The Sumatra Earthquake and Tsunami December 26, 2004

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(thanks also to Bryce Hand and Michael Hubenthal)

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 100 years.

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 withstand 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
- 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 very nearly 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? ____________________

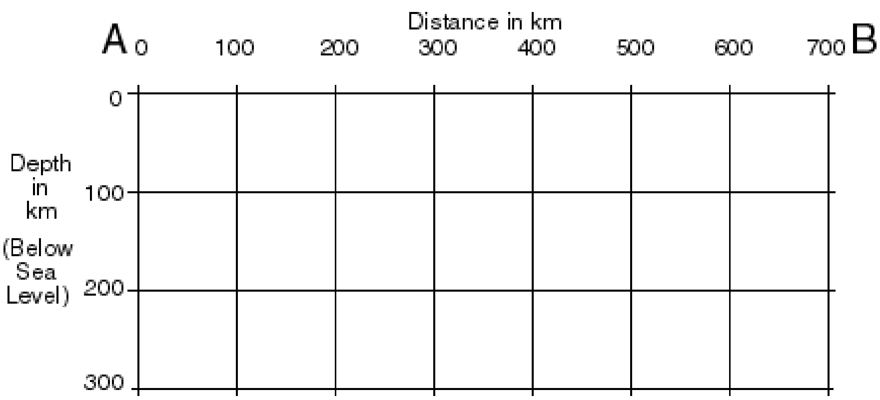
3. The ‘quake occurred about 150 km (90 mi) northeast of the plate boundary (see map section below, right), and at a depth of about 30 km (18 mi).

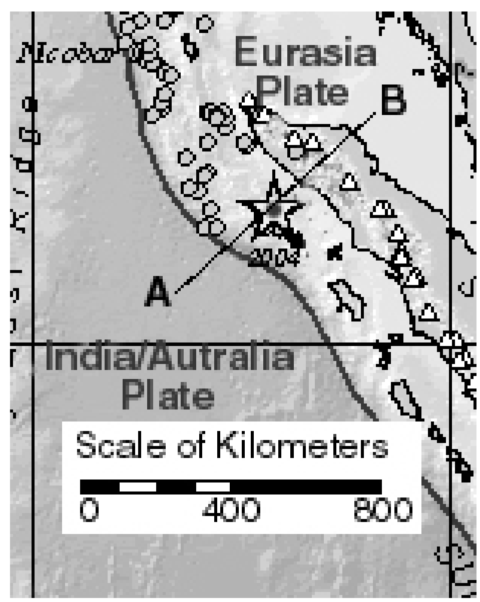
   a. Explain how this information helps you to determine which plate is being subducted. ____________________

   ____

   ____

   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 _______________________

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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 seismographs: PALK, DGAR, and COCO on the next page.

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? _____________________

   ____

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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.

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*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 ___________________________
- Indonesia __________________________
- Myanmar ___________________________
- Somalia ____________________________

Current Total number casualties ______________________ Date _____________

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

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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 know 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)

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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:

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____

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(*Cite your sources or attach the originals)

Web Resources:

Indonesian Earthquake page:

