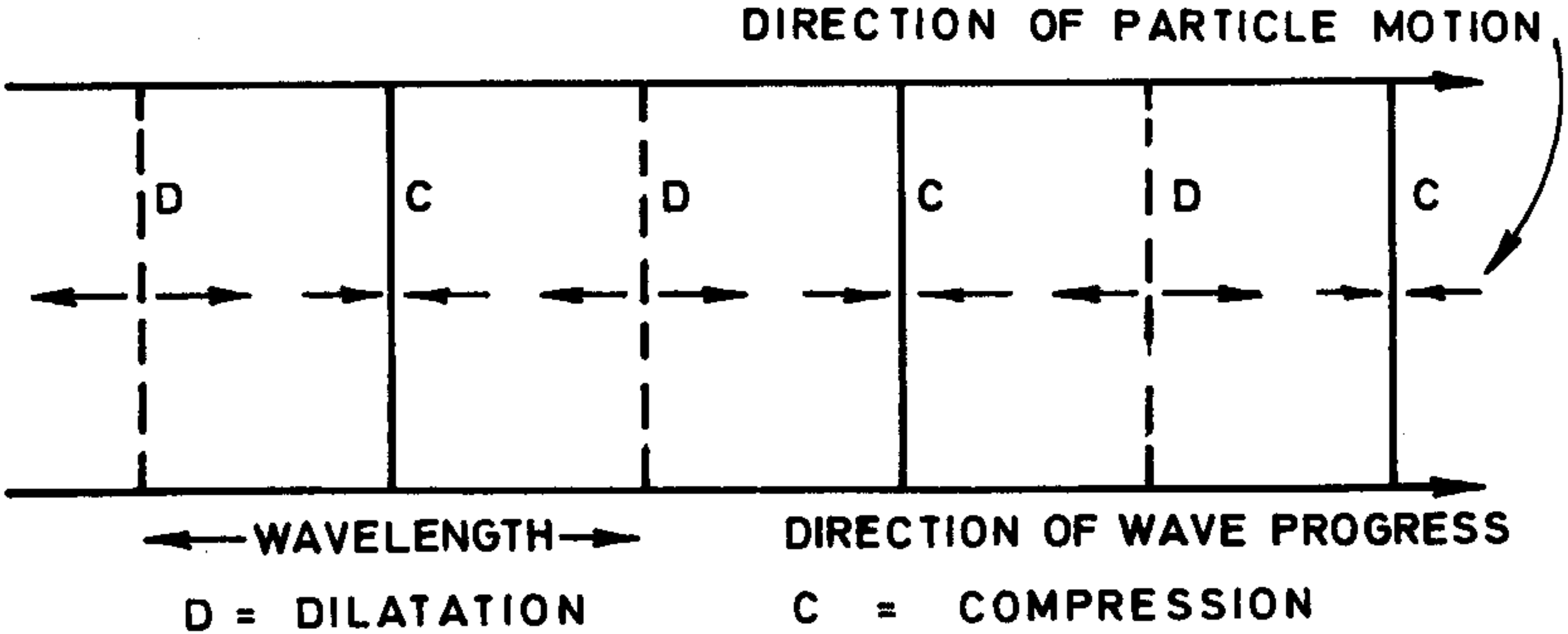
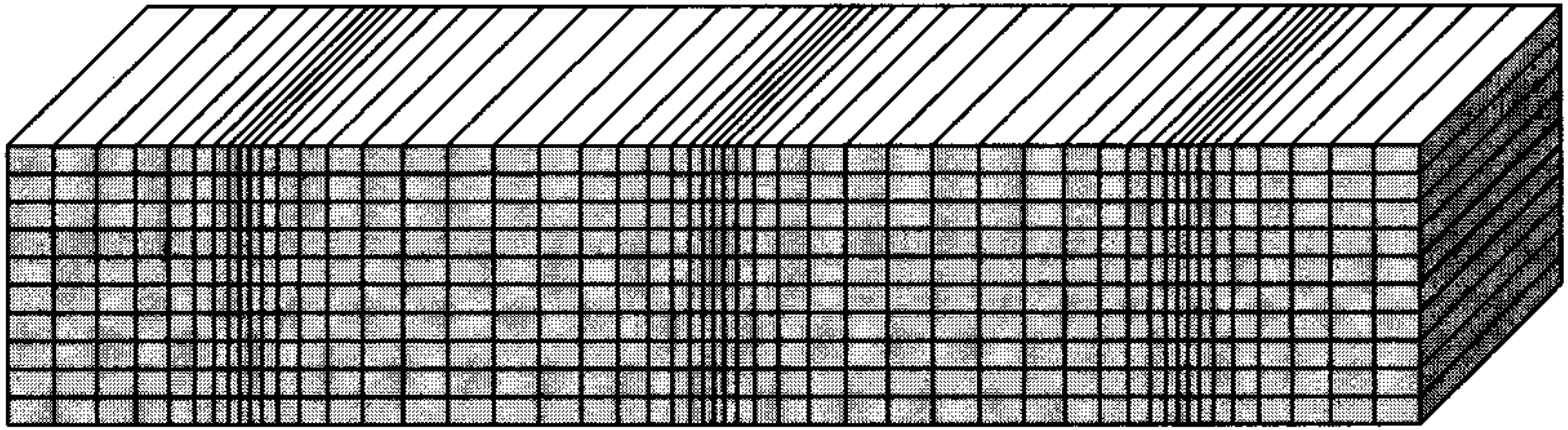
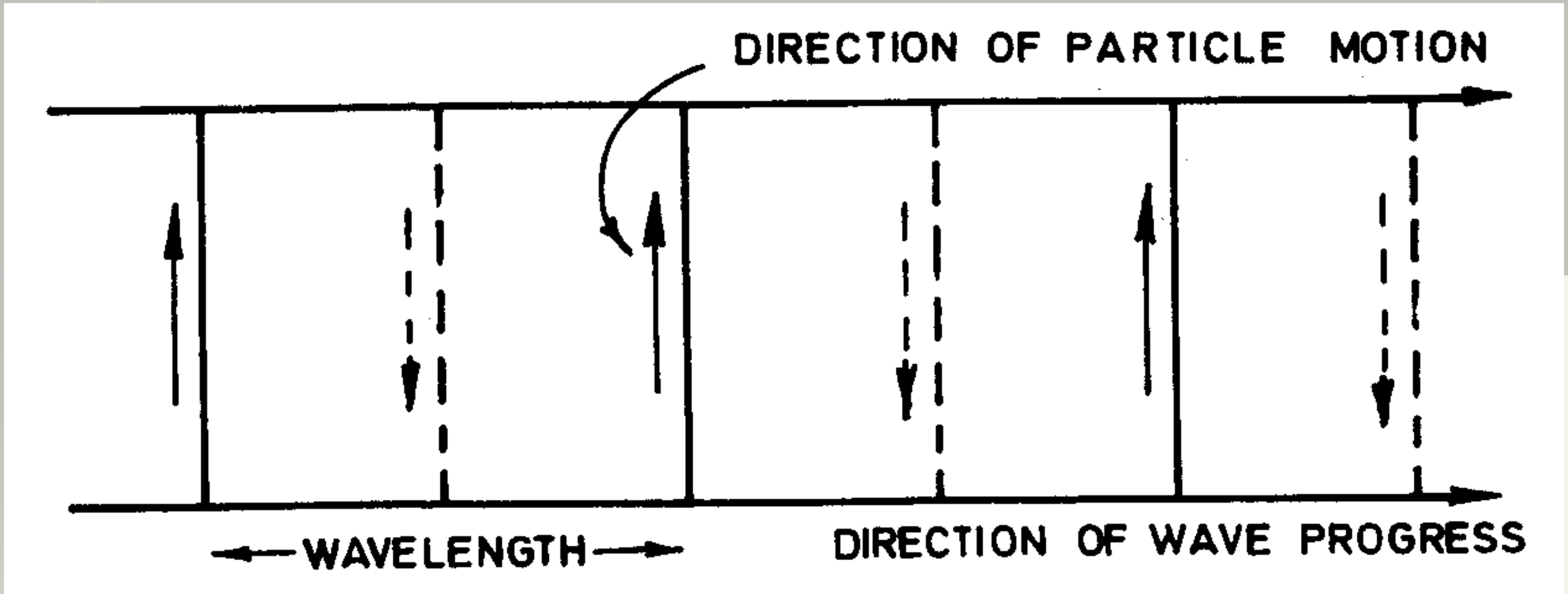
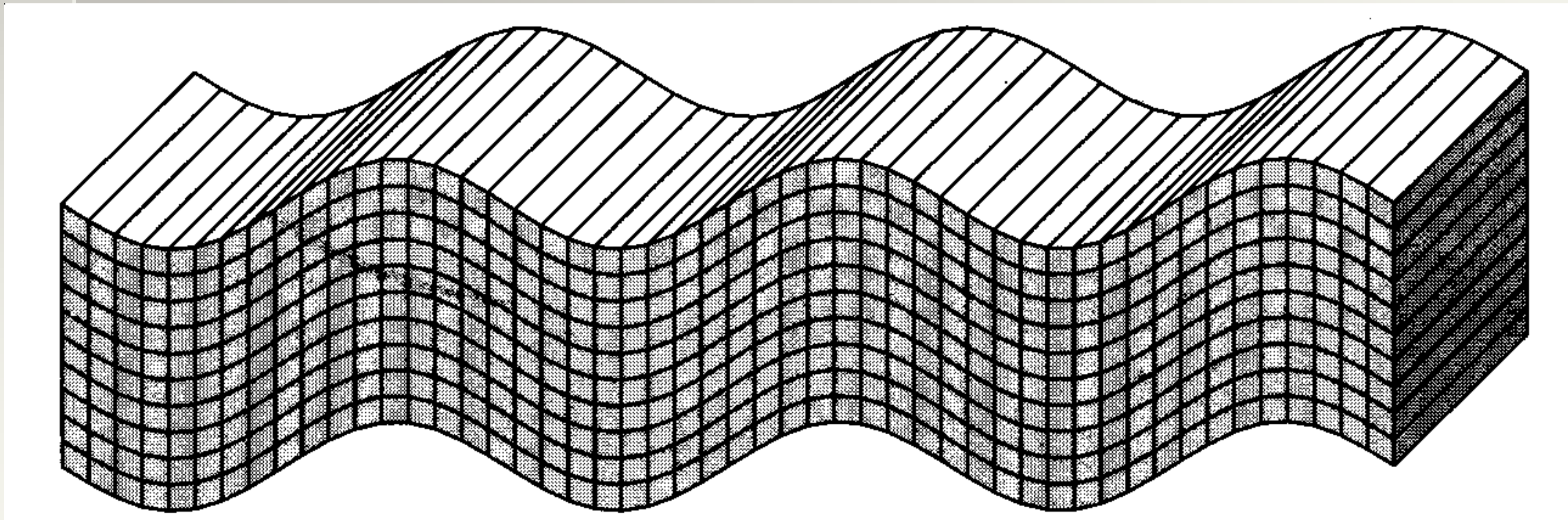
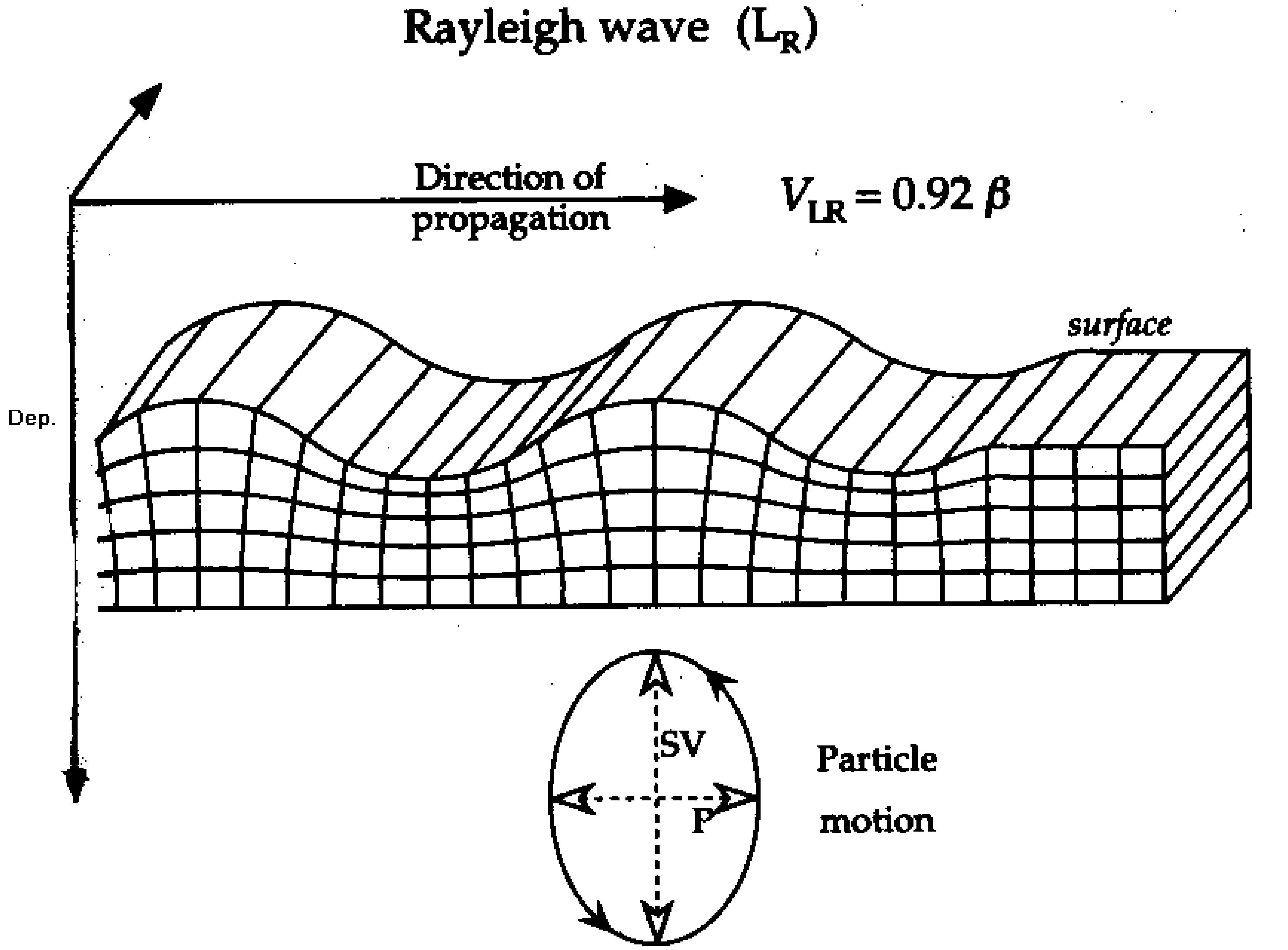

