Seismograms, phase picks, earthquake locations, tectonics

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Istituto Nazionale di

Geofisica e Vulcanologia


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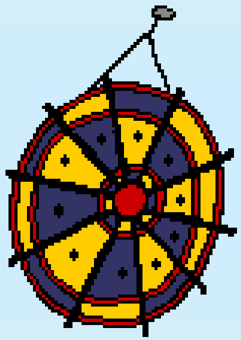


BLUEBUDDIES

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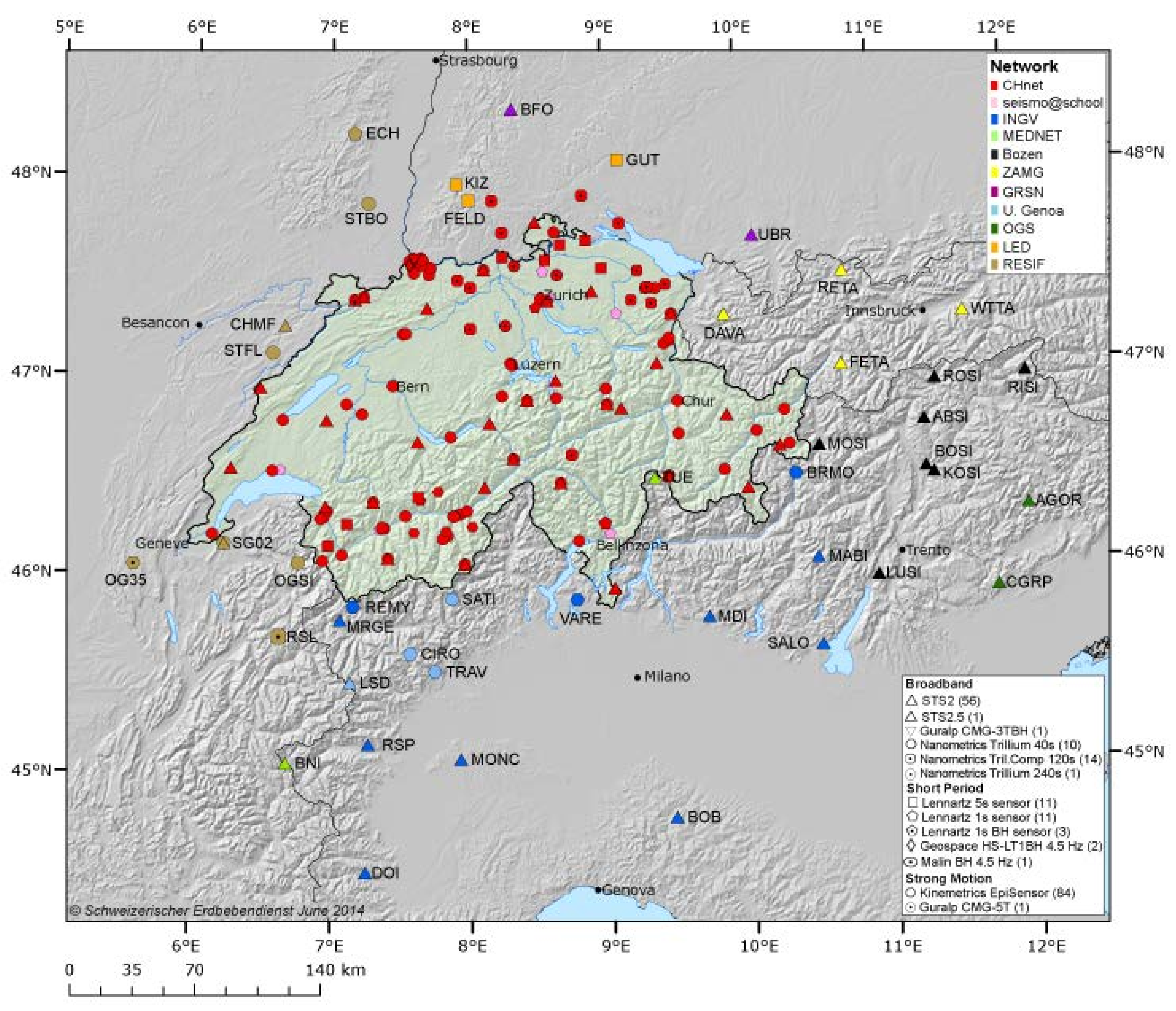

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RESIF
Broadband
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STS2.5 (1)
Guralp CMG-3TBH (1)
Nanometrics Trillium 40s (10)
Nanometrics Tril.Comp 120s (14)
Nanometrics Trillium 240s (1)
Short Period
Lennartz 5s sensor (11)
Lennartz 1s sensor (11)
Lennartz 1s BH sensor (3)
Geospace HS-LT1BH 4.5 Hz (2)
Malin BH 4.5 Hz (1)
Strong Motion
Kinemetrics EpiSensor (84)
Guralp CMG-5T (1)
Strasbourg
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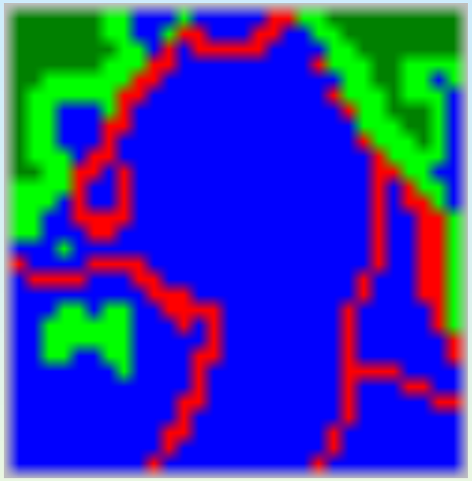

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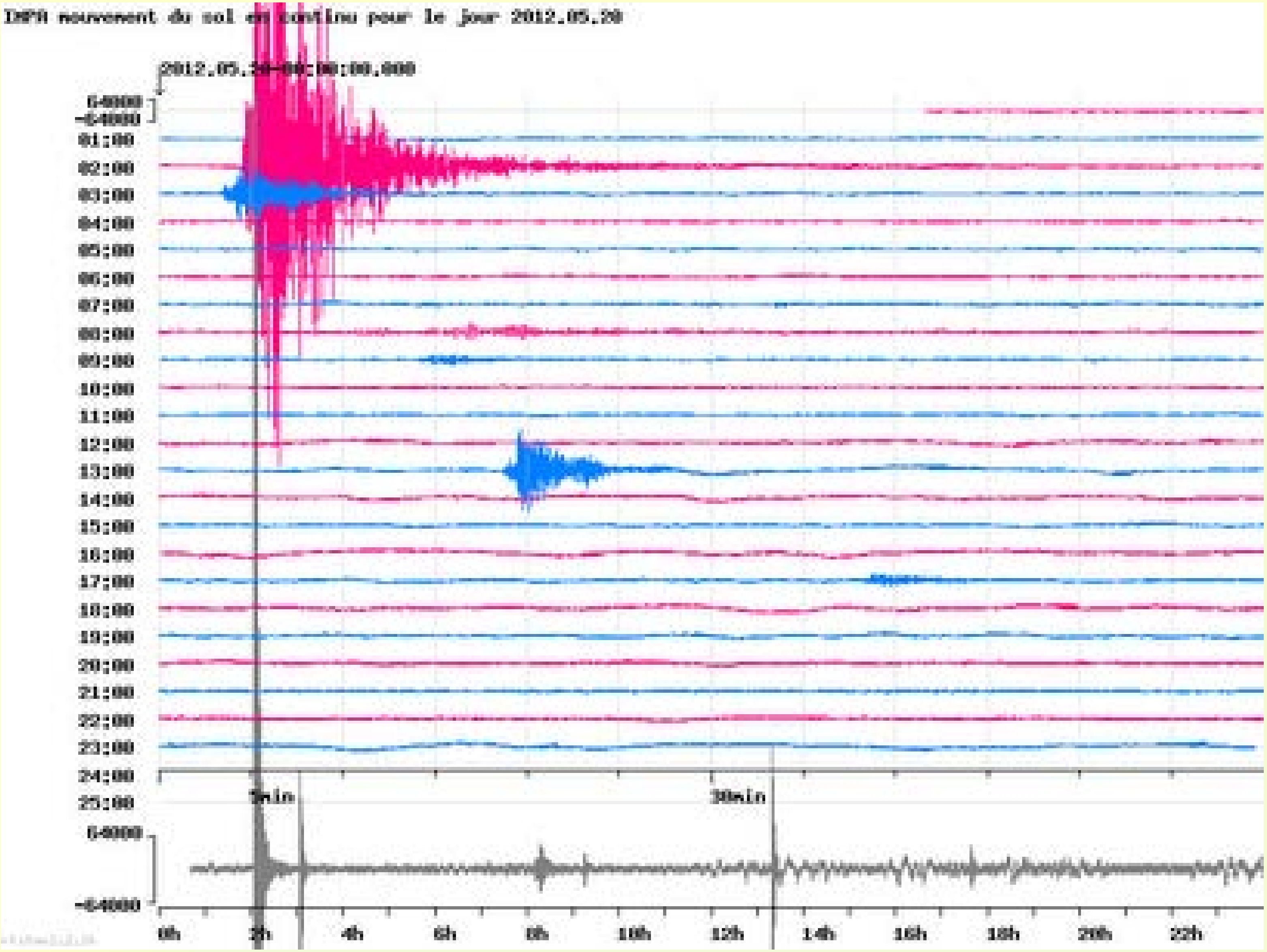

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What does “locating an earthquake mean” ?

Determine origin time, latitude, longitude and depth of the point where, in first approximation, the rupture occurred.

The rupture does not occur on a single point, but on an area.

Location with one seismograms

Location with three seismograms

Location with more seismograms

SHORT GLOSSARY

Seismogram: a plot of the velocity – acceleration of the Earth, time vs amplitude

Phase picking: action meant to identify seismic wave on a seismogram

Velocity model: is a layered approximation of the real Earth. Velocity for layers or block

Why it is important to know where an earthquake has occurred ?

