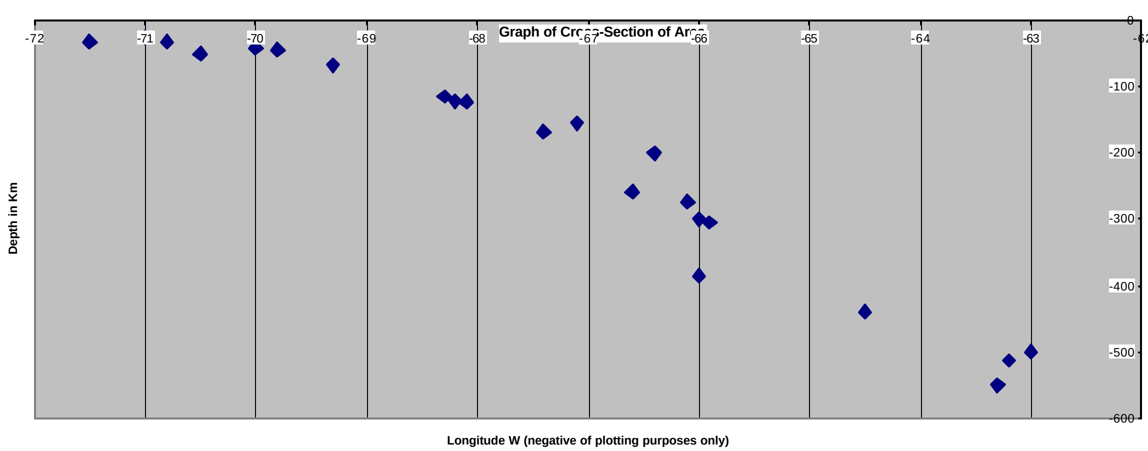

Figure T-2. Graph of cross section of map area with no vertical exaggeration showing the true angle of dip of the Nazca Plate beneath the South American Plate.

Making Conclusions

It is important to make the connection of earthquakes and moving rocks, as mentioned above. A key point is what causes the earthquakes - motion. The teacher should try to have students make connections between this motion and the continental and oceanic plates of crust interacting in this region. Since the motion of the plate is not given, it is important to think about the densities of the plates, and to look at the map showing ridges and trenches to figure out which direction the Nazca plate is probably moving (see included map of plate boundaries).

The teacher should also, through discussion of questions, have students come up with ideas about the trench located off the coast. Further discussion could deal with the Andes and their formation from hot magma welling up from the deep below the continental crust. Encourage ideas about where the hot stuff comes from. Finally the teacher should hand out or show an overhead of a diagram of the subducting Nazca plate below the South American plate to indicate what geologists believe is happening in the area. Overall, however, one of the most important points to cover in this activity is that actual data is used and taken as is, plotted in an appropriate manner, and then interpreted to give the best explanation. The activity fits in well with the discussion of the history of plate tectonics.

Resources

An excellent video source for this topic is the *Planet Earth* series. Several of the videos cover plate tectonics theory, especially *The Living Machine*, and show footage of mid-ocean ridge activity and underwater pillow basalt formation (in Hawaii). There are also excellent graphics showing the three boundary types in the first episode. It can be ordered from most earth science catalogs or from www.cduniverse.com.

An online resource describing plate tectonics and showing a subduction boundary is located at http://www.seismo.unr.edu/ftp/pub/louie/class/100/plate-tectonics.html

Data for the earthquakes was obtained via Internet from various sources such as the National Earthquake Research Center in Boulder, CO.

To get even more real data or to update the data we present, go to http://quake.wr.usgs.gov
This site also has additional resource links.

