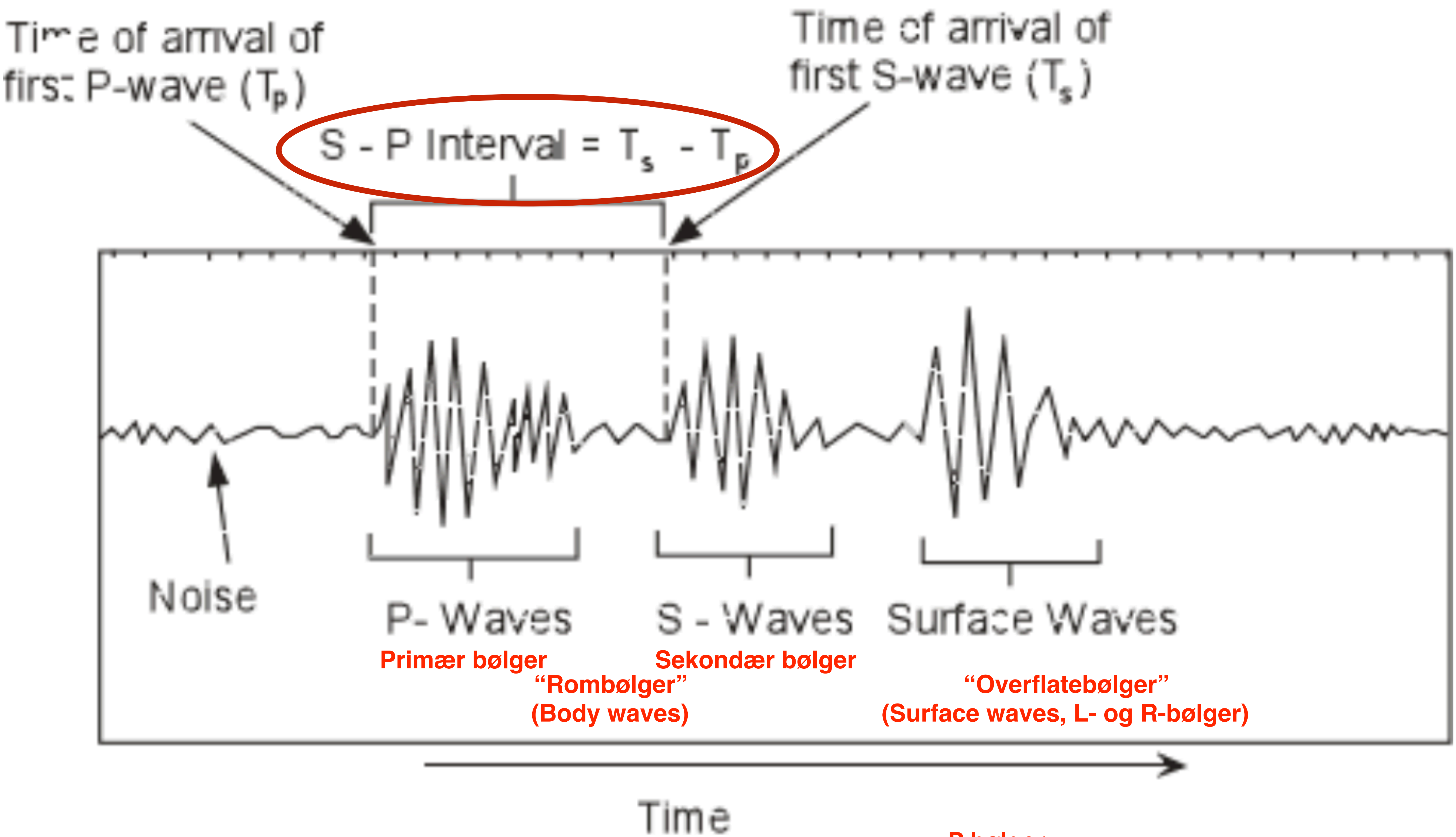
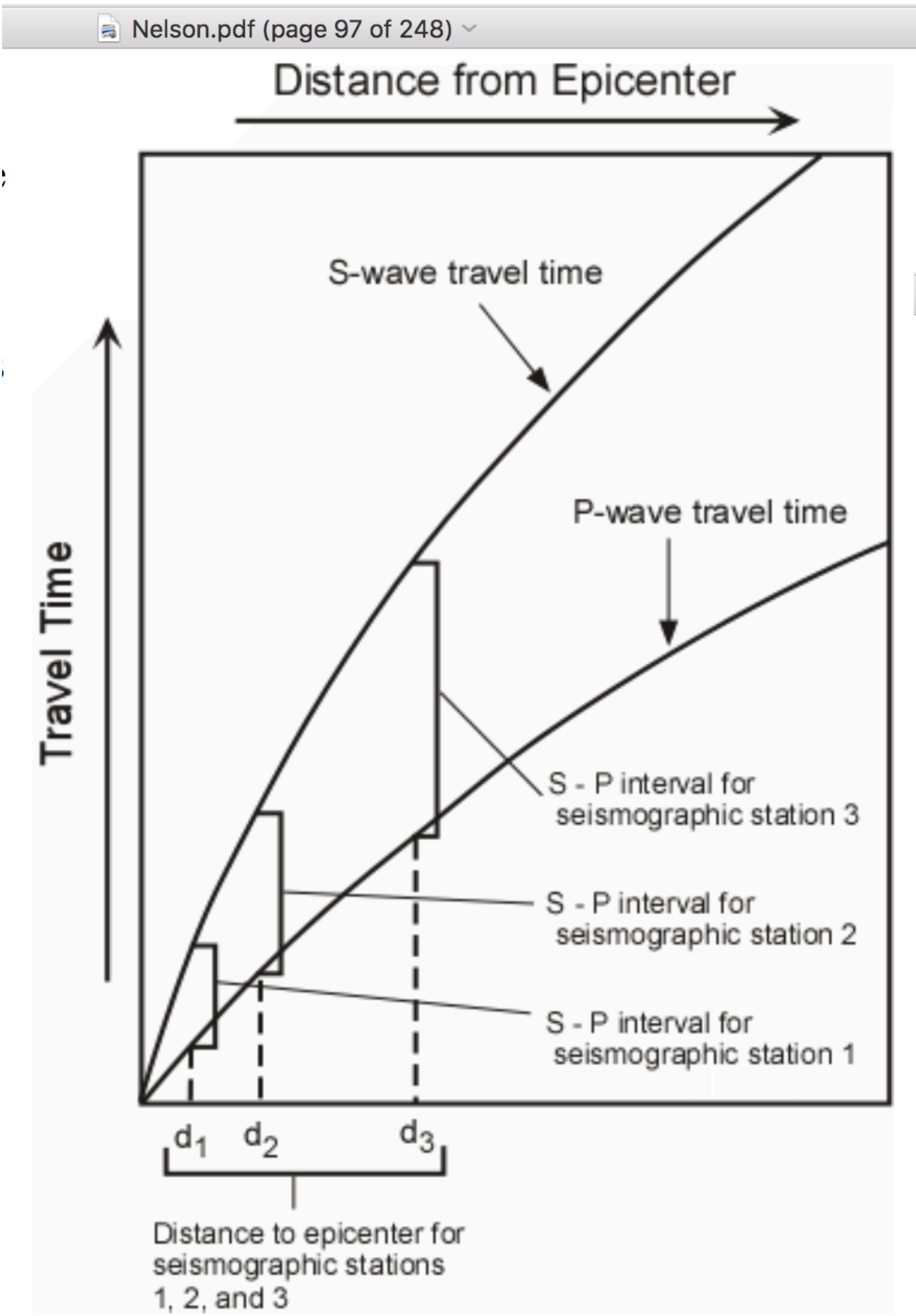
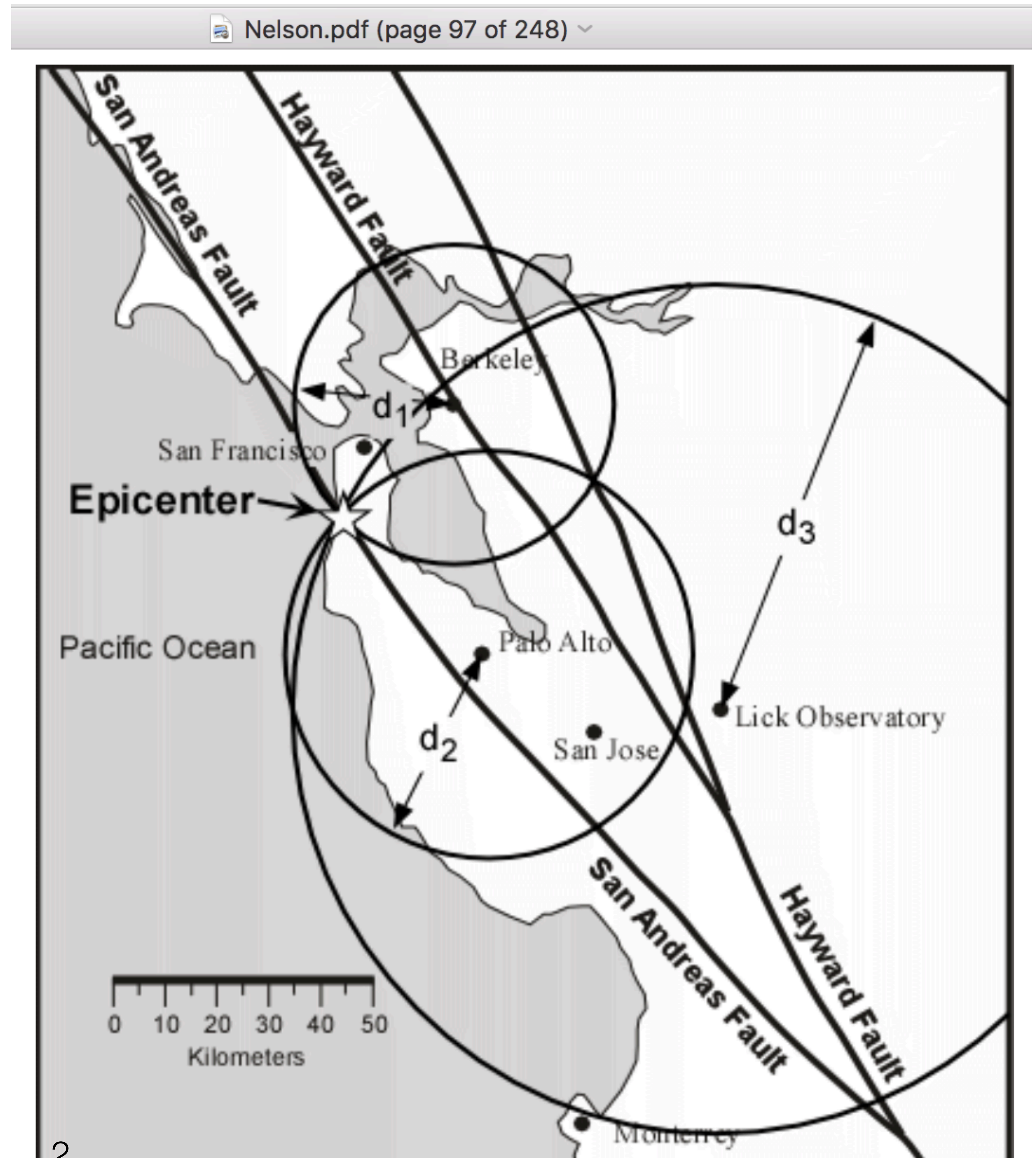


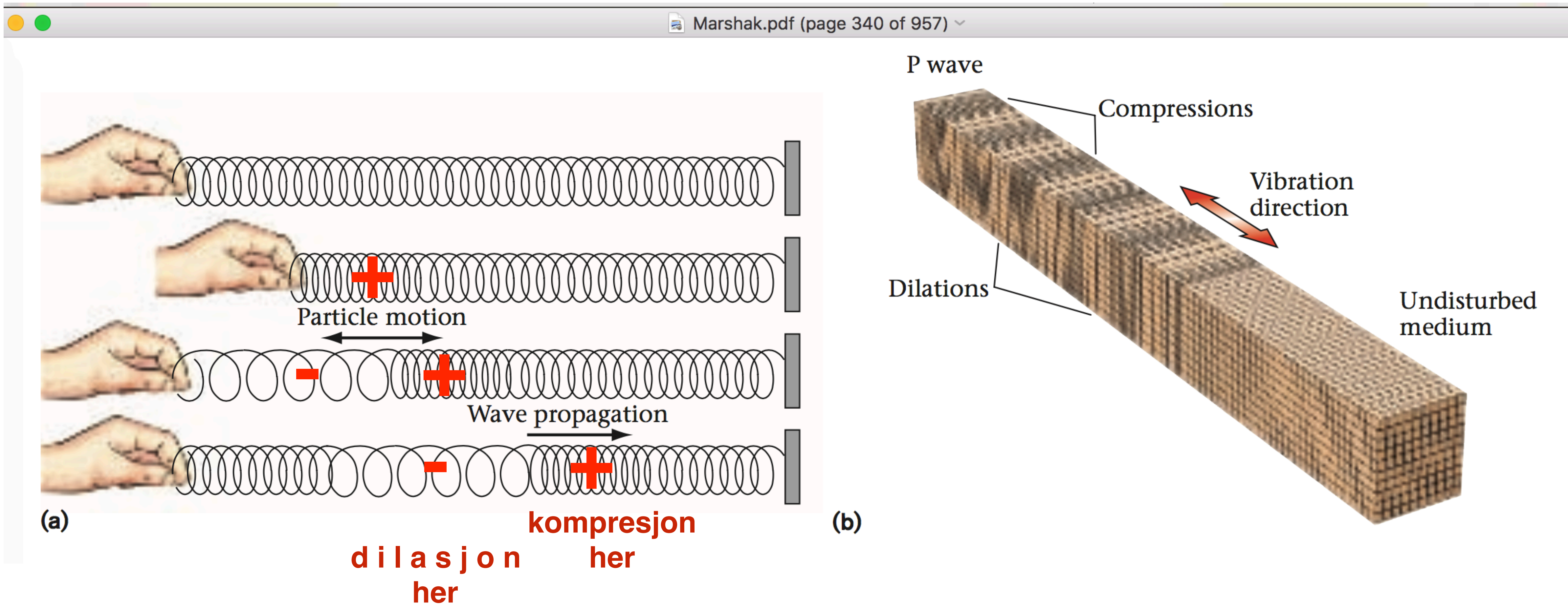
P bølger
S bølger
etterpå kommer L-bølger og R-bølger



“S minus P” tidsinterval gir avstand. Hvis du kjenner avstand fra 3 steder, har du unik plassering.



FIRST MOTION STUDY



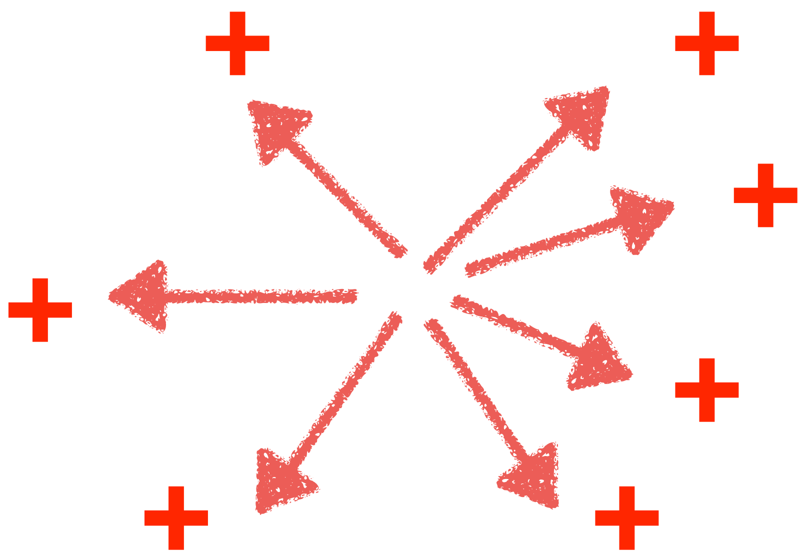
Den "FØRSTE BEVEGELSE" her er kompresjon (+).
Fordi hånden presser fjæren frem (+).

Hvis man drar tilbake i stedet for å presse,
blir første bevegelse dilasjon (-).

earthquake.usgs.gov/learn/glossary/?term=first%20motion

first motion pensum for oss, men ikke i Nelson.

On a seismogram, the first motion is the direction of ground motion as the P wave arrives at the seismometer. Upward ground motion indicates an expansion in the source region; downward motion indicates a contraction.



Ved en atombombe test f.eks. i Nord Korea,
blir det kompresjon (ekspansjon) i alle retninger.

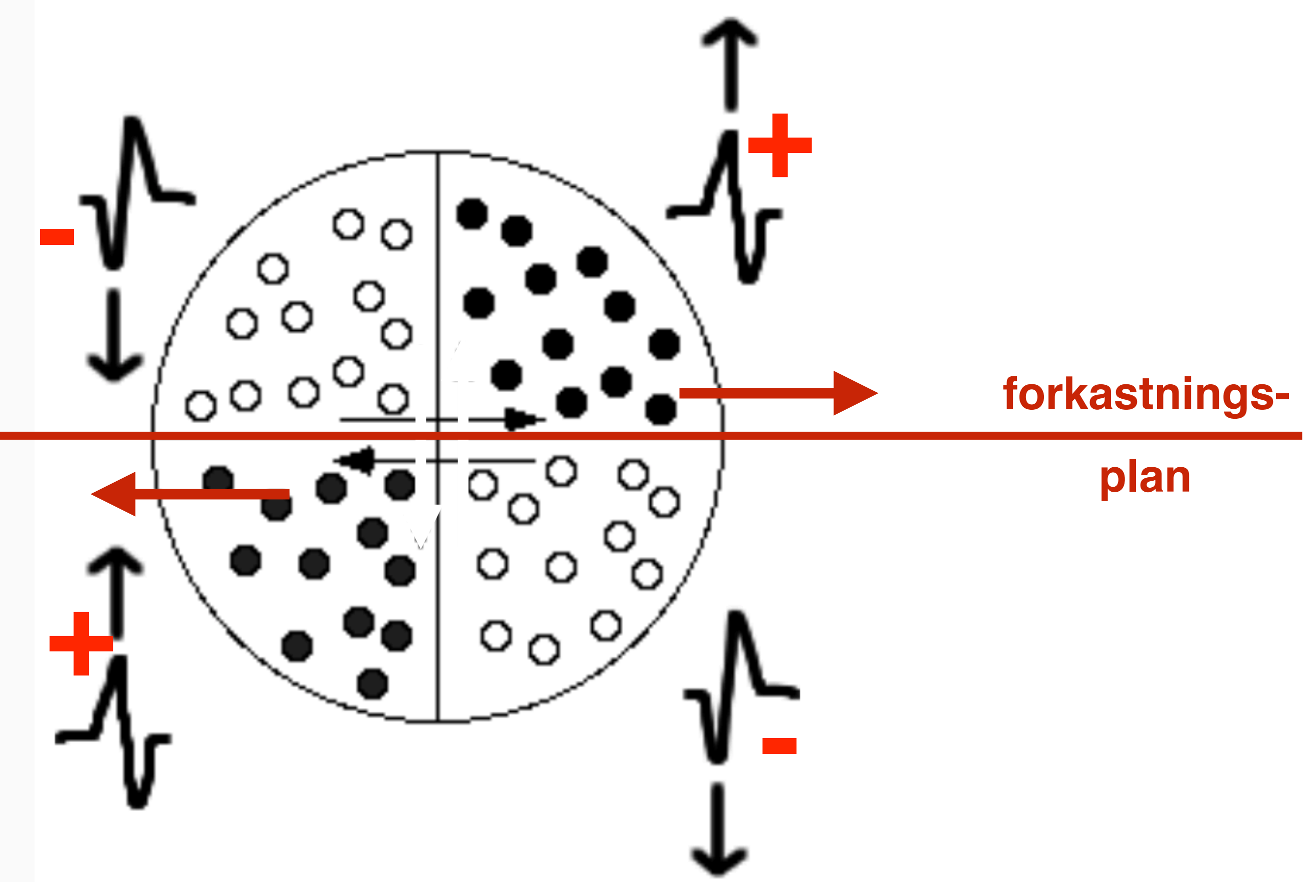
Alle verdens seismiske stasjoner registrerer
kompresjon som *første bevegelse*.

https://en.wikipedia.org/wiki/P-wave#/media/File:Ondes_compression_2d_20_petit.gif

earthquake.usgs.gov/learn/glossary/?term=first%20motion

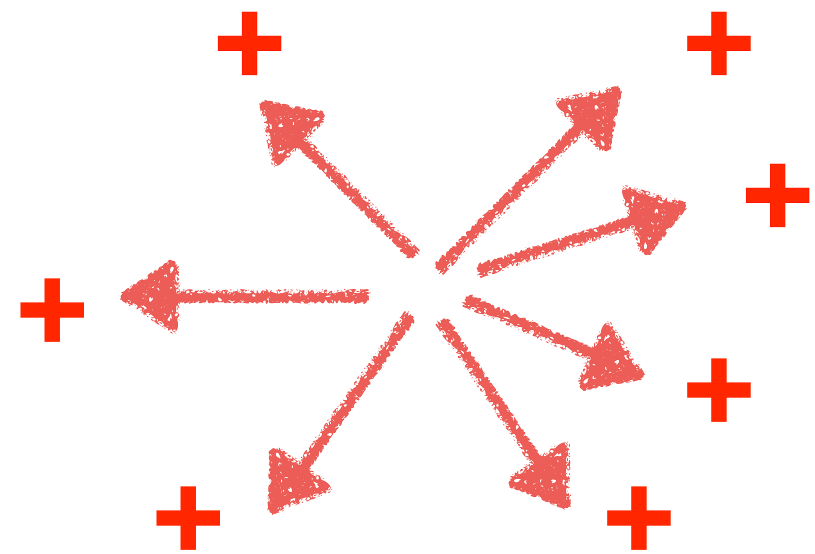
first motion

On a seismogram, the first motion is the direction of ground motion as the P wave arrives at the seismometer. Upward ground motion indicates an expansion in the source region; downward motion indicates a contraction.