DIRECTION OF PARTICLE MOTION
D
C
D
C
D
C
WAVELENGTH
DIRECTION OF WAVE PROGRESS
D = DILATATION
C = COMPRESSION

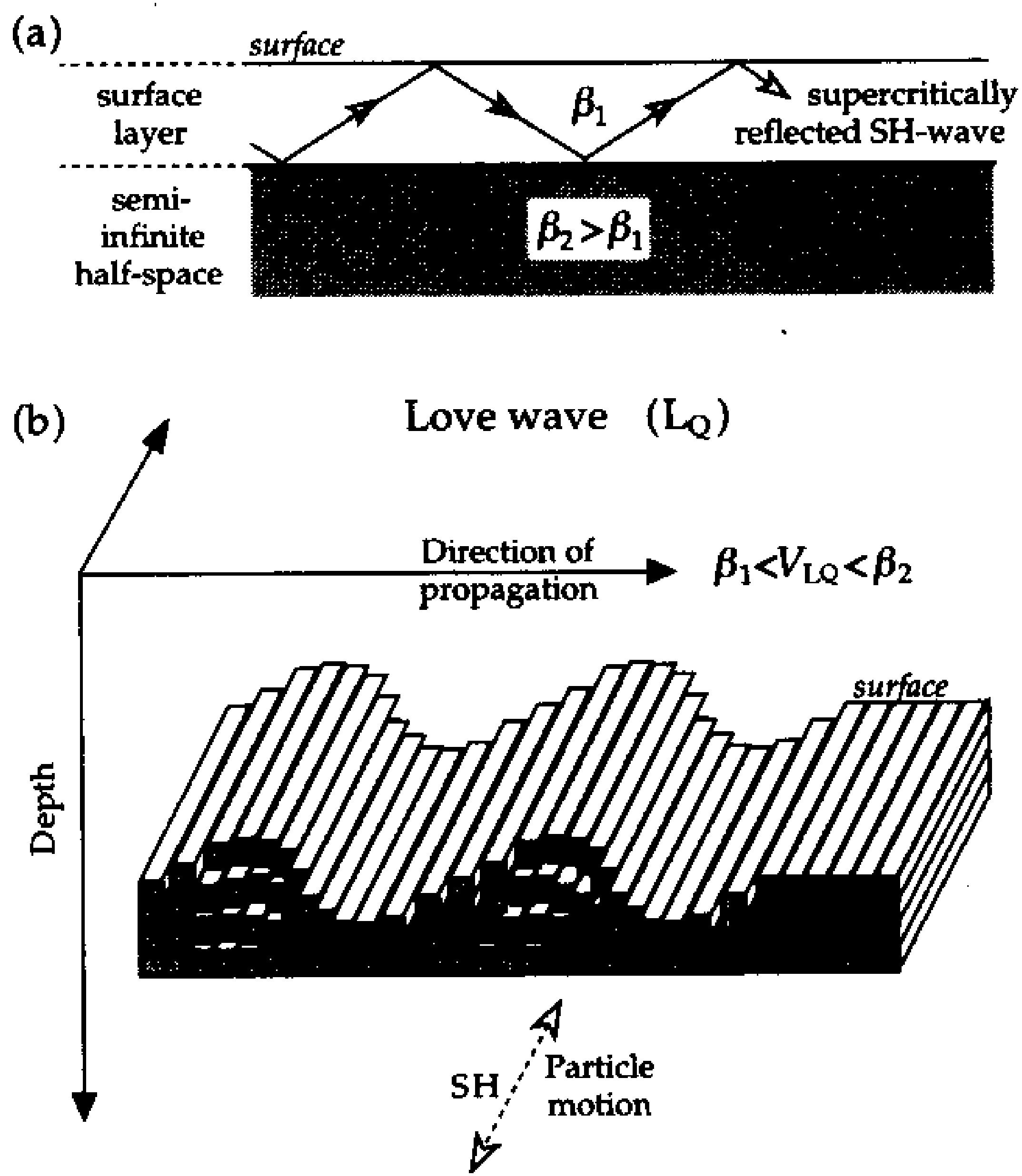



DIRECTION OF PARTICLE MOTION
WAVELENGTH
DIRECTION OF WAVE PROGRESS

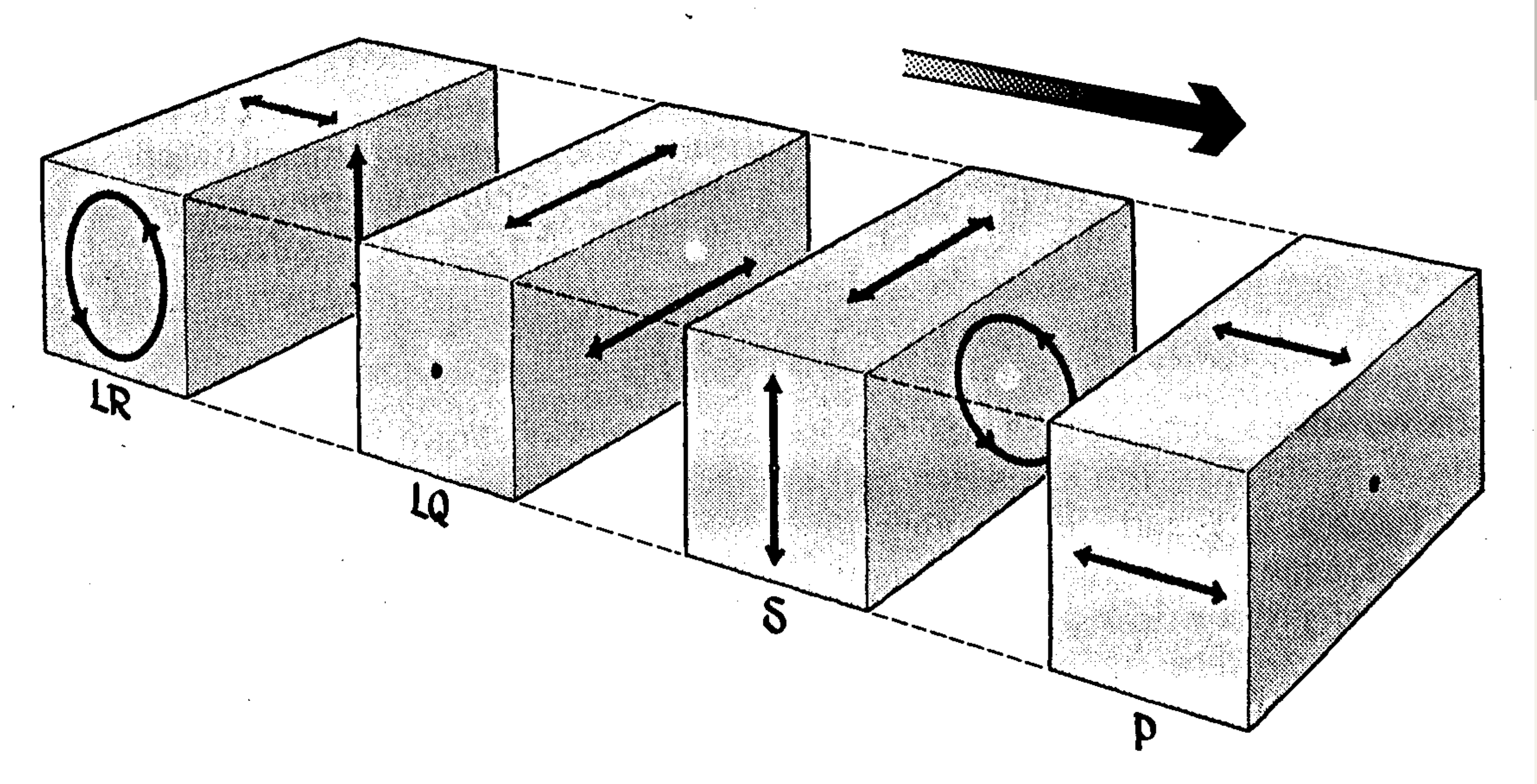


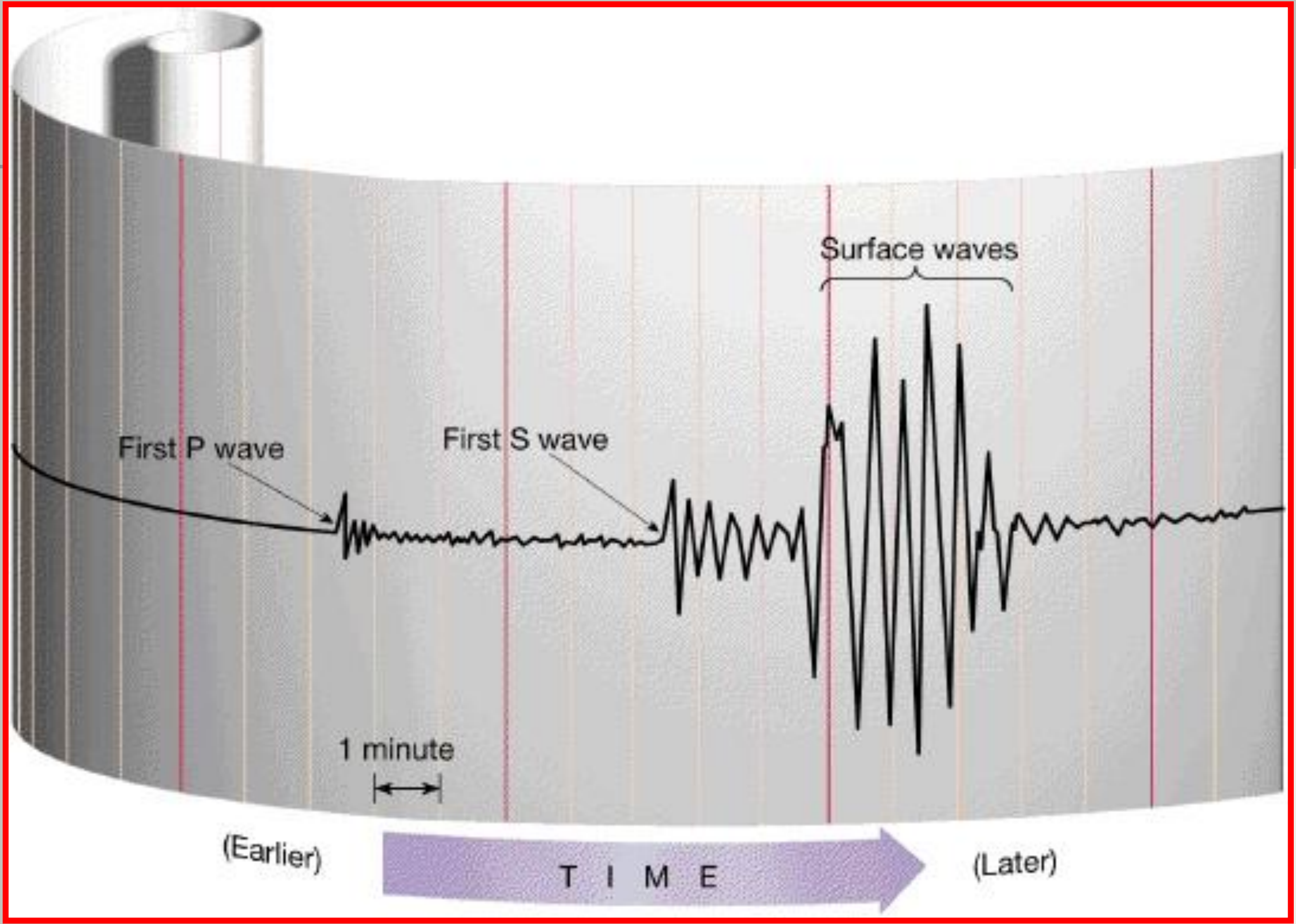


Rayleigh wave (L_R)
Direction of propagation
$V_{LR} = 0.92\,\beta$
surface
Dep.
SV
P
Particle motion



(a)
surface
surface layer
β_1
supercritically reflected SH-wave
semi-infinite half-space
$\beta_2 > \beta_1$
(b)
Love wave (L_Q)
Direction of propagation
$\beta_1 < V_{LQ} < \beta_2$
surface
Depth
SH
Particle motion