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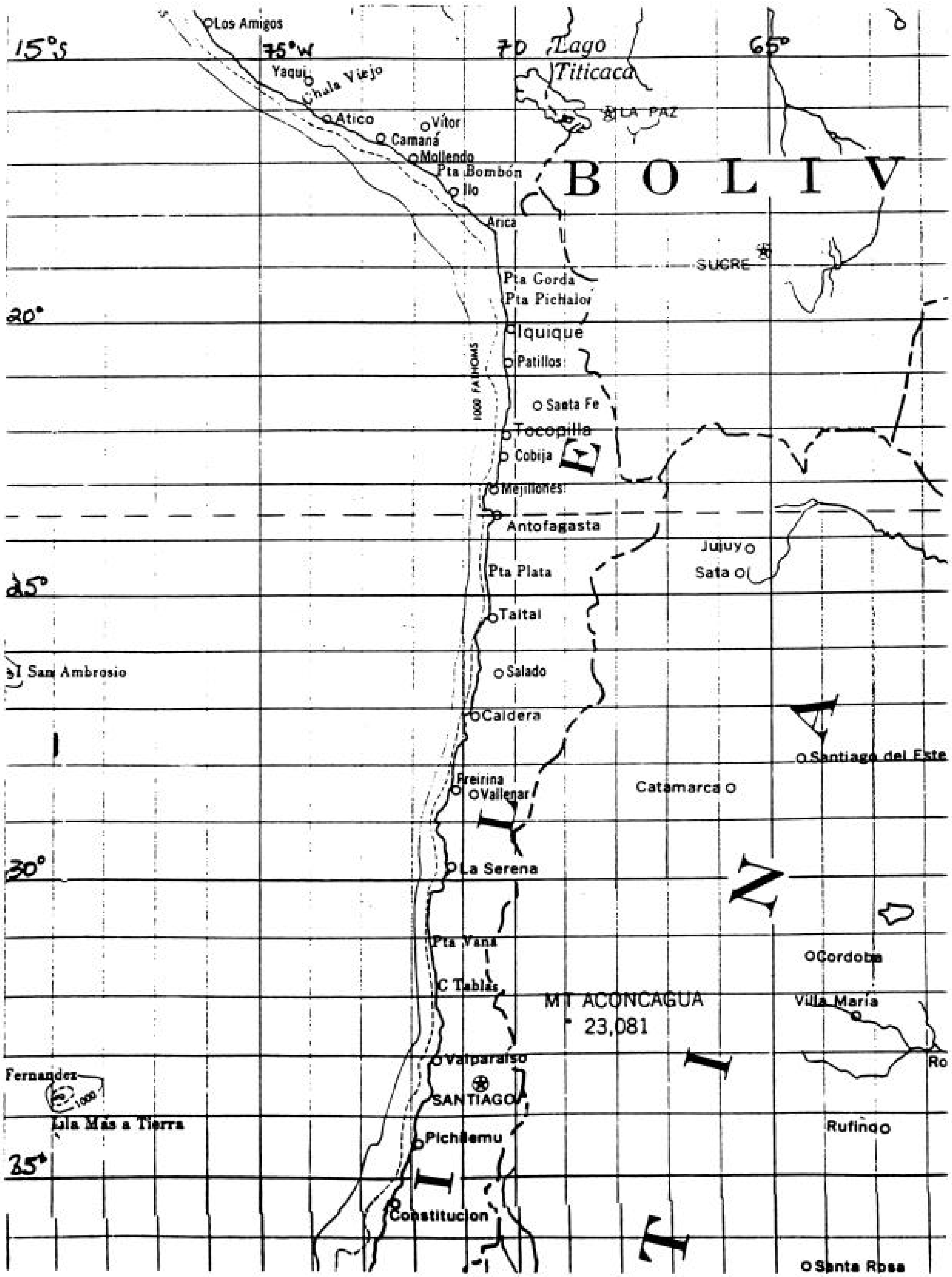

Map of South America between latitudes 35°S and 15°S and between longitudes 70°W and 62°W.

