The Sumatra Earthquake and Tsunami
December 26, 2004

Introduction: The incredible damage and tragic loss of life resulting from the 9.0 magnitude earthquake and ensuing tsunami was shocking and almost beyond belief. The event marked the most devastating natural disaster to hit the world in the last century.

While earthquakes are somewhat unpredictable, and always beyond our control, earthquake related tsunamis can be measured and predicted in time to provide some warning to residents of susceptible coastal areas, and shoreline structures can be built to withstand the force of a tsunami. And there are natural warning signs of impending tsunamis, too, that properly understood and heeded can give individuals along the shore time to get to higher ground. Unfortunately for the tens of thousands of victims of the tsunami, a warning system did not exist in the Indian Ocean Basin, most shoreline structures were not built to reduce the destruction from the force of a tsunami, and many people on the shores did not recognize or understand the warnings nature provided.

We will learn from this tragedy, and hopefully work to provide better warning systems, better construction, and better natural disaster preparedness education in the future.

In this lab you'll study seismograms from 3 different seismic stations recording the magnitude 9.0 Sumatra earthquake of December 26th, 2004. By comparing the arrival times of the P and S waves on each seismogram, you'll be able to determine the distance from the epicenter to each station. Using that data, you can accurately map the location of the epicenter of the earthquake. Once you've located the epicenter, you'll calculate the position of the tsunami generated by the quake at one hour intervals. From those determinations, you will be able to predict how much time people had before the tsunami crashed onto their shores. Finally, you will investigate some of the ways people can lessen the impact of the next great tsunami.

Materials:
- 2 sets of 3 seismograms from the same earthquake (included here)
- Drawing compass
- *P-* and *S-wave* travel time curves (included here)
- Tectonic map of the world
- Maps 1 and 2 for plotting the earthquake epicenter (included here)
- Scrap paper for calculations
- Web resources

Procedure Part 1: Finding the Epicenter

1. Read the time of the P and S waves at each station and place that information in your data table below. Read each arrival time to the nearest second. Note: The first vertical line marks the P-wave arrival and the second vertical line marks the S-wave arrival time.

2. Devise a way to determine the amount of time that elapsed between the arrival of the P and S waves at each station. One way is to subtract the P-wave arrival time from the S-wave arrival time (S-P), though there is a more direct way to get that information off the seismogram. Double check and record your results in DATA TABLE 1.

3. Use the P and S wave travel-time curves to find the distance from each station to the earthquake epicenter. Do this by finding the unique epicenter distance where the difference in the P and S wave travel times is exactly equal to the difference you calculated from the seismogram. Record that distance in the last column of the data table.

4. On the "Indonesian Earthquake" map, use the map scale and your compass to draw circles around each station of a radius equal to the epicenter distances that you just determined using the travel time curves.

5. The intersection of the 3 circles marks the epicenter of the 'quake. Label it "Epicenter" on your map.

DATA TABLE 1:

Seismograph Station	P-wave Arrival	S-wave Arrival	Time Difference (S – P)	Epicenter Distance
IC.LSA				
KMBO				
GUMO				

Part 1 Questions/Activities: (Use whatever resources you need)

1. Which seismic station is located farthest from the epicenter?_____

   a. How could you have determined which was farthest by simply looking the seismograms? _____

   _____

   _____

2. The quake occurred on a tectonic plate boundary. Refer to the tectonic map to answer the following questions:

   a. Between what 2 tectonic plates did this 'quake occur? _____ and _____

   b. How are the plates moving relative to each other in the area of the 'quake?_____

   _____

   c. What term describes this kind of plate boundary? _____

3. The focus of the quake occurred about 150 km (90 mi) northeast of the surface expression of the plate boundary (see map section below, right), and at a depth of about 30 km (18 mi).