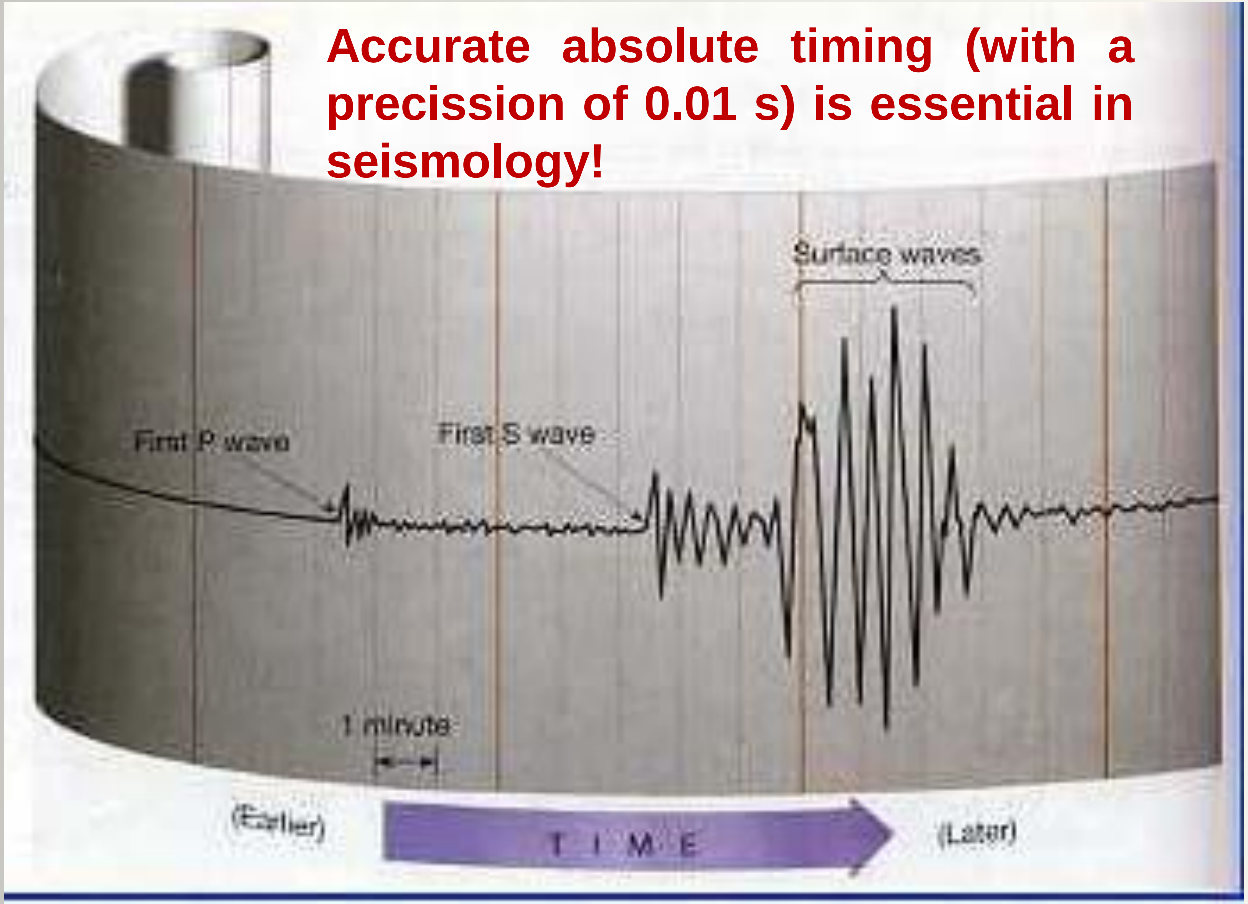

LR
LQ
S
P

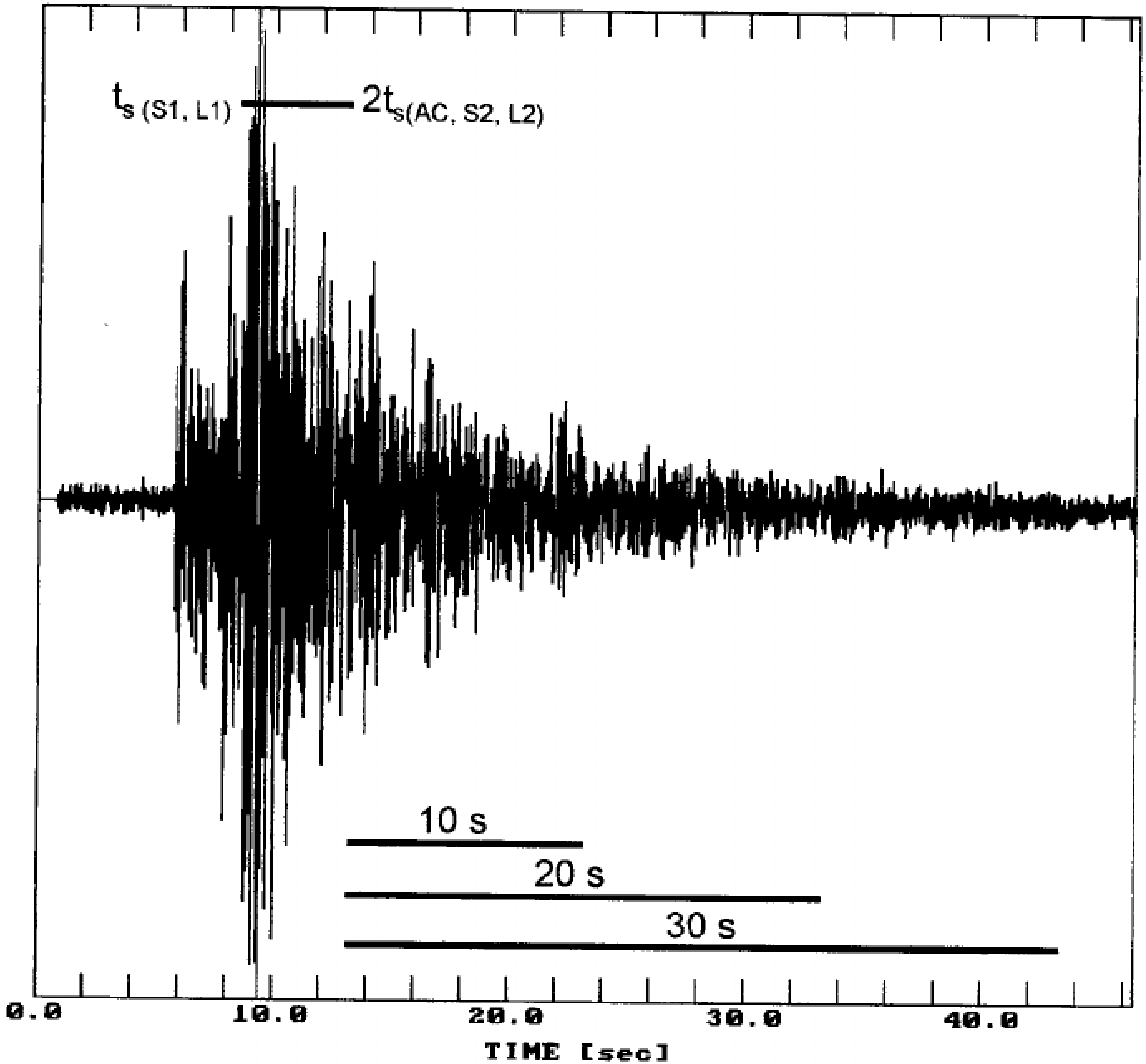

Surface waves
First P wave
First S wave
1 minute
(Earlier)
T I M E
(Later)

Observational Seismology
Locating Earthquakes

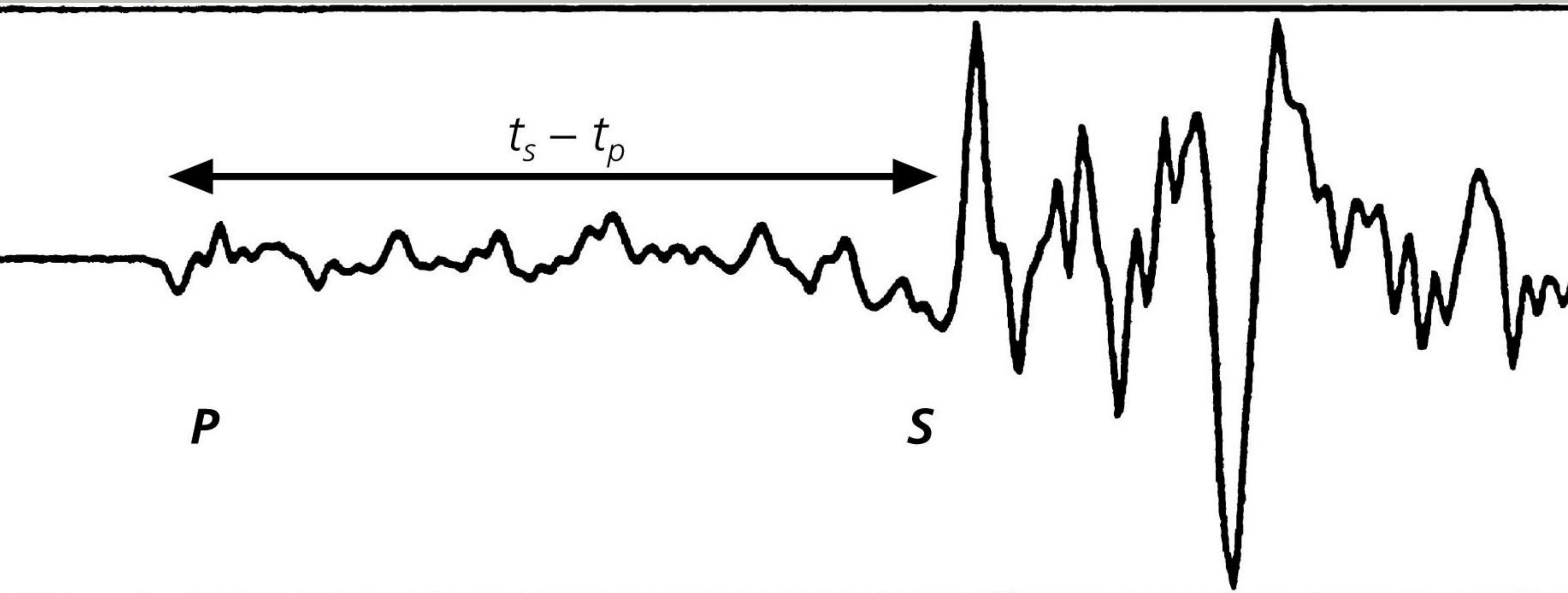
- To locate an earthquake we need precise readings of the times when P - and S - waves arrive at a number of seismic stations.

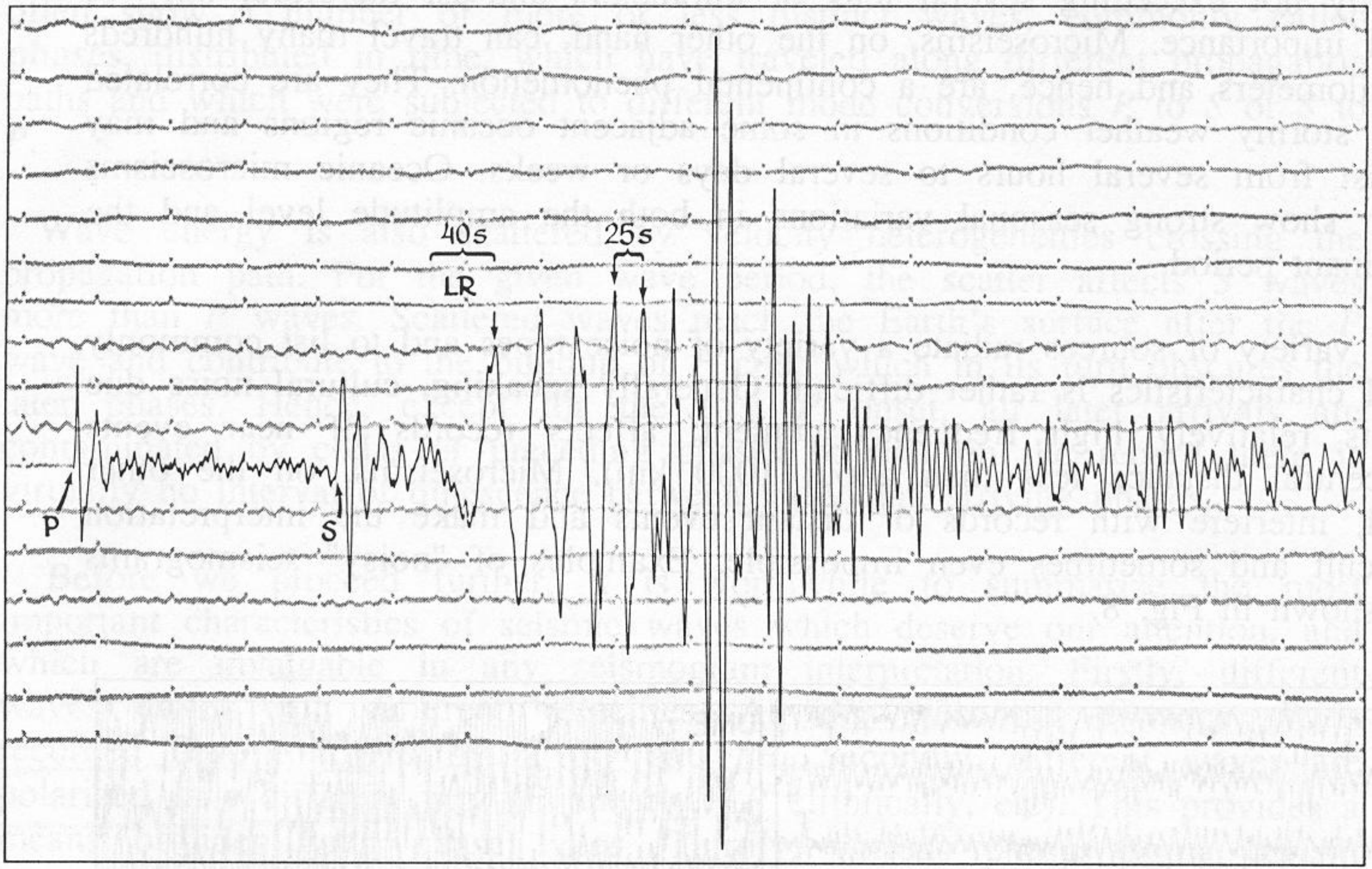
Accurate absolute timing (with a precission of 0.01 s) is essential in seismology!

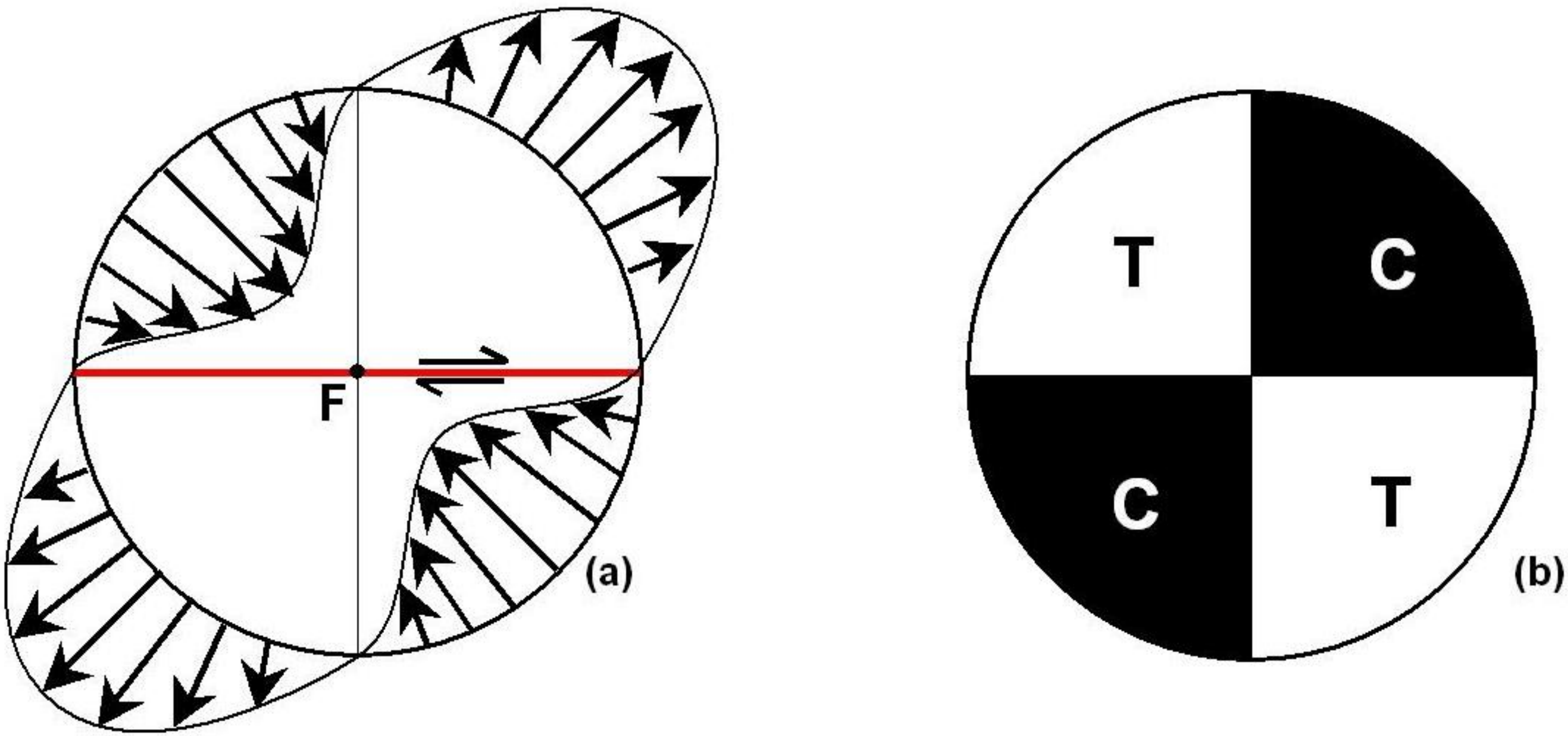




t_s (S1, L1)
2t_s(AC, S2, L2)
10 s
20 s
30 s
0.0
10.0
20.0
30.0
40.0
TIME [sec]