Right after the quake

- To rapidly know the area that has been shaken in order to organize the assistance
- To estimate the amount of people involved (densily inhabited, touristic areas)

In a long term

- To understand which fault caused the earthquake
- To compile or update maps of seismicity
- To update hazard maps
- To make in depth studies of the interior of the earth

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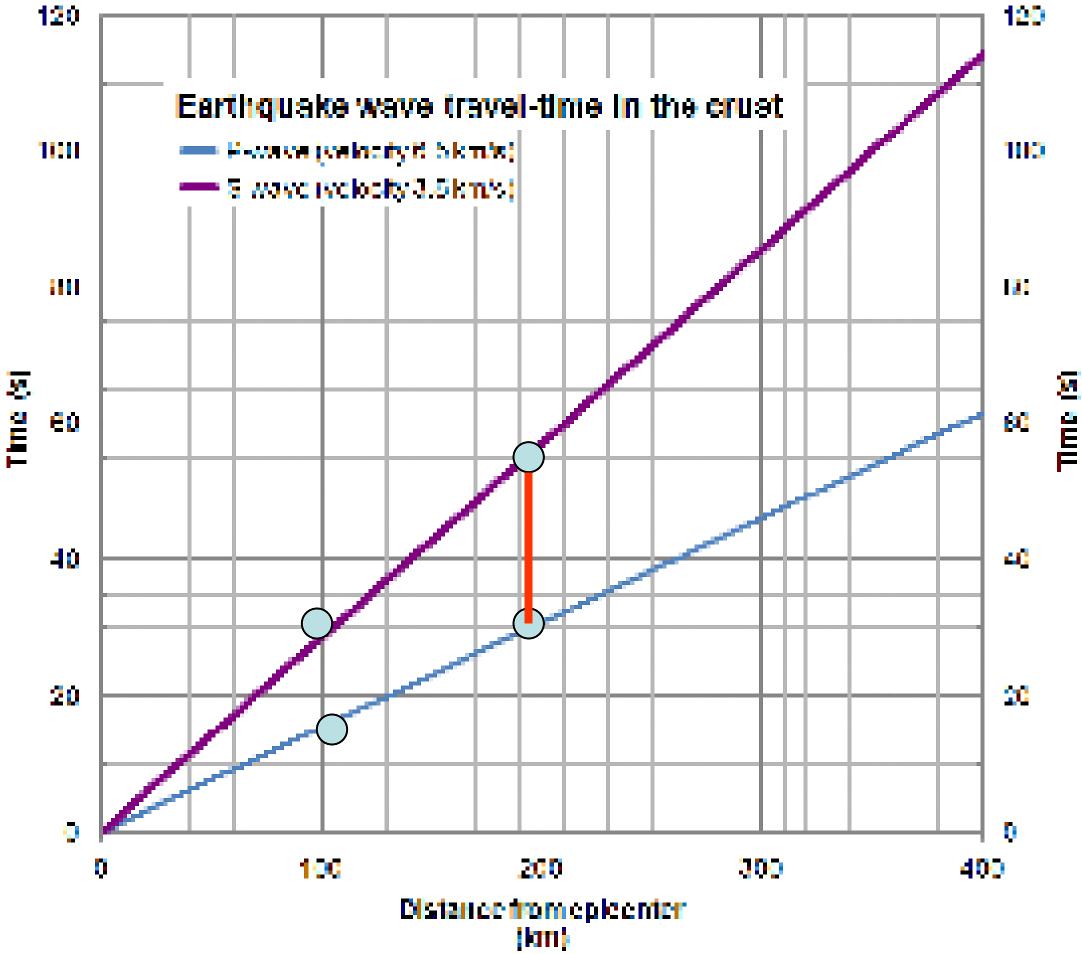
LOCATION WITH ONE SEISMOGRAM



GENERAL INFORMATION

P-wave velocity = 6.5 kilometers/s	S-wave velocity = 3.5 kilometers /s
Distance = Velocity x Time	Time = Distance / Velocity
1 km = 0.62137 miles	1 mile = 1.60934 kilometers

P waves

100 km: 100/6.5= 15.3

200 km: 200/6.5= 30.7

S waves

100 km: 100/3.5= 28.6

200 km: 200/3.5= 57.2

S-P: 27.2 sec = 200 km

RULE OF THUMB: DISTANCE = TIME LAG TIMES 8

In fact:

$$D = \frac{Ts - Tp}{\sqrt{3}} \, Vp = (Ts-Tp) * (Vp / 0.732)$$

(Vp / 0.732) is 8 for most upper crust velocities and, in general, for the average value of the crust (which is around 5.8 – 6.2)

LOCATION WITH ONE SEISMOGRAM

Mystery Epicenter
Group # 0 - Example

Name (s): ______________________

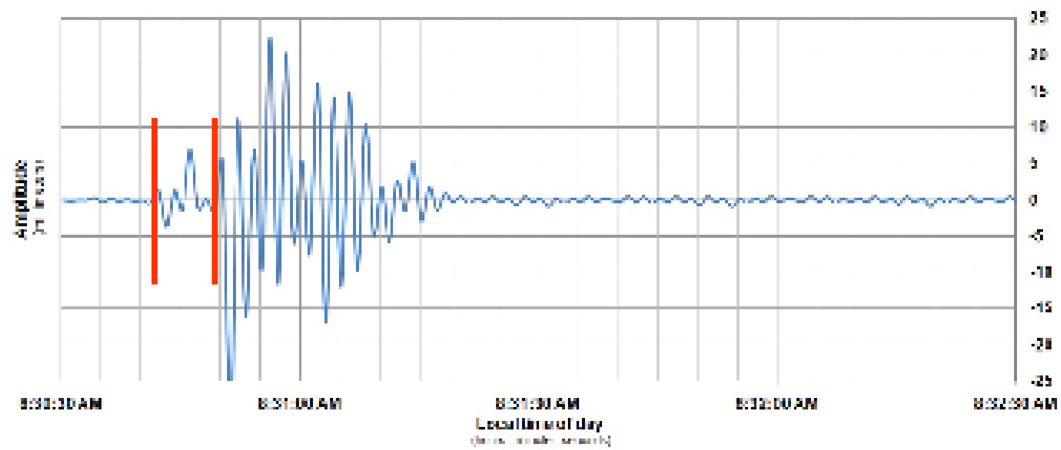
____

____

Date: ______________________

1. Mark the first arrival of the P-wave on each seismogram.
2. Mark the first arrival of the S-wave on each seismogram.
3. Write down your data in the box to the right of each seismogram.
4. Get the "distance from the epicenter" from the graph you made earlier using the "S-P lag time" that you recorded at your seismic station.

Seismogram - Group # 0 Example - Station A



Station A

Arrival time P-wave ______________

Arrival time S-wave ______________

S-P lag time (s) ______________

Distance from epicenter (km) (kilometers) ______________

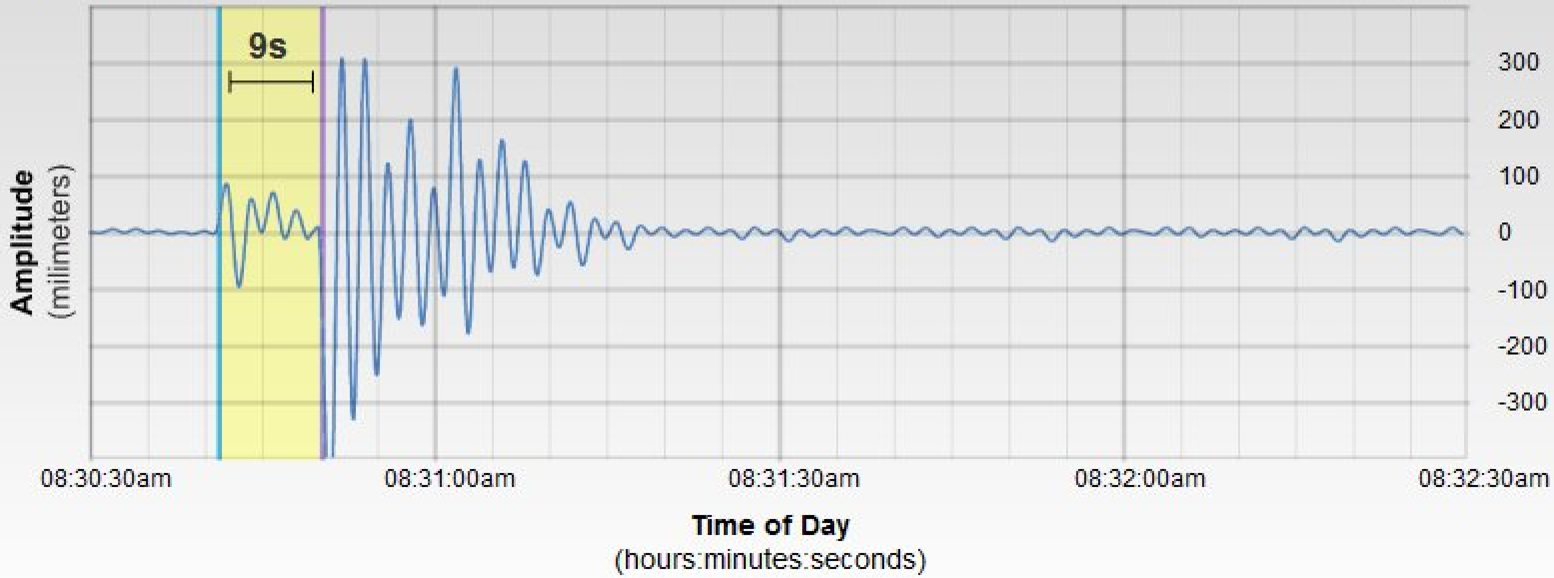
Reading a seismogram

To determine the distance to an earthquake epicenter

earthguide

Group #0, Station A

Group: Demo Station: A



P-Wave Start Time

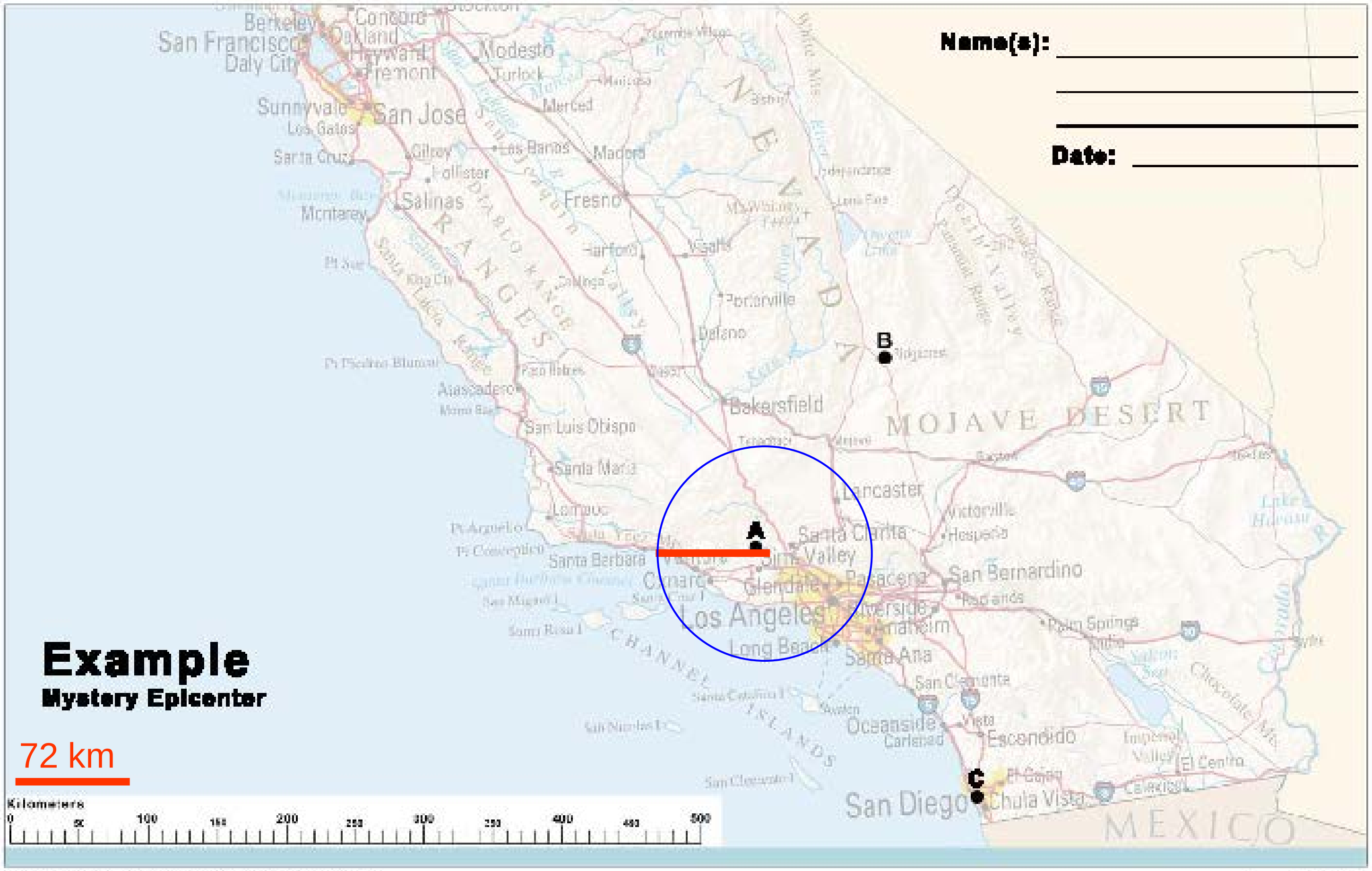
08 : 30 : 41

S-Wave Start Time

08 : 30 : 50

Show Lag Time

Good job! Take note of what the lagtime is.