   a. Explain how this information helps you to determine which plate is

   being subducted. _____

   _____

   _____

   b. On the grid below, draw a properly scaled profile of the plate boundary region along line A-B. Draw the plate boundary, and mark the location of the earthquake focus with a small star.
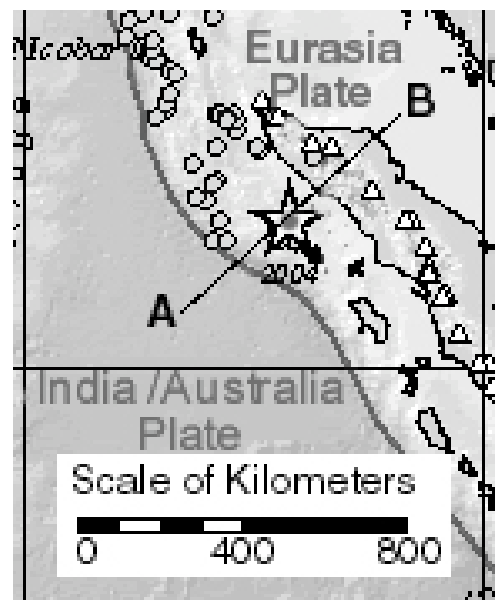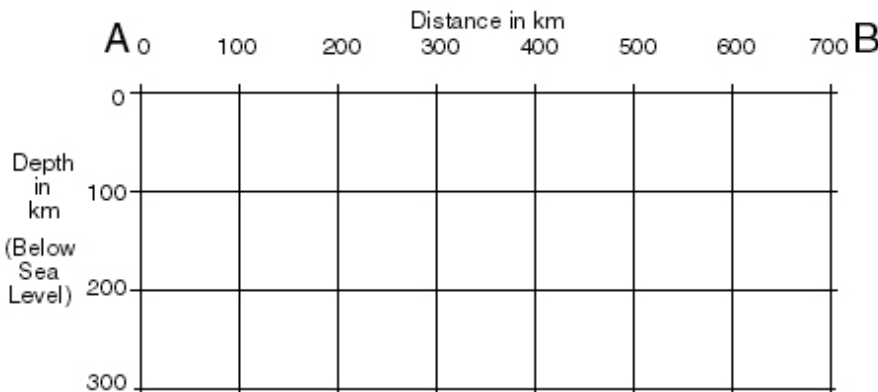
4. For each station, subtract the P-wave travel time from the time that the station first felt the P-wave. This will tell you when the P-wave left – and when the earthquake actually occurred! You will need to use your reference tables to answer these questions.

Show your work here!

IC.LSA: _____   KMBO: _____   GUMO: _____

Check with one of the web resources to find the actual time of the quake and record it here: _____

*Cite your source of information:_____

Explain why there might be some variation among the times you've recorded above _____

_____

Procedure Part 2: Using more data to find the epicenter

Now that you have an idea where the earthquake originated you will use three closer seismograph stations to more accurately pinpoint the location of the epicenter.

1. Label the following Countries on MAP 2: (Use whatever resources you need)

   India, Sri Lanka, Somalia, Sumatra (Indonesia), Myanmar, Thailand,

2. Follow the same procedures used in Part 1 to find the epicenter on Map 2.

   *You will need to use the seismograms from stations: PALK, DGAR, and COCO.

DATA TABLE 2:

Seismograph Station	P-wave Arrival	S-wave Arrival	Time Difference (S – P)	Epicenter Distance
PALK				
DGAR				
COCO				

Part 2 Question:

1. Why do you need at least three seismic stations to find the epicenter of the quake?_____

_____

_____

Procedure Part 3: Predicting the Arrival of Tsunami Waves

The speed at which a tsunami moves through the ocean is dependant largely on the depth of the ocean. The tsunami generated by this quake moved at an average speed of about 600 kilometers per hour. Though tsunamis travel fast, their wave heights are at most only a few feet, and the wavelengths are over 100 km long (!), so they are often unnoticed as they pass beneath ships at sea. As they approach shallow water near the coast however, tsunami waves slow down, the wavelength shortens, and heights may increase to many meters. http://vulcan.wr.usgs.gov/Glossary/Tsunami/description_tsunami.html

Assume the tsunami generated by the Great Sumatra Quake traveled 600 km/hr in the open ocean. On Map 2, draw and label circles around the epicenter showing the distance the tsunami had traveled in 1 hour, 2 hours, 3 hours, and 4 hours.

(You should have four labeled circles surrounding your epicenter representing the position of the leading edge of the tsunami as it traveled through the ocean after the earthquake occurred)

Procedure Part 4: Speed of Seismic Waves

On the data table below, list the 6 seismic stations you've used in order of increasing distance from the epicenter.
Fill in the P-wave travel time (convert minutes and seconds to seconds) and distance data, and finally calculate and record the average speed of the P-waves arriving at each station.

DATA TABLE 3:

Station	Epicenter Distance (km)	P-Wave Travel Time (s)	Average Speed of Recorded P-Waves (km/s)

At first glimpse, the results of your calculations may be surprising. How can the differences in average speed be explained? Investigate the way the seismic waves travel through the earth, and explain why the waves arriving at more distant places travel at a higher average speed.

