Name _____

Challenge Activity

Geophysics of Earthquakes

The Sumatra Earthquake and Tsunami
December 26, 2004

Background: 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. In addition, there are natural warning signs of impending tsunamis, that when 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.

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.

Materials:

- Drawing compass
- 2 sets of 3 seismograms from the same earthquake (Seismogram Set 1 & Seismogram Set 2)
- *P*- and *S-wave* travel time curve
- Tectonic map of the world
- Maps 1, 2, and 3
- Scrap paper for calculations
- Red & blue pencil

Part 1 Procedure: Finding the Epicenter

1. Read the time of the P and S waves at each seismograph station and place that information in DATA TABLE 1 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. Next determine the amount of time that elapsed between the arrival of the P and S waves at each station. One way to do this is to subtract the P-wave arrival time from the S-wave arrival time (S-P). 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. Mark each corresponding station on the travel time curve with a red pencil.
4. On Map 1, 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 earthquake. Label it with a red star and the words "Epicenter" on your map.

DATA TABLE 1:

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

Part 1 Questions (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. For each station, subtract the P-wave travel time (from the travel time curve) 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!

P-wave arrival time:
IC.LSA: _____ KMBO: _____ GUMO: _____

P-wave travel time:
IC.LSA: _____ KMBO: _____ GUMO: _____

Estimated time of earthquake:
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 _____

_____

Part 2 Procedure: 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: **India, Sri Lanka, Somalia, Sumatra (Indonesia), Myanmar, Thailand**

2. Follow the same procedures used in Part 1 to find the epicenter on Map 2. Don't forget to label it on the map! *You will need to use the seismograms from set 2 (stations PALK, DGAR, and COCO).

DATA TABLE 2:

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

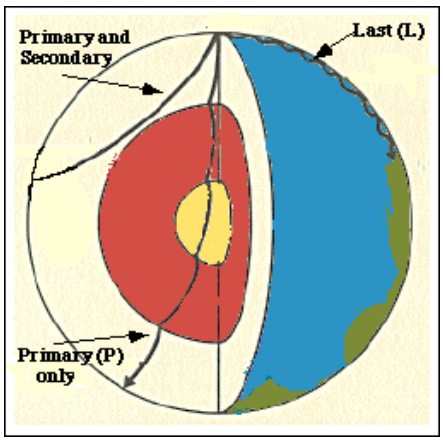
Part 3 Procedure: Speed of Seismic Waves

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 (from the travel time curve, convert minutes 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? Think about the way the seismic waves travel through the Earth (different layers, how they vary), and explain why the waves arriving at more distant places travel at a higher average speed.



Part 4 Procedure: 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.

1. Assume the tsunami generated by the Great Sumatra Quake traveled 600 km/hr in the open ocean. On Map 2, draw (blue pencil) 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)

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

   - India _____
   - Sri Lanka _____
   - Thailand _____
   - Indonesia _____

Current Total number casualties _____

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

_____

5. Had a warning system been in effect, would there have been time to warn the residents of Aceh at the northern tip of Sumatra? _____

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

_____

Web Resources:

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

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/

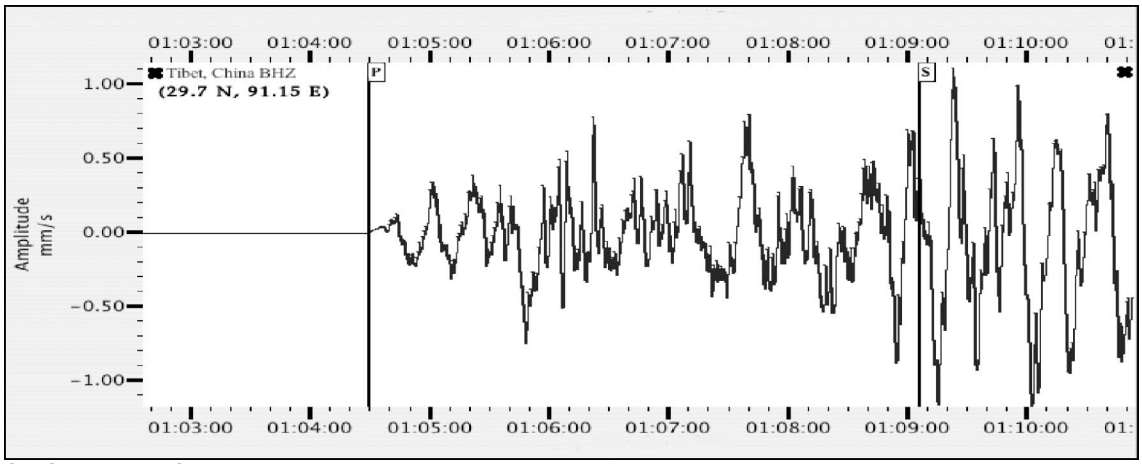
CNN's special coverage of the event:
http://www.cnn.com/SPECIALS/2004/tsunami.disaster/