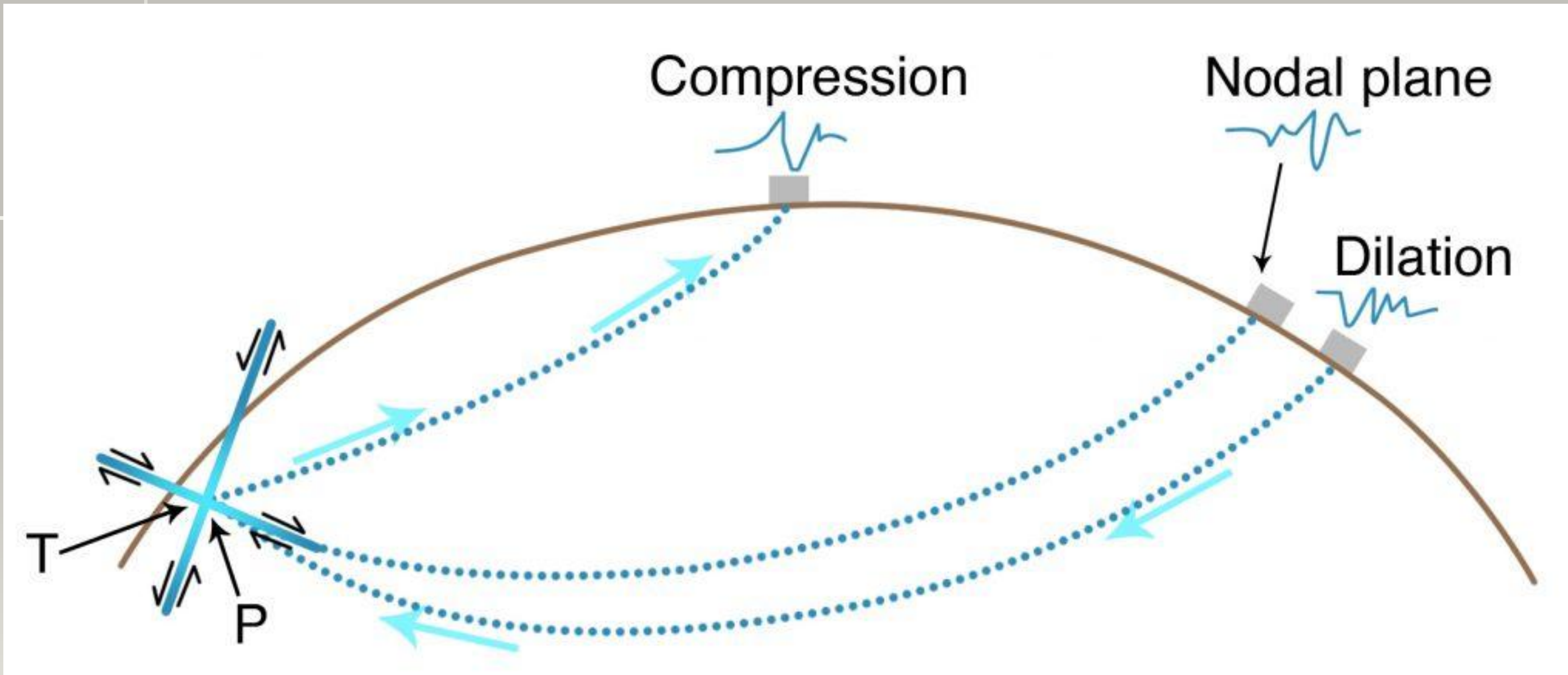

$t_s - t_p$
P
S


40s
LR
25s
P
S



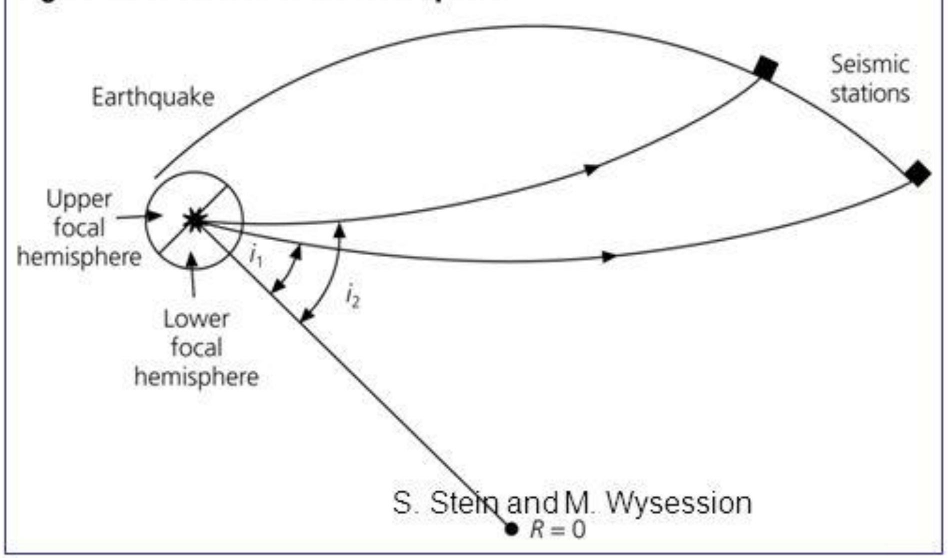
Schematic diagram showing the direction of initial movement of particles around the focus (F) of an earthquake on a W-E dextral strike-slip fault, viewed from above (a) and the equivalent zones of compressional (C) and tensional (T) sense first motion in the seismic waves radiating outward (b).

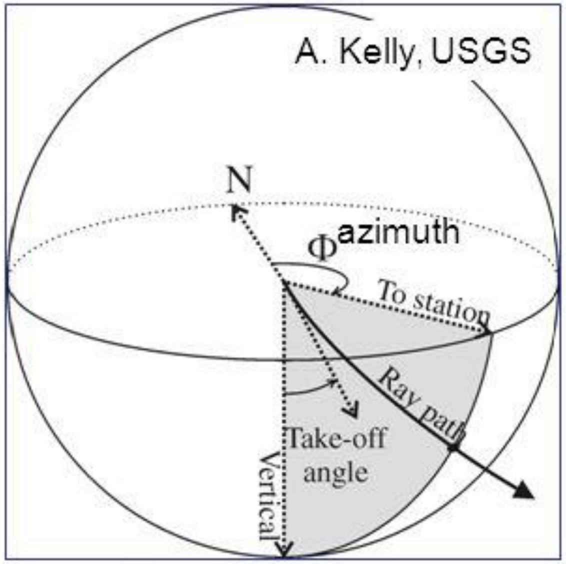
Note that due to the symmetry, an identical pattern would result from movement on an N-S sinistral strike-slip fault passing through the focus

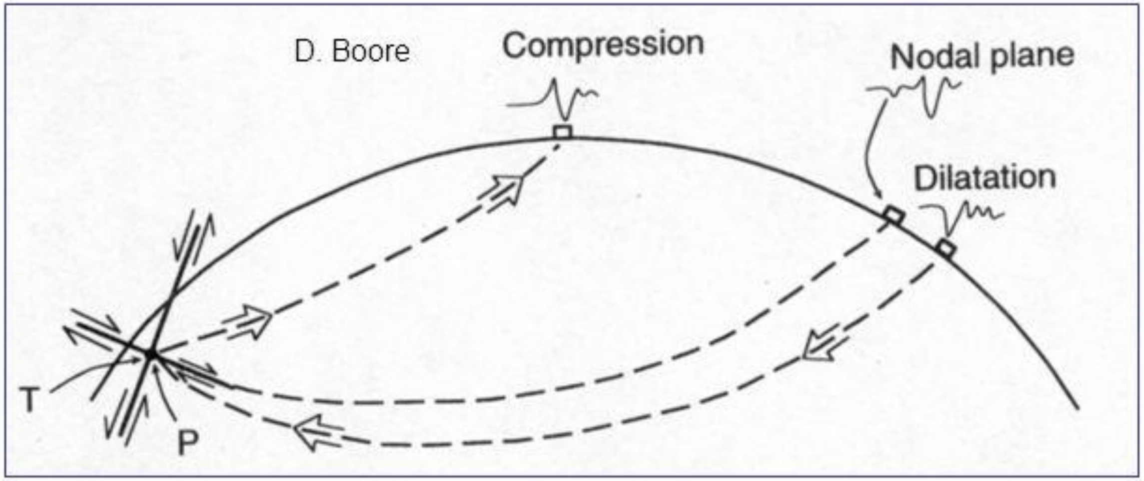

Compression
Nodal plane
Dilation
T
P

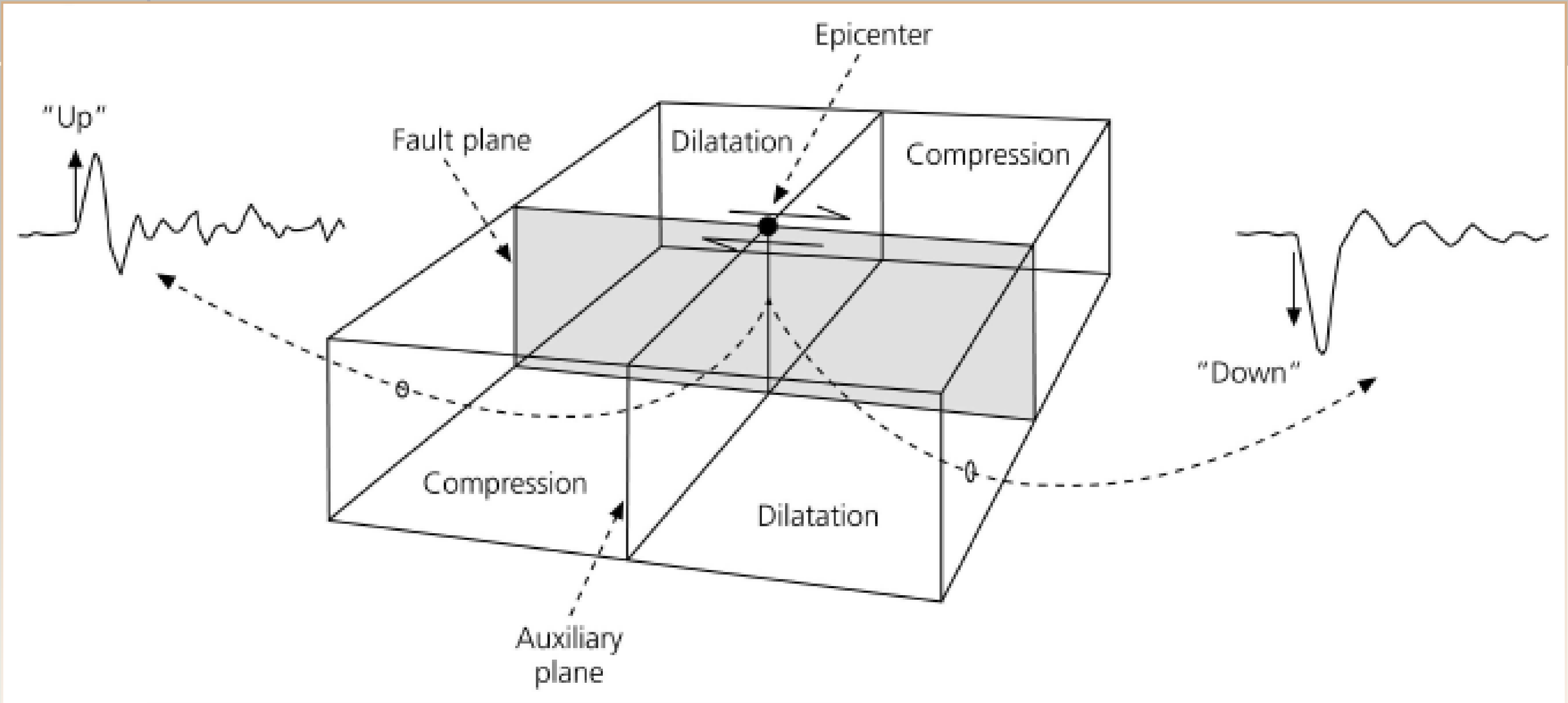
To determine the fault plane solution using the first motions, the observations at stations (Earth surface) have to be converted to observations over a sphere (of infinitesimal radius) around the source. The position on the sphere is determined by the take-off angle (computed from the slope of the travel-time curve).

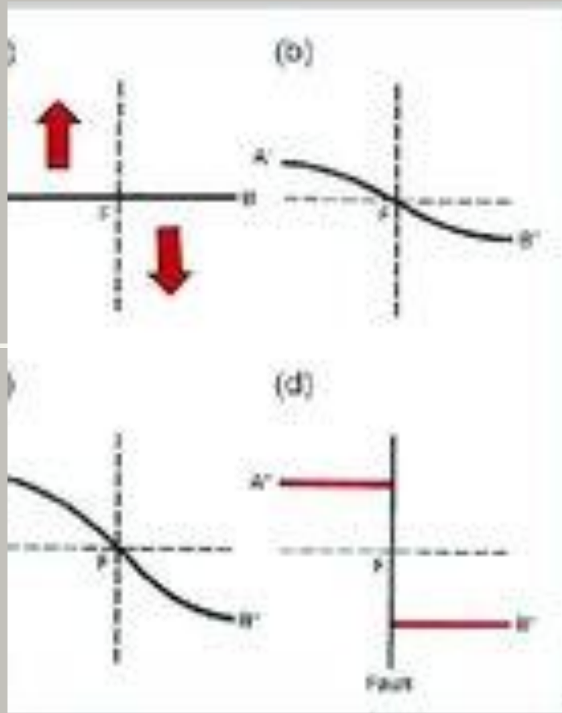
Figure 4.2-8: Cartoon of the focal sphere.