Midtpunkt i sirkelen er jordskjelvs Fokus

Ved dette dekstral jordskjelv,
blir det 2 soner med kompresjon (kontraksjon)
og 2 soner med dilasjon (ekspansjon).



Ved en atombombe test i Nord Korea,
blir det kompresjon (ekspansjon) i alle retninger.

Alle verdens seismiske stasjoner registrerer
KOMPRESJON som første bevegelse.

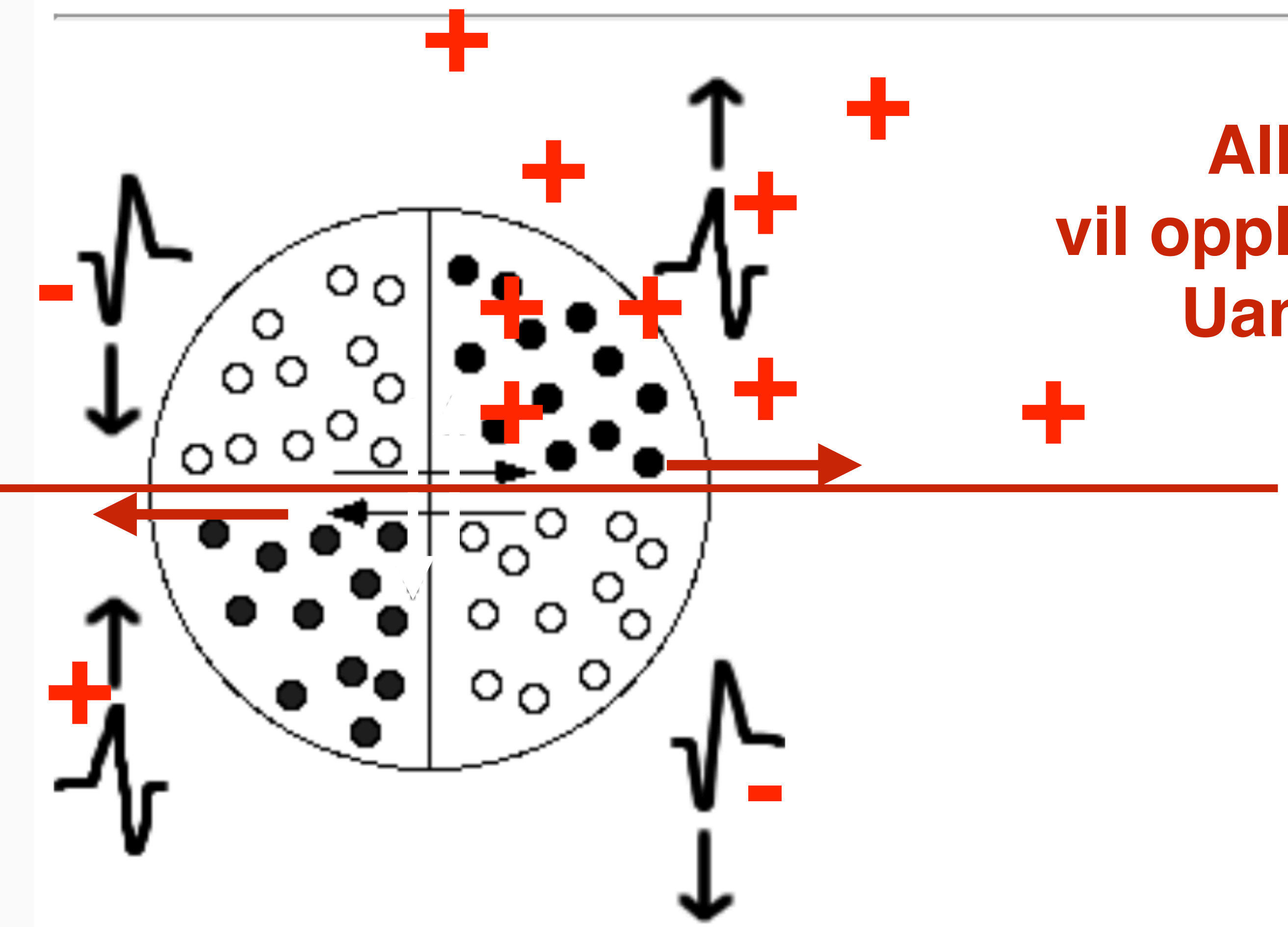
\+ KOMPRESJON

\- DILASJON

earthquake.usgs.gov/learn/glossary/?term=first%20motion

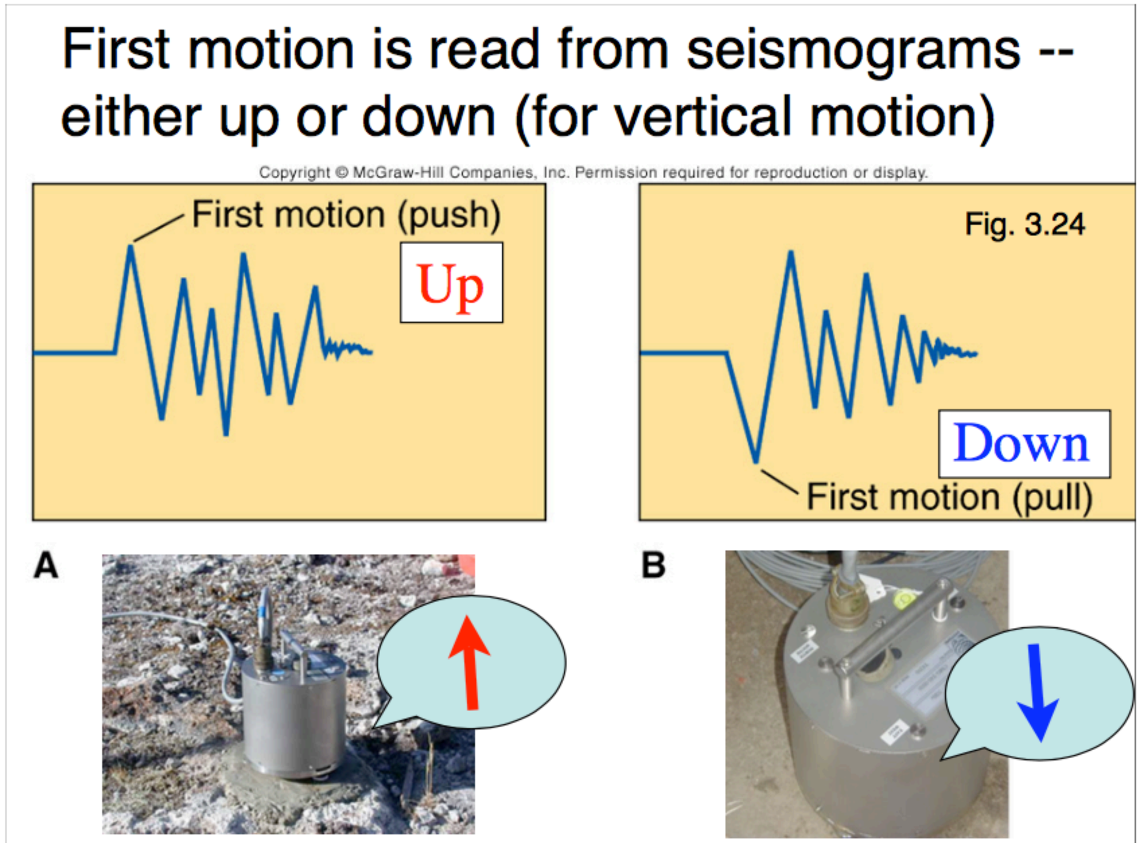
first motion

On a seismogram, the first motion is the direction of ground motion as the P wave arrives at the seismometer. Upward ground motion indicates an expansion in the source region; downward motion indicates a contraction.

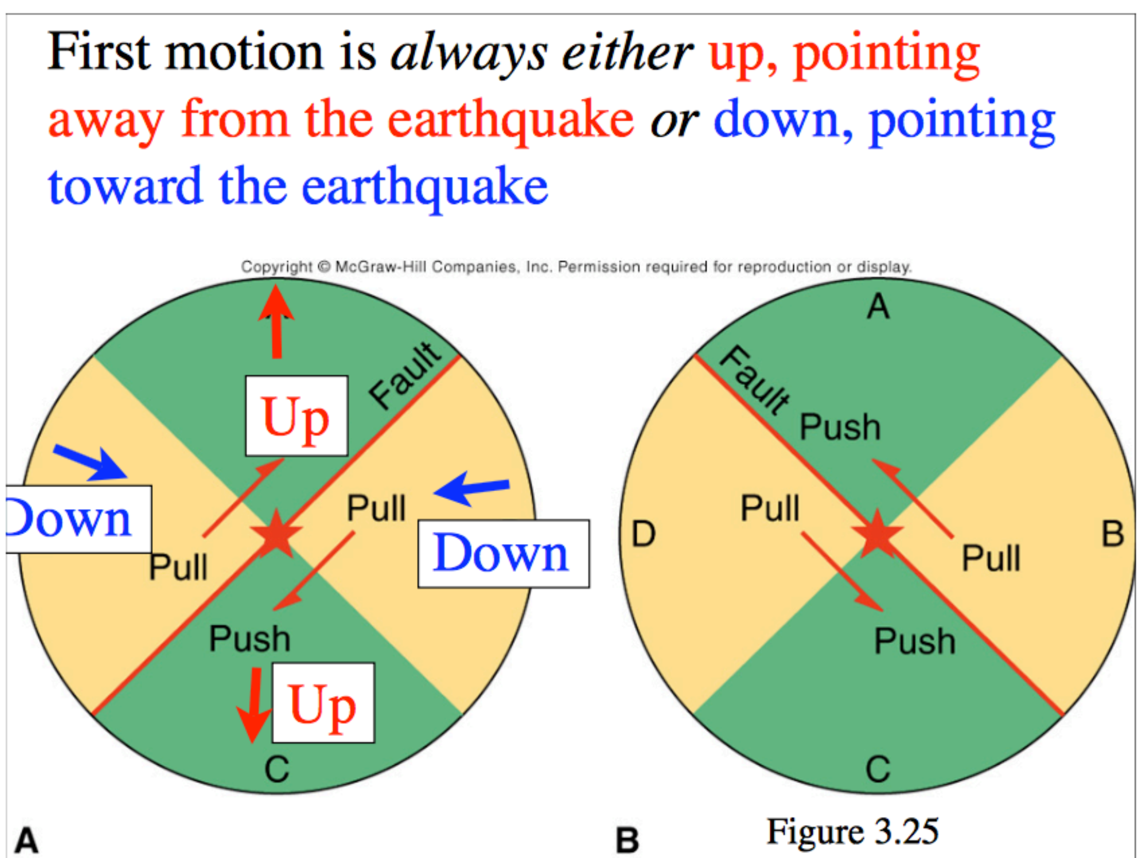


Alle seismogramer i denne kvadrant,
vil oppleve kompresjon som første bevegelse.
Uansett hvor i verden de befinner seg.

www.eoas.ubc.ca/courses/eosc110/sec201/earthquakes/Earthquakes3_4up.pd



Up - kompresjon
Down - dilasjon



(Men første mosjon gir ikke et unikt forkastningsplan. Det er alltid 2 mulige forkastningsplaner, og du må ha mer informasjon for å velge hvilket plan er riktig.

www.eoas.ubc.ca/courses/eosc110/sec201/earthquakes/Earthquakes3_4up.pd

First motion is read from seismograms -- either up or down (for vertical motion)

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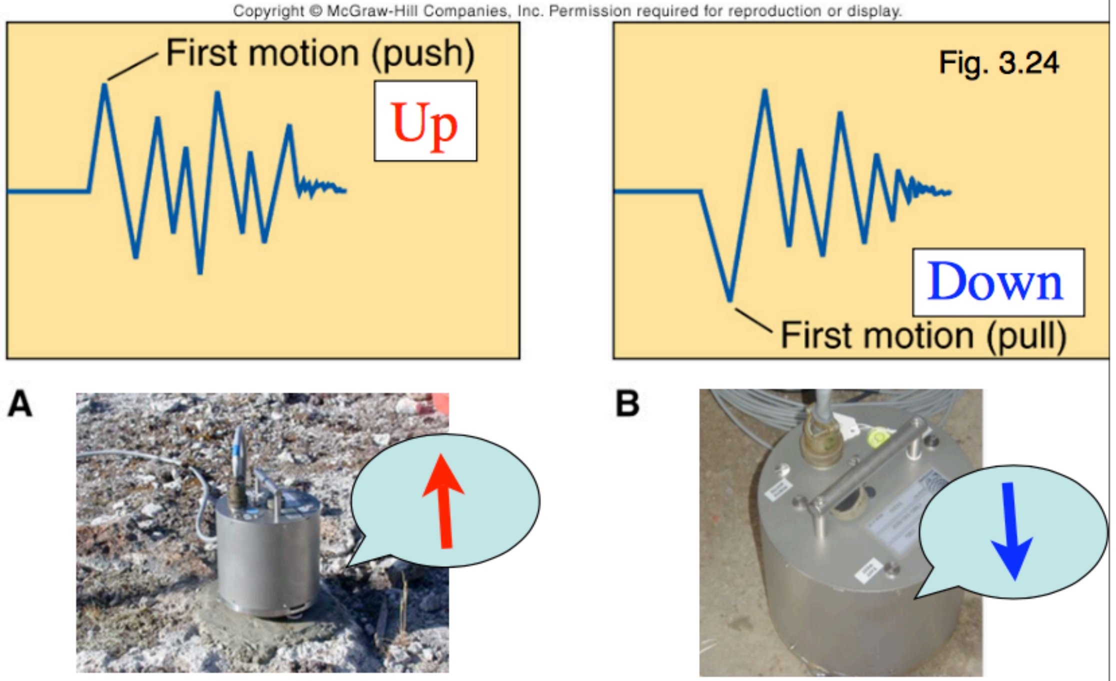
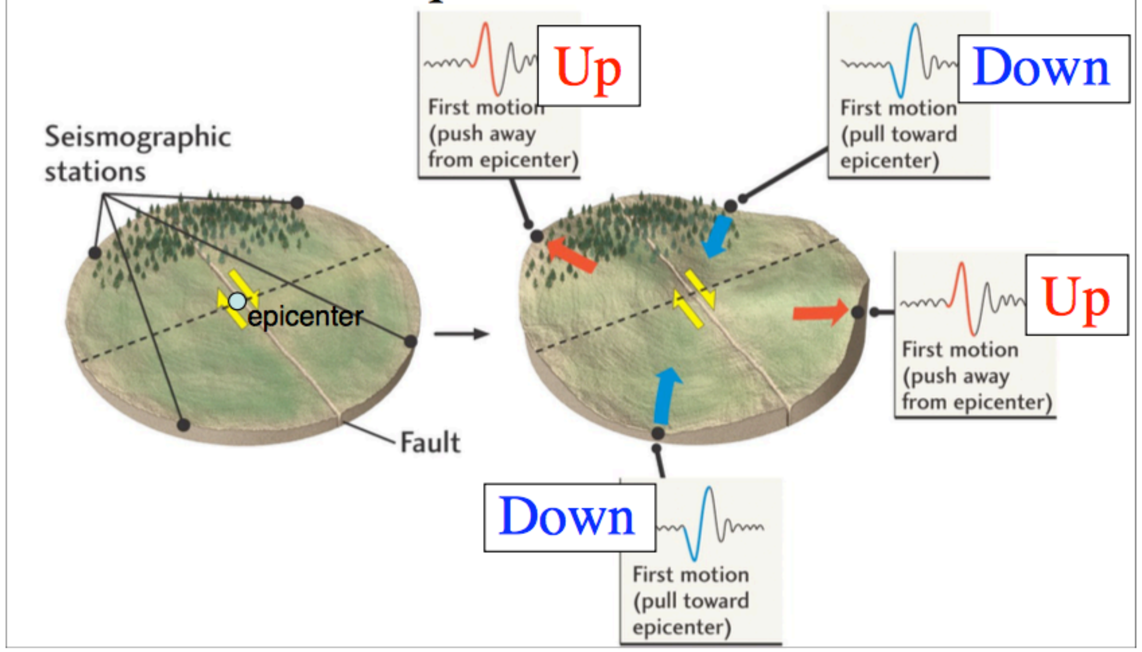


First motion is *always either* up, pointing away from the earthquake *or* down, pointing toward the earthquake



First motion is *always either* up, pointing away from the earthquake *or* down, pointing toward the earthquake