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

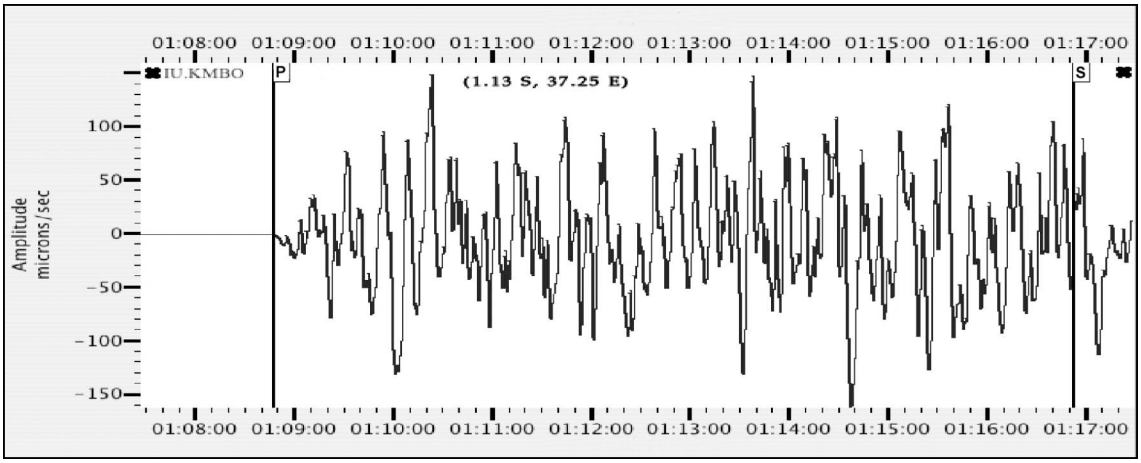
FEMA's tsunami pages:
http://www.fema.gov/areyouready/tsunamis.shtm