http://www.bedford.k12.ny.us/flhs/science/images/tsunami2004/

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

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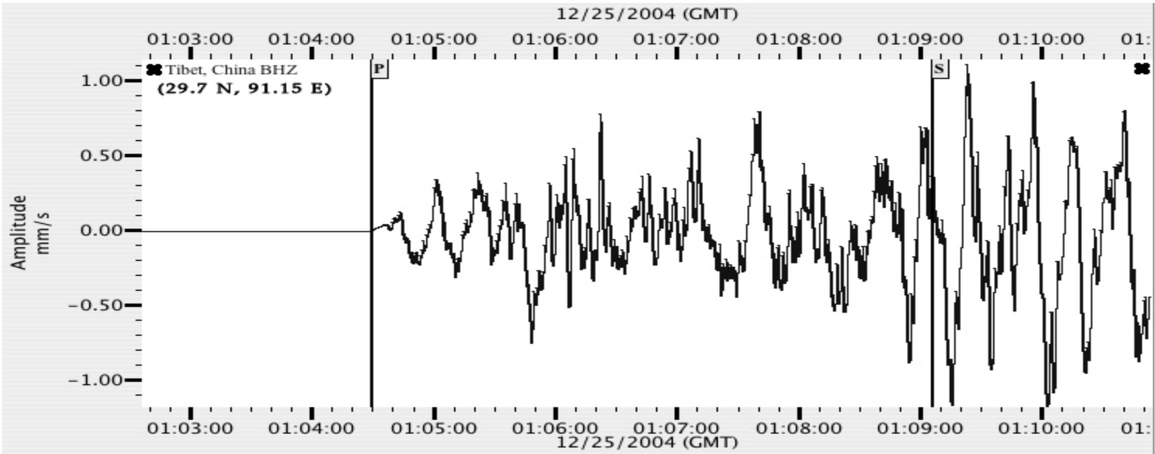
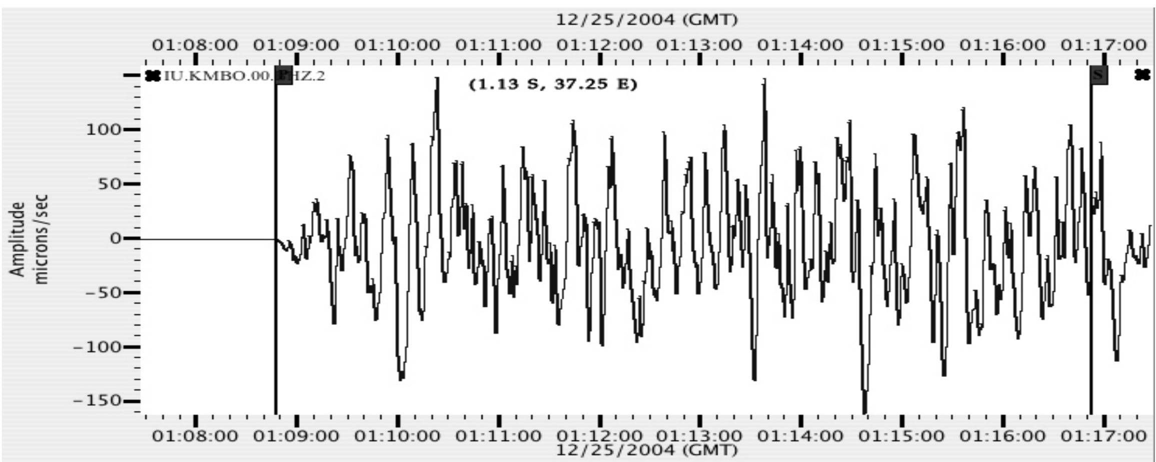
Maps and Charts