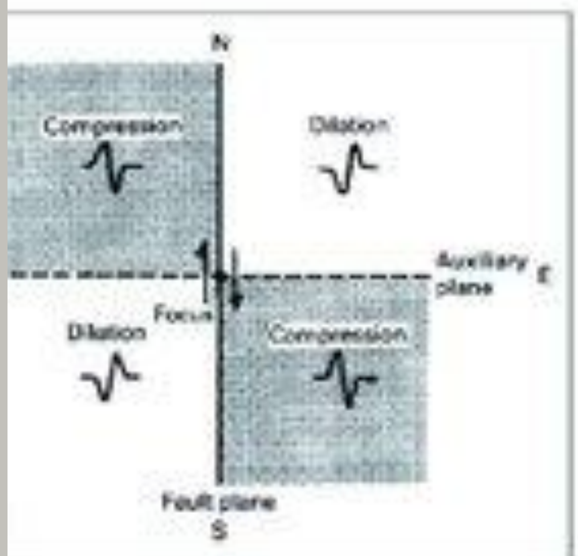


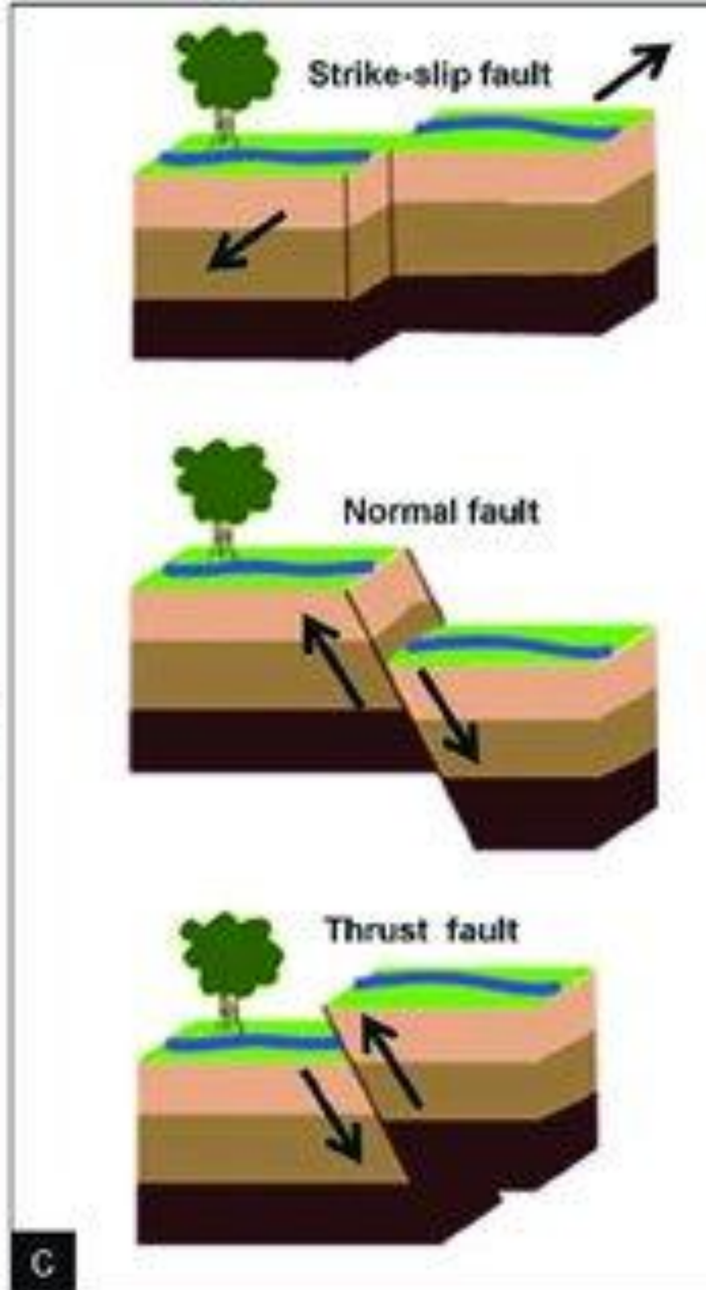


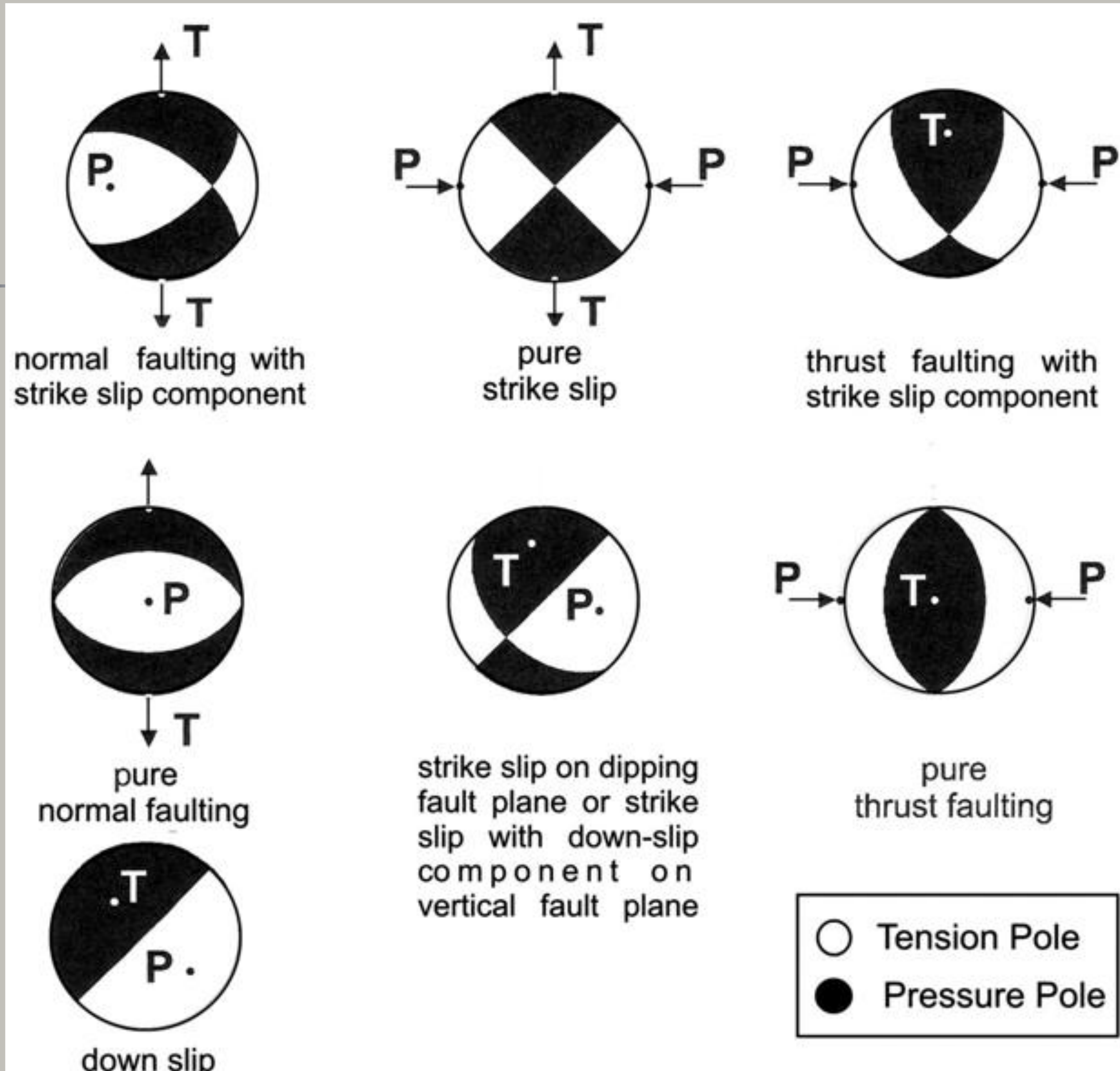


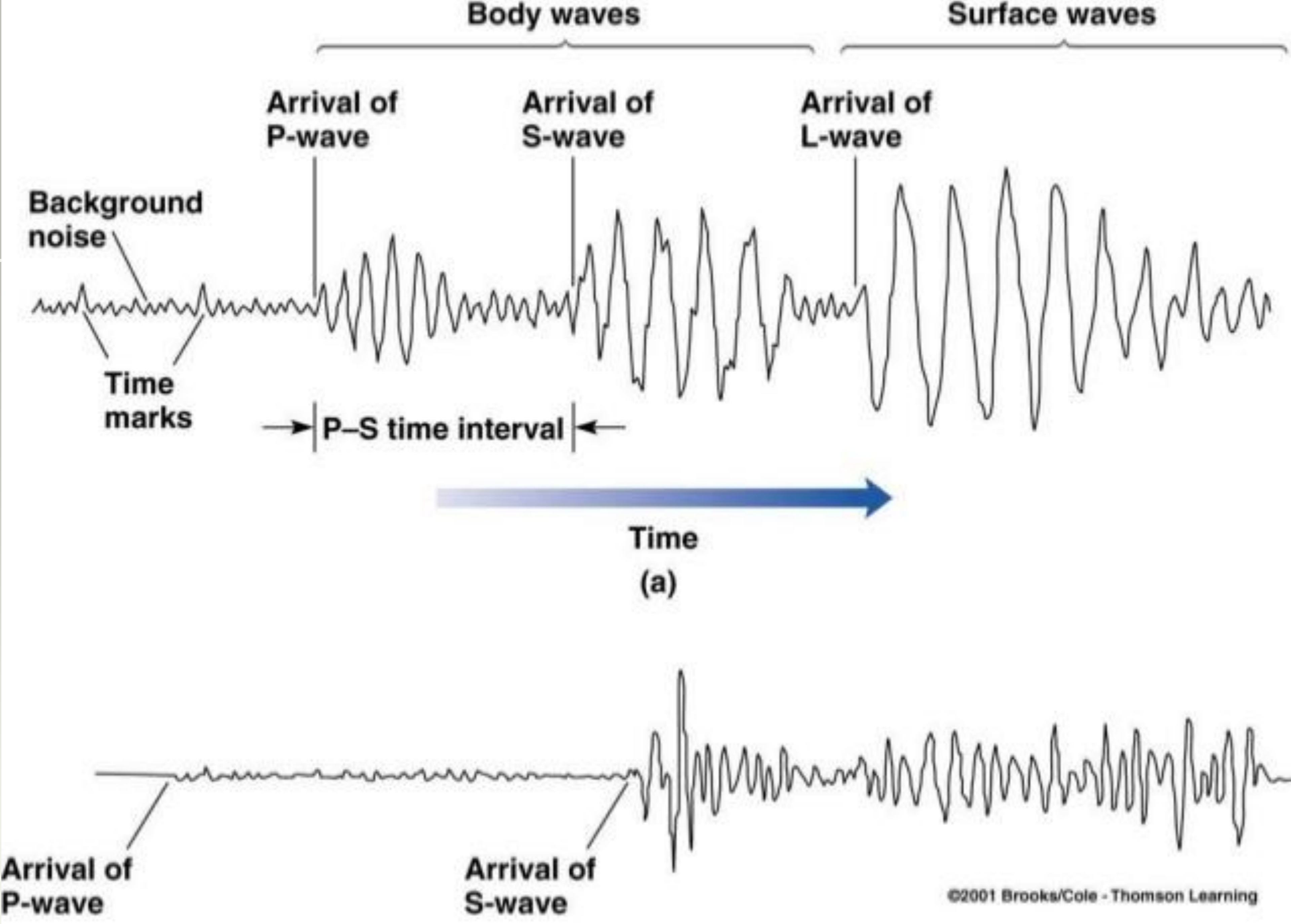

Epicenter
"Up"
Fault plane
Dilatation
Compression
"Down"
θ
θ
Compression
Dilatation
Auxiliary plane

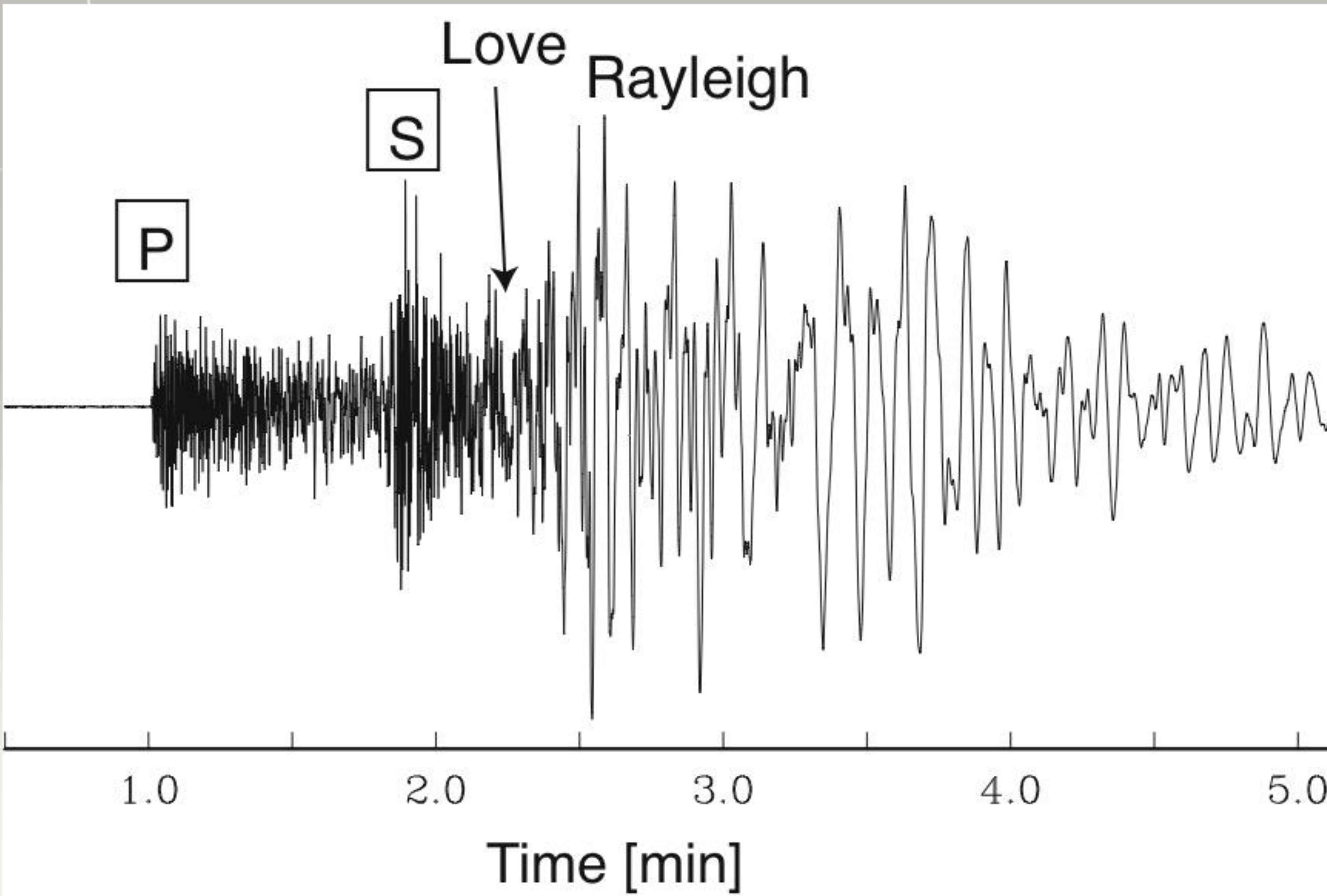

(b)
A'
B
F
B'
(d)
A'
B'
Fault


N
Compression
Dilation
Auxiliary plane
E
Focus
Dilation
Compression
Fault plane
S