_____

_____

_____

_____

*Cite your sources of information: _____

Concluding Questions (Use whatever resources you need)

1. Investigate the number of people killed by the tsunami in the following countries:

- India _____
- Sri Lanka _____
- Thailand _____
- Myanmar _____
- Somalia _____

Current Total number casualties _____

Why do you suppose Indonesia's casualty rate was so high? _____

_____

Had a warning system been in effect, would there have been time to warn the residents of Aceh at the

northern tip of Sumatra?_____

How might the residents of Aceh have known that there was some danger of a tsunami before it actually
arrived? _____

_____

Cite source(s) of information: (You may attach articles of interest to your lab report)

_____

_____

_____

2. Using MAP 2 and the tsunami circles that you drew, estimate the amount of time that these countries had
   before the tsunami crashed onto their shores.

- India _____
- Sri Lanka _____
- Thailand _____
- Indonesia _____
- Myanmar _____
- Somalia _____

3. Based on the videos you watched, how much time do you believe you would need to get to a place of safety to

   escape the wrath of the tsunami once the first wave came ashore? _____

   Where would you go? Why? _____

   _____

   _____

4. Assume that you live in small town on the coast of Oregon.
   What geologic conditions exist in that part of the world that might cause a tsunami?

   _____

   _____

   What should you know and how should you be prepared for a tsunami?_____

   _____

   _____

5. Tsunamis are likely to occur when large earthquakes occur on the seafloor, as happens in the Pacific Ocean. Investigate and briefly describe the warning system that exists in the Pacific Ocean. Why do you think no such system exists in the Indian Ocean?
(*Cite your sources or attach the originals)

   Summarize of your findings here:

   _____

   _____

   _____

   _____

   _____

   (*Cite your sources or attach the originals)

Web Resources:

Indonesian Earthquake Web pages by the authors:
   http://www.bedford.k12.ny.us/flhs/science/images/tsunami2004/
   http://www.wilson.wnyric.org/t/drobison/regents/WellOrganized/tsunami.htm

STANYS WEBSHARE (share different versions)
   http://www.wilson.wnyric.org/t/drobison/webshare/index.php

GEE software for real time data from hundreds of seismic stations:
   http://www.seis.sc.edu/gee/

IRIS Data Management Center
   http://www.iris.edu/

USGS Earthquake Hazards page:
   http://eqhazmaps.usgs.gov/

USGS pages regarding this quake:
   http://earthquake.usgs.gov/eqinthenews/2004/usslav/

CNN's special coverage of the event:
   http://www.cnn.com/SPECIALS/2004/tsunami.disaster/

Yahoo News coverage of the event:
   http://news.yahoo.com/asiadisaster

FEMA's tsunami pages:
   http://www.fema.gov/areyouready/tsunamis.shtm

APOD The Powerful Sumatra-Andaman Islands Earthquake
   http://antwrp.gsfc.nasa.gov/apod/ap050302.html

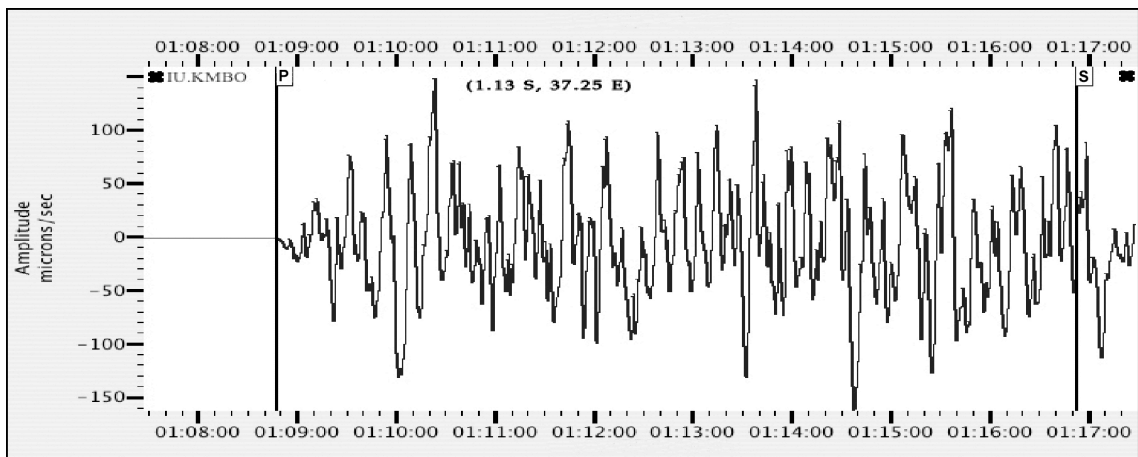Contact the Authors: Dave Robison (drobison@wilson.wnyric.org); Steve Kluge (skluge@bedford.k12.ny.us)