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

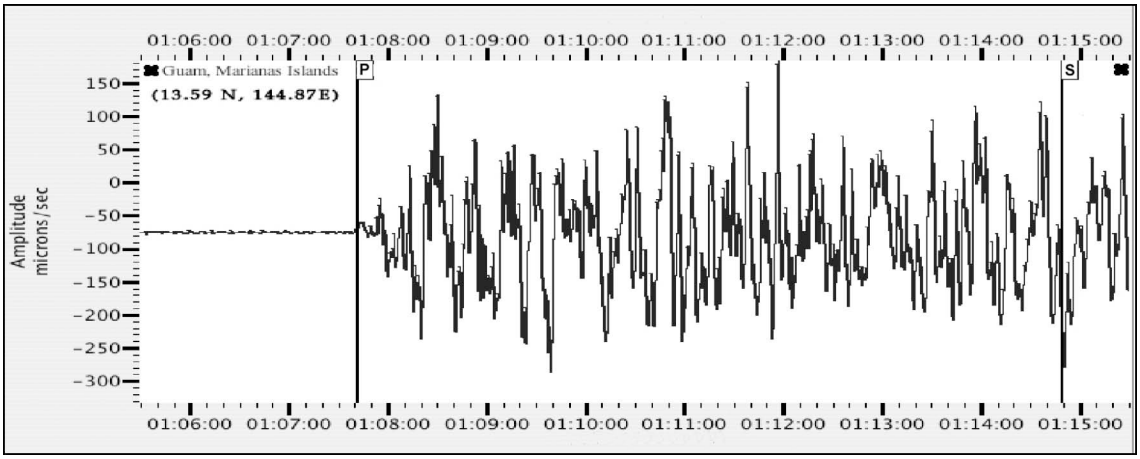
Seismogram Set #1



IC.LSA (Tibet, China): Latitude:29.7 N, Longitude:91.15 E



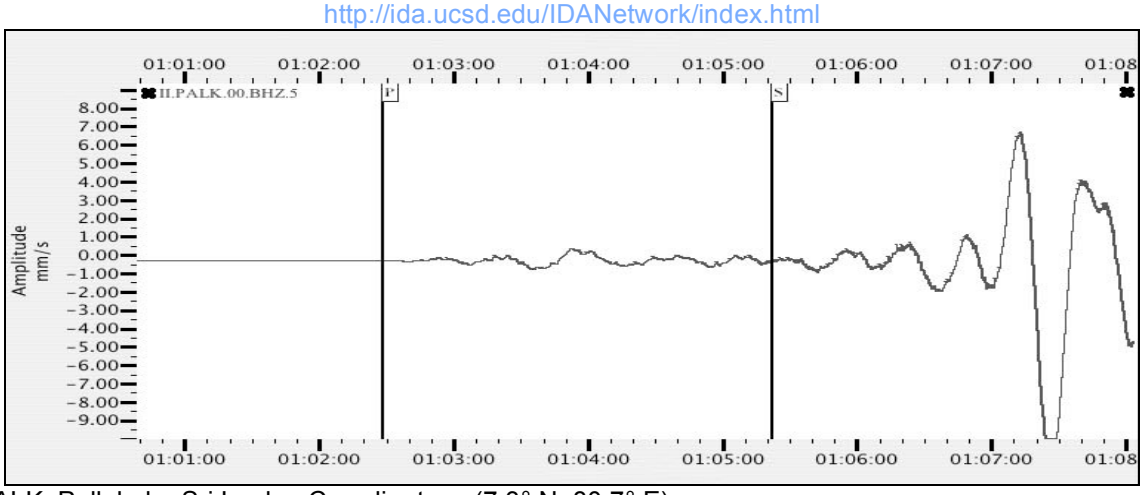
KMBO Latitude: 1.13 S, Longitude: 37.25 E



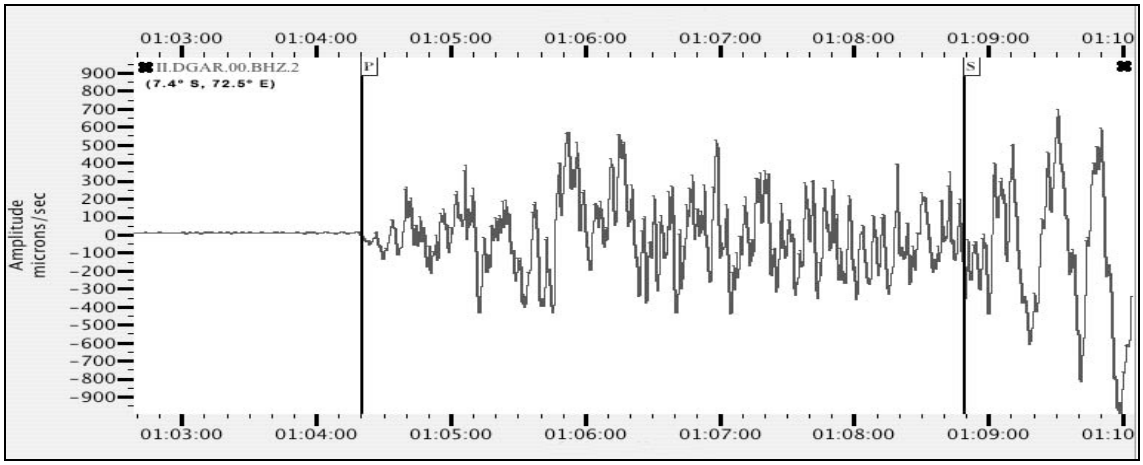
GUMO - Guam, Mariana Islands Latitude: 13.59 N, Longitude: 144.87 E

Seismogram Set #2

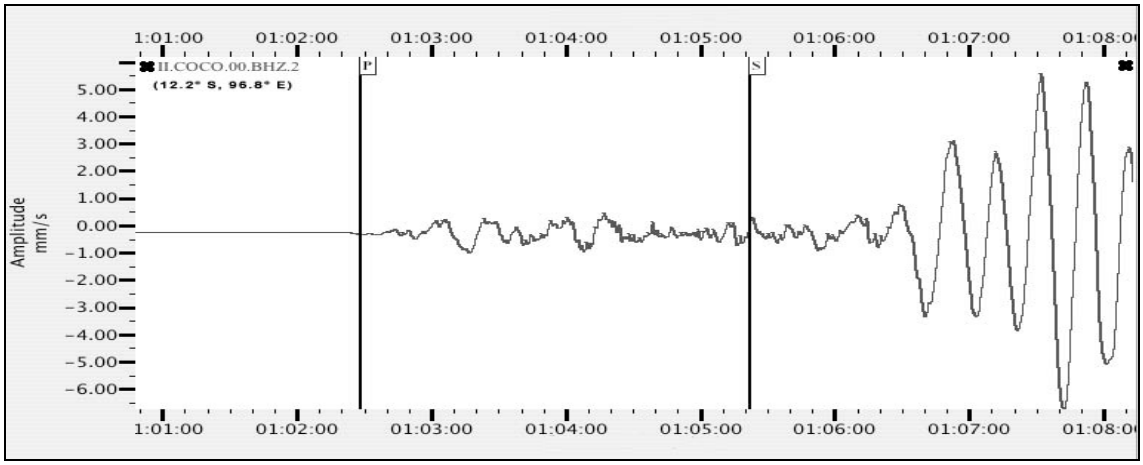
http://ida.ucsd.edu/IDANetwork/index.html