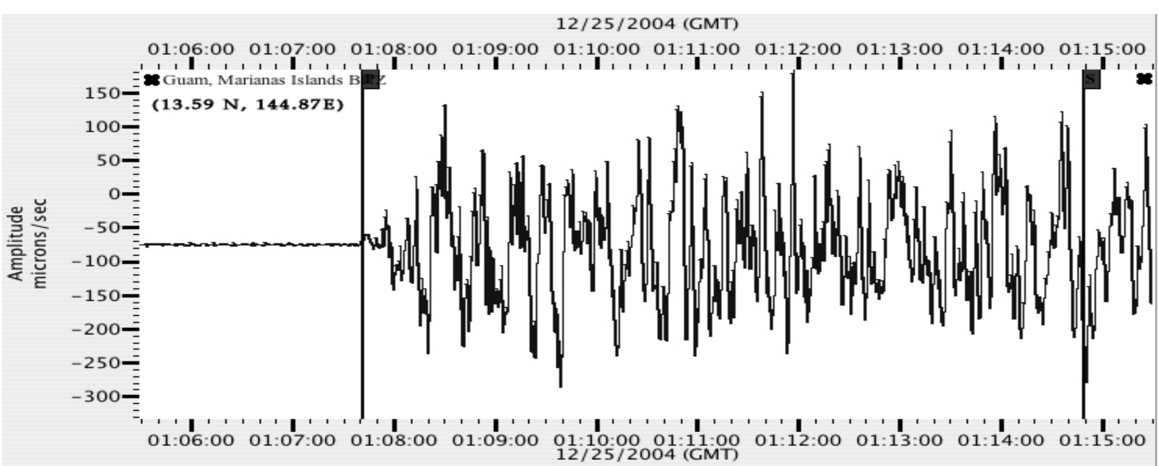
SEISMOGRAMS for Part 1



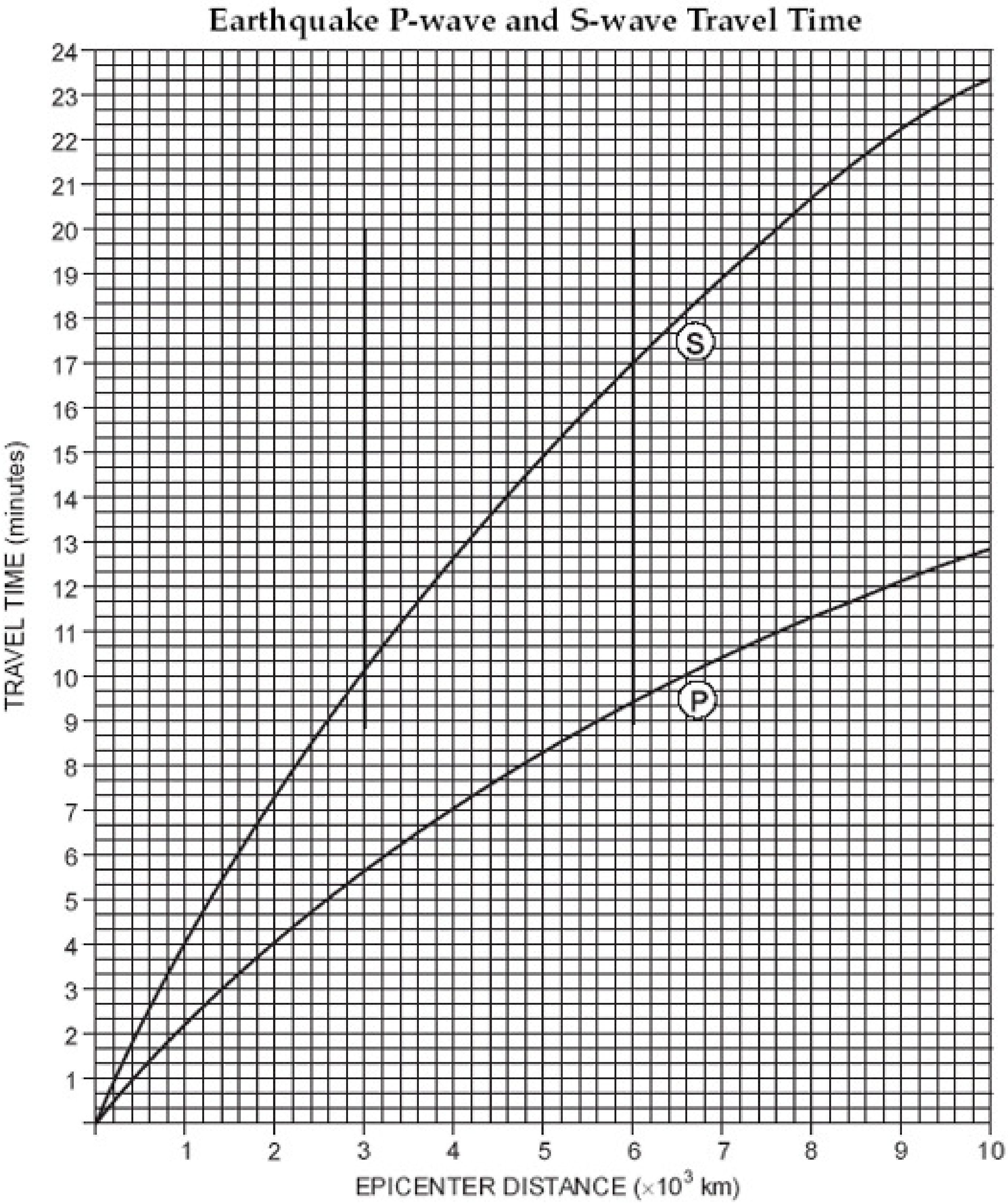
IC.LSA (Tibet, China): Latitude:29.7 N, Longitude:91.15 E
http://www.fdsn.org/station_book/IC/LSA/lsa.html