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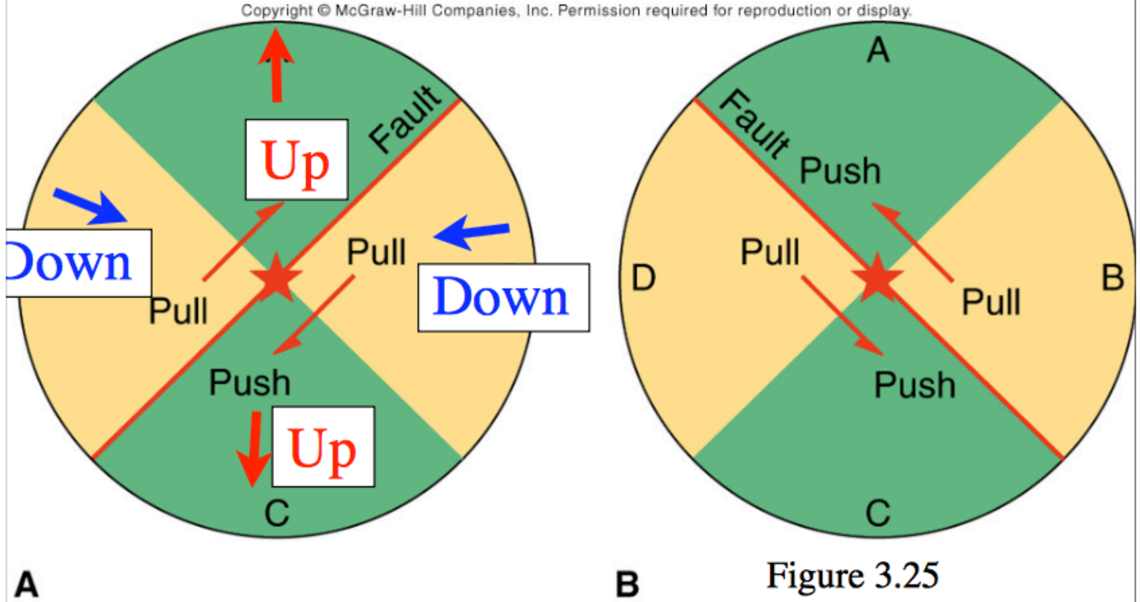
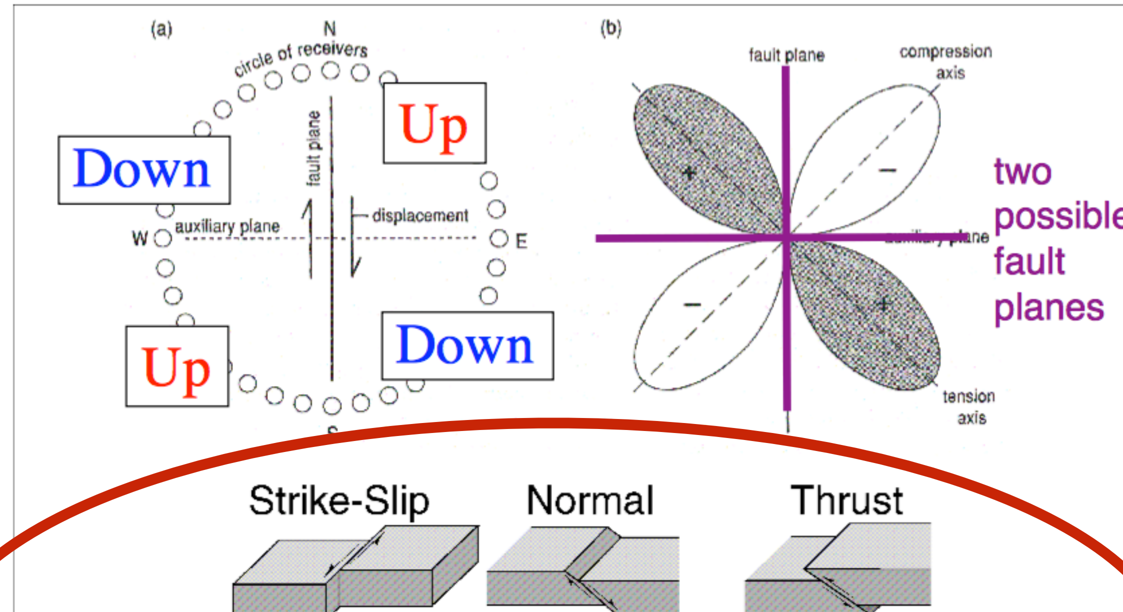
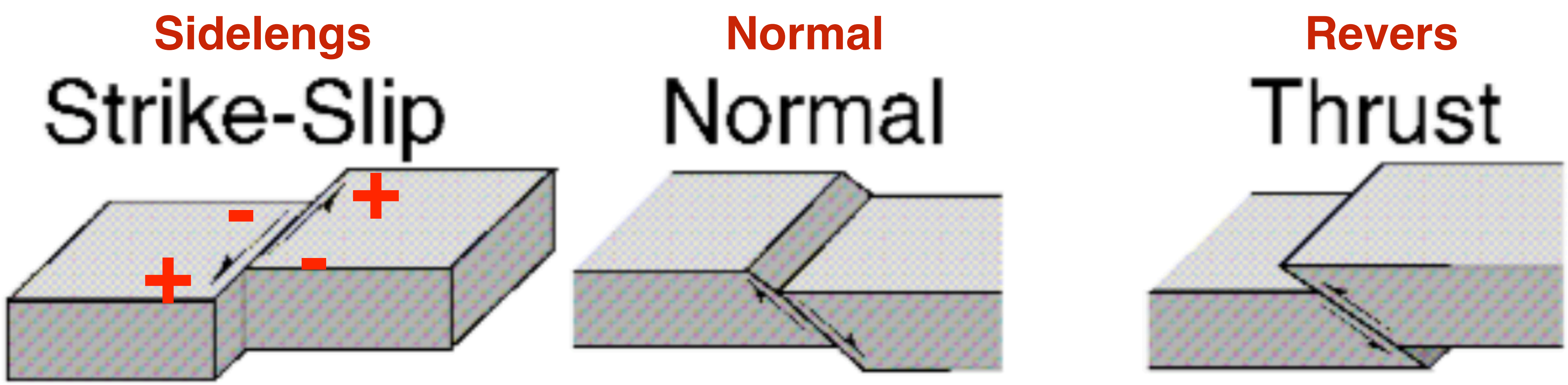


Figure 3.25



Første mosjon viser om bevegelsen er
sidelengs, normal, eller revers

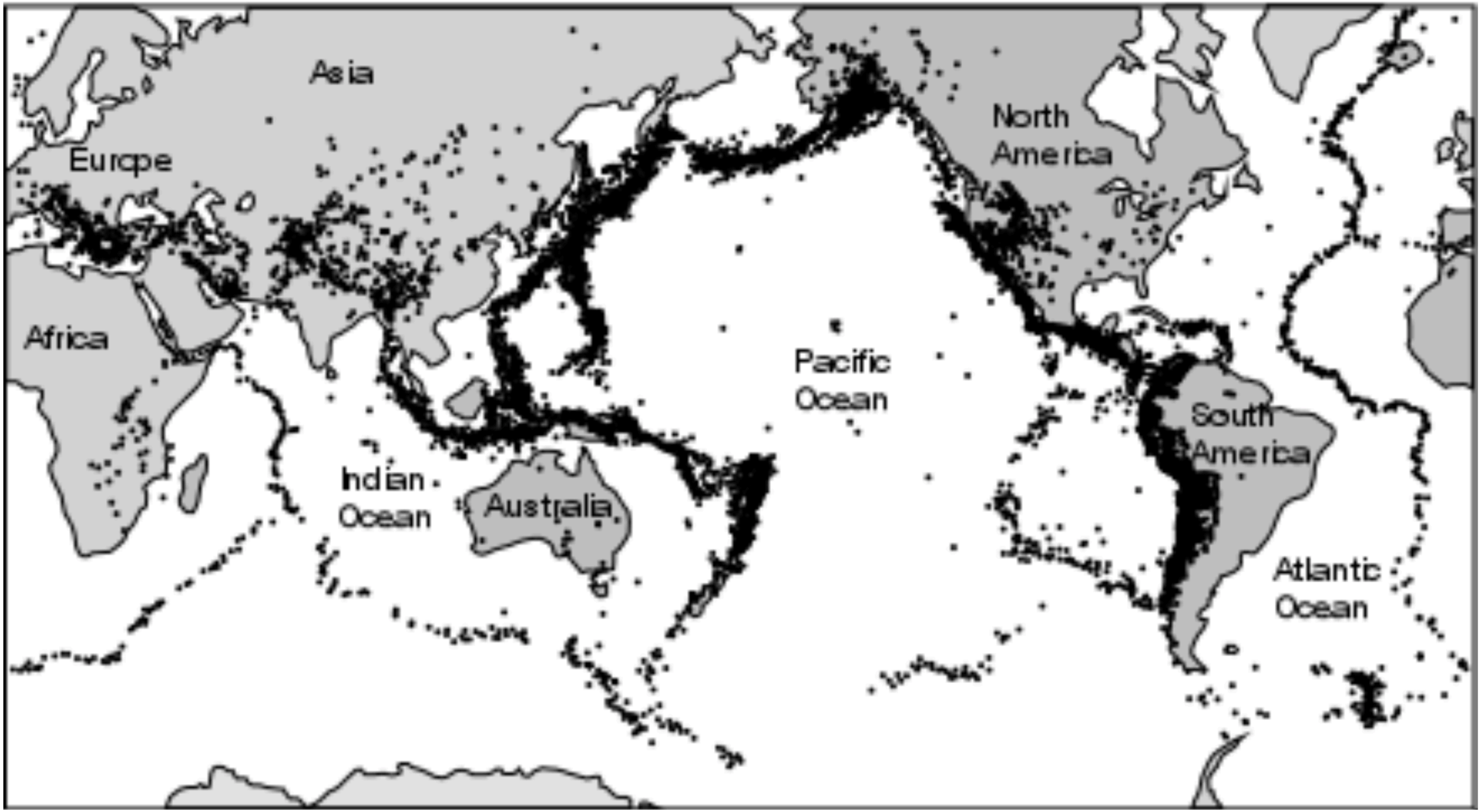


Kan også bestemme om det er

sidelengs, normal, eller revers.

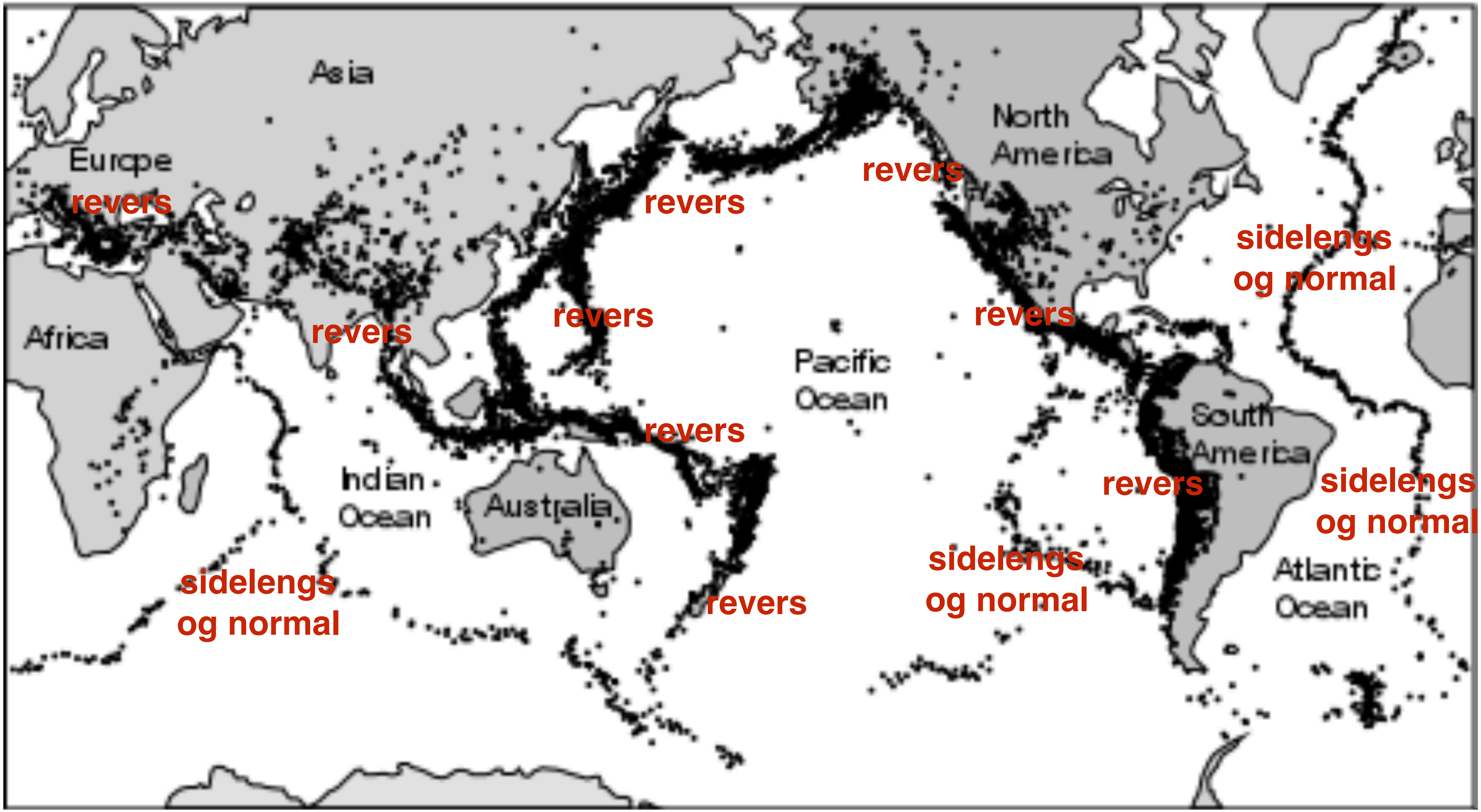
men for komplisert for meg å tegne + -

World Seismicity 1961 - 1967

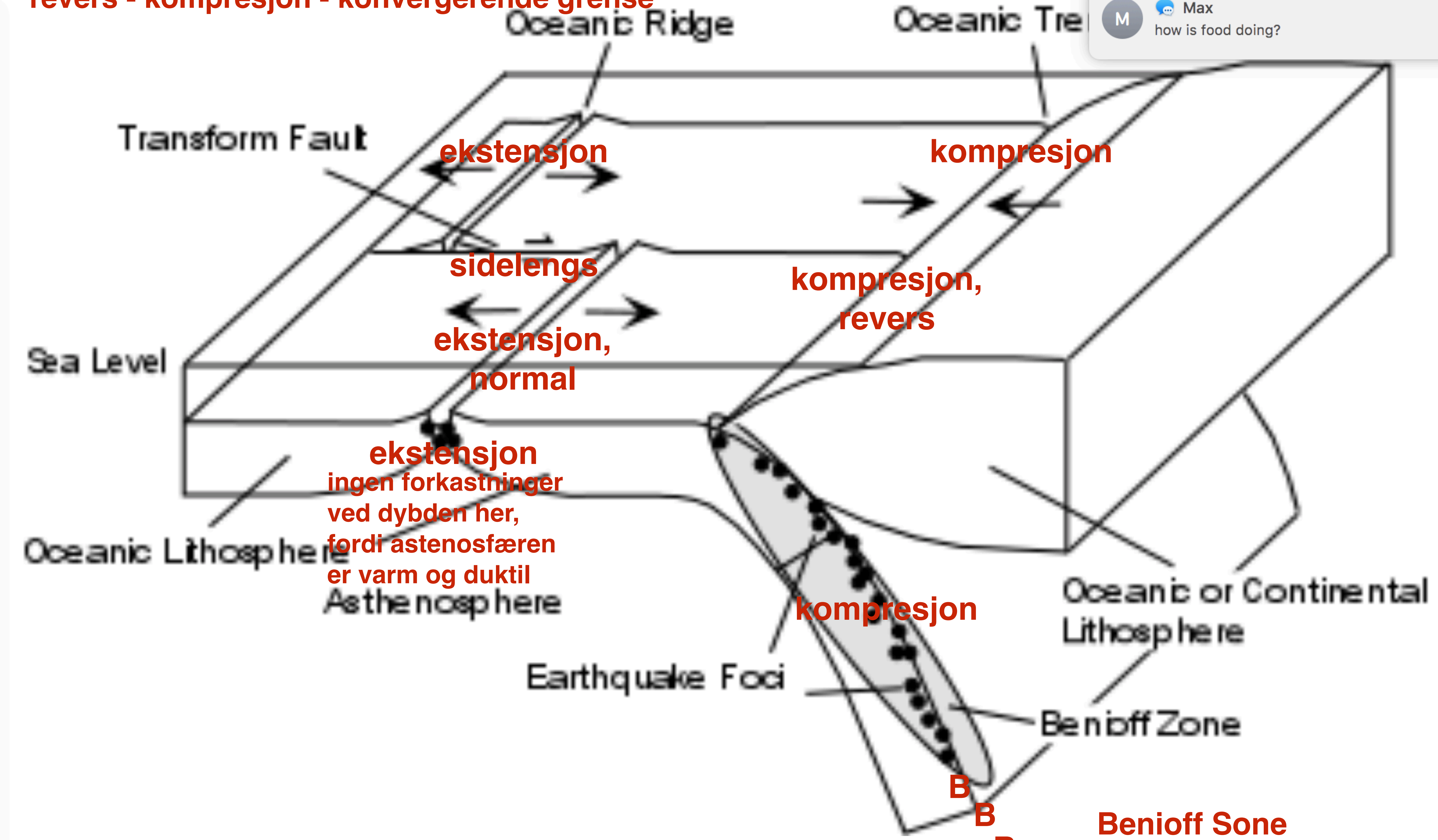


Vi kan bruke Ts—Tp for å bestemme nøyaktig hvor hvert jordskjelv er.
Og vi kan bruke Første mosjon for å bestemme om det er sidelengs, normal, eller revers.