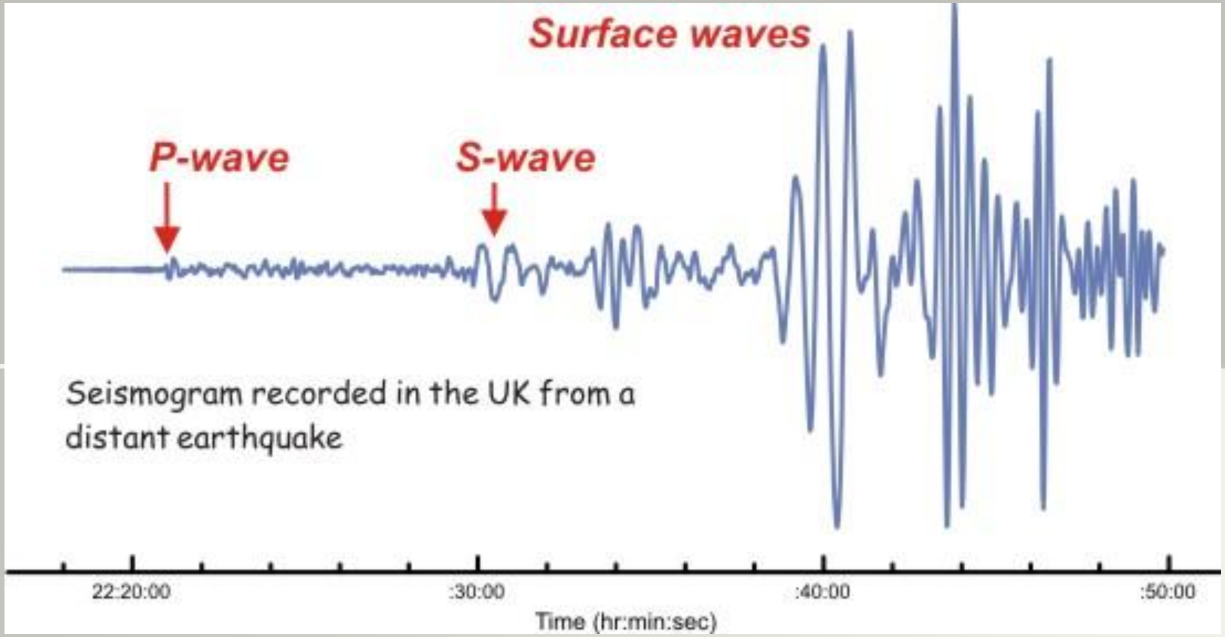

Strike-slip fault
Normal fault
Thrust fault
C


T
P.
T
normal faulting with strike slip component
T
P
P
T
pure strike slip
T.
P
P
thrust faulting with strike slip component
·P
T
pure normal faulting
T
P.
strike slip on dipping fault plane or strike slip with down-slip component on vertical fault plane
P
T.
P
pure thrust faulting
.T
P
down slip
Tension Pole
Pressure Pole

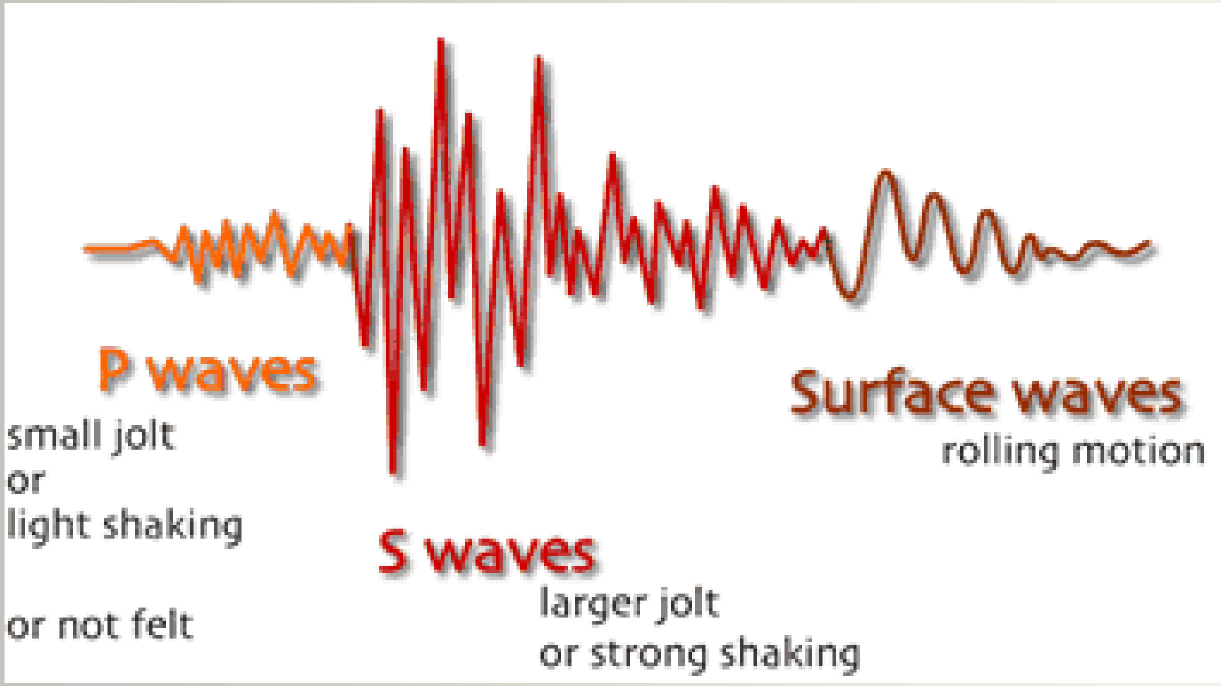

Body waves
Surface waves
Arrival of P-wave
Arrival of S-wave
Arrival of L-wave
Background noise
Time marks
P–S time interval
Time
(a)
Arrival of P-wave
Arrival of S-wave
©2001 Brooks/Cole - Thomson Learning



P
S
Love
Rayleigh
1.0
2.0
3.0
4.0
5.0
Time [min]

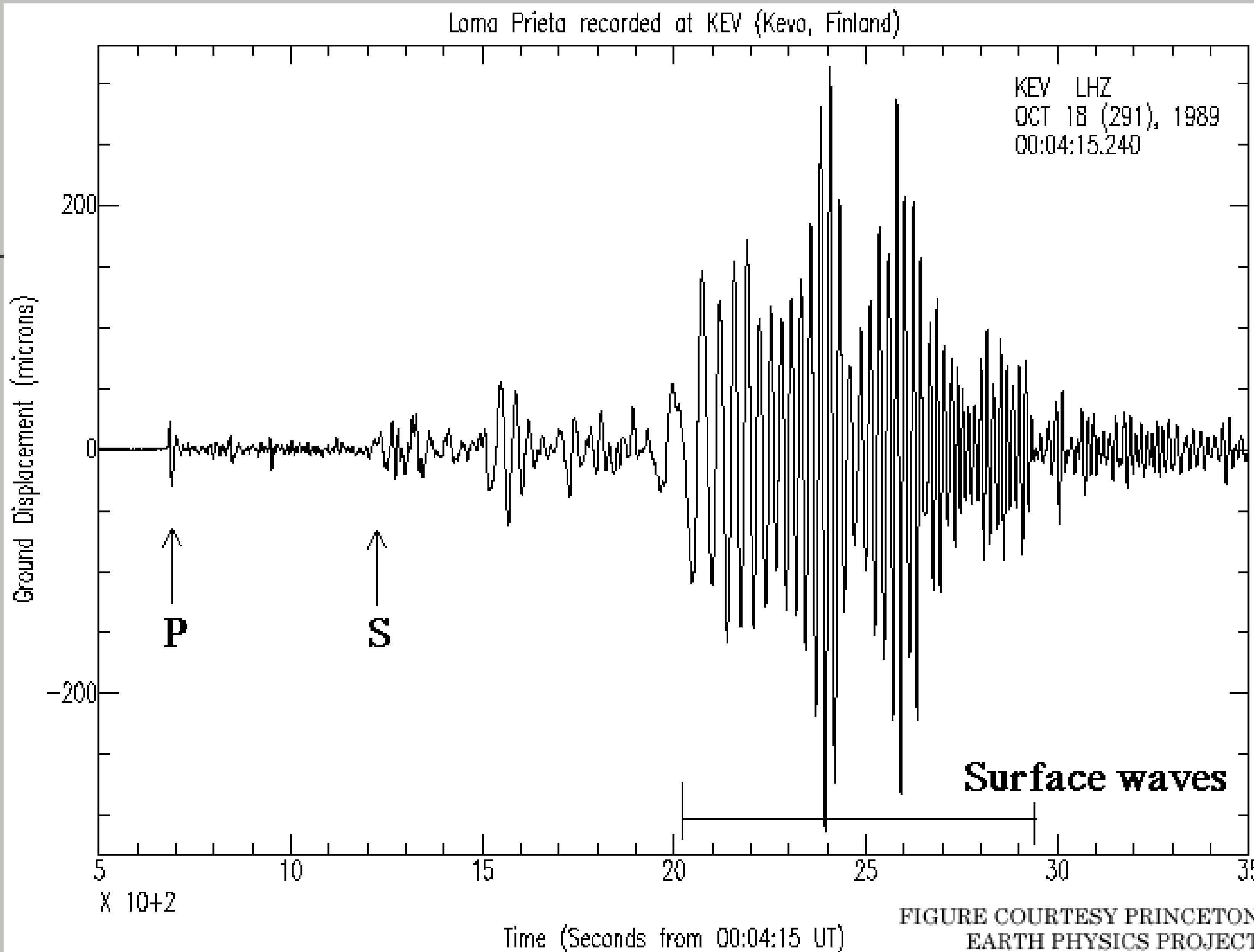


Surface waves
P-wave
S-wave
Seismogram recorded in the UK from a distant earthquake
22:20:00
:30:00
:40:00
:50:00
Time (hr:min:sec)