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

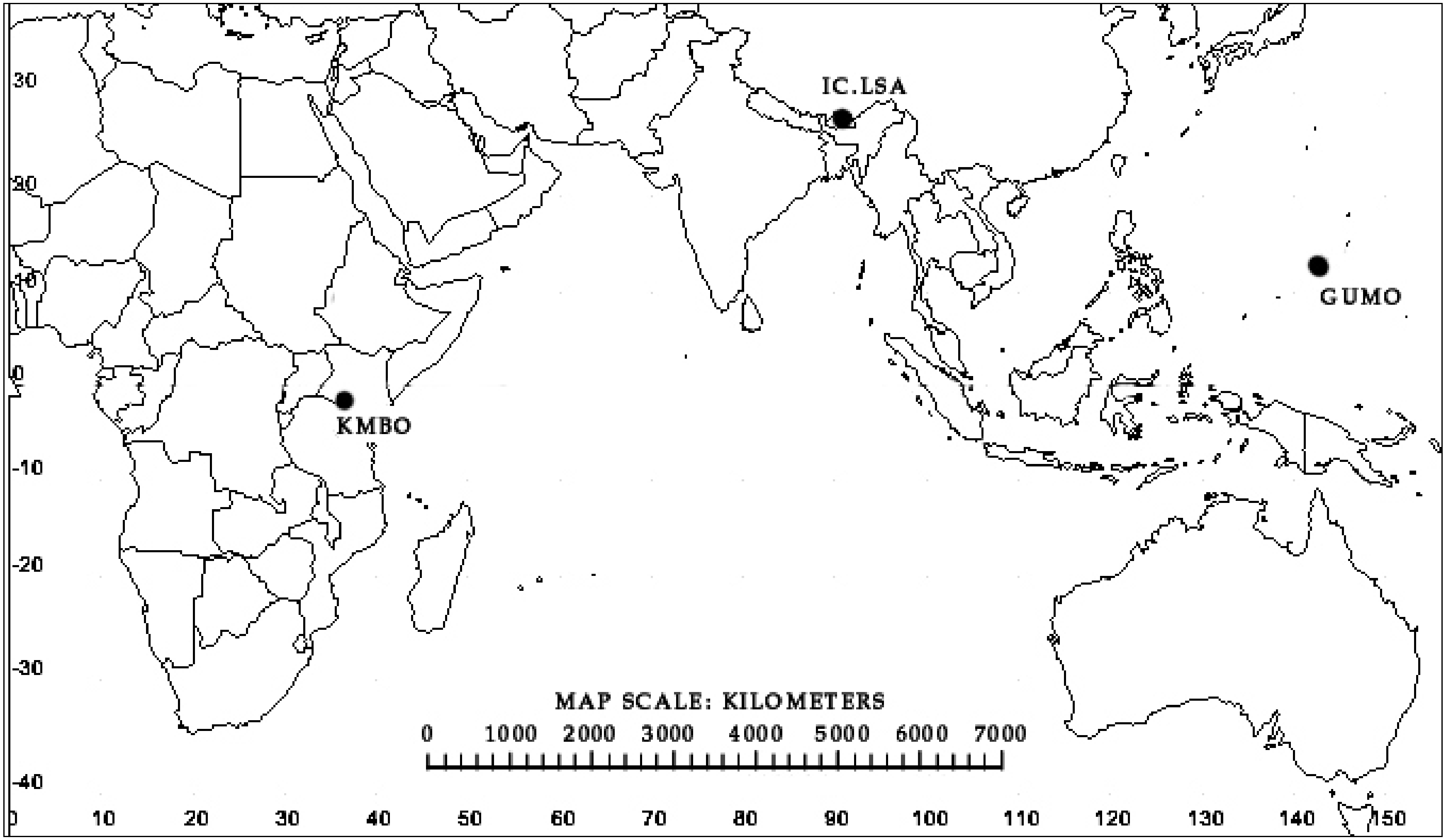


GUMO - Guam, Mariana Islands Latitude: 13.59 N, Longitude: 144.87 E
http://www.fdsn.org/station_book/IU/GUMO/gumo.html