Maps and Charts
SEISMOGRAMS for Part 1
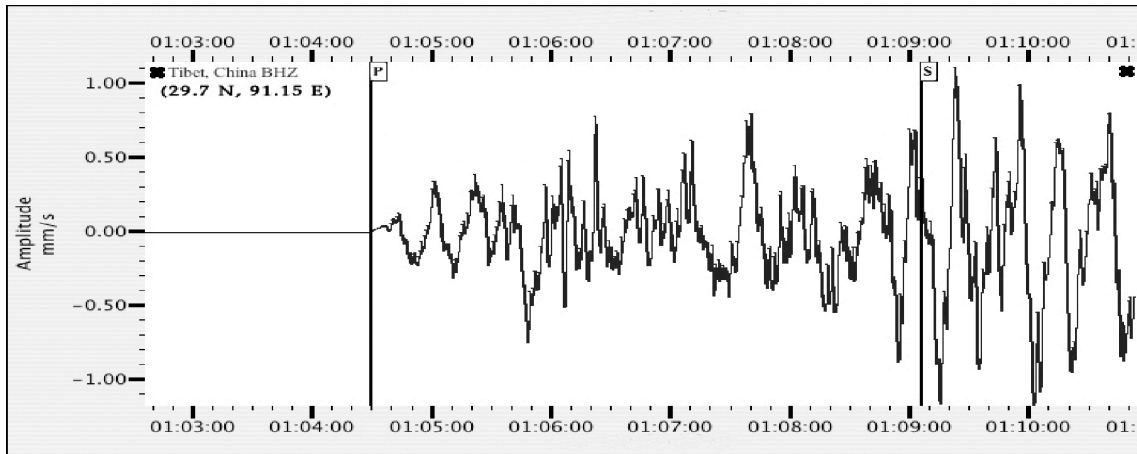
IC.LSA (Tibet, China): Latitude:29.7 N, Longitude:91.15 E
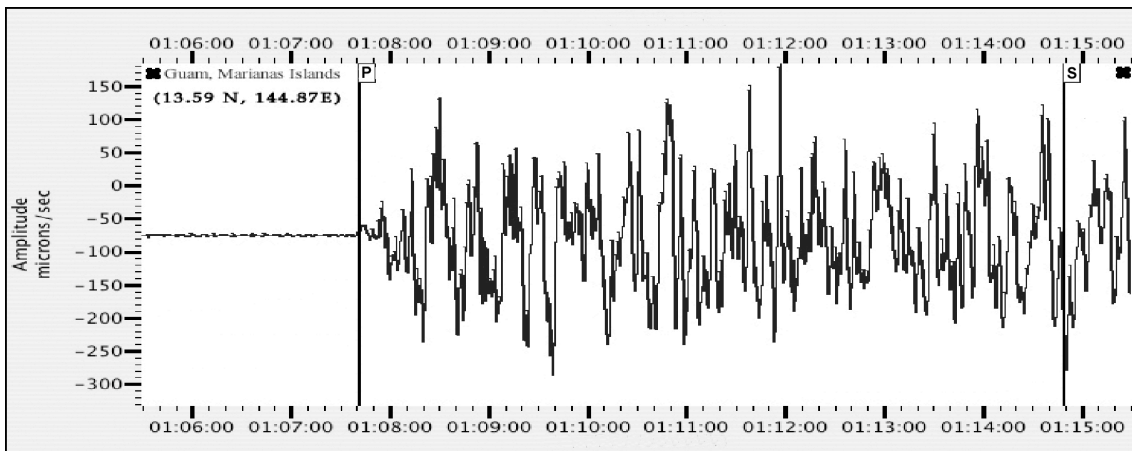http://www.fdsn.org/station_book/IC/LSA/lsa.html

KMBO Latitude: 1.13 S, Longitude: 37.25 E
http://www.fdsn.org/station_book/IU/KMBO/kmbo.html