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

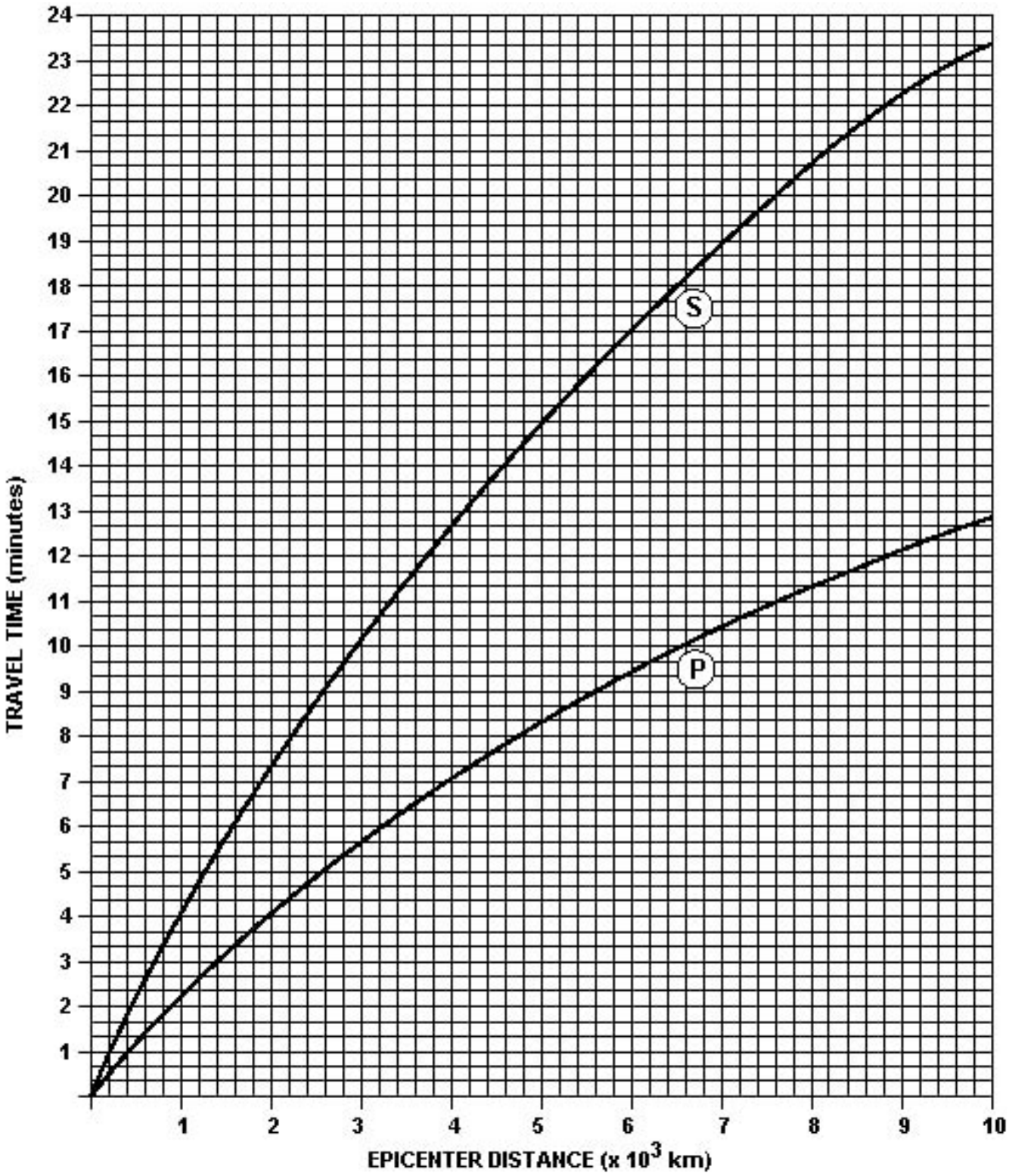


DGAR, Diego Garcia, British Indian Ocean Territory: Coordinates: (7.4° S, 72.5° E)