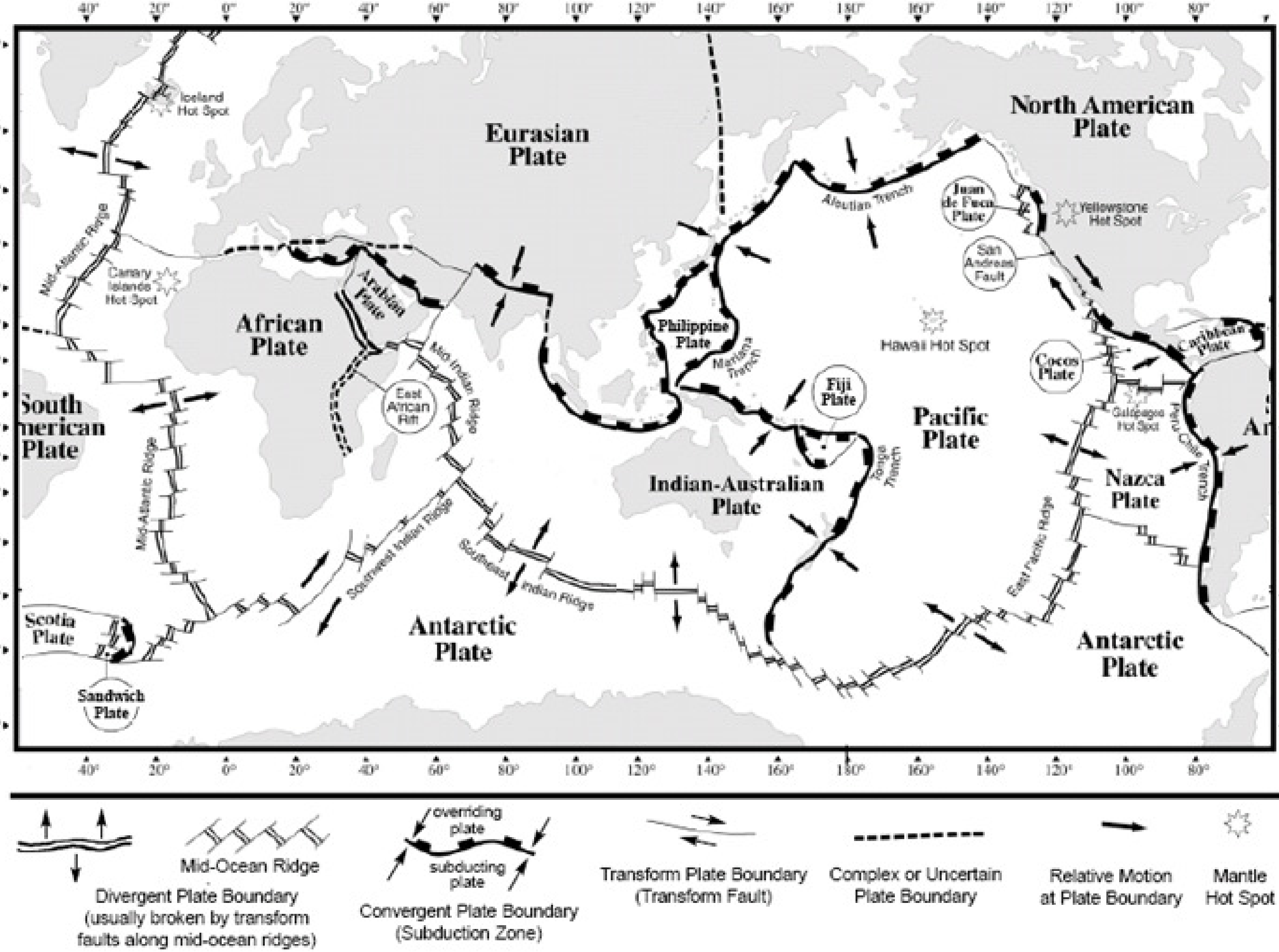
(Chart from the New York State Earth Science Reference Tables)