STUDENT GUIDE **Name: _________________**

Real Evidence of a Subducting Plate

Introduction

As you've learned in this unit, the uppermost crust of the Earth is believed to be made up of a series of plates. The rocks that make up the continental plates are lighter colored and less dense than the rocks that make up the oceanic plates. Earthquakes and volcanoes are the result of the interaction of the rocks that make up these plates, and the kinds of earthquakes and volcanoes produced depends on whether the plates are coming together, spreading apart, or sliding past each other.

The theory of plate tectonics has been widely accepted because of the many pieces of evidence that support it. You have already discussed some of the evidence in this unit. Like solving a jigsaw puzzle, scientists look for the best explanation that fits all the data available. In the following lab, you will be looking at earthquake data and determining if plate tectonics can explain what you find.

EARTHQUAKES AND FAULTS

Earthquakes and faults are caused by the movement of the earth's crust as it is pushed together or pulled apart. As the movement occurs, the rocks will often break and grind together, releasing vibrations of energy into the ground. The plane along which the rocks break and move is called a **fault** (see figure 1). This fault can occur near the ground surface where humans can actually see it, or deep below the ground. The technology we use to detect earthquakes can actually tell us exactly where the faulting has occurred below the surface. Figure 1 shows two blocks of earth that are sliding against each other. The location at which the rocks actually break during a single event is called the **focus (**or hypocenter) of the earthquake.

The point on the earth's surface that is directly above the focus is called the **epicenter**. This is the area where the most violent shaking will occur because it is directly above the actual rock movement.

Procedure

On your data table you will find information on earthquakes near the west coast of South America. Provided are the latitude, longitude, depth and magnitude (how strong the earthquake was) of each earthquake.

Your research will require you to take the data provided on earthquakes, construct a 3-D dimensional model of these events, and determine what type of pattern (if any) that the earthquakes create in the region.

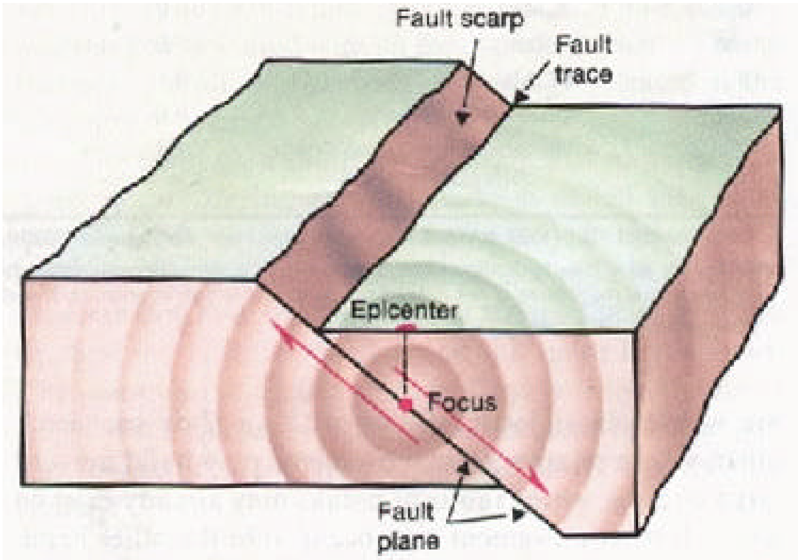

Figure 1. Diagram showing a fault plane (Image courtesy of Kian H. Chong, Univ. of California, Davis)

1. Locate the epicenter of each earthquake and plot it on the map provided.

To do this you must plot the latitude and longitude of the epicenter. Latitude is the measure of the distance north and south of the equator, like the x-axis of a graph. Longitude is the measure of the distance east and west of the prime meridian, like the y-axis of a graph. See figure 2 for help on plotting the points. You are given one line of latitude and one line of longitude for each. Like a graph, you need to find where these two lines meet – that will be the location of the earthquake epicenter. We will plot the first point together in class.

2. Lay the box on its side and tape the map on what is now the top surface of the box. Orient the map so that the boundary between the ocean and the continent is perpendicular to the open end of the box.