GUMO - Guam, Mariana Islands Latitude: 13.59 N, Longitude: 144.87 E
http://www.fdsn.org/station_book/IU/GUMO/gumo.html
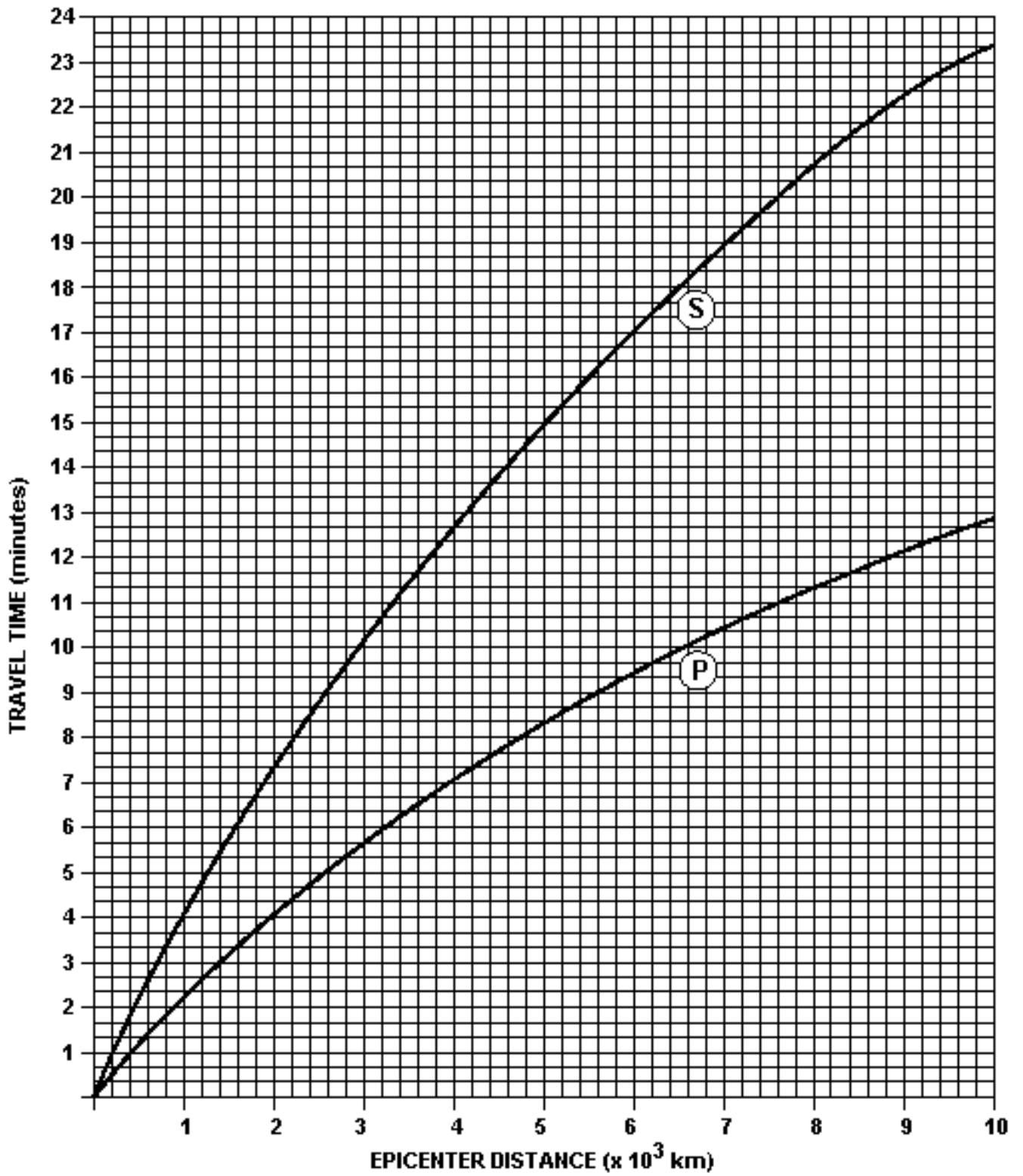