World Seismicity 1961 - 1967

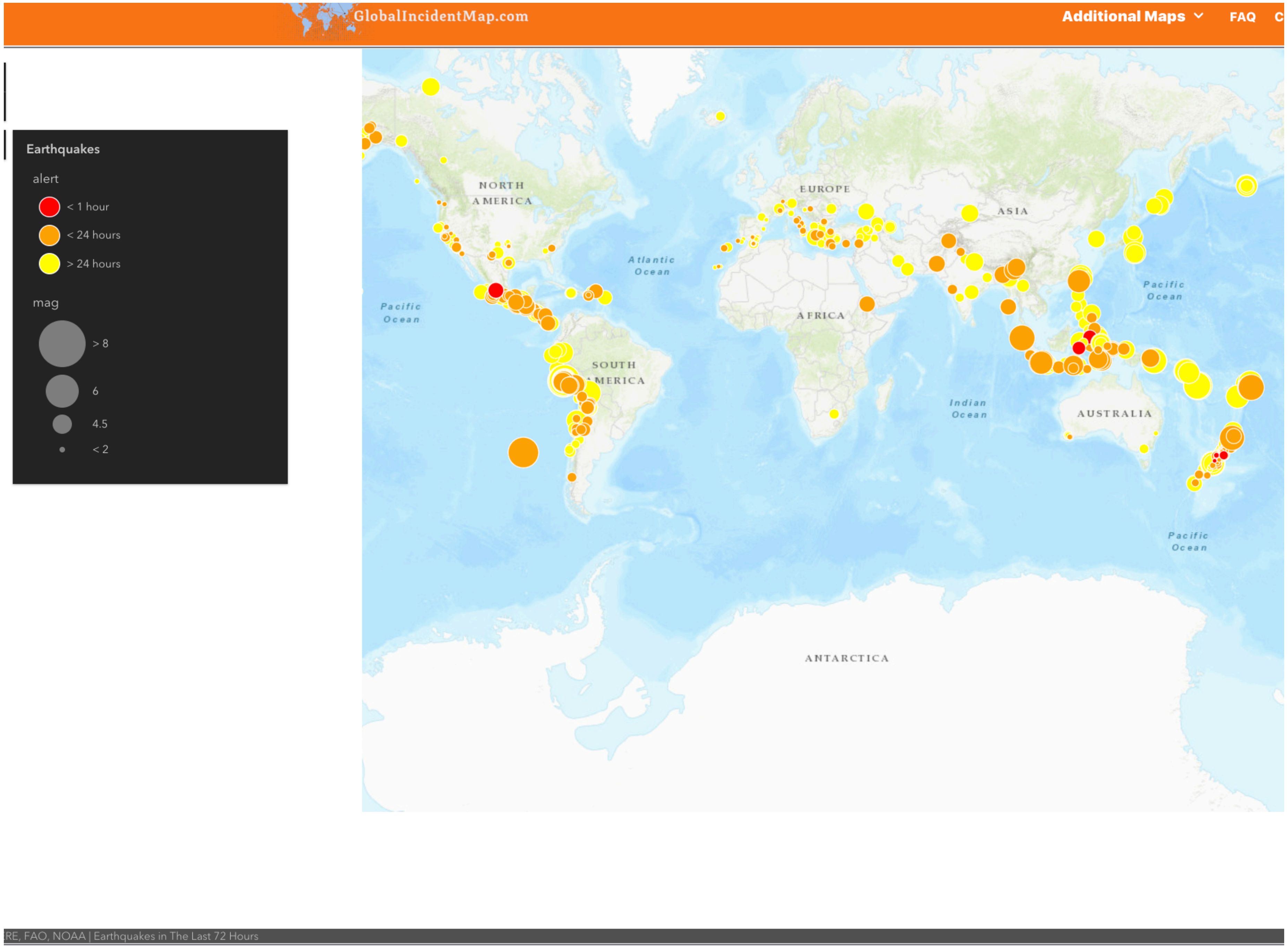


sidelengs - transform grense
normal - ekstensjon - divergerende grense
revers - kompresjon - konvergerende grense



Benioff Sone
går ned til
700 km fordi bergarter
der er kald og sprø

klikk her for de siste jordskjelvene i verden:
http://quakes.globalincidentmap.com



791 Earthquakes In the Last 72 Hours

Show 50 entries

Search:

	DATETIME	LOCATION	MAGNITUDE	DEPTH (KM)	SOURCE
●	10/31/2022, 12:29:57 PM	10 km north-west of Hastings	**2.8**	**27.85**	**GEONET**

Standard skala for jordskjelv styrke:

"Richter skala"

Man beregner Richter Magnitude ved å plotte Amplitude og Avstand på dette nomogram

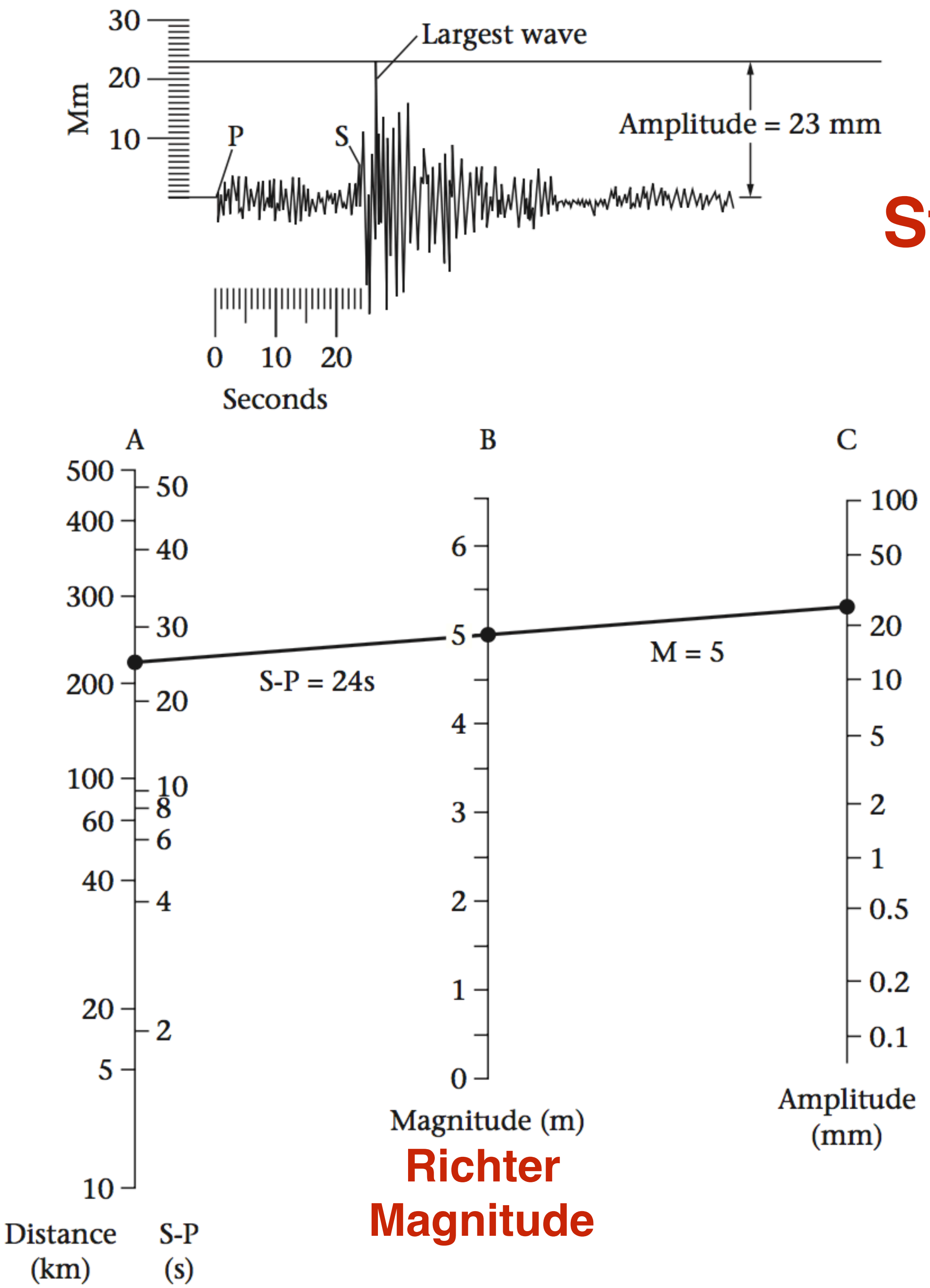
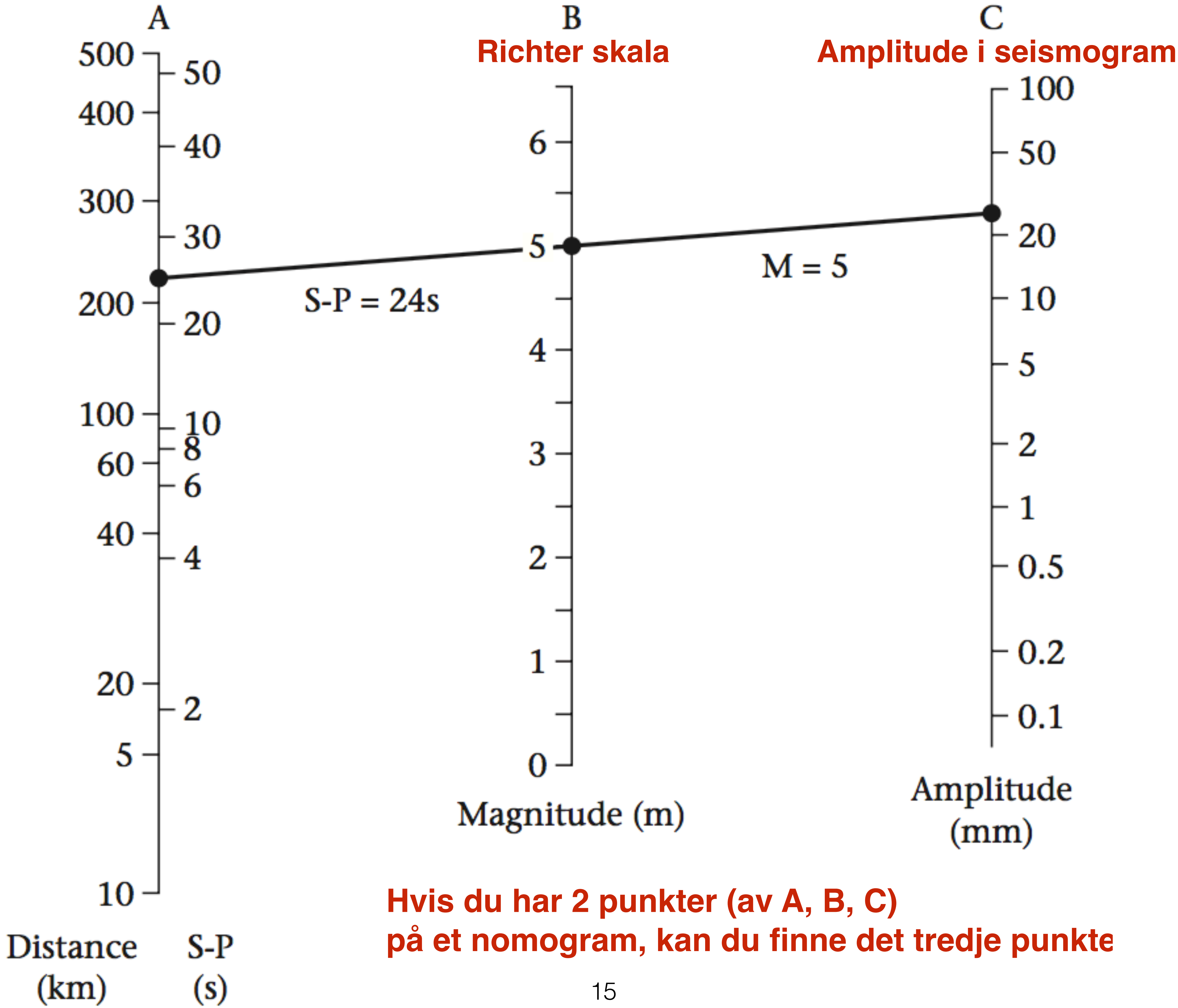
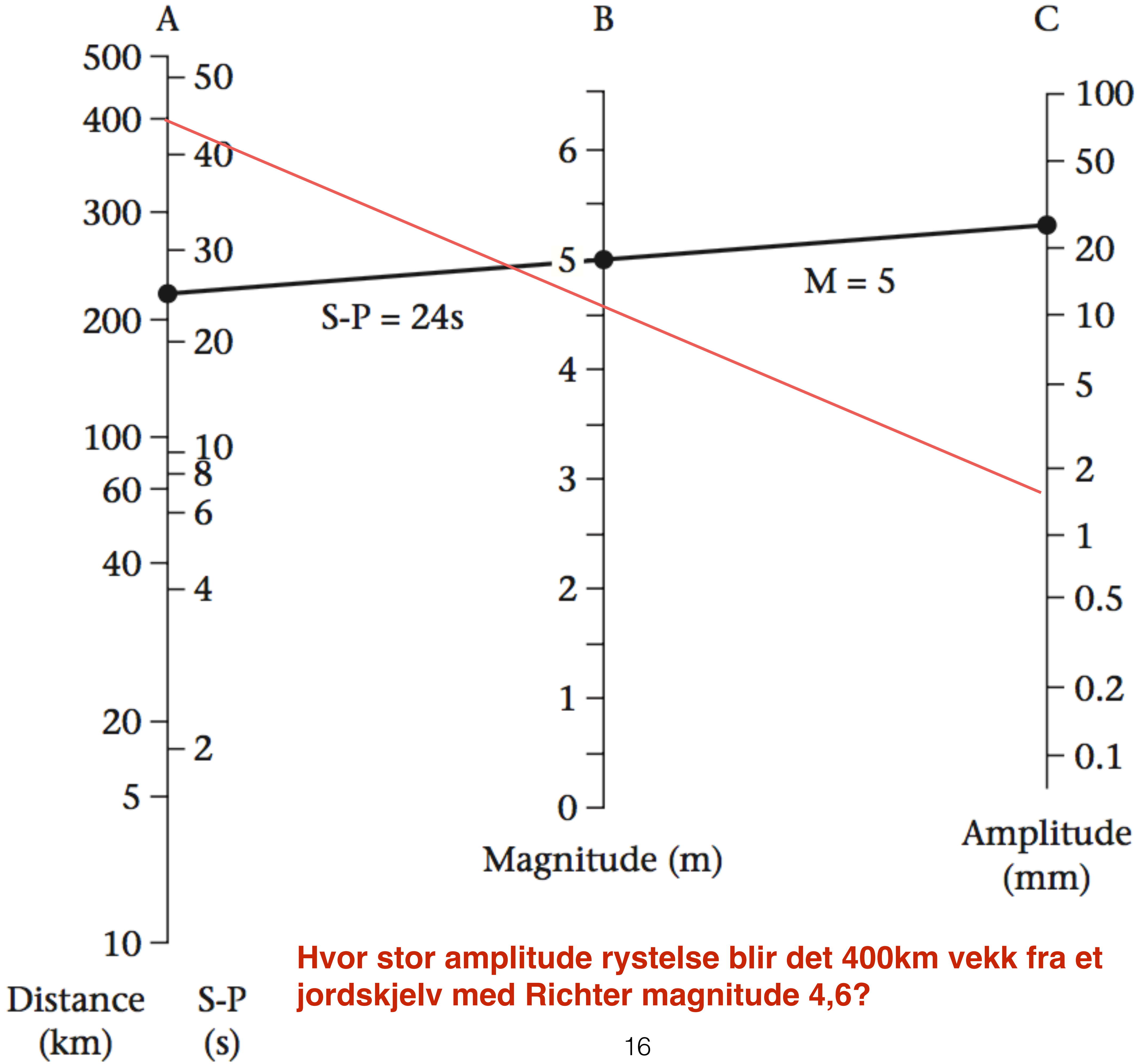


FIGURE 10.18 To calculate the Richter magnitude from a seismogram, first measure the S-minus-P time to determine the distance to the epicenter; then measure the height, or amplitude (in mm), of the largest wave recorded by the seismograph. Draw a line from the point on column A representing the S-minus-P time to the point on column C representing the wave amplitude, and read the Richter magnitude (m) off column B. Note that if the earthquake were much closer, then the same amplitude in the seismogram would yield a smaller-magnitude earthquake. We must take the distance to the epicenter into account because seismic waves grow smaller in amplitude with increasing distance from the epicenter.

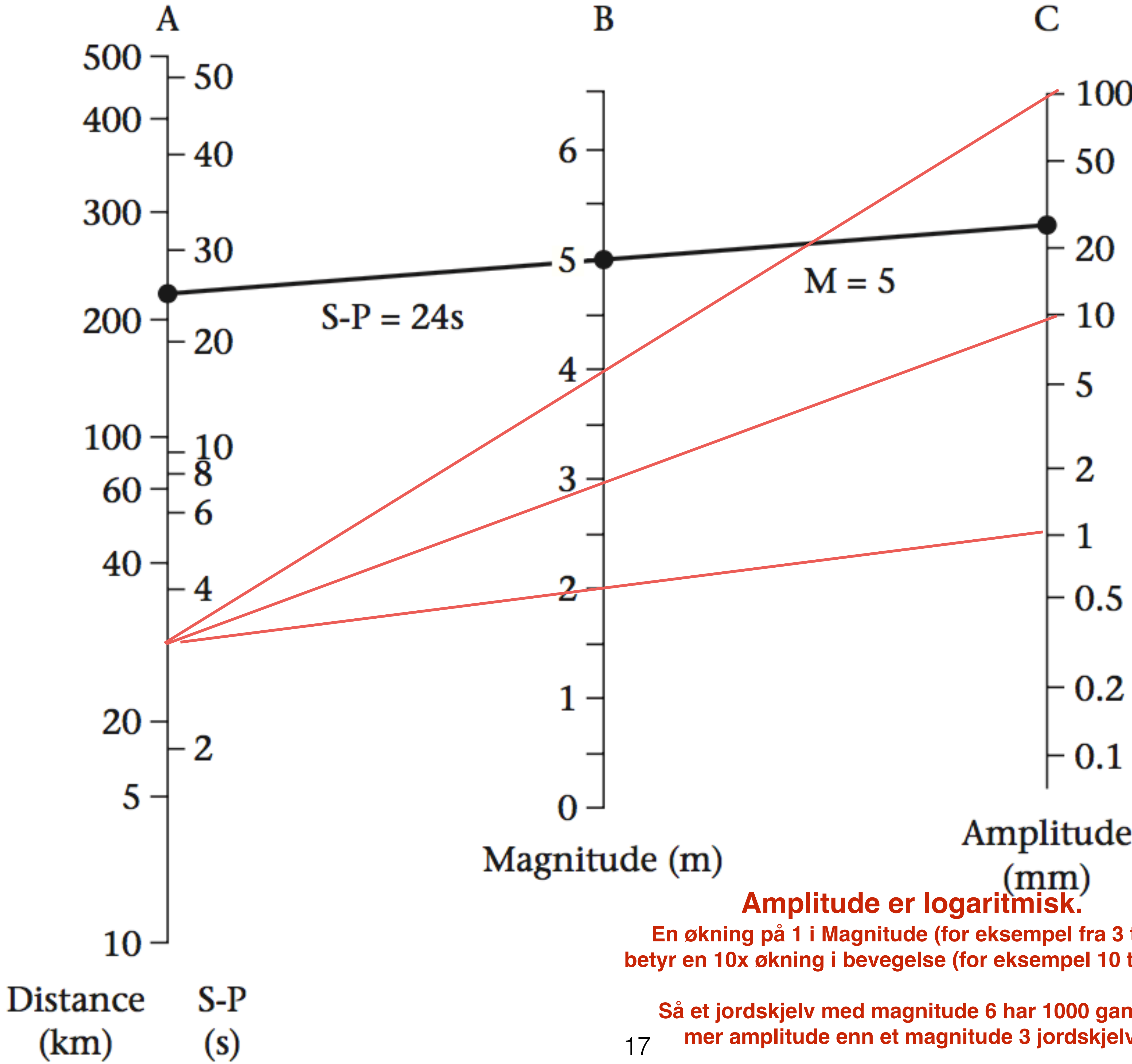
(et slik treskala-diagram kalles et "nomogram")



Hvis du har 2 punkter (av A, B, C)
på et nomogram, kan du finne det tredje punkte



Hvor stor amplitude rystelse blir det 400km vekk fra et jordskjelv med Richter magnitude 4,6?



Amplitude er logaritmisk.

En økning på 1 i Magnitude (for eksempel fra 3 til 4) betyr en 10x økning i bevegelse (for eksempel 10 til 100).

Så et jordskjelv med magnitude 6 har 1000 ganger mer amplitude enn et magnitude 3 jordskjelv.

Nelson.pdf (page 98 of 248)

Magnitude	Energy (ergs)	Factor
1	2.0×10^{13}	31 x
2	6.3×10^{14}	
3	2.0×10^{16}	31 x
4	6.3×10^{17}	
5	2.0×10^{19}	31 x
6	6.3×10^{20}	
7	2.0×10^{22}	31 x
8	6.3×10^{23}	

Fra sist bilde,
vet vi at en økning på 1 i Magnitude betyr en 10x økning i Amplitude.

Men en økning på 1 i Magnitude betyr 31x økning i ENERGI.

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Frequency of Earthquakes of Different Magnitude Worldwide

Magnitude	Number of Earthquakes per Year	Description (“Offisielle” Begrep)
> 8.5	0.3	Great
8.0 - 8.4	1	
7.5 - 7.9	3	Major
7.0 - 7.4	15	
6.6 - 6.9	56	
6.0 - 6.5	210	Destructive
5.0 - 5.9	800	Damaging
4.0 - 4.9	6,200	Minor
3.0 - 3.9	49,000	
2.0 - 2.9	300,000	
0 - 1.9	700,000	

Mer enn 2 per dag i verden

for å sjekke siste døgn:
http://quakes.globalincidentmap.com

her er
"Mercalli skala."
ikke Richter skala.

Kan brukes for historiske jordskjelv.

Underholdende å lese,
men brukes ikke.
Det er Richter "magnitude"
skala som brukes.