Mystery Detectives - Mystery Epicenter

At this stage, we know the distance from the hypocenter; the earthquake lays somewhere on the circle of equidistance from the station. With this information only it is not possible to locate the earthquake.

If a three component seismogram is available, then it would be possibile to use the first onset of each component of the seismogram to make a reconstruction of the azimuth to the source. The accuracy in the determination is very low.

However, once the distance is computed, the P travel time can also be known. Subtracting this value from the P wave time, one can obtain the origin time.

In our case, 72 / 6.5 = 11 sec

Origin time = 08:30:41 – 00:00:11 = **08:30:30**

Adding the data from another seismogram will not be enough to determine the epicenter. In fact…..

Mystery Epicenter
Group # 0 - Example

Name (s): ____________________

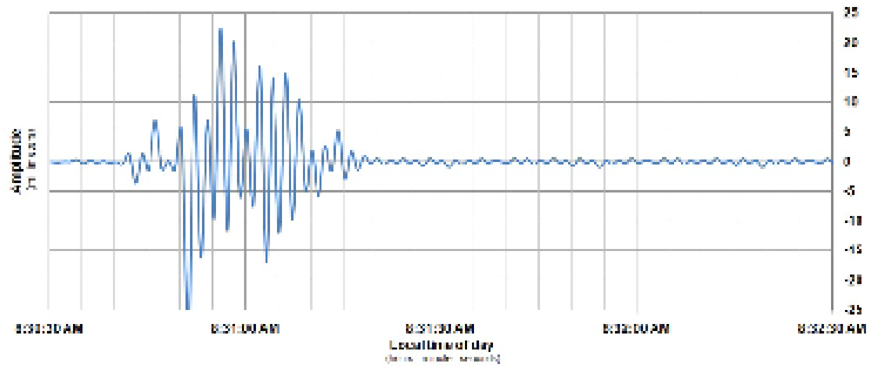
____

____

Date: ____________________

1. Mark the first arrival of the P-wave on each seismogram.
2. Mark the first arrival of the S-wave on each seismogram.
3. Write down your data in the box to the right of each seismogram.
4. Get the "distance from the epicenter" from the graph you made earlier using the "S-P lag time" that you recorded at your seismic station.

Seismogram - Group # 0 Example - Station A



Station A

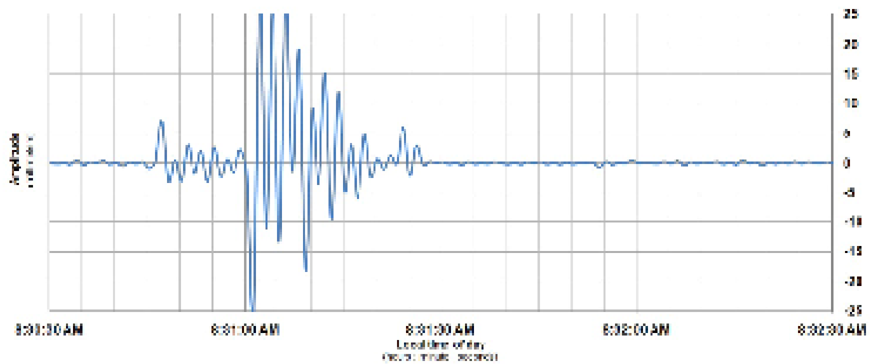
Arrival time P-wave ____________

Arrival time S-wave ____________

S-P lag time (s) 9

Distance from epicenter (km) (kilometers) ____________

Seismogram - Group # 0 Example - Station B



Station B

Arrival time P-wave ____________

Arrival time S-wave ____________

S-P lag time (s) ____________

Distance from epicenter (km) (kilometers) ____________

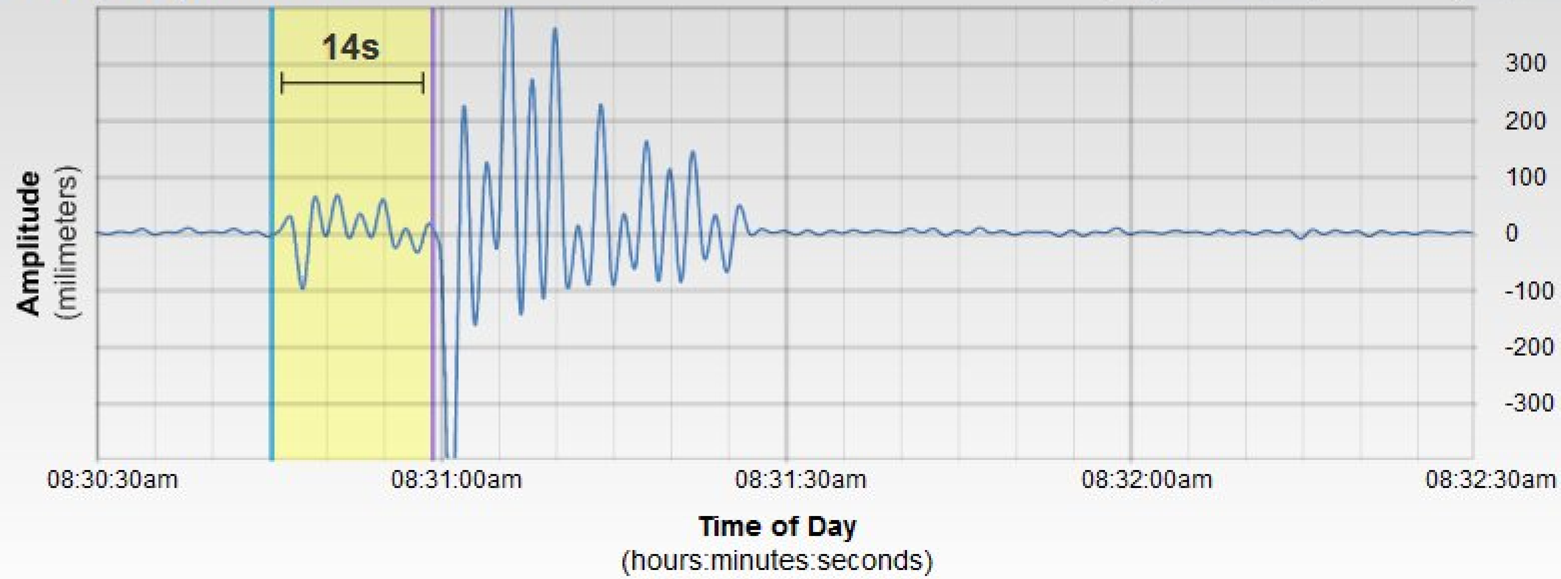
Reading a seismogram

To determine the distance to an earthquake epicenter

earthguide

Group #0, Station B

Group: Demo Station: B



P-Wave Start Time

08 : 30 : 45

S-Wave Start Time

08 : 30 : 59

Show Lag Time

Good job! Take note of what the lagtime is.

Mystery Epicenter
Group # 0 - Example

Name (s): ______________________

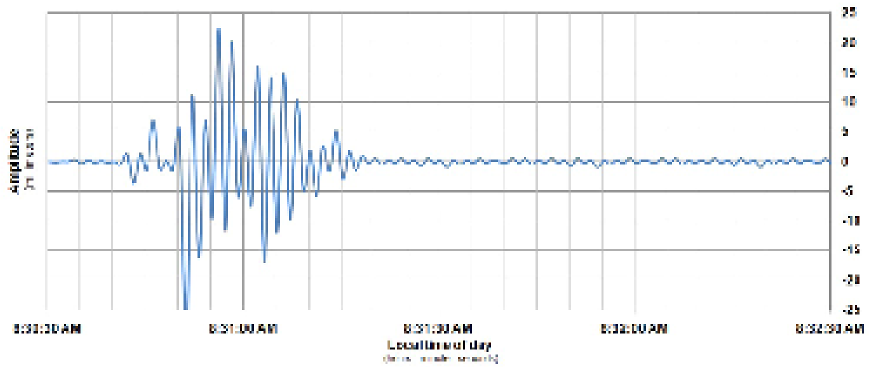
____

____

Date: ______________________

1. Mark the first arrival of the P-wave on each seismogram.
2. Mark the first arrival of the S-wave on each seismogram.
3. Write down your data in the box to the right of each seismogram.
4. Get the "distance from the epicenter" from the graph you made earlier using the "S-P lag time" that you recorded at your seismic station.