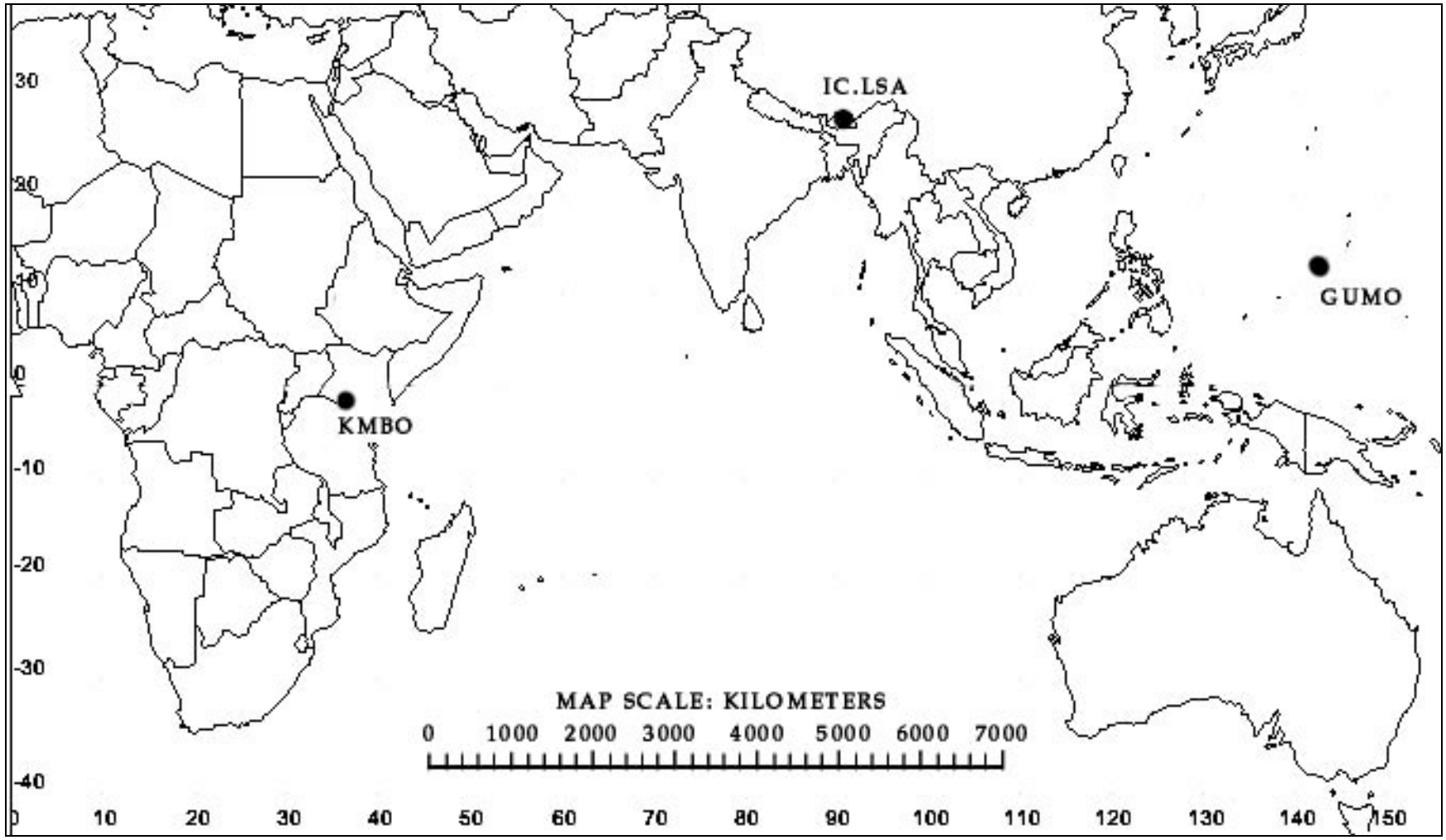
COCO, Cocos (Keeling) Islands, Australia: Coordinates: (12.2° S, 96.8° E)