Det finnes bedre skalaer enn Richters,
men Richters er i vanlig bruk…

Intensity	Characteristic Effects	Richter Scale Equivalent
I	People do not feel any Earth movement	<3.4
II	A few people notice movement if at rest and/or on upper floors of tall buildings	
III	People indoors feel movement. Hanging objects swing back and forth. People outdoors might not realize that an earthquake is occurring	4.2
IV	People indoors feel movement. Hanging objects swing. Dishes, windows, and doors rattle. Feels like a heavy truck hitting walls. Some people outdoors may feel movement. Parked cars rock.	4.3 - 4.8
V	Almost everyone feels movement. Sleeping people are awakened. Doors swing open/close. Dishes break. Small objects move or are turned over. Trees shake. Liquids spill from open containers	4.9-5.4
VI	Everyone feels movement. People have trouble walking. Objects fall from shelves. Pictures fall off walls. Furniture moves. Plaster in walls may crack. Trees and bushes shake. Damage slight in poorly built buildings.	5.5 - 6.1
VII	People have difficulty standing. Drivers feel cars shaking. Furniture breaks. Loose bricks fall from buildings. Damage slight to moderate in well-built buildings; considerable in poorly built buildings.	5.5 - 6.1
VIII	Drivers have trouble steering. Houses not bolted down shift on foundations. Towers & chimneys twist and fall. Well-built buildings suffer slight damage. Poorly built structures severely damaged. Tree branches break. Hillsides crack if ground is wet. Water levels in wells change.	6.2 - 6.9
IX	Well-built buildings suffer considerable damage. Houses not bolted down move off foundations. Some underground pipes broken. Ground cracks. Serious damage to Reservoirs.	6.2 - 6.9
X	Most buildings & their foundations destroyed. Some bridges destroyed. Dams damaged. Large landslides occur. Water thrown on the banks of canals, rivers, lakes. Ground cracks in large areas. Railroad tracks bent slightly.	7.0 - 7.3
XI	Most buildings collapse. Some bridges destroyed. Large cracks appear in the ground. Underground pipelines destroyed. Railroad tracks badly bent.	7.4 - 7.9
XII	Almost everything is destroyed. Objects thrown into the air. Ground moves in waves or ripples. Large amounts of rock may move.	>8.0

- The Modified Mercalli Scale is shown in the table above. Note that correspondence

“stick, slip” (“rykk og napp”?)

(Marshak figur)

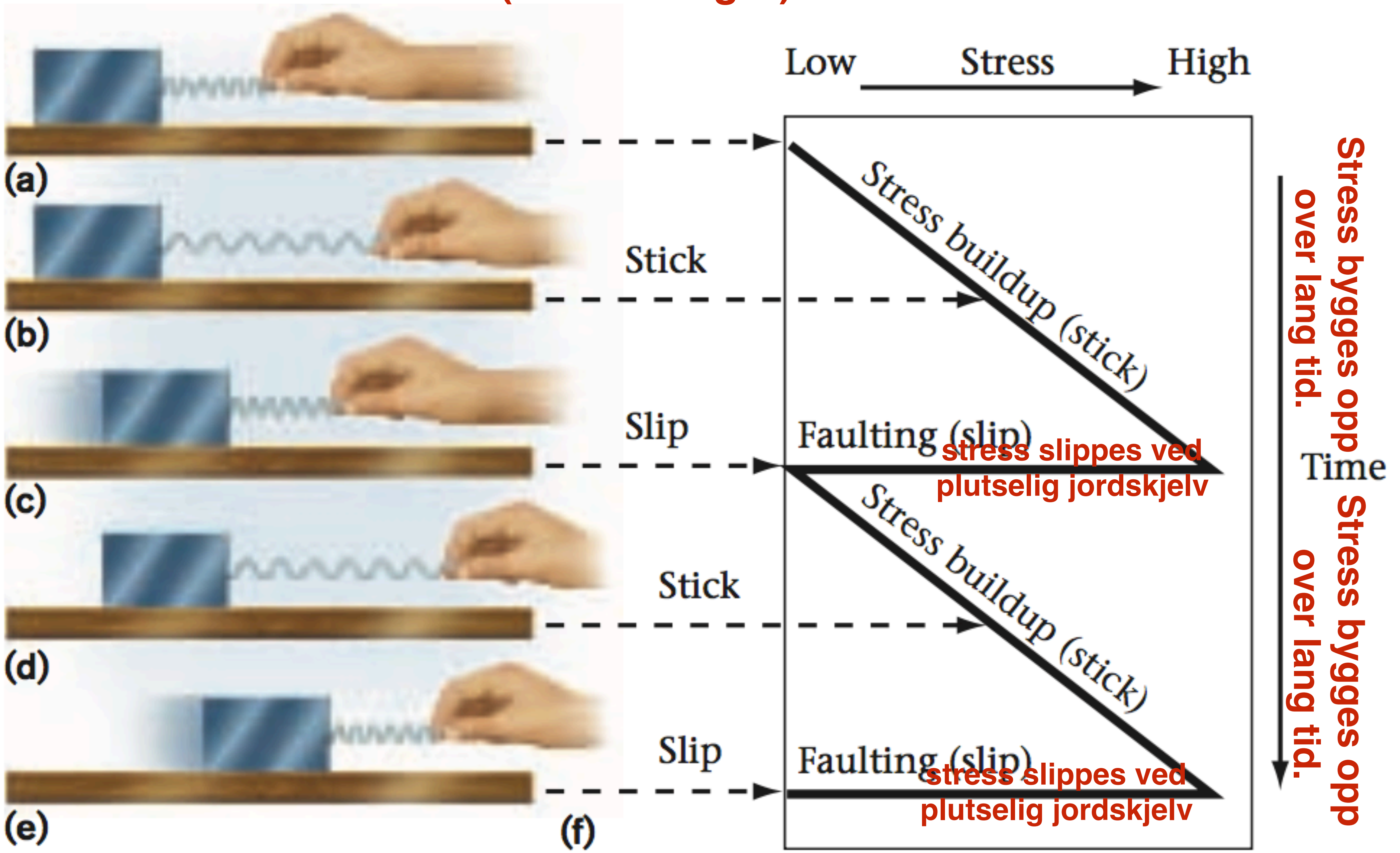
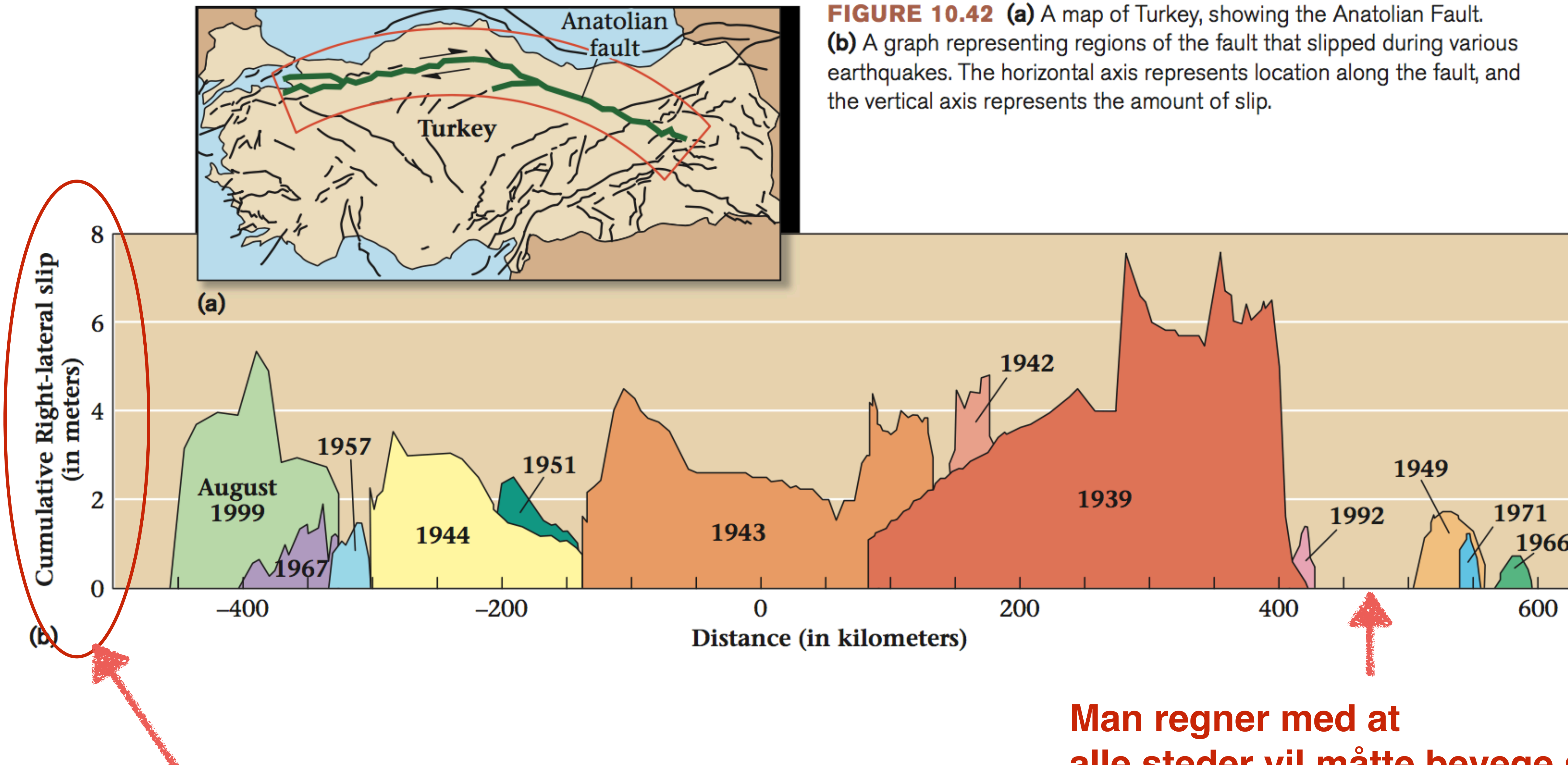


FIGURE 10.42 **(a)** A map of Turkey, showing the Anatolian Fault. **(b)** A graph representing regions of the fault that slipped during various earthquakes. The horizontal axis represents location along the fault, and the vertical axis represents the amount of slip.



Selv verdens aller største jordskjelv innebærer ikke mer enn ca. 8 meters forkastningssprang.

(og ingen jordkjelver er større enn ca. Magnitude 9)

Man regner med at alle steder vil måtte bevege seg over et viss tidsrom.

Det er kanskje farlig mye stress her.

Men forkastningsbevegelse kan også foregå som creep (sig) uten mye stress og uten jordskjelv!

sepwww.stanford.edu/oldsep/joe/fault_images/Hol

A walking tour of the Calaveras fault in Hollister, California

http://sepwww.stanford.edu/oldsep/joe/fault_images/Hollister.html

Introduction

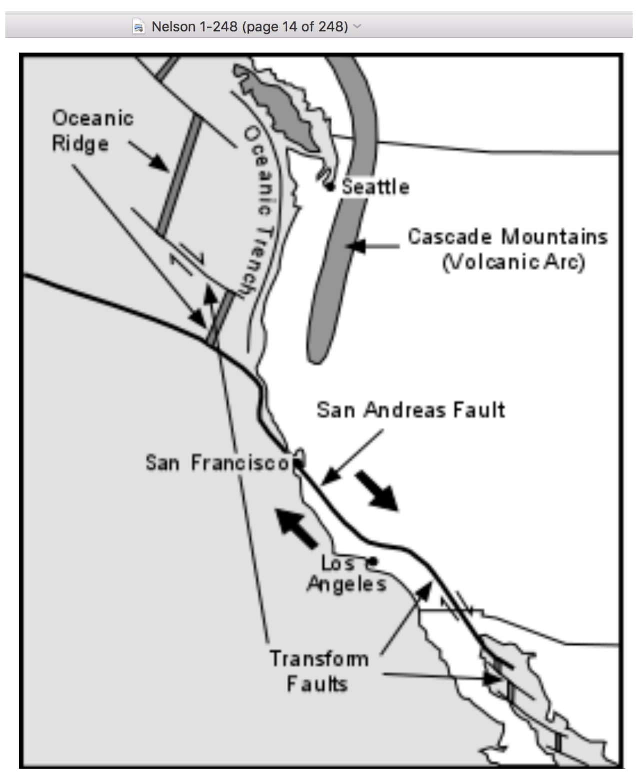
Hollister, California is located South of the San Francisco Bay area. (Here is a regional map courtesy of Xerox PARC.)

In the Bay area there are three major faults, from West to East the San Andreas, the Hayward, and the Calaveras; all are part of the San Andreas fault system. The USGS continuously monitors their activity. All of these are ``right-lateral strike-slip faults'', which means that the motion is predominantly horizontal, with the land on the West side of the fault moving North.

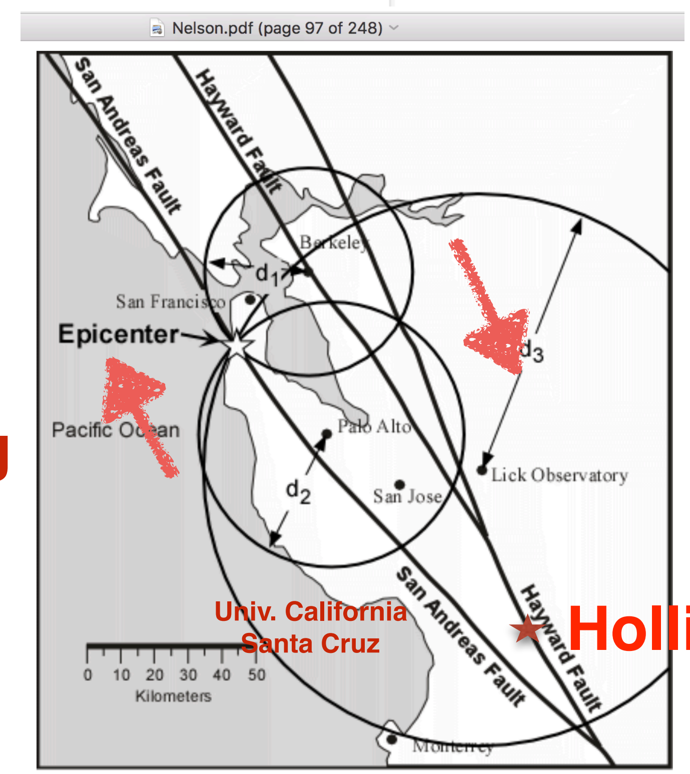
South of the Bay Area the Hayward and Calaveras merge into the San Andreas. Hollister is located just North of where this happens, right on top of the Southern end of the Calaveras fault.

What makes Hollister particularly interesting to geophysicists is that from San Juan Bautista (HERE) to just North of Parkfield (HERE) the faults in the San Andreas system are not ``stuck'': instead of moving only during major earthquakes, the usual pattern for faults, they continuously ``creep''. As a result of this creep, Hollister is being **ripped in two,** for the most part along a remarkably narrow zone running right through the middle of town.

Here is a map showing the approximate active trace of the fault for the part of town covered in our tour.



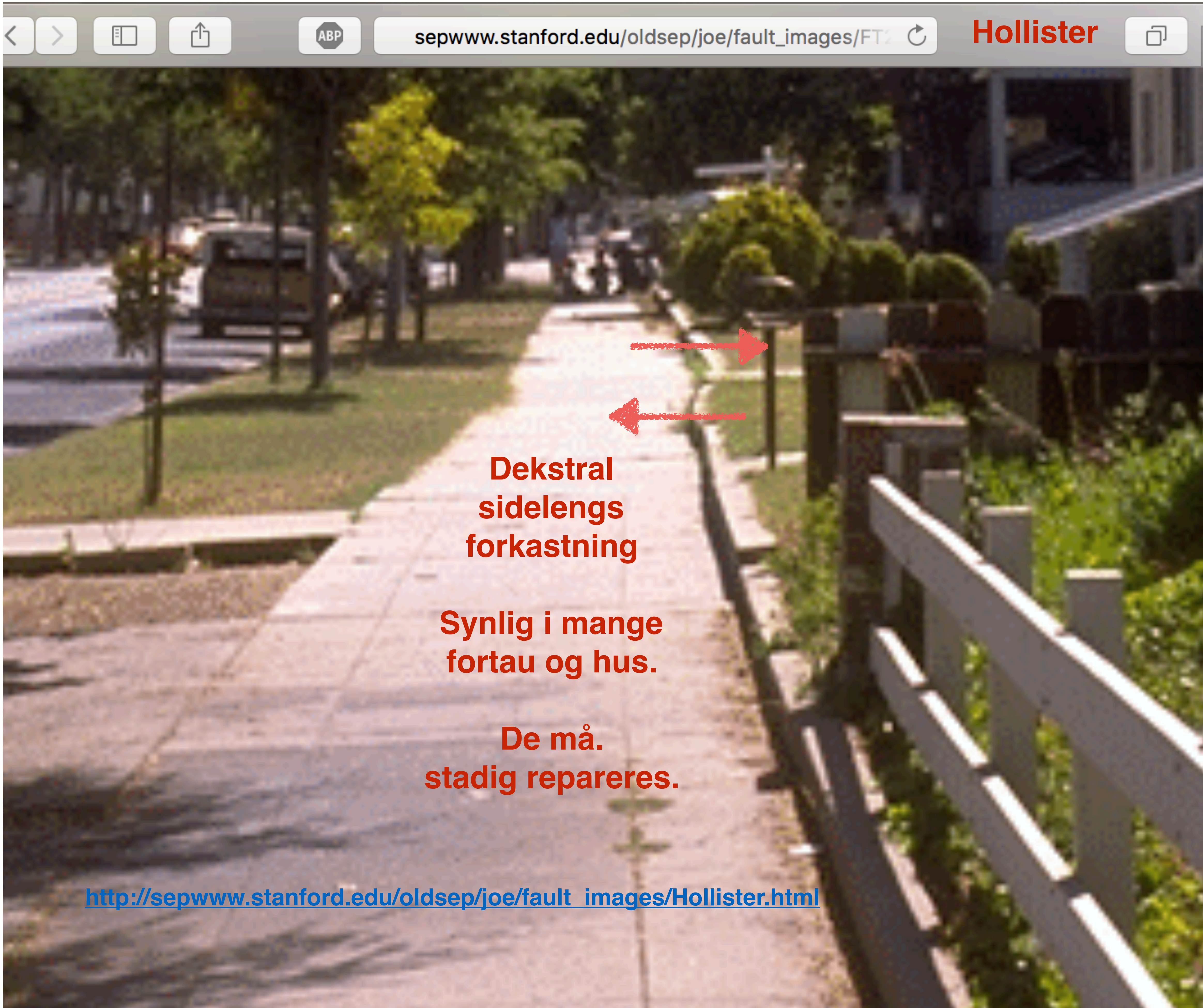
dekstral sidelengs forkastning



Hollister

I tettstedet Hollister foregår forkastnings-bevegelse hele tiden uten jordskjelv

Hollister



Dekstral sidelengs forkastning

Synlig i mange fortau og hus.