The map represents the surface of the land, while the open side of the box represents your view of the crust beneath the surface. This view is called a cross-section view of the earth. Figure 3 shows a cross-section of the area in South America that we are studying along the Tropic of Capricorn (23.5^o S latitude).

3. At each epicenter point, punch a hole with the pushpin through the map and box. The hole needs to be big enough to push a piece of your thread through (but not too big!). Hang a Styrofoam ball so that it represent the focus of each earthquake:

For each of your epicenters, you have information about the depth of the earthquake. To make a three-dimensional representation of the earthquakes in this area, you are going to use a Styrofoam ball to represent where the FOCUS of the earthquake is. From the epicenter, you need to hang a Styrofoam ball on a length of string that represents the depth of the earthquake. Be careful of your scale!!

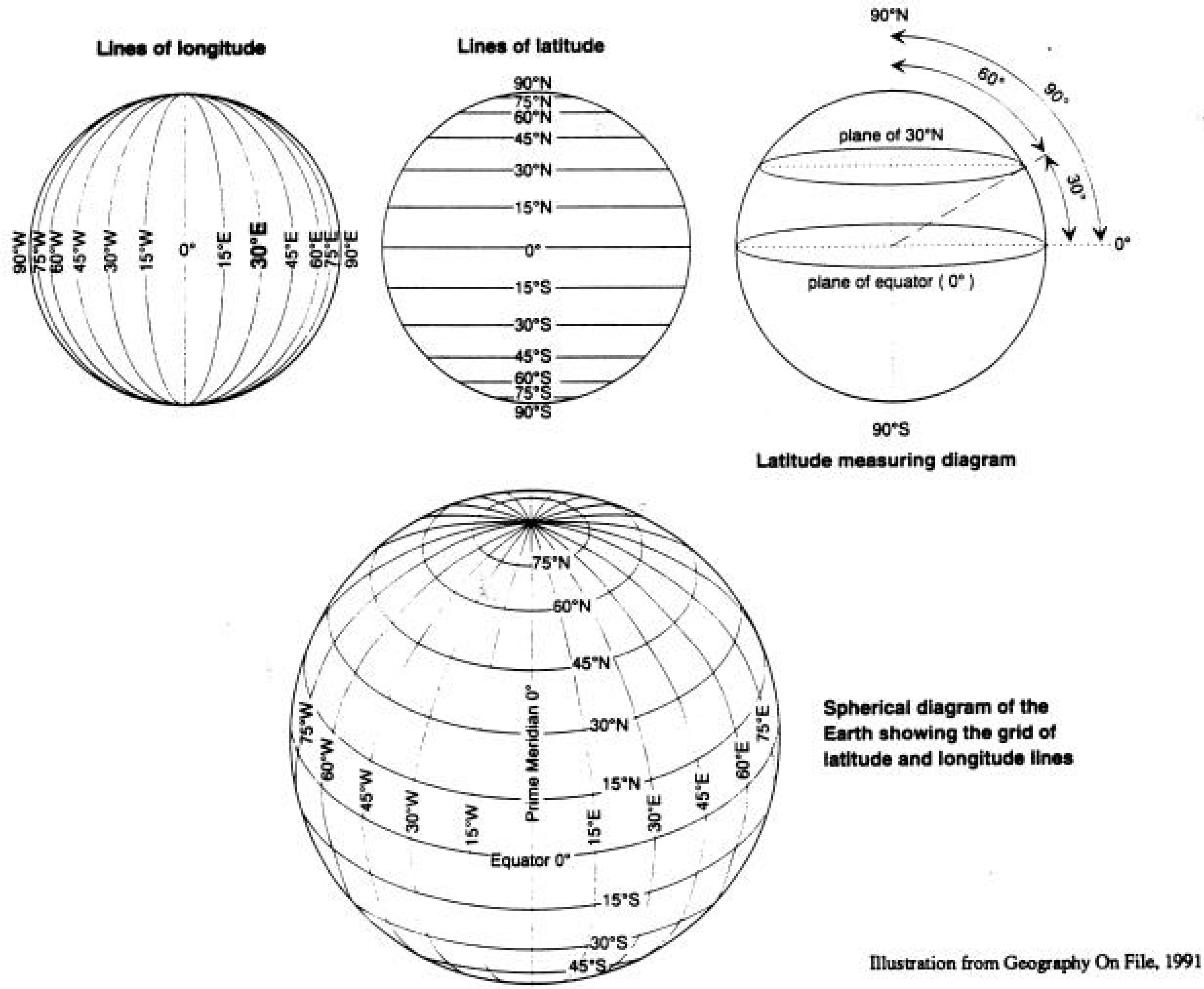

Figure 2. Lines of latitude and longitude of the Earth.

REMEMBER: you must consider the deepest earthquake and use a scale so that it will fit into the box. You should most often use the same scale as the one used for the map of South America. However, scientists sometimes change the vertical scale so that the feature you are studying shows up better for analysis. Most 3-D globes you see that show the