P & S-wave Travel Time Curve

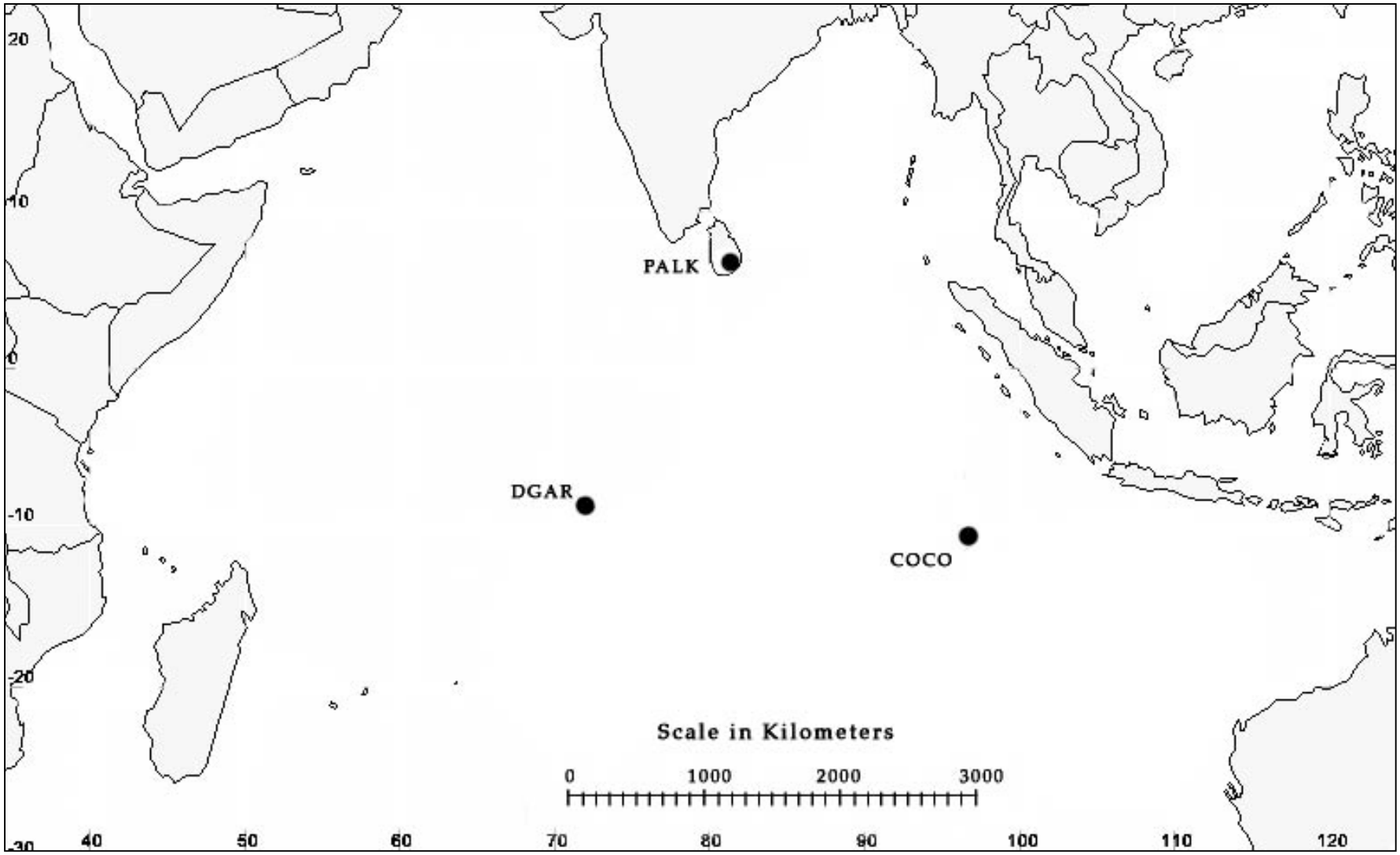


(Chart from the New York State Earth Science Reference Tables)