De må. stadig repareres.

http://sepwww.stanford.edu/oldsep/joe/fault_images/Hollister.html

Not Secure | http://sepwww.stanford.edu/oldsep/joe/fault_images/hollmapA.html

Hollister Map showing Calaveras fault

This map is courtesy of the US Census bureau Tiger map server. Click on the map to bring up the (unannotated) to see this map ``in context''.

ferdig med “seismologi.” Nå er det:

’Seismikk’ og Jordens indre struktur

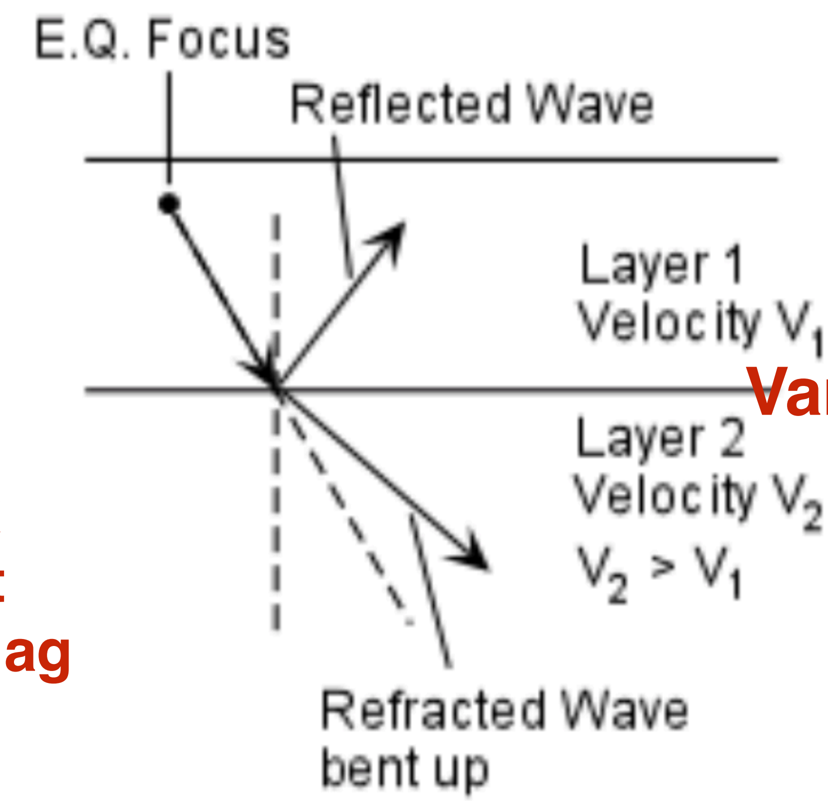
Seismisk refraksjon (brytning) tilsvarer lys brytning

Bølger kan tegnes som stråler (*rays*).

Når en stråle treffer en hastighetsgrense, vil strålen deles i to: en *reflektert* stråle og en *refraktert* (brytet) stråle

Nelson.pdf (page 108 of 248)

1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the interface, the waves will be refracted or bent upward relative to their original path.



Vanlig i grensen mellom skorpe og mantel

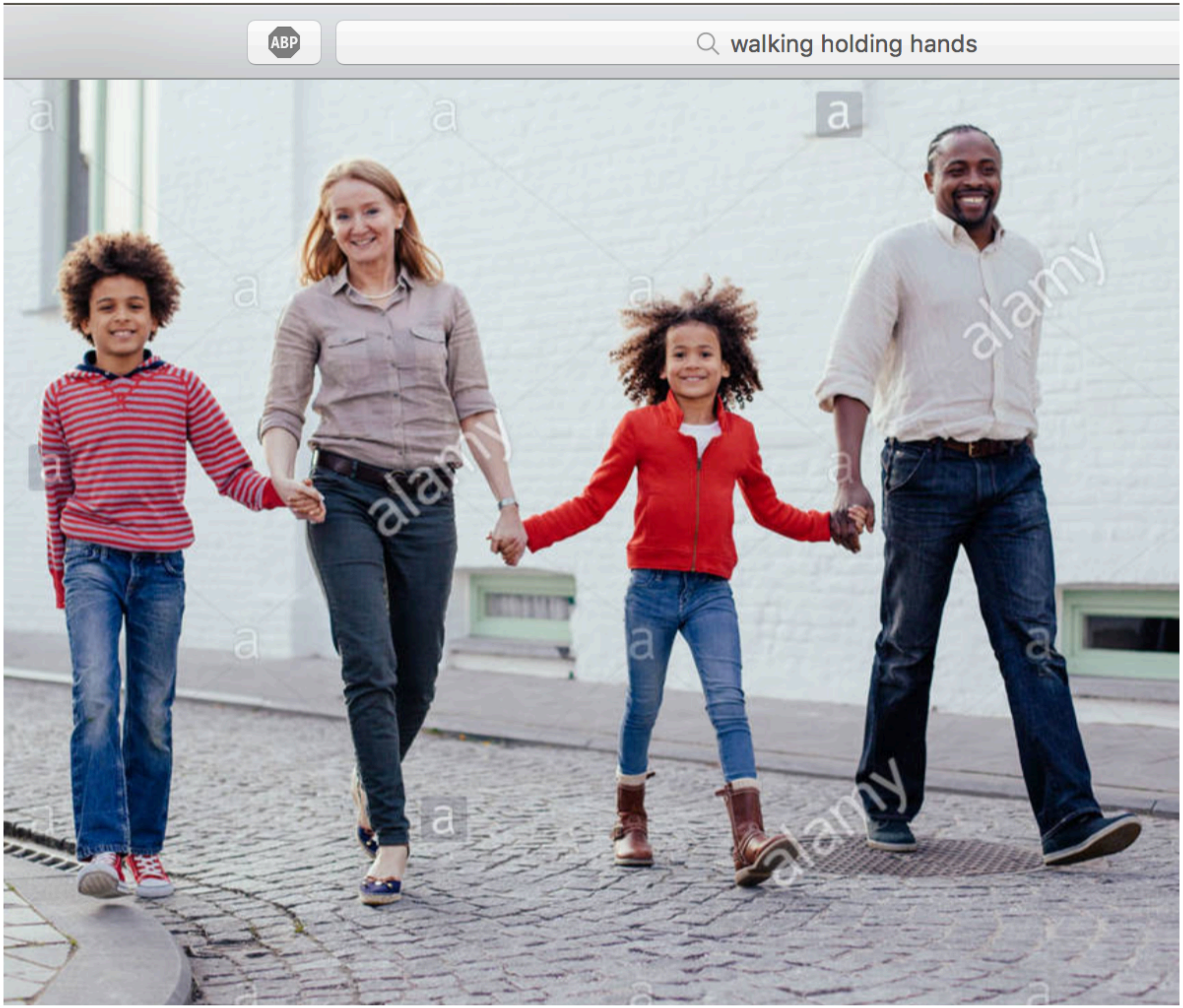
Raskere seismisk hastighet i et dypere lag

Hvis noe *(for eksempel lysbølger, seismiske bølger, bildekk)* går saktere på en side av en hastighetsgrense, bryter det mot den saktere retningen.

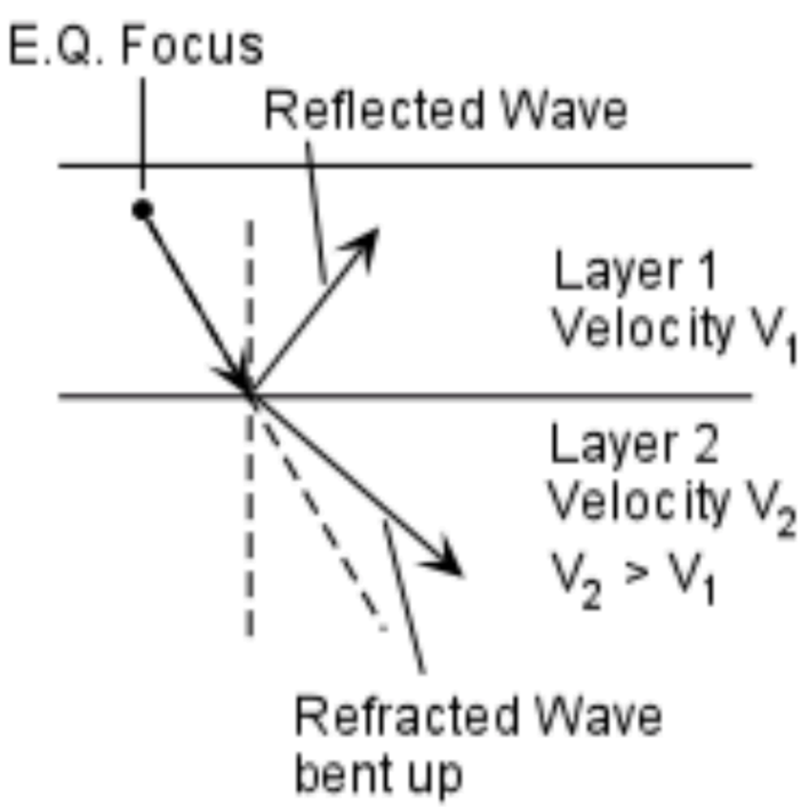
2 hjul i asfalt
har høy hastighet

2 hjul på sand har lav hastighet

**Hvis gutten går litt saktere og mannen fortere,
vil alle svinge (bryte) mot gutten.
Slik er det også med seismiske bølger.**



1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the interface, the waves will be refracted or bent upward relative to their original path.



Seismisk hastighet øker gradvis nedover, innenfor mantelen

4 lag med

(a)

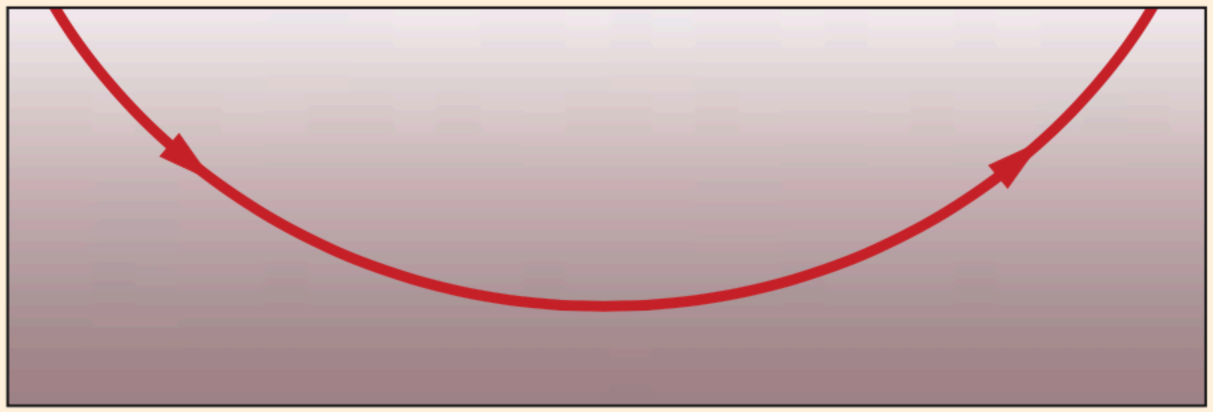
<— økende

<— seismisk

<— hastighet

<— nedover

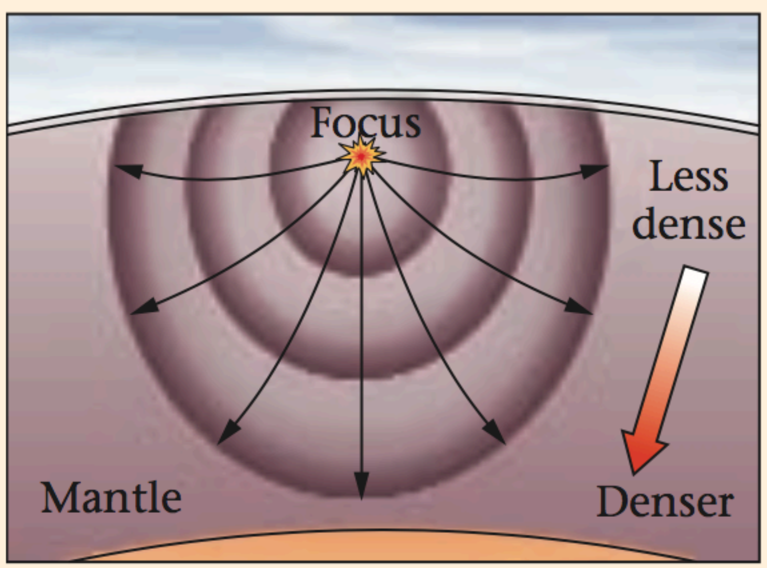
Her er det 4 lag og 3 grenser.
Brytning oppover
ved hver grense.



(b)

gradvis
økende
seismisk
hastighet
nedover

Her er det ingen grenser.
Gradvis brytning.



(c)

Curved rays in a mantle whose density increases gradually with depth

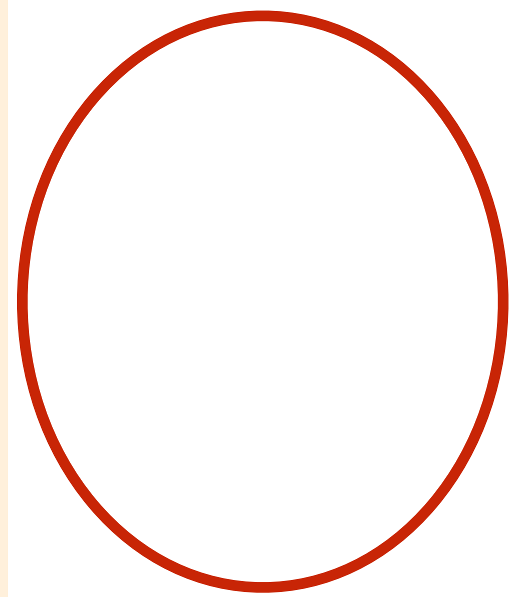


FIGURE D.8 **(a)** In a stack of layers in which seismic waves travel at different velocities (fastest in the lowest layer), a seismic ray gradually bends around and heads back to the surface. The curve consists of several distinct segments. **(b)** If the mantle's density increased gradually with depth, the ray would define a smooth curve. **(c)** Since the velocity of seismic waves increases with depth, wave fronts are oblong and seismic rays curve.

bølgefronter er
derfor ovale,
ikke sirkulære

går raskere ned
enn horisontalt

Marshak.pdf (page 380 of 957)

(a)
(b)
(c)

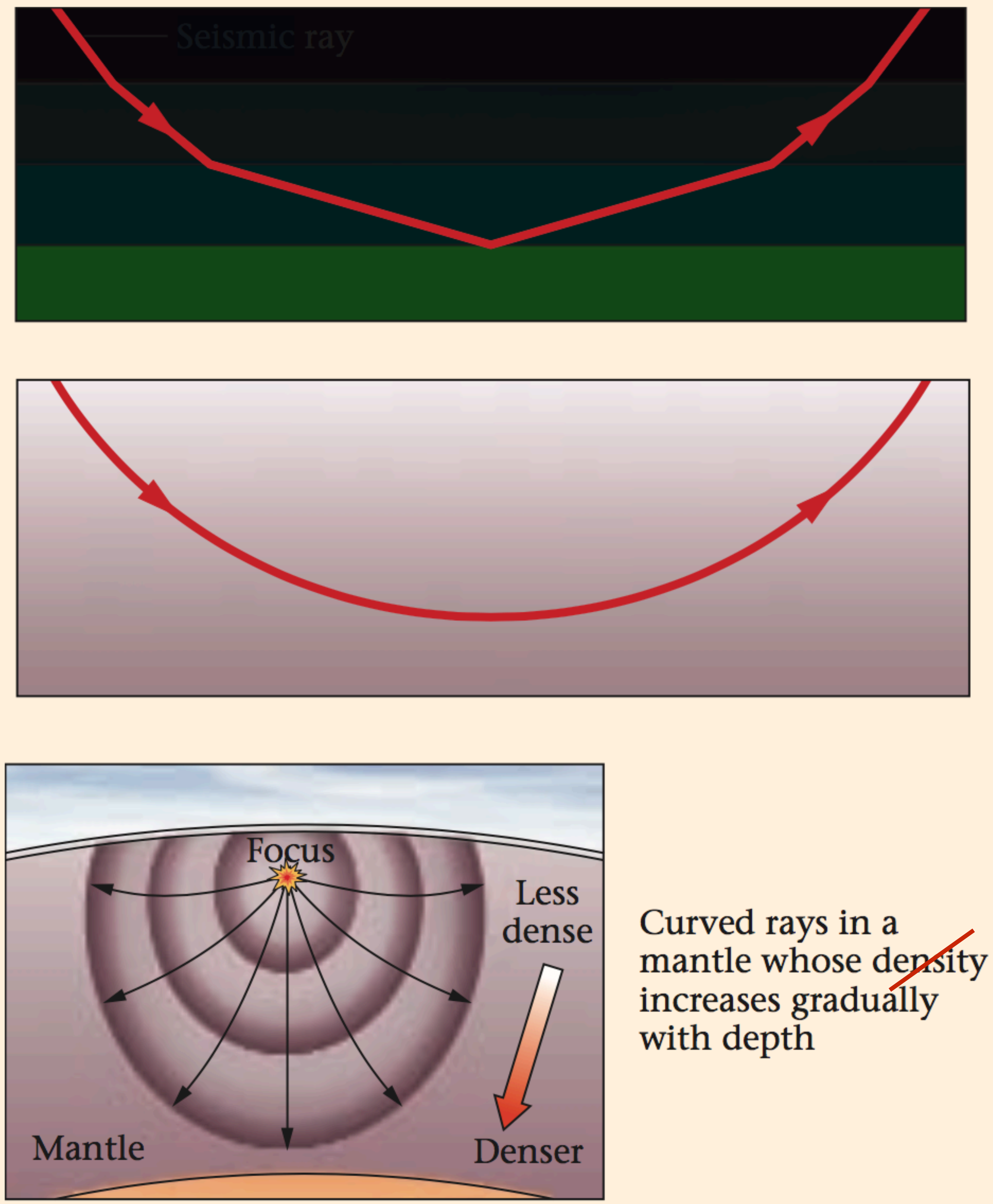


FIGURE D.8 **(a)** In a stack of layers in which seismic waves travel at different velocities (fastest in the lowest layer), a seismic ray gradually bends around and heads back to the surface. The curve consists of several distinct segments. **(b)** If the mantle's density increased gradually with depth, the ray would define a smooth curve. **(c)** Since the velocity of seismic waves increases with depth, wave fronts are oblong and seismic rays curve.

Nelson.pdf (page 95 of 248)

$$V_p = \sqrt{[(K+4/3\mu)/\rho]}$$

1,33*μ*

Marshak misforstår her.

Han sier at V *øker* på grunn av økende ρ

Fra hastighets formel (Nelson s.95) ser vi at V blir *mindre*

med økende ρ (densitet)

Hastighet øker nedover fordi økning i *μ* (stivhet) har mer betydning enn økning i ρ.