mountains on the earth have an "exaggerated vertical scale," otherwise even the highest mountains would barely show up. For your South American map, the distance between each degree of latitude and between each degree of longitude is about 111 km (~69 miles). That is your scale. If your deepest earthquake is 500 km, that may only be about 5 cm deep! Differences in depth wouldn't show up very well, so you may want to exaggerate the vertical scale. Perhaps you would rather make the scale 4 times more than the actual scale. Therefore your deepest ball would be at 20 cm. Experiment with this and determine which scale fits your box and your purpose best.

To hang the Styrofoam balls, you need to first attach one end of the string to the Styrofoam ball. You then need to determine the length of the string that will represent the depth of the earthquake. Mark the string at that point. Pull the string up through the hole you made at the epicenter until the ball is at the correct depth. Repeat for each of the earthquakes.

4. When you are finished with your model, please answer the results questions:

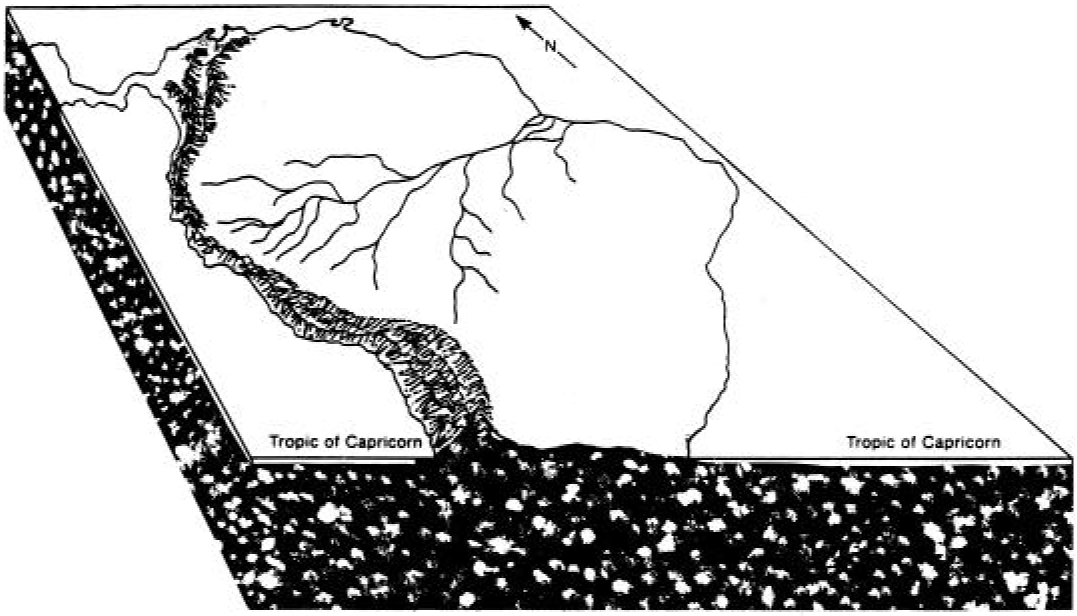

Figure 3. A cross-section of South America along the Tropic of Capricorn. Notice sea-level and the Andes mountains that rise high above the rest of the continent.
Illustration from CEEP (Crustal Evolution Education Project, Wards Natural Science Establishment, Inc.)