Seismogram - Group # 0 Example - Station A



Station A

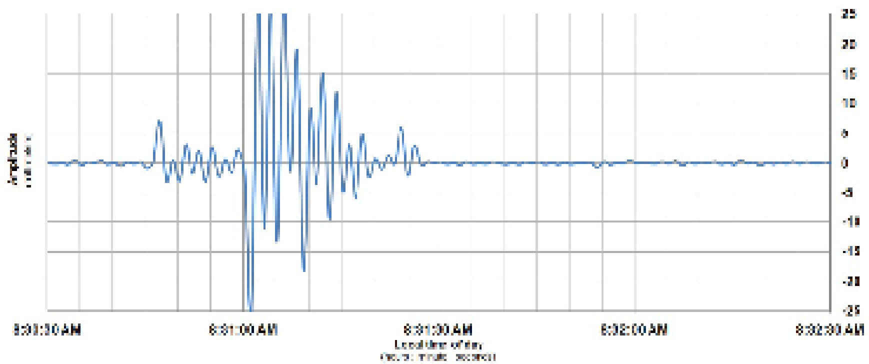
Arrival time P-wave ____________

Arrival time S-wave ____________

S-P lag time (s) 9

Distance from epicenter (km) (kilometers) ____________

Seismogram - Group # 0 Example - Station B



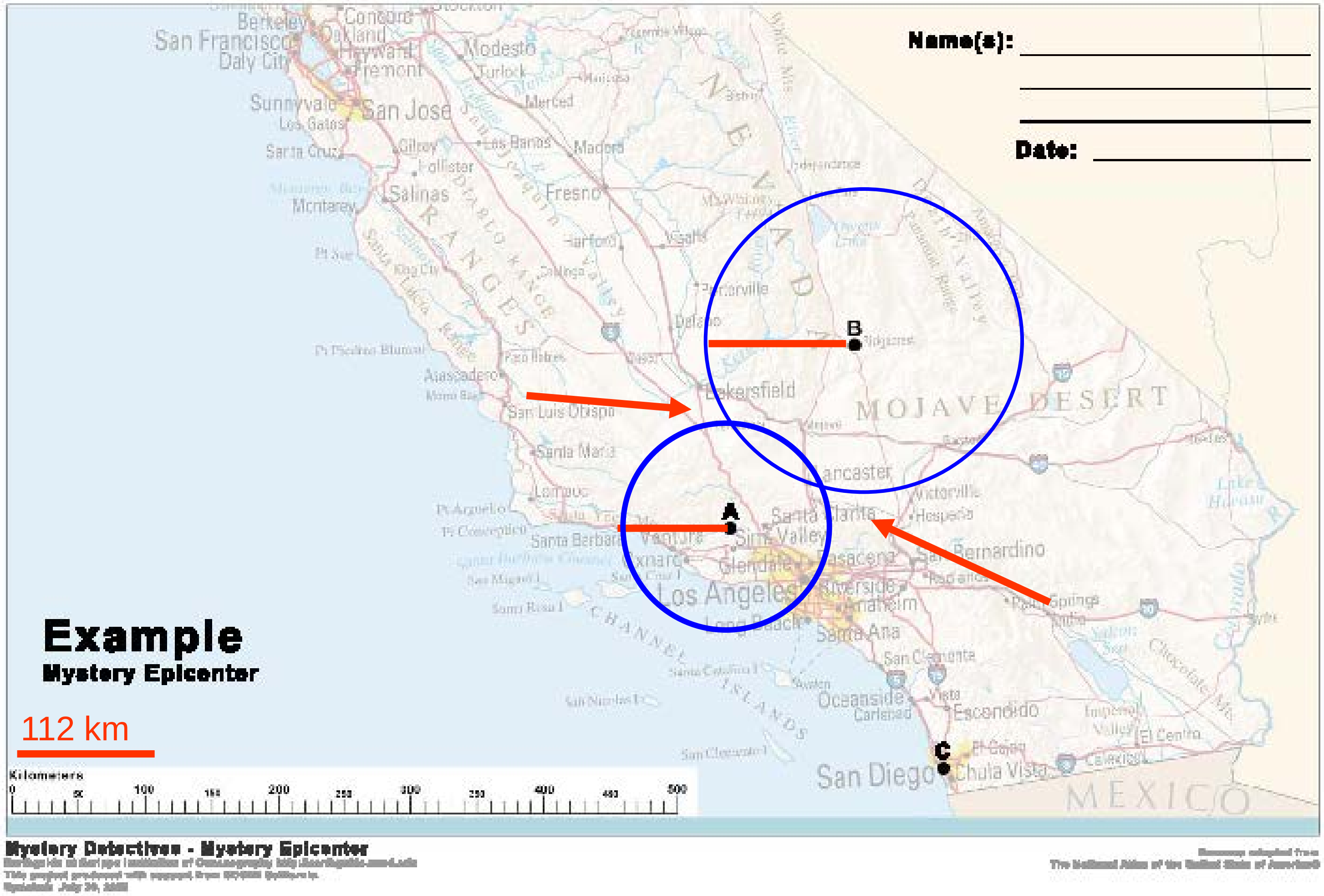
Station B

Arrival time P-wave ____________

Arrival time S-wave ____________

S-P lag time (s) 14

Distance from epicenter (km) (kilometers) 112



We just fix an area where the earthquake is supposed to have occurred and two locations

Mystery Epicenter
Group # 0 - Example

Name (s): ____________________

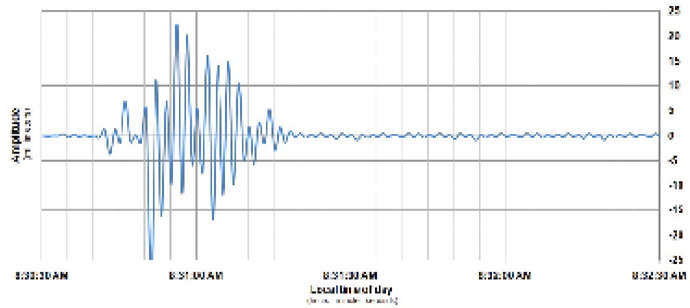
____

____

Date: ____________________

1. Mark the first arrival of the P-wave on each seismogram.
2. Mark the first arrival of the S-wave on each seismogram.
3. Write down your data in the box to the right of each seismogram.
4. Get the "distance from the epicenter" from the graph you made earlier using the "S-P lag time" that you recorded at your seismic station.

Seismogram - Group # 0 Example - Station A



Station A

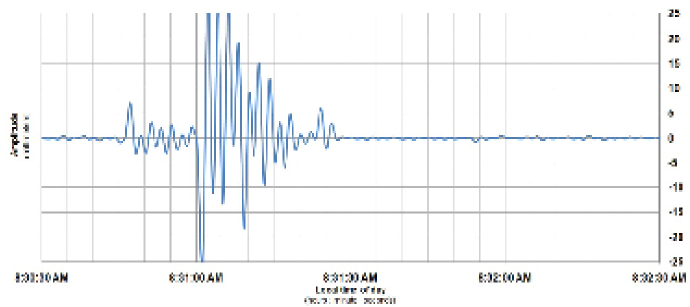
Arrival time P-wave ____________

Arrival time S-wave ____________

S-P lag time (s) ____________

Distance from epicenter (km) (kilometers) ____________

Seismogram - Group # 0 Example - Station B



Station B

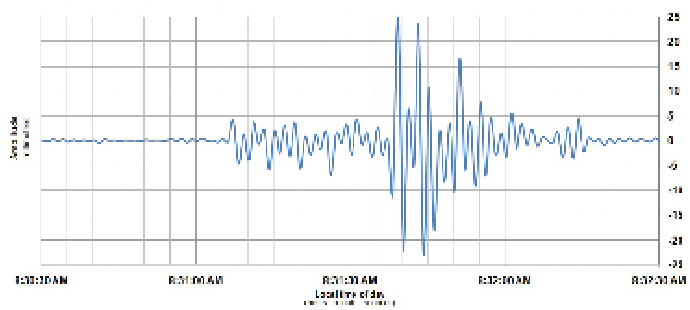
Arrival time P-wave ____________

Arrival time S-wave ____________

S-P lag time (s) ____________

Distance from epicenter (km) (kilometers) ____________

Seismogram - Group # 0 Example - Station C



Station C

Arrival time P-wave ____________

Arrival time S-wave ____________

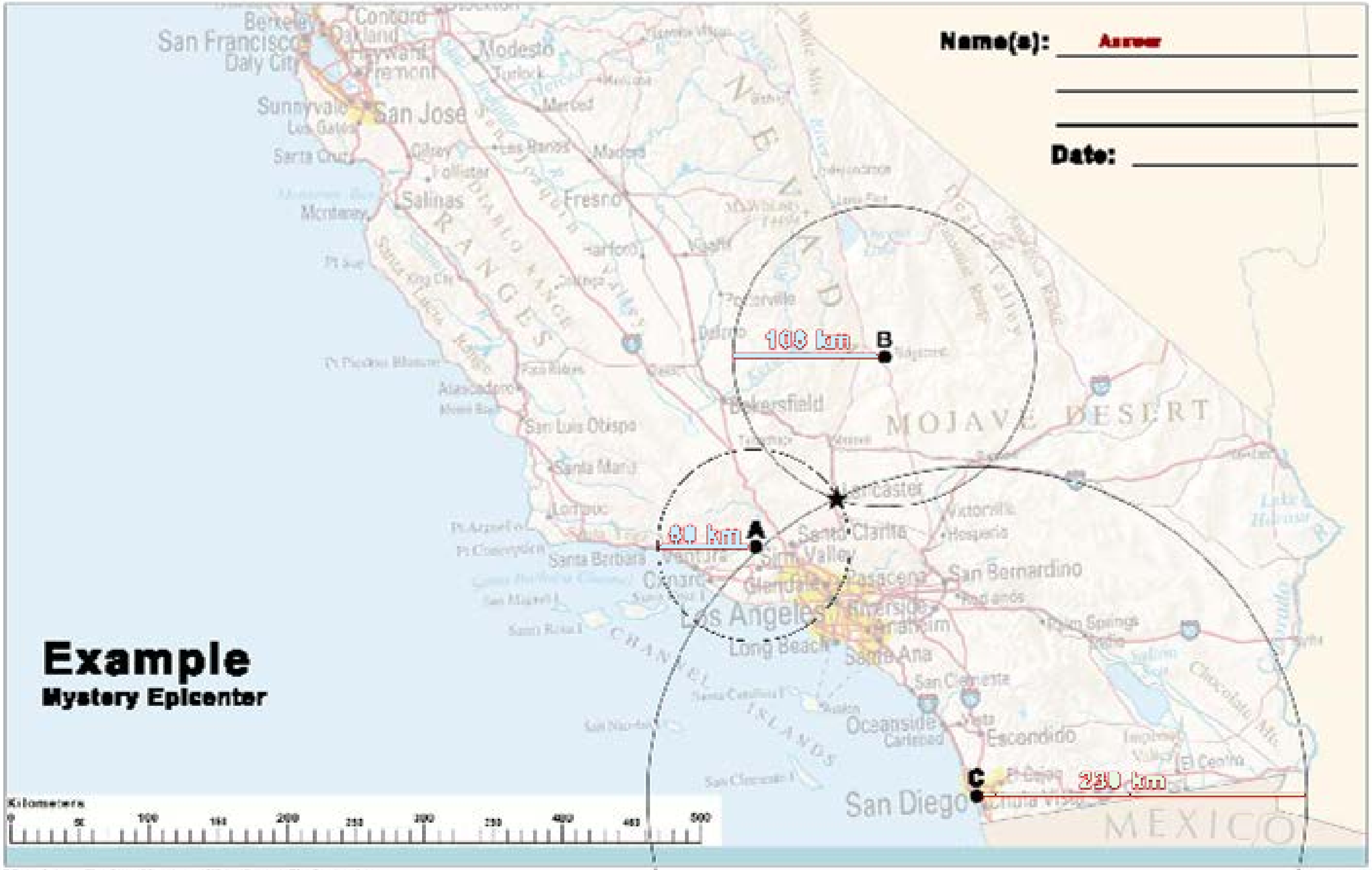
S-P lag time (s) ____________

Distance from epicenter (km) (kilometers) ____________

Earthquake epicenter activity

Earthguide at Geosciences Research Division, Scripps Institution of Oceanography http://earthguide.ucsd.edu
This project produced with support from COSEE California.
Updated: July 30, 2009