Nelson 1-248 (page 95 of 248)

$$V_p = \sqrt{[(K+4/3\mu)/\rho]} \qquad V_S = \sqrt{\mu/\rho}$$

K+1,33μ

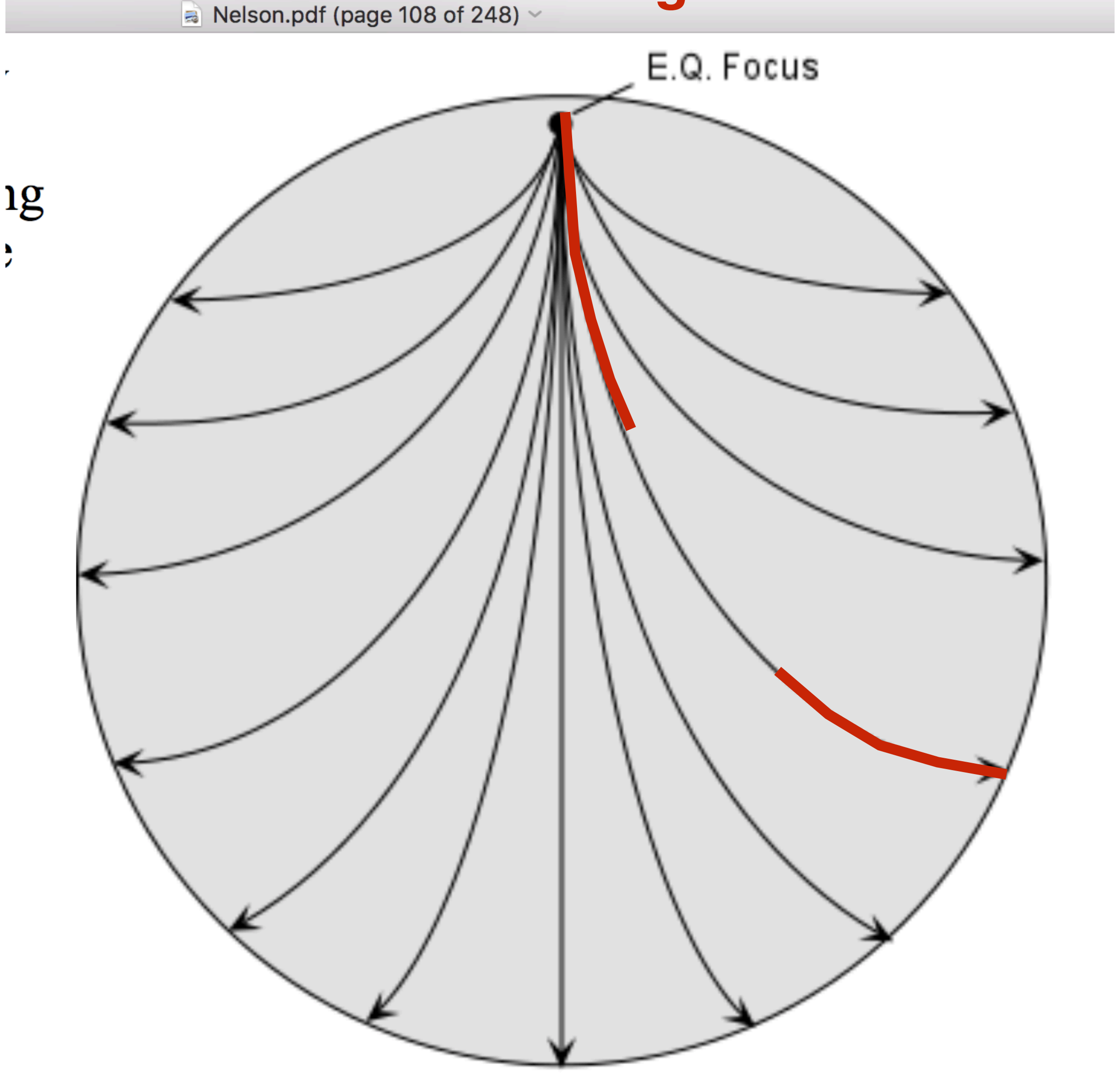
Where, V_p is the velocity of the P-wave, K is the incompressibility of the material, μ is the rigidity of the material, and ρ is the density of the material.

stivhet

Du trenger ikke pugge formlene.

Men du ser av formelene at hastigheten er høyere når STIVHETEN er mer.

Hvis jordkloden var homogen
uten kjerne og med økende
seismisk hastighet nedover.



If wave velocity continuously increases downward
all waves will travel along curved paths refracting back
toward the surface

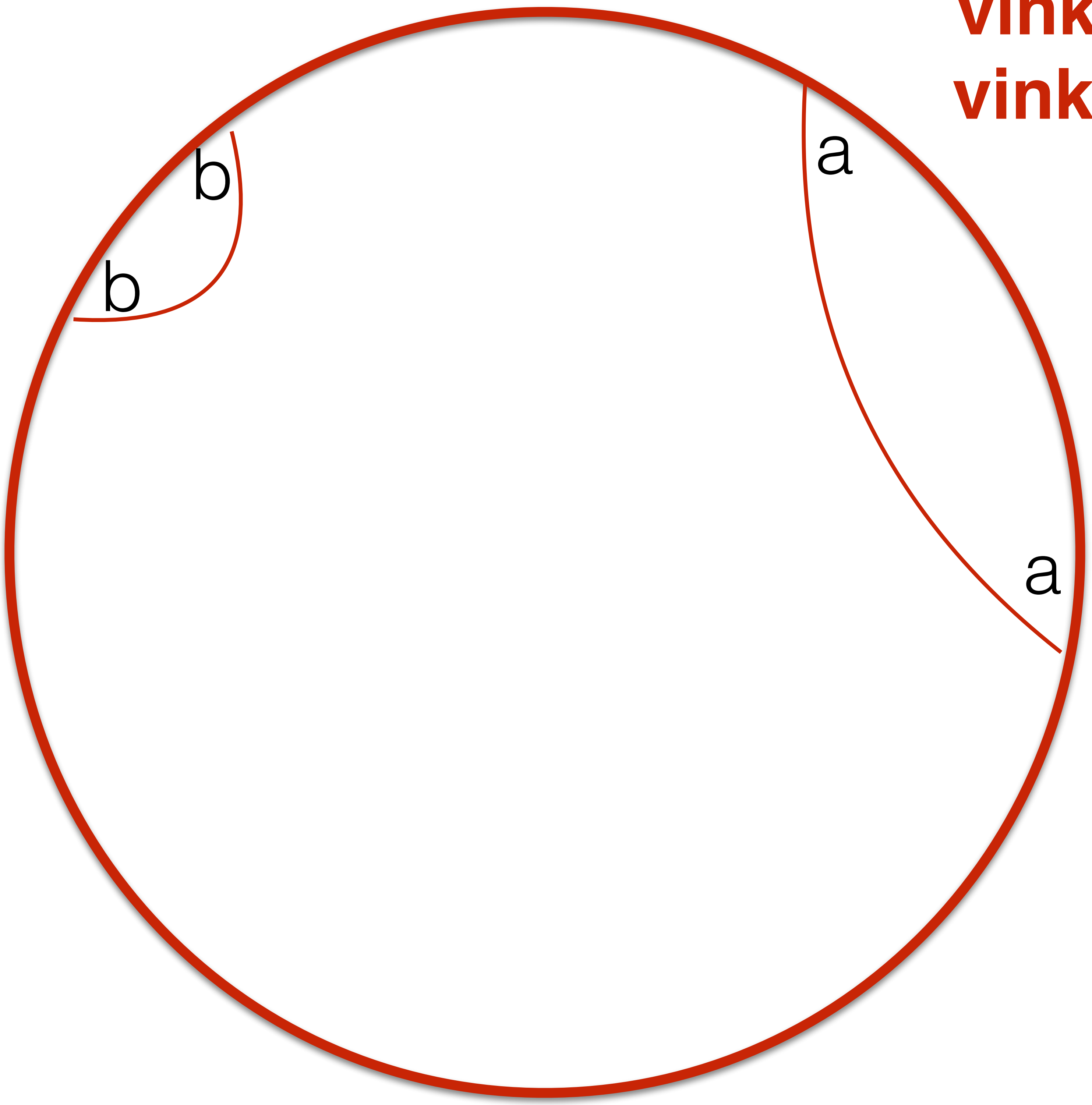
Seismiske bølger bryter
mot den SAKTE siden
av de usynlige grensene.

Det er saktere lag oppover i jordkloden.
Derfor bøyes de UTOVER/OPPOVER.

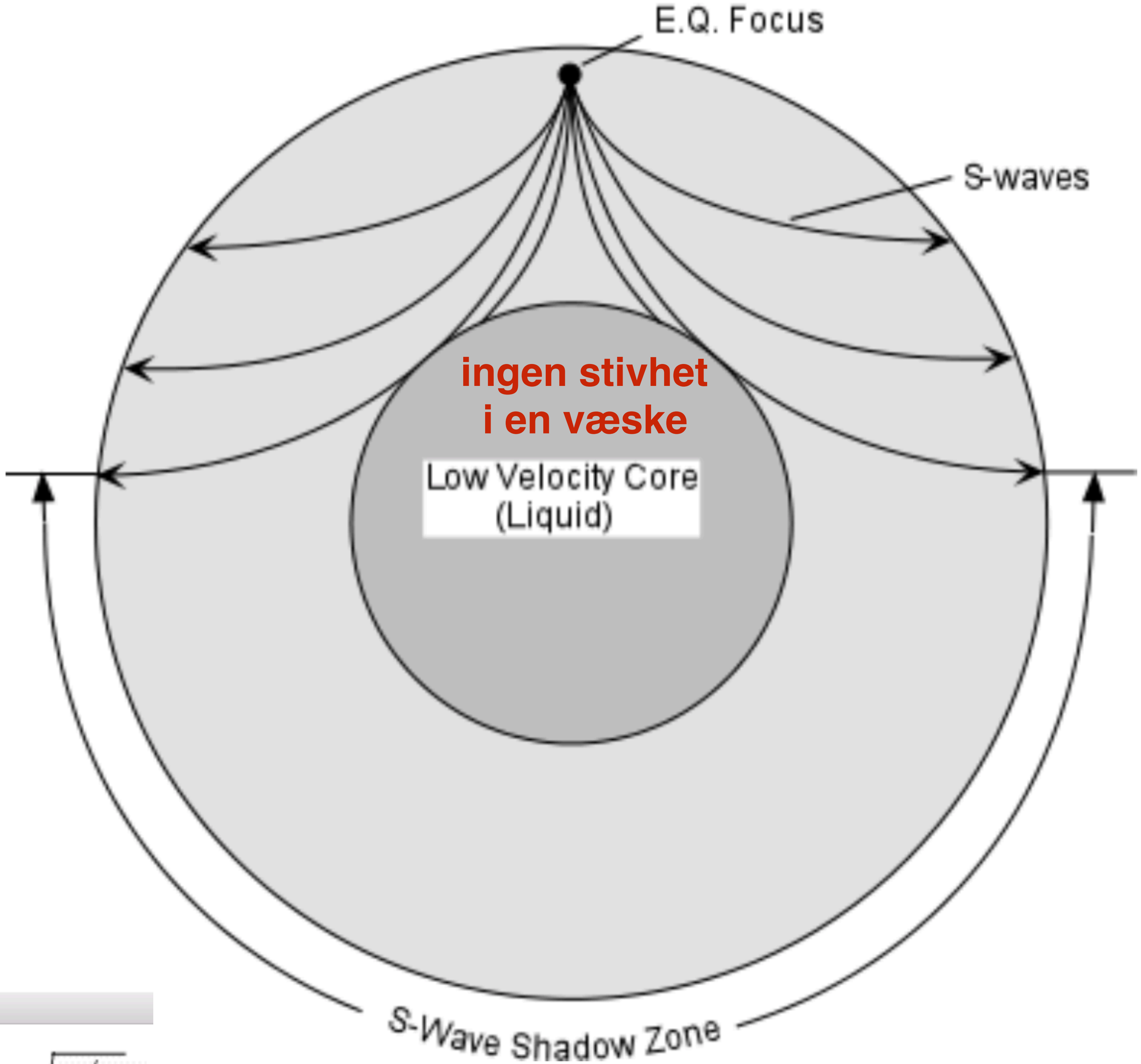
Nelsons stråler er ikke tegnet helt riktig.
Vinkel inn skal være samme som vinkel ut,
Alle stråler bør være SYMMETRISKE buer.

Før eksempel: mine røde linjer viser feil. De bør ha
samme bue form.

må være samme vinkel
vinkel a = a
vinkel b = b



Thus, the S-wave shadow zone is best explained by a liquid outer core.

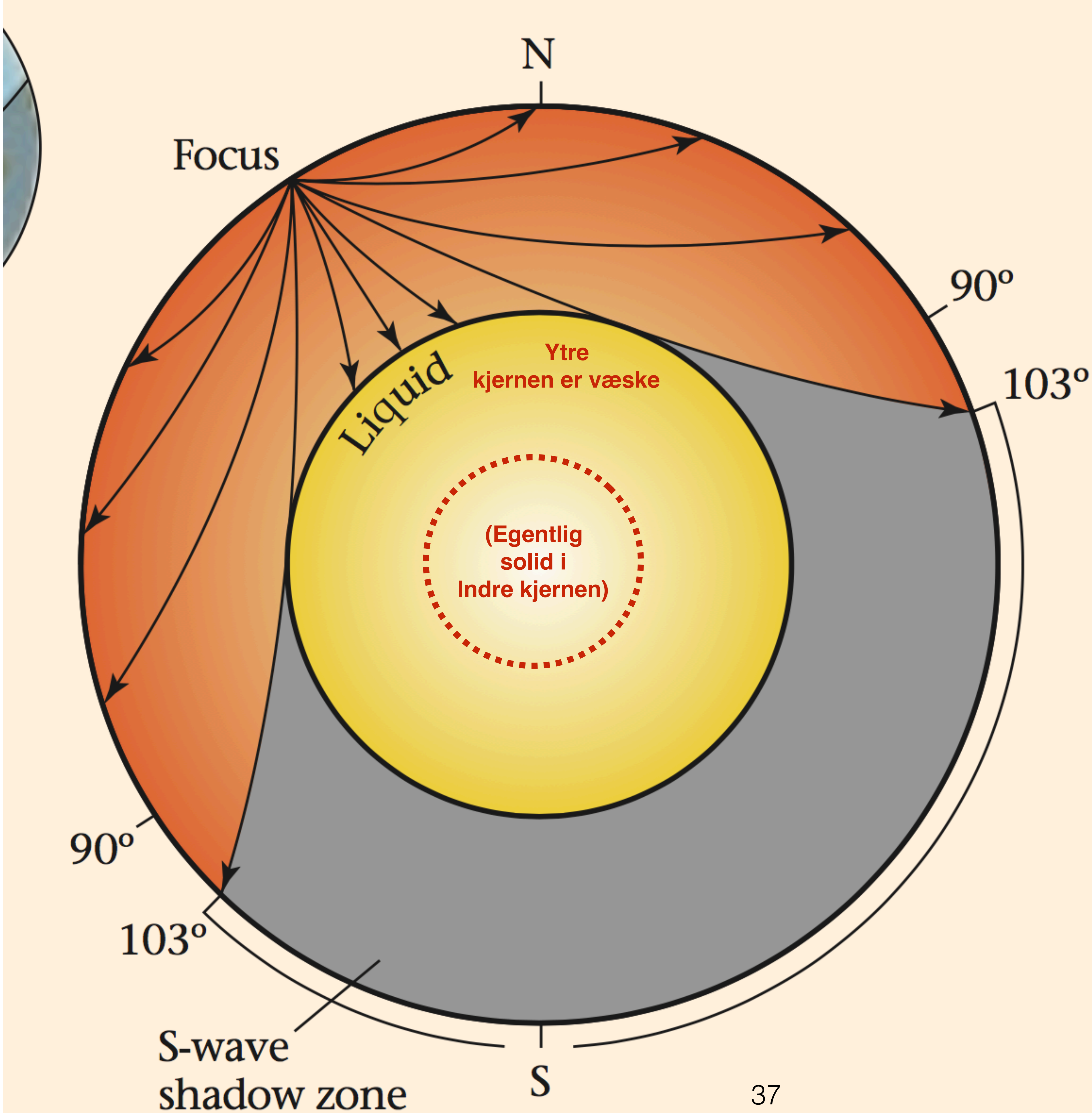


$$V_p = \sqrt{[(K+4/3\mu)/\rho]}$$

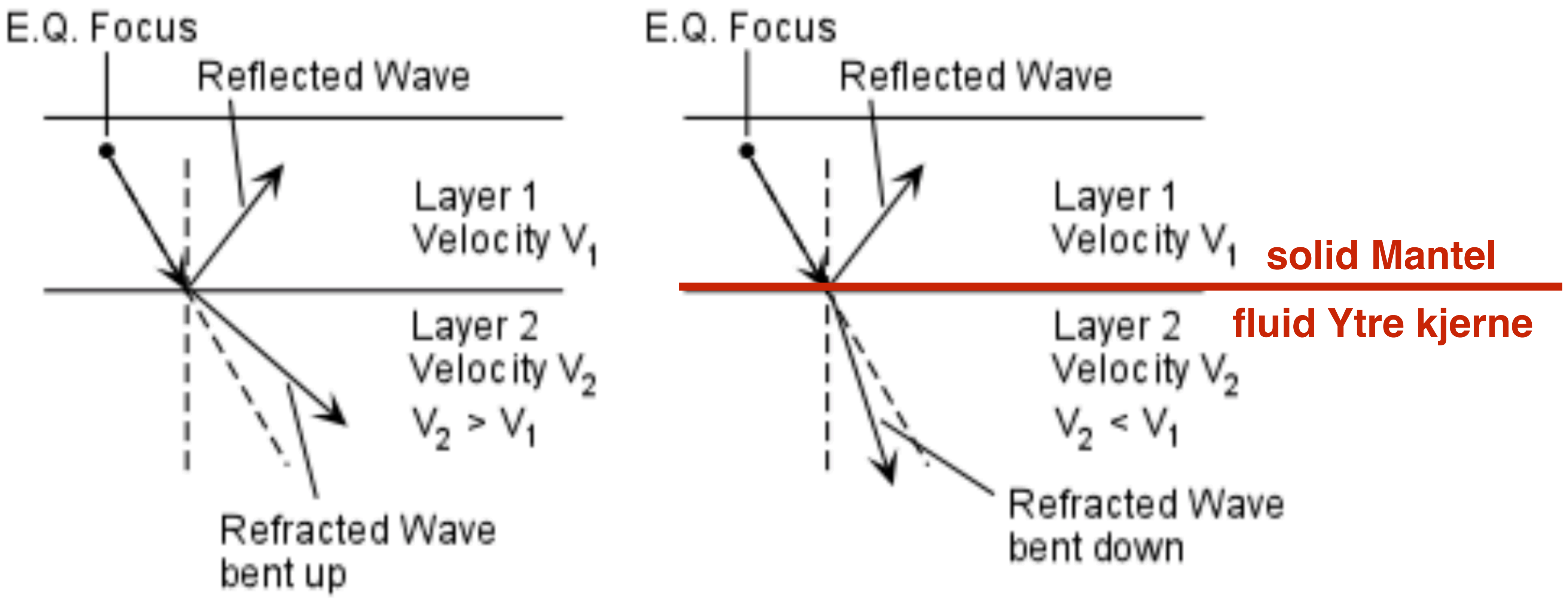
For P-bølger, når stivhet er null, er K fortsatt gjeldende.

$$V_S = \sqrt{\mu/\rho}$$

For S-bølger, når stivhet er null, er hastighet null.