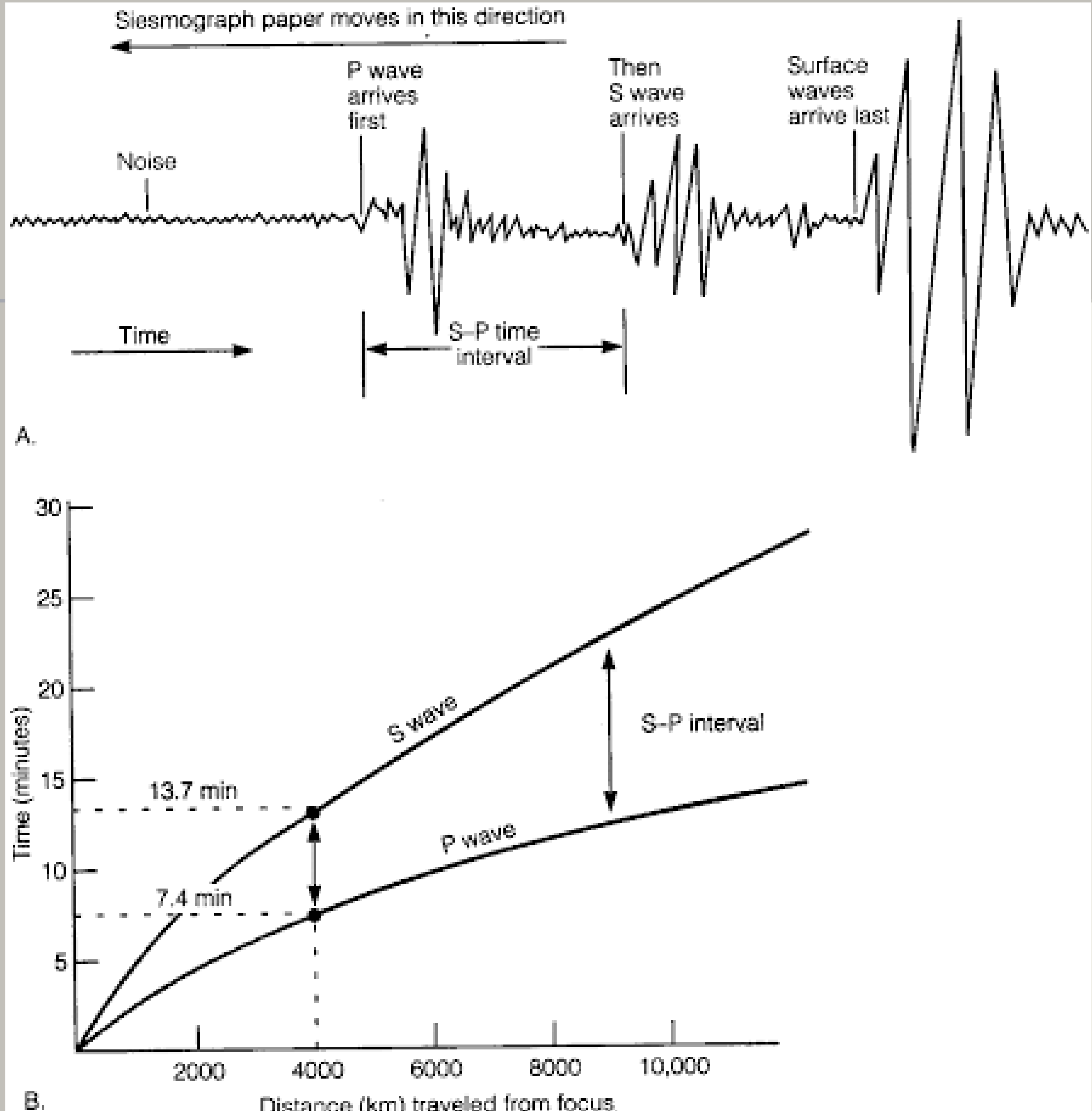


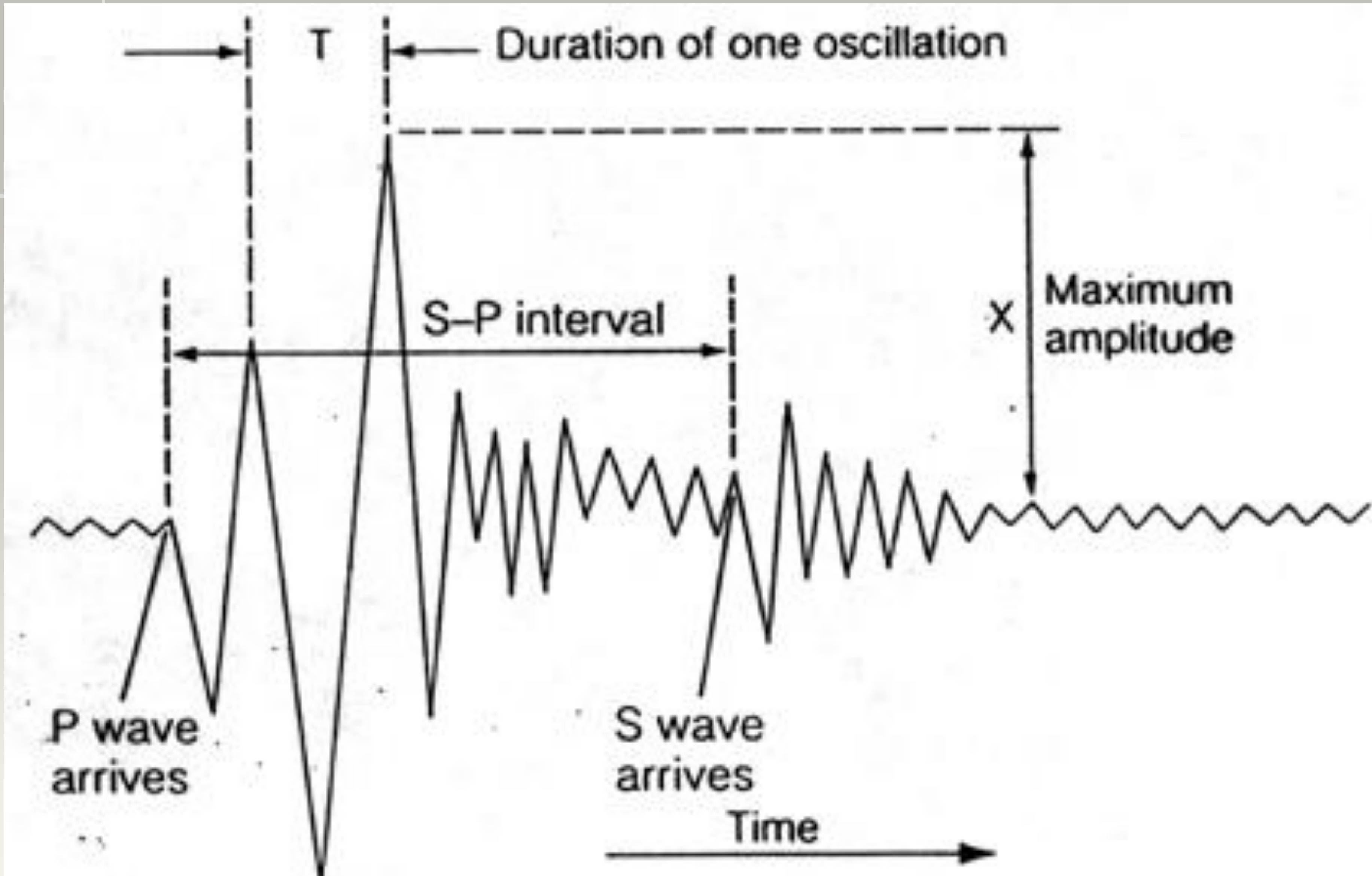
P waves
small jolt
or
light shaking

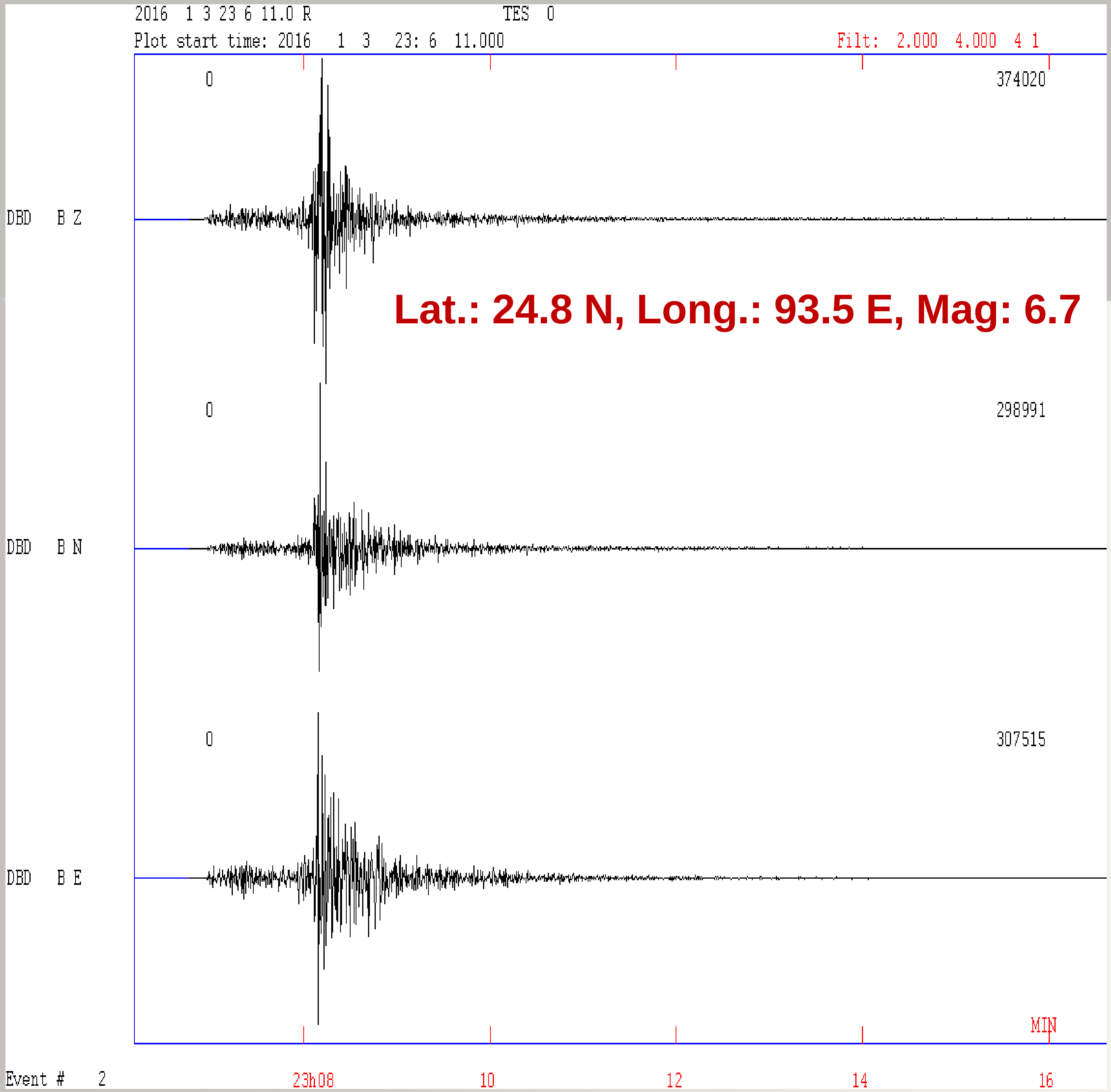
or not felt
S waves
larger jolt
or strong shaking
Surface waves
rolling motion

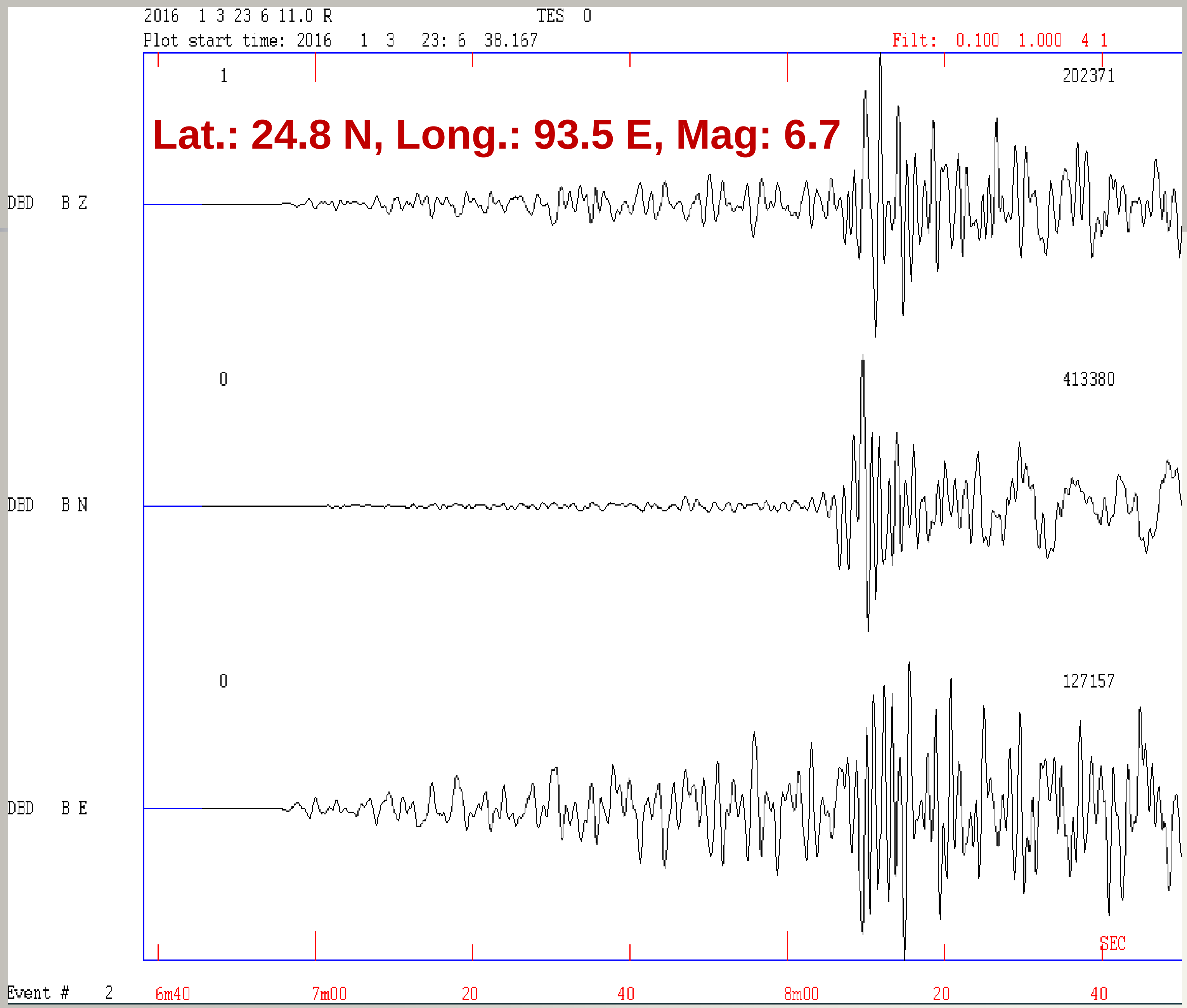


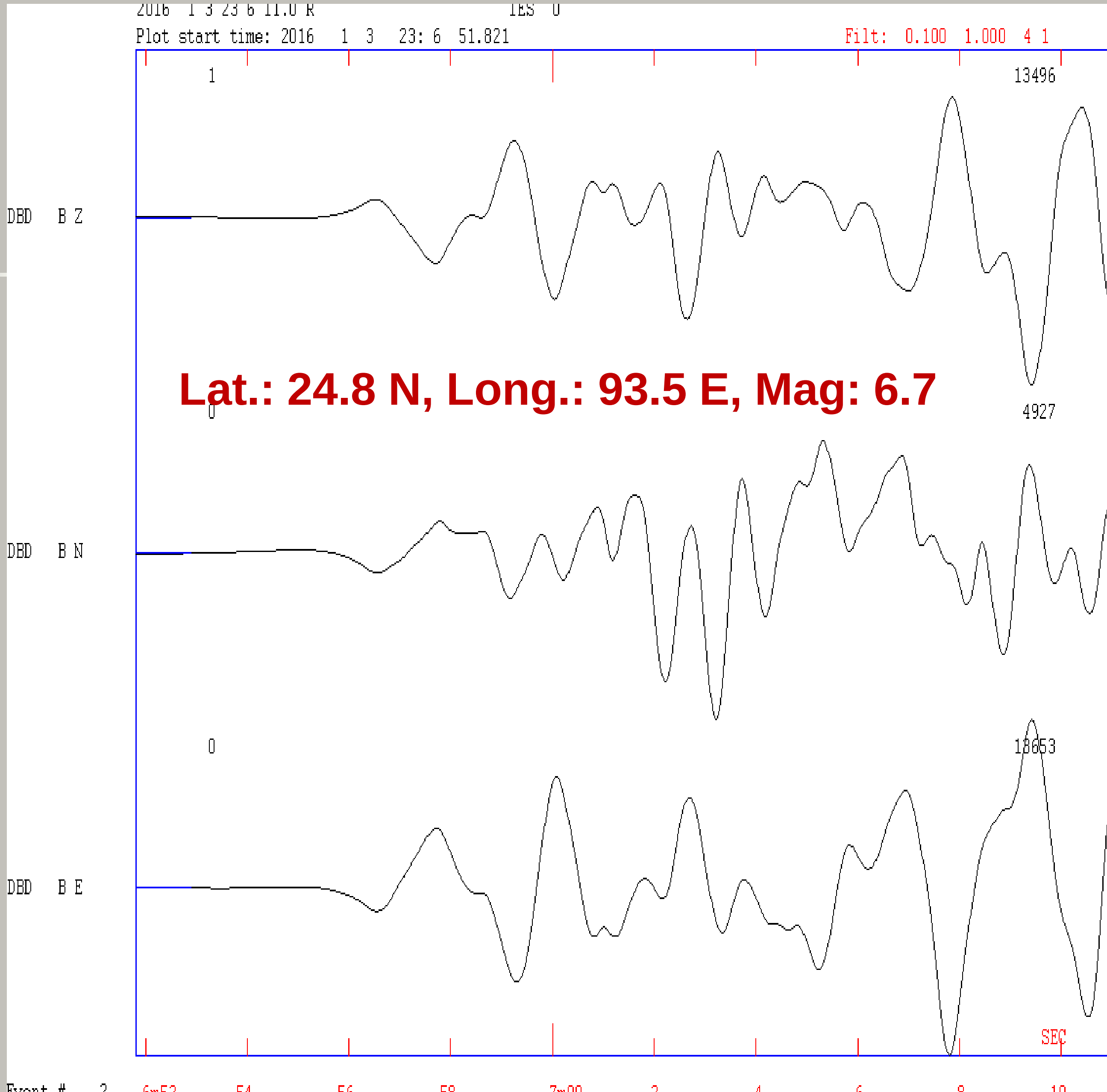
Loma Prieta recorded at KEV (Kevo, Finland)
KEV LHZ
OCT 18 (291), 1989
00:04:15.240
200
0
-200
Ground Displacement (microns)
P
S
Surface waves
5
10
15
20
25
30
35
X 10+2
Time (Seconds from 00:04:15 UT)
FIGURE COURTESY PRINCETON
EARTH PHYSICS PROJECT


Siesmograph paper moves in this direction
P wave arrives first
Then S wave arrives
Surface waves arrive last
Noise
Time
S–P time interval
A.
30
25
20
15
10
5
Time (minutes)
S wave
S–P interval
13.7 min
P wave
7.4 min
2000
4000
6000
8000
10,000
B.
Distance (km) traveled from focus

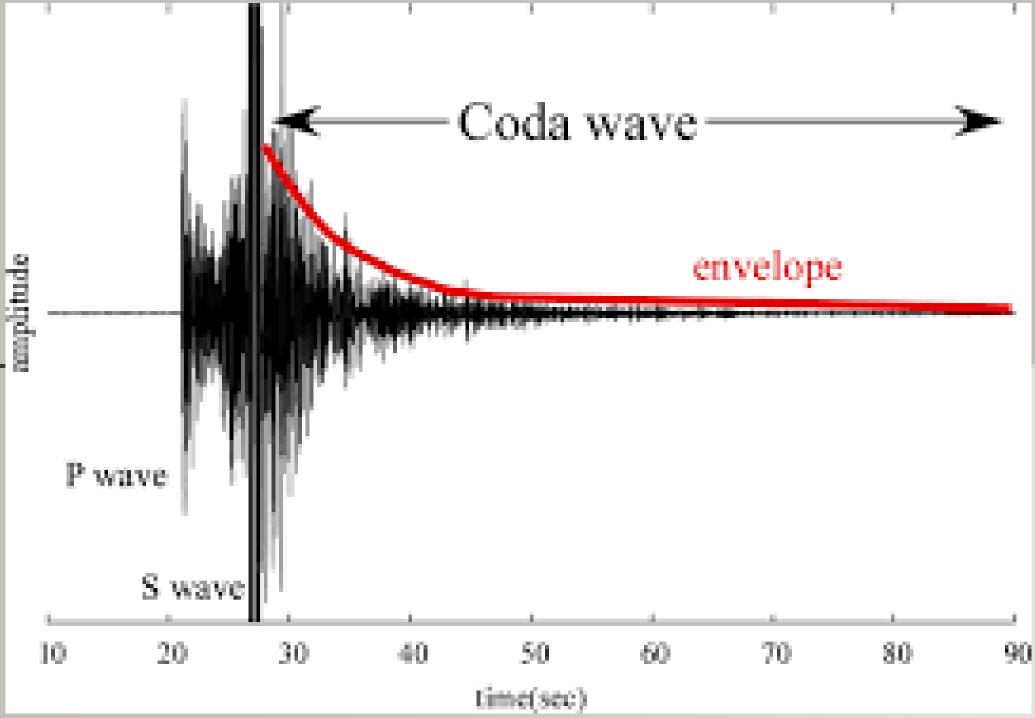

T
Duration of one oscillation
S–P interval
X
Maximum amplitude
P wave arrives
S wave arrives
Time