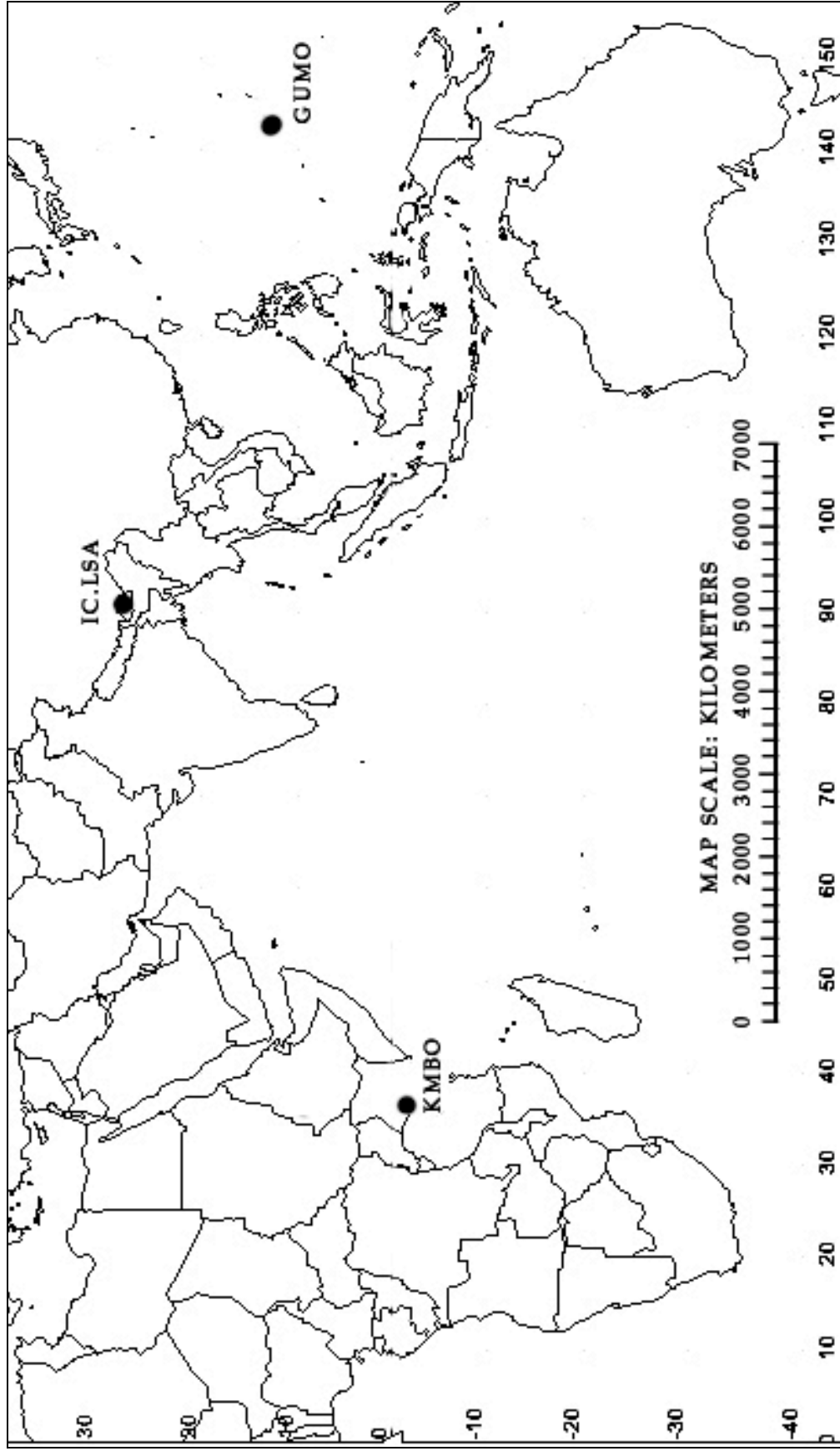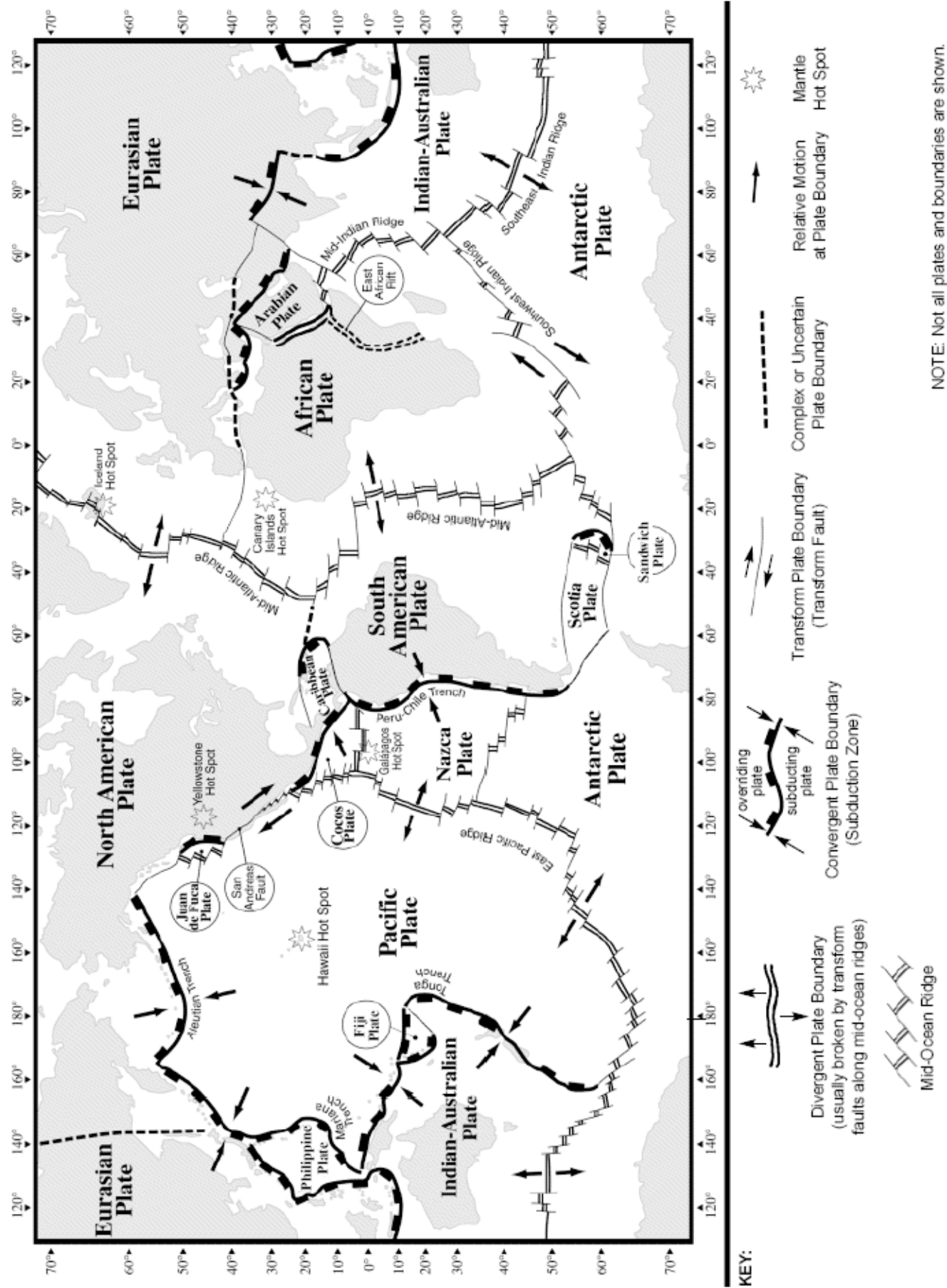
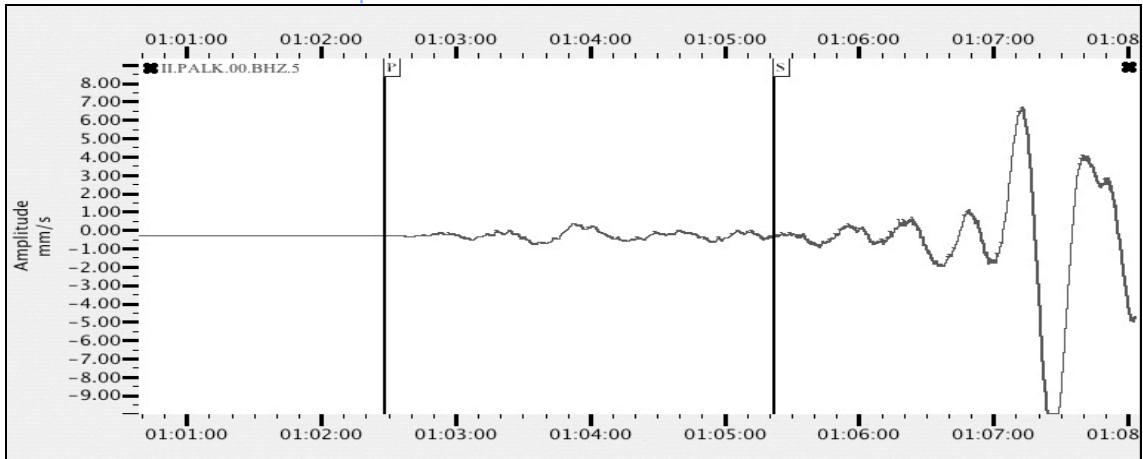(Chart from the New York State Earth Science Reference Tables)