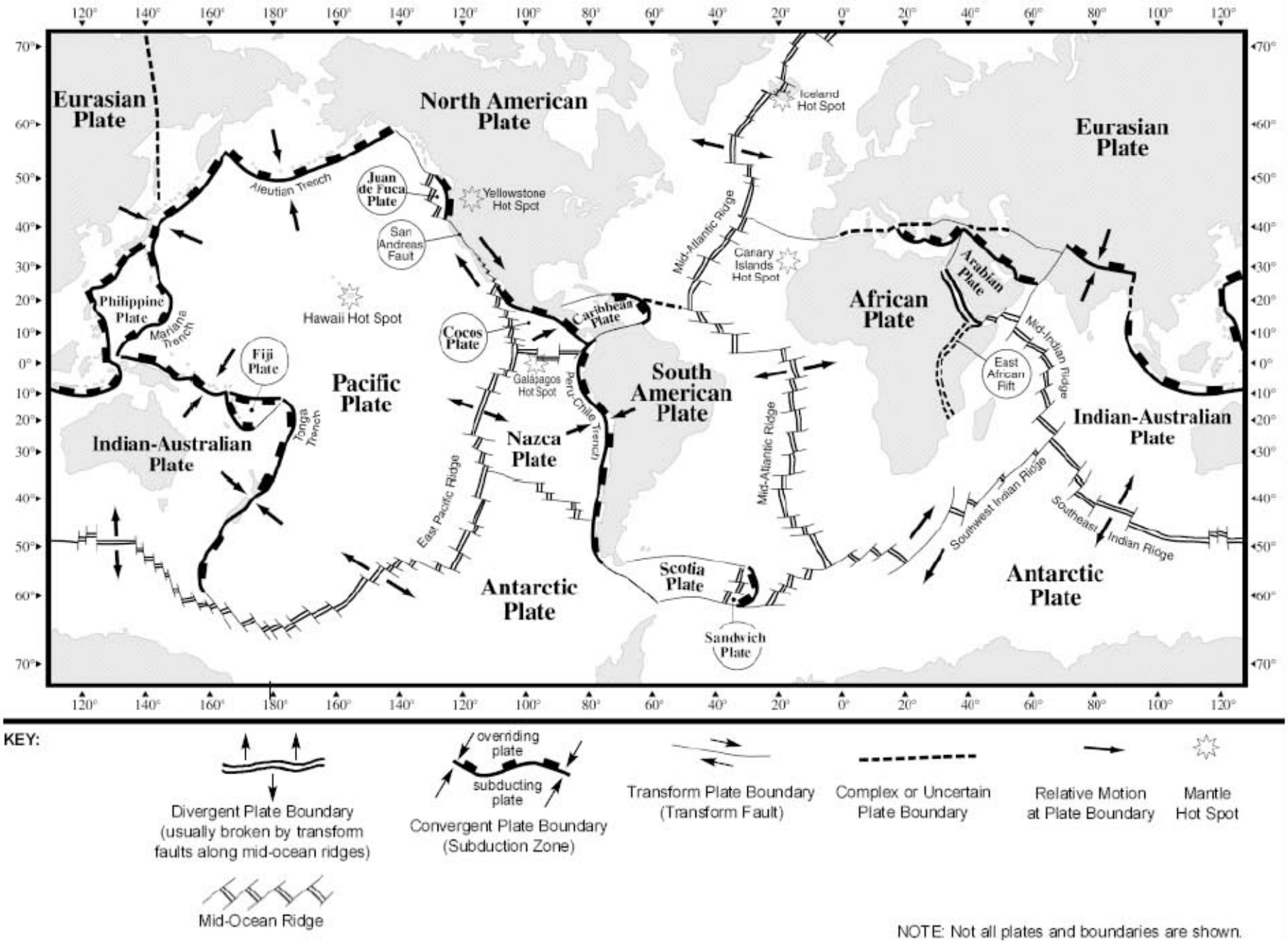
Map 1



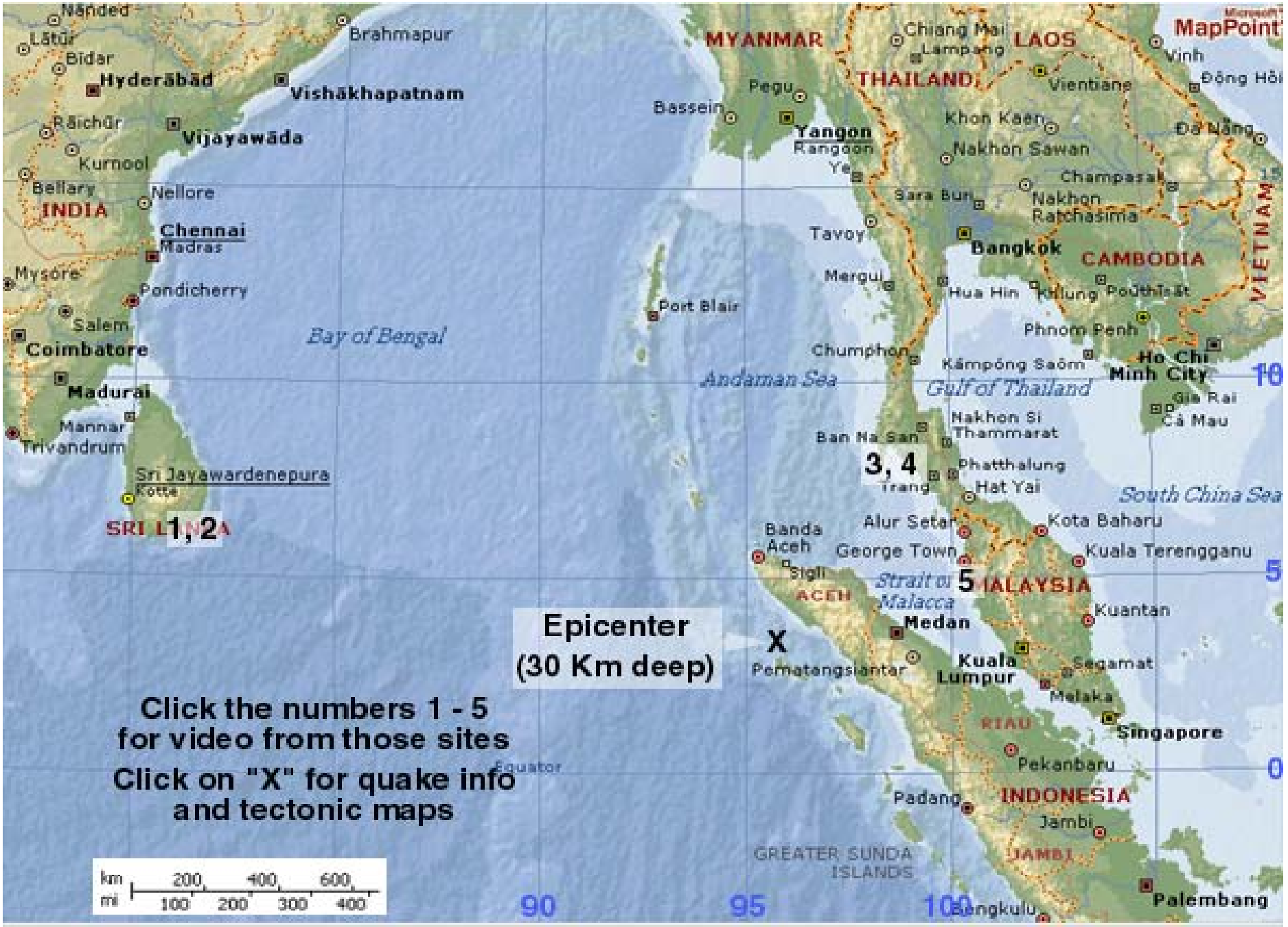
Map 2



Tectonic Map of World



Map 3


Nānded
Lātūr
Bidar
Hyderābād
Brahmapur
Vishākhapatnam
Rāichūr
Vijayawāda
Kurnool
Bellary
Nellore
INDIA
Chennai
Madras
Mysore
Pondicherry
Salem
Coimbatore
Madurai
Mannar
Trivandrum
Sri Jayawardenepura
Kotte
SRI LANKA
1, 2
Bay of Bengal
Port Blair
MYANMAR
Pegu
Bassein
Yangon
Rangoon
Ye
Tavoy
Mergui
Andaman Sea
Chumphon
Ban Na San
Nakhon Si Thammarat
Phatthalung
Trang
3, 4
Hat Yai
Alur Setar
Banda Aceh
Sigli
ACEH
George Town
Strait of Malacca
5
MALAYSIA
Medan
Pematangsiantar
Epicenter
(30 Km deep)
X
Kuala Lumpur
Kuantan
Segamat
Melaka
Singapore
RIAU
Pekanbaru
Padang
INDONESIA
Jambi
JAMBI
GREATER SUNDA ISLANDS
Bengkulu
Palembang
Equator
Click the numbers 1 - 5
for video from those sites
Click on "X" for quake info
and tectonic maps
km
mi
200
400
600
100
200
300
400
90
95
100
Chiang Mai
Lampang
LAOS
THAILAND
Vientiane
Khon Kaen
Nakhon Sawan
Sara Buri
Champasak
Nakhon Ratchasima
Bangkok
CAMBODIA
Hua Hin
Kulung
Phnom Penh
Kâmpóng Saôm
Gulf of Thailand
Vinh
Đồng Hới
Đà Nẵng
VIETNAM
Ho Chi Minh City
Gia Rai
Cà Mau
South China Sea
Kota Baharu
Kuala Terengganu
MapPoint