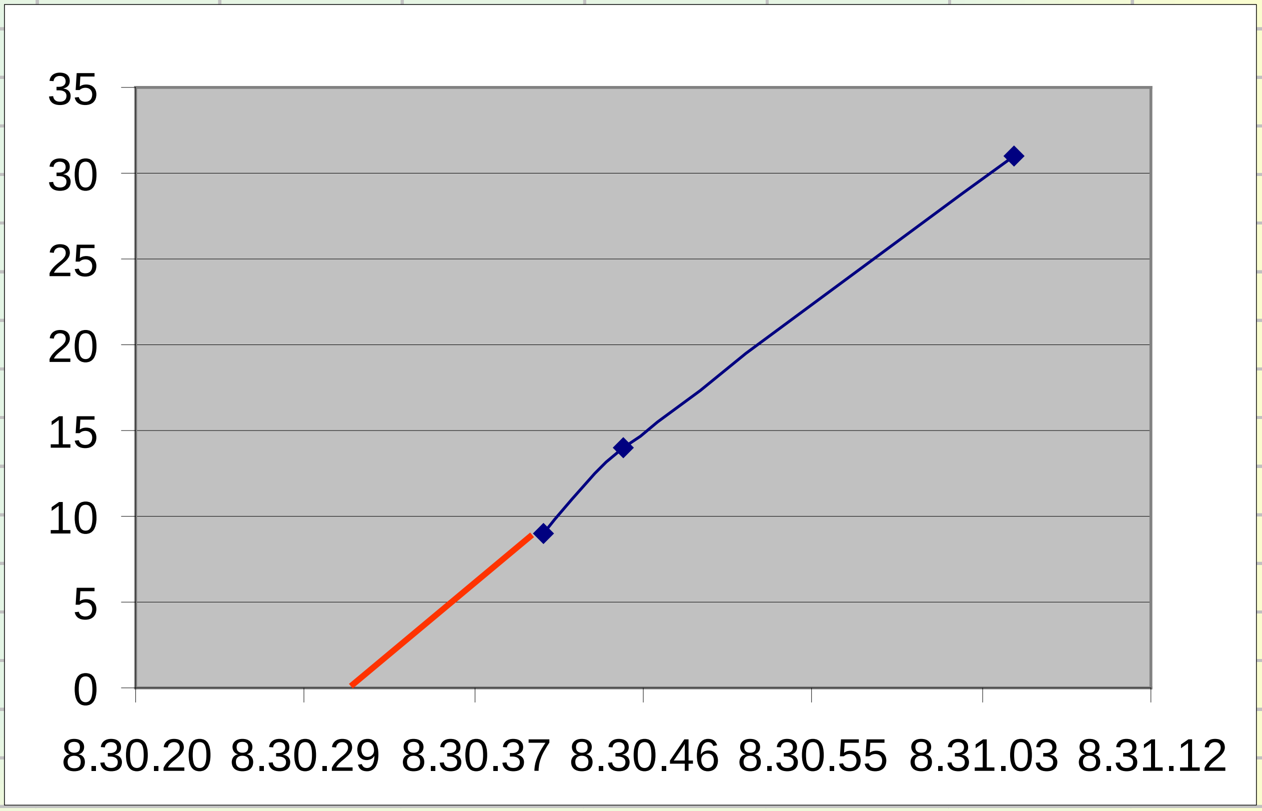

Reading a seismogram
To determine the distance to an earthquake epicenter
earthguide
Group #0, Station C
Group: Demo
Station: C
31s
Amplitude (milimeters)
300
200
100
0
-100
-200
-300
08:30:30am
08:31:00am
08:31:30am
08:32:00am
08:32:30am
Time of Day
(hours:minutes:seconds)
P-Wave Start Time
08 : 31 : 05
S-Wave Start Time
08 : 31 : 36
Show Lag Time
Good job! Take note of what the lagtime is.



Mystery Detectives - Mystery Epicenter

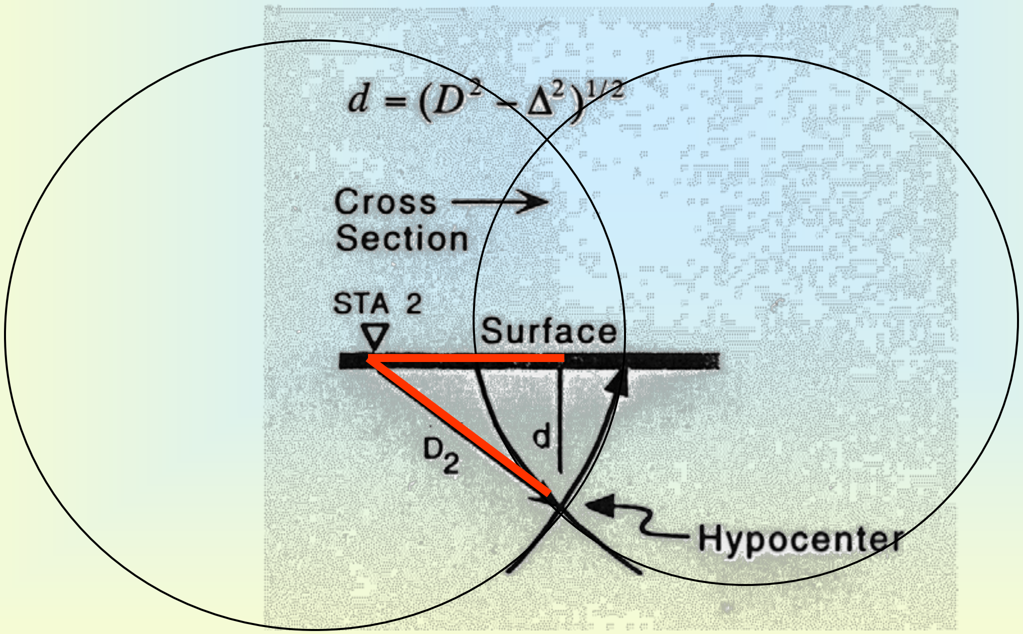
Origin time ?

It is possible to plot a Wadati diagram….

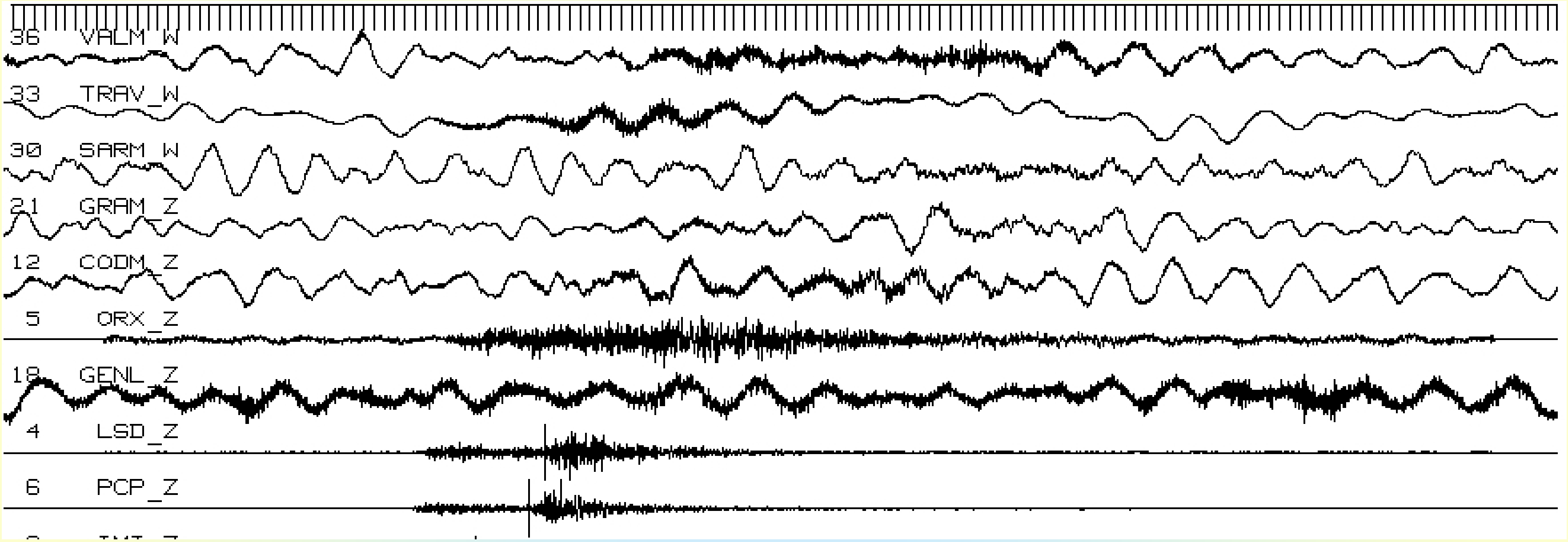


Depth……

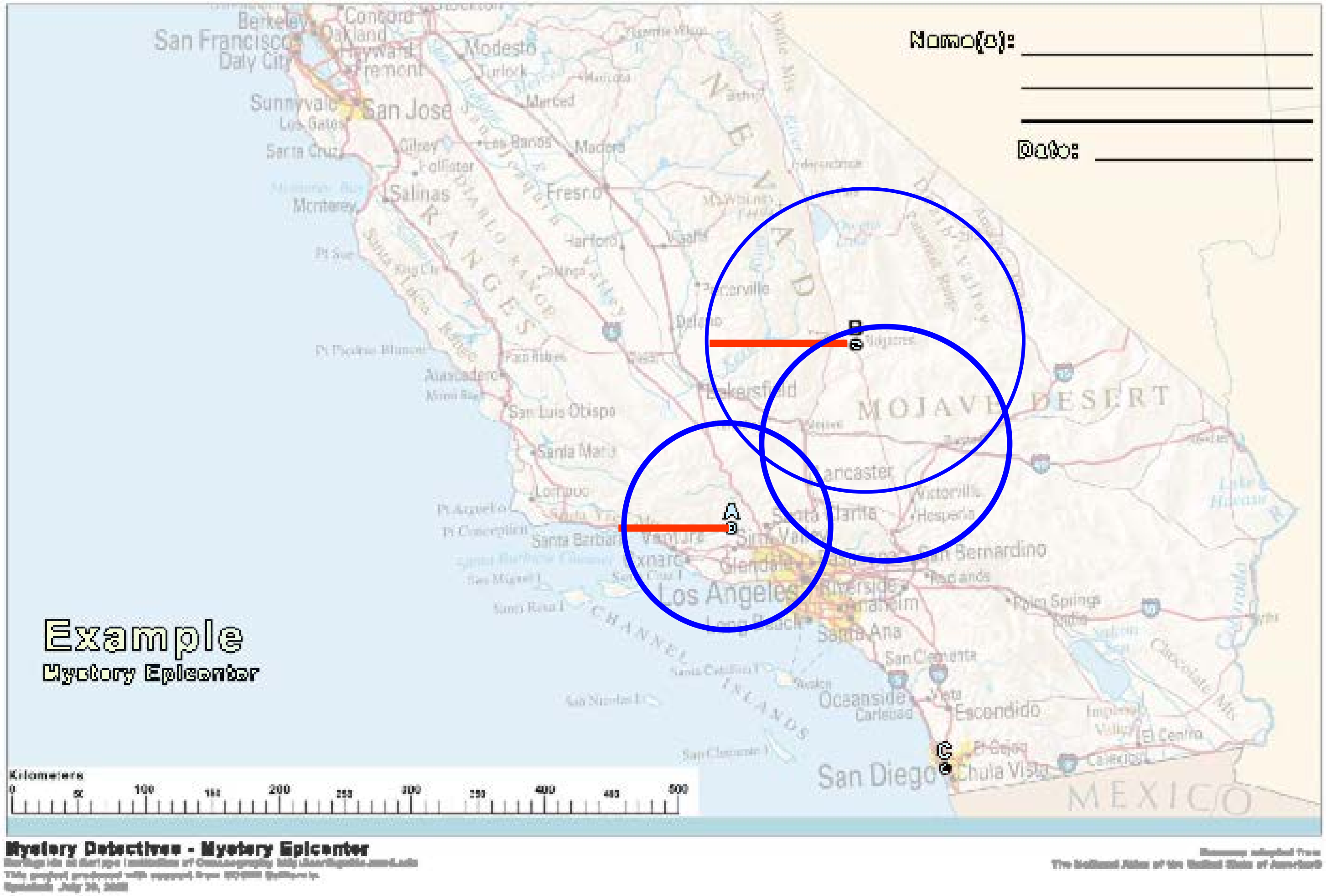
If instead of drawing circles we draw hemispheres, they will give a point which is under the surface. The ray of the half-sphere will be the distance D, the projection on the surface (which is the distance between the station and the epicenter) is Δ. The depth d will be determined taking the square root of the difference between D squared and Δ squared.