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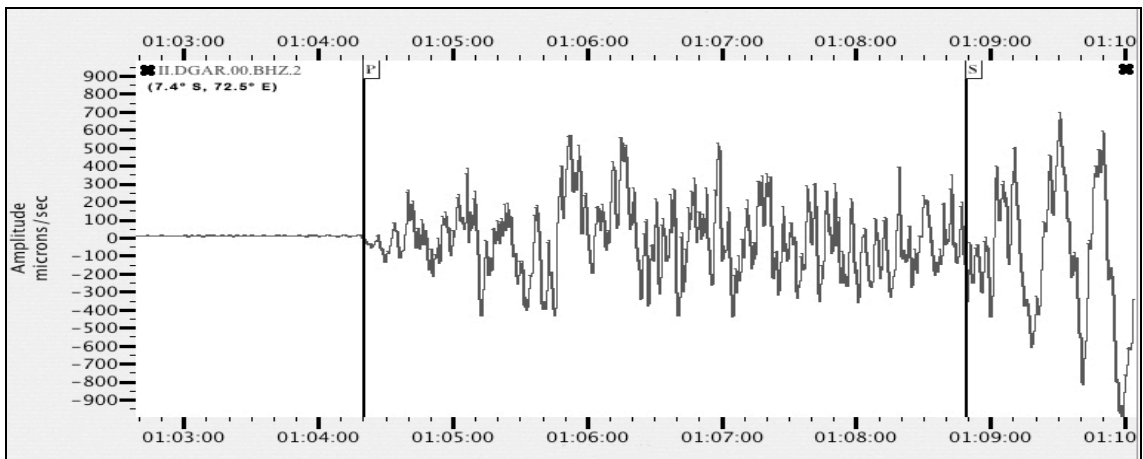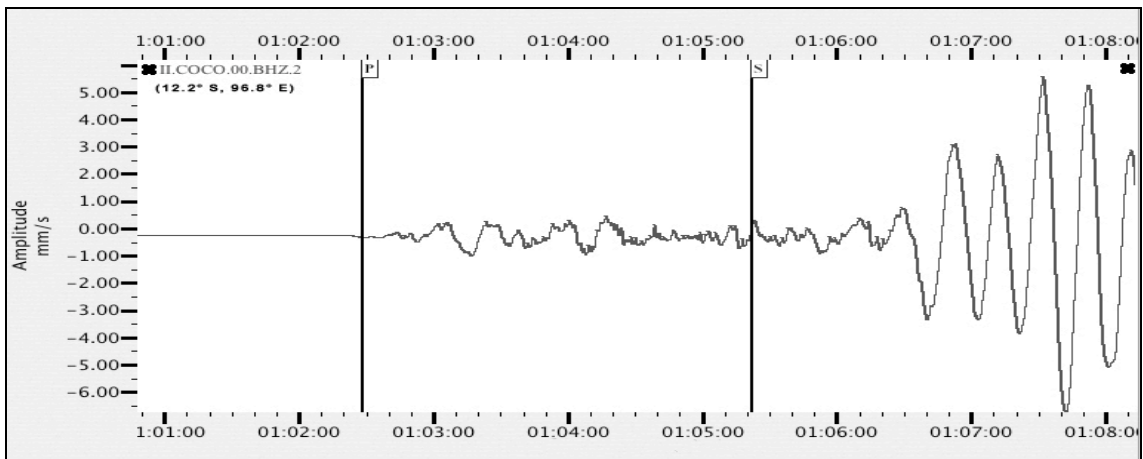# The Great Sumatra Earthquake of 12/26/2004 (Map 1)