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



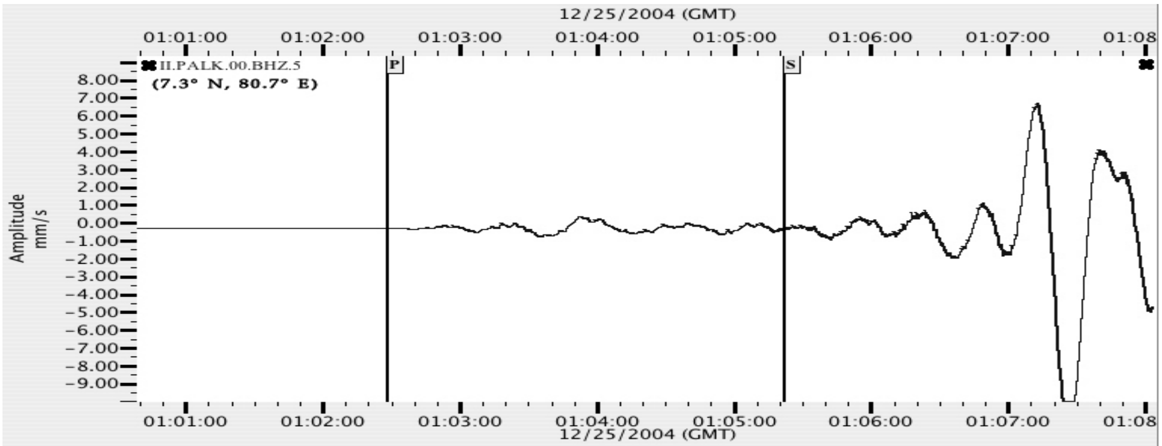
Tectonic Plates of the World

(modified from the New York State Earth Science Reference Tables)



SEISMOGRAPHS for Part 2

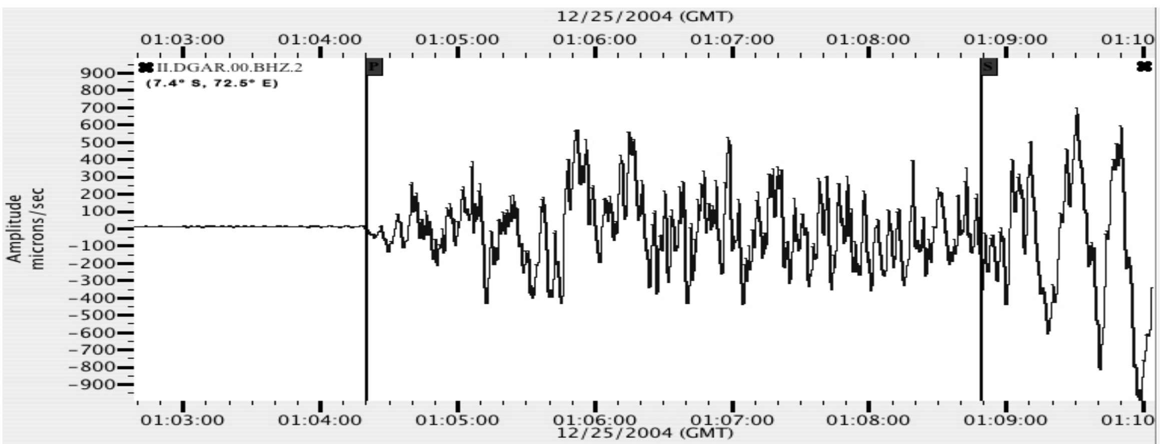
http://ida.ucsd.edu/IDANetwork/index.html



PALK, Pallekele, Sri Lanka: Coordinates: (7.3° N, 80.7° E)

http://ida.ucsd.edu/Stations/palk/index.html

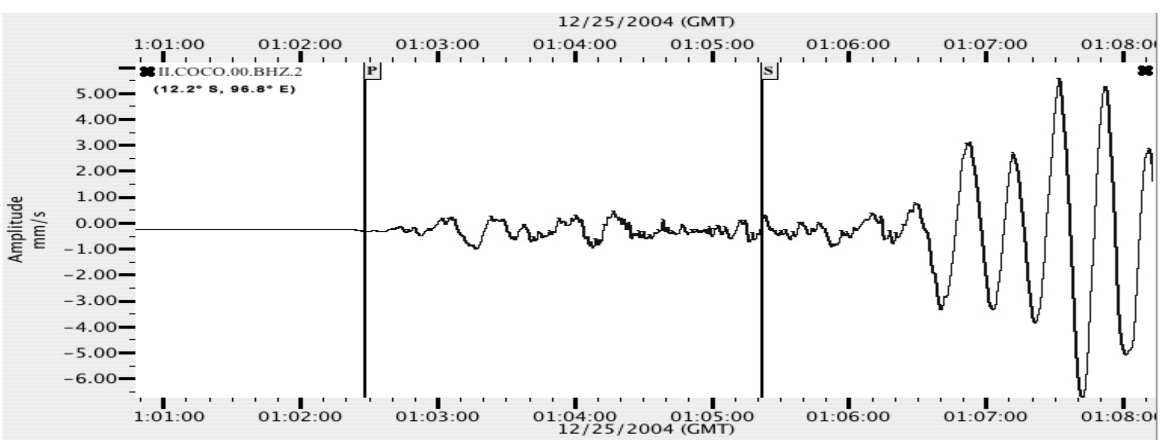
http://ida.ucsd.edu/public/II/PALK/palk.html



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)