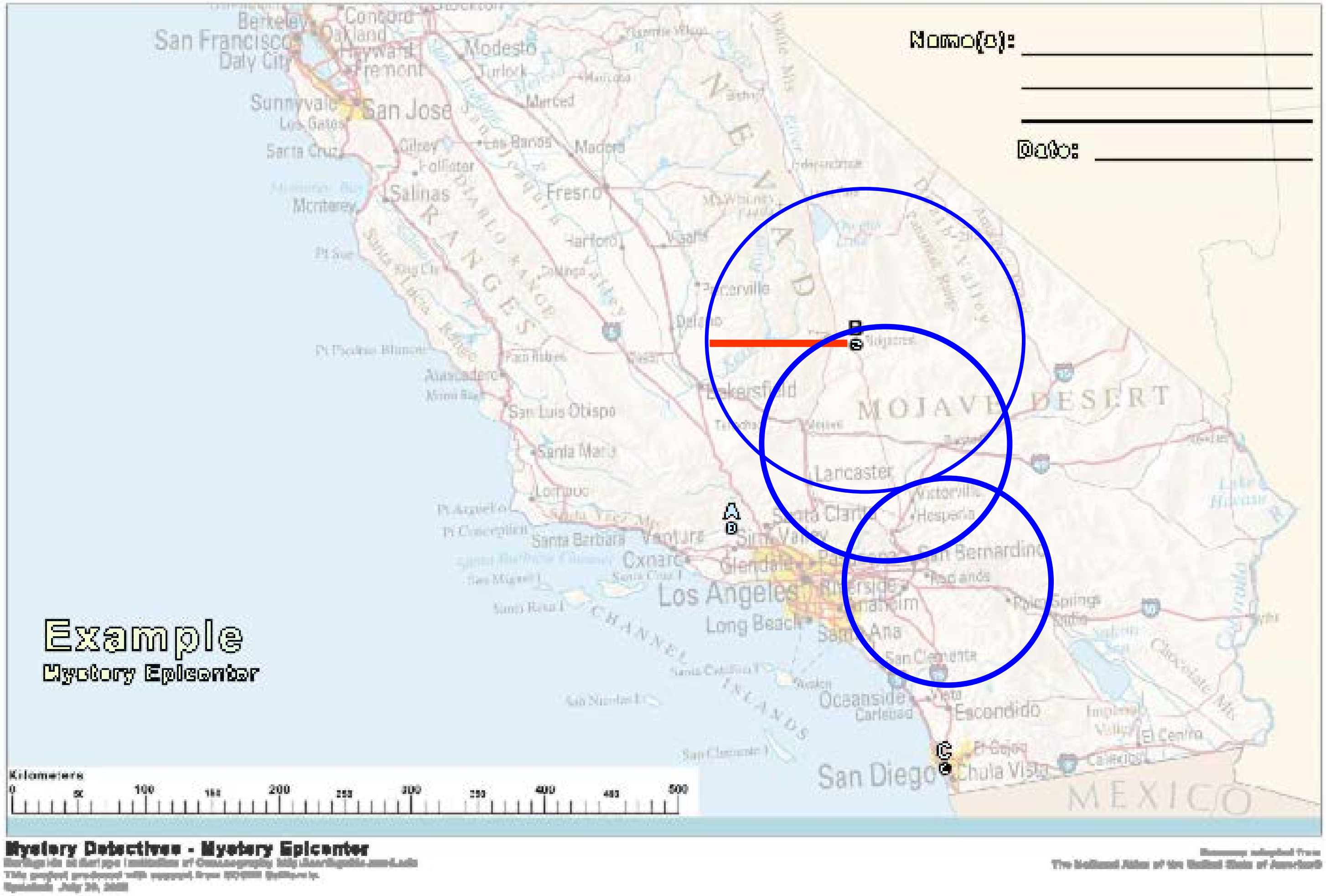
It does not work if…..



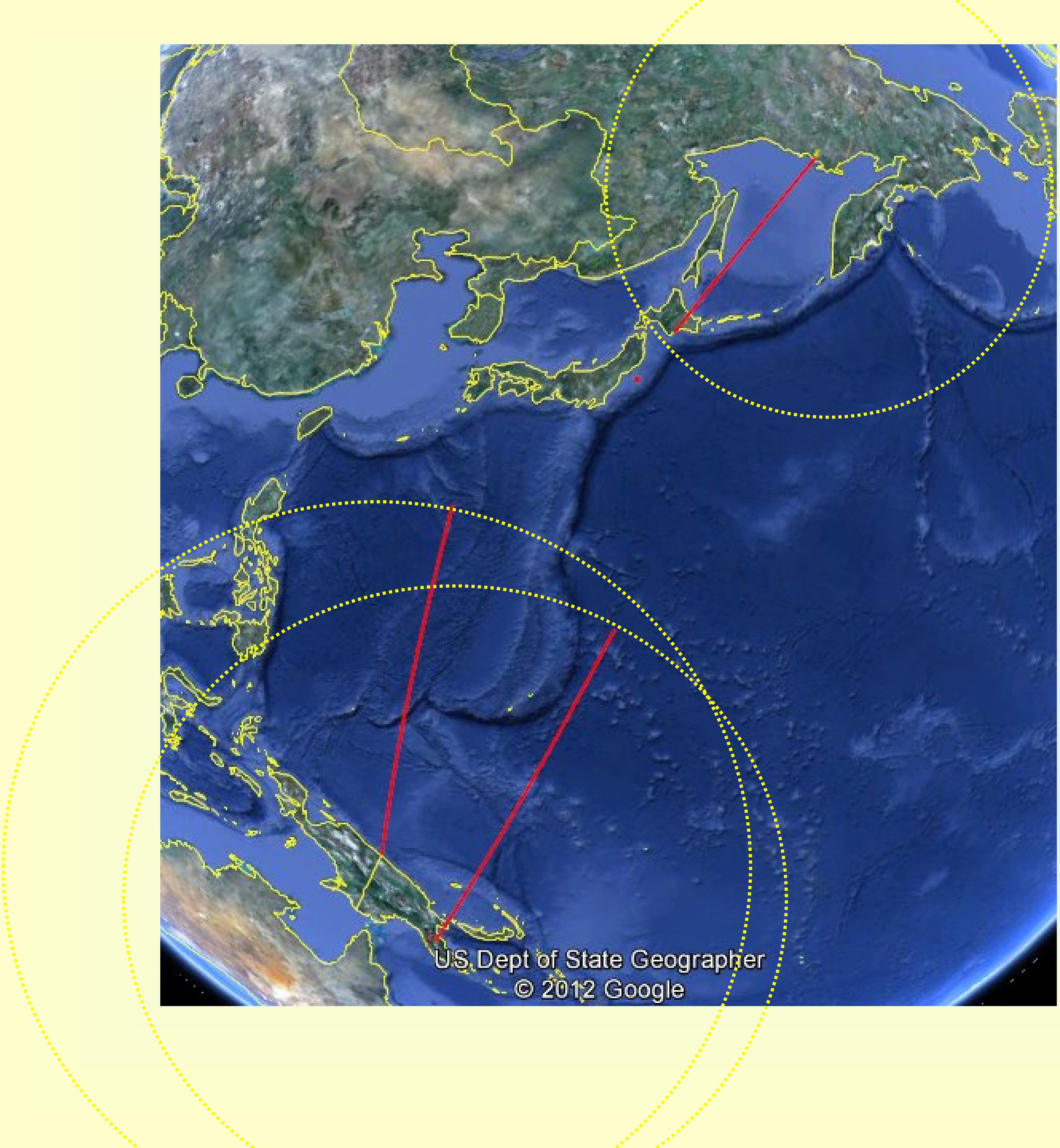
…unreadable seismograms….



…azimuthal distribution of stations…



…azimuthal distribution of stations…



The seismic waves travel in the mantle where the velocities are much higher and change with depth.

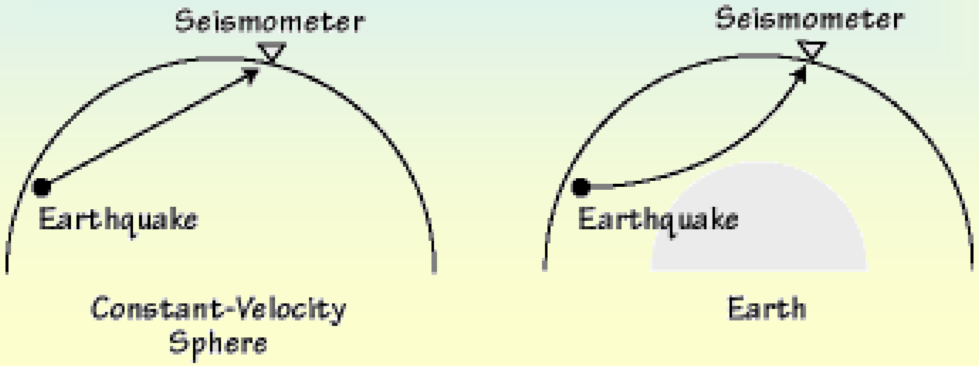
The approximation of displaying portion of the Earth on a planar map fails.

The ray path is not direct; the ray refracted and reflected

It is a typical inverse problem. In fact we have observations of the phenomenon (seismic recordings and consequently phase readings) and we want to find a model that can justify them.

The problem in solved via the GCC method: **guess, compute, compare**. An initial guess about the solution is made; according to it, a computation of the parameters to be included in the inversion is carried out; the results of this computation are compared to the real data. If they match, the solution is reached, if not a new guess is made and the process starts over from the beginning.

The problem is indeed complicated by non-linearity, by the errors associated to the observations (even when automatic phase picking is applied) which are of course unknown and unpredictable, by the overdetermined character of the resulting inverse problem (there are four unknowns (ot-lat-lon-depth) and several dozens observations, by the limitation of tracing rays in a non-real earth.



How strong is the earthquake ?