MAP SCALE: KILOMETERS

GUMO

IC.LSA

KMBO

Plate tectonics map showing the major tectonic plates and boundaries.

Plates labeled: Eurasian Plate, North American Plate, African Plate, Arabian Plate, South American Plate, Indian-Australian Plate, Antarctic Plate, Pacific Plate, Nazca Plate, Cocos Plate, Caribbean Plate, Scotia Plate, Sandwich Plate, Juan de Fuca Plate, Fiji Plate, Philippine Plate.

Features: Iceland Hot Spot, Canary Islands Hot Spot, Yellowstone Hot Spot, Galápagos Hot Spot, Hawaii Hot Spot, Mid-Atlantic Ridge, Mid-Indian Ridge, East African Rift, Southeast Indian Ridge, Southwest Indian Ridge, East Pacific Ridge, Peru-Chile Trench, Aleutian Trench, Tonga Trench, Mariana Trench, San Andreas Fault.

KEY:

Divergent Plate Boundary (usually broken by transform faults along mid-ocean ridges)

Mid-Ocean Ridge

Convergent Plate Boundary (Subduction Zone) — overriding plate / subducting plate

Transform Plate Boundary (Transform Fault)

Complex or Uncertain Plate Boundary

Relative Motion at Plate Boundary

Mantle Hot Spot

NOTE: Not all plates and boundaries are shown.

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http://ida.ucsd.edu/IDANetwork/index.html

PALK, Pallekele, Sri Lanka: Coordinates: (7.3° N, 80.7° E)
http://ida.ucsd.edu/Stations/palk/index.html
http://ida.ucsd.edu/public/II/PALK/palk.html

DGAR, Diego Garcia, British Indian Ocean Territory: Coordinates: (7.4° S, 72.5° E)
http://ida.ucsd.edu/Stations/dgar/index.html
http://ida.ucsd.edu/public/II/DGAR/dgar.html

COCO, Cocos (Keeling) Islands, Australia: Coordinates: (12.2° S, 96.8° E)
http://ida.ucsd.edu/Stations/coco/index.html
http://ida.ucsd.edu/public/II/COCO/coco.html

The Great Sumatra Earthquake of 12/26/2004 (Map 2)