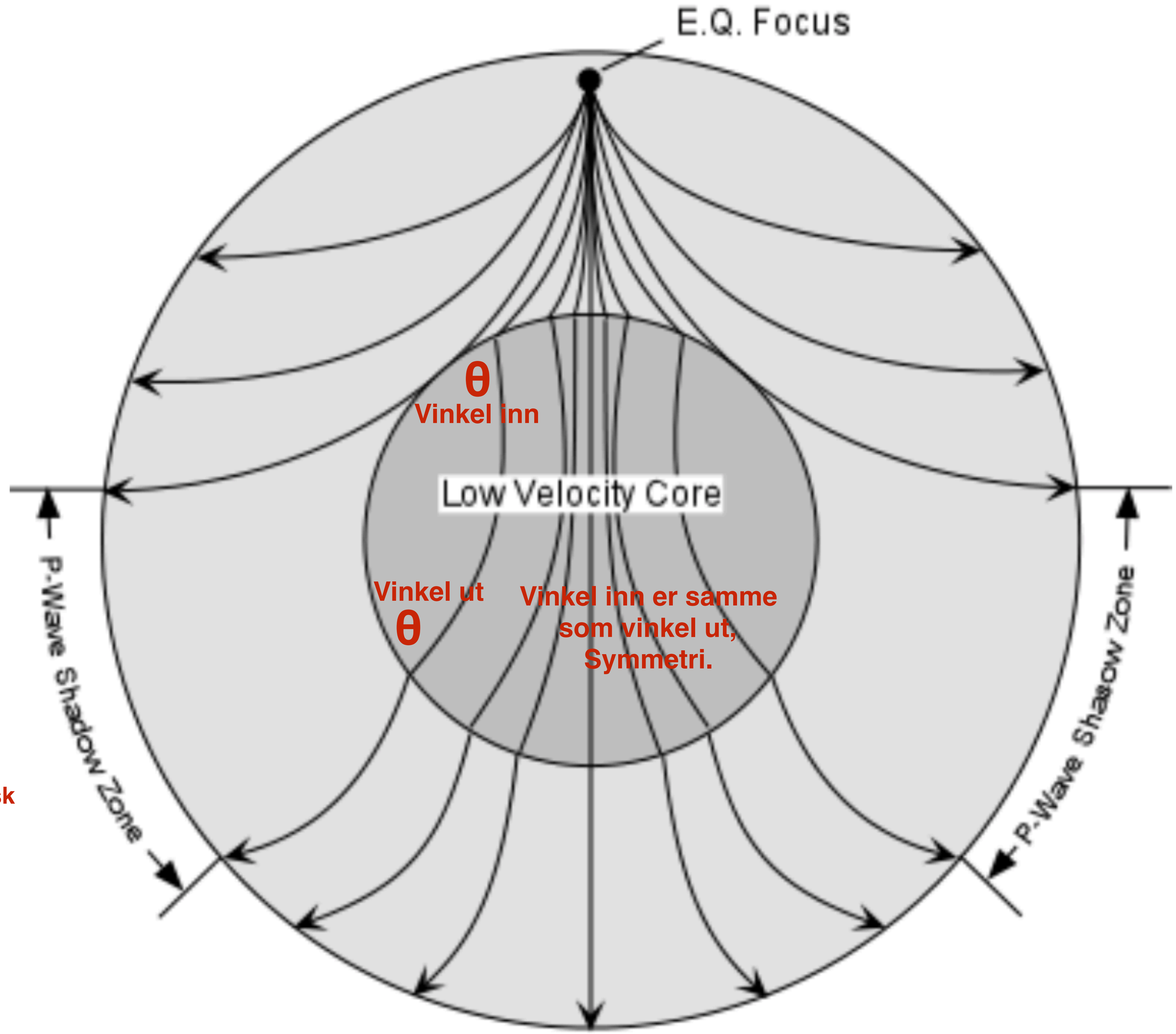

N
Focus
90°
103°
Liquid
Ytre
kjernen er væske
(Egentlig
solid i
Indre kjernen)
90°
103°
S-wave
shadow zone
S

1. If the seismic wave velocity in the rock above an interface is less than the seismic wave velocity in the rock below the interface, the waves will be refracted or bent upward relative to their original path.

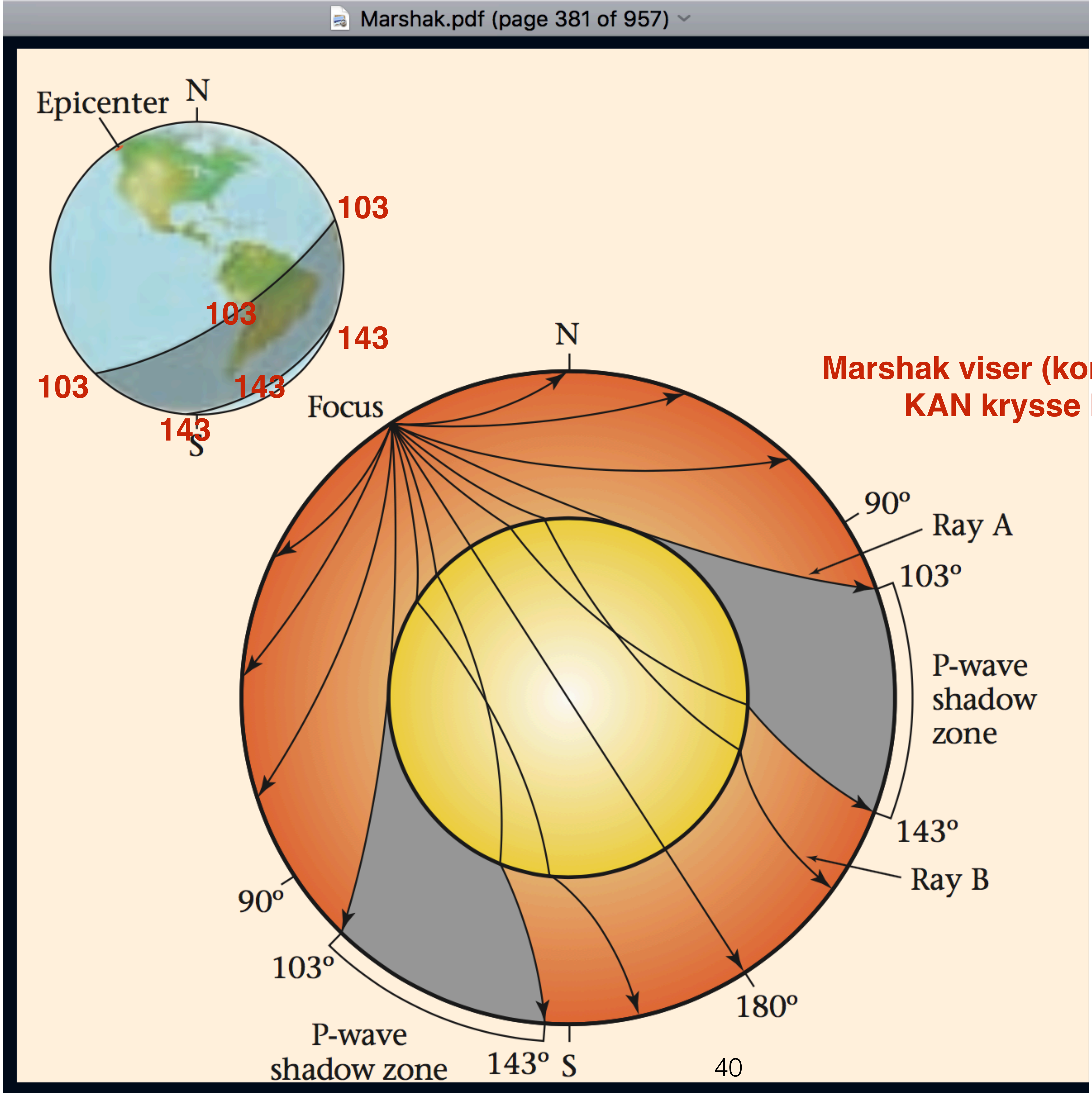


For P-bølger er det lavere seismisk hastighet i jordens Ytre kjerne. Derfor brytes strålene nedover.

This zone is called a P-wave shadow zone.

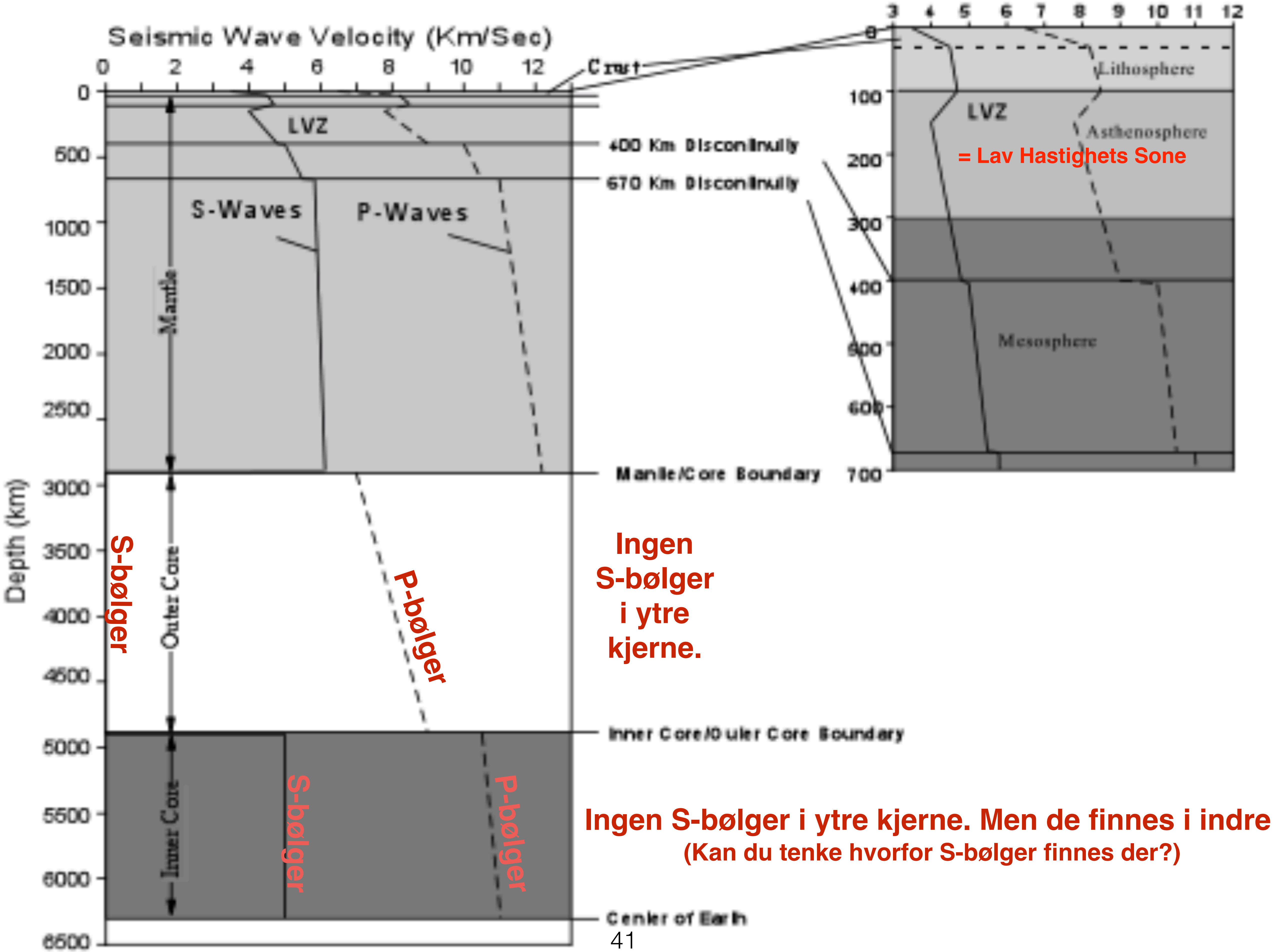


For P-bølger er det lavere seismisk hastighet i jordens ytre kjerne. Derfor brytes strålene nedover.



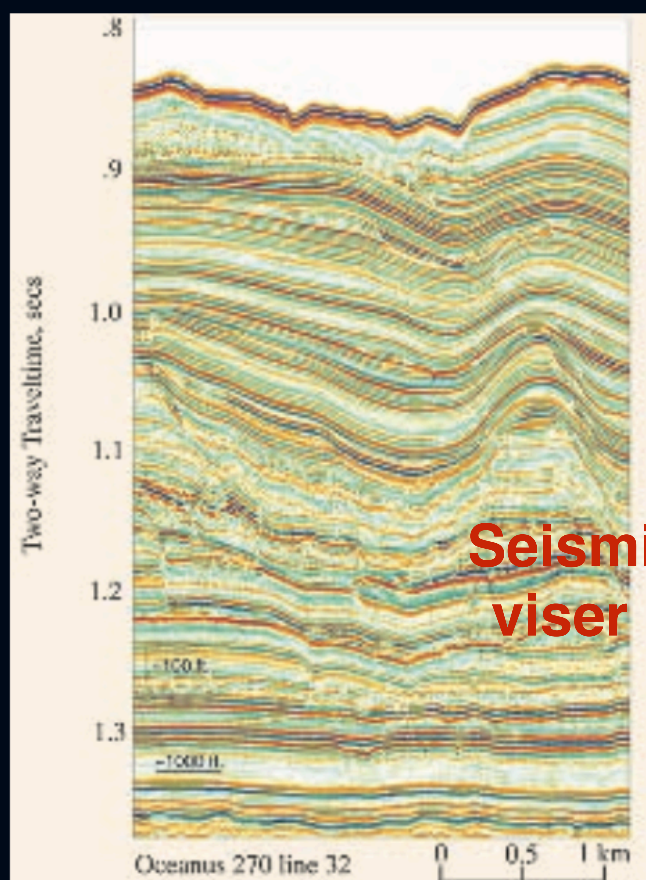
Marshak viser (korrekt) at strålene KAN krysse hverandre!

103°-143°


Seismic Wave Velocity (Km/Sec)
Depth (km)
Crust
LVZ
400 Km Discontinuity
670 Km Discontinuity
S-Waves
P-Waves
Mantle
Mantle/Core Boundary
Outer Core
Inner Core
Inner Core/Outer Core Boundary
Center of Earth
Lithosphere
Asthenosphere
= Lav Hastighets Sone
Mesosphere
S-bølger
P-bølger
Ingen S-bølger i ytre kjerne.
S-bølger
P-bølger
Ingen S-bølger i ytre kjerne. Men de finnes i indre!
(Kan du tenke hvorfor S-bølger finnes der?)

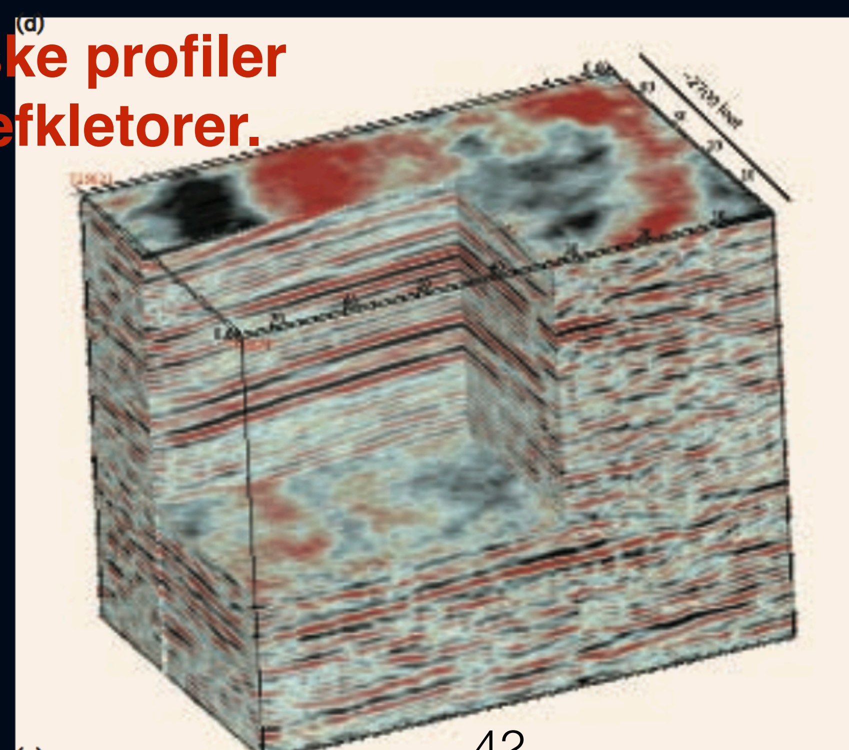
(a)

(b)



(c)

(d)



(e)

Seismiske profiler
viser refkletorer.

FIGURE D.17 **(a)** Trucks thumping on the ground to generate the signal needed for making a seismic-reflection profile. **(b)** Analyzing data with a computer. **(c)** A seismic-reflection profile. The colored stripes are layers of strata. **(d)** A ship collecting seismic data at sea. **(e)** This image shows layers of subsurface strata in 3-D. Computers can expose different cross-section and map-view slices of the image. From such data, important features such as faults (indicated by colored surfaces) can be located.

"Seismikk"

Man bruker sprengninger eller vibrasjoner på land og luftkanoner i vann for å forske på jordens indre struktur.

Seismisk refleksjon: hver stråle reflekteres fra en grense.

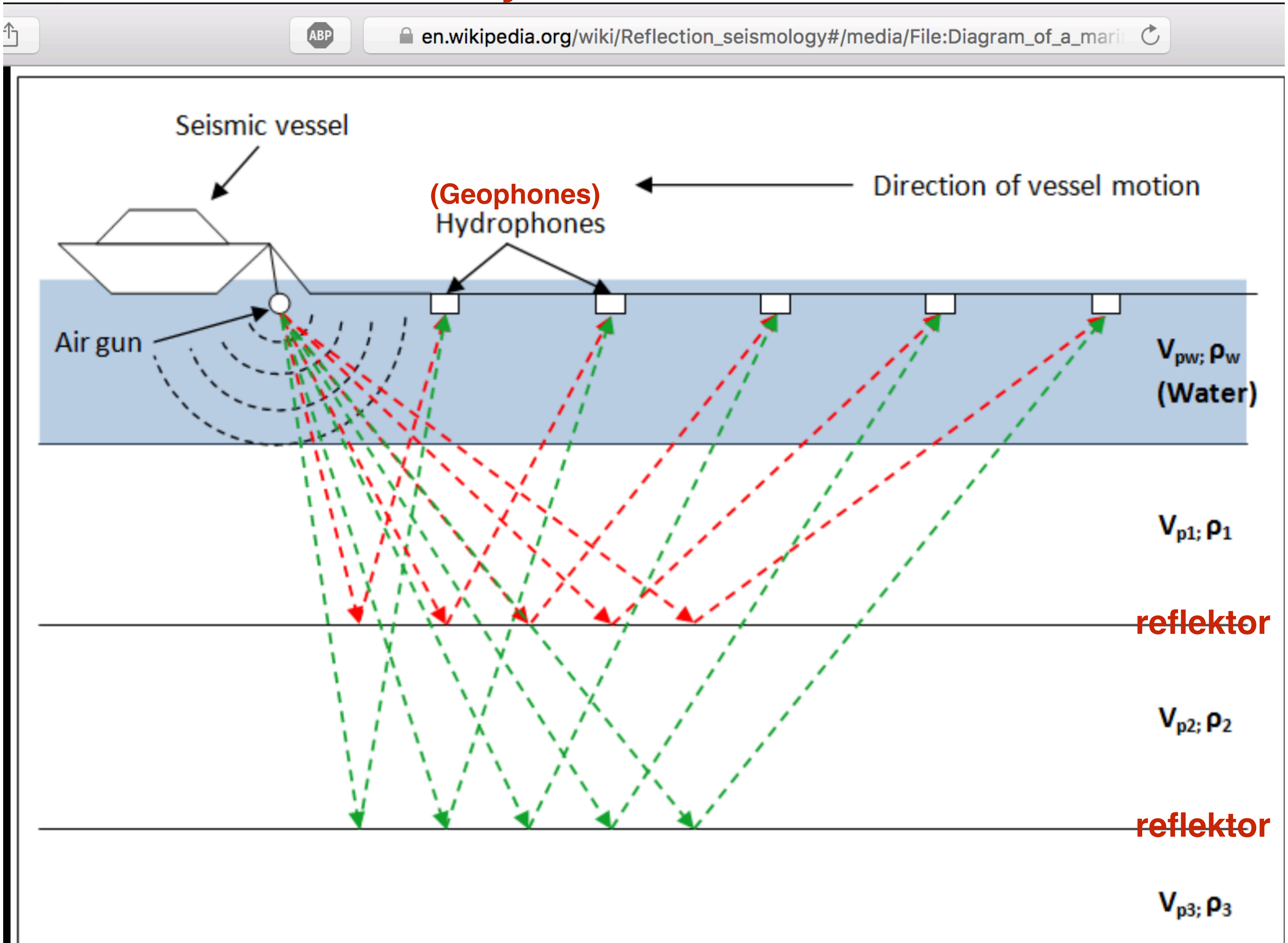


Diagram of a marine towed streamer seismic survey with the raypaths that result from a single shot by an airgun into a streamer containing 5 hydrophones.

--- = raypaths to first reflector; --- = raypaths to second reflector;

Seismisk refraksjon:

hver stråle brytes og går rask under grensen, før den kommer opp igjen.
Det er bare den første som kommer frem som er viktig,
og den første er den som går like under grensen til det raskere bergartslaget.