Two ways for computing :

Mercalli scale

Richter magnitude

Mercalli_Scale[1].swf

Pros and cons

Don’t need instruments

Takes a long time to compute, depends on the construction technique and materials, cannot be computed if no evidences are detected

The Richter magnitude of a quake is: the base 10 logarithm of the maximum displacement in micrometers, of the line produced by a Wood-Anderson seismograph, located 100 km from the epicenter of an earthquake.

Richter defined his magnitude 0 earthquake as that which produced a maximum amplitude of 0.001 mm at a distance of 100 km. Each successively larger magnitude was defined as a 10-fold increase in amplitude beyond the base level. Thus, a maximum seismogram amplitude (at a distance of 100 km) of 0.01 mm
represents ML 1.0, 0.1 mm equals ML 2.0, 1 mm equals ML 3.0, and so on.

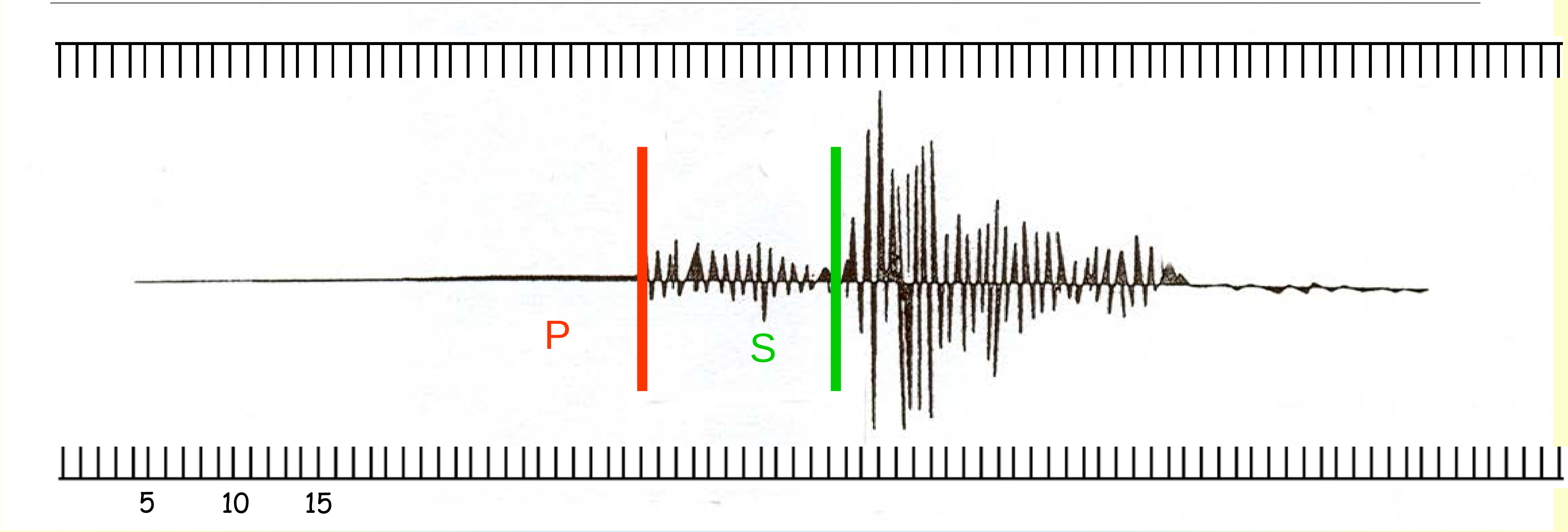
The magnitude defined by Richter is valid only for California (where it was proposed) and for seismograms obtained with a standard Wood-Anderson seismograph.

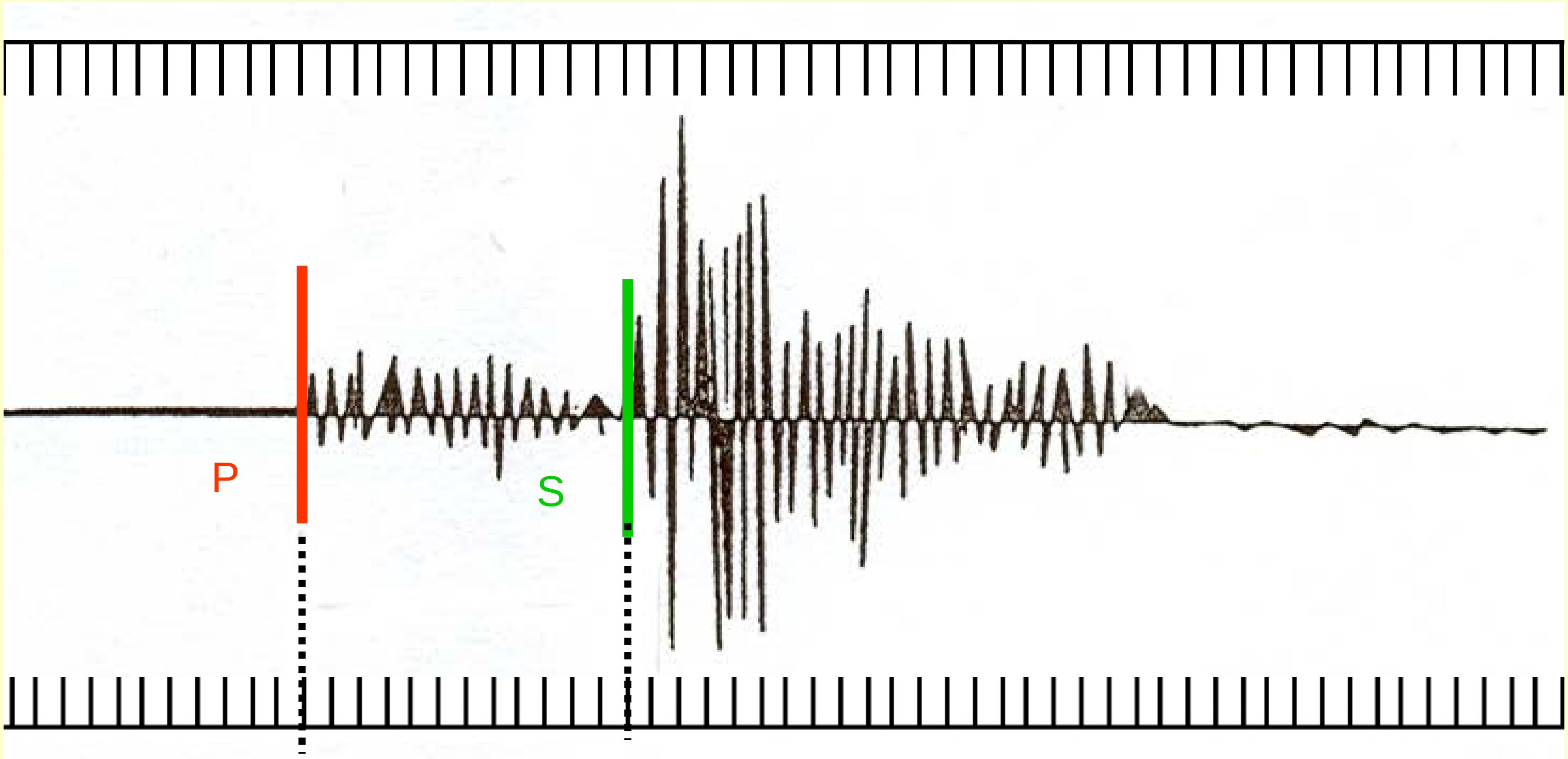
Magnitude has no minimum or maximum limit. However the maximum value ever recorded was about 9.5 (Chile, 1960). We currently detect several magnitude 0 and few negative magnitude earthquakes. In principle they do seldom exceed magnitude -1, but this threshold is only limited by the sensitivity of the instruments used.

It must be underlined that, conversely to what happens with the Mercalli scale, the magnitude is the same at every seismogram and it does not depend on the distance from the epicenter.

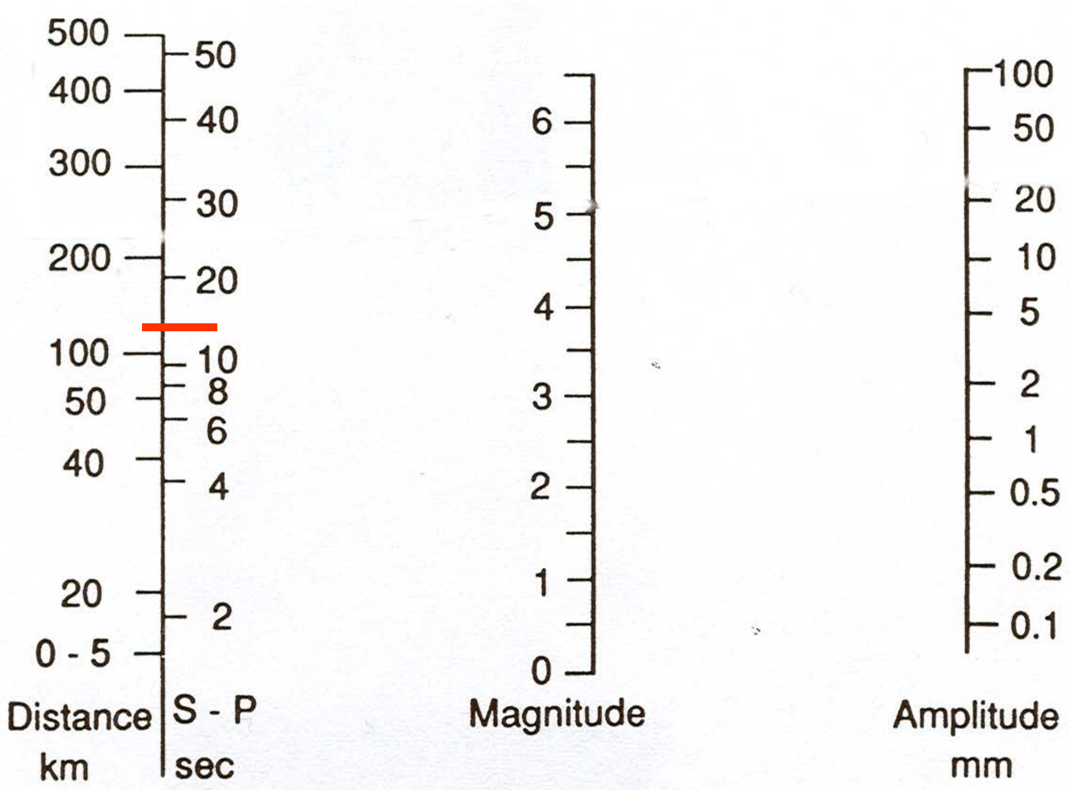
It is widely accepted that the threshold above which an earthquake can cause damages is 4.5. Such consequences are in principle reported when the distance to the epicenter is very small.