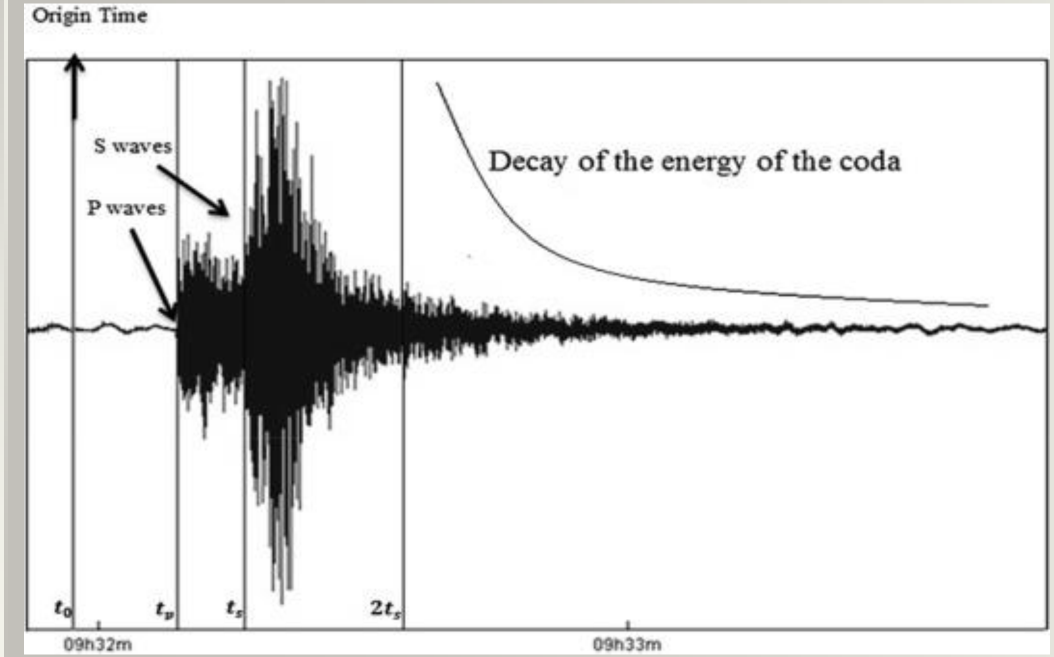

2016 1 3 23 6 11.0 R
TES 0
Plot start time: 2016 1 3 23: 6 11.000
Filt: 2.000 4.000 4 1
0
374020
DBD B Z
Lat.: 24.8 N, Long.: 93.5 E, Mag: 6.7
0
298991
DBD B N
0
307515
DBD B E
MIN
Event # 2
23h08
10
12
14
16

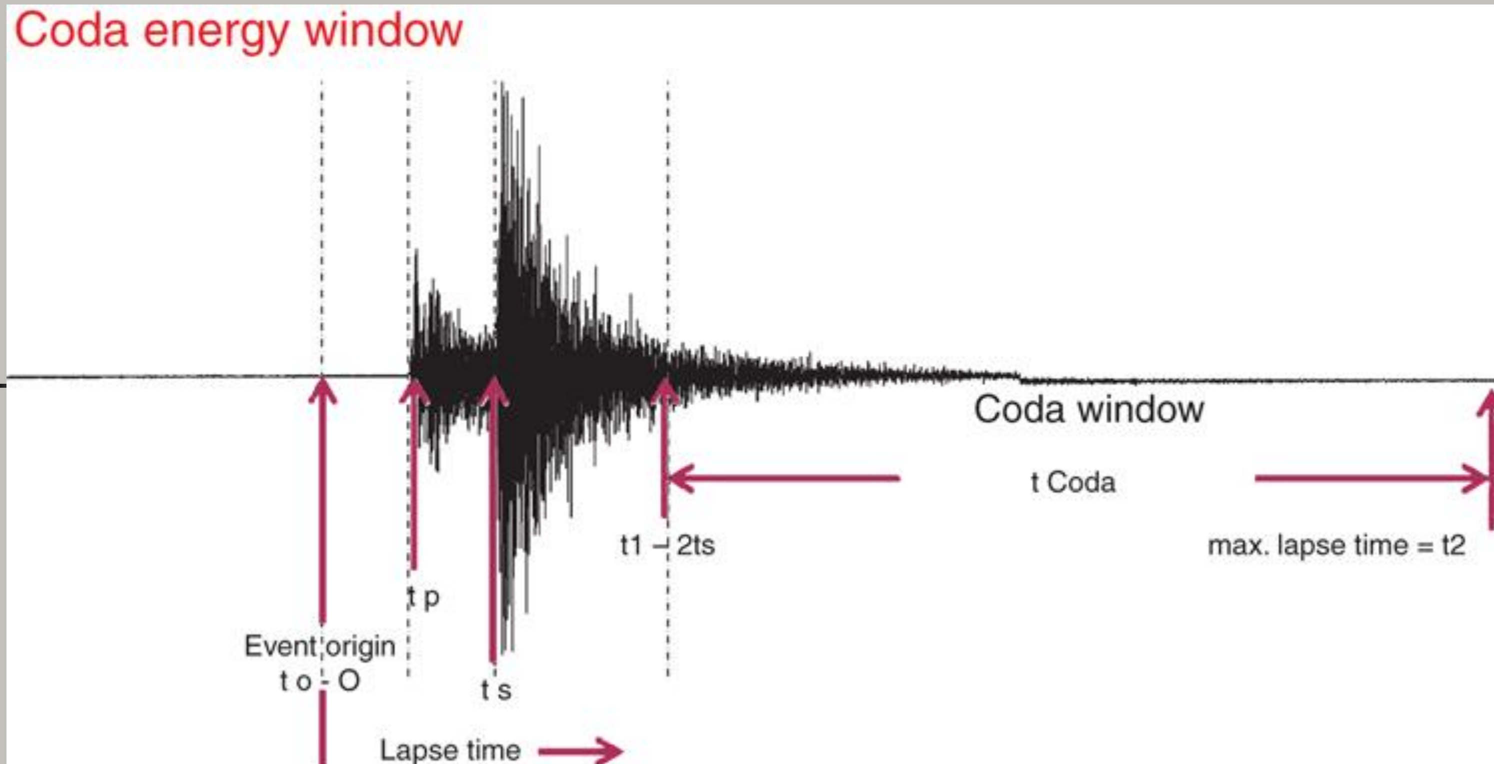

2016 1 3 23 6 11.0 R
TES 0
Plot start time: 2016 1 3 23: 6 38.167
Filt: 0.100 1.000 4 1
Lat.: 24.8 N, Long.: 93.5 E, Mag: 6.7
1
202371
DBD B Z
0
413380
DBD B N
0
127157
DBD B E
SEC
Event # 2
6m40
7m00
20
40
8m00
20
40



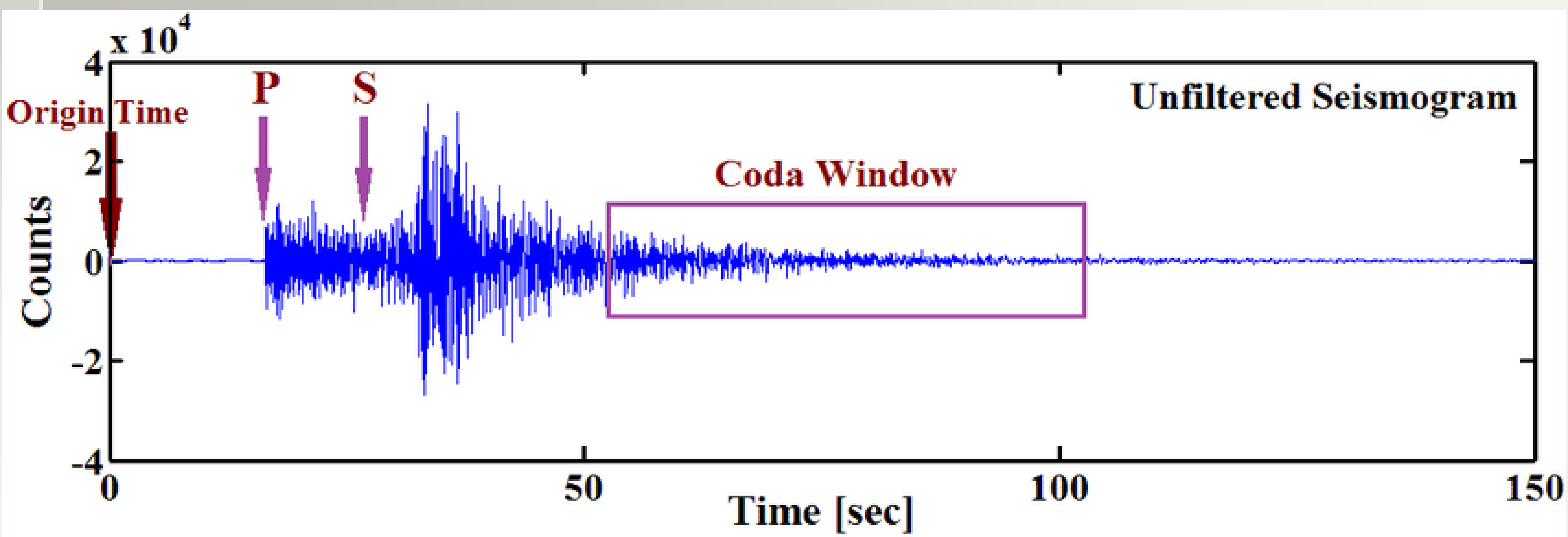
Lat.: 24.8 N, Long.: 93.5 E, Mag: 6.7


Coda wave
envelope
amplitude
P wave
S wave
10
20
30
40
50
60
70
80
90
time(sec)


Origin Time
S waves
P waves
Decay of the energy of the coda
t_0
t_p
t_s
$2t_s$
09h32m
09h33m



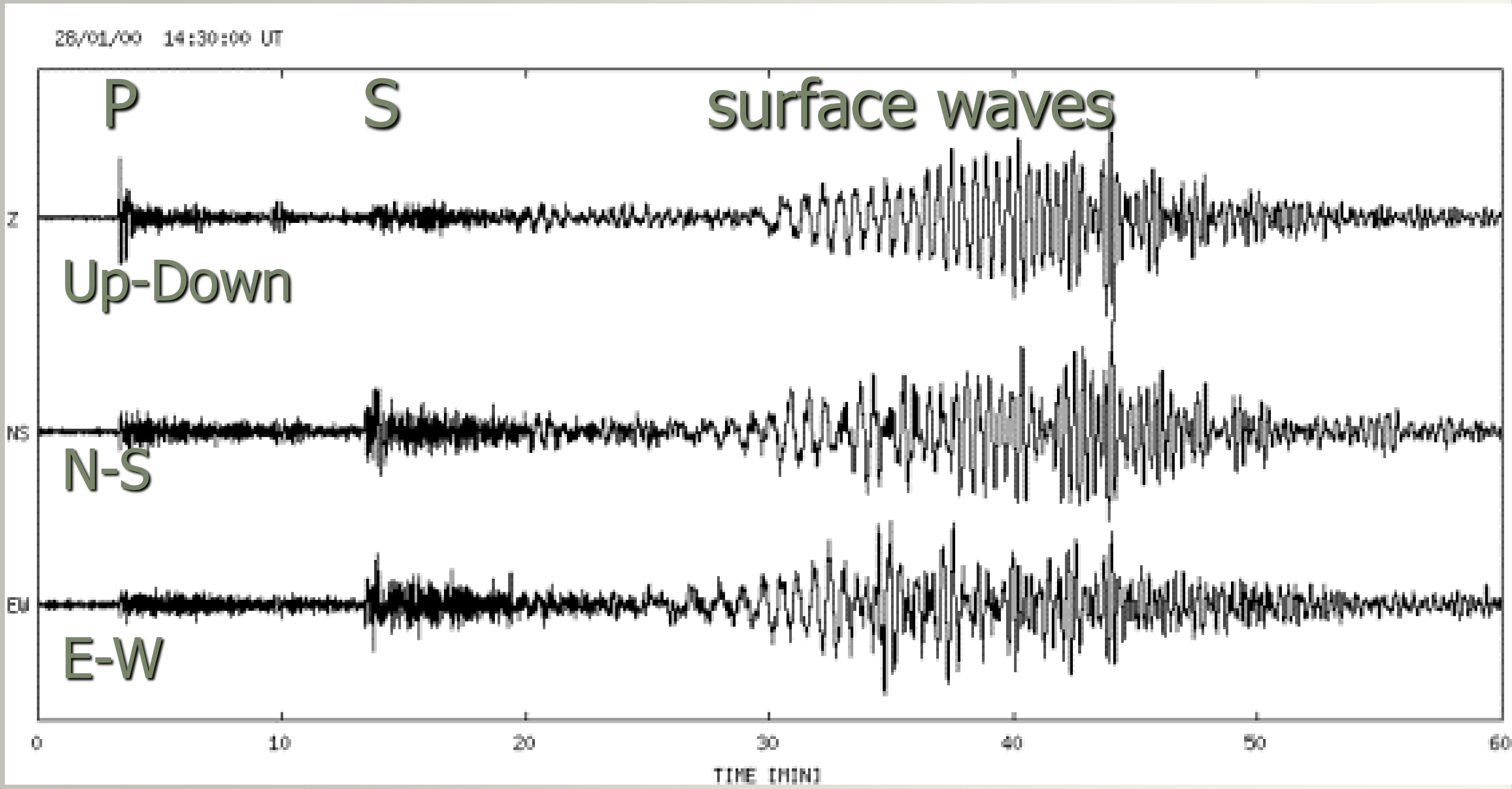
Coda energy window
Coda window
t Coda
t1 = 2ts
max. lapse time = t2
t p
Event origin
t o = O
t s
Lapse time



x 10^4
Origin Time
P
S
Unfiltered Seismogram
Coda Window
Counts
Time [sec]
4
2
0
-2
-4
0
50
100
150

Seismogram

Seismogram of Earthquake of Magnitude 6.5



Observational Seismology
Locating Earthquakes

- After we know the distance of epicentre from at least three stations we may find the epicentre like the adjacent figure.

- There are more sofisticated methods of locating positions of earthquake foci. This is a classic example of an *inverse problem.*