TABLE 1. Table with data from actual earthquakes in South America from 1993-1994.

Station	Latitude (S)	Longitude (W)	Depth (Km)	Magnitude
1	19.8	66.6	259	4.6
2	27.8	63.2	513	5.1
3	26.2	63.3	550	4.8
4	31.2	71.5	33	5.0
5	23.2	66.4	200	4.8
6	23.5	71.0	25	5.0
7	24.5	70.8	33	5.0
8	21.3	68.2	122	4.7
9	23.6	70.0	42	5.0
10	23.5	70.5	50	NA
11	22.9	68.3	115	4.8
12	34.1	69.8	45	NA
13	22.3	66.1	274	5.0
14	23.2	69.3	67	4.9
15	22.5	67.4	168	4.5
16	19.5	65.8	305	4.5
17	21.4	68.1	123	5.1
18	27.0	63	500	4.9
19	27.2	67.1	155	4.7
20	20.4	66.0	300	4.5
21	25.6	66.0	385	5.0
22	22.2	64.5	440	4.8

Looking at the Results:
Please answer the following questions:

1. What information does an epicenter provide about an earthquake?

2. What is the difference between the focus and the epicenter of an earthquake?

3. What is happening to the rocks at the focus of an earthquake, and what do we call this?

4. What do you notice about the depth of the focus of the earthquakes as you go further inland from the coast of South America?

5. What appears to be happening to the two plates that meet along the west coast of South America, according to your model?

6. Draw and label a diagram or make a model showing what is happening to the plates along the west coast of SA as you described in question 5:

Making Conclusions:

1. Describe the type of plate boundary which you think is present along the west coast of South America.

2. Explain how your data supports your conclusions in question 1.

3. How can our model explain the deep trench that lies just off the coast of South America?

4. Looking at the maps of the world attached (figure 4), can you find some other areas where this same type of plate boundary is occurring?