Tempo in secondi (ogni tacca un secondo)





12 secondi



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Magnitude
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10
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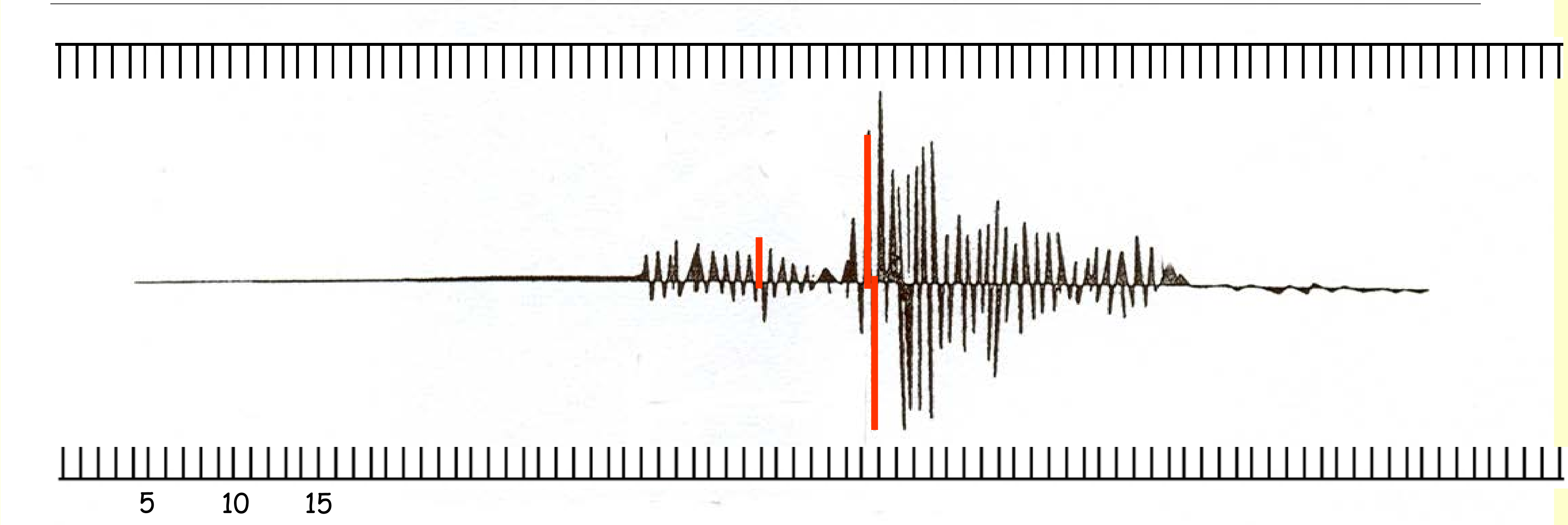
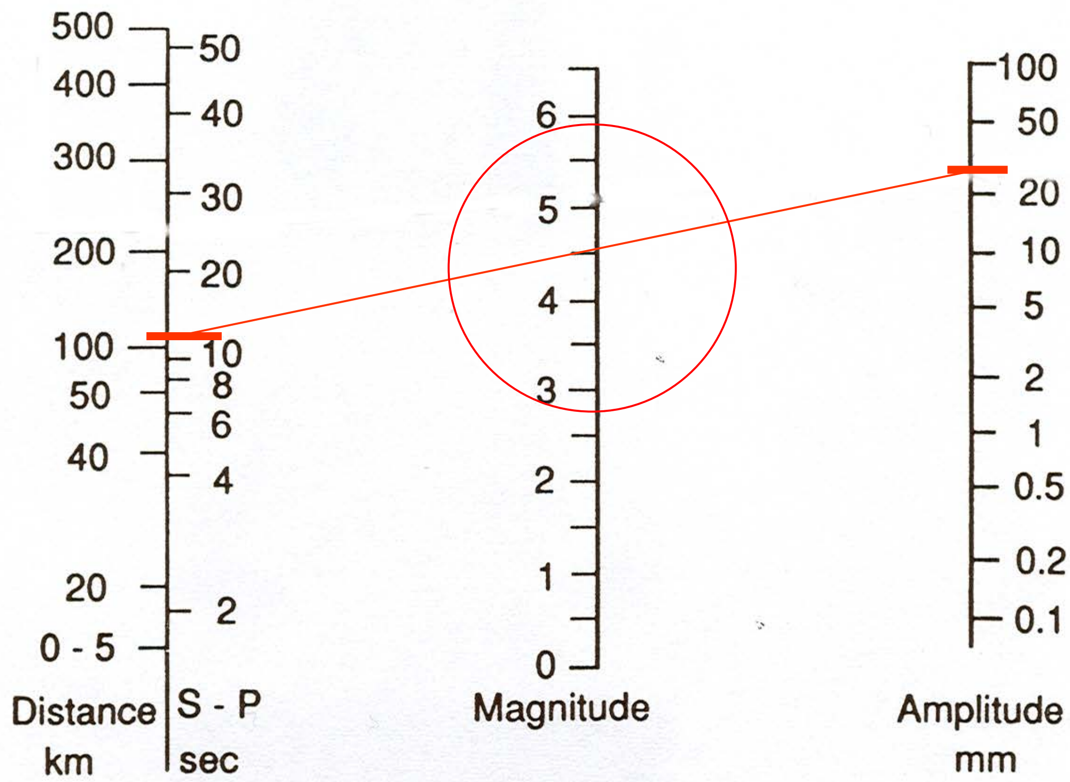
0.1
Amplitude
mm

Tempo in secondi (ogni tacca un secondo)





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Distance
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Magnitude
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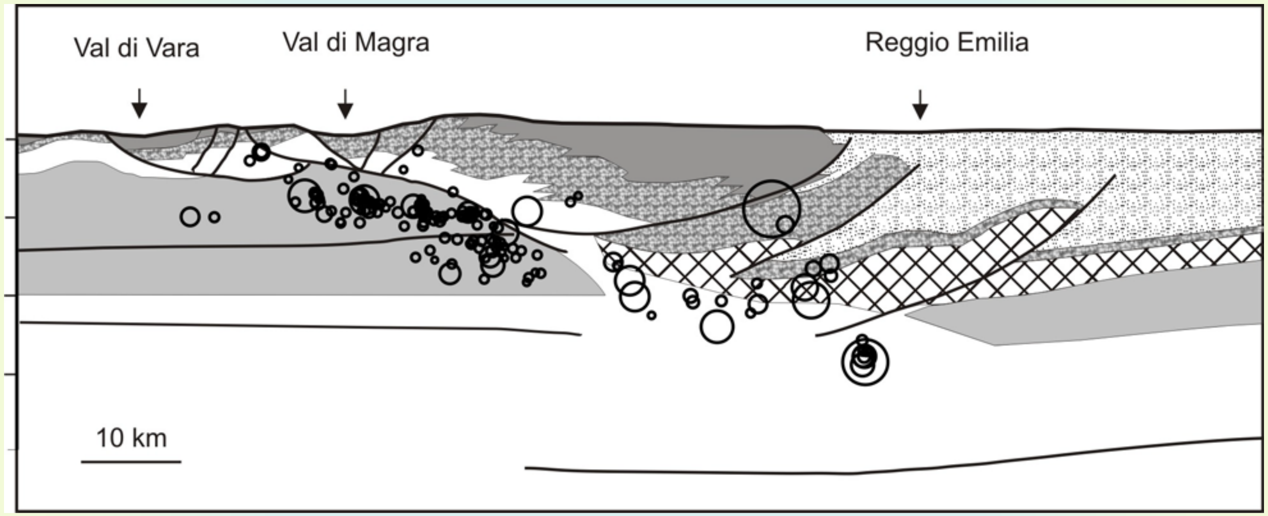
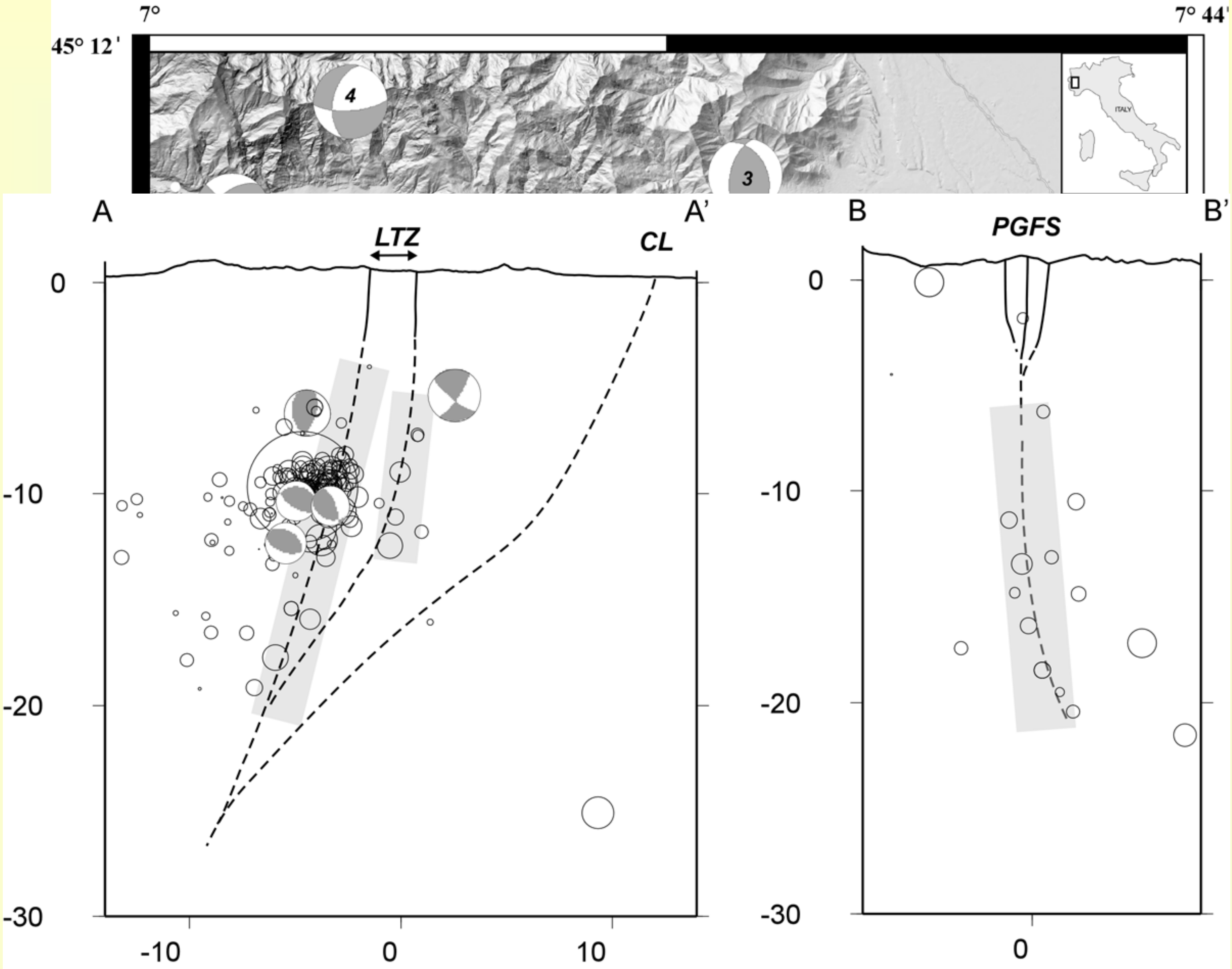
0.5
0.2
0.1
Amplitude
mm

Modified Mercalli Scale vs. Richter Scale

Category	Effects	Richter Scale (approximate)
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8



Val di Vara
Val di Magra
Reggio Emilia
10 km


7°
7° 44'
45° 12'
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3
ITALY
A
A'
LTZ
CL
B
B'
PGFS
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-10
-20
-30
-10
0
10
0
-10
-20
-30
0