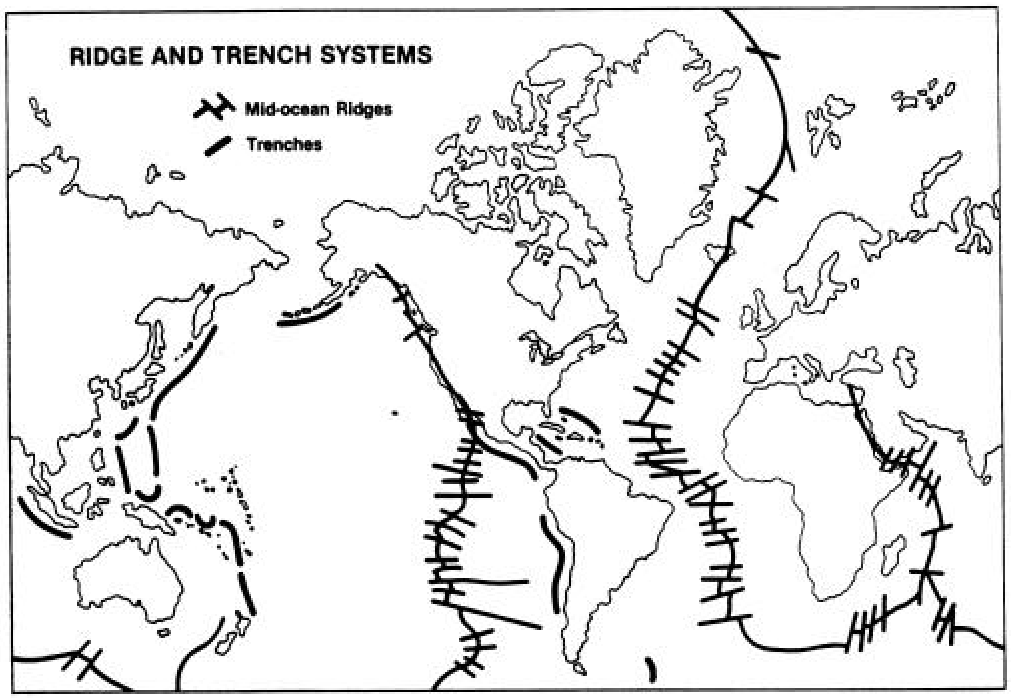

Figure 4. Ridge and trench systems of the world. Ridges are where new ocean crust is being formed (plates are moving apart). Trenches are formed where an oceanic plate is being subducted (plates are coming together). Figure from Global Science Laboratory Manual, John W. Christensen, Kendall/Hunt Publishing.

Going Further

1. Consider the following: How is volcanism related to this type of boundary (study where it is in relation to the trench and plates)?

2. Mt. St. Helens is part of a volcanic belt formed under similar conditions as the Andes Mountains. Search the Internet of library for seismicity data regarding the Oregon/Washington coast of the United States. What is happening there? What are the differences between this area and the SA coast?

Facts from the USGS earthquake site: http://earthquake.usgs.gov/4kids/facts.html

1. The **largest recorded earthquake in the United States** was a magnitude 9.2 that struck Prince William Sound, Alaska on Good Friday, March 28, 1964.
2. The **largest recorded earthquake in the world** was a magnitude 9.5 (Mw) in Chile on May 22, 1960.
3. The **earliest reported earthquake in California** was felt in 1769 by the exploring expedition of Gaspar de Portola while the group was camping about 48 kilometers (30 miles) southeast of Los Angeles.
4. The **average rate of motion across the San Andreas Fault Zone** during the past 3 million years is 56 mm/yr (2 in/yr). This is about the same rate at which your fingernails grow. Assuming this rate continues, scientists project that Los Angeles and San Francisco will be adjacent to one another in approximately 15 million years.
5. The **East African Rift System** is a 50-60 km (31-37 miles) wide zone of active volcanics and faulting that extends north-south in eastern Africa for more than 3000 km (1864 miles) from Ethiopia in the north to Zambezi in the south. It is a rare example of an active continental rift zone, where a continental plate is attempting to split into two plates which are moving away from one another.
6. The **first "pendulum seismoscope"** to measure the shaking of the ground during an earthquake was developed in 1751, and it wasn't until 1855 that faults were recognized as the source of earthquakes.
7. Although both are sea waves, a **tsunami and a tidal wave** are two different unrelated phenomenon. A tidal wave is a large sea wave produced by high winds, and a tsunami is a sea wave caused by an underwater earthquake or landslide (usually triggered by an earthquake) displacing the ocean water.
8. The **hypocenter** of an earthquake is the location beneath the earth's surface where the rupture of the fault begins. The **epicenter** of an earthquake is the location directly above the hypocenter on the surface of the earth.
9. The **greatest mountain range** is the Mid-Ocean Ridge, extending 64,374 km (40,000 mi) from the Arctic Ocean to the Atlantic Ocean, around Africa, Asia, and Australia, and under the Pacific Ocean to the west coast of North America. It has a greatest height of 4207 m (13,800 ft) above the base ocean depth.
10. The world's **greatest land mountain range** is the Himalaya-Karakoram. It contains 96 of the world's 109 peaks of over 7317 m (24,000 ft). The longest range is the Andes of South America which is 7564 km (4700 mi) in length. Both were created by the movement of tectonic plates.
11. It is estimated that there are **500,000 detectable earthquakes** in the world each year. 100,000 of those can be felt, and 100 of them cause damage.